MAKING THE NEW ZEALAND HOUSE

1792 – 1982

BY

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ABSTRACT

A systematic investigation was undertaken of the techniques (materials and technologies) used to construct the shell of the New Zealand house (envelope and interior linings) between 1792 and 1982. Using census, manufacturing and import statistics with analysis of local and international archives and publications, principal techniques were selected and documented. A review of local construction and building publications provide a background to the development of construction education and training, as well as the speed of change.

Analysis of census data showed that from 1858 to 1981 the majority of dwelling walls in terms of construction (appearance) were timber, brick, board or concrete, while the structure was timber frame. Analysis of import data for seven materials (galvanised iron, asbestos cement, cement, window glass, wood nails, gypsum and roofing slate) from 1870 to 1965 found the UK was a majority supplier until 1925, except for USA gypsum. For the rest of the period, the UK continued to play a preeminent role with increasing Australian imports and local manufacture.

Examination of archival and published information on techniques used for the sub-floor, floor, wall (construction and structure), fenestration, roof and thermal insulation provide an overview of country of orign, decade of arrival, spread of use and, if relevant, reasons for failure. Forty materials (including earth and brick, stone, cement and concrete, timber and ferrous metals) and twenty-four technologies are documented. Revised dates of first NZ use are provided for eight of these e.g. the shift from balloon to platform framing occurred in the early 1880s rather than 1890s. Three case studies examine different aspects of the techniques (nails 1860 to 1965, hollow concrete blocks 1904 to 1910 and camerated concrete 1908 to 1920).

The research shows that timber was the predominant structural (framing) material from 1792 to 1982. From the 1930s there was a shift away from timber construction (external appearance) to a wider range of products, including brick, board (asbestos- and more recently fibre-cement) and concrete. A new chronological classification of house development is proposed.

These techniques travelled in a variety of ways and at speeds which indicate over this time New Zealand was technologically well connected and supported an innovative construction sector.

The techniques covered are: **Boards:** asbestos, and cellulose fibre-cement, particle, plywood, pumice, softboard, and hardboard; **Bricks:** double and veneer; **Building paper**; **Cement and lime**: local and imported; **Concrete**: hollow block, monolithic, reinforced, Camerated, Oratonu and Pearse patents; **Fired earth:** bricks and terracotta roof tiles; **Floors:** concrete slab, suspended, and terrazzo; **Framing**: balloon, braced, light steel, and platform; **Insulation:** cork, fibreglass, macerated paper, perlite, pumice, foil, and mineral wool; **Iron and Steel**: cast and wrought iron, steel; **Linings**: fibrous plaster, plasterboard and wet; metal tile, shingles and slates; **Nails**: cut, hand-made, wire and plates; **Piles:** concrete, native timber and stone; **Roof**: strutted and truss rafter; **Roofing:** aluminium, corrugated iron, ; **Sub-floor:** vapour barrier, walls and ventilation; **Timber:** air and kiln drying, glulam, native, pit-saw and preservative treatments; **Wall constructions**: earth, log, slab, solid timber, raupo and stone; **Weatherboards**; and **Windows:** glass, aluminium, steel and timber frames.

Acknowledgements

This research has used a wide range of New Zealand archival records, formal publications and contemporary newspapers. Each topic has been investigated in terms of published and unpublished materials such as catalogues, leaflets and other ephemera. In general, it has been found that much of the material of interest is beyond the lifespan of possible living respondents, so use has been made of contemporary reports, whether in newspapers, journals or books. Formal architectural and general history books have helped provide background, but principally original historical sources have been used – contemporary books, articles, newspapers, films and correspondence.

The development over the past decade of internet accessible and searchable archive indexes, library catalogues, books, journals and newspapers has opened a rich resource for historical research, allowing the tracing of what would have once been impossible trails. Automated Optical Character Recognition (OCR) has provided powerful access to millions of pages of early newspapers, while the voluntary work of those involved in genealogy has opened up the fine details of many archives. These improvements are far from perfect, so although the breadth of resource has improved, research time and skills have not changed. For example, in Papers Past (paperspast.natlib.govt.nz), the character string "&c" (commonly used in advertisements to indicate other products are available) is often converted through OCR to "ice", confusing any research exploring early use of thermal insulation.

However, electronic access has not yet replaced the careful examination of library and archive resources including hard copy archives, newspapers, microfilm and microfiche, books and journals which provide access to material that is unavailable in electronic or online format.

Thanks are due to the many building owners, archivists, librarians, owners of second hand bookshops, sellers of old New Zealand material on Trademe, heritage architects, observant builders as well as the staff of local museums, Historic Places Trust (now Heritage New Zealand) and today's building industries from around NZ and the world who have helped provide much of this material.

Geo-location maps have been generated using BachGeo (www.batchgeo.com).

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- **House owners and occupants:** of various houses I have asked for information and who without exception have been supportive of this work
- **International Libraries:** Library of Congress, British Library, National Library of Australia, State Library of Victoria, State Library of NSW, Historic Houses Trust (Sydney) Caroline Simpson Library.
- **Museums**: Te Papa, local museums including: Appleby Fire Museum, Central Otago, Nelson, Motueka, Otago, Puke Ariki New Plymouth, Wellington's Museum of City & Sea.
- **NZ Libraries**: Parliamentary Library, National Library, Alexander Turnbull Library, Dunedin, Christchurch, Wellington & Auckland city libraries as well as local libraries in Hutt City, Westport, Whangarei
- **National Library of New Zealand and Alexander Turnbull Library online resources**: PapersPast, AtoJsOnline, Matapihi, Tapuhi, IndexNZ, DigitalNZ, NZ Libraries Catalogue, Transactions and Proceedings of the Royal Society of New Zealand 1868-1961
- **Online & electronic resources:** NZ Electronic Text Centre (VUW), New Zealand Gazette Archive, NZ Society of Genealogists, New Zealand Legal Information Institute, University of Auckland's Early New Zealand Statutes, Statistics New Zealand Yearbooks, GeoNet
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Even with this amazing support from a wide range of people, all errors and omissions remain the sole responsibility of the author.

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Table 1 provides conversions from imperial to metric.

Table 1: Imperial to Metric Conversion

Weight	1 ton = 20 cwt = 2240 lb = 1,016kg = 1.016 tonne 1 cwt = 1 hundredweight = 4 qtr. (12.7kg) = 112 pounds = 50.8kg 1 keg nails = 100 lb = 45.4kg;
Pressure	1 psi = 6.9 kPa
Distance	1in (also written 1") = 2.54cm 1ft = 12in = 0.3048m 1yd = 3ft = 36" = 0.9144m
Area	$1ft^2 = 0.093m^2$ $1yd^2 = 0.836m^2$
Superficial Foot (super ft)	1ft by 1ft (Timber 1 super ft = 1ft x 1ft x 1" thick) Equivalent to North American "board foot" for timber Used for glass imports 1890-1935
Thermal resistance (R)	$1\ ft^2\ hr.°F\ /BTU = 0.176110m^2.°C/\ W^{-1}$

Table 2 provides an extract from the "Schedule of Measurements for Conversion to a Uniform Tonnage Basis" for building materials, required to be used in preparation of port statistical returns (Census and Statistics Office, 1924b, p. xv). For this research, the term *cask of cement* is assumed to have the same meaning as *barrel of cement*. Unfortunately, originally the conversion factor was not constant. Van Oss (2006, p. iv) notes the US barrel of cement varied in weight from 265 to 380 lb (120.5kg to 172.7kg) depending on the type of cement, reporting source and reporting region.

Table 2: Conversion Factors (Building materials)

Product	Units/ton	kg
Bricks	320	3.2
Cement, bags	18	56.4
Cement, casks	6	169.3
Timber - hardwood (Sup ft)	320	3.2
Timber - softwood (Sup ft)	480	2.1

Conventions

Values are given in original units (weight or value) unless otherwise specified. Countries are referred to by the name used at that time e.g. Czechoslovakia rather than Czech Republic.

Prices are given in the currency of the day. To convert to modern values, the Reserve Bank of New Zealand CPI calculator may be used:

http://www.rbnz.govt.nz/monetary_policy/inflation_calculator/

Direct quotes are given in double quote marks, with long quotations given as indented text. Italics are used for book titles, and to highlight words, or groups of words, with specific, trade, statistical or other special meaning. Normally only the first use will be italicised.

Image sources are referenced either in the text which first refers to them or in a footnote. Where not referenced they are the author's own work

In order to minimise the repetition of references to the various statistics, two summary tables of references are provided in the Appendix (page 326).

Abbreviations

Table 3 lists the abbreviations used in this thesis.

Table 3: Abbreviations

ABC	Automated Building Components Inc.
AEWS	Army Education Welfare Service
ANZS	Australia and New Zealand Standard
ATL	Alexander Turnbull Library (www.natlib.govt.nz/atl)
BRANZ	Building Research Association of New Zealand
c.d.v.	current domestic value
c.i.f.	cost, insurance and freight (value)
DHW	Domestic Hot Water
DPC	Damp Proof Course (used under bricks, etc)
DPM	Damp Proof Membrane (used on ground)
DSIR	Department of Scientific and Industrial Research
EBANZ	Earth Builder's Association of New Zealand
f.o.b.	free-on-board (value)
FTA	Fletcher Trust Archives (www.fclarchives.co.nz)
GPR	Ground Penetrating Radar
ICI	Imperial Chemical Industries
LBANZ	Log Builders' Association of New Zealand
n.o.d.	Not Otherwise Defined
NASH	National Association of Steel Framed Housing Inc.
NZBC	New Zealand Building Code
NZS	New Zealand Standard
P.T.&G.	Plain, Tongue and Groove (also known as Parallel Tongue and Groove)
T.&G.	Tongue and Groove
PPG	Pittsburgh Plate Glass process
TPA	Timber Preservation Authority
UK	United Kingdom
USA	United States of America

Photograph Sources

Table 4 gives the sources of photographs and where known the photographer.

Table 4: Photograph Sources

Figure	Image Source	Photographer (if known)
23	ATL Ref: 1/1-002623-G	Frederick Ashby Hargreaves
24	ATL 1/2-003135; F	
34	ATL E-455-f-039-4	
40	ATL 1/2-029026-G	
41	FTA 6242P/19	
43	FTA 6240P/14	
44	FTA 6240P/9	
46	ATL 1/2-078096-G	
48	ATL PAColl-3039, G-648-½-APG	Godber Album
49	FTA 9104P/40	
50	ATL 1/2-029351-F	
51	ATL 1/2-029142-F	
55	Graeme Beattie	Graeme Beattie
61	Museum of NZ Te Papa Tongarewa Ref C.001712	James McDonald
62	Museum of NZ Te Papa Tongarewa Ref B.023521	George L. Adkin
81	ATL 1/4-091167\F	Robert E. Wells
90	FTA 6021P/1	
91	FTA 6021P/2	
96	David Kernohan	David Kernohan
109	FTA 6144P/76 . 6144P-76	
112	NZ Fibreglass Ltd.	
110	Mary O'Keeffe	Chris Jacomb

1 Introduction

On 14 September 1792 a sealing gang landed at Luncheon Cove, Dusky Sound. By the end of November 1792 "they had completed a dwelling house, 40ft long, 18ft broad, and 15ft high" (12.1m x 5.5m x 44.6m) (McNab, 1909, p. 93). This was probably the first European house constructed in New Zealand, built and clad in the tradition of boat builders in wood cut or split from trees growing nearby. In early December the crew experienced an earthquake, the first for a New Zealand European style house (Raven, 1914, p. 512).

Over the next 190 years, New Zealand house building evolved, changing not only because of knowledge gained through the country's close involvement in international trade but also because of the innovation, imagination and interests of its inhabitants.

It would appear that by the 1880s the basic structure of the New Zealand house was largely established. It comprised a timber frame, weatherboard cladding and corrugated iron roofing. The following century led to local manufacture of most of the materials required, the adaptation of international or invention of local technologies of building, and the development of a skilled workforce. As noted in an article in "*The Architectural Review*":

> "Tradition has rendered the techniques of timber uses so automatic that the phrase 'according to the best trade practice' could almost completely specify the construction of a normal house" ([Martin], 1959, p. 222)[1].

This research will explore the development of building techniques used in the New Zealand house from the earliest European settlers to the demise of the made-in New Zealand house by the early 1980s, seeking to understand their origins and development.

[1] This comes from an article on New Zealand in "Commonwealth 1: Special Issue" edited by Nikolaus Pevsner. The acknowledgements suggest this piece was written by the New Zealand correspondent.

1.1 Background

People's daily lives are intertwined with their houses and as a consequence much research has focused on the development of house design and appearance. However, there has been no systematic and comprehensive examination of the development of house building techniques, where these originated and why they were used. This is the gap in knowledge addressed by this thesis.

The thesis will examine how the New Zealand house developed from the 1790s to the 1980s (Section 1.6). It will explore how and why the unique combination of environment, resources, skills and imports led to the creation of the 1980s *made in New Zealand house*. It examines the drivers for the use of local and imported techniques, and explores what led to their modification for the local environment.

To the victor go not only the spoils, but also the luxury of writing the history. Conquering kings, armies and pharaohs have all worked to ensure their version of history was left as the truth. For example, knowledge of the origin of the caryatid is from Vitruvius, the Roman historian reporting on the victory of the Greeks over the Caryae (Vitruvius Pollio, Morgan, & Warren, 1914, p. 6 (Book I, Chapter 1, Para 5)). The obliterated Caryae, if Vitruvius was correct, cannot offer their version (T. G. Smith & Vitruvius Pollio, 2003, p. 214).

In modern New Zealand stories have also evolved to better support the victors, these being the successful businesses that defeated, conquered or subsumed their competitors. A consequence is that tracing how houses came to be built in the way they are is not simple. Often the story is only found through exploring hidden or previously overlooked routes.

This thesis will explore the development of the building techniques that form the the structure and construction of the New Zealand houseto 1982. It focuses on the typical timber-framed house, but also deals with other construction systems used in permanent dwellings such as earth, brick, stone and concrete.

It will examine a selection of the most important techniques, exploring the combinations of the effects of environment, local resources, skills and imports. It will look for the key drivers in the use of local and imported techniques, and identify the concerns that led to their modification for the New Zealand environment.

1.2 Research Question

Where, why and when did the techniques used in the 1980s New Zealand house shell (exterior and interior) originate?

1.3 Research Aim

The research will undertake a systematic investigation of the origins and use of techniques for building the New Zealand house shell (exterior and interior) between 1792 and 1982.

1.4 Research Objectives

To address the broad subject area covered by the research aim, the following research objectives have been identified:

1. **Select and document** the principal building techniques (materials and technologies) for detailed investigation.
2. Construct the **historical time line** of five key materials found in New Zealand houses (earth, stone, concrete, timber, and ferrous metals).
3. Trace and document the historical time line of the various techniques (materials and technologies) that support the **named components** of the New Zealand house (foundation, floor, walls, fenestration, and ceiling/roof).

The use of the proposed five key materials can be traced back to the earliest days of European settlement. They continue to be used, although nowadays earth and stone only to a limited extent. The term *component* includes the main constructional parts of the house, from the ground to the roof. The changes in these will be traced over the time period, with case studies used to explore selected issues in greater depth.

Many of these techniques were imported, but they were then modified to suit the local environment. The thesis will explore when, why and how these changes were made to the selected techniques.

1.5 Coverage

This thesis is concerned with the development of the techniques that supported the development of the New Zealand house. For this purpose, **techniques** are divided into two headings:

- **Material**: A product which is used, with or without additional processing, in the construction of a house e.g. cement, brick
- **Technology**: An idea or system which is implemented using a material to construct all or part of a house e.g. nail, perimeter foundation wall

A technology may form part of a building system, as an example the nail is a technology but it is used in timber framing which is a building system.

It is also important to differentiate between construction and structure:

- **Construction**: envelope or surface materials
- **Structure**: material supporting the construction

Thus a brick veneer wall construction could have either a timber-frame or steel-frame structure, while a double-brick cavity wall is both the structure and construction.

1.6 Time Period

Three important changes lead to the selection of 1982 as an appropriate endpoint.

Firstly, within a few years of its election, the 1984 Labour government had dismantled much of the protection or encouragement of local manufacture (King, 2003, p. 487). Secondly, the late 1980s saw the closure of much local manufacturing which shifted overseas, whether as a consequence of accident, as was the case in the 1990 fire that destroyed McSkimming's Benhar sanitary ware factory (Section 5.2.2.1), or the changes in technology coupled with Government policy that led to the 1991 closure of the NZ Window Glass Whangarei plant (Section 6.6.2). Thirdly, 1981 saw the removal of the dwelling construction questions from the Census (Section 4.1).

Together these led the research to focus on 1792 to 1982, a period of 190 years from the construction of the first European house to a house which could almost be built entirely with New Zealand manufactured materials and technologies. Figure 1 shows such a "made in New Zealand" house in the Nelson region. Built in 1970, from the brick foundation walls to the corrugated iron roof, the house is almost totally constructed from New Zealand grown, manufactured or modified materials and technologies.

Materials	**Made or Originated in New Zealand**
Timber	Native timbers, inc. rimu, matai
Concrete	Cement
Brick	Foundation wall
Ferrous Metal	Corrugated iron. Nails.
Components	
Foundation	Concrete perimeter
Floor	Concrete Basement, Suspended Matai
Walls	Hardboard, Softboard & Weatherside
Openings	Glass, timber frames
Ceiling/roof	Soft board, truss roof, corrugated iron
Services	
DHW	Cylinder & element
Space heating	Electric heaters
Sanitation	Toilet, hand basin, sinks, taps
Lighting	Wiring, switches, plugs & shades

Figure 1: Last of the 'All-New Zealand' Houses?

This thesis explores part of its story.

2 Research Method

This chapter develops the scope and coverage, sets out the organisation, and provides a description of the research methodology. It concludes with a brief overview of the thesis.

2.1 Organisation

Francis Duffy divided the building costs for commercial office buildings into three layers: shell; services; and scenery (Duffy, 1990, pp. 17–18). Brand (1997, pp. 12–13) developed this further by including a fourth category "set", described as "all the things that twitch around daily to monthly" (Table 5). Overarching these layers is society which establishes the conditions within which buildings exist.

Table 5: Buildings over Time

Term	Description
Society	Micro- and Macro-environment within which the building exists
Shell	Structure, which lasts the lifetime of the building (UK 50 years, North America 35 years)
Services	Cabling, plumbing, air conditioning, and elevators (15 years)
Scenery	Layout of partitions, dropped ceilings, etc. (5-7 years)
Set	Shifting of furniture by the occupants (Variable: days to months)

Table 6 applies this breakdown to the New Zealand house, adding legislative requirements from the New Zealand Building Code (NZBC). NZBC Clause B2 Durability sets out the time period during which different building elements must continue to satisfy the performance requirements (Department of Building and Housing, 2011a, pp. 3–4). Table 6 provides a structure to meet the research objectives by separating the layers based on longevity.

Table 6: NZ House over Time

Layer	Longevity	NZBC Clause B2	Example	Description
Shell	Life	50 yrs.	Structure and its components	• Sub-floor (piles), Floor, Wall, Fenestration, Roof • Stone, Timber, Concrete, Steel, Glass • Fixings: nails, screws
Services	15 yrs.	15 yrs.	Cabling, plumbing, etc.	• Sanitation: cold & hot water, sewerage, toilets, basins • Distribution: pipes, wiring • Fuels: solid, gas, electricity, oil
Scenery	5-7 yrs.	5 yrs.	Layout	• Finishes: Paint, wallpaper, decoration • Built-in heaters & lighting
Set	Flexible	Not covered	Shifting of furniture	• Furniture, appliances, etc. • Space heating & cooling plant and equipment

This research is only concerned with the shell layer. Although some aspects of the set may be considered as semi-permanent fixtures, such as a central heating system, they are not included. Table 7 cross-tabulates the different materials (rows) against the components (columns), although not all materials or components will be covered in this research. The five materials selected as key to the development of the NZ house are shaded.

Table 7: Research Coverage by Component

Topics (Key)	**Shell (Components)**				
Material	**Sub-floor**	**Floor**	**Wall / Ceiling**	**Fenestration**	**Roof**
Local Plant Materials		✔	✔		✔
1. Earth & Brick			✔		✔
2. Stone	✔	✔	✔		
3. Cement & Concrete	✔	✔	✔		✔
4. Timber	✔	✔	✔	✔	✔
Other plant materials		✔	✔		✔
Wood Products	✔	✔	✔	✔	✔
5. Ferrous Metals		✔	✔	✔	✔
Non-ferrous metal			✔	✔	✔
Glass				✔	
Plastics			✔	✔	✔
Plaster			✔		
Thermal Insulation		✔	✔		✔

Table 7 shows that a linear approach is not suitable for this research. This matrix will be used to guide the discussion of each topic to ensure complete coverage.

The thesis structure that allows for exploration of the individual topics and their interactions is set out in Table 8.

Table 8: Thesis Structure

Chapters	Description
1. Introduction	Background, coverage
2. Methodology	Research approach & methodology
3. Construction	
Construction & Structure	1858-1981 Censuses of Dwellings (wall & roof)
Imports	1870 – 1970 Import Statistics
4. NZ Publications	Newspapers, Trade Training, Do-it-yourself, Design, Business & Product Histories
5. Materials	
Local plant materials	Raupo & other native plants
Earth and Fired Earth	Sod, cob, adobe, pisé, wattle-and-daub, mud-and-stud, brick
Stone	Potential and practical building stones. Successes & failures.
Cement & Concrete	Imports. Lime & cement production. Concrete
Timber	Native (indigenous) & exotic timbers. Processing, preservatives, manufactured timber products (plywood, particle board)
Ferrous metals	Early attempts at production. Imports. Cast iron, wrought iron & steel
6. Components	
Sub-floor	Piles, wall foundations, ventilation and moisture
Floor	Suspended floors, Concrete slab-on-ground. Moisture control
Wall - structure	Timber-frame, light steel-frame, concrete (monolithic and block)
Wall – interior lining	Wet systems, dry systems
Wall – ext. cladding	Weatherboard, building paper, fibre-cement boards, pumice boards
Fenestration	Imports & NZ made glass, frames
Roof	Structure (strutted & truss), roofing (clay, concrete, corrugated iron & metal tiles)
Thermal Insulation	Cork, Mineral wools, Pumice, Perlite, Vermiculite, Macerated paper, Reflective foil.
7. Case Studies	
Nails	1860 to 1965.
Hollow concrete blocks	1904 to 1910
Camerated concrete	1908 to 1920
8. Discussion	Chronological & country of origin, Dating a house
9. Conclusions	Conclusions
References	
Appendix	Chronological classifications. Statistics references. Summary table

2.2 Scope

This thesis is concerned with the evolution of building techniques, not the people who used them, the behaviours the techniques encouraged (or discouraged) or the cultural consequences. The social history, in many cases, cannot be isolated from the technical history but the research driver is the latter, not the former.

The focus is on the majority of houses. Although some techniques adopted early by the wealthy may become common in most houses this can take many years. As an example, the English ice house (providing seasonal storage for natural winter snow and ice) has a history dating back to at least 1633 in the homes of the wealthy, but only in the 1930s did electrical refrigeration bring this service to more modest homes (Hardyment, 1992, pp. 100–108).

Many other technical and societal changes have supported changed building techniques, but are excluded from this thesis, as set out in Table 9.

Table 9: Exclusions

Layer	Topics	Description and Examples
Society	Codes & Standards	Local Government by-laws; Standards (NZ or imported); NZBC
	Commerce	Buying & selling of houses, "Parade of Homes" and show homes, catalogues, building movers
	Economics	Issues of cost or cost benefit of one technique against others, including Government subsidies or special support
	Education	Development of professional or trade training.
	Legislation	National and Provincial (pre-1876) legislation, local by-laws
	Prefabrication	Building transport, Whole-house or Component factory manufacture
	Professions	Development of the trades & professions - surveyors, quantity surveyors, engineers, architects, carpenters, plumbers, valuers
	Research	Materials testing. Building and construction research organisations
	Tools	Specialist hand and power tools (initially powered by water and steam but in more recent years electricity, gas and compressed air)
Shell	Materials	Non-ferrous metals and Plastics
Services	Energy	Electricity, Gas (town and natural), Liquid fuels (oil, plant and animal), Solid fuels (wood, coal)
	Services	Lighting, DHW, Space Conditioning, Water and Sanitation
Scenery	Decorative Finishes	Paint, wallpaper
	Design & Style	Appearance and fashion
	Fittings & Fixtures	Door knobs, Handles, Locks, Joinery

In the course of the research material has been collected on some topics which are omitted from this thesis and some of which has been published, for example on early New Zealand building controls (Isaacs, 2012).

2.3 Summary Review

Chapter 1 sets out the structure and background to the thesis. It sets out the research aim and objectives, as well as defining key terms and the research coverage.

Chapter 2 describes the thesis research methodology, based around the society, shell, services, scenery and set layer model. The research is primarily concerned with the shell layer. The house is divided into components (sub-floor, floor, wall/ceiling, fenestration and roof) which are matched against materials or technologies. Chapter 2 also sets out the research scope.

Chapter 3 provides a review of New Zealand publications dealing with house construction. These include: early newspaper articles; trade training publications; do-it-yourself guides; house design and business; and product histories.

Chapter 4 reports on analysis of the 26 national censuses conducted from 1858 to 1981, as well as early Nelson and Auckland censuses. A question was asked about the materials of the house outer walls, while from 1961 the roof materials were also requested. Limitations of the census and use of the data are discussed. The census results are analysed both in terms of the construction (appearance or surface materials) as well as the structure (support).

This chapter also explores official import statistics and their use to understand the source of selected materials. Galvanised iron is used as an example to trace changes in the provision of statistics and to illustrate the types of information that can be derived.

Chapter 5 examines the key materials listed in Chapter 2: early settler use of local plant materials; earth and brick; stone; cement and concrete; timber; and ferrous metals including cast iron, wrought iron and steel.

Chapter 6 examines the development of a range of other materials and technologies, whether imported or made locally, based on building components:

- **Foundations**: piles, perimeter foundation walls
- **Floors**: suspended timber floors (including: sub-floor moisture control, ventilators and damp proof membrane), concrete slab-on-grade (including moisture control)
- **Wall structure**: timber-framed (including slab, solid timber, light timber framing, nail plates), light steel framing, monolithic concrete (including poured, Oratonu patent, Pearse patent) and hollow concrete blocks
- **Interior linings**: wet systems, dry systems (fibrous plaster and plaster board)
- **Exterior claddings**: weatherboards, building paper, fibre-cement boards, pumice boards
- **Fenestration**: imported and locally made glass, window frames
- **Roof**: structure (strutted and truss roofs), slates, shingles, corrugated iron, metal roof tiles
- **Thermal insulation**: cork, man-made mineral insulation, pumice, perlite and vermiculite, macerated paper, reflective foil

Chapter 7 provides a series of case studies which explore the arrival, development and diffusion of three building techniques:

- **Nails** from 1860 to 1965
- **Hollow concrete blocks** from 1904 to 1910
- **Camerated concrete** (type of monolithic concrete) from 1908 to 1920

Chapter 8 brings together the findings from the previous chapters to explore the origins of the techniques, both in terms of the country of origin and local manufacture, that helped create the 1980s New Zealand house. A series of graphs provide guidance for house dating based on the presence (or absence) of the different materials or technologies. Finally it provides conclusions and recommendations for future research.

Bibliography provides the list of references.

Appendix provides additional information in the form of tables on different approaches to time classification from a number of NZ publications; a summary table of references to census and import statistics; and a summary table of the techniques discussed in Chapter 8.

3 New Zealand Publications

This section explores literature where aspects of the development of New Zealand building techniques have been documented. International comparisons are discussed in the relevant sections, while Chapter 8 examines the wider situation.

It examines the support for the creation (and alteration) of New Zealand houses through publications including those for for the professional or do-it-yourself enthusiast. It documents how house design has been covered in a range of publications including newspapers, trade and do-it-yourself publications, reviews and overviews, and finally examines published business and product histories.

3.1 Early Newspapers

Early local newspapers not only included advertisements for tools and materials but also for the hire of tradesmen – examples are given in Section 5.2.1.

Newspapers regularly included extracts of interest culled from overseas newspapers. The weekly Otago Witness published a series of articles in 1862 in the "Agricultural and Pastoral" section under the heading "Economic Building … different styles of cheap building":

- **Concrete**: entitled "M. Coignet's Concrete", was reprinted from the "*South Australian Register"*, of June 4, 1857 (Otago Witness, p. 3, 7 Jun 1862), and was followed by a further article by B. Herschel Babbage reprinted from the "*Farm and Garden"* (Otago Witness, p. 6, 21 Jun 1862).
- **Pisé:** was reprinted from the *Yeoman* (Otago Witness, p. 3, 14 Jun 1862) with a brief addition in a later article referencing Wall's "*Cottages for the Peasantry and for Emigrants"* (Otago Witness, p. 6, 21 Jun 1862).
- **Adobe**: was discussed only in the editorial summary (Otago Witness, p. 4, 28 Jun 1862).

On completion of the series, the editorial concluded:

> "Our object in thus entering into details has been to lay the advantages of each of these three styles of economical building clearly before our readers, in the hope that some may be induced to

> give one or other of them a trial, as we feel convinced that it only needs a fair trial to make the superiority of these systems of building abundantly manifest. In the neighborhood [sic] of town, or where lime is readily procurable, concrete is undoubtedly the best; the farmer or runholder in the interior will find the pisé the cheapest and most convenient; and the digger will, by means of the cheap and simple 'adobe,' be able to have a warm and cozy cottage, instead of a damp and chilly tent, and may thus secure himself against the rheumatic and other diseases, which are, as often as not, the result of insufficient shelter" (Otago Witness, p. 4, 28 Jun 1862).

Although they have been used for tracing and elucidating the development and distribution of the technologies, newspapers (daily and weekly) and journals can only be considered as surrogates for actual activity. Published items are limited by:

- **the interests of the newspaper:** the monthly trade magazine *Progress* (later *Building Progress*) reported in detail on building and construction issues, but this was not the case for more general newspapers;
- **what was 'news' in that location at that time:** not everything of relevance to building and construction was of interest. When a large house, in the course of removal, was left standing for days in Colombo St for several days complaints were made to the Christchurch City Council and the Commissioner of Police (Lamb, 1963, p. 64). The local daily newspaper (*The Press*) did not mention any problem, while the other local newspaper reported briefly that "part of the A.1. Hotel, Colombo street" had been moved and "deposited in the midst of Lincoln road, where it now remains" (Lyttelton Times, p. 2, 31 Oct 1865); and
- **payment for advertising**: Oratonu patent concrete was invented in 1911 by a Dunedin based company (Section 6.3.3.2), but the first newspaper mention was a Christchurch advertisement in 1912 (The Press, p. 18, 24 Aug 1912).

To achieve an improved record of activity, it would be necessary to trace specific techniques through their actual use but this would only be possible by detailed examination of either building permit paper records or site inspections, and was outside the scope of this research.

3.2 Materials and Trade Training

Books about houses and how to design and build them from England, the United States of America and Australia have been available on the New Zealand market since the earliest days of settlement. For example in 1843 Nelson shopkeeper C. Elliot had for sale, along with books of religious instruction and books for children, *Works of Instruction* which included:

> "Pocket Directors and Price Books for Engineers, Mill-Wrights, Cabinet-Makers, Carpenters, Smiths, Brick-layers, Stone Masons, Plasters, Slaters, Plumbers, Painters, Glaziers, &c." (Nelson Examiner and New Zealand Chronicle, p. 297, 12 August 1843)

Tradesmen also travelled with their books. Copies of some of these early instruction books are held in many libraries, and in more recent years appear in local book and on-line auctions. For example, Mr Joseph Fowler arrived in Lyttelton in April 1863 where he worked as a builder (Evening Post, p. 8, 27 May 1910). It would seem that he had purchased in London a second hand copy of Peter Nicholson's 1797 book "*The Carpenter and Joiner's Assistant*", which he inscribed inside the back cover with "Joseph Fowler, Canterbury, New Zealand" while leaving the original purchasers' name in the front[2]. Other books have accidently travelled hidden within furniture[3].

Although buildings could be constructed from materials close at hand, by the late 1860s there was interest in better understanding these materials, demonstrated by papers delivered to the New Zealand Institute and its regional societies. Interestingly the first paper in the "*Transactions and Proceedings of the New Zealand Institute*" dealt with the opportunities for concrete buildings (Rosier, 1990).

British immigrant Edward Dobson was an engineer, surveyor, explorer and lecturer (Starky, 1993) He was already a published author with four books in Weale’s Rudimentary Series before he arrived in New Zealand in 1850:

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[2] Copy in possession of author

[3] Pers. Com. Concerning the history of a copy of 'Langley Chest Book' Barry Read, 25 Oct 2009

- No. 22: "*Rudiments of the Art of Building"* (Dobson, 1849b)
- No. 23: "*Rudimentary Treatise on the Manufacture of Bricks and Tiles"* (Dobson, 1850b);
- No. 25: "*Rudimentary Treatise on Masonry and Stonecutting"* (Dobson, 1849a); and
- No. 44: "*Rudimentary Treatise on Foundations and Concrete Works"* (Dobson, 1850a).

As Canterbury Provincial Engineer, Dobson was involved in a range of works, but was also interested in education. He gave public lectures, covering a range of engineering and construction topics, including a series of four lectures on foundations at the Christchurch High School in September 1866, organised "by the directors of the High School who wished to provide pupils with instruction in science and mechanics" (Dobson, 1866). For participants, ten books published in London were recommended, two of which Dobson had authored ("*Art of Building"* (Dobson, 1849b) and "*Foundations and Concrete Works"* (Dobson, 1850a)). The earliest book in the reference list was published in 1827 with the most recent in 1863[4], suggesting good connections between New Zealand and England. These lectures were judged "the first attempt to make physical science a branch of regular instruction in this colony" (Starky, 1993).

In 1869 Dobson moved to Australia as public works had almost stopped in Canterbury, but returned in 1876. In 1877 he published "*Pioneer Engineering: a treatise on the engineering operations connected with the settlement of waste land in new countries"* (Dobson, 1877), which drew on his New Zealand experience (Dobson, 1868, 1869) but was published in England, probably due to his residence in Australia from 1869 to 1876 (Starky, 1993), as well as his existing relationship with the publisher.

In 1885 he gave twelve lectures on building construction at Canterbury College (Dobson, 1885), and in 1887 gave the opening address to the School of Engineering at Canterbury

[4] Full list of books (as no publication dates were given in the advertisement, all possibly relevant dates are provided): *Art of Building* (Dobson, 1849b); *Foundations and Concrete Works* (Dobson, 1850a); *Limes and Cements, and Light Houses* (Burnell, 1850) (Weale's Rudimentary Series)**;** Egypt (Lane, 1837), *Elgin Marbles* (Ellis, 1833), and *Pompeii* (Clarke, Donaldson, Gell, & Mazois, 1832), published by the Society for the Diffusion of Useful Knowledge; Cresy's *Encyclopaedia of Civil Engineering* (Cresy, 1847); *Tennant's Ceylon* (Tennent, 1860); Lyell's *Antiquity of Man* (Lyell, 1863); Scrope's *Volcanoes of Auvergne* -(Scrope, 1858).

College (Figure 2), largely concerned with issues of surveying (Dobson, 1887). He lectured there part-time until 1892. Dobson died in Christchurch on 19 September 1908 (Starky, 1993).

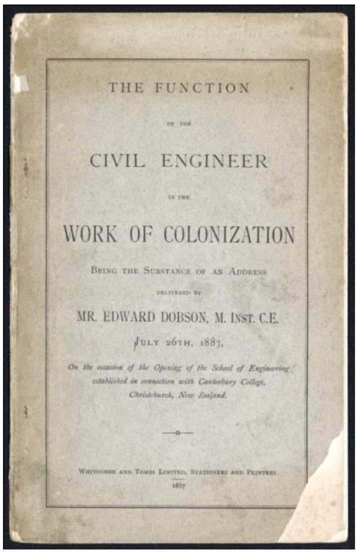


Figure 2: Edward Dobson's Opening Address, School of Engineering, 26 July 1887

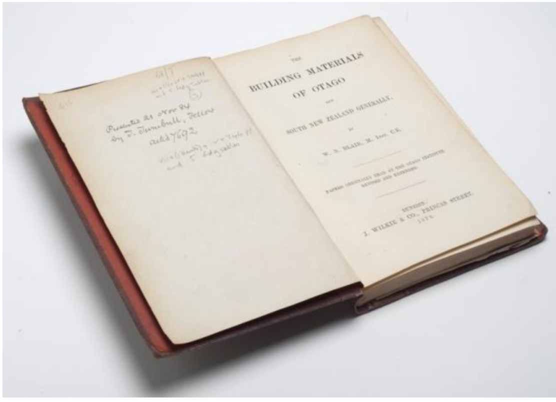


Figure 3: "Building Materials of Otago and South New Zealand Generally" by W.N. Blair.

William Newsham Blair's "*The Building Materials of Otago and South New Zealand Generally"* (Blair, 1879) was the first New Zealand published construction book. Scottish born and educated, William Newsham Blair was unable to find work following his training in civil engineering, so immigrated to New Zealand in 1863, aged 23. He was immediately employed to help develop infrastructure to support the recent discovery of gold. His later jobs included: District Engineer of Railways; consultant to the Dunedin City Council on gas works issues (Blair, 1870) and the town water supply (1877a, 1877b, 1882); and assistant and then Engineer-in-Chief of the Public Works Department. He died in Wellington in 1891 after a lengthy illness (T. Williams, 1993).

In 1875 and 1876, in a series of four papers delivered to the Otago Institute in Dunedin, Blair set out a detailed review of his and others research into the building materials of Otago. His first paper dealt with "*Building Stones"* (Otago Daily Times, p. 2, 14 Jul 1875); the second with "*Bricks"* (Otago Daily Times, p. 5, 29 Sep 1875); the third with "*Limes, Cements, and their Aggregates"* (Otago Daily Times, p. 3, 6 Sep 1876); and the fourth with "*Timbers"* (Otago Daily Times, p. 3, 1 Nov 1876). They were then published in the Transactions of the

New Zealand Institute (Blair, 1875, 1876a, 1876b), and in turn formed the basis of his book (Blair, 1879). Figure 3 shows the copy of Blair's book donated by Thomas Turnbull to the RIBA library. This 239 page book, published by J. Wilkie & Co., Dunedin and printed by Coulls and Culling, Dunedin, was the first New Zealand book to provide research and measurement based data on building materials (A. G. Bagnall, Williams, & Griffith, 1980a, 1980b). A page count reveals 40% of the book deals with stones, bricks, concrete and roofing slates, 18% with limes, cements and aggregates, 39% with timbers and 4% with metals, perhaps reflecting a desire to build in the more permanent materials. In the 1886 Yearbook, tree species and the timber industry were covered in six pages (pp. 216-221) while building stones had five pages (pp. 79-83) (Cooper & Stewart, 1886).

In the absence of other technical documentation, businesses used Blair's book for comparative advertising. Mr James McDonald (Section 5.4.3.4) was delighted to point out that Blair concluded the "Waihola Limestone (which is now called the Milburn Limestone) ... cannot be pronounced good" and that the Oamaru limestone which he used was "The BEST LIME for building purposes hitherto discovered in Otago" (Otago Daily Times, p. 3, 18 Dec 1888).

As more was learnt about the performance of timbers, papers on their qualities were also presented to the learned societies (L. J. Bagnall, 1886; Bartley, 1885). By the late 1880s earthquakes were also of concern, with both W.M. Maskell and Thomas Turnbull presenting papers on architecture and earthquakes to the New Zealand Institute in 1888 (Maskell, 1888; Turnbull, 1888).

The first New Zealand book relating to carpentry held by any library is the Department of Education's 1902 "*Handwork for Schools: Woodwork*" (Isaac, 1902). It provided basic training in the use of tools and instruction to make simple items, such as a folding chair. As well as "helping teachers who are taking up woodwork in school classes" it also set out the expectations for a two year woodwork course under the Manual and Technical Instruction Act 1900 (Isaac, 1902, p. 3).

It was not until 1944 that a New Zealand book more suited for adult learners was published. A set of five carpentry booklets, totalling 640 pages including assignments and correct answers, were prepared for the Army Education Welfare Service (AEWS) by Mr. R.H. Smith of Tauranga (R. H. Smith, 1944a). Designed for the training of adult soldiers, these five booklets covered the full range of skills required to construct a wooden building, from the planning, foundations, construction and completion. A separate book, also prepared by Mr Smith, was entitled "*Drawing for Carpenters and Joiners*" (R. H. Smith, 1944b).

Post WW-II, the AEWS booklets were not considered suitable for apprentices, as they had been designed for adults and did not relate to the Trade Certification Board syllabus (New Zealand Technical Correspondence School, 1951, Minute to Dr. Lee from R.W. Cumberworth, 8 July 1953), although they may well have been used by teachers to help with class preparation.

In 1951, the New Zealand Carpentry and Joinery Apprenticeship Committee inquired from the Government whether a "text book in carpentry and joinery" could be prepared for use by apprentices (New Zealand Technical Correspondence School, 1951, Letter dated 9 May 1951 from Commissioner of Apprenticeship to Director of Education), but action was slow. The catalyst was the National Housing Conference, held in Wellington from 4 to 7 August 1953, which was called to explore ways of dealing with post-WW II housing issues. A wide range of topics was covered, from reducing costs of construction, financing and land through to encouragement to assist those wanting to build their own home (National Housing Conference, 1953, General Information for Delegates and Observers). The Government's preliminary statement recognised that although the number of people employed in the building industry had increased since the end of the War, these numbers might not be sufficient (National Housing Conference, 1953 Item 2, Preliminary Statement by the Government, 24 July 1953).

The New Zealand Master Builders' Federation in its proposal to the conference, under item two concerned with reducing costs, was clear in noting the need for "an authoritative text-book on carpentry and joinery, based on New Zealand building practice" (National Housing Conference, 1953, Item 2(b), Summary of Views of Organizations). The concept was well accepted, with the Gasfitters Union requesting their trade should be included (National Housing Conference, 1953, Conference Proceedings Session 4, Agenda Item No. 2). The proposal was adopted:

> "That the Government should give immediate authority for the preparation of trade text books suitable for the electrical, plumbing and gas fitting, carpentry, joinery and plastering apprentices." (National Housing Conference, 1953, Records of the Conference. Conference Resolution No. 17 Agenda Item Number (20). 7 August 1953).

The logic behind the request was that increasing the numbers and quality of apprentices would ultimately result in more building tradesmen and a resultant reduction in the cost of housing. A Cabinet Paper *Preparation of Trade Textbooks in the Building Industry* was swiftly prepared and approved on 22 October 1953, with the first book to be "*Carpentry"* at an estimated cost £1,600 (New Zealand Technical Correspondence School, 1955, Cabinet Paper C.P. (53) 1099 22 Oct 1953).

As well as the AEWS booklets, the book "*The Australian Carpenter*" by C. Lloyd, first published in 1948 (Lloyd, 1948), and reprinted numerous times, was already well known in New Zealand. It was used as a base for the new carpentry textbook, but was completely rewritten to focus on the syllabus of the NZ Trade Certificate (New Zealand Technical Correspondence School, 1951, Minute to Dr. Lee from R.W. Cumberworth, 8 July 1953).

A committee was formed with representatives from the NZ Carpenters and Joiners' Union, Commissioner of Apprenticeship, NZ Master Builders' Federation, Post Primary Teachers' Association, Department of Education, and Technical Correspondence School (Minutes of Meeting 10 Feb 1954, New Zealand Technical Correspondence School, 1951). The committee met three times to develop the coverage and style of the proposed book (New Zealand Technical Correspondence School, 1951, Minutes for meetings: 8 July 1953; 17 February 1954; and 17 June 1954).

"*Carpentry in New Zealand*" was published in June 1958, and copies were distributed at a discount through the NZ Master Builders' Federation to apprentices, teachers and schools, while bookshops supplied copies at full price for other purchasers (New Zealand Technical Correspondence School, 1951, memo F58/5 2 July 1958 from Superintendent of Technical Education). As well as guidance on tools, measurement and construction, it covered the use of native and local exotic (notably pine) timbers.

The title page of the 1958 edition notes the book was "written and prepared for publication by The Technical Correspondence School of the New Zealand Department of Education" (Technical Correspondence School, 1958). However, the staff involved in the writing are not named in any official records, and continue to be anonymous (Government Printing Office, 1984; New Zealand Technical Correspondence School, 1955). Due to the illustrations staff of the Technical Correspondence School being fully employed on other work (New Zealand Technical Correspondence School, 1951, Memorandum for Director of Education from Principal, 25 March 1955), the near 500 illustrations (New Zealand Technical Correspondence School, 1951, letter from Superintendent of Technical Education to Minister of Housing, 23 May 1956) were prepared by Geoffrey Nees, a Wellington architect, who reported he was employing five draughtsmen to complete the work (New Zealand Technical Correspondence School, 1951, Letters from Mr Nees dated 14 June 1955, 25 Aug 1955).

Once the book was published and promoted, some industry participants felt it would lead to undesirable competition from do-it-yourself home owners. The NZ Master Builders' Federation was not happy with its promotion to "the 'Do It Yourself' householder" (New Zealand Technical Correspondence School, 1951, letter from Director NZMBF to Director of Education 14 July 1958), nor were the Otago Carpenters, Joiners and Joiners Machinists Industrial Union of Workers (New Zealand Technical Correspondence School, 1951, letter from Secretary to Minister for Education 4 August 1958). The concerns are interesting, as the Australian book was originally advertised as being suitable for the home handyman (A.N.B., 1948).

There were only compliments about the quality of the publication with, for example, the Director of the NZ Master Builders Federation writing to the Minister of Education offering their praise for the fine quality of "the excellent publication" (New Zealand Technical Correspondence School, 1951, letter from Minister of Education to Director, NZMBF 4 May 1953). The book was very popular, with some 33,600 copies printed between June 1958 and September 1973 (Government Printing Office, 1984, Notes inside cover of folder).

The publication continued unchanged, except for a new cover and conversion to metric units in 1977, until the third edition was published in 1980. The final printing was in 1987 (New Zealand Technical Correspondence Institute, 1977, 1980, 1987; Technical Correspondence School, 1958; 1966, 1973).

The only commercial opposition appears to have been the text "*Woodwork – for student, apprentice and handyman*" published in 1968 by Whitcombe and Tombs Ltd Its introduction states its purpose was to cover the scope of the School Certificate prescription. It also covered the full range of building work for a conventional timber-frame shed with either a suspended or concrete slab-on-ground floor and weatherboard or asbestos cement sheet cladding (Wilkins, 1968, pp. 9, 281–318). The revised metric edition was published in 1973 and a third edition in 1981 (Wilkins, 1973, 1981).

In addition to commercially available publications and standards, from the 1950s and 1960s the New Zealand Forest Service published guides on the use of New Zealand building timbers, including local (indigenous and exotic) as well as imported timbers (J. S. Reid, 1950, 1956, 1961). The Building Research Bureau (A. G. Wells, 1970), in 1970 renamed the *Building Research Association of New Zealand,* from 1959 to the end of 1982 published 232 bulletins on issues of concern to the industry.

3.3 Do-it-yourself

Do-it-yourself guides also have a long New Zealand history, starting with "*Brett's Colonists' Guide and Cyclopaedia of Useful Knowledge*" (Leys, 1883, 1897, 1902). The 830 page, 1883 publication provided guidance for building a new home (with four plans provided), creating a farm, making jam, or even building an icehouse (Leys, 1883, pp. 723–734).

The 1897 second edition (Leys, 1897) grew to 1208 pages and added another house design as well as a detailed specification prepared by architects Mitchell and Watt (Leys, 1897, pp. 1131–1147). The 1902 third edition (Leys, 1902) did not provide any additional house building information. Brett's importance was recognised in it being the only construction related book selected for a 1993 exhibition of the books which had shaped New Zealand (Bartel, Snell, Barr, & Barr, 1993, p. 12).

About 1900, R.J. Stark & Co, booksellers and stationers of Dunedin, published "Starks Practical Carpenter, Joiner, and General Mechanic" (R.J. Stark & Co., c1900) (Figure 4). This research found it is identical to books published by Cole's Book Arcade of Melbourne (Coles's Book Arcade, c1900) and Dymocks Book Arcade of Sydney (Dymock's Book Arcade, 1903), and all were printed in the UK. The text is identical to the UK published "Every Man His Own Mechanic" (Chilton-Young, c1886), even to the recommended London shops. Thus though New Zealand published, it was not a New Zealand written or based book.

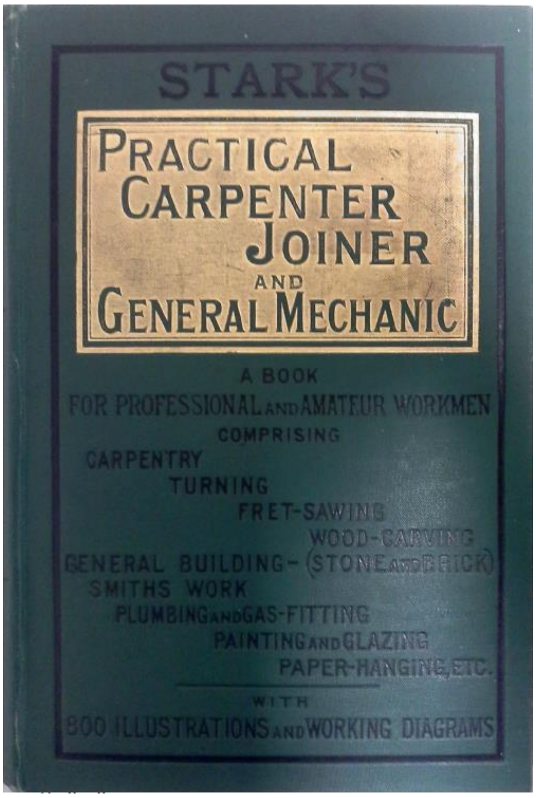


Figure 4: Stark's Practical Carpenter, Joiner and General Mechanic (c1900)

Figure 5: Do it yourself (1939)

"*Do-it-yourself Tells You How*" is the first New Zealand written and published book listed in the National Library catalogue specifically for the home handyman (Figure 5). The first edition was published in 1939, and its popularity demonstrated by the issuing of three editions in four years (The NZ Dairy Produce Exporter Newspaper Co., 1939; 1941, 1942). Enthusiastic amateurs reported on their construction experiences, such as Charlotte Preston Larkin's tale of building her adobe cottage (Larkin, 1949), or the Stephens family's 1950s pisé house (Stephens & Stephens, 1981) (Section 5.2.1).

More recently, the small size of the New Zealand market led to local editions. In the 1950s the "*Australian Picture Handyman*" (Colorgravure Publications, 1950a) crossed the Tasman after local adaption to become "*The New Zealand Picture Handyman*" (Colorgravure Publications, 1950b).

Interest in the restoration of older houses led to a number of local publications to guide the repair, renovation and refurbishment. Probably the first New Zealand book on this topic was prepared by architect Chris Cochran for the New Zealand Historic Places Trust in 1980, ultimately going through 3 editions (Cochran, 1980, 1984; 1991). The following year, successful renovator Neil Harrap self-published "*Buying & Restoring a House*" (Harrap, 1981) (Table 47). Martin Hill's "*Restoring with Style*" followed in 1985 (M. Hill, 1985). Stuart Arden and Ian Bowman's "*The New Zealand Period House – A Conservation Guide*" also provides an overview of the development of house styles and use of materials (Table 49) (Arden & Bowman, 2004, pp. 13–14). BRANZ's 2010 and 2011 Renovate series provide an age specific series based around a common core of guidance (Elkink, 2010a, 2010b, 2011a, 2011b; Pringle, 2010).

Guides for house purchasers, whether from consumer organisations such as "*Your Dream House*" (Consumers' Institute of New Zealand, 1976, 1982), "*Housing in Auckland*" (Auckland City Council Community Advisory Service, 1972), or commercial publishers "*Home Sweet Home*" (G. Wilson, 1981) towards the end of the research period were a popular way for home buyers to learn what to look for in older homes, notably when dealing with uniquely New Zealand problems such as the deterioration of totara timber piles.

Although international magazines were imported from the late 1960s, guidance was also briefly available in locally published magazines. "*HOW: New Zealand's magazine for the home handyman*" was published every two months from 1968 to 1972 in association with the Building Centres of New Zealand, and provided ideas ranging from repairing antiques to building a garage (Lambert, 1970, p. 1). According to the National Library of New Zealand catalogue other publications included: "*New Zealand Homes: the magazine for home builders and renovators*" which lasted only four issues from January to April 1979 and "*Hometime*" which was published monthly from February 1980 to July 1981.

3.4 Design and Construction

Although there had been at least two previous exhibitions of New Zealand housing (Skinner, 2008, p. 60), the Auckland School of Architecture's 1954 exhibition "*Home Building 1814-1954: the new zealand [sic] tradition*" with associated catalogue provided a chronological overview of housing (Table 46), complete with assessments of the designs. It also provided a single page on "The Development of Local Building Materials" which dealt with three materials (earthenware roofing tiles, Gibraltar Board and Vibrapac Blocks) made by the catalogue sponsors, Winstone Ltd (Garrett, 1954, pp. 20, 24).

The evolution of New Zealand house design has been explored in a range of published works, firstly for colonial architecture (Stacpoole, 1976) and then in the 1990s for bungalows (Ashford, 1994) and villas (Stewart, 1992). In the 2000s both the villa (Reynolds, Hansen, & Salmond, 2009) and the bungalow (Reynolds & Stock, 2014) have been re-examined. Toomath's 1996 book "*Built in New Zealand – The Houses We Live In*" was the first to explore in detail the American influence on the design of New Zealand houses (Toomath, 1996).

More recently "*We Call it Home*" (Schrader & Birkinshaw, 2005) provided a social history of state housing. Although each of these deals with building techniques, only Jeremy Salmond's "*Old New Zealand Houses 1800 – 1940*" (Salmond, 1989) provides an overview of the development of New Zealand building techniques. Salmond's text is based around three time periods (1800-60; 1860-1910; 1910-40), exploring the building techniques through illustrating their relevance to the changing New Zealand house design (Table 48).

A small number of publications, largely written by those involved in valuation, have examined changing house styles. Bates (1957), used houses in Auckland to trace changes in house planning, external and interior design, construction and other issues by decade from 1860 to 1955 (Table 50). He noted that changes in architecture, method or material style, except in the case of emergencies, could take several years. Cooke (1975) uses annotated exterior photographs of 385 houses to trace change from early historic houses through to 1975.

Beacon Pathway, as part of its research to improve the sustainability of new and existing houses, developed a typology to inform this goal (Page & Fung, 2008; Ryan, Burgess, & Easton, 2008).

3.5 Business and Product Histories

Some building product suppliers have produced their own historical publications: Winstone Limited (F. A. Simpson, 1965); James Hardie Industries (Carroll, 1987); and New Zealand Forest Products (Healy, 1982) although they tend to be based on the business development, rather than the products. Some of the larger construction companies have also commissioned histories: Naylor Love (Patterson & Naylor Love Construction Limited, 2010); Hawkins Construction (Ferens, 2010); Downer and Company (Downer and Company, 1983; Manning, 1983, 1983); John McLean and Sons (McLean, 2002); and Fletcher Construction (P. Shaw, 2009; J. Smith, 2009).

Some construction products have been researched and documented. "*Cast in Concrete*" looks at the use of this material from 1850 to 1939 (Thornton, 1996), while both "*Colonial Furniture in New Zealand*" (Northcote-Bade, 1971) and "*Furniture of the New Zealand Colonial Era*" (Cottrell, 2006) provide design, business and technology review of furniture as well as material of direct relevance to buildings. The most recent New Zealand housing design history only briefly acknowledges the role of changing construction techniques in shaping the design of the New Zealand house (Lloyd-Jenkins, 2004).

3.6 Summary

This chapter has provided an overview of sources for information on the development of the technologies and materials used in the New Zealand house. These publications and others specifically relating to the different techniques will be used in later chapters.

It has been shown that, newspapers and other regular publications have maintained interest in building, whether bringing to their readers' attention international discoveries or promoting local business activity. While limited by their specific interest, current news or the ability of businesses to pay for advertising, newspapers and journals offer a valuable view of activity at the time of publication.

This research has shown that trade training materials and publications were initially imported, but from the 1860s papers given to local learned societies and local schools started to develop a local view. Edward Dobson's book on pioneer engineering was published in London in 1877, while W.N. Blair's 1879 treatise on building materials was the first locally published book. Later in the study period, background and evidence based guidance material became available, notably from the New Zealand Forest Service (and its predecessors) or the Building Research Bureau which was formed in 1959. This research has for the first time traced the development of New Zealand education books. It was not until 1902 that a local carpentry book was published, albeit for school classes. Another 42 years lapsed before the AEWS published a set of five carpentry booklets for adult training in 1944. The 1948 "*The Australian Carpenter*" was available in New Zealand, and acted as the model for the Government Printer's 1958 publication for trade certificate students, "*Carpentry in New Zealand*." This remained the principal source of house building knowledge through its numerous reprints and three editions. Its commercial opposition, first published in 1968 with a metric revision in 1973 and a third edition in 1981, was aimed at School Certificate level students. Do-it-yourself guides have a longer history, with "*Brett's Colonists' Guide"* first published in 1883, with expanded editions in 1897 and 1902. This research has for the first time shown a 1900s book previously thought to be of New Zealand origin was in fact England-sourced and published. The first local home handyman guide was published in 1939. In later years, overseas publications were revised for New Zealand conditions. Perhaps the most popular topics were on selecting a house and the refurbishment of older homes, with a number of books published from 1976.

Although the first local publication exploring building materials might be considered as the catalogue to the Auckland School of Architecture's 1954 exhibition, it was limited to the sponsor's fine products. From the mid-1970s, a select number of books have explored specific house designs, with Toomath's 1996 book notably exploring links to the USA.

Business and product histories offer some background, although many are written from a business, rather than technology viewpoint. Concrete has been well served with a New Zealand history, but the same is not true for other materials, notably brick.

All of these publications have a common thread of exploring an aspect of the development of houses, but focused on their specific topic. None cover the broader issue of the development of the techniques involved in the construction of the shell of the New Zealand house, the subject of this research.

4 National Statistics

Understanding the development of the New Zealand house can either be based on detailed investigation of a limited number of buildings, or from broad data collected for some other purpose, such as census or import statistics. The first part of this chapter provides an analysis of the construction of the house shell based on census data from 1858 to 1981. The second part examines published import statistics for selected building products from 1870 to 1975. Together they provide an overview of changes in the construction of and materials used in the New Zealand house from 1858 to 1982. To minimise duplication, statistical publication references are listed in the Appendix (page 326).

4.1 Census Dwelling Statistics

From 1858 the regular censuses recorded the appearance of house walls. The reports stressed the importance of timber walls, but the proportion of dwellings with timber walls decreased from 1916 (Figure 10) until in 1981 "fewer than half of the country's dwellings were clad in timber" (New Zealand Department of Statistics, 1985, p. 119). But was this change in construction appearance matched by changes in the wall structure?

It was not until 1925 that the annual collection of statistics on building and construction activity commenced (Lloyd Prichard, 1970, p. 332), making census data the only way to trace changes in house construction over a long time period.

4.1.1 Early Censuses

Prior to the official censuses, the Crown Colony (1840 to 1852) statistics enumerated and classified for the main centres and other locations (Auckland; Wellington; Wanganui; Nelson; Akaroa; New Plymouth; and Dunedin, Port Chambers and country districts) the wall construction and roofing. The two centres with the longest time coverage are Auckland and Nelson (Hardie, 1954, pp. 33–37, 105–106).

From its earliest European settlement, Auckland was a city built of wood and raupo, as detailed in Table 10 for the decade 1842 to 1852 (Lloyd Prichard, 1970, p. 62, Table 21). The percentages give the proportion of that construction material for that year. It is clear that the vast majority of buildings were made of wood and the even more flammable raupo, with a steady decline (except for an unexplained 1848 blip) in the number of raupo houses following implementation of the Raupo Houses Ordinance 1842 (Government of New Zealand, 1842). Dwelling construction data was not collected in the 1851 census.

Table 10: Auckland Building Construction 1842 to 1852 (non-Maori population)

Year	Stone or Brick		Wood		Raupo		Total
1842	3	1%	331	76%	101	23%	435
1843	9	2%	447	77%	126	22%	582
1844	10	2%	444	79%	105	19%	559
1845	17	2%	603	84%	100	14%	720
1848	45	3%	987	65%	481	32%	1,513
1849	47	3%	1440	86%	187	11%	1,674
1851							1,938
1852	103	5%	1937	86%	157	7%	2,246

A similar pattern occurred elsewhere. Table 11 shows that although the New Zealand Company settlement of Nelson started in 1845 with similar proportions of wood (43%) and earth (49%) houses, just five years later wood was a clear leader (60%) over earth (30%) wall construction (Hardie, 1954, p. 106). There were fewer brick and even fewer stone buildings, with very small changes in their numbers from year to year.

Table 11: Nelson Building Construction 1845 to 1850 (non-Maori population)

Year	Stone		Brick		Wood		Earth		TOTAL.
1845	3	0.5%	50	8%	283	43%	324	49%	660
1846	3	0.5%	48	8%	290	49%	250	42%	591
1847	0	0.0%	54	10%	311	55%	196	35%	561
1850	6	0.8%	53	7%	458	60%	229	30%	766

Note: count includes both town and district

The data shows that during the earliest years of European settlement in both Auckland and Nelson, there was an increasing dominance of timber houses.

4.1.2 Census of Outer Walls and Roof

From 1858 to 1981 the national census of population and dwellings asked about the material of the dwelling outer walls, although until 1951 data was only collected for European, not Maori, dwellings. Data on roof materials for inhabited private dwellings were only collected from 1961 to 1981 (Statistics New Zealand, 2006a, pp. 59–63).

The coverage of dwelling wall construction has varied in censuses over time:

- 1858 to 1911 *Inhabited Dwellings*, excluding those occupied solely by Maori.
- 1916 to 1921 *Inhabited Private Dwellings and Tenements*, excluding Maori
- 1926 to 1945 *Inhabited Private Dwellings*, excluding Maori

- 1951 to 1971 *Inhabited Permanent Private Dwellings* including Maori.
- 1976 to 1981 *Occupied Permanent Private Dwellings* including Maori.

From 1874 to 1921 wall construction was reported not only for inhabited private dwellings and tenements, but also separately for unoccupied or under construction private dwellings (Census and Statistics Office, 1924a, p. 26). Pre-1926 reported numbers included temporary dwellings (Census and Statistics Office, 1931a, p. 3), although in the 1936 Census *Temporary Dwellings* numbered only 2,864 (0.8%) out of 339,846 private dwellings, while for comparison 15,222 (4.5%) baches or holiday houses were recorded.

For this research, which is interested in the overall trends, census data on wall and roof materials has been treated as a consistent time series.

Wall and roof material questions were last asked in the 1981 Census. They were then dropped as relatively little use had been made of data from previous censuses and there had been coding difficulties due to respondents providing brand rather than material names (e.g. the trade name *Fibrolite* rather than the generic term *asbestos* (Section 6.5.3).The 1986 Census report suggested this question could be supplanted by data from valuation records, which include details of roof and wall materials (New Zealand Department of Statistics, 1988, pp. 104–105).

However, previous experience with valuation records (Isaacs, Lee, & Donn, 1995, p. 63) found that they provide a snapshot at the time the records are analysed, but do not account for buildings that have been demolished (e.g. a house built in 1890 but demolished in 1950 will not appear in a 2012 analysis of valuation records). Additionally approximately 10% of residential valuation records lack a date, normally the decade, of construction. Together these make it difficult to develop a reliable time series. That study did not analyse valuation records for residential wall or roof materials, but noted that for commercial buildings the coding was based on the visible roof or wall appearance (Isaacs, 1996, pp. 82–85).

4.1.3 Using the Census

As there is no other nationally consistent time-series, census data provides a solution. However, five important issues must be considered.

Firstly the census is concerned with dwellings, not buildings (or houses). A dwelling is defined as "any accommodation unit which is self-contained at least in respect of sleeping cooking and dining facilities"(New Zealand Department of Statistics, 1981). A dwelling is not necessarily a building: a house may be one dwelling; but a block of flats will be a number of dwellings. This is relevant when considering both the number (one building may contain five dwellings) and the construction (which may differ for single dwellings and those in multi-storey buildings). When only a very small proportion of buildings contain more than one dwelling, it is not unreasonable to ignore this issue (New Zealand Department of Statistics, 1969, p. 5). It was not until the 1976 Census that a *not applicable* category was introduced for dwellings with another dwelling overhead (New Zealand Department of Statistics, 1975, p. 7) (see Section 6.3.4.5).

Secondly the census reports on what dwelling exists on census day, not what was there in the past. It does not record changes in the use of buildings, such as a single dwelling being converted to two or more dwellings, nor does it record demolitions. In theory it should be possible to make house-by-house comparisons across two or more censuses, but only if individual forms were retained and confidentiality requirements could be met.

Thirdly the census results are constrained by what the respondent reports, which may, or may not be correct.

Fourthly there is a limit on what can be tabulated for publication. In order to maintain confidentiality small numbers of respondents may make it impossible to publish any detail, with a count of 3 (of anything) the normal minimum published value. For example, the 1966 Census reported 5 dwellings with slab walls so could not give a regional breakdown.

Finally, society and terminology change regularly, requiring changes in census content and question wording. These changes can make it difficult to compare responses between censuses. This highlights the unyielding tension in the collection of census data between change and continuity (Statistics New Zealand, 1997, p. 54).

4.1.4 Census Questions and Reporting

One consequence is that over time there have been changes both in the coverage and presentation of census statistics. Until the 1936 Census, householders were provided with a brief list of possible materials e.g. in 1931:

> "whether wood, concrete, brick, stone, asbestos, iron, &c."

Just five years later, in 1936 more detailed instructions were provided:

> "A house with brick walls and wooden gables should be described as 'Brick'. Walls of galvanized iron secured to wooden studs should be described as 'Iron'. Where, for example, front and back walls are of wood and side walls of iron, the correct entry would be 'Wood and iron'."

From 1971 tick boxes were provided for six materials (*Wood or timber*; *Brick*; *Rough cast*; *Galvanised iron or tin (sheet or corrugated)*; *Wallboard of asbestos type*; and *Concrete*). For the 1976 and 1981 Censuses, eight materials were listed although the respondent could, as before, provide their own description (Statistics New Zealand, 2006c).

In the report of the 1858 Census, the first in which questions about dwelling construction were asked, the results were only reported under three headings (*Wood; Stone or Brick;* and *Other Materials*) with an additional heading added in 1861 (*Raupo*) and another in 1864 (*Tents*). These headings remained until 1874, when a further two were added (*Cob, Huts*) and *Wood* became *Wood, Iron or Lath-and-plaster*. In 1878 *Stone or Brick* became *Stone, Brick or Concrete*.

The published headings then remained mostly constant until 1916 when brick, concrete, iron, stone, and wood were separately enumerated. One consequence is that it is not possible to analyse many materials separately for the nine censuses from 1871 to 1916.

These headings remained until 1926 when 36 variations were provided. The single *Wood, Iron or Lath-and-plaster* became three headings: *Wood*; *Wattle and Daub*; and *Wood and Iron*. For the following figures, all types of weatherboards are included under *Wood and Iron* while *Sheet* includes asbestos cement, plaster and other types of sheet boards.

Although the analysis is largely reported here as percentages, the number of dwellings increased from 12,812 in 1858 to 1,004,300 in 1981 (Figure 6).

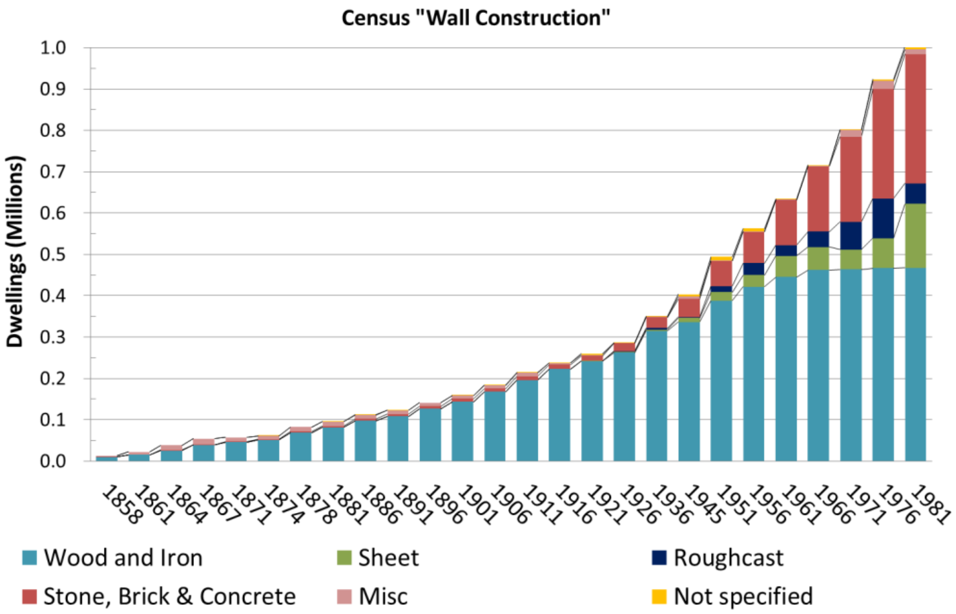


Figure 6: External Wall Construction by Count 1858 to 1981

Reclassification of materials and combinations of materials may also have had an impact on their apparent use. For example for the 1971 Census, imitation stone was reclassified from being counted as *Stone* to being part of *Brick* (see Roskill Stone, section 5.3.4). The numbers of stone dwellings had increased from 3,478 (0.5% of dwellings) in 1961 to 10,362 (1.4%) in 1966, but then fell in 1971 to 2,475 (0.3%) due to this reclassification (New Zealand Department of Statistics, 1975, p. 7).

4.1.5 Wall Construction Materials

Figure 7 provides a summary of wall construction material from the 1858 to 1981 Censuses. The percentage of *Not specified* has always been low, peaking at 1.8% (8,807 dwellings) in 1951.

From the 1858 Census wooden buildings were reported separately. The *Wood, Iron or Lath-and-plaster* combined category was reported from 1874, but only in 1916 was *Iron* reported separately as a cladding. It is assumed galvanised iron was included in the *Other Materials* category for 1858 and 1861, and then under *Canvas, Misc. or Not Specified* from 1864 to 1871, presumably because comparatively few buildings used this material. Even so, galvanised iron and iron houses were both included in Auckland newspaper import lists in 1854 (Daily Southern Cross, p. 2, 29 Dec 1854).

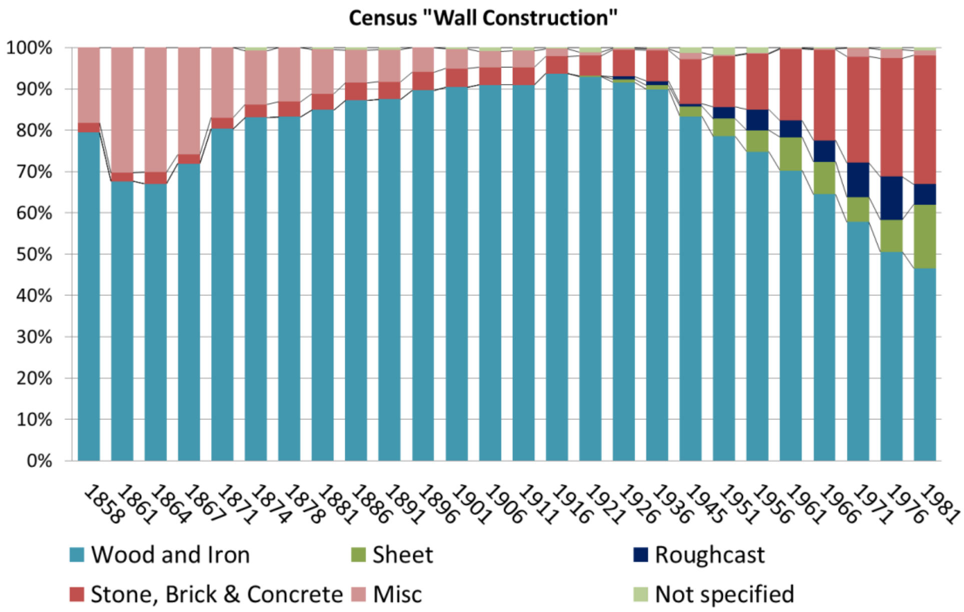


Figure 7: External Wall Construction Percent 1858 to 1981

Operational decisions also play a role in the way data is reported. For example, in the 1921 Census, dwellings with a wooden front but corrugated iron sides were included under *Wood* (Census and Statistics Office, 1924a, p. 9).

From 1858 to 1981, just four types of cladding (alone or mixed) were used in most dwellings. They accounted for a minimum of 67% (in 1864) to a maximum of 97.2% (1926) of dwellings. Even in 1981, these four types of cladding were found on 92.4% of dwellings:

- **Wood**: maximum of 92.2% in 1916, falling to a minimum of 45.8% in 1981
- **Brick**: first appeared in 1878 with 3.6% of dwellings increasing to a maximum 19.4% in 1971
- **Sheet:** asbestos first appeared in 1921 with 0.2% of dwellings, reaching a maximum of 15.4% in 1981
- **Concrete** (poured or block): first appeared in 1916 with 0.7% of dwellings, with a maximum of 13.6% in 1981

Five cladding types are worth considering in more detail:

Asbestos sheet was first advertised in 1904 (Section 6.5.3) and appeared initially in the 1921 Census (466 dwellings). The main increase in use occurred post-WWII with 21,163 dwellings in 1951 (up from 1,999 in 1945) using asbestos sheet alone or in combination with other materials. The numbers grew steadily to 72,319 dwellings in 1976 (7.8% of dwellings), but the material was dropped in the 1981 Census, apparently replaced by *Board*. It is possible the census numbers underestimate the use of asbestos, as a householder not knowledgeable about the material could easily report it as being a proprietary brand of wallboard (Census and Statistics Office, 1931a, p. 3).

Roughcast or stucco was initially a decorative finish for brick (Figure 95) and concrete construction but became a popular finish for timber-frame buildings as it appeared to have the solidity of masonry (Salmond, 1989, pp. 204–205). The cladding could be rigid sheet materials (precast cement wallboard, asbestos cement board) or close boarded timber, or a non-rigid backing such as waterproofed building paper or felt impregnated with bitumen (Technical Correspondence School, 1958, p. 162). Roughcast does not appear until the 1926 Census when it is recorded as being on *Wood or a Surface n.o.d.* (Not Otherwise Defined).

The combined **Stone, Brick and Concrete** category accounted for less than 5% of dwellings until 1921, growing in importance to 29% in 1976. It was not until 1916 that the three materials were separately reported, and after 1926 that any combinations were also listed e.g. *Brick and Wood*. In 1916 there were 1,284 stone-walled dwellings, increasing slowly until 1961 when the use of the term *stone veneer* resulted in a jump to 3,478 dwellings.

The **Miscellaneous** category in Figure 7 includes a wide range of materials present only in small numbers, as well as *Huts*. The range of materials changed over time, but included sod, clay, cob, raupo, canvas, and board as well as those explicitly reported in the census as *Miscellaneous* or *Other*. Figure 7 shows that as the reported details increase, the percentage reported as miscellaneous decreases.

4.1.5.1 Miscellaneous Wall Construction

Figure 8 provides a breakdown of the miscellaneous category, as well as showing the reported percentage of total dwellings.

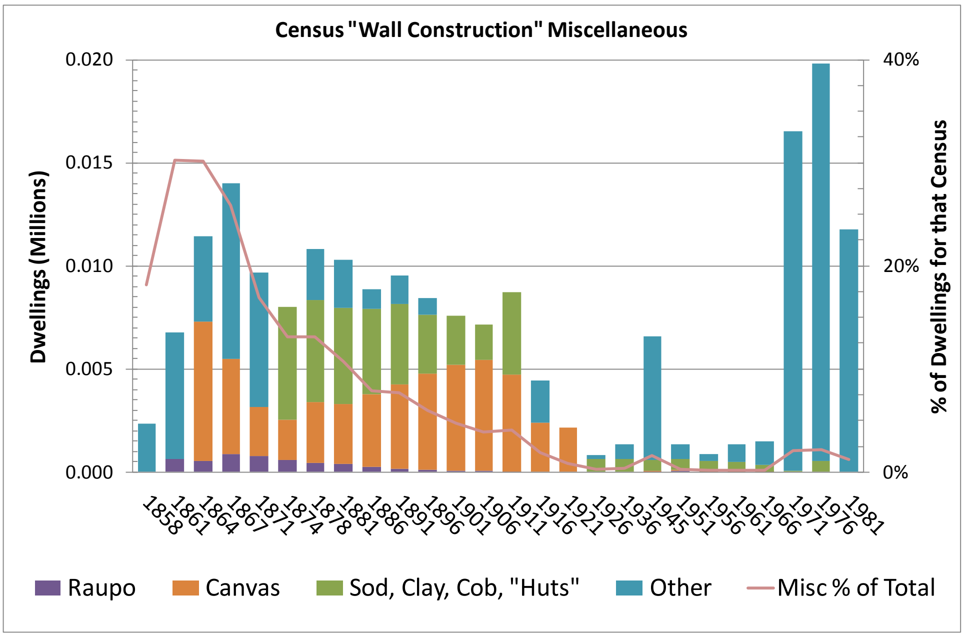


Figure 8: "Miscellaneous" wall construction 1858 to 1981

Although **raupo** houses were never built in large numbers, raupo played an important role in providing quick, easily built shelter for early settlers (Leys, 1883, p. 16). The number of raupo houses fell from 630 in 1861 to 23 in 1911 (Section 5.1.1). The jump to 63 raupo houses in 1951 may have been due to the inclusion of Maori dwellings in the census.

Canvas played an important role for many years, notably used in temporary dwellings. The category *Tents & Dwellings with Canvas Roofs* was reported from 1864 to 1921, and accounted for over 2,000 dwellings in each census. No canvas category was reported in the 1926 and 1936 Censuses, but when *Canvas, calico, sacking, etc*. was listed in 1945 only 71 dwellings were counted, falling to a single dwelling in 1966 when it was last reported.

Huts (single room dwellings) were reported along with cob, sod, rammed earth (pisé), earthen blocks and sun-dried bricks (adobe) construction, falling from 5,483 dwellings in 1874 to 4,019 in 1911. From 1926 a finer detail of reporting was provided (*cob*; *cob and iron*; *cob and wood*) but the reported numbers ranged from 619 dwellings in 1926 to a low of 77 in 1971, and then increased to 534 in 1976. It is possible that these fluctuations are due to some construction categories being merged to meet confidentiality or other requirements, as it is very unlikely that 278 earth houses were demolished between 1966 and 1971, and then 457 built between 1971 and 1976.

The highest percentages of **unnamed** or miscellaneous construction occur in the three censuses from 1861 to 1867. These covered the gold rushes in Central Otago (Gabriels Gully, 1861) and West Coast (Hohonu, 1864) (McLintock, 1966, p. 256 Vol. 2), when large numbers of temporary dwellings would have been required for transient miners and supporting services. For example, in the 1864 Census out of 37,996 dwellings, there were 6,742 tents (18%) and 4,150 of unknown construction (11%). Most of the fall in the proportions of wood and iron can be accounted for by removing the Otago Province from the statistics, leaving only a small dip in 1867.

4.1.5.2 Multiple Wall Materials

From 1926 the increased resolution of the published statistics allows for a better understanding of the use of multiple (two or more) wall materials in individual dwellings, such as *Wood and Iron*. In 1926 only 3.6% of dwellings used more than one material, but by 1976 this had increased to 13.4% of dwellings, falling to 12.7% in 1981.

The *Mixed: Three or More Materials* category first appeared in 1936 when it accounted for 0.1% of dwellings, increasing to 0.9% in 1971 and 1.4% in 1976. It was not included in the 1981 Census report. This increase may also be related to the increasing number of multiple dwelling flats, apartments or town houses, as will be discussed later.

In 1981, for the first and only time, a cross-tabulation of the primary and secondary wall materials was provided (New Zealand Department of Statistics, 1983, p. 23, Table 18). Figure 9 shows the number (in thousands) and percentage of dwellings by main material type reporting no secondary material. In 1981, of the 1,003,113 permanent private dwellings 87% (874,560) reported a single main wall material, matching closely to the reported combinations in previous years. 437,000 or 89% of all timber or wood clad dwellings reported the use of no secondary wall material.

In 1981 only four combinations of materials were reported as present in more than 10,000 dwellings: *Wood + Brick* 9%; *Wood + Wallboard* 13%; *Wood + Artificial stone/block* 10%; and

Brick + Artificial stone/block 8%. These four combinations account for 52,791 dwellings or 41% of all the dwellings reporting a combination of wall materials.

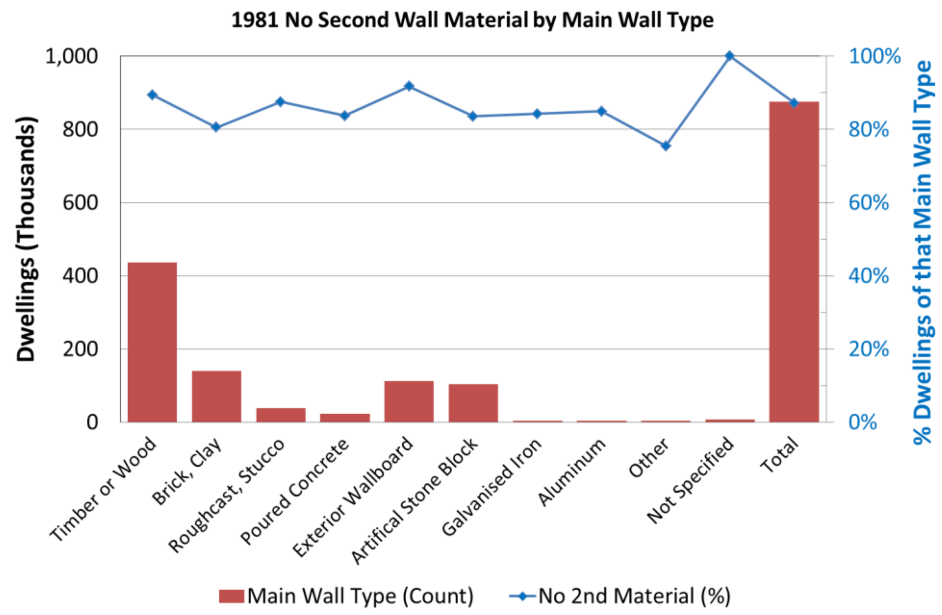


Figure 9: Dwellings With Only One Wall Material 1981 Census

4.1.6 Wall Structure

It was not until the 1970s that the light steel-frame industry offered any competition for timber framing (Section 6.3.2). It is therefore not unreasonable to assume that until 1981 any cladding material that required a frame would be supported by a timber structure.

Materials such as masonry (stone or concrete block), earth (cob, pisé, adobe), canvas or those materials reported as *not specified* must be assumed to perform both construction and structural roles, although in later years, as discussed, these materials are a small proportion of the total.

Prior to the 1931 Napier earthquake, cavity or double brick was not uncommon, but after that event brick veneer became standard (Section 5.2.2.2). For analysis, it has been assumed that all brick dwellings reported after 1931 are brick veneer on timber-frame. As Figure 7 shows, from 1881 to 1921 *Stone, Brick and Concrete* walls were found in about 4% of dwellings, increasing in 1936 to 7.5%. In 1926 there were 8,874 brick walled dwellings, with a 50% increase to 13,303 in 1936.

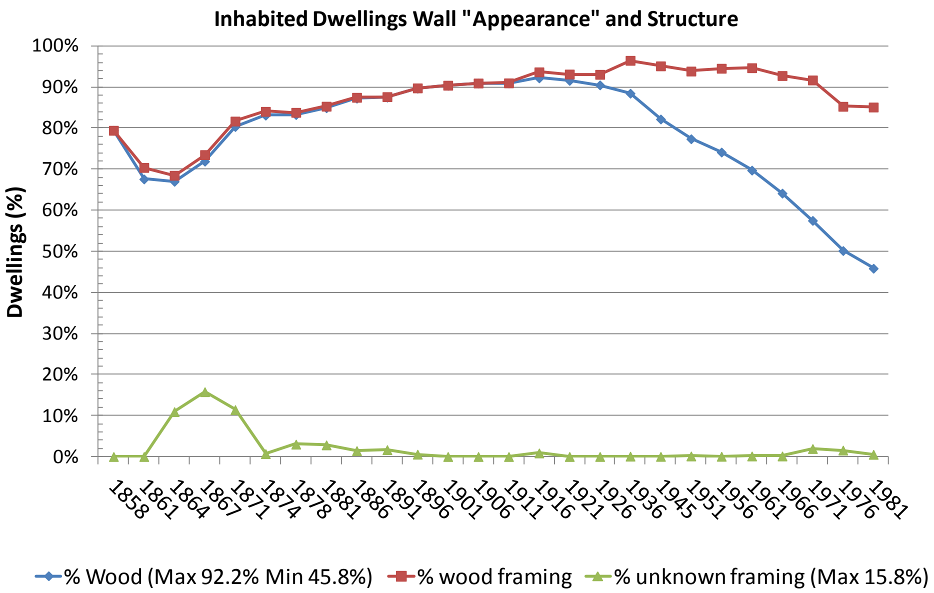


Figure 10: External Wall Structure 1858 to 1981

Figure 10 re-analyses the census data based on the structure, plotting the percentage of dwellings with external walls with wood appearance (construction) and wood structure. Although the two track each other closely until 1911, from 1936 there is a divergence. The lower line in Figure 10 gives the percentage of dwellings with unknown framing. Apart from the 1864 to 1871 period, it was possible to allocate a structure for all but a very small percentage of dwellings (under 2%). This suggests that this analysis of the relative importance of timber framing is robust.

While the census reporting, as discussed previously, has focused on the wooden wall appearance (construction) which by 1981 described fewer than 50% of dwellings, in reality wooden framing (structure) has largely maintained its primacy, only declining below 90% of dwellings after 1971.

Table 52 (see Appendix p. 327), using the same data as Figure 6, gives the absolute number of inhabited dwellings and the net change (after demolitions and new builds) on an annual basis (total change in the inter-census period divided by the number of years) reported by structural type.

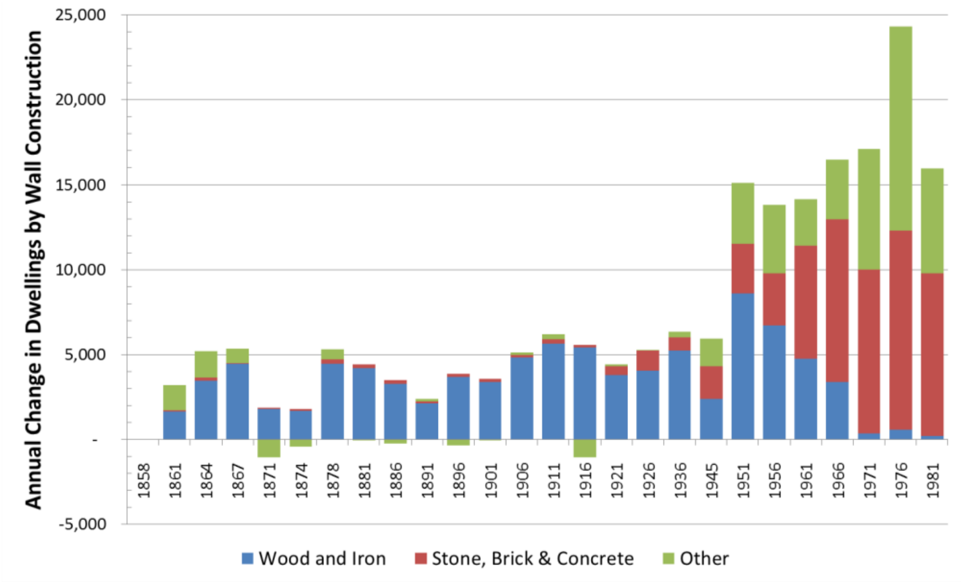


Figure 11: Annualised Change in Dwelling Numbers by Wall Construction 1858 to 1981

Figure 11 gives the annualised change in the number of dwellings by wall construction types between censuses from 1858 to 1981, where positive is a net increase in that type of wall structure and negative a net decrease. To maintain consistency, it has been necessary to combine stone, brick and concrete into a single category, but the more detailed division is shown in Figure 6. The decrease for the *Other* category in 1871 and 1873 was due to the reduced number of canvas dwellings, while in 1896 and 1916 the fall was in dwellings listed as *Sod, Clay, Cob and Huts*.

Figure 11 shows that although the number of dwellings with timber and iron cladding grew very strongly post WWII, it fell from 1951 to 1971 as timber was replaced by other claddings (mainly roughcast on cement board and plain asbestos cement board) and concrete construction.

Figure 12 shows the annualised change in dwelling numbers by wall structure from the 1858 Census to 1981 Census. Comparing Figure 11 and Figure 12 shows that timber structure remained dominant for almost every census period, except for the period to 1976 when the use of concrete (in-situ or block) structure was ascendant.

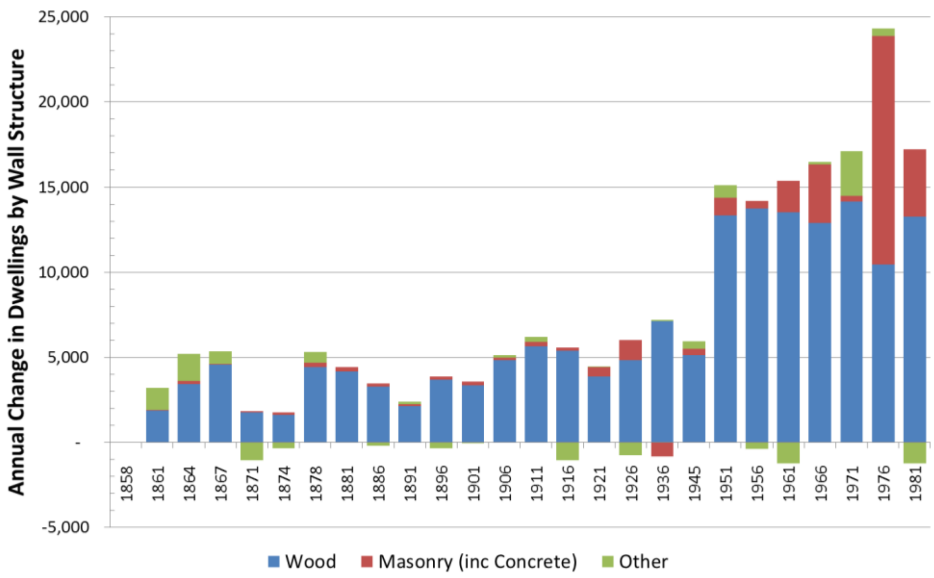


Figure 12: Annualised Change in Dwelling Numbers by Wall Structure 1858 to 1981

4.1.7 Roofing Materials

Roof material statistics were collected by the 1961 to 1981 Censuses. Even when a *Not Applicable* category was included in 1976 (Section 4.1.3), the reports still did not provide the number of buildings, as the number of dwellings per building was not reported. In 1981 only 1.8% of dwellings (17,877) reported the roof question was *not applicable*.

The roofing terminology used in the census remained reasonably constant from 1961 to 1981. In 1961 and 1966 nine roofing materials were provided (*Iron*, *Aluminium*, *Asbestos*, *Other Metals*, *Tiles*, *Slates*, *Bituminous fabric*, *Other Material*, and *Not Specified*). Additions or changes made in the following years were: 1971 one additional material (*Tile-shaped roofs*); 1976 two new categories (*Combination 2 or more* and *Not Applicable*); and in 1981 tiles were divided into two (*Pressed Metal Tiles* and *Tiles of Clay or Concrete*).

In each of the five censuses, only two roof materials were reported as being on more than 100,000 dwellings or over 10% of all dwellings, *Galvanised iron or tin (sheet or corrugated)* and *Tiles (concrete, clay or asbestos)*, as shown in Figure 13. In 1981 when reported separately, *Pressed metal tiles* (11.3%) and *Tiles of Clay or Concrete* (21%) were each present in over 10% of dwellings, but as data is not available for the previous censuses, they are combined here and reported as *Tiles*.

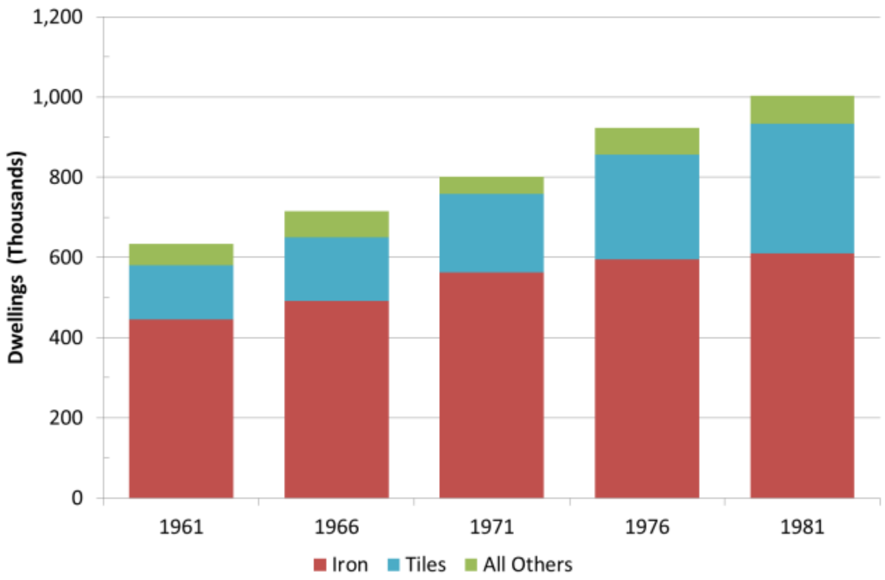


Figure 13: Roof Construction Count 1858 to 1981

Figure 14 gives the percentage of each roofing type. Iron roofing fell from a high of 70% in 1961 to a low of 61% in 1971, while tiles increased from 21% in 1961 to 32% in 1981, at least in part due to the increased use of pressed metal tiles.

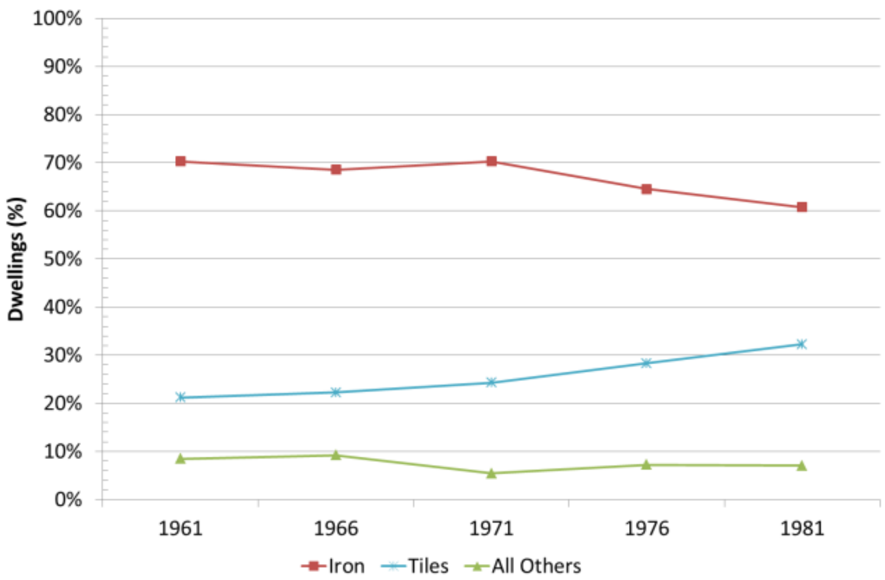


Figure 14: Roof Construction % 1858 to 1981

The total for all other materials ranged from 5.4% (1971) to 9.2% (1966). Figure 15 plots, on a much expanded scale, the number of dwellings for the different materials making up the *All others* category.

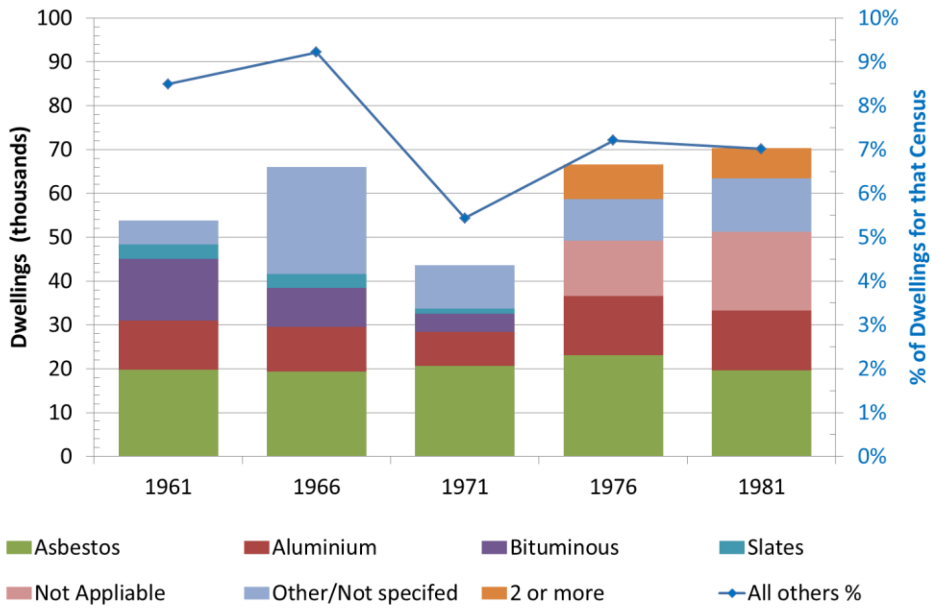


Figure 15: "Other" Roof Constructions 1858 to 1981

Asbestos, which includes sheet or corrugated product, is the only *Other* roof material with over 3% in any census (19,728 dwellings in 1961). The numbers remained reasonably steady with a drop to 2% in 1981 (19,641 dwellings). Aluminium roofing was reported from 1961 with 11,222 (1.8%) dwellings, falling to 7,823 (1%) in 1971, then rising to 13,466 (1.5%) in 1976. The reason for this apparent loss of 3,399 dwellings followed by increase of 5,643 is unclear. A combination of roofing materials, reported for 1976 and 1981, only account for a maximum of 7,884 (0.9%) dwellings in 1976.

Figure 16 gives the annualised change in the number of dwellings by roof construction types between censuses from 1961 to 1981. The number of new dwellings with iron roofs increased from 1966 to 1971, but then fell to 1981. The change in the annual number of other roof materials suggests this is due to untrained people determining (or guessing) their dwelling roof type.

Figure 16: Annualised Change in Dwelling Numbers by Roof Type 1961 to 1981

4.1.8 Wall and Roof Combinations

From 1961 to 1981 the collection of both roof and wall constructions allowed reporting and analysis of the combinations. From the first report, the most popular dwelling was timber clad with a corrugated iron (or *tin*) roof (New Zealand Department of Statistics, 1969, p. 5).

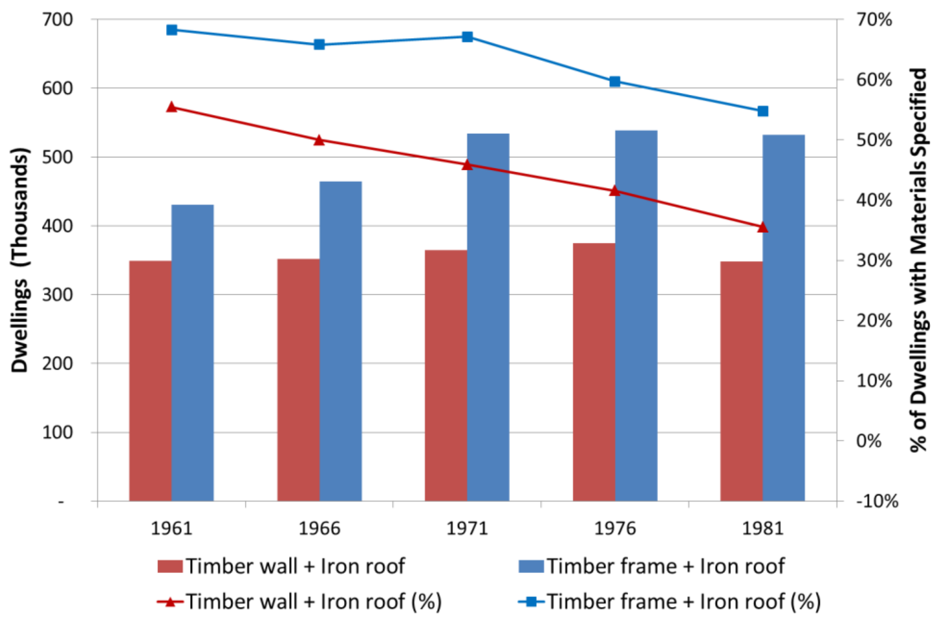


Figure 17: Wall and Roof Combinations 1961 to 1981

Figure 17 gives the number and percentage of dwellings with timber wall and iron roof or timber wall framing and iron roof. Timber wall and iron roof in 1961 accounted for 55% of dwellings with specified wall and roof materials, falling to 36% in 1981. Re-interpretation of the data shows that timber-frame with iron roofs in 1961 accounted for 68% of dwellings with specified wall and roof materials, falling to 55% in 1981.

4.1.9 Discussion

> "By 1971 the proportion of wooden homes was down to 58 percent, and the 1981 Census was the first in New Zealand's history to report that fewer than half of the country's dwellings were clad in timber." (New Zealand Department of Statistics, 1985, pp. 119–120)

This section has shown that, despite the conclusion from the 1981 census about the wall construction, the overwhelming majority of New Zealand dwellings had a timber wall structure from the 1860s to 1981. Timber cladding was being replaced by asbestos cement (or in later years fibre-cement) board and brick veneer, while in later years timber framing was replaced by concrete, principally concrete blocks. It has also been shown that corrugated iron and tiles dominated roofing in the period 1961-1981. Arden & Bowman (2004, p. 38) suggest two types of wall system: timber stud frames and solid brick or stone dominate New Zealand housing. While this may be helpful for renovators working on a narrow range of heritage houses, the analysis reported here shows that from 1858 to 1981, timber-framed dwellings have always been in the majority.

This analysis shows for the first time that a small number of materials account for the large majority of house wall constructions over the 122 years of census data. Four claddings (timber, brick, sheet and concrete) were a minimum of 67% in 1864 and a maximum of 97.2% in 1926 of all dwellings. However, even allowing for the wide use of temporary accommodation during the 1860s-1870s gold rush, wood framing has always been the majority of dwelling structures, maintaining its importance even as the claddings shifted away from timber.

Was this small number of construction materials due to a lack of design imagination; a conservative construction industry; the availability only of a limited range of materials; or that the innovation was evolutionary rather than revolutionary? The following sections explore firstly the import source of selected materials and then the origins of a wide variety of techniques.

4.2 Import Statistics

Since 1841 summary statistics on merchandise external trade (imports) have been published by Statistics New Zealand, its predecessors, and the Customs Authorities. Over this period, these statistics have become increasingly detailed (Statistics New Zealand, 2004, pp. 153–158). Import statistics provide a way of exploring the countries of origin of many construction materials.

Official import statistics from 1870 to 1980 have been examined to determine their use to trace the value, quantities and origins of seven building materials: asbestos sheet; cement; window glass; galvanised iron; nails; gypsum; and roofing slates. These seven were selected as they are specific products that could be easily tracked through the import statistics. The first five were at some time made in New Zealand, the sixth (gypsum) is a critical raw material for plasterboard and the last had a full life cycle within the period of interest.

There have been significant changes in the way the data is collected and categorised. The Customs Department compiled the import and export statistics until 1961, when Statistics Department took over. From 1 July 1962 to 30 June 1967, statistics were published in accordance with the Standard International Trade Classification (Revised). On 1 July 1967, a new Customs Tariff became effective and was based on a completely different classification, the Brussels Tariff Nomenclature. In July 1978, data began to be published under the Standard International Trade Classification Revision 2 (Statistics New Zealand, 2013).

Data has been extracted from the relevant reports for 1868 and 1869 and then on a five yearly cycle from 1870 (see Table 56 for references). These publications are only available in paper form, and in many cases the only copy is held at Statistics NZ's Wellington Head Office. Based on experience with detailed analysis of annual nail import statistics (Section 7.1), five yearly data (1880, 1885, 1890 …) provides an acceptable time series. Where necessary, import statistics for additional years were investigated. In some reports, more than one year's data was provided (e.g. in the 1930 report data is provided for 1928, 1929 and 1930) and this was also recorded for analysis.

However, as will be discussed in the following section, a consequence of the data collection and reporting changes is that it is difficult to establish a quantity time series for most products, although value was always reported.

4.2.1 Units of Quantity

The only building products that can be traced both in weight and value over the entire period 1870 to 1970 are nails and corrugated iron, which were continuously reported in units of weight, although roofing slates were reported as count except for 1890 when the weight was given.

Table 12 summarises the various reporting unit from 1870 to 1970. In some cases conversion to common units is impossible, as conversion factors cannot be found. In 1870 *Plaster of Paris and Cement* were combined and the quantity reported in units of *Packages and Casks*. Glass imports were initially counted as *packages*, but by 1890 they were measured in *super ft.* and by 1940 in *square feet*.

Different units of quantity could be used for different but closely related categories. For example, from 1916 a new statistical heading 839A *Asbestos corrugated roofing sheets* was introduced. In 1920 839A imports were reported by weight, but in the following years imports were reported by count, as for the older 839 *Asbestos sheets, slates and tiles*.

Table 12: Imported Construction Material Units 1870-1970

Year	Asbestos	Cement	Glass	Galvanised Iron	Nails	Gypsum	Slate
1870	-	Packages & Casks	pkg	Ton cwt	cwt	Packages & Casks	Number
1875	-	Mix	pkg	Ton cwt	cwt	Mix	Number
1880	-	Barrel	pkg	Ton	cwt	Barrel	Number
1885	-	Barrel	pkg	Ton	cwt	Barrel	Number
1890	-	Barrel	super ft	Cwt	cwt	Barrel	lb
1895	-	Barrel	super ft	Cwt	cwt	Barrel	Number
1900	-	Barrel	super ft	Cwt	cwt	cwt	Number
1905	-	Barrel	super ft	Cwt	cwt	cwt	Number
1910	-	Barrel	super ft	Cwt	cwt	cwt	Number
1915	Number	Barrel	super ft	Cwt	cwt	cwt	Number
1920	Number & Cwt	Barrel	super ft	Cwt	cwt	cwt	Number
1926	Number	cwt	super ft	Cwt	cwt	cwt	Number
1930	Number	cwt	super ft	Cwt	cwt	cwt	Number
1935	Number	cwt	super ft	Cwt	cwt	cwt	Number
1940	yd^2	cwt	ft^2	Cwt	cwt	cwt	Number
1945	yd^2	cwt	ft^2	Cwt	cwt	cwt	-
1950	yd^2	cwt	ft^2	Cwt	cwt	cwt	Number
1955	yd^2 & Number	cwt	ft^2	Cwt	cwt	cwt	Number
1960	yd^2 & Number	cwt	ft^2	Cwt	cwt	cwt	Number
1965	yd^2	cwt	ft^2	Cwt	cwt	cwt	Number
1970	yd^2	cwt	ft^2	Cwt	cwt	cwt	Number

Both gypsum and cement imports were initially reported in barrels, but in 1921 the unit changed to hundredweight. Table 2 gives Conversion Factors for selected building materials.

Even where quantities are reported in the statistics, they cannot be considered fully reliable. The 1950 import statistics report noted that where Customs duties were collected on an *ad valorem* basis (import value) details of quantities were not required, and experience had shown that "such particulars are not always correctly furnished" (Census and Statistics Office, 1952b, p. 6).

4.2.2 Statistical Headings: Example Galvanised Iron

In addition to changing units, the statistical headings and definitions changed over time. The following discussion and Table 13 provide, as an example, the changes for galvanised iron:

- In 1868, imports of *Iron: Galvanised* were provided as quantity (ton, cwt & qtr) (Government Statistician, Registrar-General's Office, 1869, p. 21).
- By 1880 the categories had changed to *Iron: Galvanised, Corrugated &c.* and *Iron: Galvanised (Plain sheet)* with the weight reported in tons (Government Statistician, Registrar-General's Office, 1881, p. 16).
- By 1905, although the same two basic categories were used, the material was given as *Iron and Steel*, correctly following the changes in base material (Section 5.6).
- In 1915 a numbering system was used, with Class XIV (a) *Metal, Unmanufactured and Partly Manufactured and Ores* including under *Iron and Steel: Plate and Sheet* the categories *430 Corrugated, Galvanized* and *432 Plain Galvanized*. Materials imported for Government use, and hence free of import duty, were separately enumerated under the same number code. Imports also included *431 Plain Black* which was presumably raw sheet for corrugating and galvanising plants (Government Statistician, Registrar-General's Office, 1916, p. 221).
- The numbering system continued, but changed as finer enumeration categories were applied. By 1930 *Plate and Sheet* categories included *440 Corrugated* and *442 Galvanised*, suggesting that products under 440 were to be processed in New Zealand galvanising plants and 442 products were to be corrugated. Another category *443 Tinned* was also enumerated, but it was for the food canning industry (Census and Statistics Office, 1931b, p. 201). For 1940, the category descriptions were unchanged but the numbers became 484 and 485.
- For the 1950 import statistics the data collection methodology had changed, creating an enlarged statistical classification. Now under Class 16 Metals, *[Steel] Plate and*

Sheet Under One Eighth Inch the categories of interest had become *1123.00 Galv. Corrugated* and *1124.00 Galvanised Flat* (Census and Statistics Office, 1952b, pp. 6, 71 & Preface).

- For 1955, a new coding system was in use, so the categories of interest became *68107.02 Galv. Corrugated* and *68107.03 Galv. Flat* (Customs Department, 1957b, p. 110).
- In 1965 the codes became *674.810.2 Other Galvanised* and *674.810.5 Worked Corrugated Galvanised* (Department of Statistics, 1967a, p. 140).
- In 1970 the coding changed, giving at least 7 different classifications covering a range of corrugated and galvanised steel sheet under 3mm thick (Department of Statistics, 1973a, p. 102, 1979, p. 347). These were unchanged in 1975 (Department of Statistics, 1978, p. 102).

Thus even though import quantities for galvanised iron can be reported over the entire time period as noted in the discussion on Table 12, the changes in definitions and reporting as shown in Table 13 make it uncertain that all relevant imports can be correctly identified from 1970, so a suitable endpoint would be before the changes to the new tariff in 1967.

Table 13: Galvanised Iron Import Categories 1870 to 1970

Year	Major & Minor headings	Categories	Weight
1870	Iron	Galvanised	Ton cwt qtr
1880		Galvanised, Corrugated &c. Galvanised (Plain sheet)	Ton
1900		Galvanised, Corrugated Galvanised Plain sheet	Cwt
1905	Iron & Steel	Galvanised, Corrugated Galvanised, Plain	Cwt
1915	Class XIV (a) Metal, Unmanufactured and Partly Manufactured and Ores Iron and Steel Plate and Sheet	430 Corrugated, Galvanised. 432 Plain, Galvanised	Cwt
1930		440 Corrugated 462 Galvanised	Cwt
1940	Plate and Sheet under ⅛ in in thickness	484 Galvanised Corrugated. 485 Galvanised Flat.	Cwt
1950	Class 16 Metals [Steel] Plate and Sheet Under ⅛ in	1123.00 Galv. Corrugated 1124.00 Galvanised Flat	Cwt
1955	[Steel] Plates and Sheets, Coated, Under ⅛ in	68107.02 Galv. Corrugated 68107.03 Galv. Flat	Cwt
1960		68107.02 Galv. Corrugated 68107.03 Galv. Flat	Cwt
1965	Group 674 – Universals, Plates and Sheets of Iron or Steel Coated Sheets, Under 3mm Iron/Steel, O/T Tim-plate, High Carbon Alloy Steel	674.810.2 Other Galvanised 674.810.5 Worked Corrugated Galvanised	Cwt
1970		674.33.11 Sheets, plates, under 3mm, not plated, coated, clad. Alloy: Corrugated, not further worked 674.81.11 Sheets, plates, under 3mm, plated, coated, clad: (Not tinned, high carbon, or alloy): Corrugated, not further worked: Galvanised 674.81.52 Sheets, plates, under 3mm, plated, coated, clad: (Not tinned, high carbon or alloy): Other, 0ther/kinds, Galvanised 674.82.10 Sheets, plates, under 3mm, plated, coated, clad: (Not tinned, high carbon or alloy): Corrugated, not further worked 674.82.52 Sheets, plates, under 3mm, plated, coated, clad. (Not tinned): High carbon: 0ther/kinds: Other: Galvanised 674.83.10 Sheets, plates, under 3mm, plated, coated, clad: (Not tinned): Alloy: Corrugated, not further worked 674.83.52 Sheets, plates, under 3mm, plated, coated, clad: tinned): Alloy: 0ther/kinds: other: Galvanised	Cwt

4.2.3 Import Values – Example Galvanised Iron

The following graphs provide an example of the detail which can be extracted from the import statistics. As discussed above, the period 1870 to 1965 has been used for analysis.

Prior to the 1915 statistics, only the *Country from whence Imported* was reported. From 1915 both this and the *Country of Origin* were reported, but from 1930 it was only *Country of Origin*. For the purposes of analysis, where available, the country of origin has been used.

From the 1920 import statistics, the value was standardised as the "market value in the country of export at the time of exportation plus 10 per cent", also termed *current domestic value* (c.d.v.) plus 10% (Statistics New Zealand, 2005, Table H2.1), expressed in New Zealand currency. This approach, when taken over all imports from all countries, was considered to cover the marine insurance and transport costs to New Zealand. The market value approximates the *free-on-board* (f.o.b.) value, while the 10% addition approximates the *cost, insurance and freight* (c.i.f.) value for all but low-value high-volume goods like grains and cement (Census and Statistics Office, 1952b, pp. 6–7). By 1965 import values were given both as c.d.v. and c.i.f., so for this analysis the c.i.f. value was used.

New Zealand converted from pounds, shillings and pence (£ s d) to dollars and cents ($) on 10 July 1967, but the 1965 import statistics were published in 1967 so used the new decimal currency (Department of Statistics, 1967a, p. 140). For the purpose of analysis, for 1965 imports the conversion of £1 = $2 has been used (New Zealand Department of Statistics, sec. 48, 1967).

Figure 18 plots from 1870 to 1975 the value in millions of pounds and quantity in thousands of tons of galvanised iron sheet imports. The reason for the leap in value, but not in quantity, in 1920 is not clear, but may be related to the global depression.

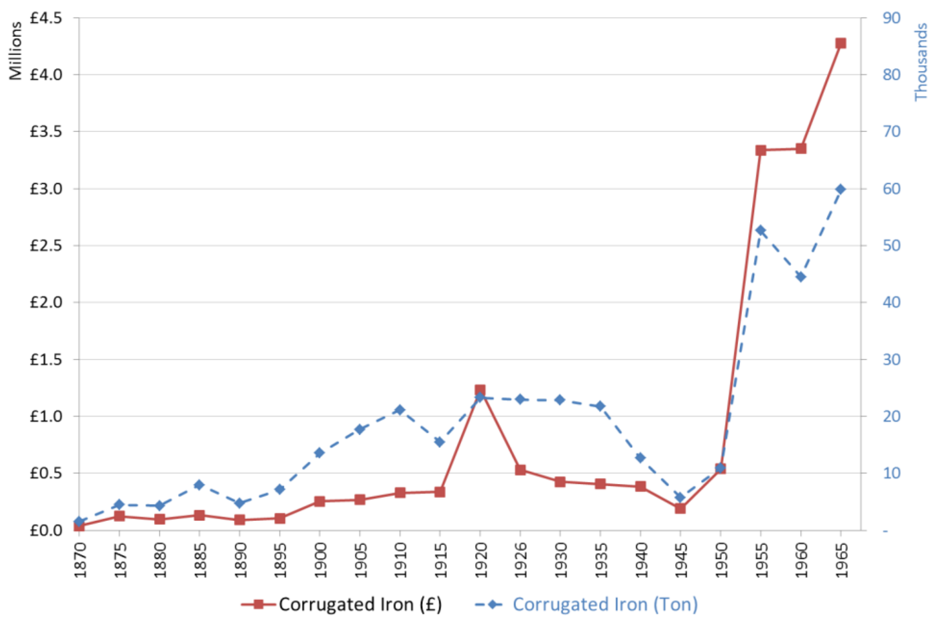


Figure 18: Galvanised Iron Imports by Value and Quantity 1870 to 1965

Figure 19 examines the imports of galvanised iron by value and quantity per person from 1870 to 1965. Person numbers are the total de facto population at 31 December for the year (Statistics New Zealand, 2005, Table A1.1). Over the period 1870 to 1935, the quantity imported ranges from 5.3kg/person in 1870 to 20.5kg/person in 1910, averaging 13.5kg/person. WWII saw the already decreasing imports fall to 3.4kg/person in 1945, but then increase sharply in the following years to a maximum of 24.7kg/person in 1955. Although the values of imports per person follow a similar pattern, the maximum value occurs in 1965 at £1.6 per person.

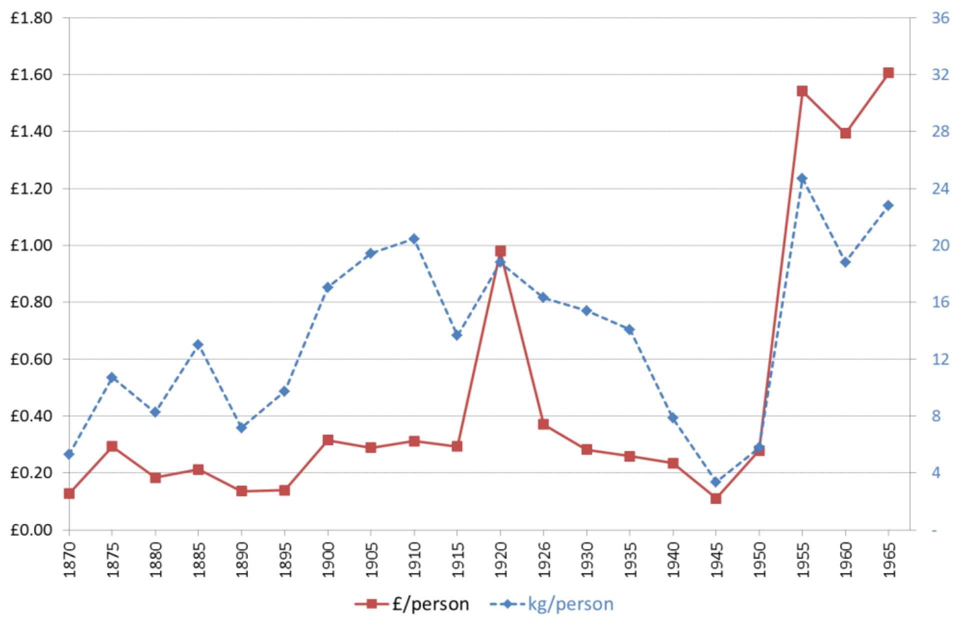


Figure 19: Galvanised Iron Imports per Person by Value and Quantity 1870 to 1965

Figure 20 plots the value of galvanised iron imports per unit quantity (£/ton) by country of origin. The unit cost of corrugated iron tracks closely for the different countries, with 1960 USA imports at 39% higher cost per unit weight than the UK imports for the same year.

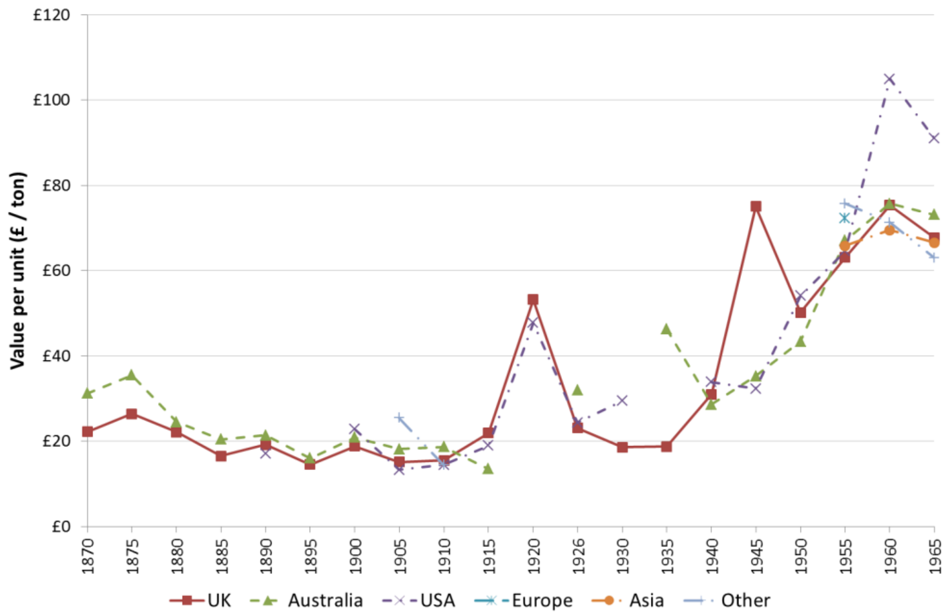


Figure 20: Galvanised Iron Imports by Value per Unit by Country 1870 to 1965

Figure 21 shows the proportion of galvanised iron imports by country from 1870 to 1965. The importance of UK imports is clear through to 1940. In 1945 World War II completely stopped UK imports, replacements coming from Australian and America. Following the war, UK imports resumed, but from the 1960s were largely replaced by Australian product.

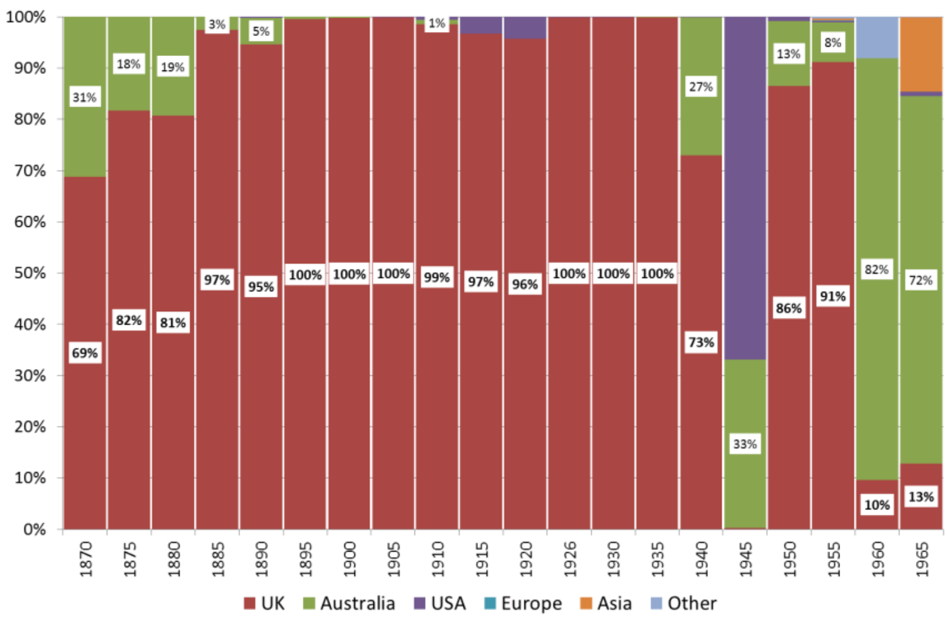


Figure 21: Galvanised Iron Imports by Value by Country 1870 to 1965

Figure 21 shows noticeable imports from the Australian colonies from 1870 to 1890, which the detailed data shows as mainly from Victoria. Although corrugated iron was imported into Australia in the 1830s, sheet steel was not made until 1914 (H. J. Cowan, 1998, p. 61; Mornement & Holloway, 2007, p. 159).

These early imports could either be re-exported product or iron imported into Victoria and processed to corrugated and/or galvanised iron. As there was no large scale Victorian manufacturing industry, it is likely it was re-exported product.

While *Iron sheet* is recorded in the import statistics, there is no indication of the thickness or whether it could be processed to corrugated iron. It is not until 1940 that the plate thickness is stated (for example *under ⅛th inch*). If it is assumed that all imported corrugated iron and galvanised flat plate became galvanised corrugated iron, then the import data provides an overview of its use.

4.2.4 Discussion

The countries of origin for each of the seven selected materials have been tracked from 1870 to 1965 in five yearly steps. The plots show for each material the percentage originating from each country or region. Although there is no standard pattern across the seven materials, in many years a sizable percentage of the imports originate in the UK.

Figure 22 divides the originating countries into four (UK, Australia, USA and Other) and indicates which was responsible for over one half of the imports (>50%) for each material for the given year. Where material imports were not recorded in a given year, a dash is shown. Figure 22 in some ways resembles a map of the world, with the British Commonwealth in red but reducing in importance as the 20th century progresses. One consequence of WWII can be seen in the 1945 appearance of USA as the main supplier of corrugated iron.

For all but asbestos cement sheets, gypsum and wood nails, the UK was responsible for over half of the imports by value in the large majority (75% to 90%) of the assessed years. The strong colonial links, coupled with the extensive production of galvanised corrugated iron, cement and window glass and the large resources of slate quarries make it unsurprising that the UK played such an important role.

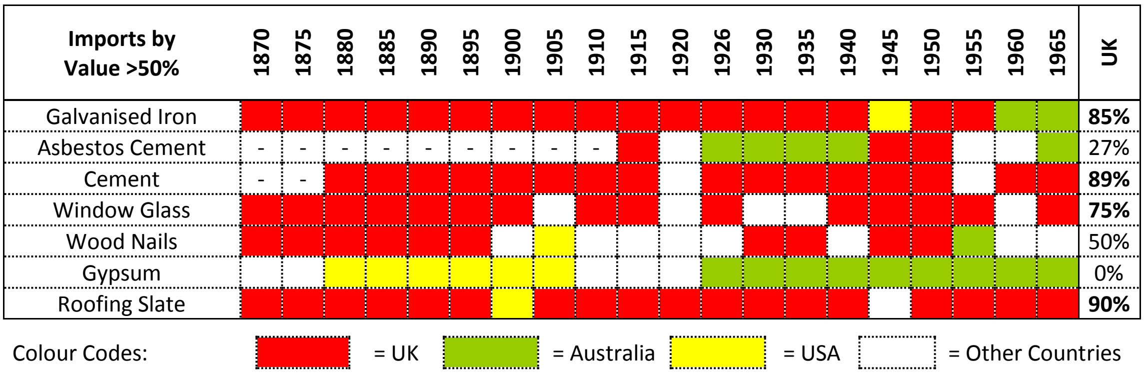


Figure 22. Country of Import Providing Over 50% of Value, 1870 to 1965

The effect of the industrialisation and extraction of the extensive mineral resources of Australia, New Zealand's near and very much larger commonwealth neighbour, was for it to take over from the UK the supply of specialised galvanised corrugated iron and asbestos cement sheeting from the 1960s. Australia also took over from the USA the supply of gypsum from the 1920s.

In some cases the apparent country of origin reported in the import statistics does not match the manufacturing processes available in that country, suggesting the product had been imported and then re-exported. Although some products were re-exported from New Zealand, a brief review has not suggested these were a significant portion of the imports. A detailed example of this will be examined in Section 7.1.

4.3 Summary

This chapter has used census and import statistics to quantify the different types of house shell construction and sources of material imports over the research period. When used in conjunction with manufacturing statistics, they provide an overview of construction changes and the materials that have supported these changes. Normalising using population or construction statistics provides a method for quantifying changes in construction technique.

Data from the 26 censuses of population and dwellings conducted between 1858 and 1981 (when questions on wall and roof materials stopped) has been used to examine changes in wall (1858 to 1981) construction and structure, and roof (1961 to 1981) construction.

While the relative importance of different wall claddings has changed, the supporting structures have not. By 1981, timber cladding had fallen from being used in 92% to under half (42%) of dwellings. It had been displaced as a cladding by brick which reached its peak use of 19% in 1971 and sheet materials (including asbestos cement board) which were used on 15% of dwellings in 1981. However, timber framing continued to be used in the majority of dwellings. Ignoring the temporary shelters needed for the 1860s gold rushes, timber framing was used in 80% of dwellings in 1858, increasing to 97% by 1936, and then declining to 85% in 1981. Part of timber's structural role was taken over by concrete, including concrete block, which was used in 14% of dwellings in 1981.

Import data is available from 1870 but after 1967 the changes in classification make historic comparisons more difficult. The import data for seven common construction materials (asbestos, cement, glass, galvanised iron, nails, gypsum and slate) has been explored. The reported units of quantity have been documented for all seven materials from 1870 to 1970.

Galvanised iron has been used as an example to illustrate the range of change not only in reported units but also in classification. Although the use of product volume would provide the best basis for comparison for this research, the official statistics noted that this can be unreliable. In the following chapters, where possible both volume and value data will be analysed.

Analysis of imports does not take into account New Zealand's industrialisation. Although imports were once the total supply, local production may have taken over to a lesser or greater extent. This will be further discussed for specific materials in later sections.

5 Materials

This section examines the building shell materials, starting with the early use of local plants, moving to five key construction materials: earth; stone; timber; cement and concrete; and ferrous metals. The technologies supporting the use of each material, as well as changes from 1792 to 1982, will be investigated and described.

Often a material has many uses, such as ferrous metals which are used for corrugated iron; nails; light steel framing; and concrete reinforcing. Uses are noted for each material, and cross-referenced to relevant sections. This chapter is not intended as a detailed study, but rather as an overview of the main changes in the use of these materials.

Imported coarse calico or canvas mounted over a wooden skeleton was widely used by early European settlers (Figure 23), providing what appeared as very temporary accommodation for those who had grown up with brick or stone buildings (Eldred-Grigg, 2008, p. 285). Tents, built of imported and local materials, were briefly used as dwellings and business premises (Section 4.1.5.1). For example, the Hotel Commercial in Collingwood, Golden Bay was built of coarse calico on a wooden skeleton, with reportedly only one door "so constructed to let in from its numerous crevices, light, heat and the sun" (Washbourn, 1970, pp. 40–41 quoted in ; Eldred-Grigg, 2008, p. 285). Portable, temporary construction is not considered further in this research.

Figure 23: Back station shepherd and his dogs c1910

5.1 Local Plant Materials

When Europeans arrived in Aotearoa they found a society that had evolved a construction tradition based on readily available local materials (Alan Taylor, 1966; D. Brown, 2009). Early settlers used readily available local materials including raupo reeds, trees and branches, earth, sod and other bush materials such as the leaves from nikau palms, as well as portable materials they had brought with them such as canvas (Salmond, 1989, p. 30).

5.1.1 Raupo and Other Native Plants

On landing, European settlers faced an immediate need for shelter. Tents, caves or natural bush canopy might be suitable for a short time, but a more substantial construction was required. The time and effort required to fell and prepare large trees made this approach a long term choice, and in the short term more accessible materials were required.

There was already a Maori tradition of using plants or smaller parts of trees, often in combination with earth (Alan Taylor, 1966, pp. 6–35). Reed or thatching was woven into place by vines or sewn with fibre from flax or ake, and, in later years, fixed with wire on a supporting timber-frame (Phillipps, 1952, pp. 40, 79).

European settlers viewed such constructions as temporary "hovels" compared to the "…well-laid-out substantially built town" (New Zealand Colonist and Port Nicholson Advertiser, p. 2, 5 Aug 1842), or in the words of a later specialist, "…one is impressed not by their strength, but by their frailty" (Phillipps, 1952, p. 40). However, this tradition supplied European settlers with quickly made, water resistant shelters (Northcote-Bade, 1958, p. 2).

Brett's Colonists' Guide advised firstly the construction of a light timber-frame with a covering of bush materials:

> "In the majority of cases it is advisable to build first a temporary house; this is often built with raupo walls and nikau roof, the framework round saplings from the bush…" (Leys, 1883, p. 16)

Raupo, from the same family as the bulrush, is a swamp plant. Easy to collect, dry and store, it can be readily assembled into useful buildings. Bunched together, thatched or neatly sewn into rows, the stems repelled water and provided a useful level of thermal insulation. The building was constructed with a timber framework, the raupo then assembled into bundles or mats and used to fill the spaces. Figure 24 illustrates such a hut in the 1870s.

Figure 24: Unidentified Maori group alongside a raupo whare, c1870s.

Raupo becomes brittle after long exposure to the weather and requires extra protection from damage. Raupo houses were not considered as durable or warm as timber houses (Phillipps, 1952, p. 79). Thatch thermal conductivity ranges from 0.07 to 0.09m°C.W^{-1} depending on material and compression (Fricker & Hughes, 2000, p. 635), so 150mm of raupo would give a wall R-value of about 2.1m².°C.W^{-1}. This is higher than the 1978 wall minimum of 1.5m².°C.W^{-1} (Standards Association of New Zealand, 1977) or the current NZBC Clause H1 Acceptable Solution minimum of 1.9m².°C.W^{-1} in Zones 1 &2 or 2.0m².°C.W^{-1} in Zone 3 (Department of Building and Housing, 2011b, p. 11, Table 1).

Raupo houses could be of considerable size. In the 1880s Thomas Potts reported a raupo house 90ft long by 36ft broad (27m x 11m) being built in nine days, and sleeping 300 people. Shape was not constrained, with rectangular, circular and oval constructions found in different locations (Phillipps, 1952, p. 46).

There was limited ventilation through the *koro pihanga*, a small opening with a sliding shutter, which provided an escape for smoke (Papakura, 1938, pp. 274, 308). Presumably, as in English houses with a central fire, the smoke from the open fire would have deposited soot on the thatching as it escaped (R. Harris, 2002, p. 25), serving as a fungicide, insecticide and preservative. Later on, the addition of a chimney would have better controlled the fire as well as improving the indoor air quality.

By 1842 fires in houses built or thatched with raupo led the Government to take action to prohibit its use in built-up areas (Cochran, 1990, p. 113) so the Raupo Houses Ordinance was passed by the Legislative Council on 3 March 1842. Concerned with the "lives and properties of persons residing in towns", where the legislation had been declared enforceable a charge of £20 per year was levied on any building "constructed wholly or in part of raupo, nikau, toitoi, wiwi, kakano, straw, or thatch of any description", with a fine of £100 for any new construction. Table 14 lists the locations in which the Ordinance was applied, and the effective date (Isaacs, 2014).

Table 14: Application of Raupo House Ordinance by Province

Date	Town/Borough	Effective	NZ Government Gazette Reference
16 May 1842	Auckland	16 Nov 1842	18 May 1842 pp. 141-2
30 Mar 1843	Wellington	1 Oct 1843	5 Apr 1843 p. 89
23 Feb 1850	Dunedin & Port Chalmers	1 Jan 1851	(New Munster) 23 Feb 1850 pp. 17-8
29 May 1850	Lyttelton		(New Munster) 25 May 1852 pp. 76-7
13 May 1852	Lyttelton & Christchurch	1 Nov 1852	(New Munster) 25 May 1852 pp. 76-7
3 Jul 1852	Lyttelton & Christchurch	1 Feb 1853	(New Munster) 15 Jul 1852 p. 102 (delay)

Figure 25 plots the number of dwellings of raupo construction reported in the censuses from 1861 to 1971, along with the proportion of the total number of dwellings. At the peak (1861) raupo dwellings accounted for just 2.8% of all dwellings, but until 1951 data was only collected for European, not Maori, dwellings.

The numbers of raupo dwellings reduced in 1858 and 1861, but 1864 saw a large increase (possibly related to the gold rushes) but over the following ten censuses the numbers reduced to 23 in 1911. There was a small peak of 63 in the 1951 Census, possibly due to the inclusion of Maori dwellings. The last census to report this type of construction was 1971.

The use of raupo and other bush materials fell from favour as more permanent materials became available, and now are seldom used except for demonstration purposes.

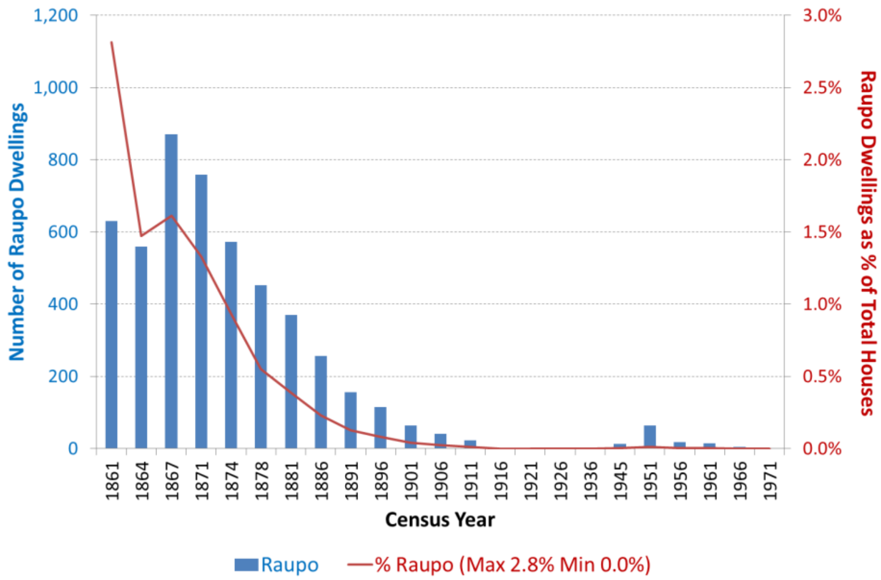


Figure 25: Raupo Dwellings 1861 to 1971

5.2 Earth and Fired Earth

Sun or air-dried earth and clay can be assembled using a number of different techniques but ultimately it retains the same chemical properties as the original material. However, clay and earth can be fired at a high temperature to create bricks, changing its properties so it is no longer water soluble.

5.2.1 Earth Construction

Earth is cheap and readily available in most areas, does not require a high level of skill to use and provides acceptable thermal and acoustic insulation, although seismic resistance must also be considered (J. Christie, 1996, p. 82). Internationally, earth was seen as "the poor man's stone" with the advantage of only requiring very simple tools (Guedes, 1979, p. 241). A Maori tradition of piling earth on the side of the wooden whare for warmth, presumably to reduce infiltration, was still used in the late 19th century (Phillipps, 1952, p. 28).

Water, the other key component of earth construction, is also freely available but at the same time it is an enemy. Falling from the sky as rain, rushing past the building as a stream or just wicking up from the ground, water leads to short term deterioration or long term ruin. In wetter climates, such as Westland and Southland, there is difficulty in drying out the construction (M. Allen, 1996, pp. 95–96). As a consequence, almost all of the older remaining earth buildings are in places of relatively low rainfall or have been well maintained.

Earth construction does not appear to have been the first choice for very many early settlers. *Brett's Colonists' Guide* does not consider earth wall construction (Leys, 1883). Regardless of the wall or roof materials, earth was commonly used for the fireplace and chimney, and in timber houses it was used to block draughts between the boards.

There are four generic earth constructions as well as combinations of earth and timber, including wattle-and-daub and mud-and-stud. The use of burnt or fired bricks is discussed in Section 5.2.2.

Sod construction, perhaps the simplest earth construction , took pieces of sod cut from the ground using readily available tools, and then assembled them into walls. Turf construction followed the same approach, but used finely cut pieces of uniform dimension. Sod was mainly used for temporary applications (M. Allen, 1997, pp. 34–35). Keeping destructive water off the walls is essential, but this can be achieved by lining the outside with planks, reeds or rushes, or a clay plaster weathercoat (Salmond, 1989, p. 38).

Cob construction was more common, with its use being reported in the 1840s and 1850s in Otago, Canterbury, Nelson, New Plymouth and Wellington. The "*NZ Journal*" of 29 August 1846 published a letter stating:

> "Cobb [sic] houses are drier than any other, and there is a Devon man that constructs cob walls at 3/- per superficial yard ... he makes them 2ft thick and pares the walls down to 18 inches ... a very neat and commodious cottage can be built for £125" (L. E. Ward, 1929, pp. 451–2).

A mixture of earth, straw and water was *puddled*, often by a packhorse constrained to walk in a circular trench into which the materials were fed. This mixture was then thrown down onto a brick or stone base course, to be trodden and compacted by the workers. Depending on the labour and the speed of drying, the wall rose at about 18 inches (45cm) a day. Like the other earth constructions, this was a fair-weather job, more suited to the spring and summer. Figure 26 shows the cob Somerset Farm Settlers Cottage in Upper Moutere, built by George and Cornelia Harvey in the summer of 1858-9 (Historic Place Category II, number 5153). Broadgreen (Figure 107), at Stoke near Nelson was built in the mid-1850s of cob (Historic Place Category 1, number 252).

Figure 26: Somerset Farm Settlers Cottage, Upper Moutere 1858-9 (cob)

Figure 27: Glens of Tekoa, North Canterbury 1859 (cob, wattle-and-daub internal walls)

Adobe construction (from the Spanish *adobar* to plaster) used sun baked, but unburned or not kiln-fired, earth blocks (Figure 28). Vitruvius (1st century AD) discusses sundried bricks, providing guidance on the raw materials and drying (Vitruvius Pollio et al., 1914, Book 2 Chapter 3). Chopped straw or grass was added to clay, although low-clay earth with sand could be used. Water was added to make a sticky mass which was then thrown into open-bottom moulds. Once dry enough not to slump, the block was removed from the mould and set to dry in the sun. Shrinking occurred as the block dried out. The blocks were then assembled into a wall, which when completed was finished, often with an earth plaster and/or lime wash. Later machine pressing units became available, such as the CINVA ram, developed in 1952 for the third world (Hall, 2012, p. 20) but widely used in many countries, including New Zealand (M. Allen, 1997, p. 26).

In a self-published booklet, Charlotte Preston Larkin describes the trials and tribulations of creating an adobe cottage (Puawananga) near Russell, Bay of Islands in the 1940s apparently without formal guidance or an instruction book. The work was hard but the house (including land) cost £159 compared to £1,500 for a conventional timber house (Larkin, 1949).

Figure 28: Charlotte Preston Larkin's house, Russell 1940s (adobe)

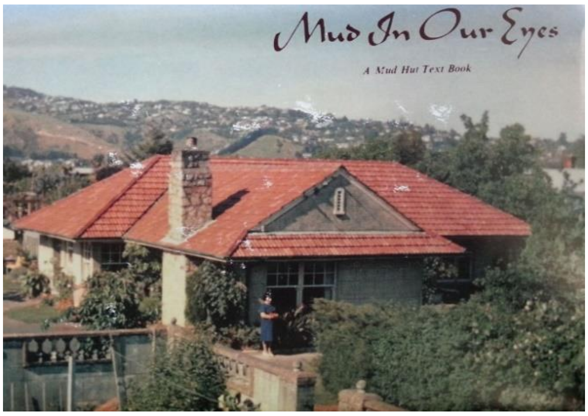


Figure 29: Stephens' House, Christchurch 1950s (pisé).

Pisé follows the basic approach of cob, but the earth is rammed into formwork to make the walls. Pisé differs from cob in three important aspects: earth mixed with small pebbles is used (rather than clay); the mix is dry (or slightly moistened) rather than wet; and is placed into removable wooden moulds and rammed hard with the *pisoir*. Pisé construction can be readily identified by the regular holes through the wall, where the *putlocks* hold the two sides of the mould together against the pressure of the rammed earth. The surfaces could be plastered, although the decorative finish from the mould surfaces could be left largely untouched.

Probably the most famous New Zealand pisé building is Pompallier House in Russell, Bay of Islands. Designed by New Zealand's first resident architect, Louis Perret, it was built by Marist priests in 1842 (Porter, 1979).

In 1851 in Lyttelton, John and George White were offering to build "Cob and Peasy walls to Houses at the most moderate rates" (Lyttelton Times, p. 1, 25 Jan 1851), while Robert Nankivele advertised he was available for building in "wood, pisé and cob" (Lyttelton Times, p. 1, 22 Feb 1851). In 1854 a contractor was available in Auckland "to undertake the erection of Pizey House (terre pisé)" (Daily Southern Cross, p. 1, 21 Feb 1854). In Nelson Charles Mason and John Woodhouse advertised their services for building in cob or pisé (Nelson Examiner and New Zealand Chronicle, p. 4, 15 Apr 1854).

Nowadays modern technologies with the use of mechanical diggers, steel moulds, tapered bolts, powered compactors and damp-proofing have made Pisé construction easier, although the need for skill remains. Figure 29 shows the cement-reinforced pisé house built by Mr and Mrs Stephens in Christchurch 1951-4 (Stephens & Stephens, 1981).

Wattle-and-daub involves the creation of infill panels by weaving thin cleft (split) lengths of hard wood. In England oak was traditionally used between upright oak staves but in New Zealand any suitable timber could be used. Early settlers in Sydney Cove used acacia, which became known as the *wattle tree* (H. J. Cowan, 1998, p. 8). The woven timber was daubed on both sides with earth mixed with straw or grass, although lime or cow dung could be added. It was finished with lime plaster.

Although cheap and quick to create, its problems have been recognised for 2000 years:

> "As for 'wattle and daub' I could wish that it had never been invented. The more it saves in time and gains in space, the greater and the more general is the disaster that it may cause; for it is made to catch fire, like torches. It seems better, therefore, to spend on walls of burnt brick, and be at expense, than to save with 'wattle and daub,' and be in danger." (Vitruvius Pollio et al., 1914, Book 2, Chapter 8, Para 20)

Salmond records the last wattle-and-daub construction was Jenkin's Cottage built in Otaki in 1869, which was bulldozed in 1985 (Salmond, 1989, p. 36). The Glens of Tekoa Homestead, Amuri, North Canterbury, was built in 1859 by William McRae. It has thick cob walls, wattle and daub partitions, timber shingle (now covered by corrugated iron) roof, broad cob chimneys and a large beech verandah (Figure 27) (Historic Place Category 1, Number 268) (Porter, 1983, pp. 33–34).

Mud-and-stud uses earth to fill the spaces between a heavier (normally timber) structure, providing one route to the English Elizabethan or Tudor style. Although a poor insulator, the heavy earth holds the temperature, acting as a thermal sink as well as keeping out draughts.

Interest in the building of earth structures, principally adobe and pisé, continues. Figure 30 provides a map showing the approximate locations of earth houses existing in the early 1990s, although in some cases a dot represents more than one building (M. Allen, 1996, p. 96). Earth buildings often tend to be in clusters:

- in the far North due to the availability of good soils and a suitable climate;
- in Wainuiomata (near Wellington) the Anker brothers built a number of houses of rammed earth in the 1950s, including six commissioned by the Government;
- the top of the South Island which combines useful soils, climate and a long history of the use of earth (Northcote-Bade, 1958);
- around Canterbury, where P.J. Alley of the Canterbury College of Engineering undertook research and promoted cement-earth homes in the 1950s; and
- in Central Otago with the combination of climate, soils and lack of timber.

Figure 31 shows the number of surviving earth buildings by decade of construction based on a mid-1990s survey, with over 430 built before 1980. Allen suggests the growth post-WWI and post-WWII was due to returning service personnel choosing to build their own houses and using earth either due to cost or possibly because they wanted something reminiscent of dwellings they had experienced overseas (M. Allen, 1997, p. 24). The 1970s saw renewed earth building activity due to cost and interest in alternative construction systems (Wilkes et al., 1972, pp. 77–83; Alister Taylor, McCormack, & Gruar, 1977, p. 109).

It is informative to compare this with the numbers reported in the censuses. Figure 8 shows the 1874 Census reported 5,483 (8.9% of total dwellings) sod, clay or cob huts, but by 1971, the last time this construction was listed, there were just 534 (0.1%). In all the inter-census periods, except for between three censuses (1906 to 1911, 1945 to 1951 and 1971 to 1976) there was a fall in the number of earth buildings (Section 4.1.6).

Figure 30: Locations of NZ Earth Buildings 1996

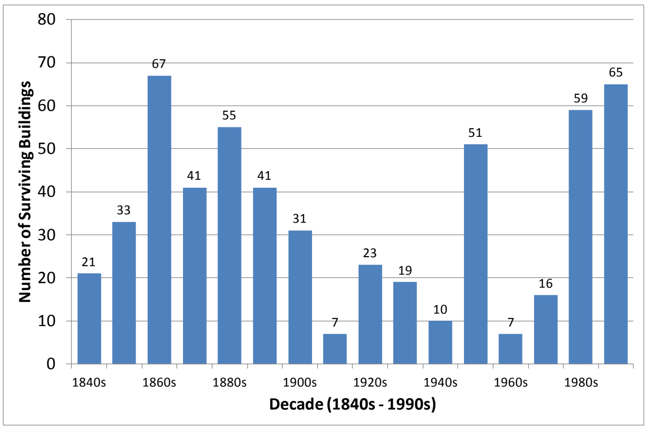


Figure 31: Decade of Construction of Surviving Earth Buildings in mid-1990s

5.2.2 Bricks

This section provides a brief overview of the development of the New Zealand brick industry, based on other publications that have explored this topic. (Thornton, 1982, pp. 114–121, 179–180) and (Salmond, 1989, pp. 45–48, 100–103) provide limited national overviews: Thornton lists 84 brickworks in 28 locations that were active between 1840 and 1906. The NZ Historic Brick Database provides a start for a future national history of the brick industry (Bickler, 2007), but to date there is no comprehensive overview of brick making in New Zealand.

A number of publications have traced the regional development of brick making:

- Northland and Auckland (Best, 1998);
- Auckland (Oliver, 2006, p. 52) (also provides an international historical review); and
- Otago (Seed, 1954).

Other publications have covered individual brick companies or works:

- Ceramco (formerly Crown Lynn Potteries, formerly Crum Brick, Tile and Pottery Co. Ltd) (Ceramco Limited & David Brett Limited, 1979; D. Scott, 1979);
- Huntly (Waikato Coalfields Museum, 2006);
- Palmerston North (Lundy, 2005); and
- Christchurch (Glenmore Brick & Tile Manufacturing Coy, 1916).

5.2.2.1 Brick Manufacture

The manufacture of quality bricks required good clay, careful preparation and uniform firing. The supervision of an experienced brickmaker provided additional certainty. In the early days of settlement, the wet clay was pressed into a mould, dried, and then fired.

In the early 1840s bricks were being manufactured in Wellington, Auckland and Nelson (Thornton, 1982, p. 114). Initially clamp kilns, such as shown in Figure 32 (Salmond, 1989, p. 47) were used, offering a short term, if wasteful, solution while waiting for the construction of more appropriate kilns. The dry bricks were stacked intertwined with fuel with spaces for the air and heat to circulate. The pile of bricks was covered with turfs or cinders and a fire was lit on one side. Over 20 to 30 days the fire was moved around the kiln. Up to 20,000 bricks could be fired in the clamp kiln but the quality was uneven (Salmond, 1989, p. 46).

Bricks could be made almost anywhere with a supply of the necessary raw materials. Figure 33 shows the second Glens of Tekoa 1865 homestead with triple-brick walls made of bricks burnt on the farm using nearby clay (Porter, 1983, pp. 33–34). (Historic Place Category 2, Number 1746).

Scotch or up-draught kilns followed. Although permanent, they still produced uneven quality bricks (Salmond, 1989, p. 102). In 1858, the German Frederick Hoffman invented the eponymous Hoffman or downdraught kiln where the heat from a fire above the kiln was drawn down through the bricks creating a more even and efficient firing. Hoffman Kilns were in use in New Zealand from the 1870s (Thornton, 1982, pp. 118, 120). The Hoffman Kiln at McSkimming's sanitary ware plant, Benhar, South Otago, (Historic Place Category 1, Number 5179) survived the 1990 fire which destroyed the rest of the plant (N. Smith, 2001, pp. 227–228).

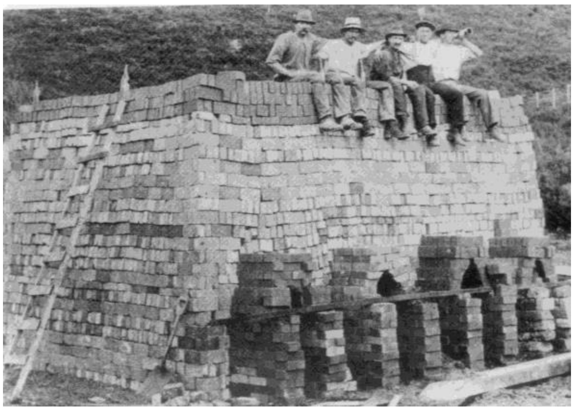


Figure 32: Clamp Kiln

Figure 33: Glens of Tekoa – Brick Homestead 1865

The brick industry grew steadily, assisted by improved mortars and the ever present danger of fire for wooden buildings. Brickworks were not attractive places, with the dirt, dust, noise and heat combining to create a desolate landscape. In 1891 there were 106 brick-, tile- or pottery-works, employing 494 hands (Table 17).

Post-WWII the continuous operation tunnel kiln replaced the earlier kiln types (Maithel & Greentech Knowledge Solutions Pvt Ltd, 2013). The clay was firstly prepared, extruded in a continuous column to be wire-cut to slightly larger than the final size and then centre perforated. The bricks were then stacked on cars and passed through a dryer tunnel, emerging after about 35 hours to enter the 72m kiln for a further two days. The entire process took about 8 days (D. Allen, 1986, p. 12; Oliver, 2006, pp. 29–31).

5.2.2.2 Brick Construction

Even if not widely used for walls, bricks provided fireproof chimneys (Figure 34). It did not take long to discover the poor performance of stone, and its man-made replacement brick, in an earthquake-lively country. The earthquake performance of brick continued to be of concern, even as building and fire legislation was being developed. Following the 5 June 1869 Christchurch earthquake, Edward Bishop (later Mayor of Christchurch) questioned the "probably additional danger to life" through the requirements of the then proposed Building Ordinance (Isaacs, 2012, p. 183).

Figure 34: John Pearse's first lodgings, Wellington Terrace, Wellington 1852

Brick construction continued to be of architectural interest. The first New Zealand book of architect designed house plans, published in 1917, provided a total of 91 house plans and/or photographs, of which 21 had brick walls (*Modern Homes of New Zealand by Architects of Standing*, 1917, pp. 77, 81, 83).

Although New Zealand continued to have earthquakes, it was not until the 1920s they changed brick construction. Ford (1929) (a reprint of extracts from (Ford, 1926)) gave a detailed review of the then understanding of earthquakes and earthquake design with respect to bricks. It suggested that brick buildings: should not be over 2 storeys; if tall and wide (e.g. theatres) have intermediate supporting floors or walls; not have too many openings in the walls; and not be poorly (dishonestly) built (Ford, 1929, p. 4). Ford added a typewritten note to the copy of his 1926 book he donated to the Alexander Turnbull Library that it was written before the Napier and Murchison earthquakes.

Following the 1931 Napier earthquake, the first Standard Model Building Bylaws[5] NZSS 95: 1935 set out requirements for reinforcing, including the use of ties "every four courses in height at not more than 27 in (69cm) centres in reach row" between the two leaves of a cavity wall constructed with clay bricks and "continuous bands of reinforced concrete carried round all external, party, and cross walls at the heights of each tier of floor joists and

[5] C.R. Ford was a member of the NZSS 95 Technical Committee

at the level of the tie beam or feet of the rafters of the roof" (New Zealand Standards Institute, 1936, pp. 30–43, Section IV).

In the 1930s, brick company publications started to promote the benefits of brick veneer over traditional cavity brick walls (Amalgamated Brick and Pipe Co. Ltd, 1938). As noted in Section 4.1.5, the impact can be seen in the increasing numbers of brick (veneer) houses.

Cowan considers the brick veneer house as an original Australian contribution to building construction (H. J. Cowan, 1998, p. 33), which matches the Building Research Bureau's view that masonry veneer was introduced from Australia (Building Research Bureau of New Zealand, 1962, p. 1). Lewis considers Canada in the 1850s a more likely origin, with New Zealand as the origin of the use of brick veneer in Australia (Lewis, 1998, pp. 6.04.2–6.04.3, 6.04 Bricks & Tiles: Brick Veneer).

The earliest reference to a New Zealand house built of "brick veneer" in Papers Past is for a house at 9 and 11 Webb Street, Wellington built in 1896 (‘Private Drainage Connection Application Plans. 9 & 11 Webb Street’, 1896) which was advertised for mortgagee sale in 1912 (Evening Post, p. 8, 13 Jul 1912), whereas the first mention in the Trove Australian newspaper collection was in 1915 for a just erected "palatial residence" in Colac, Victoria. (The Colac Herald, p. 2, 14 Jun 1915).

5.3 Stone

Stone was never a widely favoured construction material, probably due to a ready supply of timber. However, in some locations the lack of trees, while in others the permanence of stone, made it a more attractive material. For example, in Kerikeri the 1821 weatherboard clad, timber-framed, two-storey Kemp House was only joined a decade later by the Stone Store (started in 1832 and completed in 1836) (Porter, 1979, pp. 15–16). The Stone Store is built from basalt sourced from a nearby creek, with sandstone imported from Sydney decoratively edging the openings and corners (P. Shaw, Morrison, & McCredie, 2003, p. 17).

In Dunedin, the family of the Reverend Thomas Burns started in a four-bedroomed, prefabricated, wooden Manse which he described in his diary as "the most conspicuous and best aired house in all Dunedin" (quoted in Findlay, 2000). Coming from a tradition of stone houses, by late 1848 he had begun to build a house in stone on a site outside the city, although the stone from the quarry on his own land proved unsuitable and stone was obtained from the New Zealand Company's quarry in Anderson Bay. The house was finished and occupied in late 1850. Structural problems, including uneven settling of the foundations, weak lime mortar and the lack of exterior plaster contributed to it being abandoned by 1865. It was demolished by the late 1870s so William Larnach could build a guest-house on the same site. It would seem that the attempt to build in Scottish stone style in the 1840s exceeded the knowledge then available (Findlay, 2000).

By the 1891 Census of Manufactories, there were nine stone quarries in New Zealand, all located in Otago province, producing 103,071 cubic feet of building stone. Compared to the 1886 Census (Table 17), there were 5 fewer quarries, the output had fallen 77% from £19,217 to £4,487, and the number of hands employed had fallen 82% from 196 to 35 (New Zealand Government, pp. 65, 67, 15 Jan 1892). By comparison, the number of saw mills had fallen from 268 to 243, the number of hands by 35% from 5,042 to 3,266 and the output by 30% from £1,177,713 to £832,959. Even in the 1880s Depression the use of stone decreased far more quickly than the use of timber, again suggesting its use in buildings had been tried and found wanting.

5.3.1 Guidance on the Use of Stone

Masonry and stone cutting skills may have travelled to New Zealand with immigrants (Salmond, 1989, p. 30), but only in the 1870s did data become readily available on the strength and suitability of New Zealand stone for building with the publication of William Newsham Blair's "*The Building Materials of Otago and South New Zealand Generally*" (Blair, 1879).

Blair's information on building stones was distributed widely, with the "*New Zealand Yearbook 1886-87 Compiled for the Use of Intending Settlers, Tourists, Merchants and Manufacturers*" providing a summary of the main building stones to be found around the country, including details on the use of cement to make concrete for walls, footpaths and kerb blocks (Cooper & Stewart, 1886, pp. 79–84; Salmond, 1989, p. 50). This information was then summarised, and updated, in the special article on building stones in the "*1892 New Zealand Yearbook*", although reported there as having come "by permission, from the works of Sir James Hector" (New Zealand Department of Statistics, pp. iv, 194–199, 1892).

Nevertheless, Blair's treatise remained the only readily available publication on New Zealand building stones until 1912 when the Department of Scientific and Industrial Research (DSIR) published "*The Geology of New Zealand*," which provided a 5 page descriptive overview including examples of buildings in which the different stones had been used (Marshall, 1912, pp. 136–140). The 1920 New Zealand Official Yearbook included a very brief description of "Building and Ornamental Stones", but no technical details (New Zealand Department of Statistics, p. 261, 1920).The next publication on building stones was not until 1927, when R. Speight published two brief articles (Marshall, 1929, p. 5) providing an overview of the range of stones available and technical data on Canterbury stones, including Oamaru limestone (Speight, 1927a, 1927b).

In 1929, the DSIR published a comprehensive bulletin dealing with building stones suitable for the construction of public and other buildings (Marshall, 1929, p. 3, E. Marsden, 'Letter of Transmittal'). Although the "*Economic Geology of New Zealand*" described the range of building stones (G. J. Williams & McKee, 1974), it was not until 1987 (beyond the scope of this research) that a further book dedicated to New Zealand building stones was published (Hayward, 1987), reflecting continuing low interest in using stone for building.

5.3.2 Building Stones

Stone is heavy and durable but while strong in compression it is weak in tension. Earthquake performance is not good without reinforcing. Most rocks are good conductors of heat; for example the same thickness of marble ($0.02 m^2.°C.W^{-1}$) has only one tenth the R-value of softwood ($0.25 m^2.°C.W^{-1}$) (Fricker & Hughes, 2000, pp. 634, 637), but the heavy rock can store the heat of the day and release it in the cool of the night, leading to a more even indoor environment.

Building stones are classified by their origin, and all types are found in New Zealand (Hayward, 1987, pp. 3–4; Marshall, 1929, p. 6):

Igneous: formed from the cooling and solidifying of molten magma from deep within the earth; these can be hard and strong (e.g. granite, basalt, quartz) or more variable when formed from ash and pumice deposits (e.g. ignimbrite);

Sedimentary: formed from sediments that have accumulated in layers under the sea, lakes or river valleys that have compacted; these are less durable but have a long tradition in Europe and more recently in Australia as building stones for both small and very large buildings (e.g. sandstone, limestone);

Metamorphic: these are igneous or sedimentary rocks that have been modified by heat, pressure and/or hot gases or solutions (e.g. marble, slate, schist).

Marshall lists nine properties to be considered, both individually and in conjunction, in order to determine the suitability of a rock for building purposes (Marshall, 1929, pp. 7–14):

Freedom from weathering-action: stable under rain, natural or man-made pollutants

Strength: able to withstand crush or fracture over a very long period

Porosity: absorb little water to minimise decay, discolouration and frost damage.

Density: higher weight per unit volume leads to high handling and transport costs

Colour: provide a suitable colour for the required purpose

Texture: provide a suitable texture for the required purpose, particularly for carving

Shaping and dressing: able to be formed to the required size and shape with minimal waste

Hardness: ability to be worked combined with toughness and mechanical resistance

Accessibility: quarry conveniently located for transport by land or water

Many New Zealand stones are unsuitable for building purposes due to their performance, excessive defects, high quarrying expense, remoteness of mine or difficult access (Marshall, 1929, p. 6). For example, Tonga Bay (located in the Abel Tasman National Park) granite was used for buildings in the 1890s, but was found to crumble badly and not retain a high polish.

Over time many stones have acquired local or trade names which may disguise or even incorrectly state the type. Table 15 lists some widely used commercial stones, their actual rock type and mine location(s).

Table 15: Modern New Zealand Commercial Building Stones

Commercial Name	Rock Type	Mine Location(s)
Cannan/Takaka/Nelson marble	Marble	Takaka Hill, Nelson Region
Coromandel Granite	Diorite or Tonalite	North End, Coromandel Peninsula
Hinuera Stone	Ignimbrite	Near Hinuera, Waikato
Hanmer Marble	Limestone	Near Hanmer, North Canterbury
Halswell Stone	Basalt	Halswell, near Christchurch
Mt Somers Stone	Limestone	Near Mt Somers, Canterbury
Oamaru Stone	Limestone	Oamaru
Putaruru Stone	Ignimbrite	Near Putaruru, Waikato
Whangarei Marble	Limestone	Near Whangarei

(Based on Hayward, 1987; Nathan & Hayward, 2013)

Power tools revolutionised the extraction and processing of building stones. Only after WWII did stone-cutting equipment enable the on-site processing of stones in the Oamaru Parkside quarry (Brocklebank & Greenaway, 1979, fig. 1 & 2). Over time, the development of power drills, wire cutters, chainsaw cutters and circular saws have allowed stone to be more readily and efficiently quarried, and cut to size and shape before finishing.

5.3.3 Sources of Stone

Although decorative stones may be transported long distances, building stones were normally obtained locally, bringing to the building the qualities of the local environment. Examples include basalt lava in Kerikeri; scoria in Auckland; greywacke in Nelson; marble in Takaka; Oamaru stone in Oamaru; and schist in Central Otago (Arden & Bowman, 2004, pp. 105–106; M. Hill, 1985, pp. 12, 17; Salmond, 1989, pp. 49–50). The use of local materials not only supported the local development of skills and expertise but, as the 1883 Brett's noted, if a stone wall tumbles down "the material for re-building is there uninjured" (Leys, 1883, pp. 76–77).

Early settlers made use of nearby stones, possibly at the house site or from nearby fields or rivers. Once transport was available, stone could be brought from further afield although this cost was still a constraint. Outside areas with limited timber resources, such as Central Otago and Christchurch, very few stone houses appear to have been constructed. One example is Isel House at Stoke, near Nelson, completed in 1915 (Figure 35). The rubble construction used the greywacke boulders from nearby Poorman's Valley, with red local bricks providing contrast around windows and at corners (Hayward, 1987, p. 35).

Figure 35: Isel House, Stoke (1915)

5.3.4 Building in Stone

Although there are many types of building stone, there are only two main wall construction techniques. *Ashlar* uses shaped and formed stones, while *rubble* uses rough stones either as found or further shaped. Although lime mortar can be used to support the stones and give shape to the construction, or cement mortar used to hold them together, walls can also be laid dry with the friction between the stones giving the strength (Salmond, 1989, pp. 49–50).

Hayward notes that by 1987 (outside the scope of this thesis, but likely to be valid for the early 1980s) the only local stones still being used to any extent in the building industry were Hinuera Ignimbrite (trade name Hinuera Stone), Oamaru Limestone, Nelson Marble and Coromandel Tonalite (Coromandel Granite). Blocks of schist, greywacke, limestone and pebbles or crushed chips of colour stones were made into panels for exterior cladding (Hayward, 1987, p. 2).

Figure 36 illustrates the use of locally sourced scoria for a dry-wall at Highwic (1860-1879), Auckland (Historic Place Category 1, Number 18). In Central Otago schist was widely used for miners' houses as well as commercial buildings such as the Ophir Post Office (Figure 37) (Historic Place Category 1, Number 341).

Figure 36: Basalt Wall, Highwic, Auckland

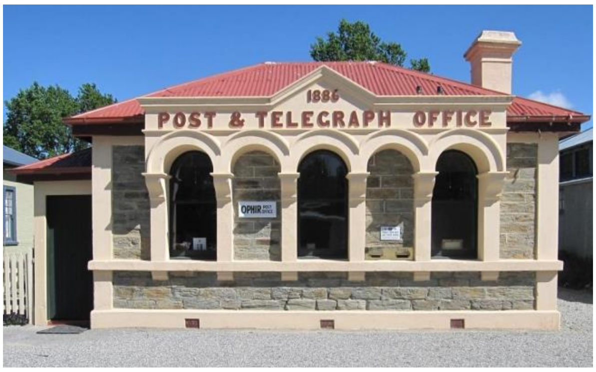


Figure 37: Ophir Post Office (1886)

Around Oamaru, limestone has been quarried since the 1860s. In 1862 the Government land sales notice reported that a "superior limestone abounds and is generally used for building purposes in the town of Oamaru" (Otago Witness, p. 4, 28 Jun 1862). Agricultural wealth supported the construction of substantial Oamaru stone buildings, many of which are still used (P. Shaw, 1995).

Hinuera Stone is a durable, acid resistant ignimbrite. It was first used in 1894 for the Bishops Palace, Ponsonby, Auckland (Hayward, 1987, p. 23), although the present quarry was established much later in 1954. The quarry is situated on a river terrace of what was once the bed of the Waikato River and in later years has been mechanised (Whyte, 2001, pp. 66–67). The rock was sawn from the quarry face, and further processed on site into a range of grades and sizes. It could be left natural or kiln-fired (to increase the colour range), and finished as sawn or split face (Oliver, 2006, p. 52).

Not all so called building stones are actually stone. Popular in the 1960s, "Roskill Stone" made by Winstone Ltd, was a rock-faced concrete brick (F. A. Simpson, 1965, p. 65).

Although internationally stone construction has a long tradition, in New Zealand the limited range of readily available local building stones, the need to build for earthquakes and the cost of skilled stonemasons have resulted in costs that are "too high to be employed in material that is not extremely attractive" (Marshall, 1929, p. 27). When coupled with the reduction in cost of other construction systems (including concrete and steel framing), stone is used more for façades than for structure.

5.4 Cement and Concrete

Cement comes in non-hydraulic and hydraulic forms. Non-hydraulic cements, such as burnt lime and gypsum, need to be kept dry in use to retain their strength. Hydraulic (water setting) cement dates back to Roman times, when naturally occurring pozzolana (silica-rich volcanic ash) was mixed with burnt lime to make a cement harder than the lime alone.

Burnt lime (or quicklime) was made from burning limestone, chalk or some other source of calcium carbonate, such as shellfish shells. The heat drove off carbon dioxide, leaving behind a material which was ground to a powder. This was then mixed with water to form a mortar to be shaped as required. The mortar set by drying, but also strengthened over time with the re-absorption of the carbon dioxide. The basic raw material requirements remain unchanged: limestone; ash or clay; fuel; and a suitable site for the processing.

The modern history of cement started with John Smeaton's 1756 Eddystone Lighthouse, where he used cement based on Welsh limestone, which naturally included clay, mixed with Italian pozzolana. By 1850 three types of cement that would set in a damp atmosphere were available: natural hydraulic cements, artificial cements and Portland cements (Elliott, 1992, pp. 150–153).

The *natural cements*, produced in Britain and America, were made by burning stone which contained a suitable mixture of lime, alumina and silica. The British products were often (incorrectly) called *Roman cement*. The *artificial cements* were made by mixing water and limestone with clay, burning it between 1,100°C and 1,300°C and then grinding the resultant glassy clinker. This was the method used by Joseph Aspdin's 1824 Portland cement, named for its resemblance to the high quality stone quarried in Portland, south-west England (Addis, 2007, p. 344). It was not until 1845 that the true *Portland cements* were available, requiring firing temperatures of about 1,370°C in order to have as complete a chemical reaction as possible between the lime and silica.

Early cement kilns were intermittent or batch production, with the first continuous kiln coming from Germany in 1880. The first successful rotary kiln, based on wet slurry, was in operation from 1900 but it took until the 1960s for the less energy intensive dry process to be brought into production (Elliott, 1992, pp. 153–160).

5.4.1 Imported Cement

From relatively early days there was an interest in the use of cement and concrete in New Zealand. In 1841 Bethune and Hunter of Wellington were advertising the public auction of "20 casks cement" which had arrived on the New Zealand Company's schooner Balley after a voyage of 3 months and 17 days (New Zealand Gazette and Wellington Spectator, p. 2, 17 Apr 1841). The following year, Ridgways, Guyton, and Co., also of Wellington, were advertising "Roman cement in puncheons, barrels, and half barrels" (New Zealand Gazette and Wellington Spectator, p. 1, 16 Sep 1843).

Figure 38 shows imports of cement, based on value, by country from 1870 to 1965. For the 1870 and 1875 import statistics only a combined *Plaster of Paris and Cement* category was provided. Until 1920, the large majority (over 90%) of cement imports were from UK. In 1920 UK imports reduced to 23% with Canada (given as 'Other' 33%) and Australia (39%) providing the majority. In the following years, the UK continued its dominance, although it was not until 1965 that it again provided such a high proportion of imports.

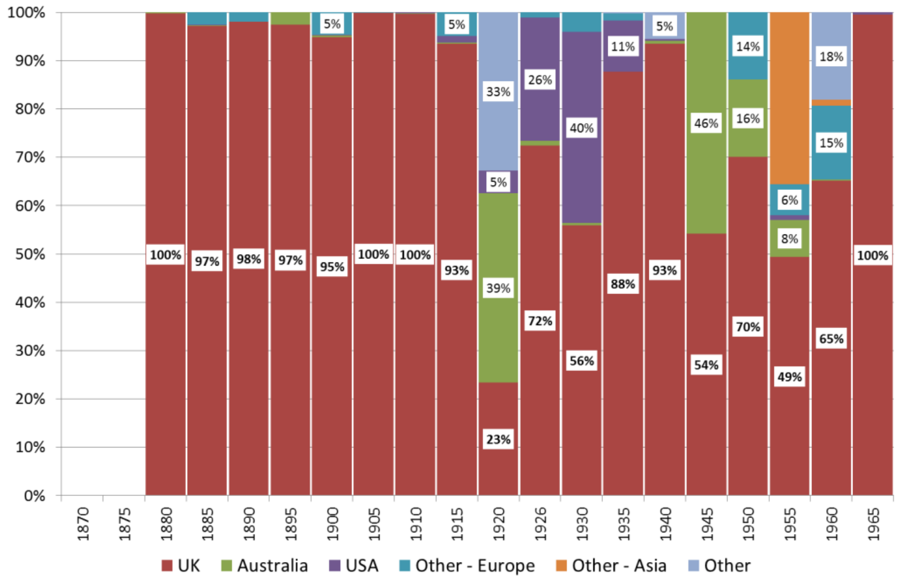


Figure 38: Cement Imports by Country 1870 to 1965

Figure 39 shows the imports of cement by value and quantity per person from 1870 to 1965. The development of the local industry can be seen in the steadily falling demand for imported product, which by 1915 was at a very low level. The large increase in imports following WWII suggests the local industry was unable to meet the demand, and as shown in Figure 38, these imports were still from the UK and then Australia.

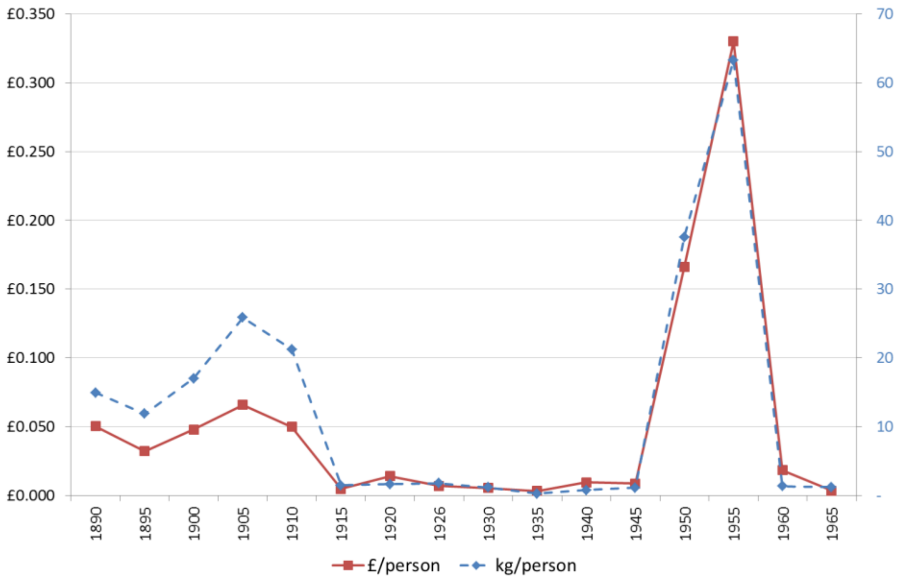


Figure 39: Cement Imports per Person by Value and Quantity 1870 to 1965

5.4.2 Local Burnt Lime

The traditional mortar for bonding masonry and brickwork was a mixture of sand and lime mixed with burnt lime, although the mortar it produced was not strong. Lime was being burnt in the Nelson district in 1843, in Otago after 1849, Warkworth 1853, Kapiti about 1865, and Northland by 1867 (Thornton, 1982, pp. 122–124).

Thornton notes that with the "surprisingly widespread early use of Portland cement" the need for lime burning for building purposes was diminished by the start of the 20th century (Thornton, 2001, p. 124). The 1978-79 Census of Manufacturing reported 3 *lime kilns (not agricultural lime)* (New Zealand Department of Statistics, p. 496, 1983).

5.4.3 Local Cement Manufacture

The 1880 Royal Commission into Local Industries (known as the Colonial Industries Commission) was established on 12 March 1880 and reported on 29 July 1880. It received, and published, 207 written submissions. The Commission made a number of recommendations including for forestry, iron, cement, improved technical education, uniform weights and measures. They were in favour of encouraging the cement industry which "should become very valuable." They recommended the Government "should offer to purchase 100 tons of cement from any bona fide local manufacturer, subject to proper tests, and the price to be the then market price of the best [imported] Portland cement" (Evening Post, p. 2, 13 Aug 1880; New Zealand Parliament, 1880, pp. 11–12).

The following years saw cement manufacture commence in Northland and Otago, as well as attempts in Fiordland and Golden Bay. Table 16 provides a summary of the evolution of the cement industry, listing the main plants, companies and amalgamations.

The 1891 Census of Manufactories reported 21 *Lime- and Cement-works*, three less than the 1886 Census, although there had been an increase of 18 hands employed to 98 (Table 17). The value of land, buildings, machinery and plant was almost the same at £33,580 out of a total value for all New Zealand manufactories and works of £5,261,826 (excluding mines and quarries) (New Zealand Government, p. 67, 15 Jan 1892).

By 1895, the Public Works Office supply contract for "Cement and lime" was met from New Zealand manufactured cement, either from J. Wilson and Co or the Milburn Lime and Cement Company (New Zealand Government, p. 571, 28 Mar 1895). In 1898, presumably in response to the development of the local industry, the Public Works store supply contract class was listed simply as "Cement (New Zealand manufacture)" (New Zealand Government, p. 536, 31 Mar 1898).

Table 16: NZ Cement Plants 1878-1989

Date	Location	Company	Closed	Merged Moved	Became / Note
1885	Warkworth	John Wilson & Co. Ltd	1929	1918	Wilson's (NZ) Portland Cement Ltd
1882	Ferntown, Golden Bay	Ferntown Coal Mine & Portland Cement Works	1886		Plant to Golden Bay Cement Co
1887	Milburn, Otago Peninsula	James McDonald		1888	Milburn Lime & Cement Co. Ltd
1890	Pelichet Bay, Dunedin	Milburn Lime & Cement Co. Ltd	1929		
1896	Limestone Island, Whangarei	NZ Portland Cement Co.	1918	1918	Wilson's (NZ) Portland Cement Ltd
1906	Motupipi, Golden Bay	NZ Atlas Cement Company	1909		
1910	Tarakohe, Golden Bay	Golden Bay Cement Works Ltd		1919	Golden Bay Cement Co. Ltd
1916	Portland, Whangarei	Dominion Portland Cement Co. Ltd		1918	Wilson's (NZ) Portland Cement Ltd
1924	Silverdale	Mappin and Co.'s Silverdale Lime Company	1924		
1919	Tarakohe, Golden Bay	Golden Bay Cement Co. Ltd	1989		
1929	Burnside, Dunedin	Milburn Lime & Cement Co. Ltd	1988		
1955	Te Kuiti	Waitomo Portland Cement Ltd	1970	1961	Golden Bay Cement Co. Ltd
1957	Clifden, Southland	Southland Cement Co. Ltd	1968	1969	NZ Cement Holdings Ltd
1959	Cape Foulwind, Westport	NZ Cement Co Ltd, Guardian Cement			NZ Cement Holdings Ltd
1963		Milburn NZ Ltd + NZ Cement Company merger			NZ Cement Holdings Ltd
1977	Burnside, Dunedin	Milburn NZ Ltd (52% Holcim)	1988		

Sources: (Jaques, 1998; New Zealand Concrete Research Association, 1984; N. Smith, 2001; Thornton, 1996)

In 1982 there were three cement plants operating: Milburn's Burnside (Dunedin) plant; NZ Cement Holdings Limited's Cape Foulwind plant (near Westport); and Golden Bay Cement's plant at Portland (south of Whangarei). Cement ships transported product to bulk storage depots around the country (T. Christie, Thompson, & Brathwaite, 2001, pp. 9, 18).

5.4.3.1 Early Failures

In 1880 a prospectus was launched to support the development of a marble and Portland cement company to be located in Caswell Sound, Fiordland (Wanganui Herald, p. 2, 21 Oct 1880). The Caswell Sound Marble and Portland Cement Company (Limited) was advertised extensively throughout New Zealand. In 1883 it shipped machinery to the remote location (Grey River Argus, p. 2, 26 Apr 1883), but by the fourth annual meeting in 1885 it was recognised the access to extract and transport the marble was inadequate, although "the refuse would make excellent cement" (Star, p. 4, 19 Dec 1885). The company quarried marble between 1881 and 1887 (T. Christie et al., 2001, p. 15), but does not appear to have manufactured cement.

In 1882 a large manufacturing plant was erected in Ferntown, Golden Bay and successfully produced cement (Grey River Argus, p. 2, 26 Dec 182; Thornton, 1996, p. 88). The plant used coal, lime and clay (or shale) extracted from the Collingwood Coal Mine or alongside the mine rail tracks (Nelson Evening Mail, p. 228 Dec 1882). In reality, although a plant was built and quality cement produced, the expected capital investment failed to eventuate (The Colonist, p. 1, 28 Mar 1885). The dry process works, which cost £2,180 to build, were claimed to be capable of making 30 tons of cement a week, as "materials necessary for Cement making exist in great abundance, and have been delivered at the Mill for 4s per ton." The plant closed and was put up for auction in Nelson (The Colonist, p. 2, 5 Aug 1886)on 9 October 1886 (Nelson Evening Mail, p. 2, 8 Oct 1886). Local Collingwood history suggests the machinery went to the Tarakohe works of the Golden Bay Cement Company (Thornton, 1982, p. 126).

At Motupipi, Golden Bay, cement manufacture was trialed in 1907 (Thornton, 1996, p. 88). The New Zealand Atlas Cement Company spent £4,000 to develop and prove coal, limestone, fireclays and potters clays resources located on the property. Cement was made and tested (The Colonist, p. 2, 27 Dec 1907). The company did not survive, and after six months the plant was reportedly closed. Two years later, notices advertising the sale of the plant reported that "in view of the large cement works to be erected at Terakohi [sic], at an early date" (Dominion, p. 16, 27 Mar 1909) the plant would be sold (The Colonist, p. 2, 20 Mar 1909). A "great slaughter ensued" with low prices being received (The Colonist, p. 4, 28 Apr 1909).

Mappin and Company's Silverdale Lime Company, on the Weiti (Wade) Estuary, Silverdale, operated a small plant manufacturing cement for a short period prior to 1924 (T. Christie et al., 2001, p. 18; Ferrar, 1934, pp. 5, 69).

5.4.3.2 Wilsons

The Warkworth hydraulic lime works was started by Nathaniel Wilson in 1866, selling under the brand *Roche*. In 1883 Wilson started experimenting with the manufacture of Portland cement, after hearing about Henry Reid's book "*Science and the Art of the Manufacture of Portland Cement*" (H. Reid, 1877). In 1885 he reportedly manufactured the first Portland Cement in New Zealand and the Southern Hemisphere, but it took some time before it was accepted by the authorities (*The Auckland Industrial Agricultural and Mining Exhibition*, 1913, p. 133; Thornton, 1996, pp. 86–87). By 1886 Wilson's cement was being used to build the New Plymouth gaol (Taranaki Herald, p. 2, 8 Nov 1886).

In a series of regular newspaper advertisements starting from 7 February 1888, hardware merchant Peter Hutson & Co. of Wellington advertised the availability of both English and New Zealand cement, noting that Wilson's cement "has been proved during the last 18 months to be equal, and in many cases to be superior, to the imported cement" (Evening Post, p. 37 Feb 1888). P. Hutson & Co. continued their promotion of Wilson's cement, including exhibiting at the 1896 Wellington Industrial Exhibition with a stand constructed entirely of New Zealand cement, bricks, statues and even a terracotta fountain (Evening Post, p. 2, 30 Dec 1896). Their advertisements continued three to four times a week until June 1899 (Evening Post, p. 3, 20 Jun 1899).

Although the production details took some time to be resolved, Wilson's grew strongly. In the early 1900s, following a visit to America of W.J. Wilson (company engineer and Nathaniel's eldest son), they set up a plant using the then revolutionary rotary kilns and tube mill. A float of preference shares in 1904 led to John Wilson Company Ltd becoming a public company (Auckland Star, p. 2, 23 Sep 1904). The Warkworth plant closed in 1929, and production moved to Whangarei and then Portland (near Whangarei) where production continued (Thornton, 1996, pp. 87–88). Figure 40 illustrates the extraction of limestone about 1925, while Figure 41 shows the unloading from ship to store of bagged cement about 1952.

Figure 40: Tractor and wagons at cement works, Limestone Island, Whangarei c1925

Figure 41: Unloading bags of cement at the Nelson Street Store, c1952

5.4.3.3 Golden Bay

As discussed above, there were at least two failed attempts to make cement commercially in the district before the Golden Bay Cement Works Limited was established in Tarakohe, Golden Bay in 1908 (Thornton, 1996, p. 88). Funds had been raised by representatives travelling through the country to promote investment (Nelson Evening Mail, p. 2, 27 Feb 1907; Wanganui Chronicle, p. 4, 14 Sep 1909). The company invested over £50,000 in plant, including an electrical rotary kiln, factory and the wharf, designed to produce 500 to 600 tons per week. The cement machinery was supplied by E. Newell and Co. of Misterton, Lincolnshire and the electrical machinery by the British Westinghouse Company (Progress, p. 132, 1 Feb 1910). In 1919 the Golden Bay Cement Company Limited took over the operations, and continued to develop the plant and expand production.

The company also expanded by acquisition, and in 1961 took over the Waitomo Portland Cement Company and its Te Kuiti plant which had been established in 1955. The Te Kuiti plant was closed in 1970. In 1982 the Golden Bay Cement Company Limited acquired Wilson's plant and company name, becoming the Golden Bay Cement Group (New Zealand Concrete Research Association, 1984).

5.4.3.4 Otago Cement

Cement manufacture in the South Island was started by James MacDonald (also spelt McDonald) at Walton Park, Green Island, Dunedin. For many years MacDonald had been burning lime at Sandymount on the Otago Peninsula, where his 1865 kilns can still be seen (N. Smith, 2001, pp. 220–221). Work on the Walton Park plant commenced about October 1886, and the cement was advertised for sale from 31 December 1886 as proving itself "superior in most cases" to imported brands (New Zealand Tablet, p. 26, 31 Dec 1886). The business ran into financial difficulties (Evening Post, p. 3, 15 May 1888) so in 1888 was sold to the Milburn Lime and Cement Company which owned a lime deposit at Milburn (Otago Daily Times, p. 3, 25 Jul 1888). The Milburn Lime and Cement Company was already promoting its cement as: "… more Economical and Cheaper than the imported article, and Engineers, Architects, Contractors, and others will receive, if required, a Guarantee of Quality and Tensile Strain" (Otago Daily Times, p. 3, 18 Dec 1888).

In 1890 the plant was moved to reclaimed land at Pelichet Bay (Otago Witness, p. 20, 9 Jan 1890), then an inlet on Otago Harbour, which was later reclaimed for the 1925 New Zealand and South Seas Exhibition, and is now known as Logan Park. The product was extensively tested, showing "the silica Portland cement to be at least thirty per cent better than the imported Portland cement" (Cyclopedia Company Limited, 1905, pp. 364–365). The Pelichet Bay plant closed in 1929 when a new cement plant was established at Burnside, Dunedin (Auckland Star, p. 4, 18 Mar 1929) which in turn was closed in 1988 (Thornton, 1996, p. 88). Milburn actively promoted cement, including publications on the manufacture, test and use of its product (Milburn Lime and Cement Company Limited, 1895).

In 1958 on the West Coast of the South Island, the New Zealand Cement Company started a new cement plant at Westport. The company merged with Milburn in 1963 to form New Zealand Cement Holdings Limited. The Westport plant grew, ultimately replacing the Burnside plant. In 1968 the company took over the Southland Cement Company Ltd which had started in 1957 (New Zealand Concrete Research Association, 1984, p. 4).

McDonald's cement continues to hold pride of place, albeit disguised, in central Dunedin. The Robert Burns statue in the Octagon (unveiled on 24 May 1887) was designed and cast in Edinburgh by Sir John Steell, and placed on a pedestal of Peterhead, Scotland, granite

(Otago Witness, pp. 12–13, 27 May 1887), but it sits on a hidden base made using local McDonald's cement. The contractor, Mr Munro, was very impressed by the quality of the cement, and on a visit to the Walton Park plant on 12 March 1887 was reported saying:

> "... he had used McDonald's cement for the Burns statue, and he would invite anyone to take a pick and try the cement for themselves. He could say it was the best cement in the country, and as long as it maintained its present quality he would not use anything else" (Otago Witness, p. 14, 18 Mar 1887).

5.4.4 Concrete

Concrete is made from cement, nowadays principally Portland, mixed with appropriate proportions of aggregate and/or sand to provide a dimensionally-stable and cost-effective filler, with the addition of water and selected additives as required to modify its properties, and the mix left to harden. The relative proportions of the components vary depending on the desired properties. For example, no coarse aggregate creates a mortar for bedding bricks or blocks, or for use as a coating to provide a smooth, durable surface finish.

Typically concrete is a grey coloured (due to iron in the cement (van Oss, 2006, p. 9)), multi-purpose, widely used construction material with many desirable benefits: excellent fire performance; strength in compression; thermal mass for modifying temperature change; ease of application; ability to be shaped; and ability to imitate stone. Adding steel mesh or bars creates reinforced concrete, and the improvement in strength in tension and resilience under earthquake loads turns it into a ubiquitous, low cost solution to many building problems.

5.4.4.1 Early History

The early innovative settlers made use of concrete for both public and private construction, moving in advance of then common European practice.

The *New Zealander* newspaper of 18 October 1848 advertised tenders for a native hospital at Wanganui "the building to be 72 feet by 40, and thirteen feet high, the walls to be of brick, stuccoed, and upon a concrete foundation" (New Zealander, p. 2, 18 Oct 1848). Two months later, local newspapers were reporting the case of Robert and David Graham of

Auckland. They had commissioned a stone and brick house with a concrete foundation, but failed to pay John Walker, the builder and architect, for his work. The case was heard in the Supreme Court and judgement was made against the Grahams, although the newspaper noted: "We think that it is a great pity this case was ever brought into Court, it ought to have been settled without litigation" (Daily Southern Cross, p. 2, 9 Dec 1848; New Zealander, p. 2, 9 Dec 1848).

The reportedly earliest evidence of concrete construction remaining in New Zealand is a "rather crude retaining wall at Fyffe House in Kaikoura" which was built by 1857 (Thornton, 1996, p. 22).

At the first annual meeting of the Wellington Philosophical Society, held on 31 January 1868, James Coutts Crawford read a paper on building materials (Crawford, 1868). He argued that there were four reasons "for the adoption of concrete as the chief building material in Wellington":

1. a shortage of building materials, except for timber;
2. protection for the damage of earthquakes and shaking by wind;
3. flat concrete roofs would perform better in the wind; and
4. there were ample supplies of sand and gravel in and near the city, and the raw materials for cement were available in both islands.

His conclusion was that "the best material to meet our requirements seems to be concrete." The Chair (The Bishop of Wellington) asked whether concrete had been tried in countries subject to earthquakes, but Crawford thought it had been principally used in France and England (Crawford, 1868; Wellington Independent, p. 4, 4 Feb 1868).

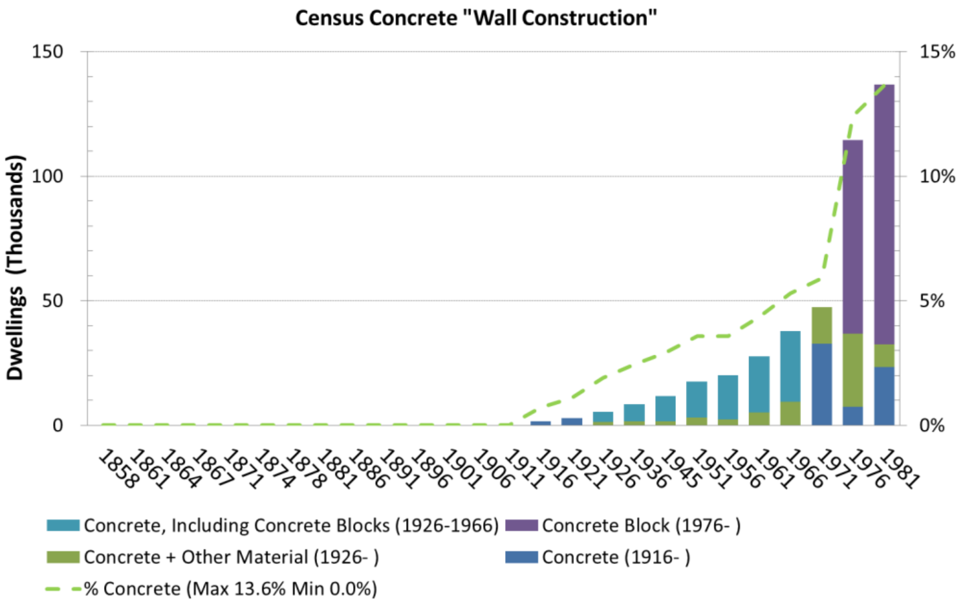


Figure 42: External Wall Concrete Construction 1858 to 1981

Figure 42 shows increasing use of concrete wall construction from the 1920s with major growth, notably in concrete blocks, occurring in the 1970s.

5.4.4.2 Reinforced Concrete

Although concrete is strong in compression, its performance is poor in tension. It was not until 1854 that the first solution that anticipated modern reinforced concrete was patented. In the patent, English builder, William B. Wilkinson, used iron cables salvaged from winding engines in tension within concrete to create fire proof dwellings (Addis, 2007, p. 346). In 1867 Joseph Monier patented a system for making flower pots using concrete reinforced with iron rods. Over the next decade Monier obtained several more patents, although the purpose did not appear to be for the iron to carry the tensile loads. His 1878 patent took the final step, showing reinforcing bars carrying the tension and shear forces. In 1885 the rights were sold to the German firm Wayss and Freytag (Addis, 2007, pp. 418–421).

Various British, American and French researchers experimented with different techniques, but it was Frenchman François Hennebique who is credited with first understanding the most effective locations to place steel reinforcement in concrete elements so that the engineering properties of the two materials complemented each other. He patented his system in 1892. Hennebique's firm, along with Wayss and Freytag, became largely responsible for the growth of reinforced concrete construction in Europe (Addis, 2007, p. 421).

Reportedly the first major use of steel reinforcing in New Zealand is the 1883 water tower at the former Railways Workshops, Christchurch. At 18 metres tall, it was built by prisoners from the Addington Prison and used several tons of carefully placed scrap metal (Progress, p. 200, 1 Jun 1906; Thornton, 1996, pp. 66–69). For comparison, the first reinforced concrete water tower constructed in Britain was built in 1900 in Bournemouth (Stanley, 1986, pp. 39–40).

Techniques for concrete reinforcing have developed over the years. Modern construction uses complex reinforcing patterns with steel rods, bent or welded into shape to distribute loads safely through the building structure. Much work has been carried out on the structural design and the overall durability of the composite steel-concrete system. Research has included investigations into the long term behaviour of reinforcing steel and methods of minimising the penetration of potentially damaging agents such as air-borne salts and carbon dioxide. Well-designed concrete need not suffer from the *concrete cancer* or *spalling* that has prematurely ended the life of some older structures. This is typically caused by the reinforcing steel corroding, and as rust occupies more space than the bare metal, it can result in pieces of concrete flaking off, further exposing the steel for the process to continue and ultimately destroy the overall structural integrity. Well-compacted dense concrete inhibits the steel rusting by providing a beneficial alkaline environment and also assists fire protection.

Concrete continues to play a crucial role in the New Zealand construction industry. The use of hollow concrete blocks is discussed in Section 6.3.4, concrete stone in Section 5.3.4, monolithic concrete in Section 6.3.3 and fibre-cement boards in Section 6.5.3.

5.5 Timber

The earliest human visitors to the shores of New Zealand viewed a well forested country. By the time of European settlement nearly half that forest had been destroyed (McKinnon, Bradley, & Kirkpatrick, 1997, Plate 12) to create clearings and for cultivation (Young, 2005, p. 43). Even so, when Captain James Cook viewed the country in 1770, he reported that there was:

> "… plenty of Excellent Timber, fit for all purposes except Ships' Masts; and perhaps upon a Close Examination some might be found not improper for that purpose" (Cook, 1893, p. 217).

Although early European settlers imported planks and scantlings (New Zealand Gazette and Wellington Spectator, p. 4, 18 Apr 1840), they quickly made use of native timbers. They found kauri was indeed suitable for masts and many other purposes. Many of the native timbers could be used for construction with minimum processing. As the population increased, coupled with industrialisation, sawn native timber became widely used.

The slow-growing native timbers could not be expected to meet an ever increasing demand, so farsighted foresters trialled a wide range of imported (exotic) trees and ultimately the most productive were selected for mass planting in exotic forests.

5.5.1 Native Forests

For early settlers, creating a house out of timber took more work than using raupo reeds (Section 5.1.1). Even small trees had to be felled before they could be assembled into a building. Depending on the tools available, the timber could then be used as rounds, or split into slabs (Section 6.3).

Of the many indigenous timbers, it was kauri that was the most internationally desirable timber due to its clean, fault-free lengths (Figure 43). It was widely used from the earliest days of European settlement, with prefabricated kauri houses being exported to San Francisco in 1849 (Toomath, 1996, p. 80). By the early 1900s large volumes of kauri were being exported to England, Australia, South Africa, Mauritius, the Pacific and China. By 1905, kauri was reportedly the only New Zealand wood to have found a British market (Sutcliffe, 1905, pp. 86–87).

Other New Zealand native timbers were used locally for butter boxes; fencing; railway sleepers; packaging; and furniture. From the 1830s these items were also exported, including across the Tasman Sea (Lewis, 1998, p. 12, Chapter 5.01 The Timber Frame: The Timber Trade). William Newsham Blair's fourth paper to the Otago Institute dealt with timber (Section 0). In it he provided detailed descriptions and physical attributes for 18 hardwoods and 11 softwoods which he considered suitable for building use (Blair, 1876b).

Although the pressure to replace the rapidly diminishing resource of native forests may not have been strong in the minds of the forest gangs, millers and merchants, it concerned those who dealt with trees and the land. In 1872 the Auckland Institute heard two papers on the growing of native trees. J. Baber's paper reported on the growth from 1851 to 1872 in Remuera, Auckland of 12 native species, including a Puriri tree which had grown to 20ft (6.1m) (Baber, 1872), while D. Hay considered the propagation of 10 different native species, including kauri (Hay, 1872).

In 1878 Thomas Kirk noted that the consequences of over exploitation, unnecessary destruction and waste of timber unable to be carried to market, were likely to lead to the exhaustion within thirty years of the "magnificent kauri forests of Auckland" (Kirk, 1878). In 1880 Kirk suggested that rather than imports, a wide range of products could be developed from the wasted native timber resource including: tar; burgundy pitch; creosote; kauri resin; oil of tar; turpentine; pitch; oil of turpentine; lampblack; potash; resin; charcoal; and wood ware (Kirk, 1880).

History records the (near) exhaustion of many native timber forests, although it took until 1939 for the export of native timbers to be mostly prohibited (McLintock, 1966, p. 720, Vol. 1). By the 1950s only 9 native tree species were locally used (Technical Correspondence School, 1958, pp. 46, 72–73). Native timbers still commercially available in 1980 are given in **bold** (New Zealand Technical Correspondence Institute, 1980, pp. 60–61):

- **Softwoods**: kauri, **rimu**, **matai**, **totara**, **kahikatea** and **miro**
- **Hardwoods**: **red beech**, **silver beech** and **tawa**.

The dwindling supplies of native timber were replaced by the relative new comer, the exotic Pinus radiata, which by the late 1950s had become "second only to rimu in commercial importance" (Technical Correspondence School, 1958, p. 73). It was not until 1996 that unsustainable logging of native forests ended (R. Taylor & Smith, 1997, p. 4.18). Many of the remaining tracts are now within a National Park, under covenant with the Queen Elizabeth II National Trust since its formation in 1977[6] or protected by their owners.

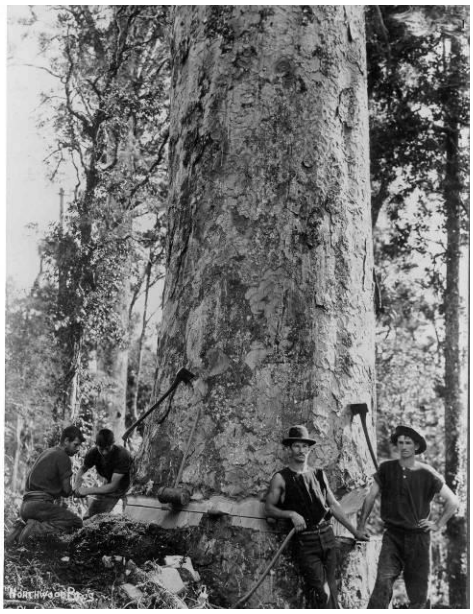


Figure 43: Gang using two man saw and associated wedges to cut kauri. c1913

Figure 44: Bullock team dragging felled kauri logs from the bush c1913

5.5.2 Exotic Forestry

European settlers wasted no time in logging and clearing forests to turn them into farmland, although windswept land was not good for settlers nor their farms. The importance of trees for farm shelter was soon realised, with the Planting of Forest Trees Ordinance 1858 passed by the Canterbury Provincial Government (Canterbury Provincial Government, 1858). Nationally, the New Zealand Forests Act that followed in 1874 (Government of New Zealand, 1874), regulated the sales of native timber and appointed a Minister of the Crown to be the Commissioner of State Forests (McLintock, 1966, p. 720, Vol 1).

The first Conservator of Forests, Captain Campbell-Walker, formerly of the Indian Forest Service, was appointed in 1875 (McLintock, 1966, p. 720, Vol 1). He soon reported to the Government on the formation of a State Forest Department and promoted this through talks in Dunedin in 1876 (Walker, 1876) and Auckland in 1877 (Walker, 1877). One issue he

[6] http://www.openspace.org.nz/

raised of immediate relevance to New Zealand was the French use of forestry to control drifting sand dunes (*reboissement*). His many proposals remained behind after he completed his term in 1877, travelling to Sydney and then returning to India (Timaru Herald, p. 8, 29 May 1877).

Thomas Kirk, already known for his concern for the long term future of native forests (Section 5.5.1), was appointed the Chief Conservator of Forests in 1885 (MacLeod, 1993). The 1885 State Forest Act (Government of New Zealand, 1885) resulted in little progress, although the 1896 timber conference led to afforestation with exotic trees from 1897 in Auckland, Canterbury, Otago and Southland (McLintock, 1966, p. 720, Vol. 1).

5.5.2.1 Exotic Experiments

From the early days of European settlement, it seems every tree known to settlers that stood a chance of growing in the New Zealand climate was trialled, although not all were successful. For example, when A.A.T.W. (William) Adams settled in Greendale, Canterbury in 1865 he farmed and planted trees. By 1908 his arboretum had 800 species of trees and shrubs (McKelvey, 2013). He reputedly cultivated 500 varieties of apple (Hegan, 1993).

Many early settlers planted exotic trees and observed their growth, often for many years. In Auckland in 1879, the Supreme Court Judge T.B. Gillies reported on the growth of 25 different species of trees he had planted on his scoria land at the foot of Mount Eden. The fastest growing of these were four specimens of Monterey Pine, with one achieving 58 feet in height (17.7m) and 7ft 6" (2.3m) in girth (Gillies, 1879). Monterey Pine had been described separately by two botanists in about 1830, one who named it Pinus insignis and the other Pinus radiata, the name used today (McLintock, 1966, p. 720, Vol. 1).

One of the earliest plantings of Pinus radiata was by John Acland in 1859 at Mt Peel Station in South Canterbury. In 1993, 134 years later, the tree stood 50 metres tall with a crown spread of 38 metres and a girth of 9 metres (Hegan, 1993, p. 95). However, the early conclusion was that while the various pine species did well under New Zealand conditions, they were not suitable timbers for building. J.B. Armstrong, of the Botanic Gardens Christchurch provided a list of 20 resinous trees and 16 hardwood trees "well adapted to the Colony of New Zealand and to the requirements of the colonial timber merchants" (Leys, 1883, pp. 252–253). Pine was ninth in the softwood list:

> "9. THE GRASS PINE (pinus insignis) – A most beautiful pine growing 100 feet high, and one of the fastest growers known; the timber is not of much value, but the tree is valuable for shelter or as a nurse tree" (Leys, 1883, p. 252)

In 1885 J. Baber reported on the plants he had previously recorded in 1872, and concluded that Pinus radiata "so much planted for its beauty and quick growth, is useless, save for firewood, although concluding that "sparingly mixed, [it] should form part of every plantation" (Baber, 1885, p. 313). Baber's conclusion is applicable to every forester: " 'Let posterity take care of itself' is an adage often used, but it must not be the creed of him who plants forest trees" (Baber, 1885, p. 314).

5.5.2.2 *Forests of Pine*

By 1890 the Forest Branch of the Lands and Survey Department had established exotic plantations near Whangarei (McLintock, 1966, pp. 891–892, Vol. 2,) and from 1897 had begun experimental tree planting in the Rotorua district and the "barren pumice region" of the Kaingaroa plains (Figure 46). The rapid growth of Pinus radiata was recognised by 1909 as an attractive commercial proposition (Healy, 1982, p. 12, quoting from appendix to the 1909-10 Forest Service Annual Report). In 1913, the Royal Commission on Forestry, whose members included William Adams and influential botanist Leonard Cockayne (A. D. Thomson, 1996), recommended that in light of the slow regeneration of native forests, the state should plant faster growing exotic forests (Hegan, 1993, pp. 94–95).

It was the work and advocacy of William Adams, based on his own experience with Pinus radiata, that so successfully influenced its selection for large-scale afforestation from the 1920s onwards (Cockayne, 1919; McKelvey, 2013). His 1915 paper had a very clear conclusion: "No other species of pine — or, indeed, tree of any other genus—yet planted in New Zealand can compare in rate of growth with this pine" (Adams, 1915, p. 220).

By 1923 the State Forest Service's publication "*Tree Planting for Profit*" estimated the return after 33 years from radiata pine to be between £250 and £500 per acre (Healy, 1982, p. 17). The promise of such returns was followed by an expansion of state exotic afforestation in the decade to 1935 (Fraser & McLauchlan, 1986, p. 167).

From the late 1920s private commercial interests actively sought finance to plant forests. The traditional method of raising a public company to invest in the long term development of forests was used, but it was not as attractive as the issue of private company bonds, particularly for the promoters raising the money (Healy, 1982, p. 64). Travelling bond salesmen sold bonds priced from £24 to £45 to some 70,000 people scattered around the world. Ultimately the Bondholders Incorporation Act 1934-5 was necessary to bring order to the chaos (Lloyd Prichard, 1970, pp. 281, 344). One of the companies to emerge from this was New Zealand Forest Products Ltd.

Pinedale, about 6km from Putaruru on the railway line to Rotorua, was established around 1939 when the village and sawmill were built to process the 3,000 acre (1,214 hectare) Pinedale block which had first been planted by Afforestation Limited in 1924 (Healy, 1982, pp. 98–99). In 1941 NZ Forest Products took over the site, setting up a second sawmill (A. W. Reed, 2002). The sawmill was supported by a garage servicing the trucks and a small office. Figure 45 shows Pinedale in about 1947, surrounded by the cutover forest. On the right of the photo is the settlement with the married men's houses, towards the centre the single men's huts and cookhouse, while to the left on a hillock stands the manager's house. Although piped water and wood burning stoves provided comfort, the outdoor toilet was not so good in the winter (Buckett, 2009).

Figure 45: Panoramic vista of Pinedale about 1947 (original 11cm x 53cm)

Pinedale provided pine for many uses during WWII as the exotic timber, already used for butter boxes, proved it could substitute for the diminishing native timber resources. It also provided an ideal location to experiment with the performance of Pinus radiata in housing, as the houses and mill were built of pine produced by the nearby Waotu sawmill. An early resident remembers weekly weighing of a floor board to determine how much moisture it had absorbed (Buckett, 2009). A preservation plant was also set up based on two pressure cylinders obtained from a redundant concrete block plant in South Auckland and a boiler from a sawmill in Tauranga (Healy, 1982, pp. 98–99). The mill output was sent by rail to the

NZ Forest Products Penrose plant. Although built to last only 10 years, the Pinedale sawmill continued to be used into the 1980s.

Over time, Pinus radiata's problem of multiple stems and weakness due to branches was solved by careful selecting of stock coupled with forest management which included planting pattern and pruning (Hegan, 1993).

Figure 46: Hut amongst pine trees c1910

5.5.3 Tree to Timber

Increasing population and the shift from a rural to urban population (McKinnon et al., 1997, fig. 65), meant it was not possible for everyone to use near at hand natural materials like stone or split timber, so there was a shift to sawn timber. Sawn timbers were lighter, easier to handle and fix, wasted less wood, and produced neater and more weathertight buildings (Salmond, 1989, p. 56). The tree, once felled, could then be cut into suitable lengths but had to be further processed before it could be used for building. The log could be cut into scantlings (framing timber) and deals (boards) by a saw powered by people or by an engine.

5.5.3.1 Pit Sawn

Pit sawing of timber could be carried out on site by two men. It had the important advantage of minimising the transport of unusable material, but although the concept was simple, the work was hard. Pit sawing has a long history, dating back at least to medieval times, usually using a frame-saw in which the blade was stretched within a wood rectangular frame (Elliott, 1992, pp. 7–8). The industrial revolution provided suitable steel of uniform thickness and the manufacturing techniques to create the 19th century pit saw (Tomlinson, 1854, p. 578).

On flat land the pit would be dug beneath the log, while on sloping land a trestle would be made to support it. One man (the *top notcher*) worked on top of the log, guiding the blade based on an axed notch at the end of the log. The other man worked in the pit and was bathed in a steady stream of sawdust. Together they pushed and pulled the 3 metre long saw, producing the distinctive straight saw marks found in many early buildings (A. H. Reed, 1964, p. 76; Salmond, 1989, p. 57).

The life of the bushman was long and hard. Kauri bushmen worked six 10 hour days a week, with Sunday for washing, odd jobs, sharpening saws, greasing jacks and perhaps a 15km walk to the nearest village for entertainment (Millen, 1984, pp. 52–53). The money they earned was very good. In the mid-1840s a pit sawyer was paid 35 shillings per 100 feet in Pigeon Bay, Canterbury (Bush Advocate, p. 2, 19 Nov 1891), while in Nelson a sawyer made £80 in five months (McAloon, 1997, p. 93 quoted in ; Cottrell, 2006, p. 234). These were good incomes when average daily rates were 5s to 8s per day (Lloyd Prichard, 1970, p. 62). An old bushman, signing himself "Fire and Brimstone", in a 1908 letter gave his clear view: "next to a funeral, pit sawing is about the slowest thing I know of" (Taranaki Herald, p. 7, 19 May 1908).

The use of pit sawing did not finish even when steam power mills had become the norm as it was still useful in isolated or difficult areas. For example, in 1904 the Round Hill Mining Company of Longwood, Southland requested tenders for 8,000 super feet of timber to be pit sawn (Southland Times, p. 1, 28 May 1904). Bushmen were still advertising their skills in "pit, sawn or broad axe work" in 1911 (Poverty Bay Herald, p. 1, 7 Mar 1911).

5.5.3.2 Sawmills

Other sources of energy offered greater power, resulting in greater processing speed and uniformity of output. Sawmills driven by water power were reportedly used as early as 300 AD in Germany, although sawmills were not common until the 1400s (Tomlinson, 1854, p. 578). In New Zealand, water-power was in use in Mercury Bay in 1838, Ngunguru in 1840, Hokianga in 1841, Kaiwharawhara (Wellington) and Horowhenua in 1842, Mahurangi and Waitemata in 1843, and Nelson in 1845 (Thornton, 1982, pp. 18–20).

Steam-power mills had the advantage of not being dependent on either water storage or a year-round flowing stream. They could also use the waste from timber processing to power the boiler to provide the steam. The first steam-powered mill was operating in Port Nicholson (Wellington) in 1840 (Wakefield, 1845, p. 160). From the 1850s, there was increasing use of steam power machinery, not just for cutting timber but also for shaping, turning and carving (Salmond, 1989, p. 91).

Each of the three basic types of powered saw were used in 19th century New Zealand (Salmond, 1989, pp. 92–93; A. Williams, 1907, p. 285):

- **Flat saw:** the saw blade moves up and down (reciprocates)
- **Circular saw**: a rapidly spinning metal disc with saw teeth
- **Band saw**: a continuous metal ribbon with saw teeth.

Versions of each saw type could be obtained with the blade horizontal or vertical. Each had its advantages and disadvantages, but the slower horizontal reciprocating machine was suggested for better control of cutting hardwood. The machinery catalogues show heavy machines unlikely to move with the action of the saw (Sutcliffe, 1905, pp. 138–139, Vol. 2).

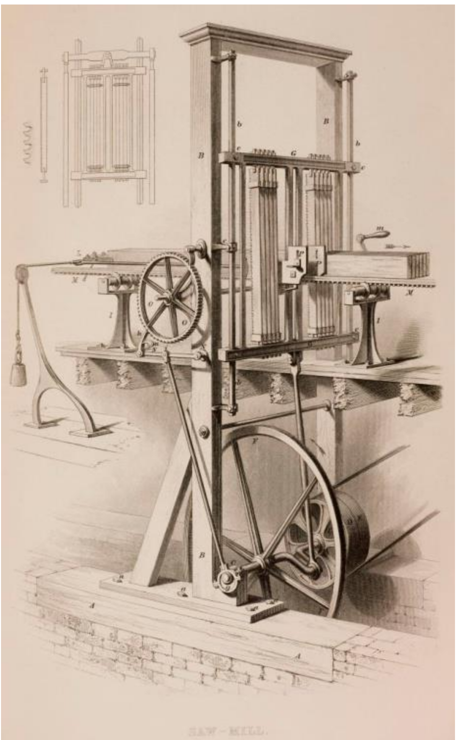


Figure 47: Deal Frame Saw for cutting square flitches of timber into boards, 1854

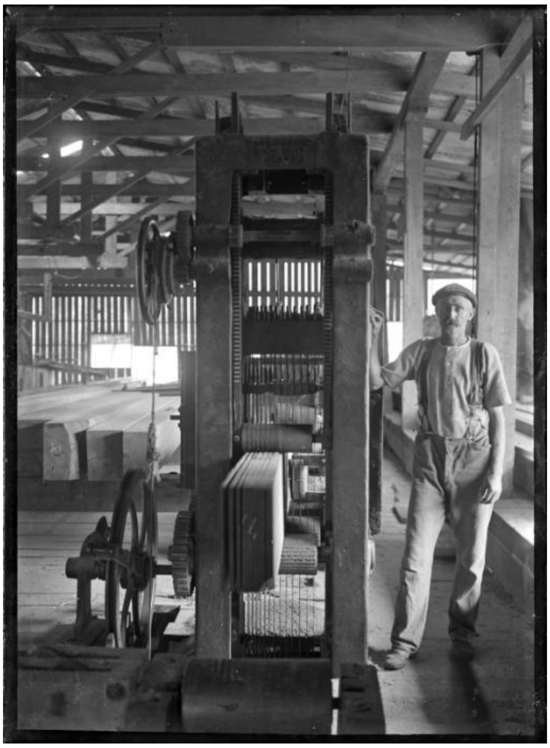


Figure 48: Machinery for cutting boards in a timber mill, 1915-6

The reciprocating saw reproduces the action of the manual saw, with from 1 to 11 individual blades. Figure 48 shows a photograph of a frame saw in use in New Zealand in the 1910s (Image used in: Cottrell, 2006, p. 236; Salmond, 1989, p. 91) which would appear to be very similar to one (Figure 47) illustrated in Tomlinson (1854, p. 582, Vol II). Such machines made from 100 to 120 strokes per minute, each 18 to 20" (44 to 50cm) long, requiring only 5 to 10 minutes to turn the prepared tree into timber boards (Tomlinson, 1854, pp. 582–584, Vol II).

Circular saws had long been used for cutting the teeth of water and clock wheels, and were introduced into England about 1790. Samuel Bentham contributed the practical arrangements "such as the bench, with the slit, parallel guide and sliding bevil-guide"[sic] (Tomlinson, 1854, p. cxlii, Vol. I), patenting it for use for timber (Cottrell, 2006, p. 234). The idea was further developed by Marc Brunel (father of Isambard Kingdom Brunel) in his 1805 patent, which fitted several pieces together by screwing them to a large flange on the saw axle. The speed of the circular saw was established by the strength of the metal and the need to remove the waste to ensure the blade did not overheat (Tomlinson, 1854, pp. 582–584). Figure 49 shows a circular saw traction bench in 1957.

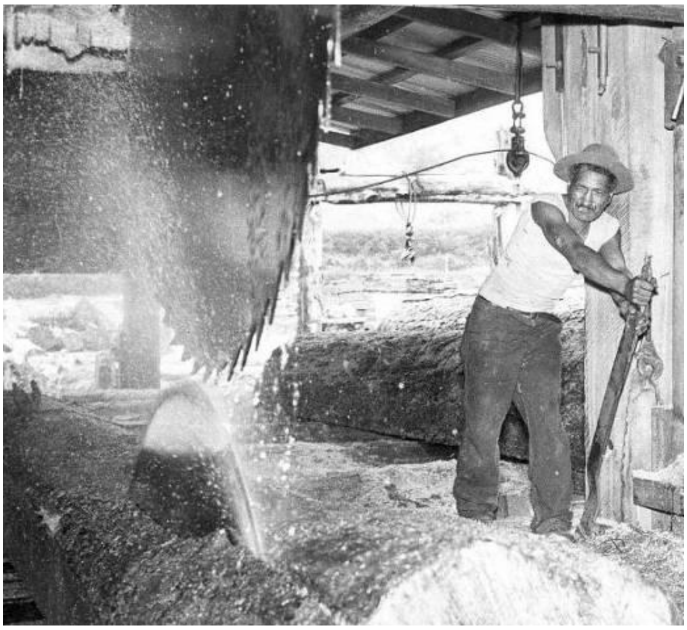


Figure 49: Ruatahuna Mill-Traction Bench. 1957

In 1842 a sawmill at "Kai Warra Warra" (modern Kaiwharawhara), Wellington, used a water wheel to power several circular saws (McLintock, 1939, pp. 12–13), while on the Manukau

Harbour a 14 horsepower Cornish Beam Engine was used to power both frame and circular saws, as well as a shingle cutter and turning lathe (Cottrell, 2006, p. 235).

The kauri timber industry at the height of its production had many very large mills. By 1874 the Kauri Timber Company's mill at Mercury Bay, Coromandel Peninsula was powered by steam (Daily Southern Cross, p. 3, 7 Dec 1874) and had a range of saws including a vertical breakdown band saw capable of handling logs up to 30ft (9.1m) in circumference (2.9m diameter), a travelling bench circular saw 72" (1.8m) in diameter and a reciprocating gang saw capable of taking a flitch 36" x 30" (0.9 x 0.8m) (Cottrell, 2006, p. 234; A. H. Reed, 1964, pp. 138–139, 158). The mill was opened in 1865 and lasted until 1922 (A. H. Reed, 1964, pp. 158–159).

In 1886 there were 268 sawmills employing 5,042 hands, although the number dropped to 243 sawmills employing 3,266 hands in 1891 (Table 17).

5.5.3.3 Transport to Site

In the very early days logs were pit sawn where they fell, but bullock teams were soon used to bring the often huge logs out of the forest to a nearby powered saw mill (Figure 44). Mechanically based capstans and tackles were also used, and any of these methods could shift logs to the nearest water course or stream where they could be floated to makeshift mills or waiting boats for transport to market.

In Northland, streams were dammed, and up to 12,000 logs were flushed down to the sea. These were then formed into rafts of 2,000 to 4,000 logs to be floated to the processing mills. The overall process was not efficient, with up to 20% of logs being lost between felling and processing into timber. It was reported that kauri logs were found as far away as the beaches of Chile and the Kermadec Islands (Cottrell, 2006, p. 258; A. H. Reed, 1964, p. 126).

5.5.4 Drying

Dry timber has many advantages. Drying is the first step in promoting durability by preventing decay, as well as reducing weight for handling and shipping. Drying not only lightens the weight (making the boards easier to shift), increases hardness and strength, but it also improves dimensional and structural stability (reducing warping and shrinkage) after the wood has been placed in a building or manufactured article (Tiemann, 1920, p. 4).

Drying became more significant as Pinus radiata replaced native timbers. Unseasoned pine was prone to sagging, so was not recommended for ceiling joists. In the 1950s, dry, seasoned, knot-free pine was found to be stronger than dry rimu, although for strength skew nailing rather than end-nailing was recommended (Building Research Bureau of New Zealand, 1959b).

5.5.4.1 Air Drying

Air drying, or seasoning, has a very long tradition. The timber is carefully stacked above the ground, with each board being separated from its neighbour by spacing timber (*fillet* or *spacer*). The moving air and sun work together to dry the timber, but require considerable land and time (Elliott, 1992, p. 17; New Zealand Technical Correspondence Institute, 1980, pp. 65–66).

5.5.4.2 Kiln Drying

Internationally, from the 1870s kiln drying provided the same benefits plus improved uniformity of drying, and as it required less land and time it provided greater profits (Elliott, 1992, pp. 17–18). In America the earliest kilns, dating from the 1860s, followed the European approach by placing the timber in a room designed to make the smoke from a wood fire pass through the material to be dried, and as a side effect darken the wood (Tiemann, 1920, pp. 35–36).

Kiln drying was soon used in New Zealand, and as noted in 1875, the approach was: "…to place the timber to be seasoned in closed buildings, in which it is exposed to a high temperature generated by steam or hot-water pipes" (Kirk, Balfour, & Ward, 1875, p. 2).

Eventually temperature, air circulation and humidity could each be controlled, allowing the moisture content to be closely regulated (New Zealand Technical Correspondence Institute, 1980, p. 66). Kiln drying can use different fuels, such as waste wood, fuel oil, natural gas, geothermal steam and in more recent years the modern technology of electric heat pumps (Carrington & Rush, 1983).

By 1939 the Government, then the largest consumer of timber, was calling for the use of rimu that was both kiln dried and treated. Eventually, only kiln drying was mandated, leading to the installation of 30 additional drying kilns. Preservative treatment (Section

5.5.5) was required for pine. It was not until 1950 that drying practices were codified into a Standard, NZSS 632:1950 Code of Practice for the Kiln Drying of Timber (New Zealand Standards Institute, 1950). This was revised in 1958 to cover the "new rapid-drying kilns" (New Zealand Standards Institute, 1958, p. 5), and then again in 1967 to provide permissible ranges for individual samples and make provision for "door core stock" (New Zealand Standards Institute, 1967, p. 5).

5.5.5 Improved Performance

Early research suggested the season in which the timber was felled played a key role in durability, but the quality of the timber and its treatment after harvesting was also important (Buchanan, 1873). This belief remained current for many years, until in 1924 experimental evidence found the seasonal event, such as spring sap rising, was not the issue but rather the weather conditions at the time the tree was cut, for example during rain (New Zealand State Forest Service, 1924b, p. 37).

Blair noted three causes of decay in timber (Blair, 1879, pp. 138–139):

- **Chemical decay**: natural decomposition by the action of the air and moisture
- **Vegetable decay or dry rot:** decomposition through the growth of fungi
- **Animal decay**: waste by the destruction caused by worms and insects.

While the opportunity for chemical decay could be minimised by drying, the others required more active protection.

Internationally, chemical based wood preservation has a very long history. Salt was used in ancient times as a preservative for ship timbers while wood for buildings was sometimes charred to prevent rot. The first USA patent for a wood preservative was in 1716 for "Oyle or Spirit of Tarr" while in the 1700s mercuric chloride and copper sulphate were first recommended. The use of zinc chloride as a preservative dates from 1815 (Freeman, Shupe, Vlosky, & Barnes, 2003, p. 9). In the 1830s, along with many other treatments, a method was patented in Britain for treating wood by *dead oil of tar* or creosote. This was one of the many by-products of the town gas industry's use of coal (Elliott, 1992, pp. 16–17). The pine-tree based preservative Stockholm pitch was available from the earliest days of European settlement (New Zealand Gazette and Wellington Spectator, p. 4, 18 Apr 1840).

Many other preservatives were also developed from the 1830s onward, often given the names of their developer or trade names. Examples include waterborne Mercuric Chloride (Kyanizing, 1832); solvent (oil) soluble Copper Naphthenate (1889); Pentachlorophenol (1928), Acid Copper Chromate (Celcure™, 1928), water soluble Copper Chrome Arsenate (CCA, 1938) (Kamesam, 1938)): water soluble Ammoniacal Copper Arsenate (ACA or Chemonite™, 1950); and water soluble boron treatments (1950s) (Freeman et al., 2003, pp. 8–10). Light Organic Solvent Preservatives (LOSP) treatments have been commercially used in New Zealand since the 1980s (Watkinson & Bennett, 1987, p. 7), although internationally they date from the 1960s (Drysdale, 2013).

In New Zealand, the first step was to understand how native (indigenous) timbers behaved under different conditions. The first published work was by Captain E.W. Ward of the Royal Engineers, Sydney in 1856. Ward tested the strength of 16 New Zealand timbers (Kirk et al., 1875, pp. 65–69). In 1855 James Balfour, of Dunedin, undertook a series of experiments on timber strength for Dunedin's 1865 New Zealand Exhibition, providing detailed information about 40 New Zealand, 10 New South Wales and 14 Tasmanian timbers, as well as an international comparison table (Kirk et al., 1875, pp. 29–64).

The first examination of the performance and durability of 38 indigenous timbers was undertaken by Thomas Kirk in response to a 22 October 1872 request from the House of Representatives' Industries Committee. The Committee's driver was clear:

> "The want of accurate knowledge on this subject cannot fail to lead to very serious results in connection with the large public works now being undertaken throughout the colony; and your committee considers that any moderate sum of money spent in this direction will be of the greatest advantage to the public interest" (New Zealand Parliament, 1874).

This valuable record of empirical evidence on the natural durability of native timber (McKelvey, 1991, p. 18) was re-published in a separate volume, accompanied by the earlier studies of Ward and Balfour (Kirk et al., 1875). For each timber type, Kirk described its physical properties, growing range, trade (domestic and export) and evidence as to its durability (Kirk et al., 1875, pp. 1–28). He also outlined three then commonly used chemical preservatives of Acetate of Lead (Hyett's method), Creosote and Chloride of Zinc, concluding that timber should be: "... deprived of its sap either by simple exposure to currents of air while protected from rain, by desiccation, or by infiltration with some preservative solution" (Kirk et al., 1875, p. 3).

A range of processes to force the preservatives into the timber were also developed, many tracing back to the Bethell pressure impregnation process, patented in 1838 (Freeman et al., 2003, p. 9). Modern timber preservation follows one of four basic approaches (Technical Correspondence School, 1958, p. 68; Timber Preservation Authority, 1958, pp. 4–5):

1. **Pressure impregnation:** preserving liquids are forced into the timber under high pressure in steel cylinders
2. **Diffusion:** water solution of preservative applied to green timber gradually diffuses to the centre
3. **Hot and cold bath:** dry timber is immersed in a heated tank of creosote or oil-soluble preservative. After a suitable time the liquid is allowed to cool or is replaced by a cold solution of the preservative
4. **Dip, brush or spray:** preservative is painted onto the timber.

The first pressure impregnation plant in Australasia was located at Woodend, near Invercargill. The plant and creosote were imported from England (Southland Times, p. 2, 16 Apr 1886; The Press, p. 2, 2 Mar 1886). In 1886 it creosoted 180,000 sleepers for the Railways Department. As creosote was not then made in New Zealand, the project was discontinued until 1902 (J. H. Smith & Carr, 1950, p. 7).

Early settlers had a range of trees of large dimension and relatively defect free providing timbers with admirable working qualities and extremely good natural durability, so by the late 1940s it was considered that "local experience of wood preservation for housing purposes is negligible" (J. H. Smith & Carr, 1950, pp. 5, 8). Faced with fast reducing supplies of the well-known native timbers and the increasing availability of the largely unknown Pinus radiata, the New Zealand building industry needed knowledge and a degree of certainty. This had been provided by many years of experience with, and research into, native timbers but not for pine. The questions to be answered were how should pine be used and what, if any, preservative treatment was required (J. S. Reid, 1956, p. 3, Preface).

Although plantation pine was described as "soft, light, nails well, fairly tough and strong, clean and straight if well grown" its principal limitation was understood, with "preservative treatment required where any likelihood of dampness [occurs]" (Technical Correspondence School, 1958, p. 73).

There was debate over the most appropriate method to improve the durability of pine, but by the early 1940s, kiln drying was seen as a solution, although some of the larger pine producers considered it unnecessary. As a consequence, the Dominion Sawmillers Federation asked "one of its largest members to investigate with all possible speed methods of preservative treating radiata pine to avoid the need for kiln drying", resulting in the introduction of a multi-salt preservative treatment (W. C. Ward, 1967, pp. 127–128). Multi-salts included mixtures of compounds of copper, zinc, arsenic and chromium (Timber Preservation Authority, 1963, p. 19).

By 1945 the State Advances Corporation required flooring and sub-flooring timbers (native and pine) to be pressure treated with multi-salts, although above ground floor level untreated pine and non-heart rimu would be accepted. A 1947 visit by New Zealand sawmillers to an Australian timber conference led to the introduction of boric acid treatment, which was initially used with tawa, then pine and other timbers (W. C. Ward, 1967, pp. 127–128). The purpose of the dip treatment was primarily to stop staining due to sapstain fungi (J. S. Reid, 1956, pp. 24–25).

Following the 1952 Committee of Enquiry into Timber Preservative Treatment (popularly termed the "Boron Enquiry") the government announced the setting up of the Timber Preservation Authority (TPA) in September 1953, but the TPA took time to develop its own regulations, which were promulgated in December 1955 (Timber Preservation Authority, 1958, p. 6; W. C. Ward, 1967, pp. 143–145).

In February 1953 two critical New Zealand Standard Codes of Practice were released (Auckland Star, p. 5, 2 Mar 1953):

- **CP2 "Use in Building of Pinus Radiata and Other Pinus Species"** provided guidance as to treatment, grading and use of pine in light timber-framed buildings (New Zealand Standards Institute, 1953a).

- **CP4 "Timber Preservation"** combined South African, British and USA standards with New Zealand research and experience to establish suitable treatments to protect pine against insect attack and fungi growth (New Zealand Standards Institute, 1953b, p. 7).

By the end of 1958 the TPA had approved 14 treatments and registered 82 plants, increasing to 230 registered plants by 1966, and thus covering 40% of all timber produced (W. C. Ward, 1967, pp. 143–145). In 1963 CP4 was replaced by "Timber Preservation in New Zealand – Specifications" (Timber Preservation Authority, 1963, p. 9).

5.5.6 Manufactured Timber Products

Timber can be processed in many ways ranging from decorative surfaces to completely new products.

Timber veneer can be used to give a different surface appearance to a suitable substrate, to provide improved strength, price, or workability, or can be layered to make plywood. Until the introduction in France around 1830 of the veneer slicer, it was saw cut with considerable waste sawdust. Around 1870 a practical version of the rotary veneer lathe enabled the production of full log veneer. Veneer panels, glued with the grain of layers criss-crossed, were being used long before the term 'plywood' emerged around WWI. Softwood plywood dates from the early 1900s, although it took some time before suitably waterproof glues were developed. Synthetic phenol-formaldehyde resins when combined with heat provide suitable waterproof qualities (Elliott, 1992, pp. 19–21).

English made, Venesta board (Venesta Limited, 1903) (normally three-ply) ceilings were advertised as being used in a bungalow to be sold in Dunedin in 1911 (Otago Daily Times, p. 12, 18 Mar 1911).

In New Zealand the first veneer plant was established by the Ellis Veneer Company about 1910 in Manunui (near Taumarunui) after Mr. J.W. Ellis visited the USA and inspected the three-ply plywood industry (Evening Post, p. 3, 5 May 1922). Although local plywood was available, New Zealand imported most of its requirements until the 1940s. Early plywood production was mainly thin interior plywoods and doorskins, using indigenous resources, mainly rimu and kahikatea. Further plants were commissioned in Auckland, Christchurch, Tauranga and Greymouth and in 1976 at Kinleith. All except the latter were designed to utilise native timbers. Although some radiata was peeled in the 1960s for thin plywood applications, only in the late 1960s was an appreciable volume of radiata construction grade plywood produced. New Zealand produced its own manufacturing and design specifications - NZS 3614:1974 "Specification for Manufacture of Construction Plywood" and NZS 3615:1974 "Specification or Strength Properties and Design Methods for Construction Plywood" (Coyte, 1981).

Finger jointing allows the creation of longer, dimensionally stable, higher strength structural timber by replacing defects, such as knots, with glued joints. Glue laminated timber (Glulam) laminates small pieces of timber to form the desired thickness and length. The maximum size is limited by transport requirements. Glulam for building use has been manufactured in New Zealand since 1957, with initial manufacturing information sourced from the UK and USA (McIntosh, 2010, pp. 1–3). The New Zealand Ministry of Works produced an inspection guide in 1957 based on an existing industry. It set out key manufacturing and inspection requirements, including a set of definitions for specialist terms (Ministry of Works, Architectural Division, 1957).

The Fletcher Industries Ltd.'s Taupo Plycopyne particle board plant at Taupo (Shearer, 1961) started production in 1959 (Ministry for Primary Industries, 2013) with Henderson and Pollard Ltd.'s subsidiary New Zealand Particle Board Ltd.'s smaller Mount Eden, Auckland plant following in 1965 (New Zealand Department of Statistics, 1964, 1965), (Building Research Bureau of New Zealand, 1969, p. 1) and a larger factory in Kumeu in 1972 (Healy, 1982, p. 208).

Some timber products, such as hardboard and softboard, are formed by little more than heat and pressure bonding together the specifically prepared timber fibres. In 1917 Beaver Board, a wood fibre board made in Canada was advertised as "sound proof, draught proof, artistic, sanitary" (*Modern Homes of New Zealand by Architects of Standing*, 1917, p. 64). By the late 1920s, imported hardboards and softboards were becoming available, including *Masonite Presdwood* from USA (New Zealand Herald, p. 16, 12 Mar 1929); *Treetex* hardboard (New Zealand Herald, p. 30, 31 Aug 1935); and *Donnacona* insulating (soft)board and *Challenge* hardboard (Evening Post, p. 22, 14 Apr 1938)

This was the same time as commercial opportunities to use the depression-era Pinus radiata plantings were being explored. In the late 1930s a trial shipment of logs from Atiamuri was sent by New Zealand Forest Products Ltd to Sweden to be processed into insulating wallboard. The Swedish production was too low, so a further American trial was undertaken. The trade difficulties with Europe due to World War II and a desire to make both softboard and hardboard led to the selection of an American plant (Healy, 1982, pp. 91–94).

Locating the plant was the next problem as it could be near the timber, fuel or the market. In the end a Penrose, Auckland location was chosen, even though the activity was classified as an "obnoxious industry." The plant opened in 1941 (Healy, 1982, pp. 95–97). As well as softboard and hardboard for interior use, an oiled-hardboard with the trade name *Weatherside* was produced for exterior use in the 1970s. It was withdrawn when it was found to be unable to withstand moisture. The plant continued to produce a range of wallboards, generating "acrid burning odours", until its closure in October 2007 (McKenzie-Minifie, 2007). The machinery was sold to be used in India (West, 2008).

Although softboard was robust, withstanding impact and knocks, and offered insulation and acoustic benefits, its fire performance was not good. The Royal Commission into New Zealand's worst fire disaster at the Christchurch store of J. Ballantyne & Co on 18 November 1947 concluded that "the inflammable nature of much of the stock and soft fibre board used throughout the building" was one of the special circumstances contributing to the rapid spread of the fire (Royal Commission into Ballantyne's Fire, 1947, pp. 30–31). Modern softboard can be factory treated with a flame retardant.

5.6 Ferrous Metals

When Captain James Cook arrived in the Pacific he found many societies existed happily without metal, recording in his journal that Maori did not recognise iron tools or nails:

> “Wednesday, 15th [November 1769]. … [Sail from Mercury Bay, Coromandel Peninsula, North Island – 36° 49'S 175° 44'E] … Neither of the Inhabitants of this Place, nor any other where we have been, know the use of Iron or set the least Value upon it, preferring the

most Trifling thing we could give them to a Nail, or any sort of Iron Tools" (Cook, 1893, 15 Nov 1769).

In June 1770, when Cook's ship Endeavour needed repair at, what is now known as, Endeavour River, Queensland, possibly the first metal processing occurred in the Pacific as nails were made as in Roman times by a blacksmith forging each one (Cook, 1893, 19 Jun 1770).

Later European settlers brought with them different metals, but of particular importance are cast and wrought iron. Steel did not become widely available until later in the 19th century, but quickly found its way to the Pacific, although it took many years before steel was made in New Zealand.

Steel is now widely used in buildings, including as reinforcing in concrete and hot rolled sections for multi-storey tower office and apartment blocks. This section is focused on New Zealand use and production of iron and steel for housing. Other uses include: light steel framing (Section 6.3.2); nails (Section 7.1); corrugated iron (Section 6.7.4); and metal roofing tiles (Section 6.7.7).

5.6.1 Iron in Construction

Iron, unlike stone or brick, performs well in both tension and compression, although it is about five times stronger in compression than tension (Elliott, 1992, p. 71). The strength of iron largely relates to the proportion of carbon in it: cast-iron has around 3% carbon, wrought iron under 0.1%, and steel a controlled proportion from 0.15 to 1.5% (Elliott, 1992, pp. 79, 92; Guedes, 1979, p. 272).

Originally smelting iron ores into metal invariably involved the use of fuel (wood or coal) and furnaces that created an uncontrolled carbon environment. Repeated striking with hammers (and in the industrial revolution, powered rollers) forced out carbon and other impurities to create wrought iron, which was less brittle than cast-iron although not as strong as steel.

Henry Cort's 1784 patent for *puddling*, where a shallow tank (*puddle*) of molten iron was heated by flames from a separate furnace, enabled easier production of wrought iron which quickly became widely used. Wrought iron could be rolled into plates or rods; plates could be riveted to form boilers or corrugated to make *corrugated iron* (Section 6.7.5), and rods could be used to make nails, and form ties for masonry or timber trusses. Riveting, developed by boiler makers and ship builders, could be used to create spans longer than 60ft (18.3m). Girders could then be made of wrought iron plates and angles, as well as Z, H and I shapes (Elliott, 1992, p. 81).

The 1854 Bessemer Converter made steel available at lower cost. Although the early tests worked well, it took another 20 years to discover (and control) the effect of phosphorous on the steel (Elliott, 1992, p. 92).

5.6.2 Cast and Wrought Iron

Blacksmiths could work with imported iron to meet a wide range of industrial, agricultural, residential and building needs. Early foundries include the 1847 Vulcan Foundry in Wellington, John Anderson's Canterbury Foundry in Christchurch (1857), the Phoenix Foundry in Auckland (1861) and A & T Burt in Dunedin (1862) (Thornton, 1982, p. 178).

The first publication of Statistics of New Zealand with a detailed breakdown of imports was for 1865. It recorded imports of bolt, bar, hoop and pig iron (but no steel) totalling 5,506 tons (5,594 tonnes) (New Zealand Registrar-General’s Office, 1866, Table 16), equivalent to 50 lbs (23kg) per head of population. For comparison, in 2010 national steel consumption was about 150kg per head of population, although about 58kg of this is from New Zealand iron sand and about 46kg from steel that has been recycled in New Zealand by Pacific Steel Ltd (A. Palmer, 2010).

The 1867 Census of Manufactories recorded 16 *Iron and Brass Foundries* throughout the country (New Zealand Registrar-General’s Office, 1868, Part I Census. Table 31), which by 1870 had increased to 28 foundries employing 855 people (Government Statistician, Registrar-General's Office, 1880, p. 347, Table V), and in 1891 to 79 foundries employing 1,787 people (New Zealand Government, p. 67, 15 Jan 1892). Table 17 provides an extract from the report on the 1891 Census of Manufactories listing those of direct relevance to building. The TOTAL row provides a comparison with all surveyed industries, excluding mines and quarries.

Table 17: Building Related Manufactories 1886 & 1891

Description of manufactories, works, &c.	Number of Works		No. of Hands employed		Approx. value of manufactures £	
	1886	1891	1886	1891	1886	1891
Stone (building) quarries	14	9	196	35	19,217	4,487
Saw-mills	268	243	5,042	3,266	1,177,713	832,959
Lime- and Cement-works	24	21	80	98	16,928	19,416
Brick-, tile- and pottery- works	126	106	598	494	91,797	56,830
Iron & brass foundries, boiler-makers, machinists & millwrights	65	79	1853	1787	368,919	403,635
Iron-pipe and fluming factories	0	2	0	4	*	*
Spouting & ridging works	10	12	70	100	25,478	33,140
Lead-headed nail factory	0	1	0	8	*	*
Copper boiler-making works	0	1	0	4	0	*
TOTAL (excluding mines, quarries, etc.)	**1,946**	**2,254**	**22,095**	**25,633**	**6,711,379**	**8,773,837**

(* = confidential) Source: (New Zealand Government, p. 67, 15 Jan 1892)

Cast-iron items in everyday household use included coal stoves from ironmaster Henry Ely Shacklock's South End Foundry which had started in Dunedin in 1871 (Angus, 1973), and kettles and pots (Drummond & Drummond, 1967, pp. 86–87). Cast-iron could be used as balustrades, valances and brackets to provide decoration (Stacpoole, 1976, p. 194).

By 1855 portable iron and timber-framed houses were being imported into New Zealand (Daily Southern Cross, p. 1, 2 Feb 1855 ; Salmond, 1989, p. 29). The benefits of iron construction were recognised in The City of Auckland Building Act 1854, which permitted buildings to be constructed of "iron or other incombustible material' without restriction, presumably due to their lack of flammability (Provincial Government of the Province of Auckland, 1854, p. 7, Schedule C ‘Rules for the Construction of Buildings’).

Although cast-iron housing was being produced in England in 1843 and promoted in New Zealand newspapers (Nelson Examiner and New Zealand Chronicle, p. 267, 17 Jun 1843), it does not seem to have been widely used, with no cast iron houses listed by Heritage New Zealand and no advertisements found in PapersPast. A two room English *wrought iron cottage* (possibly a building covered in corrugated wrought iron) was auctioned in Auckland on 14 May 1851 (New Zealander, p. 1, 10 May 1851) but no other reference to wrought iron housing has been found.

5.6.3 Local Steel

New Zealand had ample supplies of iron ore in the form of iron sands located on the west coast of the North Island from Kaipara Harbour to Whanganui and on the west coast of the South Island, and limonite in Northland and at Onekaka near Nelson (G. J. Williams &

McKee, 1974, pp. 7–8). Various attempts were made to produce iron, starting in 1849 with a blast furnace in New Plymouth which failed as the iron sand blocked the draught (Martin, 1955, p. 325). In 1866, 100 tons (102 tonnes) of Taranaki iron sand was sent to Staffordshire, England where it was manufactured into iron (Chambers, 1917, p. 223).

In 1882 a puddling furnace was built in Onehunga, using coal from Westport and Newcastle and local ironsand. Trials in February 1883 exceeded all expectations (Chambers, 1917, p. 225), and samples of the iron sent to Christchurch were successfully made into horse shoe nails which were reported to be "equal to the best Swedish [iron] when properly rolled or manufactured" (Otago Witness, p. 9, 2 Jun 1883). The first ironmaster, Mr W.H. Jones, on 21 December 1883 shot a bricklayer after an argument over a game of cards and was sentenced to fourteen years hard labour (Evening Post, p. 2, 22 Dec 1883). The next ironmaster, capable but elderly, died in the position, while the third broke down due to ill health. The lack of experienced people coupled with the problems of the ironsand, meant the plant never produced suitable quality iron again, and was ultimately broken up and sold in China (Chambers, 1917, p. 230).

Sir Henry Bessemer (inventor of the Bessemer Converter, 1854) experimented in 1886 with iron sand, but concluded that while best quality iron and steel could be produced, to do so would require considerable research, and "he was too old to go on with it" (Chambers, 1917, p. 223). It was not until 1969 that New Zealand Steel's Glenbrook plant, using the direct reduction process for reducing iron sand into metallic iron, established a technically and economically viable steel industry (New Zealand Department of Statistics, Chapter 17, 1970).

Iron was produced using local limonite ore, coal and limestone from 1920 to 1935 in Onekaka, Golden Bay by the Onekaka Iron & Steel Co (Figure 50). The plant initially produced pig iron (Figure 51) but in 1927 installed a cast iron pipe making plant, producing pipes which were used in Auckland, New Plymouth and Nelson.

In addition to steel production from sand, Pacific Steel commenced operations in Auckland in 1962 recycling steel scrap into bar products (rounds, angles, flats, and square) (New Zealand Department of Statistics, Chapter 18, 1962).

Figure 50: Clydesdale horse pulling cart of molten iron. Onekaka. c1920s

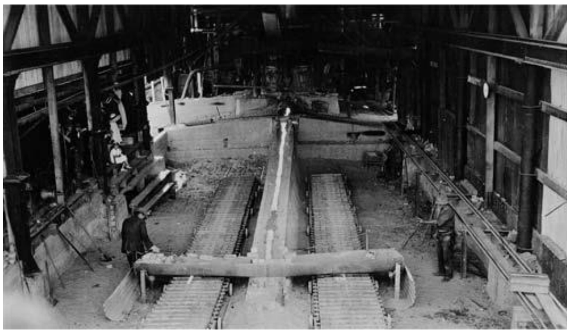


Figure 51: Molten iron running into moulds. Onekaka. c1920s

5.7 Summary

This chapter has examined the key materials used for construction of the house shell from the time of earliest European settlement, based on analysis of the Census results (Section 4.1).

Although plant materials were critical for early settlers requiring immediate shelter, by the time of the 1861 census they only represented 2.8% of all dwellings. Even with their good thermal performance, their limited life coupled with poor fire and moisture performance meant they soon fell from favour.

Earth construction (including sod, cob, adobe, pisé, wattle-and-daub and mud-and-stud) was not widely popular method of construction, although the 1950s saw an increase in interest. Bricks were widely used, with brickworks active from the 1840s. Improvements in kiln technology led to improved brick quality and reliability. As well as brick walls (double or triple brick), bricks were also used to construct chimneys, although not always with satisfactory earthquake performance. Although this was recognised by some as an issue from the 1860s, following the 1931 Napier earthquake the shift began to brick veneer with a timber frame.

Stone was never a widely favoured construction material, although used in some locations. Although there were many types available, stone quickly became of more value for façades rather than construction.

Imported cement was available from the earliest days of European settlement, with burnt lime produced from the 1840s. Cement was being made from the 1880s, although not all companies were successful. From the 1860s concrete was promoted as the best material for building, although it was not until 1976 that over 5% of dwellings had concrete walls, whether monolithic or concrete block.

Indigenous timbers were widely used, although the unsustainable logging of native forests led to reduced supplies in the 1970s and complete cessation in 1996, after the time covered by this research. Following extensive experimentation with a wide range of exotic timbers, by 1915 Pinus radiata had been selected as having the best growth. Extensive plantings followed and by the late 1950s, pine was in wide use. Timber processing methods developed from the pit-saw through water and steam powered mills to the modern mill.

The first step to timber preservation was drying. Air drying has a very long tradition, but while internationally kiln drying only dates from the 1860s it had arrived in New Zealand by 1875. Early work on native timber durability was followed by the use of appropriate of preservative systems. The first pressure impregnation plant was in operation in 1886. Preservative treatment was essential for pine, although initially kiln drying was considered adequate. By the mid-1940s multi-salt preservatives were in use and required for Government funded housing. Boron treatment was formalised in the 1950s.

Plywood, the first manufactured timber product, was first made in New Zealand about 1910, followed by softboard and hardboard in 1941, and particle board in 1959.

The indigenous societies of the Pacific did not have ferrous metals until the arrival of Europeans. Captain James Cook brought iron tools and nails. Imported cast and wrought iron was sufficient for local use, although a number of attempts were made to produce iron or steel from local mineral deposits or iron sands. It was not until 1969 that a viable steel industry was established.

A common aspect was the use of innovation and the adoption of new products with improved performance, whether practical or financial. Although some uses of these key materials have been noted, the next chapter will focus on the use of these and other materials, examining their application in the construction of the house shell.

6 Components

This section explores house components and the different techniques used in their construction. It starts with the sub- floor and traces the various technologies and materials used in the floor, wall, window and roof, finishing with thermal insulation. Although the focus is on houses, selected examples from non-domestic buildings have also been included.

6.1 Foundations

Foundations are the critical first step in building. If incorrectly placed, designed or unstable, what follows cannot be corrected (Technical Correspondence School, 1958, p. 75).

Foundations are defined as "walls, block or piles which transmit the weight of a structure to the underlying ground" (Technical Correspondence School, 1958, p. 81). The two basic building foundations types have not changed greatly since Roman times: a footing made of timber, stone or concrete that distributes the load over a sufficiently large area; or a series of deep driven piles that either rest on rock or are held in place by friction. The type of soil and building size helps define the most appropriate foundation (Addis, 2007, p. 454).

6.1.1 Piles

In early timber-based houses, corner posts were placed directly into the soil which also formed the floor (Salmond, 1989, p. 59). Walls of earth construction needed to be kept dry, so a stone or brick base was used as the earliest Damp Proof Course (DPC). Piles would lift a suspended floor above the damp earth.

Early New Zealand timber houses used a wide variety of pile materials. Fyffe House, Kaikoura, dates from the mid-1840s and stands on piles made from discarded whalebone vertebrae from the whaling industry (J. Harris, 1994, p. 14). Locally sourced, shaped river stone piles (Figure 52) still support Ranzau, Hope, near Nelson, built around 1844. Lady Barker reported on the materials for their high country house being transported from Christchurch in March 1866:

> "… two dray-loads of small rough-hewn stone piles, which are first let into the ground six or eight feet apart: the foundation joists rest on these, so as just to keep the flooring from touching the earth. I did not like this plan (which is the usual one) at all, as it seemed to me so insecure for the house to rest only on these stones" (Barker, 1871, p. 49, Letter VII).

Figure 52: Close view of shaped stone pile and weatherboard at Ranzau (built 1844)

Figure 53: Piles in restored Alberton (built 1863)

Foreground: modern timber jack stud on pre-cast concrete pile.
Background: original timber (puriri) pile with scoria wall behind

Early timber piles were originally rough tree logs standing on end, often native puriri or totara. While native timbers had extremely good natural durability in ground contact, the life of most was not infinite. Discussion at an 1873 Wellington presentation on the durability of NZ timber included an audience comment that the "very best heart of totara piles were quite rotten after being only 6 years in the ground" (Buchanan, 1873). A few years later, Blair (1879, pp. 150–180) reported on a wide range of heart timber used for house blocks:

- **manuka** of which "old settlers had a high opinion of the durability" but under ordinary circumstances would last only 6 to 10 years;
- **kowhai** which lasted over 17 years;
- **fuchsia** which lasted over 20 years;
- **broadleaf** (kapuka) whose durability had yet to be established as it had "never been known to fail";

- **kamai** which also had never failed;
- **cedar** (kaikawaka) of which a sample had survived 8 years in the ground;
- **totara** which had lasted 26 years in ground contact; while
- **white pine** (kahikatea) would not even last 2 years and should not be used.

Later research found heart rimu would last 3-6 years in ground contact, heart kauri 10-12 years and heart matai 12-15 years while heart totara and heart silver pine would last 25 to 35 years (J. H. Smith & Carr, 1950, p. 5).

Anyone who has purchased a house on old timber piles knows the delights of undulating and sloping floors coupled with sticking windows and doors due to differential movement of parts of the house. As the timber slowly rotted at or just beneath the ground level, parts of the house would sink, making a screwdriver or strong metal rod a standard inspection kit item from the 1960s onwards. This was used to stab sub-soil pile to see if was still sound. If not, then one of the first jobs for the new owner was new piles (G. Wilson, 1981, p. 34).

Built in Auckland in 1863, Alberton (Historic Places Category 1, number 26) originally stood on timber piles with scoria perimeter walls. When the house passed to the care of the Historic Places Trust in the early 1970s timber piles were replaced with precast concrete piles and treated timber jack-studs. Just one of the original timber piles remain (Figure 53).

As an example, after 90 years the piles in a 1908 house on a relatively dry site had decayed and dropped until some floor joists touched the ground. When the house was lifted using hydraulic jacks (Figure 54) the bottom of the piles looked like decayed, spongy wooden teeth. They were replaced with modern treated timber piles, the house lowered back down leaving a 400mm air gap above the ground, and with the floors levelled as far as possible.

After 1900, square sawn totara blocks were common, but brick piers could be used or, after 1905, octagonal glazed earthenware blocks (Salmond, 1989, pp. 112–113). Piles could also be made in-situ by filling empty 4 gallon kerosene tins with concrete, as in this 1929 example (Figure 55).

Figure 54: 90 year old Totara piles after house was lifted

Figure 55: Kerosene Tin filled with concrete used as a house pile

Mr G. Rhodes, Builder, exhibited *concrete house blocks* at the Auckland Agricultural Show in 1895 (Auckland Star, p. 4, 1 Nov 1895). The exact date of the first use of concrete piles has not been established, but they were being used for houses in: Dunedin in 1903 (Otago Daily Times, p. 8, 10 May 1904); Christchurch in 1907 (The Press, p. 11, 9 Sep 1907); and Motueka in 1909 (History Students of Motueka High, 1999, p. 28). By the time of a 1917 plans book, most of the houses for which details were provided used concrete house-blocks (*Modern Homes of New Zealand by Architects of Standing*, 1917). Firth were manufacturing concrete precast piles at their Rangiriri site in the late 1920s (Whyte, 2001, pp. 30–31). Concrete piles were in wide use by the 1930s (Consumers' Institute of New Zealand, 1972, p. 9).

6.1.2 Perimeter Foundation Walls

Perimeter foundation walls could be built in stone, brick (plastered or plain) or (after 1900) in concrete (Arden & Bowman, 2004, p. 82). In the UK Portland cement was used in house foundations from the mid-1850s (Douglas, 1997, p. 111).

In England (Douglas, 1998b, p. 76), as well as in NZ (Salmond, 1989, p. 118), problems with moisture travelling up the foundation wall led to the requirement for a DPC, which could be made of slate or asphalt. The Auckland City Bylaws 1924 permitted the use of: "sheet lead of not less weight than 4 lbs per superficial foot, asphalt ½-inch thick, slates laid on or covered by cement or other approved material" (Auckland City, 1925, para. 41).

Ford (1929) noted the undesirable consequences of using oily bituminous felt as a DPC for brick walls, as it provided a complete plane of separation between the wall and its foundations. He recommended the use of a keyed joint, where the asphalt was carried over a brick keying into the layer above (Ford, 1929, p. 5).

6.2 Floors

Table 18 provides a UK focused chronology of ground floor constructions. At the time of the first European settlements (dashed line), flagstones were in decline in the UK with suspended timber floors becoming common, if not ubiquitous (Douglas, 1997, p. 110). Assuming this was also the case in other European countries, the settlers brought with them the full range of historic flooring techniques.

Table 18: Historical use of ground floor constructions in UK houses

Type of Construction	Pre-1600	1600-1699	1700-1799	1800-1899	1900-
Rammed earth					
Stone/slate flags					
Timber on earth/flags					
Ceramic tiles					
Suspended timber					
Solid concrete					
Suspended concrete					

-> Pakeha settlers

Source: (Douglas, 1997, p. 110)

Pre-European, Maori housing had solid rammed-earth floors, made hard and compact by repeated use, a feature which could be readily incorporated in early European housing. Rammed earth floors were not considered hygienic as they could easily become damp, dusty and shabby, and were impossible to keep clean. In the UK rushes and herbs were used to reduce dust and smells (Douglas, 1997, p. 110), while in NZ the sleeping house floor was covered with dried fern (rarauhe), or raupo, or both and on these were placed whariki (mats) plaited from flax, paopao and kiekiewere (Papakura, 1938, p. 284; Phillipps, 1952, p. 23).

6.2.1 Suspended Floors

Compared with earth or concrete floors, suspended floors are more quickly laid; are suitable for sloping, non-level, unstable or filled sites; can deal better with issues of ground heave or clay shrinkage; and can be insulated during or after construction. As they are lighter, the suspended timber floor also reduces the dead load.

The 1833 Waitangi Treaty House (prefabricated in Sydney) had flooring of Australian ironbark (Drummond & Drummond, 1967, p. 71). By 1848 locally made suspended floors were in use, as reported by Janet Bannerman of Otago: "the totara lining of its walls was close and sound enough, but the white pine floorboards had shrunk leaving draughty gaps" (Drummond & Drummond, 1967, p. 89).

Plain wide boards were fixed to joists spanning between the walls, and in better houses the edges of the boards were tongued and grooved (T.&G.) (Salmond, 1989, p. 60). In the UK, traditional floors of timber joists consisted of T.&G. softwood 20-25mm thick and 75-300mm wide (Douglas, 1999, p. 219).

By the 1880s, suspended timber floors were expected in timber houses, with the various cottage designs provided in *Brett's Colonists' Guide* having P.T.&G. [7]"medium or second-class flooring" (Leys, 1883, pp. 723–734). For Brett's 2nd edition, specifications were provided: "Lay the floors with 6in x 1in p.t.g., cramped and double nailed with 2 ¼ brads. Punched in, and the joints planed off flush" (Leys, 1897, p. 1143).

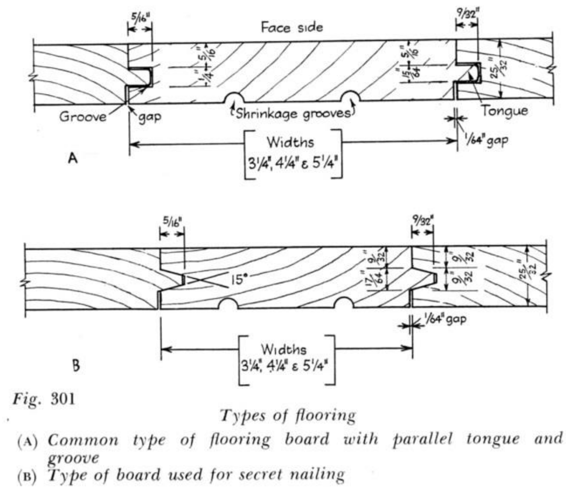
In 1924, the NZ State Forest Service was recommending double-layer flooring, with a layer of heavy asbestos (Section 6.5.3) or other incombustible material between the finished and rough floor in order to provide improved insulation (both thermal and acoustic) and fire resistance (New Zealand State Forest Service, 1924b, p. 35).

For the 1958 edition of "*Carpentry in New Zealand*" flooring was solely P.T. & G. (Figure 56), made of heart timber such as rimu or matai, or preservative treated non-heart timber except when more than 4ft (1.2m) above ground level (Technical Correspondence School, 1958, pp. 166–170). The 1980 revised edition listed the most commonly used flooring materials as "particle-board, plywood and tongue and groove wooden flooring." Notable changes over 22 years included: use of treated radiata pine P.T. & G. flooring although native timbers such as matai, rimu and tawa were used to provide a natural finish; instructions for laying particle board on concrete; use of particle board tiles; and the use of

[7] P.T.&G. = Plain, Tongue and Groove (New Zealand Standards Institute., 1956, p. 167), but also known as Parallel Tongue and Groove (Technical Correspondence School, 1958, pp. 166–170)

automatic nailing machines powered either by compressed air or carbon dioxide (New Zealand Technical Correspondence Institute, 1980, pp. 222–231).

Native timbers (Section 5.5.1) were replaced by exotics from the early 1970s, although the majority of housing had T.&G. flooring into the 1980s (G. Wilson, 1981, p. 39). By the mid to late 1970s, sheets of 18mm thick, surface-screwed, tongued and grooved boards 600-900mm wide, became more popular (Figure 57). Particle-board was cheaper and could be laid more swiftly than conventional, narrow timber boards (Douglas, 1999, p. 219).



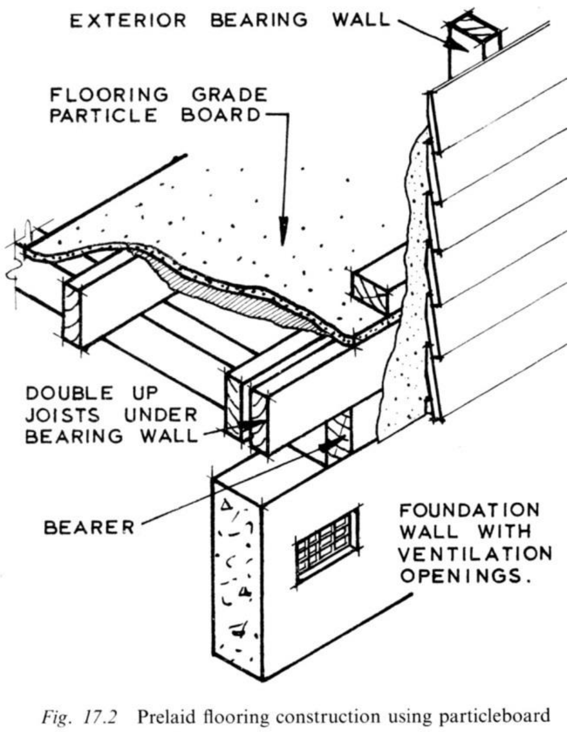


Figure 56: Flooring Boards 1958

Figure 57: Particle Board Flooring 1980

6.2.2 Concrete Slab-on-Grade Floors

Although Invermay (Section 6.3.3.1) does not have concrete floors, a cow shed built in 1862 at Tarureka, near Featherston does (Thornton, 1996, p. 24), suggesting the technology was understood.

Compared to suspended timber floors, concrete slab-on-ground (also known as slab-on-grade) floors have lower cost, no deterioration over time, are termite and vermin proof, fire resistant and draught proof (Technical Correspondence School, 1958, p. 87). They must be laid over a Damp Proof Membrane (DPM) (Building Research Bureau of New Zealand, 1966a,

p. 1) and if required, a layer of hard fill to provide a level platform. As well as the same range of coverings usable on timber flooring (including linoleum, carpet or tiles) concrete can be left natural, polished or ground (terrazzo).

Figure 58, based on the BRANZ House Condition Surveys (Saville-Smith, Jowett, Jones, Buckett, & Marston, 2011), show the use of concrete slab-on-ground floors by decade in existing houses. The slab floors reported in pre-1950 houses are probably a result of replacements, extensions or additions to existing suspended timber floored houses, rather than original (Page, 2014). Starting from the 1950s, the use of concrete slabs grew from 3% of new houses to 49% in the 1980s, and close to 80% in the following two decades.

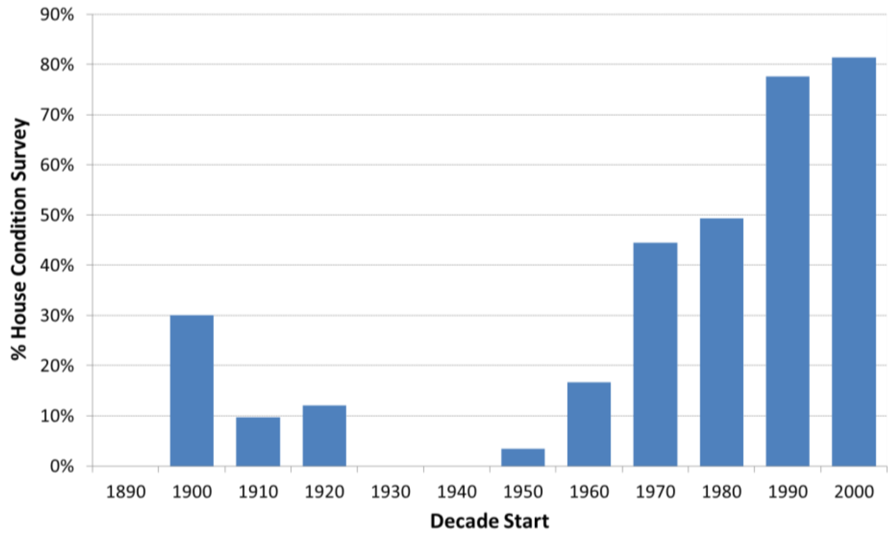


Figure 58: Use of Concrete Slab Flooring by Decade

In the 1960s, sawdust concrete (1 cement: 1 sand: 1 sawdust) was suggested as a topping for a conventional concrete floor, to provide moderate compressive strength, improved thermal performance, and a reduction in noise levels (Building Research Bureau of New Zealand, 1967c)

Terrazzo (ground and polished concrete which may contain high quality stones) was used in the new 1897 Dunedin Hospital theatre and instrument room (Otago Witness, p. 9, 28 Oct 1897) and a few years later in Wellington Hospital's Victoria Operating Theatre (Evening Post, p. 4, 4 Oct 1901). A more decorative use was in the foyer of the Empire Theatre in Dunedin (Otago Daily Times, p. 11, 4 Mar 1916). These are earlier than the 1927 introduction suggested by Salmond (1989, p. 211), although a newspaper report in 1926 suggested that *Venetian Marble Terrazzo* had only just arrived in New Zealand due to the efforts of an Auckland plasterer, Mr L. Bater, following his overseas trip (Auckland Star, p. 10, 17 Dec 1926). Advertisements in Auckland for Mosaic Terrazzo (NZ) Ltd commenced mid-1927 (New Zealand Herald, p. 15, 16 Jul 1927).

6.2.3 Ground Moisture Control

The three main sources of dampness for ground floors are condensation, sub-soil moisture and construction moisture such as drying of wet trade building materials (D. J. Harris, 1995, p. 11). Other sources of moisture include: leaking services; spillages; and rainwater penetration (Douglas, 1998a, p. 18).

Ground moisture is able to migrate to internal spaces, whether through an open sub-floor or an on-ground material. A vapour resistant ground cover (or vapour barrier) can be used on the ground beneath suspended floors, or under slab-on-ground floors (where it is a DPM). In both cases the role is to minimise ground-sourced or sub-floor moisture entering the building. These are of two basic types:

- **in-situ coatings** (e.g. asphalt, bitumen, epoxy resins) create a jointless membrane and were first used in the 1930s (D. J. Harris, 1995, p. 12).; and
- **preformed sheeting** (e.g. polyethylene sheeting) which requires the joints to be taped or welted to create a continuous membrane (Douglas, 1998b, pp. 78–79). Polyethylene (or polythene) is a widely used ground vapour barrier. Developed by the UK's Imperial Chemical Industries (ICI) in the mid-1940s, it was introduced to the USA construction industry by Visking in 1954. From the early 1960s it was used in the UK for both suspended and concrete slab-on-ground floors (Douglas, 1998a, p. 20, 1998b, p. 76).

6.2.3.1 Open Sub-floor

The open pattern of free-standing isolated piles coupled with a perimeter wall of timber lattice, spaced boards (Arden & Bowman, 2004, pp. 81, 38) or even a series of drilled holes in the cladding (Cochran, 1980, p. 49), provided for removal of moisture. Continuous walls required the deliberate inclusion of vermin-proof sub-floor ventilators.

More recently ventilators made of precast concrete (New Zealand Technical Correspondence Institute, 1980, p. 86) or pressed metal have replaced the earlier cast iron with intricate hole patterns (Fearnley, 1975, pp. 37–39; M. Hill, 1985, p. 13) (Figure 59)

Figure 60 shows a 1958 vermin proof precast concrete ventilator. They were to be evenly spaced in the foundation wall at not more than 6ft (1.8m) centres, starting at 2ft 6" (0.76m) from the corner (Technical Correspondence School, 1958, pp. 85–86).

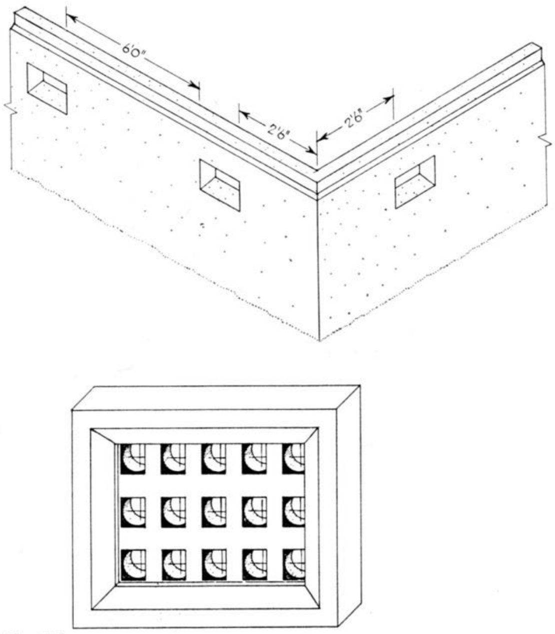


Figure 59: Sub-floor ventilator 1908

Figure 60: Typical precast concrete ventilator 1950s

Although discussed as part of the development of the 1924 "Model Building By-law" (see Section 6.7.3) it was not until NZSS 95:1944 Part IX Clause 920 '*Foundation Ventilation*' that specific requirements finally found their way into the by-laws, as previously trade practice had been sufficient. NZSS 95 required sub-floor foundation vents of ½in^2/ft^2 (1 to 288 or 0.35%), to be spaced a minimum of 6ft (1.8m) apart and 2ft 6 " (0.76m) from corners. Vents had to be as close to the bottom plate as possible, vermin proof and designed to exclude animals and poultry (New Zealand Standards Institute, 1944). Further advice for builders was provided in their trade magazine (Finch, 1960), which in turn was based on a UK publication (Ministry of Works (UK), 1959) edited to "conform to NZ conditions" (Building Research Bureau of New Zealand, 1960, p. 4).

The first reference to the use of a vapour resistant ground cover for suspended floors appears in the USA Federal Housing Administration's 1946 Technical Bulletin No. 38 (Advanced Energy, 2005, p. 4), with the first recommended USA use in 1949 (TenWolde & Glass, 2013, p. 10). Adequate ventilation is required to provide an escape route to protect the construction materials from problems that can arise due to dampness: physical (moisture-induced expansion); chemical (sulphate attack); or biological (fungal growth).

In 1960 the Building Research Bureau of New Zealand recommended the use of polythene film for situations where ventilation was inadequate to ensure a dry sub-floor (Building Research Bureau of New Zealand, 1960, pp. 3–4). It referenced publications from UK, Australian, Canadian and USA organisations, but the equation to calculate ventilator area was from a USA publication (Dunlap, 1949, pp. 14–15). The use of polythene film was not included in the referenced UK publication (Ministry of Works (UK), 1959) or the 2nd edition of the USA publication (Dunlap, 1950). The UK publication, even in its 4th edition, did not include the use of polythene (Ministry of Works (UK), 1973).

It was not until the 1980s that the sub-floor moisture levels and the effect of ground covers were investigated. Although outside the study time period, New Zealand data comes from a 1982 to 1984 study which found average ground evaporation of 400gm.m^{-2}/day in a survey of the sub-floor spaces in 60 suspended floor houses (Trethowen, 1994, p. 1427), averaging about 300gm.m^{-2}/day in Auckland and Christchurch and 550gm.m^{-2}/day in Wellington (Trethowen, 1987, p. 8). These compare with 495gm.m^{-2}/day reported in 1948 in an American basement (D. J. Harris, 1995, p. 12; Rose, 1994, p. 1293). A 1982 NZ pilot study of 10 Invercargill houses found the use of polyethylene film over the ground in the sub-floor was from 70% to 95% effective at reducing moisture levels (Trethowen, 1988, p. 9, 1994, p. 1427).

6.2.3.2 On-ground Floors

Traditional on-ground flooring (earth, stone, bricks or clay tiles) breathes, allowing moisture to be absorbed and evaporate, eventually requiring it to be removed from internal spaces. A dense concrete floor or a solid floor made of a thick layer of high strength hydraulic lime will act as a partial DPM (Oxley Conservation, 2012, pp. 9–10), but will still have some water vapour permeability (Building Research Bureau of New Zealand, 1966a, p. 2), In general moisture can rise through a concrete slab due to capillary action, requiring some form of DPM. Where the surrounding soil has significant hydrostatic pressure, more specialised *tanking* is required (Building Research Bureau of New Zealand, 1966a, p. 1). Wall structure

As noted in Chapter 4, over the study period most houses have been built with timber framing, although concrete increased in importance from the 1950s. This section examines the development of timber framing, steel framing and the use of concrete.

6.3 Timber-framed Construction

In timber-framed construction the weight of the roof and the rest of the building is carried on a timber-frame (Salmond, 1989, p. 30). The 1905 "*The Modern Carpenter and Joiner and Cabinet Maker*" divided timber framing into four classes (Sutcliffe, 1905, pp. 109–110 Vol. 6):

1. **Solid timber**: the complete structural wall is made of solid timber;
2. **Heavy timber framing**: the structural timber-frame is designed to support the whole of the load;
3. **Light timber framing**: the structure relies on the cladding and linings as well as the framing to support the load; and
4. **Half-timber work**: the heavier and exposed-to-view studs bear their share, but the infill brick also supports the load

In early years of European settlement, slab houses could be rapidly constructed from the then readily available large trees. Heavy timber framing requires a supply of large dimension timbers, placing greater demand on older forests than light timber framing, and ultimately hastening deforestation in the absence of new plantings.

During the 19th century New Zealand had a ready supply of native timber (Section 5.4) but with a rapidly increasing population there was a need to construct large numbers of buildings relatively quickly and cheaply. Technology supported this development, with improved tools and eventually the availability of machine made nails (Section 7.1).

6.3.1.1 Slab Houses

Europeans brought the ability to cut and disassemble the large trees then readily found throughout New Zealand. Kauri, rimu, totara and kahikatea could be readily split by a reasonably skilled bushman into slabs about 2" (5cm) thick and 10 to 12" (25cm to 30cm) broad and about 7 feet (2.1m) long (Leys, 1883, p. 16). Similar "vertically laid structural plank houses" were used in North America from the early 1610s, but based on sawn timber (M. J. O'Brien, 2013, pp. 49–50).

The most important advantage of slab construction compared to raupo (Section 5.1) was the reduced danger from fire, although greater effort was required to ensure a warm interior. Both slab and raupo houses were built on a supporting timber-frame (Leys, 1883, p. 16; Phillipps, 1952, p. 40). The chimney could be made of corrugated iron or even timber, but would be lined with stones or bricks to keep the fire well away from the slab walls.

The 1883 *Brett's Colonists' Guide* advised:

> "If the settler is a new arrival, he will find it to his advantage to employ a good bushman to help in splitting and in the erection of his house – the size will depend on his family requirements" (Leys, 1883, p. 16).

The roof could be made with readily available materials such as thatch or split timber shingles. The slab house was not expected to last forever:

> "The following summer, if means will allow, a weatherboard house can be built, and the slab house devoted to other purposes; as a stable or cow house it should last fifteen or twenty years" (Leys, 1883, p. 16).

Slab walls were only reported in the five censuses from 1945 to 1966, with a maximum count of 21 in 1956. Table 19 lists the slab buildings on the Heritage NZ (formerly New Zealand Historic Places Trust) register.

Table 19: Heritage NZ Registered Slab Buildings

Name	Location	Year	Registration
Sayer's Slab Whare	Carterton	c 1859	7429
Slab Cottage	Okains Bay (Banks Peninsula)	c 1880	5371
Springvale Station Totara Slab Whare	Tikokino (Hawkes Bay)	unknown	1056
Rai Valley Cottage	Rai Valley	1881	329
The Levels Cottage	South Canterbury	1850s	4906
The Cuddy	Te Waimate	1854	49
Slab Cottage	Orari Gorge Station (South Canterbury)	c 1860	7763
Westlawn Hut	Argo Road, Waioru Military Camp,	c 1900	7610
McManaway's Pataka	Te Houhou Road, Rata	mid 1800s	7608

Source: Register search 16 May 2014. www.heritage.org.nz

6.3.1.2 *Solid Timber Walls*

New Zealand did not appear to widely adopt the *log cabin* so popular in memories of frontier America, although there was already an indigenous version. Phillipps describes the walls as being assembled from logs laid horizontally supported between a series of double upright poles. These poles could be small round wood or even ponga logs. A lining of raupo, toetoe reeds or cabbage tree leaves could then be used to reduce draughts and create a warm interior (Phillipps, 1952, pp. 47–48). Figure 61 shows the log-walled whare built at the Christchurch Exhibition in 1906 (J. Cowan, 1910, pp. 310–322). Figure 62 provides an undated illustration of a log cabin near Lake Wanaka. It has been assumed the use of Maori log construction finished about the same time as wider use of raupo.

Interest in log walled houses developed after Canadian log builder, B. Allan Mackie, visited New Zealand to tutor log building courses, leading to the 1982 formation of the Log Builders' Association of New Zealand (LBANZ) (Knight & Brook, 1988).

Figure 61: Log-walled whare at the Christchurch Exhibition, 1906.

Figure 62: "Log cabin" at Wilkin River, Lake Wanaka (date unknown).

Samuel Hurst Seager's 1898 summer house for the Macmillian Brown family in the Cashmere Hills Christchurch used thick horizontal boards in a log-cabin style (P. Shaw et al., 2003, p. 85) in the style of the later Fraemohs, not Lockwood as suggested by Ashford (1994, pp. 12–14) (Historic Place Category I, number 3674)

It was not until mid-century that solid timber wall construction systems were developed by La Grouw Corporation, Rotorua, under the Lockwood name (Gainsford, 2006; La Grouw Corporation Ltd, 2013) and by Fraemohs Homes of Kaiapoi (Fraemohs Homes Ltd, 2014).

The Lockwood components (timber pieces and aluminium jointing sections) are factory manufactured and transported for final assembly on site. Figure 63 shows the early Lockwood patented connector system (Loghem & Grouw, 1957).

Early in 1969 Fraemohs Industries Ltd, originally a pine miller and exporter, commenced research into the development of a solid timber house. The structure used interlocking beams (Figure 64), which could be "easily assembled with carpentry skill and with a minimum of tools." Originally it was intended to use a Danish design, but the cost was such that the company developed its own system (Fraemohs Industries Ltd, 1969; Littler, 1969).

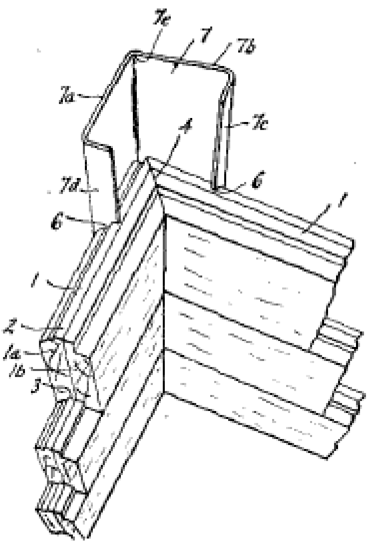


Figure 63: Lockwood Connector System (1957)

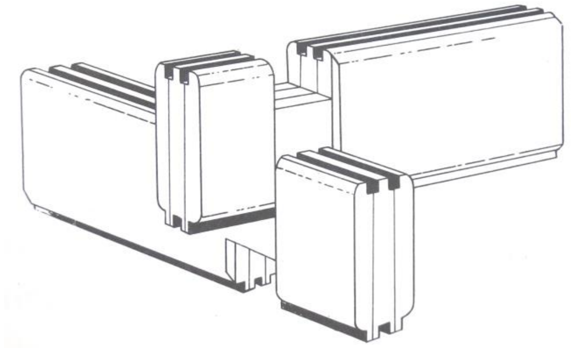


Figure 64: Fraemohs Connector System (1969)

6.3.1.3 Light timber framing

In frame construction, the load bearing structure functions independently of the enclosing elements (envelope), permitting longer open spans and layout flexibility (Deplazes, 2013, p. 98). Light timber framing has evolved in response to the availability of tools and fastening systems. Three basic light framing types have been used in New Zealand:

- Braced framing
- Balloon
- Platform

A fourth system, Post and Beam, takes the loads from the roof and floor beams, transfers them to the vertical posts and then to the footings (Rosenfeld, 1971, pp. 162–166). Although promoted by Rosenfeld, it does not seem to have been widely adopted.

Changes in technique, such as the widespread availability of relatively low cost nails, coupled with the improved speed and reduced cost of construction resulted in the change from braced to balloon to platform light timber framing. However, given the lack of New Zealand specific construction publications (Section 3.2), it was not until the development of formal construction standards that a uniform approach occurred.

For timber buildings, this process commenced with NZSS 95 *Standard Code of Building By-laws Part IX – Light timber Construction* (New Zealand Standards Institute, 1936, pt. IX) which in 1956 incorporated the use of pine (New Zealand Standards Institute, 1956). Then it became NZSS 1900 Chapter 6.1 (New Zealand Standards Institute, 1964) which in turn became NZS 3604 (Standards Association of New Zealand, 1978).

6.3.1.3.1 Braced Framing

The traditional braced-framing used mortise-and-tenon joints to create a rigid structure able to withstand the live and dead loads of a house. Figure 65 shows a 1797 drawing of a braced frame trussed partition (Nicholson, 1797, Plate 10). At the top of the diagram the "end of the joists of the floor" are held in place by the "keys put between the steady joists", while the diagonal "braces to keep the building steady" are on both the top and bottom of the partition. Each piece of timber is carefully cut into its neighbour, a skilled, complex and relatively time consuming job.

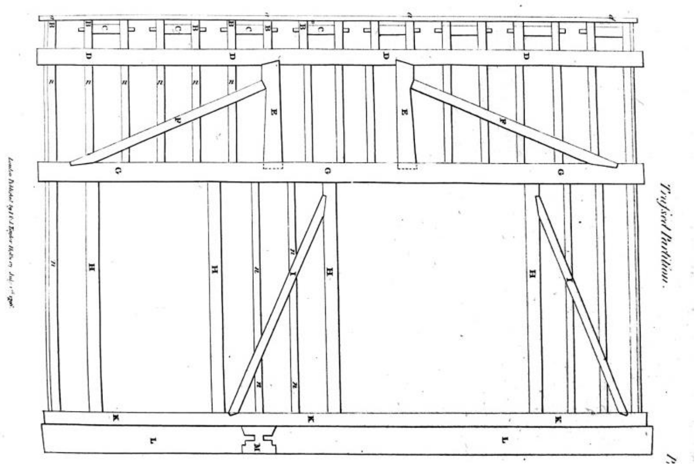


Figure 65: Braced Frame Trussed Partition

It is most likely the first New Zealand European style building used braced framing (Section 1.1). However, by the time large-scale European immigration to New Zealand had commenced, pressure on resources internationally had led to the development of framing systems that minimised the waste of smaller pieces of timber.

6.3.1.3.2 Balloon Framing

By the early to mid-1800s industrialisation was changing timber-frame construction, notably in the USA where smaller and standardised timber sizes from more efficient sawmills; simplified joints due to the high cost of skilled labour; and the extensive use of cut, and then wire, nails all helped to make timber-framed houses cheaper (Lewis, 2009, p. 67). Scantlings, timber less than 5 inches (125mm) square (Parker, 1875, p. 241), whether built up from smaller timber pieces or from a larger piece that had been cut to size, provided support for more walls than the same volume of heavy timber framing.

Balloon framing, reputedly named to denigrate its lightness and presumed frailty (Bryson, 1998, p. 190), was an outcome. Figure 66 shows a schematic of balloon framing (Sutcliffe, 1905, pp. 109–110, Vol. 6) with the studs continuous from the bottom to top plate. The ground floor joists are notched into the sill and nailed to the studs, while the first floor joists are supported by a plate cut into the stud and also secured with nails.

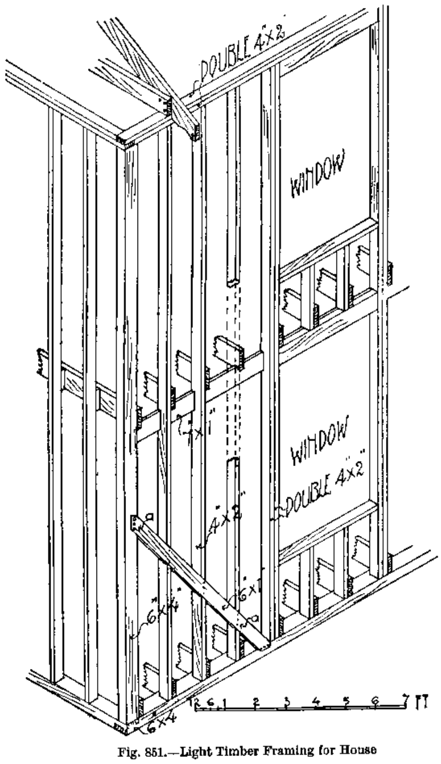


Figure 66: Balloon Frame Construction

Figure 67: Carcass of a NZ balloon-framed house c1874

Figure 67 shows the carcass of a Thorndon, Wellington balloon-framed house built about 1874 (Cochran, 1980, p. 53). Lining boards (sarking) provided lateral bracing. Balloon framing tolerated inexperienced carpenters and could be assembled quickly (Elliott, 1992, p. 18). Sprague put forward that balloon framing started in Chicago in about 1832 (Sprague, 1981) but Bell (1983, pp. 65–66) suggests that the process which led to the balloon frame started in the south-eastern counties of England "for reasons probably more complex than a shortage of building timber", but then continued in the USA and British colonies. By the mid-19th century, in widely separated parts of the world a remarkably similar form of construction using 100x50mm studs spaced at about 45cm centres was in use. Cladding and lining appropriate to the local climate and social standing of the building were then nailed to this frame. More recently Lewis (2009, p. 51) argued that it was in use in the American mid-west by the 1850s.

By the 1920s, balloon framing had been largely replaced in New Zealand by platform framing, although there was still interest in promoting its use due to its greater stability and lower cost (New Zealand State Forest Service, 1924b, pp. 34–35). It was also seen as having potentially greater earthquake strength by providing the vertical continuity lacked by platform framing (Ford, 1926, pp. 91–92). By 1944 balloon framing was acceptable in Christchurch but not in Auckland (R. H. Smith, 1944a, pp. 100–109, Part III).

Figure 68: Interior view of platform framing and building paper c1911

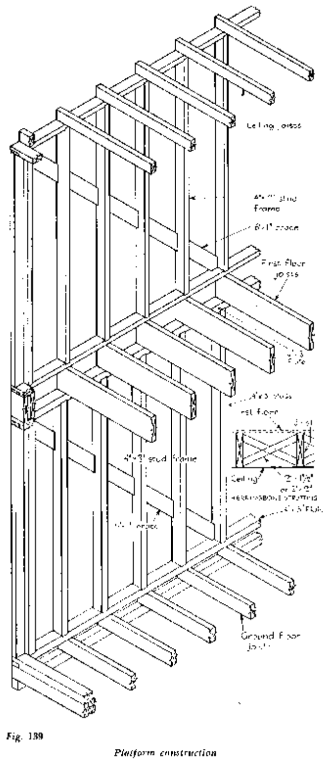


Figure 69: Platform Frame Construction

6.3.1.3.3 Platform Framing

As demand grew, the availability of continuous lengths of timber able to stretch over more than one floor waned. Balloon framing also provided undesirable connections between the floors for the passage of vermin, draughts and fire. The platform frame (Figure 69) used shorter lengths of timber with the walls for each floor being framed separately above and below the floor joists (Technical Correspondence School, 1958, p. 100).

Features of the platform frame were used in New Zealand from the 1890s. Studs were butted and nailed instead of mortised into the plates, and a separate bottom plate (*vermin plate*) was placed on the floor joists before the wall frame was set up (Salmond, 1989, p. 113). Analysis of import statistics matches this observation, indicating a major change in nail imports in the early 1880s (Section 7.1.3). By the 1930s the platform frame had taken over

(Arden & Bowman, 2004, pp. 38–39) and remains in use. Figure 68 shows the interior of a platform frame house, Aro Valley, Wellington built about 1911.

While the U.S.A platform frame uses sheathing underneath the cladding to provide structural bracing (M. J. O'Brien, 2010, p. 48), in New Zealand this is achieved through the bracing provided by the interior lining, since the late-1970s codified in NZS 3604 (Shelton, 2007, p. 6).

6.3.1.4 Nail plates

Nail-plate fastenings had been used in the USA since about 1956, and by the mid-1960s there were some 6 different types, with subsidiary manufacturing plants in Canada and Australia (Evans, 1965, p. 3).

Two basic types of nail plates were available. Figure 71 illustrates a sheet steel plate with nails force-fitted through holes. Figure 70 shows a gang-nail plate made of either 14 or 18 gauge galvanised steel pressed so it has a number of projecting tines (Jureit, 1959). The largest plates had 112 tines, each of which could develop an ultimate strength of 200 lbs (91kg) in jointed dry radiata pine. The timber to be joined was cut, assembled on a jig table and then a hydraulic or pneumatic press forced the plates home (Evans, 1965, pp. 3–4).

In 1963, Carter Merchants Ltd began investigating the manufacture of roof trusses and sub-floor members using *Gang-nails*™ (Sprott, 1963). On 11 April 1963 the American company Automated Building Components Inc. (ABC) incorporated Automated Building Components (New Zealand) Limited as a private company, which changed its name on 27 May 1976 to Gang-Nail N. Z. Limited (New Zealand Companies Office, 2014, Company 64512). The company, jointly owned by ABC and L.J. Fisher & Co. Ltd, Auckland (Section 6.7.7) was the New Zealand gang-nail licensee. The connectors were initially imported from Australia and later made in New Zealand (W. W. Williams, 1964).

Other companies with an interest in New Zealand included A.J. & J.W. Dicker Pty Ltd, NSW with the *Steel-grip* connector and Timber Engineering Co. Pty Ltd, NSW with the *Trip-L-Grip* framing anchor.

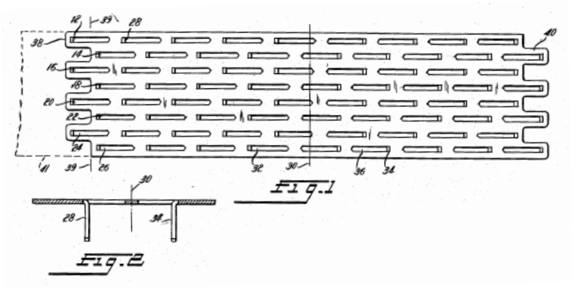


Figure 70: US Patent 2877520. Connector (17 Mar 1959)

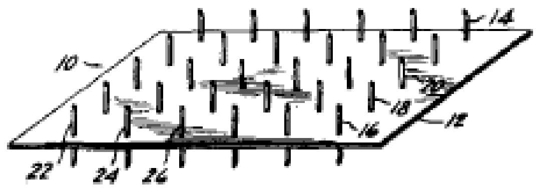


Figure 71: NZ Patent 146367 Timber Connector, Joint (14 Sep 1966)

Nail-plate construction was quickly adopted in New Zealand. A 1963 Napier builders' catalogue only listed nails (Robert Holt & Sons Ltd, 1963, p. 45), but two years later nails had been pushed to page 86 while the "Gang-nail Trusses" full page advertisement was on page 14. The advertisement stated trusses could be made in lengths of up to 40ft (12.2m) and widths of 12ft (3.6m). The original gang-nail truss connector plate in 14 gauge galvanised steel was available in 55 sizes and the newer 18 gauge steel plate in 49 sizes. A smaller wall panel nail was designed for prefabricating 4 x 2 timbers into panels (Robert Holt & Sons Ltd, 1965, pp. 86, 14).

By January 1965 four gang-nail fabricators had been licensed and one press installed (W. W. Williams, 1965). October 1967 saw 11 authorised fabricators, with a further 4 to follow shortly (Sear, 1967). By June 1974 there were 20 fabricators around New Zealand (Automated Building Components (NZ) Ltd, 1973).

The widespread availability of pressed nail plates and their use in making prefabricated roof assemblies helped trussed roofing take over from the strutted roof (Section 6.7.1).

6.3.2 Light Steel Framing

Heavy steel framing for large-building construction was developed in the USA during the last years of the 19th century (Friedman, 2010, p. 50), but it was not suitable for the free-standing house. After World War I, structural sections were made from cold rolled steel strip or sheet by rolling or bending. These sections were then built up into more complex sections by mechanised spot welding. In 1935, a French complex of 1,200 apartments was built using this light steel framing system (Guedes, 1979, p. 276).

The first light steel framing plant started operation in Wellington in 1970 (C. Davis, 2009)[8]. The structural development of the steel-frame industry started under American and later Australian standards (Standards Australia, 1974, 1988). Light steel framing was not widely used by the end of the research period.

6.3.3 Monolithic Concrete

Thornton (1996) provides a comprehensive review of the use of New Zealand concrete construction from 1850 to 1939. This section provides a broad summary, focusing on the evolution of monolithic concrete construction and its national diffusion, as well as providing examples of New Zealand patented systems.

6.3.3.1 Poured Concrete

William Newsham Blair described the monolithic system as "laying the soft ingredient between frames in the position they are ultimately intended to occupy." He concluded it is not as good as blocks as there is the risk of faulty materials, but it "is much cheaper, and on that account is more generally adopted" (Blair, 1879, pp. 65–66). The historic origins of the two systems differ. Block grew out of the tradition of masonry (Section 5.3) while monolithic concrete traces to the tradition of pisé (Section 5.2.1) (P. H. Simpson, 1989, p. 109).

Thornton records the oldest extant concrete house as Invermay (Thornton, 1996, p. 23). Located about 13km by road from Dunedin, this two-storey, nine room, concrete house was built in 1862 by settler John Gow. Since 1956 it has been owned by the University of Otago (Galer, 1981, p. 26).

With the addition of reinforcing, concrete provides long lived and durable buildings, although issues of moisture and thermal performance still need attention. In particular the early 1900s saw a number of New Zealand systems designed to create improved concrete walls. Fanciful names were given to these products, such as *Oratonu*, *Konka* and *Fabricona*, or the construction was named after its inventor, such as *Pearse's Patent*. A close international watch continued, with a British rubber mould system suggested for local use (Fraenkel, 1949, pp. 12–13).

[8] See http://www.nashnz.org.nz/

6.3.3.2 Oratonu Patent

In April 1911 James Annand, builder of Dunedin, patented his improved method for the construction of concrete buildings (Annand, 1911), with further improvements in October 1912 (Annand, 1912). The method was advertised as *Oratonu* or everlasting concrete. The monolithic concrete wall was poured on site using a special mould (Figure 72). The two 3" (75mm) thin walls of concrete were separated by a 3" (75mm) cavity, and tied together with wire clips (Rowley, 1919, p. 211). The patent states Annand was aware of "Goddard's system of camerated concrete buildings" (Section 7.3) as well as the Australian patented systems of Morgan and Stanbourough, but notes "compared with my system these are expensive and do not dispense with cement or waterproof facings" (Annand, 1911).

The Oratonu Patent Concrete Company's product was advertised as "absolutely damp proof." As well as being cool in summer and warm in winter it was low maintenance and insured at the "lowest rate" (Wanganui Chronicle, p. 7, 25 Apr 1914). Oratonu was used for Government housing, with 10 workmen's dwellings built in Timaru by 1914 (Timaru Herald, p. 5, 7 Feb 1914). This led to concrete housing being seen by the 1919 Secretary of Labour as having the advantages of fire resistance and lower long term costs (Rowley, 1919, p. 211).

James Annand closed his contracting business, with his plant and furniture auctioned on 6 February 1913 (Otago Daily Times, p. 10, 3 Feb 1913), although he continued with his inventions, including NZ Patent 35,065 "Encasing Wooden Buildings With Concrete", a development of his 1911 patent (Annand, 1914).

Oratonu was widely advertised. The list gives locations and dates, while Figure 73 maps the earliest advertisements:

- Christchurch (The Press, p. 18, 24 Aug 1912);
- Timaru (Timaru Herald, p. 5, 7 Feb 1914);
- Whanganui (Wanganui Chronicle, p. 7, 25 Apr 1914);
- Wairarapa (Wairarapa Daily Times, p. 4, 5 May 1914);
- Hutt Valley (Hutt Valley Independent, p. 3, 9 May 1914);
- Dunedin (Otago Daily Times, p. 11, 10 Oct 1914).

The last advertisement for Oratonu was found in Papers Past on 22 May 1915 (Otago Daily Times, p. 12, 22 May 1915), after which the system seems to have disappeared apart from the 1919 reference above.

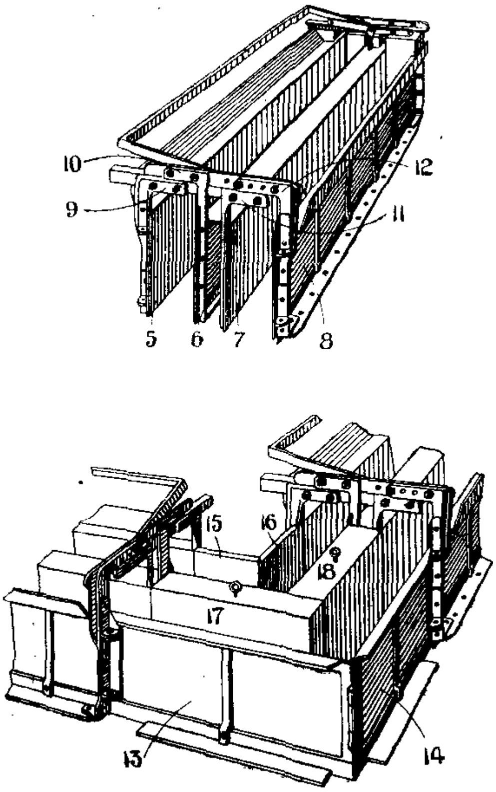


Figure 72: Oratonu Concrete Framework, Patent 32,127. 17 October 1912

Figure 73: Map of Earliest Oratonu Concrete Advertisements by Location 1912 to 1914

6.3.3.3 Pearse Patent

William Pearse, a builder from Fielding, patented his "Monolithic Concrete System" in August 1920 (Pearse, 1920) (Figure 74). The horizontal stays and the angled struts (held in place by iron straps) resist the outward pressure of the wet concrete, holding both the inner and outer layers firmly in place until the concrete has hardened (Figure 75). The width of each layer, as well as the gap between them, can be adjusted with iron or other suitable ties used to keep the two layers in place. Although the boxing could be used to create a wall without a gap, the patent points out this would also remove the benefits of the air gap which allowed air drawn from vents below floor level to circulate within the walls and provide fresh air to the house (Evening Post, p. 11, 18 Aug 1923). Pearse advertised: "Criticism invited to prove that it is not the speediest, sanitary and most durable of any system ever introduced for overtaking the shortage of dwellings and giving a gilt-edged security to financiers" (Evening Post, p. 12, 9 Aug 1923).

Pearse seems to have been the main user of his patent. Based on a search of Wellington City archives, he built 4 houses around Wellington from 1922 to 1927, but after then there is no evidence of its use.

Figure 74: House Built with Pearse's Patented Concrete Cavity Walls 1923

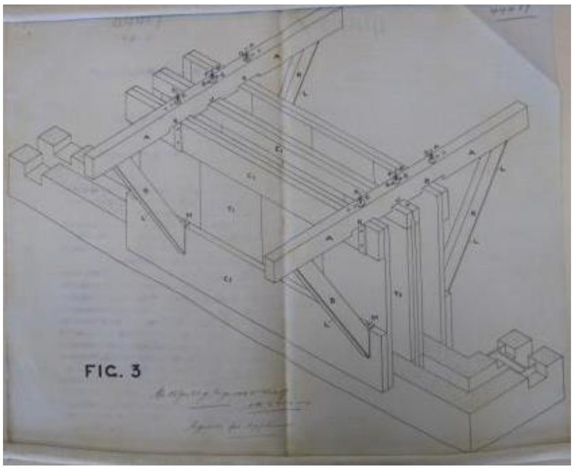


Figure 75: Boxing for Pearse's Patent Concrete Cavity. Patent 44,437. 11 August 1920

6.3.4 Concrete Blocks

This section begins with a review of the invention of the modern, commercial, hollow concrete block and then provides an overview of the use of hollow concrete block in New Zealand from 1906 to 1980.

Thornton only documents the use of concrete blocks to 1922 (Thornton, 1996, pp. 173–174). Section 7.2 provides a case study of the first New Zealand business established to manufacture and build with hollow concrete blocks, while this section fills in the missing history for the rest of New Zealand. It is consequently longer than other sections in this chapter.

6.3.4.1 Hollow Concrete Blocks

The use of concrete blocks was not unknown in the mid-1800s. Blair recorded that in England solid concrete blocks were "manufactured in large quantities by machinery and form excellent building material" with a "common mixture being one part cement to six parts sand." He also noted that moulded blocks "for arch-stones, quoins, sills, lintels, steps and mouldings of all kind" were "laid like stones or brick" (Blair, 1879, p. 66).

Precast concrete blocks date from the 1830s (Addis, 2007, p. 618; Friedman, 2010, p. 135), with *cast-stone* (the use of concrete as substitute for natural stone) in use from the late 1860s (Cowden & Wessel, 1995, p. 87). Pre-casting had the advantage of allowing the components, and possibly the entire structure, to be prepared at a suitable site for later transport to the final location. Solid concrete blocks had an obvious disadvantage, their weight. A solid block measuring 12 x 9 x 32 inches (30 x 23 x 81cm) could weigh 180 pounds (82kg), making it beyond the capacity of one man to lift and requiring the use of a hand-cranked derrick or crane (P. H. Simpson, 1989, p. 112). The most obvious way to reduce the block's weight was to reduce the amount of concrete.

The earliest patent referring to hollow concrete blocks was awarded to Joseph Gibbs in 1850 (British Patent 13,071) while C.S. Hutchinson was awarded the first US Patent (53,004) in 1866 (Torrance, 1906, pp. 206–208). Simpson argues that these early patents did not lead to the widespread production of hollow concrete block. It was not until Harmon S. Palmer had experimented for ten years, including building six houses in Chicago in 1897, that he brought together manufacturing and design concepts that led to the creation of the modern hollow concrete block (P. H. Simpson, 1999a, p. 11). Isaacs (2015, p. 92) provides a comprehensive list of Palmer's patents.

Palmer's first patent was in 1887 for a "Machine for Molding Building Blocks" (Figure 76). It introduced the combination of a removable bottom plate, a vertically moving core-block with a spur-pinion mechanism, and hinged end-plates, although it produced a solid block (H. S. Palmer, 1887). Palmer's second patent machine, which from the drawings and descriptions was probably made of cast-iron, had a tapering core and a mechanism which slightly withdrew the core before releasing the sides(H. S. Palmer, 1899). His last machine was a complex, sophisticated piece of automated machinery capable of producing the full range of block shapes with a wide range of control over the production and removal of the block from the machine (Figure 77), (H. S. Palmer, 1906)

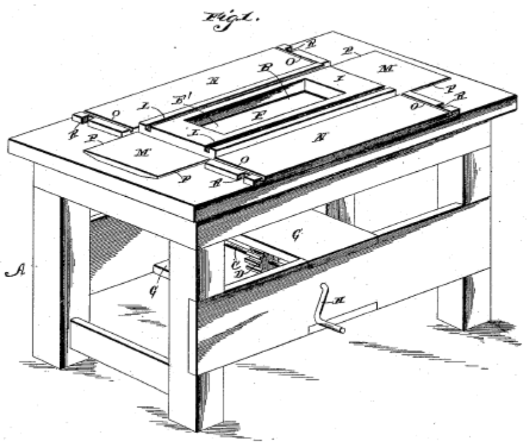


Figure 76: US Patent 375,377. Machine for Molding Building Blocks. 27 Dec 1887

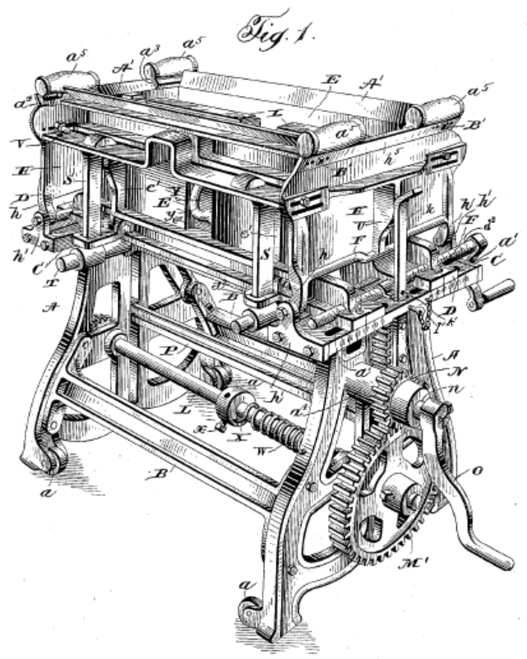


Figure 77: US Patent 828,767. Machine for Making Concrete Blocks. 14 August 1906

When the machine was coupled with his 1901 patent 674,874 (filed on 21 March 1900, issued 28 May 1901) for a "Concrete Wall for Buildings" (H. S. Palmer, 1901) (Figure 78), it provided the impetus needed to create a widely usable concrete construction system. The object of Palmer's block was to "simplify, cheapen, and to produce stronger buildings as well as more efficient in protecting from the elements." The cavity created "a thin wall of stone ... to receive the rain ... that a few hours of sunshine will remove all dampness, leaving the walls dry and the building in a sanitary and healthy condition." The cavities could also be used "as a ventilator, which can be connected with every room in the house, thereby securing a circulation of air of the most desirable kind" (H. S. Palmer, 1901).

The 1901 patent included designs for a range of blocks, including blocks with notches or "receptacles to receive the floor-joists and a bottom on which the joists rest" to permit the use of suspended floors, as well as a specialist chimney or pilaster block. The corner block is of particular interest, as it has a long side (full block length) and a short side (half block length) (Figure 78). This block first creates a corner without any joint and secondly provides a perfect bond for the next course merely by being reversed (H. S. Palmer, 1901).

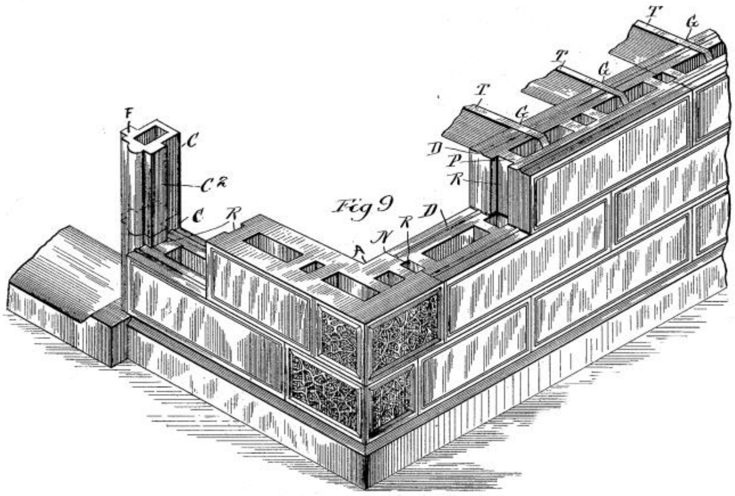


Figure 78: US Patent 674,874 Concrete Wall For Buildings. 28 May 1901

By 1906 there were reportedly 1,000 companies and individuals in the USA making hollow concrete blocks and by 1907 nearly 100 companies making machines in competition with Palmer (Newberry, 1906a, p. 118; P. H. Simpson, 1989, p. 109). From 1905, in the USA the industry began to organise. The Concrete Block Machine Manufacturers Association was founded in 1905, the Concrete Producers Association in 1918, and the Concrete Block Manufacturers Association in 1919. This in turn led to standard sizes being agreed by 1924 and by 1930 the 8 x 8 x 16 in (203 x 203 x 406mm) nominal size (later to become the 200mm standard metric size) had become the most common block (P. H. Simpson, Hunderman, & Slaton, 1995).

In the USA individuals could purchase a hollow concrete block machine through companies such as Sears, Roebuck who were advertising their "Wizard Concrete Building Block machines" in 1907 (Sears, Roebuck and Company, 1971, pp. 574–576), and possibly earlier. A sum of $42.50 would purchase the machine, while the Company would provide a free "Book of Modern Homes Building Plans" from which the house plan could be selected, including a "handsome nine-bedroom concrete residence", requiring only $1,995 to build, paint and complete it ready for occupancy (Sears, Roebuck and Company, 1971, p. 597). By the 1917 Catalogue, the machine had received some additional design input and had increased in cost to $57.50 (P. H. Simpson, 1989, p. 113).

In New Zealand, the Farmers' Trading Company (and its predecessor Laidlaw Leeds) occupied a similar place in the market producing and distributing an annual catalogue[9]. Although the catalogue listings included cement (Farmers' Trading Company Ltd, 1927, p. 144), in the period 1909 to 1917 there is no evidence that concrete blocks or other similar building materials were ever included (Margaret Aish, 2013).

6.3.4.2 Hollow Concrete Blocks Wellington and beyond: 1906-1910

The earliest New Zealand use of hollow concrete blocks dates to 1904 with the formation of the Wellington Hollow Concrete Block Company which used a Palmer machine (Section 7.2). No evidence has been found of the use of hollow concrete blocks for house construction outside Wellington prior to 1906. However, businesses in other locations quickly made up for this lag.

By 12 January 1906, Mr Frank Palliser, a Timaru builder, had imported a Palmer's machine; the local Timaru Borough Council had made a special addition to the building by-law to permit the use of hollow concrete blocks; and Palliser had presented a concrete drinking fountain to be placed at Caroline Bay (Wanganui Herald, p. 5, 12 Jan 1906). Just two years later, Timaru was promoting itself as exporting: "sunny-tempered people and hollow concrete building blocks, but retains large numbers of both for its own use" (Evening Post, p. 9, 3 Jul 1912).

At least one new Wellington business had an interest in hollow concrete blocks in 1906. Moore and Varlow, House and Land Agents of 20 Customhouse Quay were advertising themselves as "Agents for the Hollow Concrete Blocks, for walls, etc.", although no name was given to the agency (Evening Post, p. 8, 13 Aug 1906).

In August 1906, Mr W.T. Cowperthwaite of Whangarei was manufacturing 8 x 8 x 16 in (200 x 200 x 400mm) hollow concrete blocks after receiving an initial order for 5,000 blocks and reportedly with considerable ongoing inquiries (Northern Advocate, p. 2, 1 Aug 1906). It is possible these were used for the new two storey building for the Whangarei Lodge of the Order of Oddfellows which opened on 24 October 1907 (New Zealand Herald, p. 5, 28 Oct 1907), although no further details have been found. Three years later, the building was

[9] See http://www.farmers.co.nz/history.html

reported as requiring repairs due to "moisture percolating through the hollow concrete blocks" (Northern Advocate, p. 4, 1 Oct 1910).

The New Zealand construction trade magazine *Progress* in its October 1906 issue set out its support for the wider use of hollow concrete blocks (Progress, p. 335, 1 Oct 1906. Editorial).

On 9 March 1907 a "Fine Modern Hollow Concrete Block Residence" was advertised as being built in King Edward Road, Mount Roskill, Auckland but the name of the block system was not provided (Auckland Star, p. 2, 9 Mar 1907) and no related advertisements have been found. Just over a year later, Kinloch Brothers, located in Three Kings Quarries (close to Mt Roskill) were advertising for a "Man, experienced in working of Hollow Concrete Block Machine and manufacture of blocks" (New Zealand Herald, p. 1, 19 Feb 1908). In August 1911, Mr Hull Kinloch put up for auction 10¾ acres (4.35 hectares) of land on Mt Eden Road with a large scoria pit and a "new House of seven rooms, built of concrete blocks" (New Zealand Herald, p. 4. 5 Aug 1911), although it is unclear whether the land was sold as Mr Kinloch continued to advertise the availability of scoria from his quarry (New Zealand Herald, p. 12, 17 Aug 1912).

From November 1906 to January 1908 C.A. Hamlin & Co advertised "Miracle Concrete Building Blocks" (Progress, p. 34, 1 Nov 1906). On 15th April 1908 an application (No 24277) was made to patent the *Miracle and Dow* concrete building block (New Zealand Government, p. 1289, 30 Apr 1908), but this application did not progress (NZ Patent Office, 1911).

The November 1907 issue of *Progress* also reported that *Miracle* plants had been imported for Mr E.J. Ible of Lower Hutt, Wellington and Wilson's Portland Cement Co, Auckland (Progress, p. 32, 1 Nov 1907). Mr Ible built a single-storey, Italianate-style bay-villa using Miracle Blocks in Knights Road, Lower Hutt (Historic Place Category 2, number 7185) as well as a set of houses in Riddlers Crescent Lower Hutt from 1908 to 1910 (Fill, Mulgan, & Davidson, 2010, p. 10). Two years later, an advertisement requesting replies to "Architect, Dominion office" advertised for a partner with £800 to £1000 capital to start a "Works for the supply of Hollow Concrete Blocks for building purposes" (Dominion, p. 1, 13 Feb 1908). The same advertisement ran for 5 insertions.

In September 1908 sections were being advertised in Hutt-Belmont with the promise: "Hollow Concrete Manufactory to be established on Township enabling concrete houses, which require no repairs or painting to be built 20 per cent cheaper than wooden houses. Compared with other sites this is equivalent to buyers getting land for nothing" (Dominion, p. 16, 19 Sep 1908).

In Dunedin, the 1908 Otago A & P Show included an exhibit from the Milburn Lime and Cement Company of the *Miracle* double air space concrete building block "for which it has secured patent rights for Otago" (Otago Witness, p. 27, 10 Jun 1908).

Progress continued its promotion of hollow concrete blocks, with a three part article by Spencer B. Newberry in the December 1906, January 1907 and February 1907 issues (Newberry, 1906b, 1907a, 1907b). Newberry's article had been first published in the August 1905 issue of "Cement and Engineering News" (USA) (Newberry, 1905b) and republished in the September 1905 issue of "The Cement Age" (USA) (Newberry, 1905c) before it was published in the second issue (May 1906) of the UK journal "Concrete and Constructional Engineering" (Newberry, 1906a). This was available in New Zealand, with paper copies still held in the University of Canterbury, University of Auckland, and Auckland Public libraries. It was also republished as a 24 page booklet "Hollow Concrete Block Building Construction" (Newberry, 1905a).

However, the article in *Progress* appears to have been taken from one of the USA publications, as the surname "Listh" (the 1878 Newcastle, British inventor of a z-shaped block) in the NZ article (Newberry, 1906b, p. 47) is spelt the same in both original USA articles (Newberry, 1905b, p. 148, 1905c, p. 238) and booklet (Newberry, 1905a, p. 5), but not in the British journal where it is correctly spelt "Lish" (Newberry, 1906a, p. 119). The major difference between the U.S.A and NZ versions, is that *Progress* did not publish the section on "Cost and Selling Price" (Newberry, 1905a, pp. 19–22).

In 1908 there were two applications made to the New Zealand Customs Department requesting import tariff reductions for hollow concrete block making machinery.

- On 3 Aug 1908 the business of Maxwell & Mann of Westport requested an import tariff reduction for a concrete block machine, stating their belief that it was a new industry. In an internal memo, the Customs Department Head Office in Wellington stated "Messrs Maxwell & Mann are mistaken in supposing that the industry is a new one in New Zealand. It has been in operation in Wellington for some time" (Secretary & Inspector of Customs, Wellington, 1908). By April 1909, Maxwell & Mann supplied the concrete blocks for "Westport's first concrete block building" built for Mr H.G. Bignall (Grey River Argus, p. 2, 5 Jan 1909), suggesting they had imported or purchased from a local agent a block making machine.

- On 23 Sept 1908 Winstone Ltd, through agent John Sutton of Auckland, requested a tariff reduction (Inspector of Customs, Auckland, 1908, p. 186, 23 Sep 1908. Letter ref 1908/1739) for a *Pioneer Junior* concrete block machine (Inspector of Customs, Auckland, 1908, p. 199, 25 Sep 1908. Letter ref 1908/1749) which was refused, apparently based on the same grounds as the Westport decision (Secretary & Collector of Customs, Wellington, 1908). Sutton appears to have promoted the machine, with a newspaper report on his visit to Matamata in 1908 offering "some use for the mining tailings at present in the river" (Ohinemuri Gazette, p. 2, 12 Oct 1908).

In 1908 Auckland, M. Duffin of the Green-lane [sic] Concrete Block Company was advertising hollow concrete blocks in lots of 1,000 to 6,000 "Well Seasoned and made of the Best Materials" (Auckland Star, p. 6, 2 May 1908).

Prior to the research reported here, the *Stone House*, Derby St, Westport (Historic Place Category 2, number 7191), was believed to have been built about 1903 for Henry George Bedell, a tailor, and his family which would have made it the first NZ hollow concrete block house. The *Singley* hollow concrete blocks, were rock faced on the ground floor and smooth finish on the first storey (The News (Westport), p. 5, 30 Apr 1991). However, examination of Buller District electoral rolls shows from 1902 Mr Bedell was in Cobden St, Westport until moving into Derby St between the closing of the 1908 roll on 31 Oct 1908 and the closing of the 1911 roll on 14 October 1911. As noted above, Maxwell & Mann advertised they had built the first concrete block building in late 1908, so it is more likely that the Stone House was built in late 1908 or during 1909. This change has now been made to the Heritage NZ register.

It was not until April 1909 that advertisements specifically for block making machinery appeared in *Progress*, from the Petty-John (of Terre Haute, Indiana, USA) company with local agent, Wm. J. Alexander of Napier (Petty-John Company, 1909).

By 1909 hollow concrete blocks were being made by prisoners at Invercargill Prison and used for house construction in the area (Thornton, 1996, p. 123). About the same time, the Property & Finance Co. was set up in Invercargill to sell from a catalogue houses built of brick, concrete or concrete block, of which block was the most popular (Thornton, 1996, p. 123). Also in 1909, the Cambridge Town Hall and associated Carnegie Library were built with a base of hollow concrete blocks "representing stonework" (Progress, p. 282, 1 Jun 1909).

When the Cambridge Borough Council called for tenders for the Town Hall, they decided to call for alternates in brick, concrete block and reinforced concrete (New Zealand Herald, p. 7, 16 Jan 1909). This would suggest that by 1909, even in provincial areas, hollow concrete block was at least seen as being viable, commercial and cost competitive.

In 1910 a tender to build the engineering school for the Napier Technical School was accepted (Poverty Bay Herald, p. 3, 24 Dec 1910), while in Hawera Mr T.N. Blackhall "contemplates new premises ... to be built of hollow concrete blocks and finished off to look like chiselled stone" (Hawera & Normanby Star, p. 6, 4 Apr 1910). In Christchurch, R.P.M. Manning and Co.'s Machinery Exchange offered for sale a "Hollow Concrete Block Machine, 30 cwt. Derrick Crane, £25" (The Press, p. 1, 18 Jul 1910).

In Wellington, hollow concrete block houses were again being built in 1910. A house in Coromandel St was issued with a building permit on 5 September 1910, although the specifications provided manufacturing and building detail but not block name:

> "The whole of the walls are to be built with hollow concrete blocks, composed of 1 part cement to 5 parts approved clean ballast, and all carefully bedded in cement mortar, 3 to 1, well pushed into joints and cross joints" (Barber, 1910).

A hollow concrete block retaining wall built at the front of the Coromandel Street section collapsed on the weekend of 7 July 1935 (Evening Post, p. 7, 8 Jul 1935). Responding with due commercial sensitivity, the Winget Concrete Block Co promptly advertised that the wall was not built of their blocks (Evening Post, p. 2, 9 Jul 1935).

Figure 79 provides a map showing the locations where hollow concrete blocks were used from 1904 to 1910 were wide spread. There is no obvious chronologically based diffusion from one or two centres.

Figure 79: Distribution of Use of Hollow Concrete Blocks 1904 to 1910

6.3.4.3 Quiet Development: 1910s-1940s

The use of hollow concrete block continued to grow. In 1919 the cement manufacturers of New Zealand published *Concrete Information: a practical handbook for all classes of concrete users*, (Figure 80) offering guidance for the use of concrete in a wide range of structures, including paths, fence posts, motor houses, stables, piggeries, steps, troughs and sheep dips. Wooden or timber moulds, timber formwork or concrete blocks were suggested for different purposes (Powell, 1919). It was edited by F.E. Powell "for the proprietors, the cement manufacturers of New Zealand." Frank Edward Powell was an English trained engineer, undertaking work on water supply, sewerage and storm water systems, roads, reinforced concrete buildings and structures (Observer, p. 15, 20 Sep 1919). A substantial amount of the text and some illustrations (notably those dealing with fence posts) are identical to the 1923 booklet "*Concrete: How it is made*" published by the Australian Portland Cement Co Pty Ltd (Australian Portland Cement Ltd, 1923). The original source of the material has yet to be confirmed, but many of the illustrations would appear to be American rather than British.

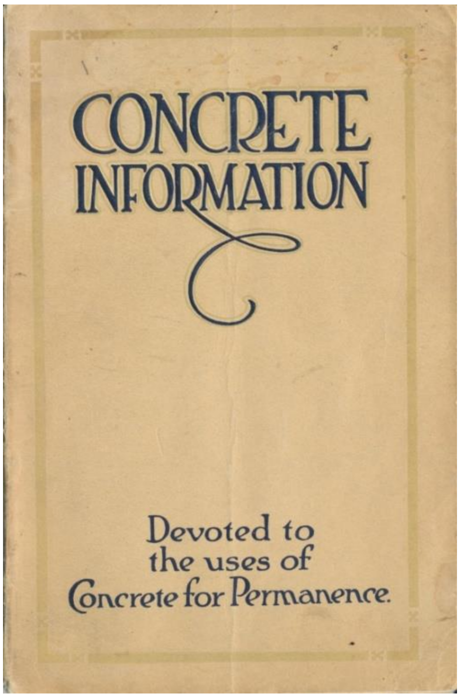


Figure 80: “Concrete Information” edited by F.E. Powell, 1919

During this period, NZ inventors patented a number of concrete block systems. For example, the *OK Dry Wall System* was described in four patents by Dunedin architect Edmund Anscombe: a hollow-wall construction (Patent 40562, application date 7 Aug 1918); concrete floor and roof construction (40563, 7 Aug 1918); concrete-block manufacture (44081 1 Jul 1920); and a concrete-block making machine (44217, 15 Jul 1920). The block was in two parts, held together where required by wall ties, in order that water would not be transferred from outside to inside. As well as Anscombe's own Dunedin house (1919), houses were built using the OK system in Central and North Otago, Dunedin (including council housing), Wellington (including Government housing in Miramar) and a range of housing in the Hawkes Bay (McCarthy, 2011).

Inventor Albert E Brooks, builder of Lower Hutt, patented his *Brooks System* which included a two piece concrete block (43506, 15 Apr 1920) and a concrete block forming machine (46477, 26 Aug 1921). The ribs of the inner and outer blocks are staggered and do not touch, the separation being maintained by a "z-shaped piece of crimped steel which forms an effective bond." A house was built using Brooks' system on Waterloo Road, Lower Hutt (Evening Post, p. 7, 15 Jan 1921).

The *Cavity Concrete Bloc* (41,240) was patented by Auckland architect Thomas Coulthard Mullions on 6 February 1919. Like Anscombe's patent, it used a two part block held together with wire ties (Mullions, 1919). The patent was taken over by The Cavity Concrete Block Limited (The Cavity Concrete Block Ltd, 1919) and advertising began for the system in 1921 (New Zealand Herald, p. 11, 14 May 1921), although the company went into voluntary liquidation in 1929 (Bishop, 1929). The company also took over the patent for a concrete block moulding machine invented by Auckland engineer Arthur Edwin Fallwell (42,110 dated 5 Aug 1919) and later advertised *Fallwell concrete blocks* which could be made in their workshops or on-site using machines they had available for hire (New Zealand Herald, p. 9, 7 Jul 1922).

In Gisborne the Inspector of Prisons reported that prisoner-made hollow concrete blocks would probably be the material of choice for a proposed high enclosing fence (Poverty Bay Herald, p. 2, 23 Jul 1914). Three months later *Square-Deal Jones* was offering for £350 (sale or exchange) a "Hollow Concrete Block and Brickmaking Business with all necessary Machinery" (Poverty Bay Herald, p. 1, 29 Oct 1914).

The Invicta Concrete Block Co., Auckland, first advertised its "manufacturers Best Patent Complet [sic] Cavity Building Block" in June 1928 (Auckland Star, p. 3, 6 Jun 1928). By February 1930, the company had sold the works site and was selling the plant, machinery and stock of blocks (Auckland Star, p. 528 Feb 1930).

In August 1925, the British Building Block Company (Auckland) Ltd promoted its *Lean* cavity concrete block system from which "Numerous beautiful homes have been erected on this system in and around Auckland." The company was also seeking investors (Auckland Star, p. 10, 29 Aug 1925), but when its promoter, Leonard John Courtney, disappeared the NZ Truth revealed he had been involved in a number of failed companies (NZ Truth, p. 3, 24 Jun 1926). Possibly under different ownership, the British Building Block Co. advertised its "cheapest and strongest" block in Wellington in 1927 (Evening Post, p. 15, 20 Aug 1927).

Papers Past (at February 2014) had only 7 papers that carried on to 1945 (2 in the Auckland region, 2 in Wellington, 3 elsewhere). In all these there are only three mentions of "hollow concrete block" from 1930 to 1945, with each offering one or two hollow concrete block moulds for sale (Auckland Star, p. 3, 28 Feb 1940, p. 3, 13 Mar 1940, p. 8, 7 Aug 1940). Over the same period, the term "concrete block" was used 608 times, mostly in the Auckland and Wellington papers, mainly for concrete block houses or buildings for sale, work related to such houses or the sale of blocks. A small number of advertisements offered concrete block machines for sale (Auckland Star, p. 20, 25 Jul 1930) or were from people wanting to buy machines (Auckland Star, p. 12, 15 Dec 1930).

One noticeable change as World War II progressed, was that concrete blocks, along with brickwork and mass concrete, were included in the Standard Specification for use in constructing surface raid shelters (Auckland Star, p. 6, 28 Jan 1942). This would suggest the use of hollow concrete blocks was growing over this period, but further detailed investigations have not been undertaken. Exploring the use of hollow concrete block in the 1930s and 1940s is an opportunity for further research.

6.3.4.4 Modern Hollow Concrete Block: 1940s-1980s

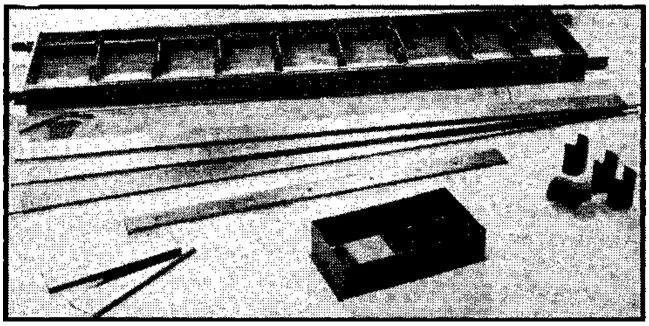
By the 1940s in New Zealand, perhaps in response to the stringencies of WWII, there are records of homemade blocks being used. Esther James, an inventor, fashion model, promoter of using locally made products, long-distance walker and builder (Barton, 1998) built her first house in concrete blocks in Mount Maunganui during World War II. She made concrete with sand from the property and made 4,000 blocks using home-made wooden moulds (James, 1965, pp. 125–138).

Figure 81 shows Jack Pullman, in March 1946 at Sandy Bay, Northland, mixing concrete to make hollow concrete blocks with a stack of these behind him. The mould with its textured face and presumably the plates from other moulds are to the front left of the photograph (R. E. Wells, 1946).

Figure 81: J. Pullman making concrete blocks at Sandy Bay. March 1946

The late 1940s saw a shift of interest in the use of hollow concrete blocks, possibly driven by the development in architecture of the Modern movement, even though New Zealand faced different constraints from those faced by war-ravaged Europe.

Possibly reflecting the increased public interest, the monthly NZ Journal of Agriculture ran a series of five articles on concrete from November 1949 to March 1950 (Eggers, 1949a, 1949b, 1950a, 1950b, 1950c) which were twice reprinted as a booklet by the Department of Agriculture (Eggers, 1952, 1957). The series included instructions for a do-it-yourself collapsible wooden mould for making solid or hollow concrete blocks, as well as an illustration showing combination metal moulds for making concrete blocks and posts (Figure 82), producing in one setting, 9 keyed blocks 18 x 4 x 8 in high (46 x 10 x 20 cm) (Eggers, 1952, pp. 17–18). This image matches the *Simplicity Moulds* (Figure 83) advertised in the January 1950 issue (Wright, Stephenson & Co. Ltd, 1950), the source of the original article (Eggers, 1950a).



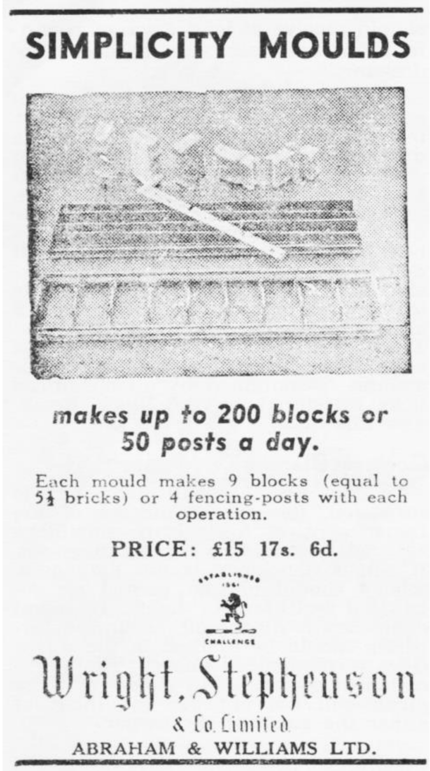


Figure 82: Combination metal moulds for making concrete blocks and posts (Jan 1950)

Figure 83: Advertisement for "Simplicity Moulds" (Jan 1950)

In the North Island, Firth Concrete Products Ltd purchased a *Rockcrete* machine in 1937 to manufacture pumice concrete blocks, each reinforced with 80 inches of No. 8 wire. They proved uneconomic, although owners Ted and Tony Firth each built block houses in Hamilton in 1938 (Whyte, 2001, p. 20). Firth now claims that "the company introduced New Zealand's first machine-made concrete blocks" (Firth Company, 2008), but the evidence presented here shows other hollow concrete block machines were in use before 1938.

The large scale, late-20th century use of concrete blocks appears to have started in Christchurch in the early 1950s, which has been confused in various publications as the start of the New Zealand use of fair faced concrete blocks. Gatley's review of modern New Zealand architecture lists the first use of fair-faced concrete block in housing in 1953 in Nelson (Gatley, 2008a, p. 65), while Lloyd-Jenkins' review of New Zealand design (Lloyd-Jenkins, 2004, p. 161) notes that Christchurch's Dorset Street Flats (1956-1957) are often claimed as the "first conscious use of concrete block and fairface concrete inside a New Zealand house or flat" (Warren & Mahoney Architects, 1989, p. 2).

In 1951 the Christchurch based Universal Block Company commenced operations with a single English *Trianco* block making machine. The company changed its name to Vibrapac Blocks Ltd in 1952, and was taken over by Winstone Ltd in 1973 (Neilson, 2011).

In 1950 Firth purchased Pyramid Concrete Ltd of Hamilton and its first post-World War II concrete block-making machine. It was considered relatively primitive, so Firth set up two additional Italian concrete block-making machines in its Rotorua factory in the mid-1950s. Presumably with sales going well, in 1958-59 they invested in three USA *Columbia* concrete block makers for their Hamilton, Hastings and Rotorua factories (Gatley, 2008b, p. 6; Whyte, 2001, p. 27). By 1967, Firth operated 7 *Columbia* block machines (Whyte, 2001, p. 34).

Winstone trademarked the name *Hollostone Blocks* on 24 July 1944 (Intellectual Property Office, 2014), and in 1944 started advertising the vibrated, hollow concrete blocks made in their Three Kings, Auckland plant (Auckland Star, p. 9, 15 Nov 1944). In 1953 a *Besser Vibrapac* machine (F. A. Simpson, 1965, p. 65) made steam-cured blocks at a rate of 5,600 blocks per 8 hour day, reportedly enough for 4 houses a day. The blocks were also expected to be used in commercial buildings in place of standard reinforced concrete (Anonymous, 1952).

The industry had grown to such a scale that in 1956 the New Zealand Concrete Masonry Association (NZCMA) was founded (Barnard, 2009, p. 6).

6.3.4.5 Census Reported Concrete Wall Construction

Figure 84 plots the number of inhabited permanent private dwellings reporting concrete wall construction, as well as the percentage of dwellings. The construction types are divided as reported in the Censuses: *Concrete* (1916 to 1921 Census); *Concrete, Including Concrete Block* (1926 to 1966); *Concrete + Other Material* (other materials include asbestos sheet, brick, corrugated iron, wood and other) (1926 Census); and *Concrete Block* (1976 to 1981). It would appear that walls of concrete block were included under *Concrete* construction for the 1971 Census, but then separated for the 1976 and 1981 Censuses. There were also changes to the wall construction question in the 1981 Census, making the categories not directly comparable with previous censuses.

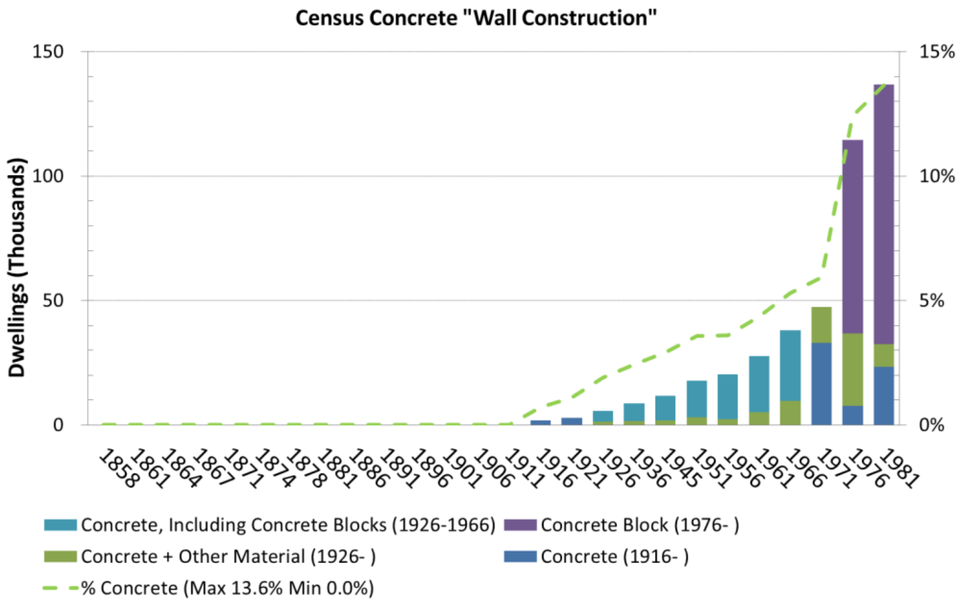


Figure 84: Census Dwellings with Concrete Wall Construction

In 1976, 68% of the concrete wall construction was reported as concrete block, while in 1981 concrete block had increased to 76% of the concrete wall construction (Figure 84). Concrete wall construction was found in less than 6% of occupied private dwellings until the 1976 Census when it increased to 12.4% and then to 13.6% in 1981.

Table 20: Numbers of Dwellings by Type at Selected Censuses

Dwelling type	Census ('000 dwellings)			
	1961	**1971**	**1976**	**1981**
Occupied permanent private dwelling				
Separate house	564	682	743	792
Attached house	(1)	(1)	35	97
House part sublet	1	5	14	(1)
Flat or apartment	53	105	118	101
Attached to business	7	5	8(2)	8
Bach or crib	9	4	5	4
Sub-total including other small groups	**634**	**802**	**923**	**1,003**
Unoccupied permanent private dwellings (3)	60	77	85	97
Under construction	11	9	14	7
Temporary (caravan, tent, etc.)	1	1	3	2
Non-private dwellings (institutions)	8	7	7	6
TOTAL all dwellings	**714**	**896**	**1032**	**1,125**

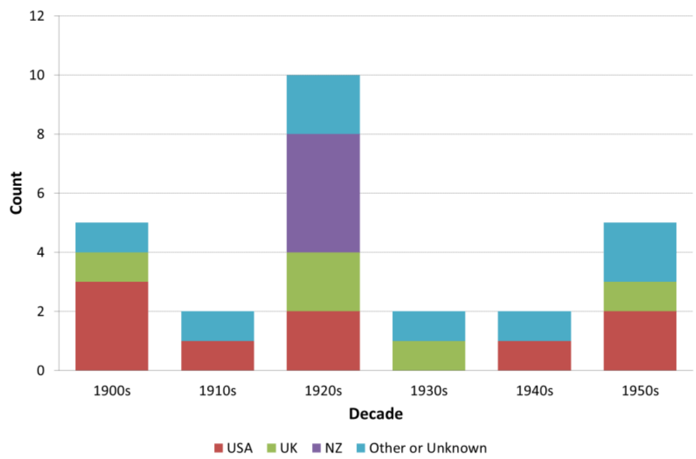
Notes:
(1) Included elsewhere in the table
(2) Change in groups in 1976 resulted in a jump in the 'dwelling attached to business'
(3) Includes homes in process of changeover from one group of occupiers to the next
Source: (New Zealand Department of Statistics, 1985, p. 118)

There were also changes in the types of dwellings over this time. In particular, Table 20 shows the number of apartments (normally multi-storey) increased from 53,000 in 1961 to

101,000 in 1981, while the number of attached dwellings (townhouses) also increased from 35,000 in 1976 (the first time this division was used) to 97,000 in 1981. Future research may establish how many of these apartments and townhouses used hollow concrete block or monolithic concrete.

6.3.4.6 Hollow Concrete Block Trade Names 1904-1959

Based on a literature review and Papers Past, Table 51 (see Appendix p. 326) provides a chronological list of the first mention of hollow concrete block trade names from 1904 to 1959. The location is the place where the blocks were used or manufactured, and where possible the country of origin of the named block system is given. Table 51 is unlikely to be comprehensive due to the limited Papers Past coverage of the post-1945 period, but is offered as starting point.



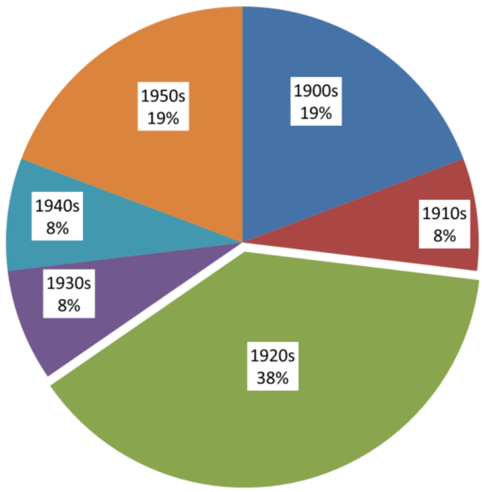


Figure 85: Count of first use of block trade name by country and decade

Table 51 lists 26 hollow concrete block systems: 9 originating in USA; 5 from UK; 4 from NZ; and 8 from other or unknown countries. Figure 85 plots the count of new block names by decade and country of origin on the left and as a pie chart by decade on the right. Although the origins of the various blocks vary, the USA and UK play key roles throughout. New Zealand inventors come to the fore in the 1920s and 1930s. The 1920s were the decade with the largest number of new trade names, with 38% of the total.

6.4 Walls and Ceilings: interior linings

In early New Zealand buildings, the exterior surfaces could be rough and unfinished, but the interior needed to be finished, at the very least, with a surface that could be kept clean while excluding undesirable vermin, winds and water. The early settler's need for shelter was paramount, and as Brett's pointed out: "inside furnishings and verandah may be done when convenient" (Leys, 1883, p. 723).

6.4.1 Wet Systems

Solid construction (earth, brick and stone) could be strapped-and-lined, but traditionally would have used a wet finish while framed houses could use wet or dry systems.

In timber-framed construction, lath-and-plaster (Figure 86) offered the opportunity for achieving a finer finish on walls and more importantly the ceiling. The lath is a horizontal strip of wood cut from a relatively soft timber that was free from warping. Nailed to the underside of the upper floor, ceiling joists or the wall studs, the timber laths were covered with up to three layers of plaster, providing a smooth, durable and fire resistant surface.

In the 1980s wet systems continued to be used, although mainly for repair and maintenance of existing buildings.

Figure 86: Lath-and-plaster - the view inside the wall

Figure 87: Sarking and Weatherboards – external view.

6.4.2 Dry Systems

Conventional wet plaster walls offered many benefits to the home owner, but the builder was faced with bringing a wet-trade into an otherwise dry construction. Dry linings were made off-site and delivered dry to site for fixing and finishing.

Rough sawn boards could be used outside as weatherboarding or inside as board lining (sarking) to which scrim and wallpaper were attached. Figure 87 shows a two storey platform frame house with rusticated weatherboard cladding on the top storey, and the lower storey sarking exposed by the removal of the kitchen. Horizontally fixed to vertical studs, sarking was wider and thinner than the exterior cladding. Even if the boards started tightly edge-butted, as they dried out draughts became an unwelcome addition to family life (G. Wilson, 1981, p. 39). P.T. & G. boards provided a tighter finish, reducing draughts and limiting the entrance of vermin, so were more often found in kitchens (Salmond, 1989, p. 33).

Although the same lining for the walls could be used for ceilings, decorative products were an alternative. Fibrous plaster could be sculpted into a wide range of decorations, and pressed steel or aluminium panels were available later (G. Wilson, 1981, p. 41). In particular, sheet linings offered a suitable low cost, low or no maintenance and self-finished wall material (Salmond, 1989, p. 204) as well as a way to reduce excessive infiltration.

Dry linings commonly available in New Zealand by the 1950s were (Technical Correspondence School, 1958, pp. 187–189):

- **Fibrous plaster sheets**: made of Plaster of Paris with fibres of flax or sisal reinforcement. Sheets were usually ⅜ inch thick and made to size on order.
- **Plaster-cored wallboard**: an unreinforced filling of Plaster of Paris and pumice between two sheets of stiff paper. Sheets were ⅜ in thick (9.5mm), 3ft (0.9m) or 4ft (1.2m) widths and in lengths from 6ft to 10ft (1.8 to 3m).
- **Wood fibre boards**: two types, Hardboard and Softboard:
    - **Hard board**: dense in structure with a hard surface finish, normally smooth but textured finishes were also available.

- **Softboard**: open textured, comparatively soft, roughened surface. Sheets were ½ inch (12.5mm) thick, 4ft (1.2m) or 4ft 6" (1.4m) wide and in lengths from 6ft to 10ft (1.8 to 3m).

Each offered a range of advantages and disadvantages, with fibrous plaster having a tendency to sag, hardboard tending to bulge out due to its natural springiness, and softboard not providing a smooth texture for wallpaper (G. Wilson, 1981, pp. 39–41).

6.4.2.1 Wood Fibre Boards

The manufacture and properties of wood fibre boards are discussed in Section 5.5.6.

6.4.2.2 Fibrous Plaster and Plaster Board

Plaster of Paris (named after the large gypsum deposits in Montmartre, Paris) was formed by heating natural gypsum rock and grinding it to a fine powder (Torres, Emeric, & Guilhem, 2006, p. 22). When mixed with water the plaster could be shaped, soon setting to a hard, but brittle, solid. It had many uses, ranging from holding broken bones while they set to creating precast decorative features for ceilings and cornices.

Figure 88 shows the proportion of gypsum imports, based on value, by country from 1870 to 1960. This analysis includes the headings: *Plaster of Paris for non-surgical use* (where separately identified); *Crude gypsum*; and *Gypsum (not manure)*. For 1870 and 1875 only a combined *Plaster of Paris and Cement* category was provided, so no separate import data is available. Although some gypsum came from the UK, the highest proportion was 26% of the total value in 1910. Up to 1905, the majority of gypsum imports were from USA, but from 1910 Australia played an increasingly important role.

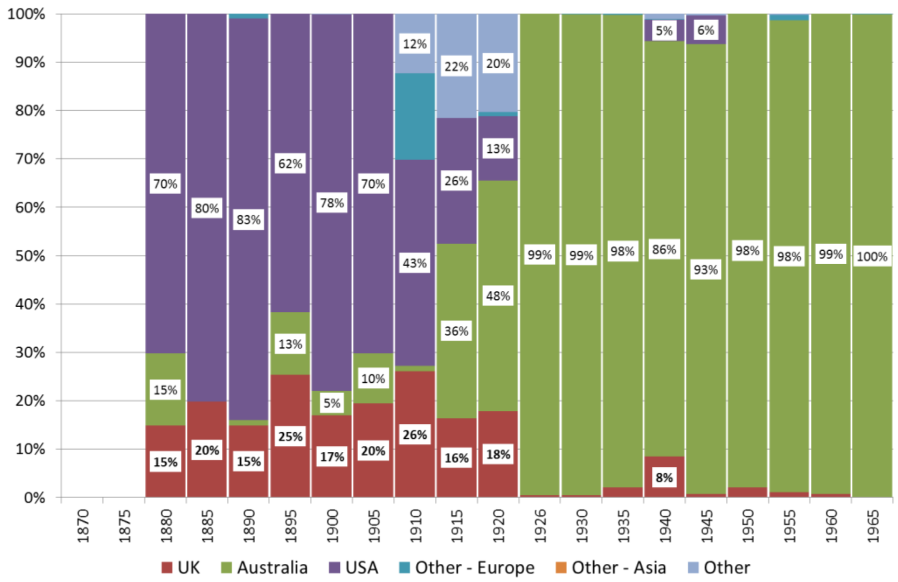


Figure 88: Gypsum Imports by Country 1870 to 1965

Figure 89 plots gypsum imports by quantity (cwt millions) and value (£ '000). Imports are very low until the 1920s, when the first plant manufacturing plaster board commenced operation. Following WWII as the use of plasterboard linings increased (replacing timber and timber products) imports started to increase, notably in the 1960s with the change in wall finishing to plasterboard.

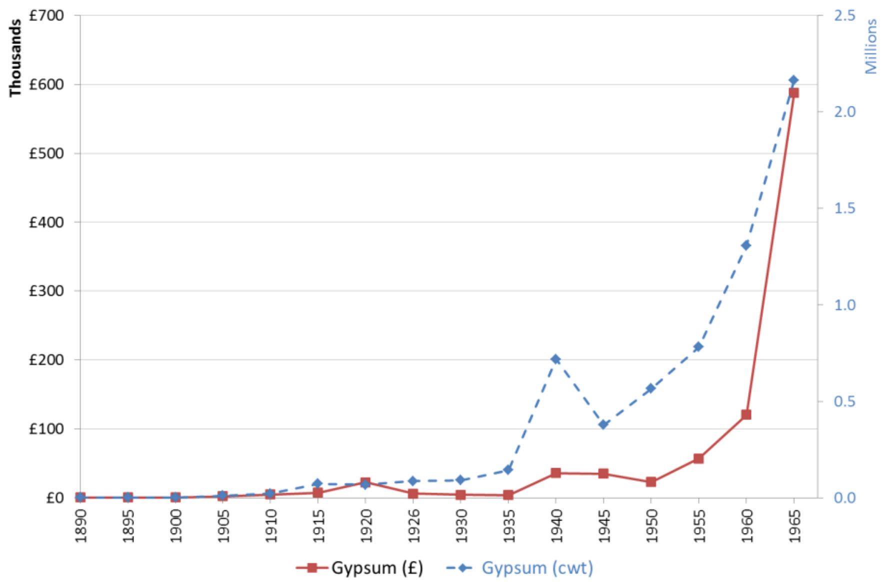


Figure 89: Gypsum Imports by Value and Quantity 1870 to 1965

Fibrous plaster products were being advertised by R. Wardrop in Dunedin from 1901 (Otago Daily Times, p. 1, 2 Dec 1901). In Wellington the NZ Carrara Fibrous Plaster Company was advertising product in May 1903 (Evening Post, p. 6, 11 May 1903) although the company first advertised for staff in December 1902 (Evening Post, p. 1, 12 Dec 1902), suggesting some delay in either starting advertising or operations. They used *Stuccolin* (Progress, p. 89, 2 Jan 1907), a patented product of Ernst Haberer & Cie., Bern (Ernst Haberer & Cie, Bern, 1906). Cast fibrous plaster sheeting was being made and sold under the name *Granlite* in Wellington by 1923 (Evening Post, p. 5, 26 Oct 1923), and a plant was operating in Auckland by November 1925 (Auckland Star, p. 1, 21 Nov 1925).

In May 1890 Augustine Sackett, a New York engineer, patented plasterboard. Table 21 lists the patents awarded to Sackett. His earliest were for a system to coat only one side of a roll of paper (Sackett, 1880a, 1880b), and later he moved to coating roofing felt (Sackett, 1884). In 1890 Sackett submitted his application for a patent for an "Inside Wall Covering." This was not the single layer of gypsum sandwiched between two layers of cardboard or paper of modern plasterboard, but was instead "from four to eight or ten sheets of paper with their intervening layers of plaster." One side of the board was to be waterproof paper, or the paper could be waterproofed by "applying to it a water-proof varnish, paint or composition" including coal-tar pitch (Sackett, 1894).

Table 21: Augustine Sackett's US Patents

Application	Issued	Patent	Title
4 Oct 1879	13 Apr 1880	226,459	Process of Coating Paper and Cloth
7 Jan 1880	24 Aug 1880	231,450	Process for Coating Paper and Cloth
11 May 1883	8 Jan 1884	291,628	Roofing Felt and Mechanism for Making the Same
23 May 1890	22 May 1894	520,123	Inside-Wall Covering
8 Mar 1899	9 May 1899	624,687	Improvements in Processes of Mixing Cement, Plaster &c.

By 1917 plasterboard was being produced in Great Britain, although not until 1946 in France (Torres et al., 2006, p. 78). In New Zealand, plasterboard was initially imported from North America (F. A. Simpson, 1965, p. 161), although the quantities must have been small as not until 1936 were plaster-board imports separately listed (Census and Statistics Office, 1937, p. 346).

Plasterboard arrived on the market in the early 1920s, with advertisements for imported *Triumph* (New Zealand Herald, p. 6, 21 Mar 1923), *Maxwell* (Evening Post, p. 5, 13 Dec 1924), *Winco* (New Zealand Herald, p. 13, 24 Jan 1925), *Peerless* (Evening Post, p. 12, 16 Feb 1926) and *Empire* boards. Although all of these plaster wallboards were imported, only

Empire was promoted as "this well-known British plaster board" (New Zealand Herald, p. 3, 4 Aug 1926).

Local manufacture commenced in 1925, often used as the first use, with the establishment of the Builder's Composite Materials Ltd, Auckland, which produced *Vidite* plasterboard (New Zealand Herald, p. 13, 2 Sep 1923). *Vidite* was awarded the Gold Medal at the NZ and South Seas Exhibition, Dunedin 1926 (New Zealand Herald, p. 17, 28 Apr 1926) as was imported *Maxwell* board (Thompson, 1927, pp. 163–164). The company changed its name in 1927 to NZ Wallboards Ltd and obtained a site in Mt Eden, Auckland. By 1932 the product name was changed to Gibraltar Board, with an advertising slogan "As solid as the rock of Gibraltar" (New Zealand Herald, p. 11, 26 Mar 1932).

Initially the manufacturing process was manual (Figure 90 and Figure 91) but automated machinery was introduced in 1931, along with the use of pumice in place of the previous sawdust. A Lower Hutt, Wellington factory was opened in 1946 and closed in 1989 (Hutt News, p. 35, 30 May 1989). A Christchurch factory opened in 1961. The Balmoral Road factory expanded considerably over the years, but in 1971 was replaced by a new plant at Penrose (F. A. Simpson, 1965, pp. 161–176).

Figure 90: Workers in NZ Wallboard factory mixing plaster by hand, 1927

Figure 91: Hand cutting to untrimmed lengths to load in to tunnel drier 1927

6.5 Wall: exterior claddings

Imported materials such as corrugated iron, cement sheet, or locally made products such as timber or brick could clad a timber-framework. Bricks (Section 5.2.2), poured or monolithic concrete (Section 6.3.3) and concrete blocks (Section 6.3.4) can be used both as structure or cladding.

6.5.1 Weatherboards

The term weatherboard was first used in 1539-40 to refer to an external cladding made from a series of boards nailed horizontally with overlapping edges (Oxford English Dictionary, 2014). Internationally terminology varies, with the USA using *weatherboard* for vertical board and battens, and *clapboard* for horizontal cladding (Lewis, 1998, pp. 8–9 Section 5.03 'The Timber Frame: Carpentry'. 4 Aug 2012).

Early settlers had access to books such as Robert Scott Burn's *The Colonist's And Emigrant's Handbook Of The Mechanical Arts* published in 1854 (Betteridge, Mathias, Goldstein, Robinson, & Leslie, 2004, p. 15). It provided guidance for the construction of log cabin, pisé, brick, stone and timber-frame houses. The frame-house, with posts driven directly into the ground, was suggested for a first temporary house, using folded canvas, asphalted cloth or waterproof felt as internal lining to create a "very snug and quickly raised house" in just two days (Burn, 1854, pp. 46–47).

Once settled, Burn suggested the next house could be covered with overlapped plain boards, and internally with timber slabs. While tongue and groove board could be used in first class work, for ordinary work the boards could be "planed or if preferred left rough." The space between the inner face and exterior weatherboarding "may be filled with some non-conducting material" such as clay or earth (Burn, 1854, pp. 48–49).

New Zealand quickly became a country of weatherboard houses and buildings but the dreams of the solid stone house were not quickly forgotten. Whether it was the 9,380 m^2 Government Building built in 1876 (Kernohan, McHaffie, Gard'ner, Kellaway, & Gray, 1994, p. 58), the 1913 Inglewood Town Hall, or a compact workers cottage in Nelson (Figure 92), timber could be dressed-up to look like stone. Rusticated weatherboard coupled with corner quoins gave the appearance of stone, without the poor earthquake performance or good fire resistance.

Plain weatherboards could be split from suitable timber (Section 6.3.1.1), sawn by hand or later by machine. Only when machinery was able to create more complex mouldings were more detailed weatherboards widely used. Although local sawmills were producing weatherboard, there were also imports from Australia (Nelson Examiner and New Zealand Chronicle, p. 2, 18 Aug 1855) and in Baltic timber (Lyttelton Times, p. 5, 26 Feb 1859; Otago Daily Times, p. 1, 10 May 1862). It is unclear when imports stopped, but Baltic weather boards were being sold in Dunedin in 1917 (Otago Daily Times, p. 14, 29 Sep 1917). Table 22 suggests it was the 1860s before rusticated weatherboards were widely used (Arden & Bowman, 2004, p. 92).

Table 22: Weatherboard Profiles and Dates of Use

Dates	**Weatherboard types**
1840s-1870s onwards	Plain board
1840s onwards	Vertical board and batten
1860s onwards	Rusticated
1910 onwards	Rebated bevel-back
1920s onwards	Splayed or bevel-back
1920s onwards	Vertical shiplap

Figure 93 illustrates 7 different weatherboard profiles: plain board; plain and rebated bevel back; rebated skewcut bevelback; shiplap; and two variations on rusticated weatherboards (Technical Correspondence School, 1958, p. 150, Fig 266). The profile names refer to the appearance of the weatherboard, either directly (plain, bevelback) or in reference to other materials (rusticated) (Nicholson, 1837, p. 84).

It took until 1948 to establish standard dimensions with the publication of NZSS 3617 *Profiles of Weatherboards, Flooring and Matchlining* (New Zealand Standards Institute, 1948), which became NZS 3617 in 1979 (Standards New Zealand, 1979).

Many native timbers proved ideal for weatherboards. Heart rimu, matai, totara and miro were considered highly suitable, while tawa, tanekaha, pukatea and totara could be used with preservative treatment. Imported American redwood, western red cedar and Australian eucalypts were also used, and in later years with the reduction in the native timber resource, treated pine (Arden & Bowman, 2004, pp. 91–2; Technical Correspondence School, 1958, p. 70).

Figure 92: House with Rusticated and Plain Weatherboards, South Street, Nelson

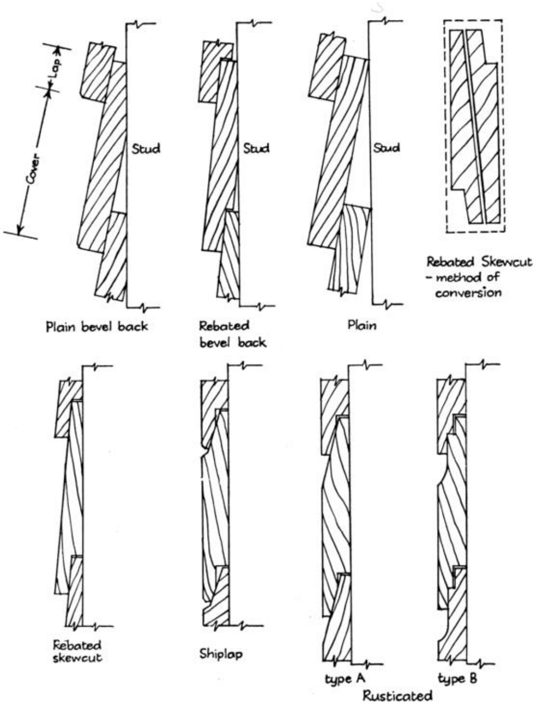


Figure 93: Common Weatherboards (1958)

6.5.2 Building Paper

Nowadays weatherboards go together with building paper, but this is a comparatively recent requirement. In 1884 Truman J. Pearch and M. W. Beardsly, of Oakland, California, patented their process for dissolving maltha, the residue from the distillation of petroleum, in bisulphide of carbon (CS_2) (T. J. Pearce & Beardsley, 1886a). They also patented a variation which could be applied to paper to form a waterproof, smoother, tougher and less flammable product which could be used for roofs and surfaces exposed to the elements and not subject to abrasion (T. J. Pearce & Beardsley, 1886b). This ultimately became bituminous building paper.

Building paper was advertised from 1898 when George Ross of Wellington promoted the use of *P & B Building paper* which was "… waterproof and will not rot. Keeps the walls dry, and prevents draughts and excludes cold" (Evening Post, p. 1, 23 Jun 1898).

This last benefit made building paper valuable given the poor wind performance of sarking. Over the next five years, building paper was promoted to reduce these unwanted draughts, with newspaper advertisements in Christchurch (The Press, p. 6, 18 Nov 1899), Palmerston

North (Manawatu Standard, p. 7, 1 Sep 1903), Hawkes Bay and Taranaki (Evening Post, p. 16, 7 May 1904).

It took some time before it became widely used. For example, Brett's 1902 edition, provides a detailed house construction specification with no requirement for building paper (Leys, 1902, p. 1143). In 1907 Wellington, Nielsen's houses following his failed concrete block business (Section 7.2.1), were timber frame with weatherboard. The specifications for the Kelburn house included building paper (house cost £724) (Nielsen, 1907c, p. 11) but it was not included in the two lower cost houses in Lyall Bay (£231 and £300) (Nielsen, 1907a, 1907b). In 1911, a moderate cost Aro Valley, Wellington house (£439) used building paper (Figure 68).

Although by the 1930s building paper was common, it was not until 1941 that the Duroid Company commenced manufacture of Malthoid brand products in Onehunga, Auckland (New Zealand Herald, p. 3, 28 Mar 1941; Scie Construction Ltd, 2014). In 1964 the use of building paper behind cladding, except brick veneer, became a requirement under NZS 1900 Chapter 6.1 (New Zealand Standards Institute, 1964) while in 1978 NZS3604 required a building wrap for all claddings from the top plate to below the joists (Standards Association of New Zealand, 1978).

6.5.3 Fibre-cement boards

The first advertisement found for asbestos goods was for H.W. Johns (later to become the Johns-Manville Company) asbestos sheathing in May 1882 (New Zealand Tablet, p. 12, 12 May 1882). The following year, the paper noted that the presbytery attached to St Mary's Catholic Church, Port Chalmers, used Johns' patent asbestos roofing which was "not only impervious to weather, but is fireproof" (New Zealand Tablet, p. 16, 15 Jun 1883).

The natural mineral fibre, asbestos, has a long history of use, with clay pots from Finland strengthened with asbestos over 4,000 years ago. In the 1880s asbestos was used on a large scale to insulate high temperature pipes and boilers (National Asbestos Medical Panel., 2006, p. 34). In New Zealand, white asbestos (chrysotile) was mined in small quantities from a single mine near Takaka from the early 1950s until the early 1960s. Since 1984, outside the research period, the importation of the more widely used blue and brown asbestos has been banned (National Asbestos Medical Panel., 2006, p. 37).

In the early 1900s there was considerable interest in the development of asbestos products in New Zealand and overseas. *Uralite*, a board made by mixing asbestos with water, chalk and silicate of soda, was reported in *The Times* on 14 August 1902 (The Times, p. 4, 14 Aug 1902). Fifty-one days later the piece appeared in the *Poverty Bay Herald*, and over the next month a further 11 newspapers included the report, all referencing *The Times* as the source. Papers Past records an average of 30 newspapers being available each day over this period, so 40% of the papers available online (12/30) included the report[10].

The modern asbestos cement board was invented in 1900 by the Austrian, Ludwig Hatschek (The Monopolies Commission (Great Britain), 1973, p. 26), and patented in 1900 as UK patents 22,139 and 6,455 (The Times, p. 5, 12 Dec 1908). The process was patented in the US (Hatschek, 1904), and reissued in 1907 (Hatschek, 1907; R. Wilson & Snodgrass, 2008, p. 4).

Asbestos cement products were first advertised in New Zealand four years after the British patent and over the next two decades many different products and trade names were advertised:

- *Cathedral* asbestos roofing tiles in Wellington in 1904 (Evening Post, p. 2, 10 Dec 1904; New Zealand Free Lance, p. 19, 17 Dec 1904);
- German made *Calmon* asbestos roofing and walling slates in Palmerston North in 1906 (Manawatu Standard, p. 6, 20 Jun 1906), although a "portable asbestos house" of this material for use in China was reported in 1900 (New Zealand Herald, p. 5, 28 Sep 1900);
- *Eternit* asbestos-cement sheets and tiles for use for lining ceilings, inside and outside walls and partitions in Wellington in 1907 (Evening Post, p. 7, 10 Sept 1907), although their Austrian origin was not stated;

[10] (Poverty Bay Herald, p. 4, 4 Oct 1902); (Oamaru Mail, p. 2, 8 Oct 1902); (Otago Daily Times, p. 4, 8 Oct 1902); (Wanganui Chronicle, p. 4, 8 Oct 1902); (Ashburton Guardian, p. 2, 10 Oct 1902); (Wanganui Herald, p. 2, 11 Oct 1902); (West Coast Times, p. 2, 14 Oct 1902); (Marlborough Express, p. 2, 15 Oct 1902); (Otago Witness, pp. 54, 64, 15 Oct 1902); (Bruce Herald, p. 3, 24 Oct 1902); (Evening Post, p. 5, 25 Oct 1902); and (Timaru Herald, p. 1, 8 Nov 1902)

- English made *Poilite* brand asbestos building sheets and roofing tiles in Auckland in 1910 (New Zealand Herald, p. 2, 20 Aug 1910), in Wellington (Evening Post, p. 5, 17 Mar 1913) and in Gisborne in 1913 (Poverty Bay Herald, p. 9, 25 Apr 1913);
- American made Johns-Manville *J-M Asbestos* and *J-M Regal* roofing, based on pure asbestos saturated with bitumen, in Wellington 1911 (Evening Post, p. 12, 27 Sep 1911); and
- Australian made '*Fibrolite*' in Nelson in 1919 (The Colonist, p. 3, 6 May 1919), in Christchurch in 1920 (The Press, p. 12, 31 Jan 1920) and nationally by 1925 (Auckland Star, p. 12, 4 Dec 1925).

Other asbestos slate or sheet trade names include: *Lamm Brand* (Dominion, p. 9, 29 Jun 1911) (later *Lammit* (Dominion, p. 10, 23 Mar 1916)); *Wingette* (New Zealand Herald, p. 12, 9 Nov 1912); *British Fibro* (Dominion, p. 11, 12 Apr 1913); *Scotch* (Otago Daily Times, p. 11, 23 Oct 1920); *Canadian* (New Zealand Herald, p. 13, 4 Mar 1922); *Durabestos* and *Fiberant* (Evening Post, p. 8, 24 Apr 1923).

Newspaper advertisements for the various asbestos cement boards often ran for considerable periods. For example the *Calmon* advertisements in the *Manawatu Standard* ran regularly from 28 October 1907 until 8 August 1908 (Manawatu Standard, p. 6, 28 Oct 1907, p. 2, 8 Aug 1908) while in the *Poverty Bay Herald* they started on 13 February 1913 and ran every few days until 30 September 1915 (Poverty Bay Herald, p. 2, 13 Feb 1913, p. 2, 30 Sep 1915). In Auckland, advertisements for *Poilite* ran from 20 August 1910 to 18 January 1915, but with the noticeable later addition of "Made in England" (New Zealand Herald, p. 2, 20 Aug 1910, p. 2, 18 Jan 1915), appealing to the patriotic fervour of a British colony at war with Germany.

Figure 94 shows the countries from which asbestos sheeting was imported from 1870 to 1965, based on import values. The first time asbestos sheeting (as opposed to asbestos fibre) was listed in the import statistics was 1915, with most imports coming from UK and Italy. Belgium first appears in the 1920 statistics. With the development of the asbestos board industry across the Tasman, Australian manufactured product gradually took over, except for the WWII impacted years, 1945 and 1950, when the UK was again the main source. Later, 1955 and 1960 show a growth in Belgium imports.

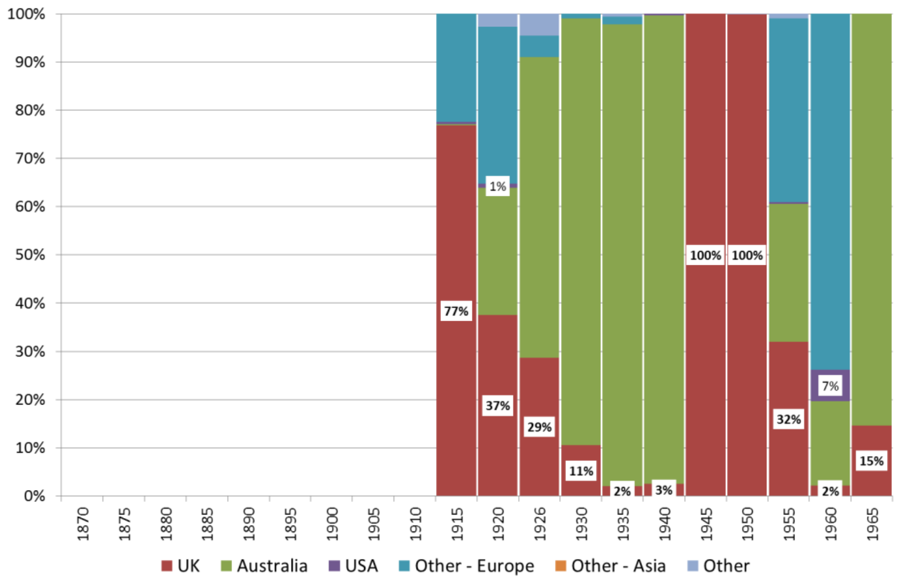


Figure 94: Asbestos Sheet Imports by Country 1870 to 1965

Although James Hardie were selling French manufactured, Hatschek process, fibro-cement in Australia in 1903, English companies also provided supplies (Carroll, 1987, pp. 49–51). In 1917 the Camellia, NSW plant commenced operation, while the Perth, Western Australia plant opened in 1921, the Brooklyn, Victoria plant in 1927, Brisbane, Queensland in 1934 and Adelaide in 1947 (Carroll, 1987, pp. 67,72, 73, 75, 107).

Figure 95: Dr McGavin's House, Willis St, Wellington 1909

Figure 95 shows the house built for Dr Donald McGavin on the corner of Willis and Ghuznee Streets in 1908 (Historic Place Category 1, number 1342). The lower walls are rough-cast over brick, the second storey half-timbered (Progress, pp. 20–21, 1 Dec 1909). The roof was reported to be originally covered with plain red English tiles, so at some stage they were replaced by corrugated asbestos roofing but the turret retains red, terracotta tiles.

The first NZ plant was opened by James Hardie at Penrose, Auckland in 1940. Its first major contract was the cladding for the Centennial Building at the 1940 Centennial Exhibition at Rongatai, Wellington. The plant manufactured an asbestos fibre-cement sheet until September 1983 (just outside the period covered by this research), when treated cellulose replaced the asbestos, although corrugated sheet manufacture was centralised on the Perth plant (Carroll, 1987, pp. 79, 218, 220, 230).

A second asbestos sheet plant was operated by Durock Industries, a subsidiary of Fletchers, in Riccarton, Christchurch from 1943 to 1974 (National Asbestos Medical Panel., 2006, pp. 35–36).

6.5.4 Pre-cast Concrete Boards

Off-site fabricated concrete panels were used for housing in the 1890s, for example. Homebush, Masterton (Figure 96), designed by Charles Tilleard Natusch in 1891. Natusch was known for his *board and batten* style, but Homebush is constructed of precast concrete slabs fitted into wooden framing with the joints covered by timber battens (Kernohan, 2003, pp. 228–229) (Historic Place Category 2, number 7685).

Figure 96: Homebush, Masterton uses precast concrete panels (1890s)

Other materials could be mixed with cement to produce sheet materials as cladding for timber-framed houses with pumice seen as a way to improve thermal performance.

Konka board, a New Zealand invention, was first advertised in 1914 (Evening Post, p. 16, 5 Nov 1914; Manawatu Standard, p. 1, 11 Sep 1914) and was made until the 1950s. Konka was a factory-made concrete board (3ft x 1ft 6"x 2") (0.9m x 0.45m x 5cm) using pumice, backed up with building paper. The joints were covered with cement impregnated hessian and the whole surface was rendered, often rough cast (Aitkens Concrete Ltd, 2009, p. 8). It was held in place by patent clips and could be used for internal or external walls (Rowley, 1919, p. 211), apparently without a timber-frame. As well as the normal lower cost and maintenance claims, Konka board was "warmer in winter and cool in summer" (Manawatu Standard, p. 5, 4 Nov 1914). Konka was made by The Konka Tiling Company of Fitzroy Street, Palmerston North, Bassett & Co of Whanganui, Aitkens Concrete of Gisborne and the Jarrah Timber Company of Christchurch (Industrial Corporation of New Zealand, 1922, p. 128).

Fabricona, another factory-produced pumice concrete sheet panel, was made in the 1940s, although only one reference has been found. The reinforced panels were used for floors and walls, with the roof and ceiling made from timber and finished with fibrous plaster. Fabricona production reportedly ended in 1951 (Anonymous, 2004).

From the 1940s, pumice was used for the manufacture of lightweight masonry and precast concrete chimney components (Building Research Bureau of New Zealand, 1966b, p. 1) (Section 6.3.4.4).

6.6 Fenestration

Early whalers (c1840) lived in raupo houses where "two square holes in the wall serve as windows, with wooden shutters for the night" (Wakefield, 1908, p. 239). The basic style continued for many years, Alice Clark describing her 1892 house in the remote Kotiti Bush, near Dargaville, as having "windows made of calico", but soon after she was the envy of the other wives in the camp for she was "the first to have glass windows put in the shanty" (A. H. Reed, 1964, p. 88).

Window glass was brought out from Europe, protected from the rigours of sea transport by straw and crates. In April 1840 the sale of window glass was advertised in Wellington (New

Zealand Gazette and Wellington Spectator, p. 1, 25 Apr 1840). The glass was from the New Zealand Company's ship Glenbervie that had left London on 2 October 1839 and arrived safely five months later on 7 March 1840. Included in its cargo were 78 boxes of glass and 24 pairs of windows (New Zealand Gazette and Wellington Spectator, p. 3, 2 May 1840).

Stained or leadlight glass was also available in the 1840s. Jabez Dean of Wellington advertised in 1849 not only *Stained Glass* but also his possession of a "superior Vice for making Window Lead" (Wellington Independent, p. 2, 7 Mar 1849). In Auckland, W. Tattersall had stained glass in "Blue, Crimson, Amber, Gold, Scarlet and Green Colours; suitable for Shop Fronts, Hall Doors, Lamps, etc." (New Zealander, p. 1, 24 Jul 1849) and the following year he had received a "Glazier's Patent Lead Vice" and was able to make "Gothic lights." These dates are 43 years earlier than the 1893 earliest example of advertising in the first study of stained glass in New Zealand homes (Phillips & Maclean, 1983, p. 28).

Windows (and doors) were more easily purchased than made in the bush (Leys, 1883, p. 723), and after their use in temporary housing, such as raupo, they could be shifted to a permanent house (Salmond, 1989, p. 68).

6.6.1 Imported Glass

Although window glass was obtainable from the 1840s, little information is available on the value of glass or its origin until 1870 and not until 1890 for consistent physical units (Section 4.2.1). Figure 97 provides the proportions of glass import values by country from 1870 to 1965, based on reported import value. Until 1932, there was no glass industry in the Australian colonies (H. J. Cowan, 1998, p. 53), so the glass most likely was re-exported.

Until 1900, the majority of window glass imports are from the UK, although a small proportion was from Europe, mainly Belgium and Germany. Imports from Germany ceased with WWI and do not resume until 1955. The majority of European glass in this period comes from Belgium. American glass is only a significant proportion in the 1915 year.

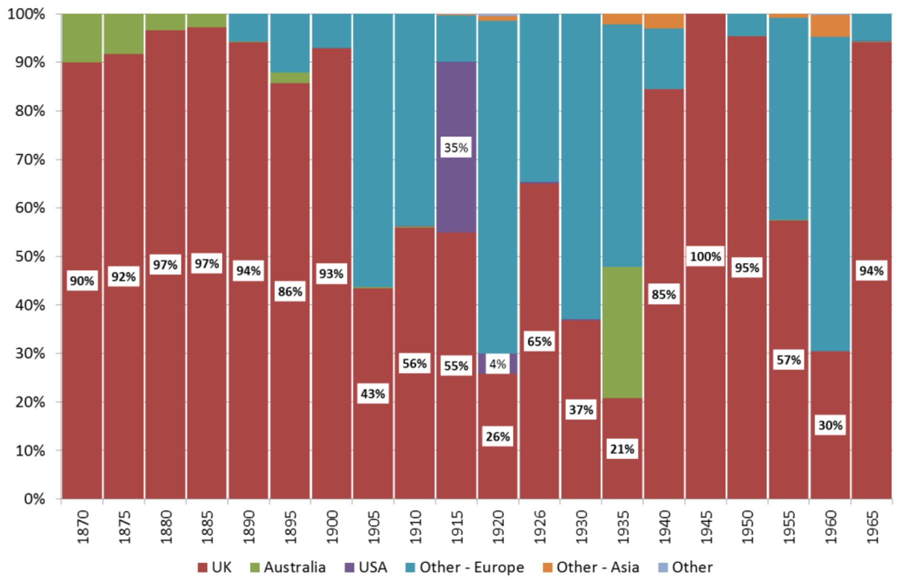


Figure 97: Glass Imports by Country 1870 to 1965

Until 1930, sheet glass was manufactured by the crown or cylinder methods. The crown process commenced with gathering a blob of glass onto the glassblower's pipe which is then mouth-blown into the form of a Florence flask. The globe is flattened out and then transferred to a solid pipe (*punty*), where the original neck (now no longer attached to the pipe and termed a *nose*) is heated and the globe spun to form a disc of glass. The glass passes through the hands of ten distinct specialists on the way to producing a sheet. The crown process involved considerable waste, both as square or rectangular panes were cut from the round disc and imperfections in the disc limited the ultimate size of the pane (McGrath, 1961, pp. 44, 49).

Originally invented in Germany (Tomlinson, 1854, pp. 775–777, Vol. 1), cylinder glass starts in a similar way to crown glass. A 25 lb (11kg) bulb of molten glass is gathered onto the end of an iron blowpipe, where it is carefully blown firstly into a ball, and then by simultaneously blowing and spinning it is expanded into a flattened ball 12 inches (30cm) to 18 inches (50cm) in diameter. The bottom half is then drawn into a long cylinder by swinging it into a 10ft (3m) deep pit. Depending on the skill of workman, a closed cylinder from 4ft (1.2m) to 7ft (2.1m) long could be made. The cylinder was then cut off, and after a diamond score on the long side it was placed in a heating oven when the glass splits and flattens under its own weight. It is then placed in an annealing furnace where it is gradually cooled. The largest sheets are about 7ft (2.1m) by 4ft (1.2m) but few workmen were skilful enough to produce such large cylinders (A. Williams, 1907, pp. 124–126). Cylinder glass was far from perfect as variations in the raw materials and the blowing resulted in waves that distort the image and its reflection, and flaws that speckle the glass. Figure 98 shows the house Ranzau at Hope, near Nelson, built about 1844. Family myth has it that the Ranzau glass was brought out from Germany wrapped in straw, and flattened by the local blacksmith before being mounted in window frames. This may explain the imperfections and waves to the glass, as shown by the reflection in Figure 99.

Figure 98: Ranzau, built c 1844

Figure 99: Ranzau window

Window glass was costly, as well as fragile, limiting its use. Brett's 1883 *No. 1 Cottage*, a 23ft (7m) square four room house (Figure 117), had four four-light double-hung sash windows costing 10s 6d each with another 15s 6d for the frame and architraves. The four rooms, kitchen, living room and two bedrooms had one window each, making just over 1 m² of glass per room (Leys, 1883, pp. 724–725).

Internationally the technology of window glass manufacture improved, initially by the mechanisation of the cylinder glass process. The Lubbers process (invented in 1896) used compressed air and a mechanical puller and by the 1920s could produce a glass cylinder 30 feet (9.1m) long and 30 inches (0.76m) diameter. But whether produced by hand or machine, a flattened glass cylinder could never be perfectly flat (Elliott, 1992, pp. 137–140).

Plate glass (thick sheet glass) was made by pouring molten glass onto a large flat iron table. At each end of the table, two strips of iron set the thickness and a large roller running on top of them formed the glass plate. Even with the best table and roller, plate glass had uneven, wavy faces and required grinding, an expensive process removing more than a third of the thickness of the rough plate (A. Williams, 1907, pp. 126–129). A better, less expensive, method was needed.

In the mid to late 1800s, many schemes were patented to draw flat sheets. The solution was finally found in Belgium. A sheet was drawn upward through a slit in a fireclay clay débiteuse or vessel floating on top of the molten, viscous glass. After much experimentation and modification, this came to be known as the Foucault process.

The first large scale Foucault production began in 1914, the year in which German troops invaded Belgium. Only in 1919 did a Foucault machine operate in England and by 1924 there were two machines in the USA. The Foucault process had two major faults. Firstly the temperature of the drawing chamber was below the temperature of devitrification, allowing glass crystals to grow. These spoilt the glass surface, so the machine needed to be stopped every 7 or 8 days. Secondly the fireclay slot resulted in *music lines* on the glass, which worsened with wear (McGrath, 1961, pp. 49–51, 79).

These problems were avoided by the Pittsburgh Plate Glass process (PPG), where the glass was drawn vertically upwards directly from the molten glass. One issue was the ribbon of glass tended to *waist*, making it impossible to maintain a constant width. This was solved by the use of air-cooled, knurled rollers just above the surface of the molten glass which cooled the edges of the just-drawn glass, making them rigid enough to resist waisting (McGrath, 1961, p. 52).

6.6.2 New Zealand Made Glass

In the late 1950s there was a growing New Zealand glass market serviced entirely by imports. McKendrick Consolidated Industries saw an opportunity to manufacture window glass, and established the McKendrick Glass Manufacturing Company Limited. Over 15 months it built a major plant around a glass tank feeding two Foucault machines, and started trials on 11 July 1962. The plant did not produce acceptable quality window glass, and closed down later that year.

In 1963 New Zealand Window Glass Ltd was formed as a partnership between Pilkington Brothers (New Zealand) Ltd and Australian Consolidated Industries Ltd Taking over the plant, the manufacturing process was changed to the PPG process, and in April 1964 commercial production commenced. Some 30,000 tonnes of glass were produced each year, in a range of thickness from 2mm to 6mm (Callan, 1989, p. 74; New Zealand Window Glass, 1982). Figure 100 shows the glass being drawn up from the tank (New Zealand Window Glass Company, 1965, Cover).

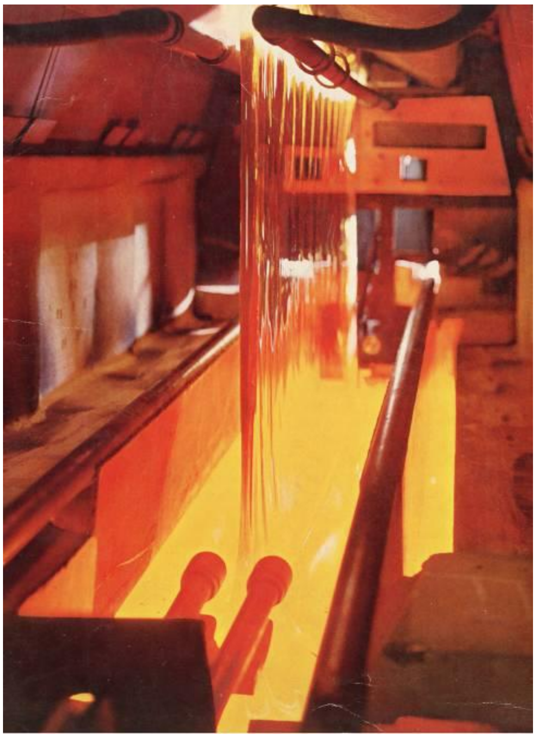


Figure 100: Drawing Glass, Whangarei Glass Works c1962

The factory was sited near Whangarei for a variety of reasons, most significant being the cheap land and finance for buildings provided by the Whangarei Harbour Board. Other factors included proximity to sand, the major raw material; closeness to the Auckland market; Whangarei's stable labour force; coupled with the availability of road, rail and sea transport (Callan, 1989, pp. 68–74).

The raw materials came from around the world, the bulkiest from nearby. In 1987 the plant used: 24,000 tonnes of silica sand from Parengarenga, NZ; 6,000 tonnes of soda ash from USA; 6,000 tonnes of dolomite from Golden Bay, NZ; 500 tonnes of limestone from Te Kuiti, NZ; 200 tonnes of feldspar from Norway or Canada; and 20 tonnes of coal dust from

Australia. By 1988, the plant employed 215 people, with a sales force of 8 based in Auckland. It produced about 600 tonnes per week or 80,000 m^2 of glass, and exported 40% of its production to Australia, Japan and the Pacific (Callan, 1989, pp. 68–74). Glass was supplied in four grades (Horticultural, Standard, Selected and Special Selected) and as quality increased, so did the price (New Zealand Window Glass, 1982).

In glass making, the price of raw materials was important, but none more so than energy. Initially the cost of energy was so low that wastage was not a problem. The 1981 regular tank rebuild saw a significant investment in thermal insulation to reduce tank heat loss and hence energy needs. By 1983, just outside the research period, natural gas had replaced oil, halving the fuel bill as well as providing a cleaner fuel (New Zealand Window Glass Ltd, 1981) and bringing the pipeline to Whangarei for the rest of the community.

The seed of the Whangarei plant's demise was sown just as planning for the plant started. The float glass process, patented by Pilkington Brothers PLC in 1959, revolutionised the manufacture of window glass. The plants produced flat glass in thicknesses from 0.4mm to 25mm and in widths up to 3m (Nippon Sheet Glass Co. Ltd, 2010, p. 57). The first float plant in the Southern Hemisphere was opened in Dandenong, Victoria in 1974, producing up to 6,000 tonnes a week (CSR Viridian New World Glass, 2010), 10 times as much as Whangarei at its peak. The Whangarei plant closed on 14 February 1991 (Northern Advocate, 2 May 1991).

6.6.3 Window Frames

Although the earliest houses were equipped with imported glazed windows (Lyttelton Times, p. 1, 8 Feb 1851), locally hand-made frames soon followed (Lyttelton Times, p. 10, 15 Apr 1854). A decade late, in 1864 the Christchurch "City Steam Saw Mills and Planing, Moulding and Joinery Works" advertised their ability to make:

> “Doors, sashes, casements, moulded skirtings, sunk and molded [sic] architraves, cornice and other mouldings, and all kinds of joinery work (equal to home manufactured) executed with dispatch”
> (Lyttelton Times, p. 127 Dec 1864).

As the number of saw mills and demand for housing increased, throughout the country catalogues provided people the ability to order direct. Figure 101, from Findlay and Company's 1874 illustrated catalogue, shows four double-hung timber sash window variations (Lister, 1874). Figure 102 illustrates two Bay Windows available about 50 years later from W.G. Bassett, Sash and Door Manufacturer and Timber Merchant of Wanganui (W.G. Bassett, c1920, p. 38)

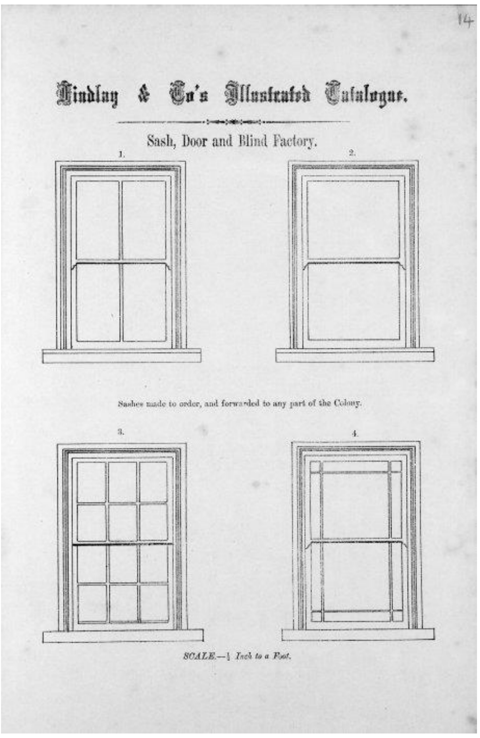


Figure 101: Findlay & Co.'s Window Sashes (1874)

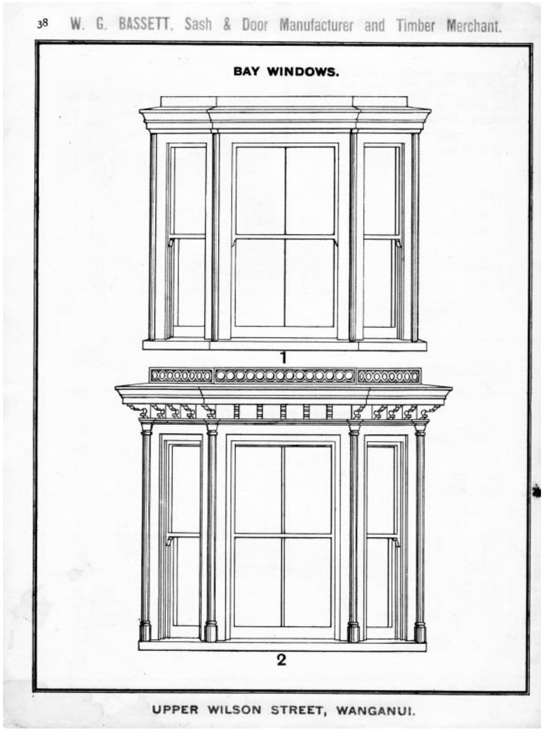


Figure 102: W.G. Bassett's Bay Windows (c1920)

In 1913 Schlaadt Brothers Ltd, engineers of Dunedin were advertising steel window sashes (Otago Daily Times, p. 7, 20 May 1913). Both brothers originated from Germany, although both spent time in London and Paris (Cyclopedia Company Limited, 1905, pp. 325–326). Their windows were more widely promoted by Briscoe and Co. Ltd the following year: "SCHLAADT'S STEEL CASEMENTS and WINDOW SASHES. For all classes of Buildings. As cheap as wood." (Evening Post, p. 12, 10 Jul 1914)

In 1926 Crittall Manufacturing Co. (NZ) Ltd was registered as a private company to manufacture steel windows and fixed lights, taking over the Dunedin workshops of Briscoe and Co. Ltd (presumably the former works of Schlaadt Brothers). It was owned by the Crittall Manufacturing Co Ltd of England and Davey and Co. of Auckland (New Zealand Herald, p. 7, 2 Sep 1926). In 1932 it took over the Auckland and Dunedin businesses of the Woolnough Window Co. Ltd, and was renamed Crittall Metal Windows (New Zealand) Ltd (Evening Post, p. 10, 12 Oct 1932).

The 1952 first edition of Cranwell's Building Supplies Catalogue listed one skylight and four louvre suppliers, but no windows (Cranwell Publishing Ltd, pp. 5/1, 5/5, 5/13, 5/17, 5/32, 1952 ed.). In England the use of aluminium in fenestration was introduced from 1950 (Tutton, Hirst, & Pearce, 2007, p. 356) and in New Zealand by the end of the 1950s. Aluminium "combines the flexibility of shape of steel and the strength and durability of bronze with the lightness of wooden frames" while remaining dimensionally stable with changes in moisture. Four suppliers existed by 1959: one was the agent for an Australian company; two fabricated locally using British extrusions; and one imported windows from Britain to customers' requirements (Building Research Bureau of New Zealand, 1959a).

The 1961 edition of Cranwell's listed four aluminium and two steel (including Crittall) window suppliers (Cranwell Publishing Ltd, p. D–13, D–15, D–26, D–27, D–49, D–51, 1961 ed.). By the 1967 edition there were 15 aluminium window and/or door suppliers (three, including Crittall, providing either steel or aluminium frames) and one plastic-steel window frame supplier, although no timber window manufacturers (joiners) found it necessary to advertise (Cranwell Publishing Ltd, pp. C–4, C–9, C–10, C–11, C–15, C–23, C–43, C–45, C–49, C–59, C–63, C–64, C–65, C–67, C–68, 1967 ed.). The Garand steel windows were promoted as being designed for use with Vibrapac Concrete Block modules (Section 6.3.4.4) (Cranwell Publishing Ltd, pp. C–4, 1967 edition; Robert Holt & Sons Ltd, 1965, p. 85).

Although the first and last editions of "Carpentry" included both timber and metal framed windows, (New Zealand Technical Correspondence Institute, 1980, p. 214; Technical Correspondence School, 1958, p. 172), by the 1980s metal framed windows were in the ascendency.

6.7 Roof

Although local plant materials such as raupo or flax could be used for thatching (Section 5.1.1), permanent dwellings required more permanent solutions. Terracotta tiles were initially imported and then made locally for a time (Section 5.2.2). Slates, shingles, corrugated iron and later pressed metal tiles each provided a different style of roofing.

6.7.1 Structure - Strutted and Truss roofs

The *couple roof*, the simplest roof structure, has a pair of rafters tied or joined together so needs walls designed to resist the outward thrust of the rafters. Adding a tie between the lower ends of the two rafters gives a *couple-close roof*, while moving the tie upwards gives a *collar roof*. Once buildings became larger, taking some of the outward load onto the internal walls was desirable. The *strutted rafter roof* (Figure 103) uses struts to transfer the load from purlins under the rafters not only to the exterior support but also to an inside partition wall or some other solid support. The strutted roof permits the use of lighter, and cheaper, rafters (Technical Correspondence School, 1958, pp. 145–146).

In the 1940s the State Advances Corporation experimented with truss roofs for new state rental house construction. The truss roof (Figure 104) is a self-contained triangular frame which transfers the loads to the supports (Technical Correspondence School, 1958, pp. 112–113). Although the experiments were successful, and builders permitted to use either strutted rafter or trussed roof in Corporation funded houses, builders preferred "the more orthodox construction, presumably because they found it more economical and convenient" (Latter, 1963).

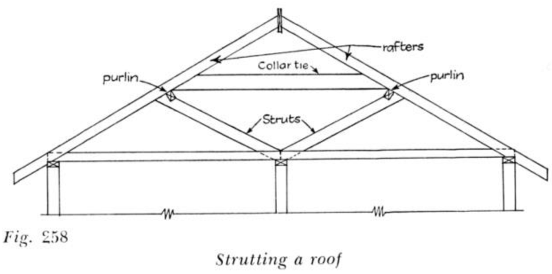


Figure 103: Strutted Roof

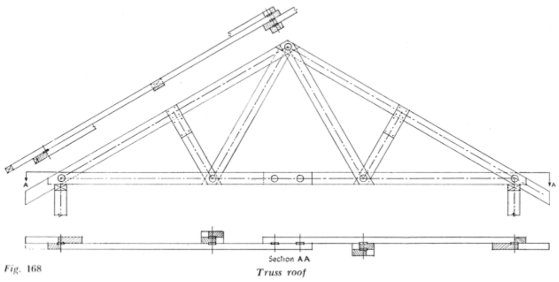


Figure 104: Truss Roof

However, this changed from the 1960s when interest grew in greater open living space. The truss roof removed the need for internal walls to carry the roof wind or gravity load, and allowed for open plan spaces. The truss roof also reduced the torsional strength and stiffness with consequential negative impact on earthquake performance (Cooney, 1979, p. 232).

Early experience with truss roofs was not good, with some roofs blowing off in strong winds, although the cause was felt to be due to poor connection between the purlins and trusses coupled with the fixing of the eaves (Latter, 1963). The industry acceptance of the truss roof links closely with the introduction of nail plate connector systems in the early 1960s (Section 6.3.1.4).

6.7.2 Slates

Slate, a low grade metamorphosed mudstone with good cleavage, was used in the UK sourced from mines in Scotland, Wales and Cornwall. Blair dedicates a section to roofing slates, concluding that while not every industry should be encouraged in a young colony, given the low-price of slates and the high cost of freight "there is little wanted to turn the scale in favour of native production" (Blair, 1879, pp. 80–89). Although local attempts to mine slate were made in the 1870s, including at Red Rocks, Wellington and at Otepopo (30km southwest of Oamaru), they were unsuccessful (Blair, 1879, pp. 87–88; Hayward, 1987, pp. 38, 56).

Broadgreen, a cob house built in the mid-1850s, has a slate roof (Figure 107), as does the 1865 second Glens of Tekoa station homestead (Figure 33).

Figure 105 shows slate imports by country from 1870 to 1965, based on value. There were no recorded imports in 1945. Until 1900, the majority by value of slate imports came from UK, although there was a sizable proportion from USA. From 1900 to 1920 imports from Belgium and France were noticeable, but not in later years.

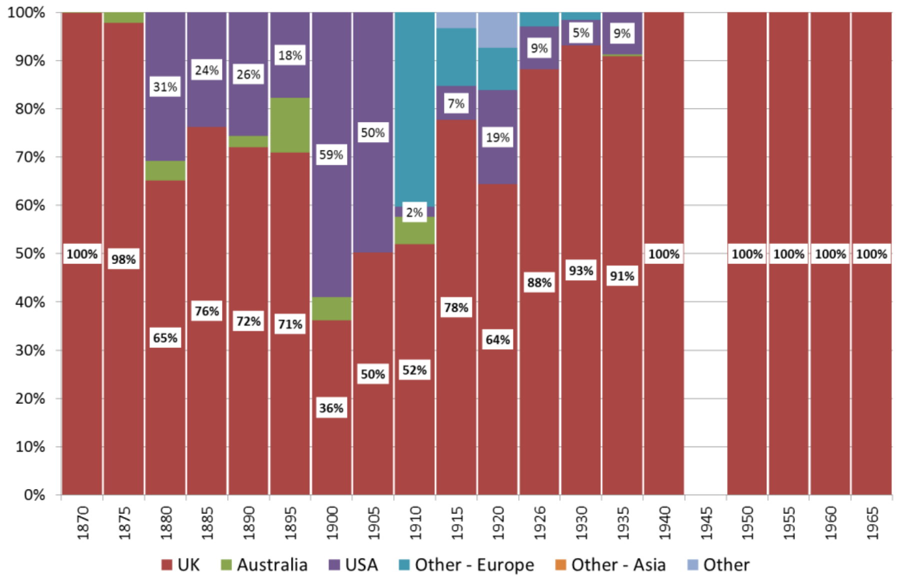


Figure 105: Slate Imports by Country 1870 to 1965

Figure 106 gives the number and value of slate imports for the period 1870 to 1965. From the mid-1920s other roofing materials took over from slate, although they continued to be used for repair and replacement.

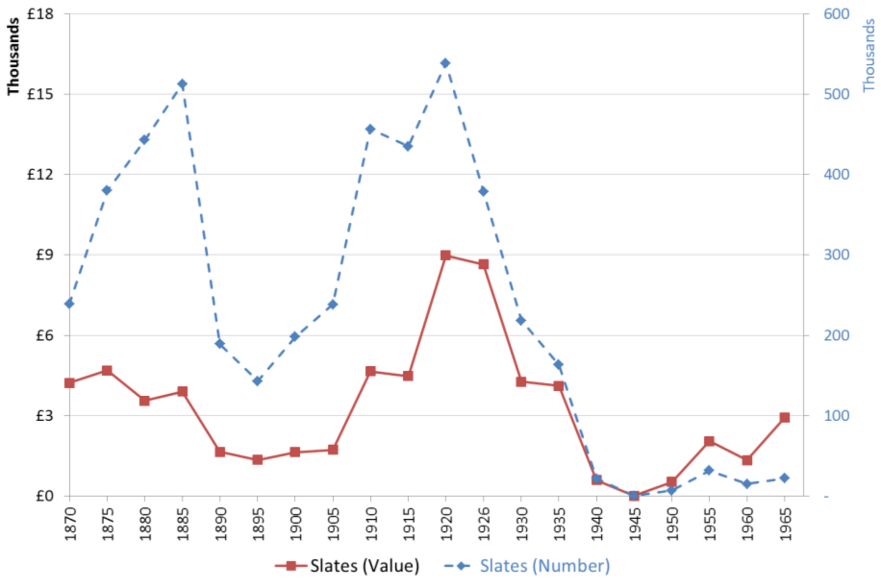


Figure 106: Slate Imports by Value and Quantity 1870 to 1965

Figure 107: Broadgreen Cob House showing Slate Roof c1855

6.7.3 Shingles

> "Of all roofs, full marks for visual enjoyment must surely go to the totara shingle, a purely New Zealand product, copied from, or inspired by, the cedar shingles from Canada and America. The lichen that grows on the weathered shingles adds much in colour and texture and the usual zinc ridge seems to have an effect either in staining or cleaning the surface in streaks. The major factor however that makes this roof so attractive visually, is the sun, which produces a surface warped and cracked, irregular and far from impervious to rain – pity" (Fearnley, 1975, p. 23).

Kauri, rewarewa, beech, kohekohe, houhere and totara were used for shingles. Totara was the most popular but prone to crack if not painted (G. L. Pearce, 1982, p. 32). Shingles, about ¼" (0.6cm) thick, were split from blocks about 17" long by 6" wide (43 x 15cm) using a shingle-knife (A. H. Reed, 1964, pp. 52, 306). Brett's provided a lime and potash based recipe for fire-proofing shingles, taken from the *Boston Cultivator* (Leys, 1883, p. 397).

Once more permanent structures appeared, shingles were an obvious roofing material. E.J. Wakefield reported on the development of Whanganui, including the building of a jail in 1840 with "shingles for the roof, having some men employed in supplying me with these things for my own house, from the groves of timber five or six miles up the country" (Wakefield, 1845, p. 82, Vol 2).

A shingle industry developed in the countryside, providing roofing for the towns. In New Plymouth the implementation of the Thatch and Straw Building Ordinance 1858, designed to replace locally the Raupo Houses Ordinance 1842, was repeatedly delayed (Isaacs, 2012, pp. 181–182) in order to protect the livelihoods of "several settlers in the bush who would have their only living taken away from them" who manufactured shingles (Taranaki Herald, p. 3, 15 Feb 1871). In Auckland, the schedule accompanying Vercoe and Harding's 1866 map reported the majority of buildings had shingle roofs (Vercoe, 1867; Vercoe & Harding, 1866).

The fire danger of shingles, particularly in cities, became of concern with shingles banned or controlled through building by-laws. The Gisborne Borough Council's 1907 by-laws explicitly banned for use on the "roof, flat or gutter" of "boarding, shingles or other combustible materials" (Gisborne Borough Council, 1907, p. 42, Clause 6). The Borough of Marton's 1912 by-laws implemented an implicit ban, requiring new roofs and any recovered roofs to use "slates, tiles, or galvanised iron of not less than 26 guage [sic]" (Marton Borough Council, 1912, p. 29, Sections 19 & 20).

The 1924 "Building Conference Relating to the Use of Timber in Building-Construction", held in Wellington from 18 to 20 June 1924, was the first New Zealand attempt to create national building regulations for timber construction. The draft 1924 "Model Building By-law" conference paper was clear as to both the use of shingles on roofs and suitable types of timber (New Zealand State Forest Service, 1924a, pp. 8, 10):

- Clause 38 "Shingles: Timber shingles shall not be used as a roof covering"
- Clause 49 "Timber for shingles: Shingles shall be of kauri, totara or kaikawaka."

However, these recommendations were not accepted by the conference, and do not appear in the final recommendations (New Zealand State Forest Service, 1924b, pp. 12–22).

Even so, the 1925 Auckland City Building By-Laws prohibited the use of roof shingles:

> "…slate, tiles, cement, concrete, galvanised iron, milled lead of not less than 6lb per square foot (29.4kg/m²), or other approved material. No shingle roof shall be recovered till the old shingles have first been taken off" (Auckland City, 1925, p. 48, Section 135).

The development of asbestos cement tiles (Section 6.5.3) provided a fire resistant shingle.

Shingles continued to be used for decoration. From the early 1900s they were used as a gable feature in the Queen Anne style (Salmond, 1989, p. 178), and from about 1915 in bungalows for hoods over windows and gable ends (Cooke, 1975, p. 262).

6.7.4 Terracotta roof tiles

Fired clay was used for terracotta roofing tiles as well as bricks (Section 5.2.2). Although in 1862 Canterbury Pottery was advertising the availability of both plain and corrugated roofing tiles (Salmond, 1989, p. 102), it must be assumed they were either imported or advertised in speculation they would be made, as when the business was closed in 1865 the only relevant stock was "Drain pipes, floor tile and flower pots" (The Press, p. 8, 23 Feb 1865).

Terracotta roofing tiles imported from France were already popular in Australia and in 1899 were used on Wellington's Basilica of the Sacred Heart, designed by Francis William Petre (Evening Post, p. 2, 17 Jul 1899) (earlier than 1901 given by Salmond (1989, p. 102)). Briscoe, MacNeil & Co. advertised the availability of a shipment of Marseilles Roofing Tiles in 1901, promoting them as "light, cool, watertight and everlasting" (New Zealand Herald, p. 4, 23 Mar 1901). Marseilles tile roofs can be found in many suburbs built around this time, such as Kelburn, Wellington. They were later advertised as "cool in summer, warm in winter", providing ventilation while being economical (Wanganui Chronicle, p. 7, 20 Apr 1910). Simple terracotta tiles could be used in a manner similar to shingles (Figure 95).

By 1919 there were reportedly three roofing tile factories in operation (New Zealand Herald, p. 7, 17 Apr 1919), of which two have been identified.

The O'Reilly brothers established the Roofing-Tile and Brick Company in Taumarunui about 1911, but after the failure of the business it was taken over by Winstones in 1915. It was claimed by them to be the first company in New Zealand to succeed "in manufacturing first-class roofing-tiles in large quantities" (Industries Select Committee, 1919, pp. 226–227). Although initially more expensive, the tiles were promoted to "cost less than iron in the long run" (New Zealand Herald, p. 17, 23 Mar 1940). The works finally shut in 1959, after an eventful history including periods of closure due to two catastrophic fires and the 1930s Great Depression.

The Abbotsford Tileries Ltd, Dunedin[11], were making clay roofing tiles in 1919 (Otago Daily Times, p. 13, 20 Nov 1919), although a major fire on 15 July 1920 closed the plant down (Otago Daily Times, p. 8, 17 Jul 1920). They were back manufacturing in 1922 (Evening Post, p. 8, 15 May 1922) but the company was put into liquidation in 1928 (Evening Post, p. 7, 29 Sep 1928).

[11] Directors of Abbotsford Tileries Ltd included James Fletcher and Henry Isaacs.

In 1948 Winstones opened another terracotta tile plant at Plimmerton, north of Wellington. The local clay proved unsuitable, so the factory stopped tile production in 1955, although continuing to make a range of other clay products (F. A. Simpson, 1965, pp. 183–184).

6.7.5 Galvanised Corrugated Iron

As with many building inventions, corrugated iron traces its origins back to the coming together of the right raw material, idea and machinery. Cast iron sheets with cast rectangular ridges had already been used in buildings, but stiffening was need to create a self-supporting, light weight product (Guedes, 1979, p. 250). The puddling process, invented 1874 (Section 5.6.1), produced large amounts of consistent quality wrought iron which could be rolled but flat, thin sheet could not withstand bending.

Corrugations provided the answer. Corrugated iron was patented in Britain in 1829, and by 1832 was used in the London Docks for a warehouse 200 feet (61m) long with a vault of 40 feet (12m). The corrugations were initially cold-formed one furrow at a time, requiring much labour and extreme precision to complete a sheet of corrugations satisfactorily. John Spencer's 1844 patent machine solved this, corrugating the iron by feeding it through a pair of longitudinally grooved rollers. This barrel corrugator constrained the sheet length to the width of the roller. If an arched sheet was desired, it could be bent by a machine with three ridged rollers (Elliott, 1992, pp. 80–83).

By the late 1880s steel had replaced the iron in corrugated iron, but the name remained unchanged. Modern materials are more likely to be referred to by their trade name or profile.

Iron rusts, and the thin sheets of corrugated iron could too easily develop holes to let in the rain. Although tin had been used as a sacrificial coating since the sixteenth century to protect iron, the 1837 patent of French chemist Ernest Sorel replaced tin with zinc. Zinc produced a hard protective layer that bonded well with iron. Sorel introduced the term *galvanise*, convinced that the bond between the iron and the zinc was the result of some form of galvanic action (Elliott, 1992, p. 82).

Dipping the corrugated iron sheet into molten zinc has now been replaced by the continuous rolling (Sendzimir) process, invented in the late 1920s by Tadeusz Sendzimir. This was put into commercial use in 1935 (Lamesch, 2005, p. 124).

Corrugated iron played an import role in providing swiftly built towns, such as the mining town of Switzers (the modern town of Waikaia, Southland). It was described in 1863: "the whole top of the hill was covered with houses just as close as they could stick, most of them of canvas and roofed with zinc" (Lapham, 1880, p. 21).

Corrugated iron may have been first rolled by R. & T. Haworth of Dunedin in 1864 or by Thomas Crompton in Christchurch in 1869 (Chapple, Maynard, Mitchell, & Viscoe, 1983, p. 27). The first galvanising and rolling plant was set up in 1886 by Samuel Parker at his Southern Cross Galvanised Iron Manufacturing Co., in Parnell, Auckland (Auckland Industrial and Mining Exhibition, 1898, p. 61; New Zealand Free Lance, p. 4, 14 Dec 1921), using imported English black iron (Arthur Cleave & Co, 1898, pp. 246–248). Until the New Zealand Steel plant, Glenbrook made steel coil in 1972, all roofing and cladding steel was imported and formed in plants around the country to meet local demand for different profiles.

Section 4.2.3 provides a detailed analysis of galvanised iron import statistics.

Figure 108: Corrugated iron clad house, Richmond

Figure 108 illustrates a house where the cladding (originally weatherboard) has been completely replaced by corrugated iron.

6.7.6 Aluminium Roofing

Aluminium alloys were first developed for use in airships in 1911. Alloys can have enhanced properties such as strength, hardness and workability compared to the pure metal. WWI and WWII saw the development of a range of products for aircraft where the light weight and high strength were critical. Since the 1950s aluminium alloys have been classified as cast and wrought, heat-treatable and non-heat-treatable. Non-heat-treatable alloys contain trace amounts of manganese and magnesium, and are used for roofing and cladding. Heat treatable alloys contain magnesium, silicone and sometimes copper, and are used for windows (Section 6.6.3), curtain walls, fasteners and structural members (Kelly, 1995, p. 48).

Aluminium roofing first became available in New Zealand as roofing tiles, similar in shape to cement tiles (Bates, 1957, p. 21). In 1956, The Farmers company used aluminium tiles provided by R.W. Sharp & Co. for their *Home of Today* exhibit at the Christchurch Industries Fair (The Farmers' Christchurch, 1956, p. 16). By 1958, corrugated aluminium sheets were widely used, as evidenced by the inclusion of instructions on their use in "*Carpentry*" (Technical Correspondence School, 1958, p. 139). Aluminium roofing was reported in the 1961 census, with 1.8% of dwellings using it, although it was never more than a minority roofing material (Section 4.1.7).

In 1967 Aluminium Distributors Ltd of Wellington noted that they had been associated with aluminium roofing "since the first sheets were imported into New Zealand from the United States of America and Britain." They provided guidance on dealing with issues of corrosion (stating that any rumours were found to be "groundless"), support, fixing and painting (Cranwell Publishing Ltd, p. 2/10, 1967 ed.).

6.7.7 Metal Roof Tiles

The 1981 Census reported 11.3% of inhabited dwellings had roofing of pressed metal tiles, presumably steel, not aluminium (Section 4.1.7). This was the first time this material type (*Pressed metal tiles with protective coating*) was separately identified in the questionnaire (New Zealand Department of Statistics, 1981, p. 3, Question 11). This was perhaps appropriate given this type of roofing was a New Zealand invention. The company history, a combination of archival records and anecdotal tales from previous and current employees, provides the main resource (K. M. Hill, 1998).

L.J. Fisher and Co was incorporated on 12 August 1938, and initially imported steel-frame buildings from Lysaghts, of Bristol, England (K. M. Hill, 1998, pp. 7–8). Lysaghts *Fraser Standard Steel Frames* promised savings in time, costs and freedom of architectural treatment (Cranwell Publishing Ltd, pp. 2–41, 2–42, 1952-53 edition). In 1954 Lou Fisher, the company's founder, read an advertisement for *Decramastic* in a British trade magazine. It was a type of bituminous coating for corrugated iron which provided added durability. As the sheets coated with the product tended to stick to each other, a layer of natural stone chip was applied. After a flying visit to Britain, Fisher obtained the rights to manufacture the product for markets outside the UK (K. M. Hill, 1998, pp. 5–6).

Initially the coating was applied to 8, 9 or 10ft corrugated iron sheets. In about 1955 the company started to manufacture a pressed metal tile, and the benefits from coating it with a durable surface were soon apparent. The first New Zealand made Decramastic roof was put on an Otahuhu, Auckland house in 1956/57. The metal tiles had many advantages, notably being about a fifth the weight of concrete or clay tiles and hence requiring a lighter roof structure. They could also be used down to a 10° roof pitch (K. M. Hill, 1998, pp. 8–11). Production grew quickly, requiring a larger plant in 1957 and an even larger plant in 1967 (K. M. Hill, 1998, pp. 12–14).

Originally the pressed-metal had been prepared under contract by Alex Harvey & Sons Ltd, but in 1967 L.J. Fisher & Co purchased its own press. This freed-up the Alex Harvey press, which started to make a competitor *Harveytile*. In 1969 the two NZ companies merged, and soon after merged with the NZ interests of Australian Consolidated Industries Ltd, forming Alex Harvey Industries Ltd. It was not until 1978, with the formation of AHI Roofing New Zealand that the manufacture of the two metal tile products came under one roof (K. M. Hill, 1998, pp. 21–25).

6.8 Thermal Insulation

Used appropriately, many natural materials help reduce the flow of heat, including raupo reeds, straw and wood. The addition of specialised thermal insulation is a relatively new invention. The first use for commercial purposes was in the 19th century with ice cool-stores insulated with sawdust or charcoal (Isaacs, 2011, p. 29). By the 1940s insulation products included "cork, pumice, or crinkled aluminium foil, and 'cell' concrete" (*Making New*

Zealand, 1940 Refrigeration No 12. p. 8). It took until the 1950s for public concern over mould and condensation problems in houses to lead to an interest in adding thermal insulation to timber-frame construction (Isaacs, 1993, p. 37).

Asbestos, although widely used as insulation for services in industrial and commercial buildings, was not widely used in houses as general thermal insulation, although the Ministry of Health states: "Houses built between 1930 and 1950 may have asbestos as insulation." Asbestos was used for textured ceilings and linings, asbestos cement boards (Section 6.5.3), protection around wood-burning stoves, pipes and spouting, and asbestos backed floor covering (Ministry of Health, 2013a, p. 7, 2013b, p. 2).

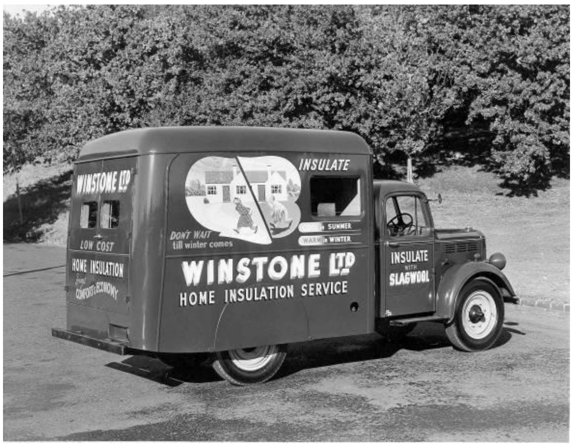


Figure 109: Winstone van - Home Insulation Services, 1955

6.8.1 Cork

Cork (the bark of the cork oak, *Quercus suber*) has long been recognised for its insulating values. Pliny the Elder, in his book 'Naturalis Historia' (c77 AD), recognised cork's ability to retard the flow of heat (Macarthur, 1994, p. 6; Thomas, 1928, pp. 1, 330). Early settlers brought the cork oak to New Zealand, with the earliest recorded tree planted in Symonds St, Auckland in 1855 by Dr Andrew Sinclair (Macarthur, 1994, p. 12). In Auckland in 1882, the bark of a cork oak was stripped by Mr Justice Gillies who tried to encourage public interest in growing a tree well suited to New Zealand climates (Leys, 1883, p. 319). Although the commercial production of cork did not develop, the cork oak can still be found in many parts of New Zealand (Macarthur, 1994).

By the 1890s, the increasing use of mechanical refrigeration required improved insulation materials. From the 1880s, there was a German patent for the manufacture of cork board by mixing cork with clay and asphalt, and then baking it (Armstrong Cork Company - Insulation Department, 1909, p. 103). By 1893 the manufacture of pure cork insulation had commenced. Baking cork particles under pressure bound them together to form products such as cork covering and cork board (Thomas, 1928, p. 29).

Cork was mainly used in New Zealand houses for flooring, starting with linoleum. Made from oxidised linseed oil mixed with ground cork, rosin, pigments and kauri gum, linoleum was invented by Fredrick Walton of England in 1860 (P. H. Simpson, 1999b, pp. 18–19) and advertised in New Zealand in 1875 (Daily Southern Cross, p. 1, 2 Jul 1875).

Cork was also used directly as floor tiles, providing both thermal and acoustic benefits. Cork flooring was used in the new Christchurch Municipal Building in 1923 (The Press, p. 4, 18 Oct 1923), but it was not until the 1930s that its use in houses was promoted, with the ideal house having "…parquet flooring or cork tiles in one or two rooms at least?"(New Zealand Herald, p. 6, 12 May 1934)

6.8.2 Pumice

Pumice, a volcanic stone with many vesiculars (cavities) (Hayward, 1987, p. 56), is a natural insulator. For example, Figure 110 shows a carved pumice container, believed to be of Maori origin used for the transport of hot coals (O'Keeffe, 2014). Pumice was used for acoustic and thermal insulation in buildings from the 1870s, such as Oruawharo (built 1879), located at Takapau, Central Hawkes Bay (Historic Place Category I, number 1048) (Oruawharo Homestead Ltd, 2014).

Josiah Clifton Firth was an early promoter of pumice for insulation. In an 1892 paper to the Auckland Institute, he argued that pumice was superior in every way to the then commonly used charcoal, as pumice was: unaffected by heat; one of the best non-conductors of heat or cold known; unaffected by the most intense cold; unaffected by damp or moisture; never generated fungoid growth; free from spontaneous combustion; not touched by rats; extremely light; perfectly clean; more satisfactory to handle than charcoal; and would not spread fire (J. C. Firth, 1892, pp. 393–394).

By the time of this address, Firth had patented his "Firth's Patent Pumice Insulator" (J. C. Firth, 1890; New Zealand Herald, p. 3, 23 Sep 1892). In later years he also patented a process for "Drying Pumice" (J. C. Firth, 1894a), and "An invention for the application of prepared pumice for insulation for insulating various structures, and for sanitary and other purposes" (E. R. Davis, 1949, p. 236; J. C. Firth, 1894b).

Firth actively promoted the use of pumice insulation in ships to avoid the "danger from spontaneous combustion through the use of charcoal insulation" (Waikato Times, p. 9, 31 March 1894). Pumice insulation was used in the Gisborne Freezing Works insulating chambers (Poverty Bay Herald, p. 2, 18 Feb 1893) and the Auckland Freezing Works (Evening Post, p. 2, 17 Oct 1894).

In 1897, Professor F. D. Brown, professor of chemistry and experimental physics at Auckland University College, published a calorimetric analysis of slag wool, charcoal and pumice, probably the first NZ measurement of the thermal properties of local materials. The results were reported as comparative flows of heat, the lower the flow the better insulator, as given in Table 23. Of particular importance was that pumice thermal performance changed only slightly over time, while charcoal absorbed moisture leading to reduced thermal performance (F. D. Brown, 1897, p. 49).

Table 23: Comparative Flow of Heat

Substance	Flow of heat
Dry slag-wool	89
Dry charcoal	100
Dry pumice	117
Ordinary pumice	120
Ordinary charcoal	157

Brown's results were then used by local businessman W.T. Firth (son of J.C. Firth) who also in an address to the Auckland Institute, promoted pumice as better suited as insulation than charcoal, notably for insulated ships. Firth argued that charcoal, even when dried, absorbed water, oxygen or "noxious gases arising from animal or vegetable matter" while calcined (heated) pumice had none of these problems (W. T. Firth, 1897, pp. 464–465).

Figure 110: Pumice charcoal carrier

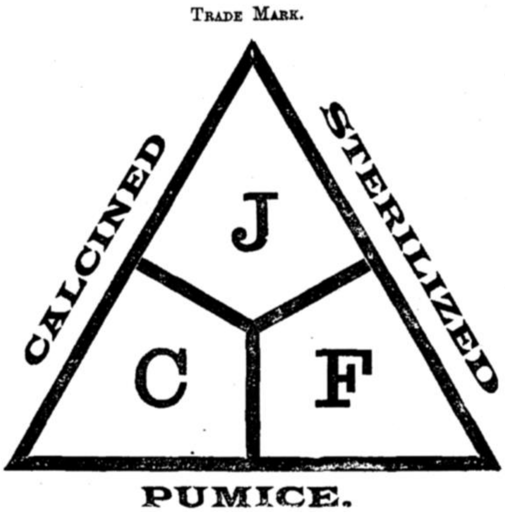


Figure 111: J.C. Firth trade mark logo 'prepared pumice for insulation'

J.C. Firth trademarked a logo (application 2209, 12 November 1897) (Figure 111) which brought together his claims (calcined sterilized pumice) and initials (JCF) (New Zealand Government, p. 2143, 25 Nov 1897). The Firth Pumice Company also produced *Pumicine* sand soap which was available with (blue label) and without (red label) carbolic (Otago Daily Times, p. 4, 15 Dec 1906).

The national importance of the manufacture of pumice-insulation was recognized by making it an essential WWI industry (New Zealand Government, p. 3020, 31 Jul 1917). The company's plant at Ohinewai, Waikato was damaged by fire on 4 October 1917 (Hawera & Normanby Star, p. 8, 6 Oct 1917) but pumice continued to have a ready market until after WWI when synthetic insulation took over. The company went into voluntary liquidation in 1927. The family continued in the concrete product industry using pumice, with the 1925 invention of the Firth Ironclad Pumice Washing Boiler. The new company ultimately become Firth Concrete Ltd (Section 6.3.4.4) (Whyte, 2001, p. 9).

6.8.3 Perlite and Vermiculite

Perlite is a naturally occurring volcanic rock containing some water. When heated quickly, the water turns into steam and expands the rock like popcorn. Perlite can expand up to 25 times its original volume (Industrial Processors Limited, 2012). It is used as insulation as loose-fill, in plaster coatings and cement products as well as for horticulture, filters and packaging.

A perlite industry began in 1954, using material from locations around the Rotorua-Taupo region (G. J. Williams & McKee, 1974, pp. 222–223). The DSIR measured perlite's performance as building insulation but noted the importance of keeping moisture away and dust contained, even to the extent of enclosing the perlite in "suitably designed polythene bags" (Bastings & Clelland, 1957, pp. 45–46). Just under a decade later although perlite's fine-grained, dusty nature required it to be sealed in polythene bags of a size "to lie readily between joists on top of ceiling boards", it was still considered preferable to bulky pumice with its high transport costs (Building Research Bureau of New Zealand, 1966c, p. 2). Although it was not widely used for house insulation, perlite was used in a lightweight concrete (Building Research Bureau of New Zealand, 1967b). No evidence has been found of imported perlite being used for house insulation prior to the local industry.

The mineral vermiculite resembles mica but when heated the small amounts of contained water expand (exfoliate) to many times their original size. Although there are vermiculite deposits in the Nelson district, they did not prove suitable for exfoliation, so imported product was used for insulation and fire protection (Building Research Bureau of New Zealand, 1967a).

6.8.4 Reflective Foil

Although the use of reflective materials as a way to reduce heat loss has long been understood, its use in buildings had to wait until a suitably robust form of product able to withstand handling and installation was available. Silsalkat foils were available at least from the 1940s (F.W. Williams & Co., 1947). In 1955 a foil laminate plant was opened so locally made reflective foils became available, with the aluminium bonded to a backing of building paper (Bastings, 1955). The product became widely used. For example, the Kerikeri Solar House built in 1976 used foil insulation in both the roof and walls (Forbes, 1977).

BRANZ published research on the use of underfloor reflective foil, finding it performed with an R-value of $1.5m^2.°C.W^{-1}$, but only with good quality workmanship and clean, dry foil. A thin film of moisture reduced the R-value to $0.9m^2.°C.W^{-1}$ (G. O'Brien, 1975, p. 17).

The use of under-floor foil insulation was promoted in local plan books (Rosenfeld, 1971, pp. 177–180), but interest in this use grew slowly. It was not until the mandatory requirement for underfloor insulation was implemented from 1 April 1978 that underfloor foil became widely used. This was achieved through the use of NZS418P:1977.

NZS 4218P introduced "specific thermal design" which permitted through the use of a heat loss formula, variations in the levels of thermal insulation (Standards Association of New Zealand, 1977). Analysis undertaken for the manufacturer of a foil-back plaster board demonstrated that using the product as wall insulation (achieving $0.85m^2.°C.W^{-1}$) would meet the requirements of NZS4218P:1977, provided the floor achieved $1.5m^2.°C.W^{-1}$ and the ceiling $3.2m^2.°C.W^{-1}$ (Beca Carter Hollings and Ferner Ltd, 1978). In-situ measurements of a range of new houses found that ceiling insulation was not being installed to this level nor was the expected wall and floor thermal performance always met (Isaacs & Trethowen, 1985, p. 9).The use of foil as a wall insulant was not removed as a method of compliance until NZS4218: 1996 (Standards New Zealand, 1996).

6.8.5 Man-made Mineral Insulation

Man-made materials developed steadily, initially as replacement for asbestos. In 1909, *Progress* included an extract from article by E. Lemaire, originally published in *La Nature* magazine, on spun glass being used for clothing, packing steam pipes, lampwicks, electrical insulation and washers for steam joints (Progress, p. 129, 1 Feb 1909).

It took a further 45 years for the DSIR to promote the local manufacture of rock wool or glasswool from widely available local materials (Otago Daily Times, p. 8, 21 Jan 1954). In August 1959 Australian Consolidated Industries announced a joint venture with the American company, Owens Corning Fibreglass Corporation to make fibreglass. The New Zealand Fibre Glass Ltd factory at Penrose, Auckland was opened in July 1961, at a cost of £300,000 (Evening Post, 20 Jul 1961). In 1970 a second plant opened in Hornby, Christchurch to meet increasing demand (Evening Post, 21 May 1974).

Glasswool, or fibreglass, is made from molten glass spun into a fibre at a temperature of about 1500°C. The fibre is sprayed with a binder (the colour depending on the manufacturer); the mixture then falls onto a conveyor belt; passes through an oven where it is cured; cut to size; and finally packaged.

Figure 112: Glass Fiberizing Process

Rock wool is made in a similar process but uses basalt rock and consequently has a higher melting point (Trethowen, 1995). *Rocwool* was imported for at least a decade prior to NZ Forest Products building a pilot scale plant at their Penrose site in the early 1970s to trial the use of local rock (Richards, 2010). A full scale production plant, based around a three-phase electric furnace, was completed in 1978 at a cost of $2.8 million dollars The USA industry used steel blast furnace slag but this was not available in New Zealand. Samples of local rock were sent to Conwed Corporation of America, but did not prove to be suitable for their production system, so an electric furnace at Burlec (UK) Ltd was trialled. This was successful so a three phase furnace was built by Burlec Ltd of Australia and a multi-wheel fiberizing system was supplied by U.S. Mineral Products Co. The plant supplied the market with blowing fibre for building insulation (*Rocwool*) and finishes (*Rocfibre*), and a range of high temperature or fire resistant insulation (*Insul-Roc*) and board products (*Rocboard*) (NZ Forest Products Ltd, 1979).

Both rock wool and fibreglass were provided in the form of blowing wools, segments and blankets.

6.8.6 Macerated Paper (Cellulose) Insulation

The 1972/3 international oil shock and New Zealand's electricity crisis led to interest in conserving heating energy through insulation based on local materials. Macerated paper provided one answer. Old paper (newspaper, magazines, cardboard) was shredded (or macerated) into small pieces for use as loose-fill insulation. It settled after installation and could shift in draughty attics. Additives were required to make it insect and fire resistant, but these also made it corrosive, particularly to metal items such as nails or nail plates (Warren, Kember, & Haas, 1983, p. 12).

6.9 Summary

This chapter has examined the technologies and materials used in New Zealand houses, from the sub-floor to the roof. Much of material presented is based on a combination of published material (including newspapers, book, magazines, journal) or unpublished resources (including national, local or business archives), and as a result is either:

- New knowledge: e.g. early use of hollow concrete blocks;
- Improves on existing knowledge: e.g. terrazzo flooring used in NZ in 1897; or
- Clarifies existing beliefs: e.g. use of building paper as wind barrier

The chapter started with the floor. Plain wide boards were first used for suspended floors, but tongue and groove followed once machine mills were established. P.T. & G. remained the most common flooring until the 1980s, when particle board and plywood flooring became available. Wide use of concrete slab-on-ground floors started in the 1950s. Terrazzo, polished concrete, was in use from the 1890s.

Piles lifted the floor above the damp ground. Stones, whalebones and native timbers were used in the earliest houses. By the 1900s, piles of totara, brick, glazed earthenware and precast concrete were being used, while stone, brick and concrete were being used for foundation walls. For on-ground floors, from the 1930s in-situ coatings and from the 1960s (based on USA publications) plastic films were recommended to control ground moisture. While these could also be used for suspended floors, moisture control was principally achieved by sub-floor ventilation. This was provided by spaced boards, drilled holes or vermin-proof sub-floor ventilators initially of cast iron but later of pressed metal or precast concrete. It was not until 1944 a numerical requirement was mandated for foundation ventilation, and not until the 1980s that sub-floor moisture levels were documented.

Early timber walling use vertical slabs split from native kauri, rimu, totara or kahikatea. This could be considered the distant ancestor of the modern horizontal solid pine wall, dating from the mid-1950.

Timber-framed construction largely followed British and American models. The earliest construction used the traditional mortise-and-tenon. Balloon framing soon came into use and in turn was replaced by platform framing in the 1880s, although it still remained of interest into the 1920s. The use and local manufacture of nails followed these changes in framing. Nail-plates, which allowed the use of the modern truss roof, date from the 1960s.

Light steel framing was first made in 1970, but was not widely used by the end of the research period.

Monolithic concrete walls have been used in New Zealand at least since 1862. A range of patents have explored ways to improve its thermal and ventilation performance including camerated concrete, Oratonu and Pearse patents.

Hollow concrete blocks arrived in New Zealand in 1904, nearly 50 years earlier than was commonly believed. Their use quickly spread, although this appears to be forgotten with the revival of interest in hollow concrete blocks in the 1950s. The origins of the various hollow concrete block machines used in New Zealand from 1904 to 1958 have been documented.

Interior finishes can be divided into wet and dry. Wet finishes were more common in solid wall constructions (earth, brick, stone, etc.), although lath-and-plaster could be used in timber-framed dwellings. Timber-framed houses could be lined with rough-sawn, match-lining, which even when covered with hessian (scrim) and wall paper provided excessive infiltration. Fibrous plaster sheets were being advertised by the early 1900s. Gypsum plaster board was being sold in 1923 and made in Auckland in 1925. Softboard and hardboard, were both made in Auckland from 1941.

Weatherboards, originally of simple, plain design, by the 1860s were manufactured in rusticated patterns to resemble stone. Bevel-back weather board was widely used from

1910. Building paper was advertised by 1898, but not until the 1930s was it widely used. In 1941 local manufactured commenced and in 1964 its use behind claddings was required.

Fibre cement board, originally using asbestos, was an Austrian invention in 1900, although various asbestos based roofing sheets had been advertised in New Zealand since 1882. The 1900s saw asbestos cement sheets made in Germany, Austria, England and America being widely advertised and in 1919 Australian made Fibrolite became available. The first New Zealand plant opened in Penrose, Auckland, in 1940 followed by a Riccarton, Christchurch plant in 1943. The asbestos was replaced by treated cellulose fibre in 1983.

New Zealand invented pumice boards were also well used. Konka board was made from 1914 into the 1950s.

Until 1963 when glass production commenced in Whangarei, all window glass was imported The plant closed in 1981, a victim of the float glass process, patented by Pilkington Brothers in 1959. Stained glass was available from the 1840s. While timber window frames were initially imported, local production had begun by the early 1850s. Steel window sashes were being made from 1913, while aluminium frames started in the late 1950s and by the 1980s were in the ascendency.

Imported slates were used until the 1920s when other materials took over. Locally made timber shingles provide interest to the roof, but by the 1920s were only permitted for decoration. Terracotta tiles, initially imported and then locally made, were used from the early 1900s to the 1950s.

Corrugated iron was being rolled in New Zealand from the 1860s, using imported sheets. The first galvanising and rolling plant was set up in 1886. The coil was imported until the New Zealand Steel plant started production in 1972. The dipping of individual sheets into molten zinc was replaced by the continuous rolling process in the 1930s. From the mid-1950s, New Zealand invented 'Decramastic' pressed roofing tiles were actively promoted. Aluminium roofing was used from the late 1950s.

Although thermal insulation has only been required in NZ houses since 1 April 1978, it has a much longer history of use. Cork floor boards were used in houses from the 1930s. Fibre glass manufacture commenced in 1961. A rocwool plant (a similar process to fibreglass but using basalt rock) opened in 1978. A perlite industry, based on natural material from the Rotorua –Taupo district began in the 1954. The use of pumice as insulation was patented in 1892, leading to the first New Zealand comparative thermal measurements in 1897. Other insulation materials include macerated paper and reflective foil, both used since the mid-1970s.

This chapter, taken together with the Chapter 4 examination of key materials, provides a broad but comprehensive overview of the principal techniques used in the typical New Zealand house. In most cases this is the first time a comprehensive chronological review has been prepared for these techniques. A common theme, first identified in Chapter 5, is the use of new materials and technologies, whether from overseas or of local invention. Not all were successful, but this analysis shows that innovation has played a major role in the development of the techniques used in the New Zealand house.

Chapter 7 will investigate three case studies to explore these issues in greater depth. Chapter 8 will examine the origins and methods of arrival of all the techniques discussed in Chapters 5, 6 and 7.

7 Case Studies

Chapter 5 explored key materials and Chapter 6 the components of the New Zealand house. As far as possible the sources of these materials and technologies were traced to their original introduction to New Zealand. This chapter takes three technologies and their applications as case studies, exploring in greater detail their origins, introduction, implementation and impact on the overall housing stock.

Table 24 provides an overview of the technique case studies given in this chapter.

Table 24: Overview of Case Study Techniques

Section	Technique	Starting Decade	Case Study Time span	Component	Product Still used?	Origin
7.1	Nails	1880s	1860-1965	All	Yes	Mixed
7.2	Hollow concrete block	1900s	1904-1910	Wall	Yes	USA
7.3	Camerated Concrete	1910s	1908-1920	Wall	No	Australia

These case studies are not intended as a random sample. Importantly, the number of case studies is limited by word count. They have been selected to provide range of countries (USA, Australia and mixed but including UK); starting decades (1880s, 1900s and 1910s); ongoing use (two still used and one no longer); and use in different components (two wall, one wide use)

7.1 Nails 1860 to 1965

> "A typical small cottage had two small rooms under a gable roof, with a frame of studs and plates – the studs mortised into the plates to reduce the need for nails which were still an expensive imported item … In the past other fixings such as wooden pegs or even sheep's bones had been used, but the timber-framed and weatherboarded house of the 1840s onwards depended on iron nails for its strength and ease of construction." (Salmond, 1989, pp. 58–59)

It could be expected that local nail manufacture would have developed early to support the extensive use of timber construction. Although different authors have postulated the existence of an indigenous nail manufacturing industry in the mid- to late-1800s (Salmond, 1989, p. 105; Cottrell, 2006, p. 429; S. Thomson, 2005, p. 107), the first nail machine was only imported in 1887 (Isaacs, 2009, p. 93).

This section examines the imports of nails into New Zealand from 1860 to 1965, compares nail imports with the nails required to build an average timber-framed house, the development of the local wire nail industry and concludes by examining the source of the nail terminology used in New Zealand in order to explore the origins of this technology.

The first nails were handmade by forming metal, normally iron, into the appropriate shape (Section 5.6). The first machine made nails were made from strip-iron rolled to the thickness of the finished nail which was then sheared (cut) to the width desired for the nail length. The cut-nail industry started in the early 1800s and by the 1860s the hand-forging industry was in decline. Cut nails still remain in use as floor brads. The next step for nail making required readily available drawn wire. From the first production to the mid-1880s this was iron, but Bessemer's process meant steel wire then took over. The machinery to make wire nails originated in France in the early 1800s (Isaacs & Cottrell, 2012, p. 119). Machine-made wire nails (points de Paris) were exhibited at the 1844 and 1855 Paris Exhibitions (Priess, 1973, pp. 87–92), and the 1851 London Great Exhibition (Royal Commission for the Exhibition of 1851, 1852, pp. 194–205).

Smaller nail sizes were made in USA from the 1850s, but it took until the 1870s for wire nails to be commonly made for construction (Varman, 1993, p. 164). In the USA less than a fifth of total 1888 nail production were wire nails, the rest being cut nails, but by 1895 wire nails were nearly three quarters of total production. Wire nail production rose from 20,000 kegs in 1880 to 125,000 kegs in 1887, while prices fell from US$ 20.00 per keg in 1875 to US$ 10.00 in 1880, then to US$ 4.81 in 1887, possibly below the cost of production (Edgerton, 1897, p. 248).

This section provides a brief summary of the development of the New Zealand nail industry up to 1910 based on Isaacs (2009) and extends this to the 1960s.

7.1.1 Imported Nail Supplies

Even from the earliest days of European settlement, the majority of dwellings were wooden framed and wooden clad (Section 4.1.5). Figure 12 (p. 42) highlighted the overwhelming predominance of wooden framed houses in the period 1858 to 1911. These required nails, the product that held the timber together.

Although prior to 1862 no nail import statistics are available, newspaper advertisements and shipping reports from 1840 provide some qualitative information. For example, the shipping report of the 7 March 1840 Wellington arrival from London of the New Zealand Company ship Glenbervie, listed 20 kegs of nails for three different retail and auction businesses, as well as many "packages" and "crates" (New Zealand Gazette and Wellington Spectator, p. 3, 2 May 1840), which possibly included nails and other building materials or tools ordered by settlers directly from England.

From the first newspapers in 1840, hardware advertisements differentiated country of origin, manufacture and type of nails. Table 25 provides some examples.

Table 25: Examples of Nail Descriptions in Newspaper Advertisements 1840-1872

Date	Newspaper (Page)	Description
18 April 1840	NZ Gazette (p.1)	'Nails direct from Britannia Works' 'Iron bar, bolt, nail and sheet'
5 November 1840	NZ Advertiser & Bay of Islands Gazette (p. 2)	'Wrought & cut nails'
9 November 1842	NZ Gazette and Wellington Spectator (p. 1)	'Nails of every description'
6 March 1847	New Zealander (p. 1)	'Patent and Cut Nails'
21 August 1847	Daily Southern Cross (p. 1)	'Ewbank's Nails'
8 July 1848	Daily Southern Cross (p. 1)	'20 Kegs Ewbank's Patent Wrought Nails from 1½ to 3 inches'
8 January 1863	Daily Southern Cross (p. 3)	'American nails, 2⅝d. to 2⅞d. per lb'
28 July 1863	Daily Southern Cross (p. 2)	'French wire nails, 1¼ in'
18 August 1865	Daily Southern Cross (p. 1)	'Ewbank's', 'Light' & 'Wire Nails'
15 September 1865	Daily Southern Cross (p. 7)	' Ewbank's Nails', 'American Cut Nails'
5 July 1866	Daily Southern Cross (p. 5)	'Ewbank's & American Cut, French Wire'
27 November 1872	Daily Southern Cross (p. 1)	'French Wire Nails' & 'English Wire Nails'

The 18 April 1840 issue of the New Zealand Gazette, the first Wellington printed issue, included two advertisements for nails. The business of Hunter and Co advertised "Iron bar, bolt, nail and sheet" landed from the Glenbervie, while the Britannia Hotel and Stores advertised "Nails direct from Britannia Works", probably referring to the Britannia Nail Works of Birmingham, England (New Zealand Gazette and Wellington Spectator, p. 1, 18 Apr 1840).

A common trade name in nail advertisements is the British *Ewbank Patent Wrought Nail*. Ewbank nails were reportedly first made in 1835 at J. J. Corde & Co.'s Dos Works in Monmouthshire (Jones, 2005). Machine made from wrought iron, as for handmade nails, they replicated more cheaply the fibrous and resilient quality of the wrought nail. They were available in the Australian colonies by 1844 (Varman, 1993, p. 158) and in New Zealand by at least 1847 (Isaacs, 2009, p. 84).

In Auckland, Connell & Ridings were advertising "20 Kegs Ewbank's Patent Wrought Nails from 1½ to 3 inches" to be sold at auction on 12 July 1848 (Daily Southern Cross, p. 1, 8 Jul 1848). In August 1849 in Wellington, Bethune and Hunter advertised for sale "62 kegs assorted Ewbank's Patent Nails" due to arrive on the ship Jane Catherine and "78 kegs Ewbank's Patent Nails" which had arrived on the ship Ennerdale on 5 June 1849 (New Zealand Spectator and Cook's Strait Guardian, p. 2, 8 Aug 1849). Across Cook Strait, on 24 October 1857 in Nelson, D. Moore was advertising "50 casks Ewbank's patent nails, assorted" on page 1 of the Nelson Examiner and New Zealand Chronicle while competitor T. C. Batchelor was advertising "60 kegs of Ewbank's patent wrought nails, from 1 ¼ in to 6 in." on page 4 (Nelson Examiner and New Zealand Chronicle, pp. 1, 4, 24 Oct 1857).

As the New Zealand nail market developed, different countries supplied nails. When S. Hague Smith announced the 1868 closing sale for his Upper Queen Street, Auckland, shop, it included "Ewbank's, Wire and American Nails" (Daily Southern Cross, p. 6, 16 Dec 1868). In 1873, J. & J. Dickey of Auckland were selling "Ewbank's and Cut Nails, French Wire Nails, 1 in. to 3 in., American Finishing Nails, ½ in. to 2½ in." (Chapman, 1873, p. 446).

Although not surprising that English, French and American nails were available in a country dependent on imports, it is notable that the merchants considered it worth differentiating between them. Even as late at 1895, McCallum and Co of Oamaru were advertising the availability of generic as well as branded nails, "Wire nails, Floor Brads, Ewbank Nails, Roofing Nails" (North Otago Times, p. 1, 17 Jun 1895).

The availability of nail rod iron, necessary for hand forging of nails, was advertised in 1847 (Wellington Independent, p. 2, 20 Oct 1847) but was last mentioned as an import in 1863 (Lyttelton Times, p. 4, 19 Aug 1863). The availability of imported nails coupled with improved transport probably made it preferable to use factory-made rather than hand-made nails.

Patent wrought iron nails were still available in 1887, although it is not clear if these were Ewbank or some other manufacturer (New Zealand Herald, p. 4, 22 Feb 1887; North Otago Times, p. 4, 10 May 1887).

The last advertisement for cut nails found was for an auction sale including "2 kegs American Cut Nails" in Nelson, 1901 (Nelson Evening Mail, p. 3, 27 Jun 1901), although the better holding power of cut nails was being discussed in newspapers in the 1920s (Auckland Star, p. 11, 23 Jan 1925; The Press, p. 5, 13 Sep 1923).

7.1.2 Import Statistics

As discussed in Section 4.2, country of origin was only reported from 1869, although import value and quantity were available from 1862. From 1869 to 1879, imports of both nails and screws were enumerated under a single category, which for this analysis has been treated as if all were nails.

Figure 113 plots the proportion of nail imports by value and main sources from 1871 to 1965 (no data could be found for 1870), while Figure 114 provides the weight of nail imports by main sources. As for Section 4.2.3, 1965 values have been converted to pounds ($2 = £1). The official import statistics are grouped by country or combined into a region where imports are of lesser value:

- **UK**
- **Australia:** NSW, Victoria, Tasmania and Western Australia
- **USA:** in early years the origin was given as Atlantic (East) or Pacific (West) Coasts, but these have always been combined to match later years.
- **Canada**
- **Other – Europe:** Germany, Belgium, Holland, Norway, Sweden
- **Other – Asia:** Japan
- **Other:** changing from year-to-year, these countries include: Ceylon; Chile; China; Czechoslovakia; Hong Kong; India; Italy; France; Switzerland; and Fiji, Tonga and South Seas Islands

In most years, very few nails were imported from these "Other" countries. The highest level of imports was in 1965 when 162 cwt (9% by weight of all nail imports) were imported from Switzerland at a cost of £13,425 (30% by value). In 1960 the average imported cost per cwt (ignoring Switzerland) was £17.15 with the Swiss nails costing on average £82.87 per cwt.

It is also important to note that although imports were attributed to the country of shipping origin, this may not have been the country of manufacture. For example, in 1877 when total nail imports were 32,634 cwt valued at £34,531, some 88 cwt of nails (value £91) were sourced from Fiji, most likely re-exports rather than Fijian manufacture.

Although some NZ nail imports were later exported, it has been assumed that neither their volumes nor values were significant. This is further discussed in Section 7.1.4

Figure 113 shows the fluctuating importance of UK nail imports. From 1871 to 1895, the UK averaged 76% by value and 85% by weight of all nail imports, falling to 14% of value in 1905 before fluctuating between 6% and 67% for the remainder of the period.

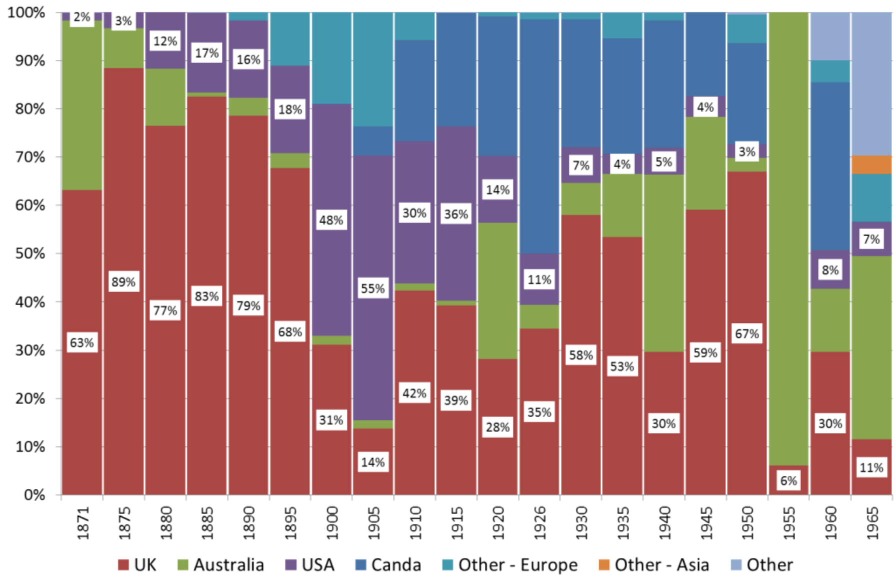


Figure 113: Sources of nail imports 1871 to 1965 by value

Figure 114 shows a reduction in nail imports from 1910, suggesting most local needs were met by the development of an indigenous nail manufacturing industry. Until 1893 the main source of imported nails is clearly British, whether from the United Kingdom or its Australian colonies. From 1893 the sources changed from Britain firstly to Europe, then the USA, and then Canada. Nails from Canada were not subject to preferential rates of duty, so it would appear unlikely that American nails were being trans-shipped for export. The large-scale entrance of Canadian suppliers from 1905 ultimately supplanted those of the USA.

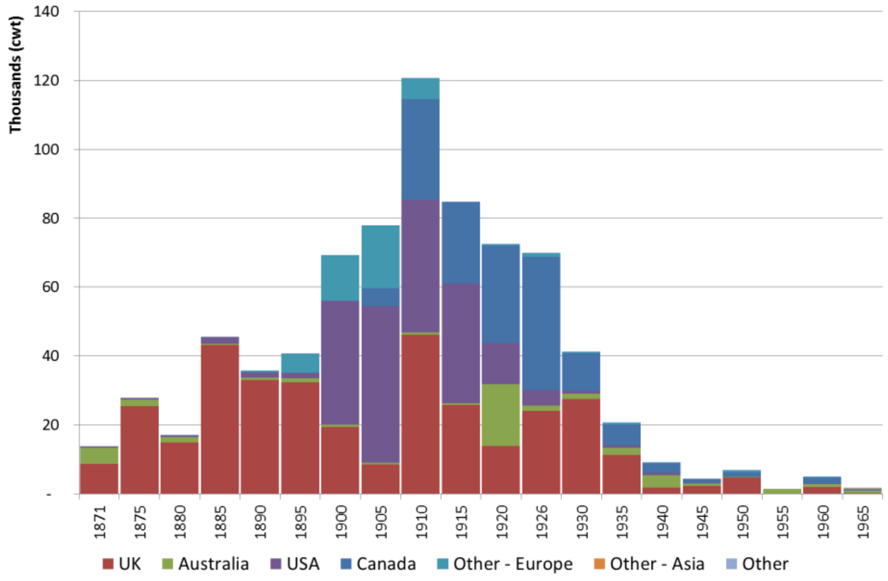


Figure 114: Sources of nail imports 1871 to 1965 by weight

Table 53 (see Appendix p. 327) provides five-yearly data from 1871 to 1965 for the unit cost of nail imports by country of origin. The average cost was calculated from the total import weight divided by the total import cost.

Table 53 shows that the cost per unit for imports from the USA plummeted from £2.97 per cwt in 1895 to £0.64 per cwt in 1900. A possible consequence can be seen in Figure 114, with USA imports increasing from 4% to 52% of the total. The reason for the price drop is probably the establishment of the USA "Wire-nail Association", a cartel of USA nail manufacturers which commenced on 1 May 1895 and lasted until 1 December 1896 (Edgerton, 1897).

Figure 115 converts the import data from 1871 to 1965 to value (£/person) and weight (kg/person) (Section 4.2.3). Figure 115 also shows local production of nails per person for the period 1945 to 1960 (Section 7.1.4).The population numbers are "Total De Facto Population" at 31 December of the relevant year (Statistics New Zealand, 2005, Table A1.1). This includes permanent residents and visitors, but excludes New Zealanders overseas.

Figure 115 shows that from 1870 to 1885 the demand for nail imports by weight per person fell, possibly as the initial need for permanent house construction was met. Initially ignoring the 1920 peak, the value of imports per person remained reasonably consistent from 1880 to 1915, but from 1926 onwards there was a gradual decline. However, the weight per person fell from 1910, declining to low levels by 1945. The local nail manufacturing industry (Section 7.1.4) was becoming active in the 1910s and is probably responsible for the reduced nail imports. The sharp peak in the cost per person around 1920 is further examined in Figure 116.

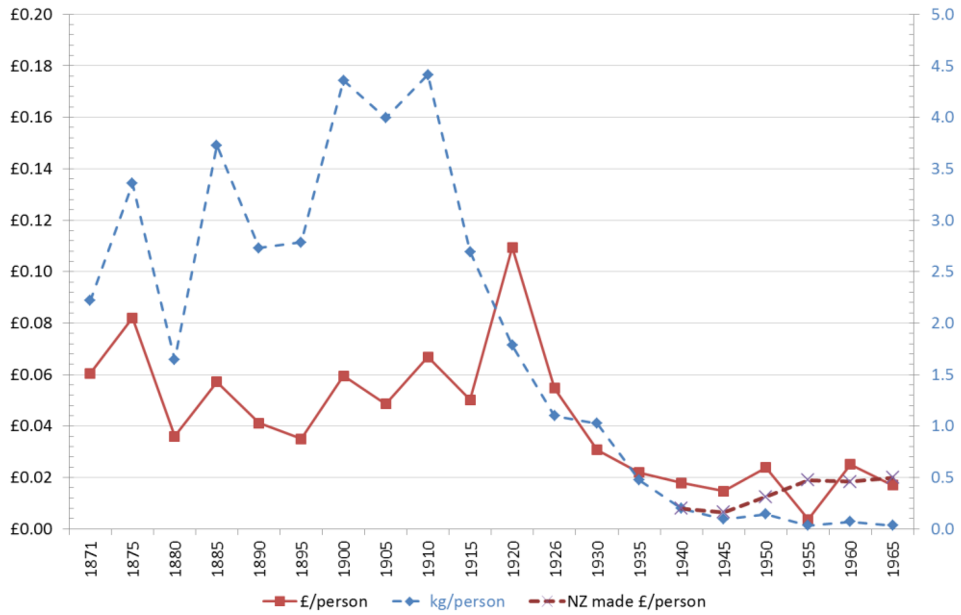


Figure 115 Nail Imports per Person by Value and Quantity 1870 to 1965

Figure 116 provides nail imports per person for selected years from 1910 to 1926. Vertical lines mark the years shown in Figure 115. Figure 116 shows a small drop in import value per person from 1910 to 1918, with a blip in 1916, but then a large increase in 1919 followed by a gradual fall, which even by 1926 was still higher than the 1918 level. The quantity per person rose strongly in 1920 before a more rapid fall to a level closer to 1918 imports per person in 1922. This was possibly due to the impact of WWI coupled with a shift in imports to more expensive, specialist nails as the lower price common nails were being made locally (Table 53).

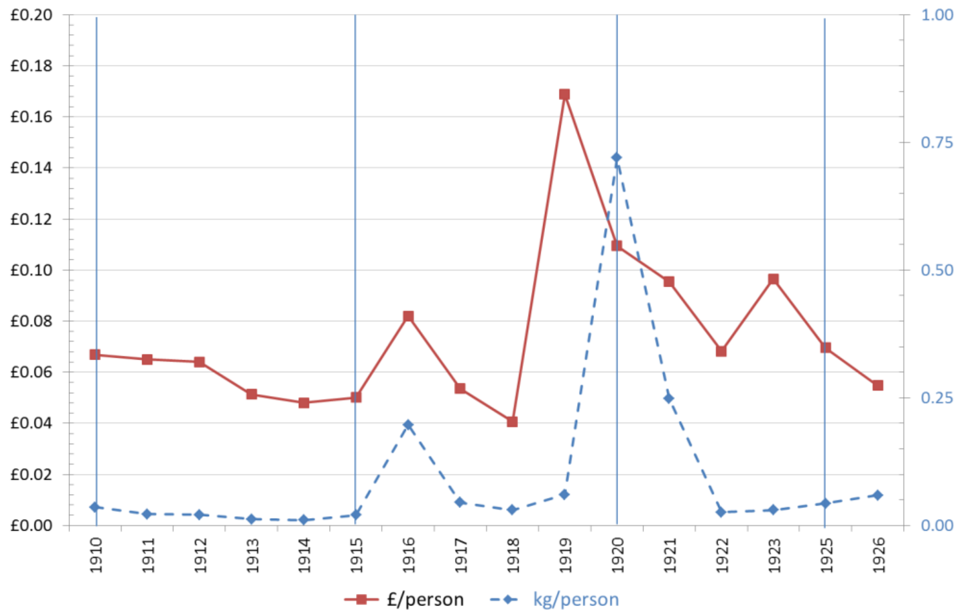


Figure 116 Nail Imports per Person by Value and Quantity 1910 to 1926

7.1.3 Nails per House

In the early days of European settlement, timber was used for all building types (residential, commercial, industrial and agricultural). The use of nails was largely limited to fixing boards for claddings and linings, with more reliance on mechanical connections in framing such as mortise-and-tenon joints, often fixed with a tree-nail or wooden peg. As nails became more readily available at a lower cost, the construction method changed to make more use of nails and less of labour.

A search was undertaken for building plans with associated material quantities but only a single source was located. As noted in Section 3.3, Brett's provided a series of four designs complete with material quantities for cottages with four to eight rooms ranging from 23ft x 26ft (7m x 8m) single storey to 33ft x 28ft (10m x 8.5m) double storey (Figure 117). The second edition increased the nail requirements for the fourth cottage, while adding a fifth design which lacked a schedule of quantities (Leys, 1897, pp. 1131–1147).

Table 26 provides a brief description and summary of the nail requirements (based on the 1897 2nd edition) for the four cottages. For the purpose of comparison, nail requirements are based on the average requirements for cottages 2, 3 and 4. They required, on average, 2.3 cwt (120kg) of floor brads and wire nails in various sizes, at an average cost of 0.19 shillings per pound.

Table 26: Brett's "Cottages for Settlers"

Cottage number & description	Area (ft^2)	Nails (lbs) 3" wire	2½" wire	2" wire	1½" wire	4"	2 ¼" brads	Total Nails (lbs)	Cost
1 "small family, limited means"	*529*	*30*	*10*	*10*	*20*		*10*	*80*	*£0 15s*
2 "similar to #3 but smaller"	672	90	15	30	60		24	219	£2 0s
3 "plain, useful, most area least money"	896	100	20	35	60		28	243	£2 5s
4 (2 storey) "showy & convenient"	924	140	56	20	56	10	40	327	£3 5s
Simple Average for Cottages 2, 3 & 4	**831**	**110**	**30**	**30**	**59**	**2.5**	**31**	**263**	**£2 10s**

For comparison, over the five years from 1881 to 1886 nail imports averaged 44,536 cwt per year (2,260 tonnes) (Government Statistician, Registrar-General's Office, 1884, 1885, 1886, 1887b). Based on the average weight of nails for the larger cottages, this would have sufficed for 19,846 houses.

Table 52 shows between the 1881 and 1886 Censuses an average of 3,253 inhabited, permanent wood structure dwellings built per year (Government Statistician, Registrar-General's Office, 1887a). Thus only about one sixth of the potential number of dwellings were built in this period. It must be assumed the remaining nails were used for other buildings required in the developing country.

It is possible that additional nails would have been required if larger houses were built. Analysis of census data from 1881 to 1886 shows 69% of new dwellings had from three to six rooms and 30% had more than six rooms (Government Statistician, Registrar-General's Office, 1882, pt. XV, 1887a, pt. XIV). The Brett's design for an 8 room cottage (No. 4) required only 20% more nails than the most complex 4 room cottage (No. 3), so this does not seem to be the sole reason for the difference.

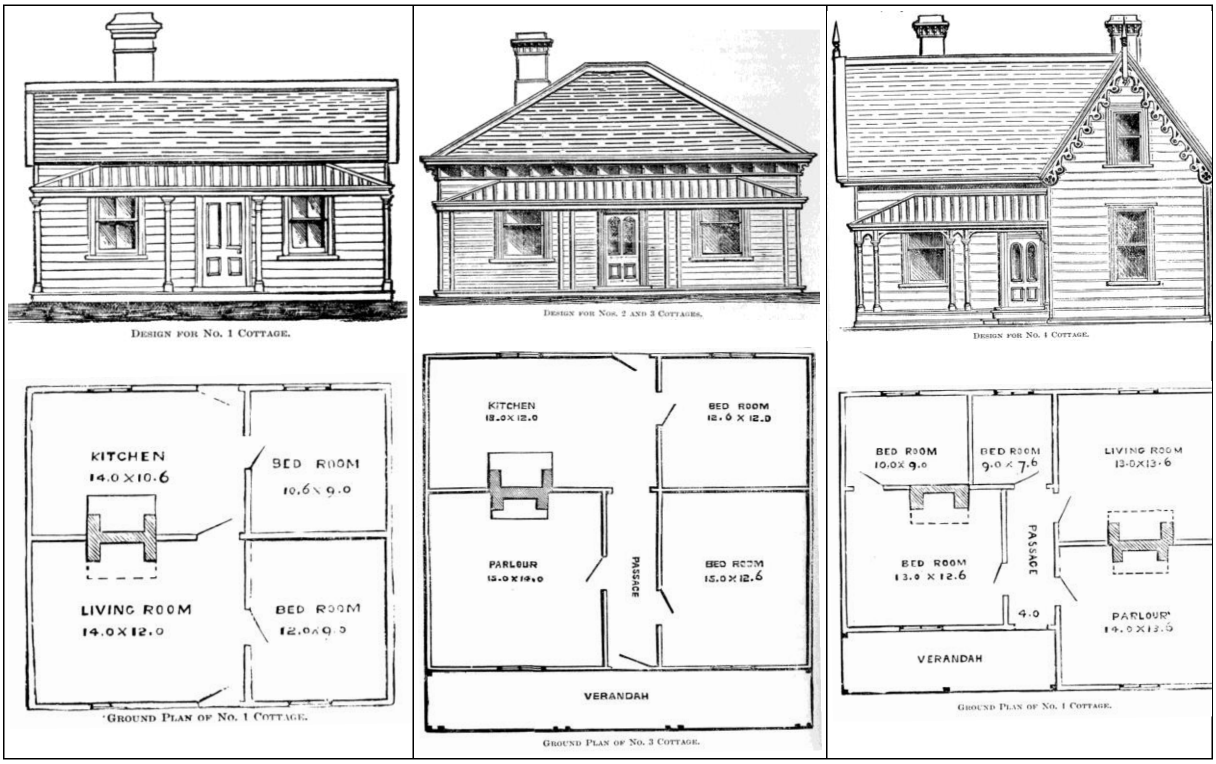


Figure 117: Brett's Colonists' Guide - Model Cottages (1883)

Figure 118 compares the average weight of nails per new wooden house with that based on Brett's model houses (Isaacs, 2013, p. 38). The average weight of the former was calculated by dividing the total imports of nails by the nett increase in the number of wooden dwellings in each inter-census period. The average weight per dwelling based on Brett's model houses takes into account the different numbers of bedrooms in the houses in each inter-census period. There are fluctuations in the average nail imports per new dwelling, shown by the dashed line. The large peak in 1874 was due to a smaller than usual increase in the average annual number of wooden houses built in from 1867 to 1878 (Table 52), while nail imports increased in 1875 (Figure 114). The trend is illustrated by the solid line, which plots the average weight of nails, with the use per dwelling largely stable from 1864 to 1881 (left) and again from 1886 to 1911 (right), but with a step from 1881 to 1886. The increase from an average of 8.6 cwt per dwelling to 15.5 cwt per dwelling suggests there was a significant change in the use of nails in the five years to 1886.

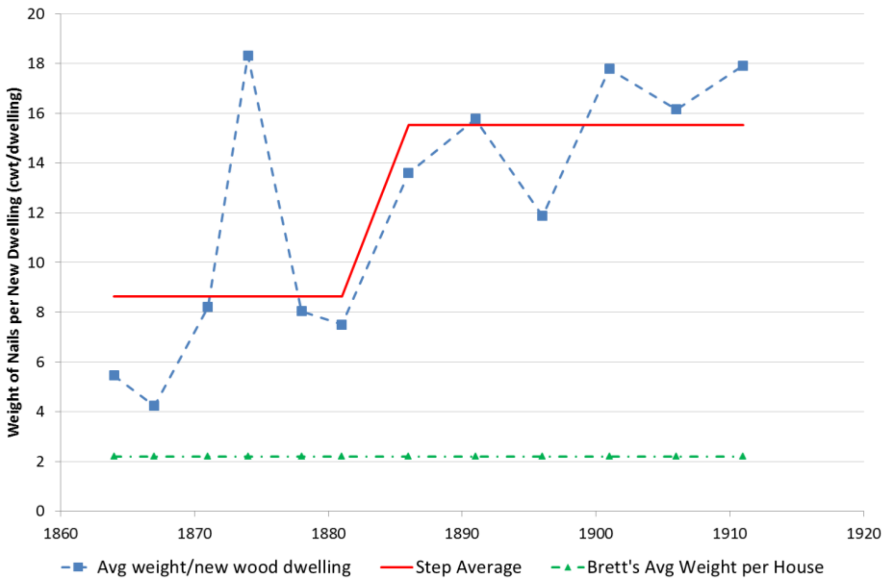


Figure 118: Average Nail Imports Per New Dwelling 1864 to 1911

While the 1880s saw a growth in the construction of town halls, railways, clubs, hotels and other public and commercial buildings, it does not seem likely this was the sole reason for the increase in nails per wooden house. One possible reason leading to increased imports of nails was a change in construction style (Isaacs, 2013, p. 39). Although Brett's does not specify construction style, it was clearly not traditional mortise-and-tenon framing so was probably balloon construction. Figure 118 suggests that the shift from balloon to platform framing, with an even greater use of nails, occurred in the 1881 to 1886 period, some five years earlier than suggested by Salmond (1989, p. 113) and fifteen years earlier than Bates (1957, p. 17) (Table 50).

Although considerable effort has been put into finding similar tabulations of nail use for different houses since 1897, only one other example has emerged. Table 27 tabulates the "nails required for an average Government house" extracted from a 1939 memorandum from the Director of Housing Construction to the Secretary for Supply. The memo, while noting that the average quantity of lead head nails for a house with an iron roof was 40 lb, did not provide a sketch plan of the houses (Director Housing Construction, 1939).

The similar nail requirement for both the timber and metal lath-and-plaster (stucco) houses in Table 27 was probably due to the nails needed to hold the metal-lath in place, nails not being required for brick veneer construction (Section 5.2.2).

Table 27: Nails Required for Average Government House 1939

Size of nail	4" x 7	3" x 9	2¼" x 11	Sundry 1½" x 2	Clouts	TOTAL (lbs)
Brick house	112	168	112	56	0	448
Timber house	112	224	112	56	0	504
Metal lath-and-plaster	112	168	112	56	56	504

Even assuming an average 94 m^2 (1,011ft^2), single storey, timber house (Baird, 1983, p. 28), the 504 lbs of nails given in Table 27 is a 54% increase over the 327 lbs for Brett's 1883 two-storey Cottage 4 in Table 26. In all but the 1½" nails, the 1939 houses require more nails than the 1883 house.

It is expected that there was a shift in housing construction techniques which led to this large difference, but this remains as a further research opportunity. The lack of data on New Zealand nail production (Section 7.1.4) will require detailed investigation of building permits and plans to determine the reason.

7.1.4 New Zealand Nail Manufacture

There are only limited statistics for nail manufacture in New Zealand, principally from 1892 to 1910, and then from 1938 to 1965.

The 1892, 1896, 1901, 1906 and 1911 Censuses of Manufactories recorded lead-head nail manufacturing establishments. Table 28 provides results from the 1892 (actually conducted during April 1891); 1896 (conducted during 1895); 1901; 1906 and 1910 Censuses of Manufacturing, Machines & Works. No nail manufactories are recorded, suggesting the primary activity was the addition of a lead-head rather than manufacture of the base nail. No nail factories were recorded in the 1867, 1878 or 1881 Censuses of Manufactories. The 1892 Census of Manufacturing reported one lead-headed nail factory in Canterbury, increasing to three in the 1897 Census plus one in Wellington and three in Auckland, but reducing to just two factories (Auckland and Wellington) in 1910. Due to the small number of works and the corresponding confidentiality limitations, financial data was only reported for 1895 and 1910.

Table 28: Lead-headed nail works 1892 to 1910

Manufacturing Census headings	**1892**	**1896**	**1901**	**1906**	**1910**
Location (Provincial District)					
Auckland		3		1	1
Wellington		1		1	1
Canterbury	1	3			
Number of works	**1**	**7**	**1**	**2**	**2**
Number of hands employed ("productive")	8	12	3	6	6
Total wages paid	£227	£494	*	*	£970
Approximate value of Manufactures, &c.	-	£2,834	*	*	£5,905
Approx. value of land, buildings, machinery & plant	-	£2,325	*	*	£3,650

* Confidential due to small number of works

Data sources: (New Zealand Government, pp. 64, 67, 14 Jan 1892); (New Zealand Government, pp. 194–5, 198–9, 25 Jan 1897); (Government Statistician, Registrar-General's Office, 1911, p. 429)

From 1912 to 1937 nail manufacturers were included under the statistical heading *Tinned Plate and Sheet Metal* manufacturing, but due to their small numbers separate data was not provided. For 1911 there were 82 *Tinned Plate and Sheet Metal* establishments with 506 productive employees but only 2 lead-head nail establishments with 6 employees.

It was not until 1938 that nail manufacturing was once again separately tabulated. Table 29 provides data on nail production from 1940 to 1965. In 1945 the number of works reduced from 7 to 6 where it remained for the rest of the period, with employment ranging from 85 to 155 people. Production statistics (weight and type of nails produced) are only available from 1951.

Figure 115 plots the value of NZ production per head from 1940 to 1965 as well as import value and weight per person, using the data in Table 29. Figure 115 suggests post WWII nail expenditure per person grew considerably, by 1965 reaching a level closer to that of 1871 than at any time in the intervening period. Production weight data is available only from 1951, and ranges from 4.9kg/person (1955) to 4.5kg/person (1965), which compares with the import high of 4.4kg/person in 1910 (Figure 115).

Table 29: NZ Nail Production 1940 to 1965

Nail-manufacture	1940	1945	1950	1955	1960	1965
Number of works (establishments)	7	6	6	6	6	6
Persons engaged	133	85	115	137	128	155
Value of Production	£323,597	£278,995	£603,645	£1,025,114	£1,099,813	$2,649,000
Nail production (tons)						
Steel wire-bright				8,322	9,004	9,321
Steel wire-Galvanised				778	742	1,120
Steel wire-Lead-headed				1,332	1,400	1,469
TOTAL steel wire nails (tons)				**10,432**	**11,146**	**11,910**
Galvanised & bright staples (tons)				1447	1,208	1,494
Nail production per person (kg)				4.9	4.7	4.5

Data sources: (Census and Statistics Department, 1950, 1954b; Census and Statistics Office, 1942a; Department of Statistics, 1957, 1968; New Zealand Department of Statistics, 1963)

Table 30 provides a summary of local nail manufacture, exports, imports and re-exports (imported and then exported without further processing) for 1955, 1960 and 1965. For these three years, imports added between 0.7% and 2.3% to the local manufacture, while re-exports were too small to be significant.

Table 30: Nail Production, Exports, Imports and Re-exports 1955 to 1965

Total £	NZ Manufacture		Exports		Imports		Re-exports	
	Weight (cwt)	Value (£)	Weight	Value	Weight	Value	Weight	Value
1955	208,640	£1,025,114	1,990	£7,689	1,390	£8,017	23	£380
1960	222,920	£1,099,813	1,548	£6,441	5,018	£60,181	5	£49
1965	238,200	£1,324,500	1,185	£6,863	1,760	£45,175	8	£572

Sources:
Production: (Department of Statistics, 1957, 1968; New Zealand Department of Statistics, 1963)
Exports & Re-Exports: (Customs Department, 1957a, 1962a; Department of Statistics, 1967a)
Imports: (Customs Department, 1957b, 1962b; Department of Statistics, 1967b)

7.1.5 'Nail' Factories and Employees - Details

Table 31 summarises the earliest New Zealand nail manufacturers for which information has been found. The date refers to the earliest reference to nail making, whether in a commercial directory, a newspaper advertisement, the issuing of a patent or investigating the purchase of manufacturing machinery (Isaacs, 2009; Warwick, 1996, pp. 75–81). It is not necessarily the date at which the company was making wire nails. Some companies added lead heads to nails but no evidence has been found that they manufactured nails. Plumbers were also known to make their own lead-headed nails, often using left-over lead already paid for by another client (Department of Industries and Commerce, 1928a).

Lead-headed nail manufacture could also be a secondary activity, as was the case for the Southern Cross Galvanised Iron Manufacturing Company Ltd of Auckland. The works, established in 1886, also made a range of galvanised products (including spouting, ridging, tanks, buckets, tubs) as well as their own *Acme* patent lead-headed roofing nail (Auckland Industrial and Mining Exhibition, 1898, p. 61).

Table 31: Early New Zealand nail manufacturers (including lead-head nails)

Date	Business	Patent	Location	Nail Type or Description
1880	J. Hill		Christchurch	Horse-shoe
1883	Samuel Parker	877	Auckland	Galvanized lead-headed roofing
1883	Joseph Venables	915	Christchurch	Tin wired, solid lead-head roofing. Wire nails c 1923.
1884	Alfred Robb & William Stokes	1,152	Christchurch	Lead-head roofing. Wire nail c 1887
1884	John Sinclair	1,165	Christchurch	'Acme' & 'Mushroom Head' Nail
1885	Henry Davenport	1,643	Wellington	Lead-head roofing nail
1887	Heathcote Wire Nail Co,		Christchurch	Wire nail
1890	Ballinger Brothers	-	Wellington	Roofing
1890	George McCaul	3,489	Auckland	Composition-metal head roofing
1894	John Alexander	-	Wellington	Lead-head nails
1897	Horace Thompson	9,436	Christchurch	Split nail
1897	D. Nicolson & Co	-	Dunedin	'Varnish and wire nail factory'
1906	Crown Nail Company	-	Dunedin	Lead-head roofing
1909	Auto Machine Manufacturing Co. Ltd	-	Auckland	Wire nail c 1913
1913	Lino Roofing Nail Manufacture		Dunedin	Lead-head. Wire nail c 1913
1917	H. Hanson & Co. Ltd		Wellington	Wire nail c 1923
1922	Auto Machine Manufacturing Co. Ltd		Wellington	Wire nail c 1922
1939	Eclipse Wire Products		Auckland & Pal. North	Wire nail c1939
1939	Pearson, Knowles & Rylands		Auckland	Wire nail c 1940

It is possible that nail manufactories existed prior to the 1880s, but the only one found is a horse shoe nail factory operated by Mr. J. Hill of Christchurch which was included in the report of the 1880 Christchurch Industrial Exhibition (Cottrell, 2006, p. 428). The factory opened in 1880 (West Coast Times, p. 2, 22 Jun 1880) and still existed in 1883 (Otago Witness, p. 9, 2 Jun 1883). No information has been found on when it closed.

The possibility that specialised employees reported their involvement with nails was explored through inspection of the 1893 Electoral Roll. Only three adult males reported occupations including the word *nail* (two in Christchurch, one in Auckland) and only one with *lead* but he was a "leadpipe maker" (D. Wilson, 2004). In Auckland, Alfred Norwood was listed as a "nail maker" and lived close to the Southern Cross Iron Works. In Christchurch, Alfred Robb reported his occupation as "nail maker" while Richard Thomas Mallet was recorded as a "nail factory employee."

In 1884 Alfred Robb and William Stokes set up in business to manufacture their patented lead-head nail. In 1886 they applied to import a nail making machine, probably the first such machine imported into New Zealand (Isaacs, 2009, pp. 92–93). Robb parted company with Stokes in about 1888 and set up the Heathcote Wire Nail Company, in the Heathcote Valley, Christchurch. It advertised wire nails both in stock and by special production (The Press, p. 1, 13 Mar 1888; Auckland Star, p. 3, 16 Mar 1888). Although no names are given in the advertisement, the location and activity matches with the Deed of Mortgage between Alfred Robb "formerly of Sydenham, Canterbury in New Zealand carpenter but now of Heathcote Valley Canterbury aforesaid nail manufacturer", William Stokes "formerly of Sydenham, aforesaid carpenter but now of Wilsons Road near Christchurch, New Zealand nail manufacturers" and Edward Ashby "accountant" dated 14 June 1887 (Robb & Stokes, 1884). The Heathcote Wire Nail Company was put up for sale in 1889 (The Press, p. 1, 17 Jul 1889) but no further information has been found. Stokes continued in business and by 1895 employed 6 boys making nails, producing £1,200 worth a year (New Zealand Parliament, 1895, p. 261), amounting to about 5% of the value of 1895 nail imports.

The first wire nail manufacturer not associated with lead-headed nail manufacture appears to have been David Nicolson's short-lived 1897 Dunedin business, D. Nicolson & Co which operated a "varnish and wire nail factory" in Willis St, Dunedin (Stone, n.d. 1897). During 1896 the Dunedin firm of Paterson & Barr, ironmongers, agreed to import 20 tons of various sizes of nail making wire to be turned into nails for them to sell, while Nicolson "commenced to get his machinery in order." The wire arrived in January 1897 but Nicolson only delivered about 24 cwt of finished nails (Paterson and Barr, 1897). Although the reasons for this failure to deliver have not been found, it appears the nail making machinery was working, as W.H. Scott, Mechanical Engineer undertook "Repairs to Cams of Nail machine £0 12s 6d" on 5 March 1897 (W. H. Scott, 1897). When Nicolson was adjudged bankrupt on 24 April 1897 (New Zealand Government, p. 952, 29 Apr 1897), the bankruptcy valuation list (total plant value £660 6s 7d) included:

- "1 large nail machine £40" and
- "4 small nail machines £120"

No information has been found on the origins of Nicolson's nail making machinery, whether it went into productive use after the sale, or was scrapped (Isaacs, 2009, p. 95).

The Auto Machine Manufacturing Company Limited started in Auckland on 10 May 1909, formed by the family of Mr William Squire Fowler for the purpose of "putting on the market in Auckland or elsewhere a large machine capable of making one length of drawn pipe at one operation" (Auto Machine Manufacturing Co. Ltd, 1909). Although the machine was not ultimately successful, even during its first year the company was interested in a wider market. The company's name was an abbreviation of the word *automatic*, based on the type of equipment the company used.

The Auto Machine company archives hold a letter dated 9 October 1909 from The National Machinery Co. of Tiffin, Ohio USA responding to a request for information on nail making machinery (National Machinery Co., 1909). However, the company records suggest it was not until 1913 that the recommendation to purchase a nail making machine was made to the company's Board of Directors (C.M.I. Ltd, 1959, p. 4).

In 1923 the Secretary of the Department of Industries and Commerce identified two businesses in three locations making nails (Secretary, Department of Industries and Commerce, 1923):

- P.H. Venables, Moorhouse Avenue, Christchurch
- The Auto Machine Manufacturing Co. Hobson St, Auckland and Wellington

In 1928 inspectors from the Department of Industries and Commerce visited the Auto Machine Manufacturing Co and the Lino Nail Company. The Auto Machine Company employed nine men working two shifts on nine machines, six of which were made in New Zealand. The company estimated imports were 6,000 tons of nails while local manufacture was about 2,300 tons with up to 1,000 tons made in Wellington (in the 1910 year, imports were 120,464 cwt or 6,023 tons, suggesting the estimate is correct). The visit to the Lino Nail Co found it had installed "a machine to make their own nails using British made wire" as they found the Canadian wire nails from the Auto Machine Company were too soft for use as lead-headed roofing nails (Department of Industries and Commerce, 1928a, 1928b). The Lino Nail Co existed in 1913 (Otago Daily Times, p. 4, 3 Oct 1913) and was listed in Wises Post Office Directory in 1917 as making roofing nails ("Lino Roofing Nail Fact. 50 Hanover St, Dun") but would appear to have started nail manufacture sometime between 1923, when Wises Directory recorded it moved to Ward St, and 1928 when the Department visited. It was taken over in 1936 by Lino Products Ltd (Dunedin), under the same ownership as the Auto Machine Manufacturing Company (New Zealand Herald, p. 7, 12 Oct 1936)

Briefing notes prepared in 1937 for the Parliamentary Under-secretary for Industry, Mr. J.A. Lee, listed four nail manufacturers in five locations (Department of Industries and Commerce, 1937):

- The Auto Machine Mfg. Co. Ltd, Nelson Street, Auckland & Wellington
- The Lino Roofing Nail Pty., Ward Street, Dunedin
- Mr. P.H. Venables, 163 Moorhouse Avenue, Christchurch
- H. Hanson & Co. Ltd, 39 Hooper Street, Wellington

In 1938, the UK business of Pearson, Knowles & Rylands Bros. NZ Ltd (PKR) wrote to the Minister for Industries and Commerce, stating they were contemplating "the erection of a Works for the Manufacture of Wire Nails in Auckland" to make 18 tons of nails a week (Pearson, Knowles & Rylands Bros. NZ Ltd, 1938). The memo to the Minister noted the nail making industry employed 60-70 male employees using 4,000 tons of wire per year, and added Eclipse Wire Products of Palmerston North as an additional manufacturer (Department of Industries and Commerce, 1938). PKR commenced manufacturing in 1940 with 6 nail machines and had doubled the number to 12 by mid-1941 (Pearson, Knowles, Ryland Bros NZ Ltd, 1941).

The following year, 1939, the Department reported that three companies (Auto Machine Company, Lino Products & Venables) had "buying and selling pool arrangements" to balance the supply, with a total of 60 wire nail making machines in four cities (Auckland, Wellington, Christchurch and Dunedin) making a complete range of steel wire nails from ½" x 20 gauge to 6" x 4 gauge. The Auto Machine Company had 16 machines in Auckland, about half of their own manufacture, and practically all the Wellington machines were of their own manufacture (Department of Industries and Commerce, 1939).

In mid-1941 the Department of Industries and Commerce requested all nail manufacturers provide information on the number of nail making machines they had in use. The response has been found for all manufactures, except Auto Machine, and is summarised in Table 32. An estimate of the Auto Machine Company machine origins is based on the statement above (Auckland 16 machines, assumed 8 NZ made; Wellington 10 machines, assume 8 NZ made). Thus of the 73 nail making machines in New Zealand in 1941, the country of manufacture can be identified for 47 (65%), with only 1 of USA manufacture.

Table 32: Nail Machines and Origins, May 1941

Nail machines May 1941			**Machine Manufacturer (where known)**						
Company	**Location**	**Total**	**Auto (NZ)**	**Kayser (German)**	**(Aust.)**	**Wafios (German)**	**National (USA)**	**Ryeson (unknown)**	**(British)**
Auto	Auckland & Wellington	28	16						
Eclipse	Pal. North	4	1	4					
Hansen	Wellington	4	1		3				
Lino	Dunedin	10	3	2		1	1	3	
PKR	Auckland	12							12
Venables	Christchurch	15							
TOTAL		73	21	6	3	1	1	3	12

Sources: (Department of Industries and Commerce, 1939), (Eclipse Wire Products Ltd, 1941; H. Hanson & Co. Ltd, 1941; Lino Products Ltd, 1939; Pearson, Knowles, Ryland Bros NZ Ltd, 1941; Venables, 1941)

P.H. Venables merged into Auto Machine in 1941 (Auto Machine Manufacturing Co. Ltd, 1941). Eclipse took over H. Hanson in 1942 (Department of Industries and Commerce, 1942).

Table 29 shows in 1965 there were still 6 nail manufacturing establishments. These would have been Auto Machine (Auckland, Wellington, Christchurch, Dunedin), PKR (Auckland) and another company located in the Wellington region (see Department of Statistics, 1973b, p. 231).

7.1.6 Nail Terminology

Unlike the USA which appears to have maintained the archaic English nail size terminology of *penny nails* (Anonymous, 1915), from the earliest records New Zealand has used length (inches or more recently millimetres) and gauge (initially imperial Standard Wire Gauge and more recently millimetres) (NZ Nail Industries Ltd, 2000, p. 12; Technical Correspondence School, 1958, pp. 33–34; Wilkins, 1968, p. 179). Even so, the term *penny nail* was widely reported in New Zealand as material extracted from American publications on the history of the name was republished in many newspapers over the years (Auckland Star, p. 5, 24 Jan 1934; New Zealand Herald, p. 6, 28 Sep 1907; New Zealand Tablet, p. 38, 11 Oct 1906). This suggests the wider public was familiar with the term, but the existing nomenclature was too strongly embedded to be changed.

Table 25 provided examples of nail advertisements from 1840 to 1872, illustrating that while dimensions were seldom given, those that exist were inches **not** penny sizes. Table 33 provides an extract from the 1863 "Permit Book" for central Whanganui district for the purchase of Ironmongery (spades and other equipment) by *friendly natives*, recorded under regulations to the Arms Act 1860 (New Zealand Government, p. 307, 6 Aug 1863, p. 354, 21 Aug 1863). It lists the purchaser, their tribe and settlement, articles purchased, date and store (White, 1863). Again, nail descriptions were all in inches.

Newspaper advertisements around the same time also used inch sizing. For example, in 1865 J. Rout of High Street, Auckland advertised a range of nails by the keg including "3in Weatherboard 3d" and "3in Ewbank's 3½ d" (Daily Southern Cross, p. 3, 23 Jan 1865).

Table 33: Extract from "Permit Book" for Friday 4th Sept 1863

Name	**Tribe**	**Settlement**	**Article**	**Date**	**Store**
Ropuhu Pahoro	Ngatipoutania	-	1/- worth 3" nails	Mon Sep 7 1863	Waters
Wtillu Mohua	Ngatipa	?	6 lb 3" nails 4 lb 2½" do. 5 lb 2" do.	19th Sep 1863	-
-	-	-	20 1½" nails 1 Short Knife	1 Oct 1863	-

Inch sizing remained in use through the peak of American nail imports in the 1880s to the early 1900s (Figure 114). In 1900, Mann & Co of Tauranga advertised "Wire nails, 2 to 6 inch, per cwt. Keg 15s 0d" (Bay of Plenty Times, p. 3, 12 Mar 1900). The 1927 Famers' catalogue included both wire and clout-head nails, all listed by length in inches (Farmers' Trading Company Ltd, 1927, pp. 100, 125). As shown in Table 27 the inch length remained in use in 1939 and even Eclipse nails advertised in a 1966 hardware catalogue used length measurements (Robert Holt & Sons Ltd, 1965, p. 86). The 1970 Fletchers Builders' Catalogue offered wire nails by gauge (5 to 20 gauge) and length (inches) for sale by weight (lb or ½ cwt) (The Fletcher Merchants Ltd, 1970).

Only one advertisement using *penny nail* has been found, but even then it was combined with an inch nail description. On 7 May 1872, John Roberton and Co.'s auction included

"Sixpenny, Eightpenny, Tenpenny Nails[12] and 4-inch Spikes" (Auckland Star, p. 3, 6 May 1872).

Thus even though nail imports from USA were significant, the term *penny nail* does not appear to have been adopted in New Zealand, while the UK terminology continued from the earliest days of European settlement.

7.1.7 Discussion

> "NAILS FROM AMERICA.
> 'I see that we are purchasing American nails; can't we get British?' asked a member at the meeting of the Napier Harbour Board on Wednesday. The chairman said the board always gave preference to British goods, but in the present case English nails were not available. Another member said he had never seen a British nail.
> The Chairman: There are a lot of storekeepers on this board.
> First Member: Yes, and patriotic ones." (New Zealand Herald, p. 5, 21 May 1923)

The earliest nails in New Zealand were brought from Europe by explorers such as Captain James Cook. Once European migration commenced, it was necessary to import European-style nails to create European style wooden housing. In the early years wrought nails were hand-made somewhere, changing over time to imported cut nails, then to imported and ultimately locally-made wire nails. Although it is not possible to state with any certainty where hand-made nails in the early years of European settlement were made, these would have been within the skills of all blacksmiths. Forged horseshoe nails were made in Christchurch in 1880.

New Zealand in the 1800s and early 1900s was an innovative society, shown not only by the number and range of patents and different types of nail, but also in the way the industry developed. The earliest New Zealand patent for a lead-headed roofing nail dates from 1883, although the first commercial directory listing for a *nail manufacturer* or *nail maker* was not until 1887.

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[12] 6d nail = 5 cm (2") long, 8d = 6.35 cm (2½"), 10d = 7.6 cm (3")

Even after the 1900s, nail making was never a major industry in New Zealand. This is unlike the USA or UK where the manufacturing scale resulted in a sizable collection of records for later historians (Loveday, 1983). Few of the early New Zealand nail making businesses continued into the twentieth century, and even then seldom retained records of their earliest days. The small industry size meant only limited official statistics were published and the commodity nature of nails limited any advertising to trade publications or company advertising sheets or catalogues, none of which appear to have survived in modern libraries or archives. Together these have resulted in the almost total disappearance of the nail industry from New Zealand's industrial history.

Analysis of the volume of imported nails compared with the construction of new houses suggests import supplies were more than adequate up to the early 1900s. From the 1860s to 1880s on average 8.6 times more nails were imported than required for house construction, while from 1886 this increased to 15.5 times. The surplus nails would have been used for construction elsewhere in the economy. The sole manufacturer (Robb & Stokes) for which a production value has been found after an extensive review of trade directories, newspapers, patents and official source, produced about 5% of the 1895 nail imports, suggesting it is highly unlikely a larger manufacturer existed. This does not close the possibility that smaller nail manufacturers in the period to 1910 remain undiscovered.

By the 1920s the local nail industry was making its own machinery, removing the need for all but specialist or large-nail making plant to be imported.

In summary, the evidence shows:

- The ready availability of lower cost nails resulted in a shift from balloon framing to platform construction between 1881 and 1886.
- In the mid- to late-19th century, not all imported nails were used for house construction, suggesting large numbers of commercial, industrial and agricultural buildings were also built in wood.
- Nail imports were initially predominantly from the UK or its Australian colonies, by 1900 American and Canadian nail imports largely replaced those from the UK;

- Local nail manufacture commenced in 1886, but it was not until 1915 that it supplied a significant part of the market, and by 1940 only specialist nails were being imported;
- At least one of the earliest (1915) local nail manufacturers used American machinery, but by the 1920s nail making machinery was made in New Zealand. By 1941, nail making machines were also imported from Australia, Germany, Britain and USA
- Only in 1939 did a UK based nail maker (PKR) commence manufacturing in New Zealand
- Nail terminology from the earliest days used English nail size terminology, not the American penny sizes (which in turn were based on archaic England terminology).

Hence, although there are strong links in both product supply and machinery to the USA, it is concluded that the nail industry was serviced from a range of countries, notably the UK.

7.2 Hollow Concrete Blocks –1904-1910

This section reviews the introduction of hollow concrete blocks to New Zealand in 1904, with the formation of the first company to promote manufacture and use. Section 6.3.4 provided a national review of the development of hollow concrete blocks from 1906 to 1981.

7.2.1 New Zealand's First Hollow Concrete Block Industry

Previous research has suggested that hollow concrete blocks were not used in New Zealand until 1909 (Thornton, 1996, p. 123) or 1910 (Ashford, 1994, p. 46). In fact it took just three years for the patent for Palmer's hollow concrete blocks to reach New Zealand, with provisional NZ patent 17,649 issued on 11 March 1904 for "A new or improved construction of stone or blocks for building purposes." This patent was issued to:

> "Niels Nielsen of Maranui, Wellington, New Zealand, Builder and George Atkinson, of Wellington aforesaid, Carpenter (nominees of Harmon S. Palmer, of 1401, Binney Street, Washington, United States of America, Inventor)" (New Zealand Government, p. 961, 31 Mar 1904).

The patent application was abandoned (i.e. complete specification not filed and the file destroyed) at some time between 22 December 1904 and 11 January 1905 (New Zealand Government, p. 64, 12 Jan 1905). Details on Palmer's hollow concrete block patents are given in Section 6.3.4.

Just under a month later, on 5 February 1905, application was made by Niels Nielsen, again as nominee for the Harmon S. Palmer Hollow Concrete Building Block Company, for an "Improved machine for moulding hollow concrete building blocks" (New Zealand Government, p. 1171, 18 May 1905). The New Zealand patent text is identical to Palmer's US Patent 727,427 issued on 5 May 1903 (application date 20 May 1902) (H. S. Palmer, 1903), including the American spelling of "mold", except for a minor change in wording in the introduction to the list of claims. The illustrations are identical, although redrawn. This became NZ Patent 19,038, gazetted on 18 May 1905 (Nielsen & Palmer, 1905).

Little is known of the origins of Niels Nielsen. The writing on the naturalisation paper (Figure 119) of Niels Nielsen of "Danmark", who had arrived in New Zealand in 1896 aged 23 years of age (Internal Affairs, 1899) matches that on the application for patent 18,666 (Figure 120) (Nielsen, 1905a), suggesting they are the same person.

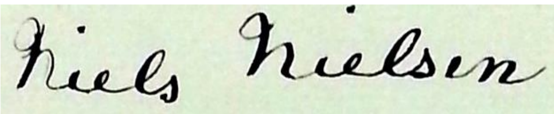


Figure 119: Signature from "Oath of Allegiance" 1 July 1899:

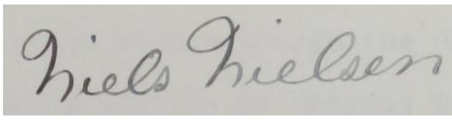


Figure 120: Signature from Patent 18666 dated 26 July 1905

Even less is known of how Nielsen learnt about Palmer's machine, how contact was made with Palmer's company or how he obtained the right to patent the machine in New Zealand.

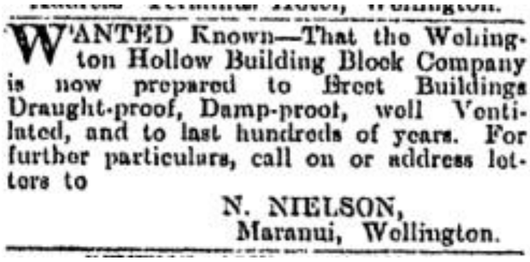
It is possible he learnt about it either through a magazine or library. Local agents were advertising mail subscriptions "posted anywhere in New Zealand" for a wide range of journals, including *Scientific American* (Otago Witness, p. 1, 7 Jan 1903). On 29 August 1903 *Scientific American* published an article on Palmer's machine including a number of illustrations of block production and use (Anonymous, 1903, pp. 148–149). Local magazines and newspapers regularly published brief extracts from overseas magazines, often many months after the foreign publication date. For example an extensive extract was provided in the *Otago Daily Times* on 12 October 1901 (Otago Daily Times, p. 12, 12 Oct 1901) from the August 1901 issue of the USA *Cement and Engineering News*.

There may also be a link through Charles William Nielsen who advertised himself as a "Barrister and Solicitor, Registered Patent Agent" (Evening Post, p. 4, 23 Jun 1902). C.W. Nielsen was authorised as Niels Nielsen's agent for patent 18,666 in 1904, but for the later patents this role was taken by the firm of Baldwin and Rayward. The timber-frame house built by Niels Nielsen after the closing of the concrete block business was for C.W. Nielsen (Nielsen, 1907c).

Table 54 (see Appendix p. 328) provides a historic timeline for activities of both Niels Nielsen and the New Zealand Hollow Concrete Block Co. Ltd. No information has been found on other aspects of his life.

7.2.1.1 Promotion and Incorporation

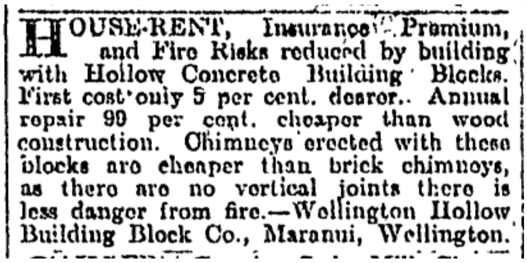
Niels Nielsen started advertising on 7 June 1904, with a series of newspaper advertisements (Figure 121 – Note spelling "Nielson" not "Nielsen") promoting buildings that were "Draught-proof, Damp-proof, well Ventilated, and to last hundreds of years" (Evening Post, p. 1, 7 June 1904). The same advertisement continued until 27 June 1904. For the advertisement on 28 June 1904 (Figure 122), Nielsen's name had been replaced by that of the Wellington Hollow Building Block Co.



WANTED Known—That the Wellington Hollow Building Block Company is now prepared to Erect Buildings Draught-proof, Damp-proof, well Ventilated, and to last hundreds of years. For further particulars, call on or address letters to

N. NIELSON,
Maranui, Wellington.

Figure 121: N. Nielsen advertisement 7 June 1904



HOUSE-RENT, Insurance Premium, and Fire Risks reduced by building with Hollow Concrete Building Blocks. First cost only 5 per cent. dearer.. Annual repair 90 per cent. cheaper than wood construction. Chimneys erected with these blocks are cheaper than brick chimneys, as there are no vertical joints there is less danger from fire.—Wellington Hollow Building Block Co., Maranui, Wellington.

Figure 122: Wellington Hollow Building Block Co. 28 June 1904

In his advertisement of 10 August 1904 Nielsen invited inspection of "Ahradson and Son's Furniture Warehouse, No. 30, Tory-street, part of which has been erected by the Wellington Hollow Concrete Building Block Company" (Evening Post, p. 1, 10 Aug 1904). This building has since been demolished. From 20 October 1904 the advertisements noted that those "who want a substantial, durable and cheap house" could see the factory and "completed houses" in Lyall Bay (Evening Post, p. 1, 20 Oct 1904). Maranui (see Figure 121) is the name given to part of the Lyall Bay foreshore facing Cook Strait, which in 1904 was part of Melrose Borough Council but is now part of Wellington (Irvine-Smith, 1948, p. 284).

Nielsen & Atkinson, as the builders, were issued with building permits by the Melrose Borough Council on 10 March 1904 for a concrete block shed and on 27 April 1904 for a hollow concrete block house on the same site, although the permit plans and associated documents no longer appear to exist (Humphris, 2012). Figure 123 shows the hollow concrete block house still on this site.

Figure 123: Lyall Bay, Wellington house

Figure 124 shows three concrete blocks (two external and one internal) from the house in Figure 123. The external blocks match those shown in Figure 125 from US patent 727,427 (NZ patent 19,038). They exhibit the shaped central core, which permits the making of half bricks, as described in the patents (Nielsen & Palmer, 1905; H. S. Palmer, 1903). The measured size of the external blocks 31" x 9" x 10" (80cm wide x 23cm high x 25cm deep) matches the dimensions given by the company (with allowance for mortar and measurement error) in Nielsen's letter of 15 Jun 1904: "the size of a full block is 31 inches long 9 inches high and gives a wall 11 inches over the rock face" (79 x 23 x 28cm) (Nielsen, 1904).

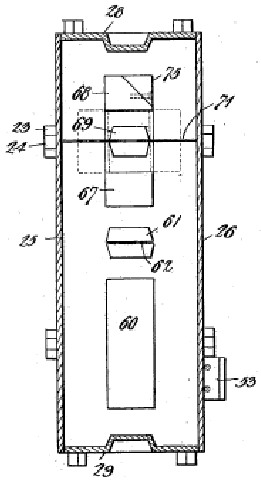


Figure 124: Blocks from Lyall Bay House. Internal block on top

Figure 125: Block Mould Illustration US Patent 727, 427 Figure 8

A search of the Building Permit books held in the Wellington City Council's archives identified three houses and one retaining wall built by Nielsen or his company. On 26 April 1904 a permit was issued by the Wellington City Council for a concrete block retaining wall shown in Figure 126 (Nielsen and Atkinson, 1904) and on 10 October 1904 for a two storey house (Figure 127) (Crichton & McKay, Architects, 1904). The Melrose Council issued a permit on 11 December 1905 for a small house made of hollow concrete blocks (Figure 128) (Nielsen, 1905b). These four constructions all still exist in 2014 (Isaacs, 2015).

Figure 126: Retaining Wall, Thompson St, Wellington

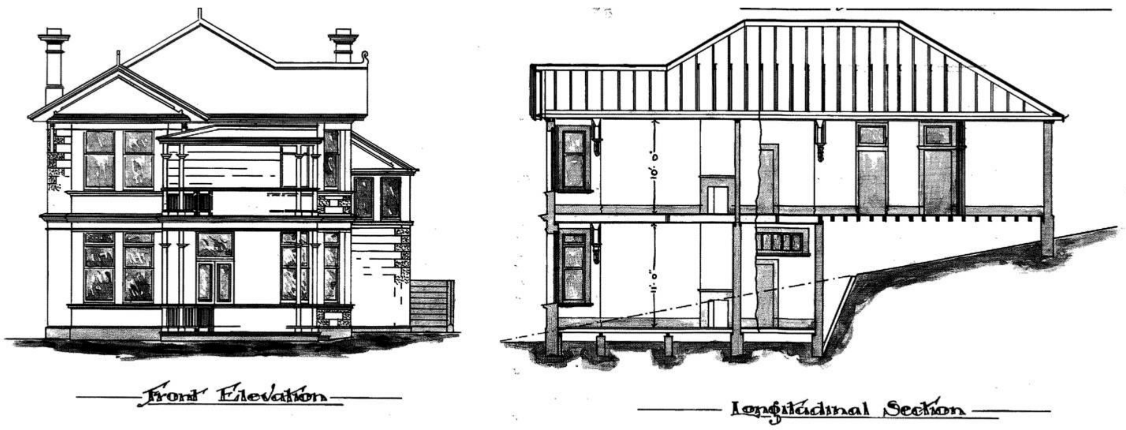


Figure 127: Roseneath House, Wellington 1904

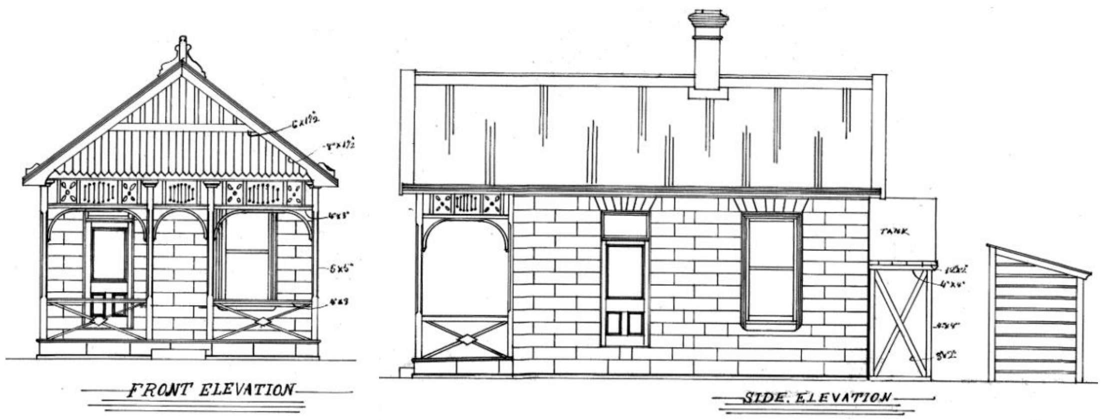


Figure 128: Lyall Bay Holiday House, Wellington 1905, 2 bedroom, Permit value £180

Figure 129: Rockface corners with fair faced hollow concrete block, Roseneath 1904

Figure 130: Rockface interleaved with fair faced hollow concrete block, Lyall Bay 1905

While the house in Figure 123 uses rock faced blocks, the next two houses used a combination of rock and plain face. Figure 129 shows only the corners of the Roseneath house were in rockface. The Lyall Bay holiday house plan in Figure 128 shows only plain face blocks, as built (Figure 130) two courses of rock face alternated with a single course of plain bocks.

Following the same practices as those used by early North American block makers (P. H. Simpson, 1999a, p. 21), Nielsen also actively promoted hollow concrete blocks to local authorities. On 15 June 1904 he wrote to the Wellington City Council requesting the building by-law be amended to allow concrete block walls to be thinner than a wall made of conventional bricks. He argued that the blocks, made of 4 parts sand to 1 part cement, had been tested to withstand a pressure of 1270 pounds per square inch (184 kPa) and had the appearance on the outside of natural stone (Nielsen, 1904). The Wellington City Engineer was not in favour, advising that if "a company wishes to have their blocks used in two storied buildings their proper course is to have a machine capable of turning out the extra thickness" (City Engineer, 1904). This view prevailed.

With business expanding, the Wellington Hollow Concrete Block Company issued a public prospectus on 14 October 1904. Shares were allocated to Nielsen for land, stocks, machinery, plant and goodwill. The annual construction of over 6,000 houses in Philadelphia was used in the prospectus to illustrate "the great strides Hollow Concrete Building Block construction is making" (NZ Hollow Concrete Building Block Company Ltd, 1904). The prospectus also reported an estimated 160,000 cubic yards (122,330 m^3) of sand on the 15 acre 23 perches (6.1 hectares) Lyall Bay site (Findlay Dalziell & Co, Solicitors, Wellington, 1904), which when removed would not only make blocks but also increase the value of the land for house construction.

The prospectus was clear on the benefits of hollow concrete blocks. It stated the "cost of erection is about 15% to 20% cheaper than brick and only 5% dearer than wood" and there was a saving of 60% to 70% in fire insurance premiums compared to wood structures. The selling price was fixed at 2s 3d per block. The daily budget (Table 34) showed two machines making 300 blocks a day (150 per machine per day) when supported by a motorised mixing machine and 5 labourers. Additional financial benefits came from the land being made available for housing through the removal of sand. Based on 275 working days per year (5½ days a week, 50 weeks per year) a gross annual profit of £4,681 5s 0d was expected (NZ Hollow Concrete Building Block Company Ltd, 1904).

Table 34: Estimated Daily Cost of Production, Sales and Profit

Materials	**£.**	**s**	**d**
24 Barrels of cement at 12/4	£14	16	0
14 yards of Sand at 4/-	£2	16	0
5 Labourers at 8/-	£2	0	0
Cost per 300 blocks	**£19**	**12**	**0**
300 blocks sold at 2s 3d	£39	15	0
MARGIN	**£14**	**3**	**0**

This production rate compares with 1906 USA rates of 100 per machine per day for 24 x 8 x 8in blocks (Rice & Torrance, 1906, p. 101) and 150 per machine per day (Newberry, 1906a, p. 20). No market prices for building materials were published in Wellington papers of the time, but 12s 4d per barrel is lower than the market prices in Dunedin of 13s 6d per barrel (Otago Daily Times, p. 1, 19 Sep 1904) and Auckland of 13s per barrel (New Zealand Herald, p. 3, 2 Nov 1904). This price may reflect a discount for bulk purchases.

Nielsen's letter to the Wellington City Council (Nielsen, 1904) included a modified (possibly in his own handwriting) advertisement from "Harmon S Palmer Hollow Concrete Building Block Co, Washington D.C. - Revolution in Building Methods" as given in Figure 131. The illustration closely followed that in the 1901 patent (Figure 78), showing only rock faced blocks. This illustration was used for the front page of the company prospectus (NZ Hollow Concrete Building Block Company Ltd, 1904).

Although the promoters had hoped to issue 6,000 shares each of £1 value, they only achieved sales of 3,200 with not all purchasers meeting the required payments in full (NZ Hollow Concrete Building Block Company, 1906). It would thus appear the company was under-capitalised from the start. Public records suggest it only built the three houses and one retaining wall noted above, and then declined.

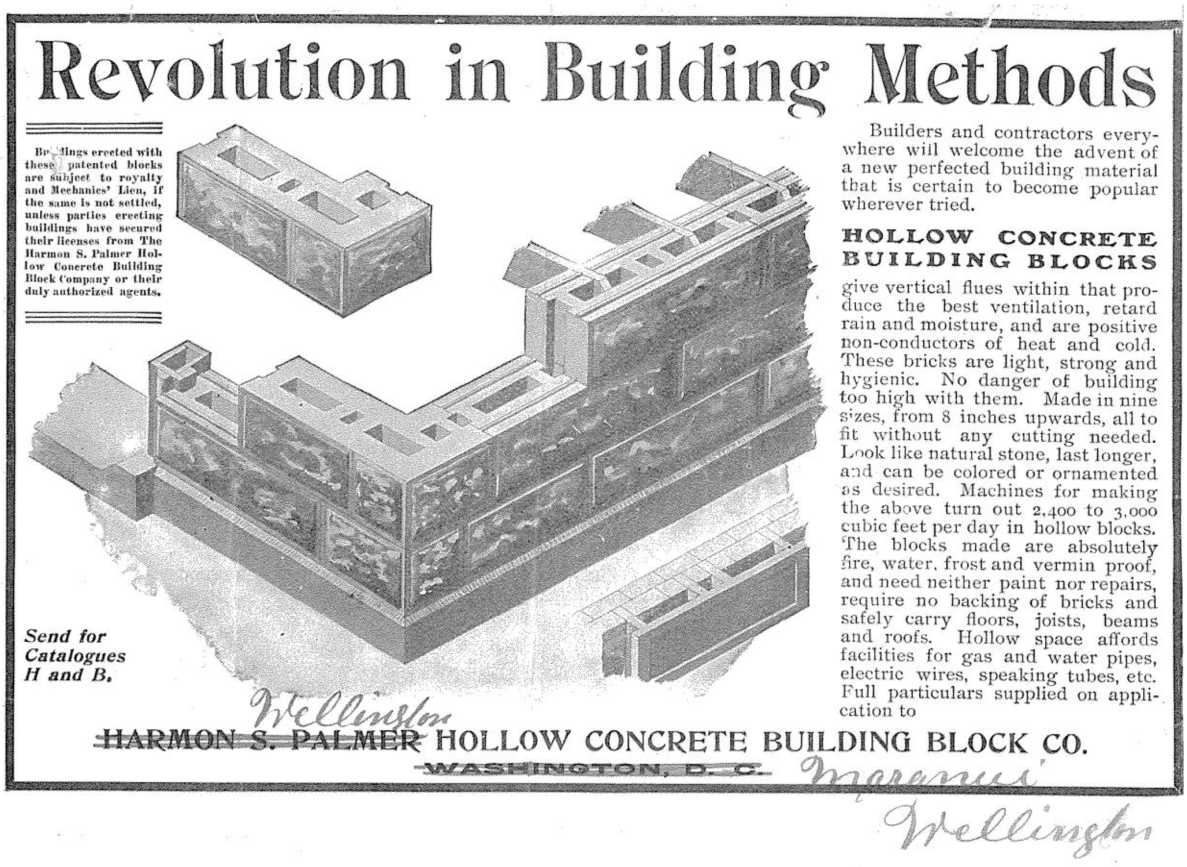


Figure 131: Modified Palmer Hollow Concrete Building Block Advertisement, 1904

The company appeared in the newspapers on 2 February 1906, when the directors were charged with failing to make a statutory declaration regarding the affairs of the company (Evening Post, p. 6, 2 Feb 1906), for which they were fined £1 and costs (Evening Post, p. 6, 12 Feb 1906). Less than 2 months later, on 20 March 1906, the Company ceased trading and was put into voluntary liquidation (New Zealand Government, p. 1137, 26 April 1906), although the process was not completed until 29 May 1934, 28 years later (New Zealand Government, p. 1660, 31 May 1934).

7.2.2 Discussion

Hollow concrete block travelled directly from America to New Zealand. The New Zealand block making machine patent was issued one year and nine months after the issuing of that patent in USA, and seven years after Palmer had first patented his block making machine. New Zealand benefitted from the delay, receiving the improved 1903 machine rather than the original 1898 version.

Similar techniques to those used by Palmer in USA were used in New Zealand to promote hollow concrete blocks to local authorities, designers, buildings and purchasers. Although rock face blocks were used in New Zealand, unlike USA they were mainly used in conjunction with plain face blocks. New Zealand also did not have the sale of block making machines to enthusiastic amateurs.

There is no direct evidence of how hollow concrete blocks arrived in New Zealand, but issues of *Scientific American* containing an article on Palmer's block were available, and a locally published article traced directly to an America (rather than UK) source. There may have also been a link between Niels Nielsen and C.W. Nielsen, the patent lawyer for the first NZ application who was also Niels Nielsen's first client after the closure of the hollow block business.

This research has identified the earliest New Zealand hollow concrete block constructions were in 1904, not the more commonly promoted 1950s. The houses made use of both rock faced (common in the USA) and plain faced blocks. Although the New Zealand Hollow Concrete Block Company Ltd did not prosper, it was the first New Zealand hollow concrete block business, with the wider industry quickly developing as discussed in Section 6.3.4. The next documented use of hollow concrete blocks was in Timaru, also using a Palmer machine (Table 51)

7.3 Camerated Concrete 1908 to 1920

Monolithic concrete has a history of NZ use from the 1850s (Section 6.3.3). Camerated concrete provides a twentieth century example of the arrival of a related technology.

7.3.1 Invention

In 1905 Henry Arthur Goddard, of Concord, Sydney, NSW patented his camerated (vaulted) concrete wall system in New South Wales (Goddard, 1905). It was patented in New Zealand in 1906 (Goddard, 1906), with a further 1910 patent for improvements to the collapsible core box (Goddard, 1910). It was patented in USA in 1908 (Goddard, 1908)

The system involved pouring concrete into formwork about 2ft (0.6m) in height with internal collapsible cores. When the concrete had set, the inner cores and exterior boards were removed, leaving a hollow concrete wall requiring a single coat of plaster to finish. The external face could be finished as desired, including having an ashlar face or being made to resemble coloured stone (Mercury, p. 2, 3 Mar 1906). Figure 132, taken from the Australian patent, shows a plan and sectional view with the collapsible core shown on the right and the wall with the core removed to the left of the "Fig 1" label (Goddard, 1905). Camerated concrete could be considered as pouring concrete blocks in-situ.

As an example of the dimensions, a camerated concrete cottage built in Nelson in 1911 had concrete walls 8¾" (220mm) deep with a 5" (127mm) cavity, and a solid concrete tie every 18" (460mm). The wall rose at the rate of a foot a day (0.3m) to the final height of 11 feet (3.4m) (Nelson Evening Mail, p. 4, 19 Aug 1911).

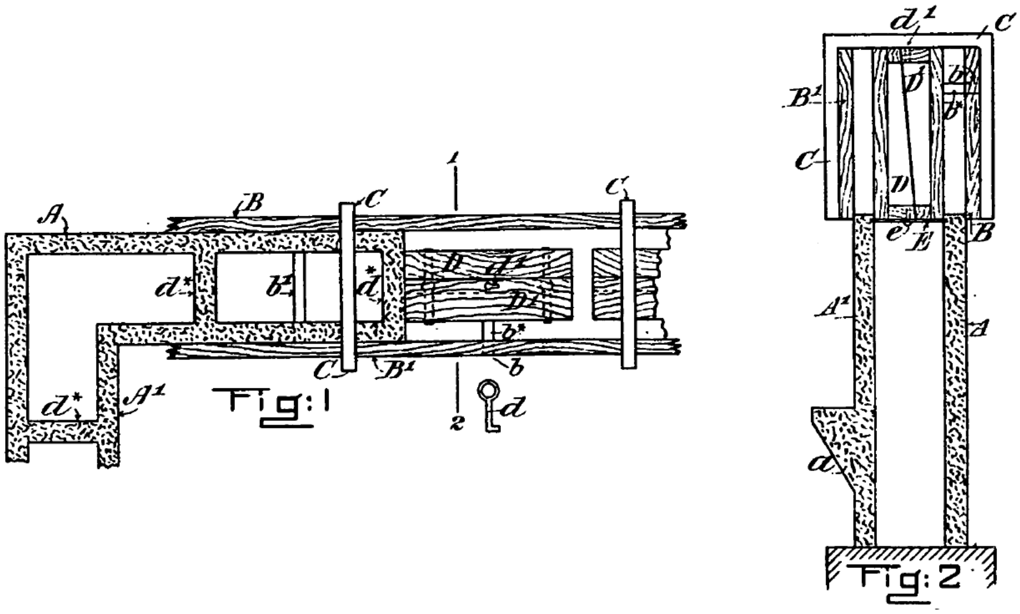


Figure 132: Plan and Cross Sectional View of Camerated Concrete Wall

About 1909, 20 houses were built by the Camerated Concrete Company on the Cintra Estate, Croydon, Sydney (Johnson, 2009, p. 95). The estate was owned by Arthur Gilbert Friend, of the W.S. Friend and Co. hardware company also of Sydney (Sunday Times, p. 5, 6 Sep 1896). A.G. Friend was an associate of Goddard (Kemp, 1995, pp. 50–52).

7.3.2 New Zealand Use

Camerated concrete was represented in New Zealand by H. Leslie Friend, with offices in Auckland and Christchurch. H. Leslie Friend was reported in New Zealand to be "a member of the family of the great Sydney hardware firm of W.S. Friend" (Observer, p. 34, 15 Aug 1908) and was A.G. Friend's brother (Commercial Publishing Company of Sydney, 1903, p.

34D–35D; Kemp, 2014). It would thus appear that camerated concrete was brought to New Zealand through the Friend family connection.

H. Leslie Friend's business represented a range of internationally sourced building products, ranging from the Malthoid Reinforced Roofing to the Emdeca Metal Decoration Co (Observer, p. 34, 15 Aug 1908). Friend actively promoted camerated concrete with regular advertisements (Progress, p. 77, 1 Jan 1909). In addition newspaper articles (The Press, p. 8, 4 Dec 1909) and local classified advertisements kept the name before the public.

As the use of camerated concrete spread, businesses began to advertise their skill. Early in 1913 Mr. George D. Ayson commenced practice in Masterton as an architect and engineer specialising in camerated concrete (Wairarapa Daily Times, p. 4, 29 Mar 1913). He advertised his services in the local newspaper each day until the end of 1914 (Wairarapa Daily Times, p. 4, 10 Dec 1914).

Local advertisements or calls for tenders for buildings were reported from 1908 to 1912 (date of first advertisement), as given in Table 35.

Table 35: Diffusion of Camerated Concrete Throughout New Zealand

• Auckland (New Zealand Herald, p. 8, 3 Sep 1908) • Hamilton (Auckland Star, p. 6, 23 Sep 1909) • Christchurch (The Press, p. 1, 2 Nov 1909) • New Plymouth (Taranaki Herald, p. 2, 25 Nov 1909) • Wellington (Evening Post, p. 6, 11 Dec 1909) • Hawera (Wanganui Chronicle, p. 7, 5 Mar 1910) • Timaru (Timaru Herald, p. 1, 30 Mar 1910)	• Eltham (Wanganui Chronicle, p. 7, 27 Jul 1910) • Takaka (Nelson Evening Mail, p. 2, 28 Feb 1911) • Napier (Dominion, p. 2, 16 Mar 1911) • Nelson (The Colonist, p. 2, 17 Mar 1911) • Whangarei (Northern Advocate, p. 4, 17 Oct 1911) • Hutt Valley (Hutt Valley Independent, p. 1, 25 Nov 1911) • Masterton (Wairarapa Daily Times, p. 1, 7 Sep 1912).

Figure 134 shows the distribution of these locations. Camerated concrete was advertised in fewer centres (14) in the 4 years after its introduction, than hollow concrete blocks (17 centres) in the first 6 years (Figure 79). Local authorities included camerated concrete in their building controls. For example, the 1912 Marton Borough General By-laws permitted the construction of side external and party walls in the town centre in "brick, stone, ferro-concrete, or camerated concrete", but interestingly not in hollow concrete block (Marton Borough Council, 1912, p. 28).

Camerated concrete was not without imitation. In 1912, Herbert Walter Shaw, builder of Upper Hutt, patented his improved means for building concrete walls (H. W. Shaw, 1912) and promoted "the Shaw 'Improved' camerated concrete patent" (Hutt Valley Independent,

p. 2, 2 Mar 1912). Shaw also patented an improved core design (H. W. Shaw, 1913), a reinforcing medium based on 2 or 3 twisted wires (H. W. Shaw, 1914a) and a complex internal wall design (H. W. Shaw, 1914b).

Shaw reportedly built a shop for Mr Gibbs and a dwelling for Mr H.R. Pearson (Hutt Valley Independent, p. 2, 27 Apr 1912). Figure 133 shows the house built for Mr Pearson on the western corner of Main and Royals Streets, Upper Hutt. Unfortunately Shaw's own home, Bezuidenhout, was destroyed by fire in August 1913 (Hutt Valley Independent, p. 3, 16 Aug 1913) but he soon announced he was to rebuild in camerated concrete (Hutt Valley Independent, p. 2, 13 Sep 1913).

In 1915 Schwartz and Coleridge, architects of Wellington, called for tenders to erect "Cottages in Camerated Concrete at Taita" (Evening Post, p. 12, 12 May 1915), although the built houses have not been found and possibly they were never built.

Newspaper reports of camerated concrete stop in 1920 (The Colonist, p. 1, 21 Apr 1920), although it is not clear whether this was due to the method becoming so well-known as to no longer require promotion, or the closing and subsequent auction of plant and equipment on 18 December 1919 of H.L. Friend's Auckland based Camerated Concrete Co. (New Zealand Herald, p. 5, 17 Dec 1919).

Figure 133: (Shaw's) Camerated Concrete House, Upper Hutt c1912

Figure 134: Distribution of Use of Camerated Concrete 1908-1912

7.3.3 Discussion

Camerated concrete was introduced to New Zealand from Australia through the family connections of its first promoter, H. Leslie Friend. From 1908 to 1912 its use spread to 14 centres throughout the North Island, and to four centres in the South Island. There does not seem to be a strong chronological link between the different places where it was advertised over this period. Camerated concrete disappeared from New Zealand newspapers post-1920, soon after the closure of H. Leslie Friend's Auckland based Camerated Concrete Company.

Unlike the other case studies, Camerated Concrete was a specific invention with its full life cycle within the research period. It provides an example of how a building technology travelled to New Zealand, showing the importance of the socio-technological pathway.

7.4 Summary

This chapter has investigated three case studies: nails, hollow concrete block and camerated concrete. Separate discussions have been provided for each case study (Sections 7.1.7, 7.2.2, 7.3.3) so are not repeated here. In each case, no previous analysis has been undertaken making this the first time such details have been reported.

Three basic methods of how the techniques came to New Zealand are illustrated by the case studies, although more than one can be used for a given technique:

- **Product**: the product became available initially through imports from overseas (nails) which was then followed by local manufacture or production
- **Intellectual property**: the product became available through the idea which was implemented in NZ (camerated concrete)
- **Machinery or manufacturing plant**: the product became available through machinery to manufacture (nails, hollow concrete block, camerated concrete)

These three basic methods were used to assess the ways in which all 64 techniques arrived – not just initially but through their life. As each technique can have more than one method of arrival, the totals do not simply add. Twenty-nine techniques arrived as directly imported products, forty-five as intellectual property or where locally invented and twenty-three as machinery or plant. Thirty-six arrived in only one way {cut nails}, twenty-three in two ways {window glass} and five in all three {cement}.

The next chapter will bring together the results from examination of the different techniques discussed in earlier chapters. It will explore the common themes and answer the research question set out in Chapter 1.

8 Discussion / Synthesis

Upon their arrival in New Zealand, European settlers adapted, imported or developed a wide range of building techniques, some of which proved to be have a limited life while others led to the 1980s urban landscape. Changes have occurred in response to the available materials, international technologies, local environment, and construction skills. This chapter brings together results from the techniques investigated in previous chapters. It examines patterns for the sources of materials and technologies, their time of arrival in New Zealand, their use and the drivers for this use and, where relevant, their obsolescence.

This research has explored the key materials (earth and fired earth, stone, cement and concrete, timber and ferrous metals) and examined the techniques which helped create the main components of the house (sub-floor, floor, wall, liming and cladding, fenestration, roof and thermal insulation). In each case, the technique has been examined from its earliest use through to recent times, and if possible its origin identified its origin. Historical timelines have been created for the a total of 64 techniques, identifying the decade of arrival, and over the period from 1792 to 1982 whether it was imported, manufactured locally or both.

Wide use has been made of published analyses and explorations of the development of New Zealand domestic architecture, but with a focus on reviewing contemporary newspapers, magazines and ephemera in order to explore as far as possible the origins of many of the techniques. This has been of particular importance in cases where new businesses have picked up older technologies and have not acknowledged (or possibly known of) the involvement of previous businesses. For the first time extensive analysis has been undertaken of the wall and roof construction questions included in the regular censuses from 1858 to 1981.

The collected data has been examined under key materials in Chapter 5, and under components in Chapter 6. The results from the case studies in Chapter 7 are now combined with the other chapters.

The numerical analysis provided in the following chapter has both positive and negative aspects. On the positive side it provides a simple way to compress and then explore the data to look for similarity and differences, and as a result opens up the data for further investigation. On the negative side, simple numerical analysis makes the assumption that all techniques are equal. This is clearly a simplification, as for example Pearse's Patent Concrete Cavity Wall was never as important as Air Drying of Timber. While accepting this limitation, the analysis raises questions which can be subject to more complex comparisons.

Examples of relevant techniques explored in the previous chapters are given in Chapter 8 in braces {}.

8.1 Eliminated Techniques

Although necessary to a full understanding of the development of the New Zealand house, twelve techniques listed in Table 36 have been excluded from further analysis. Three were important at the time of use but do not have direct links to the houses of the 1980s, six were methods of production, and three are included under other headings.

Table 36: Techniques Excluded from Analysis

Section	Technique	Start Decade Import /Use	Start Decade Made	End Decade Import /Use	End Decade Made	Reason for Exclusion
5.1.1	Raupo and Other Native Plants	1790		1870		No links to modern house
5.5.3.1	Pit-saw	1790		1910		Production
5.5.3.2	Hydro-power saw	1830				Production
5.5.3.2	Power saw (steam, petrol, electric)	1860				Production
5.6	Steel	*1880*	1960	1980	1980	Production
5.5.1	Native Forests	1840	1790	1960	1960	Production
5.5.2	Exotic Forestry	1840	1930	1980	1980	Production
6.3	Log Walls/Cabin	1790		1900		No links to modern house
6.3	Slab (Timber)	1840		*1900*		No links to modern house
6.6.1	Window Glass – Imported	1840		1980		Included in Window Glass
7.1	Nails Case Study – Imports	1840		1980		Included in Nails
7.1	Nails Case Study - Manufacturing		1880		1980	Included in Nails

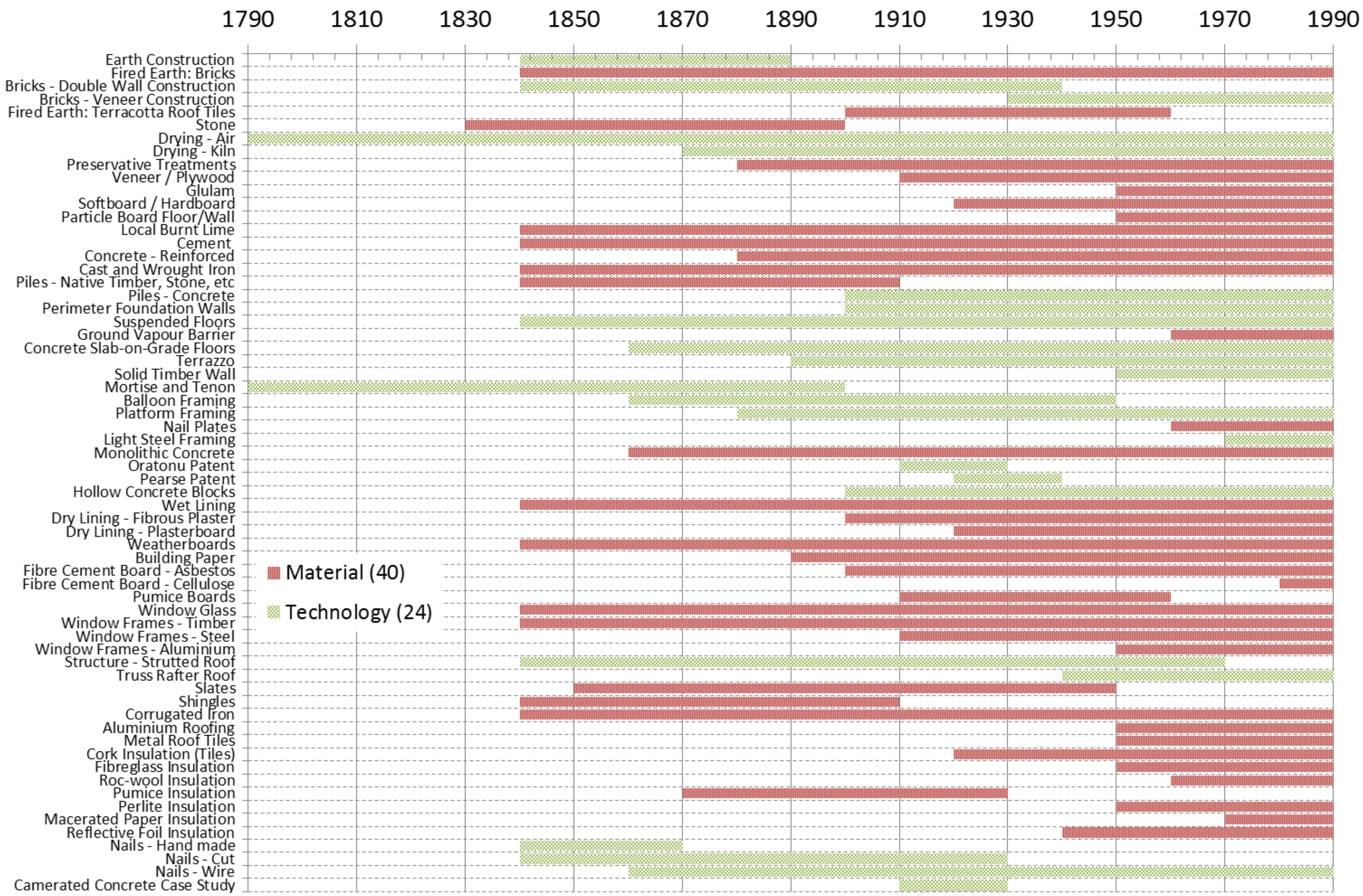


Figure 135: New Zealand House Techniques – Time Line

8.2 Chronological Overview

Table 57 (see Appendix starting p. 331) provides a detailed summary for 64 techniques based on the material presented in the previous chapters. Table 57 gives the start and end decade of use and manufacture, relevant component(s), whether it is still in current use, whether it is used with timber framing, and country(s) of origin.

Figure 135 plots a time line for each technique. The time axis in this and other graphs in this chapter runs to 1990 to include cellulose fibre cement board. Techniques are separately identified as either material (red, 62% of the total) or technology (green, 38%).

Of particular interest in Figure 135 are the large numbers of techniques which remained in use into the 1980s, with just over a quarter (27%) stopped being used by 1982

8.2.1 Start and End Dates

For some techniques, the start and end years can be determined from specific references, such as the date hollow concrete blocks were patented. In other cases it is necessary to use official statistics, whether census or import (Chapter 4). Import statistics tend not to include a specific material or technology until its use is large enough to be noticed. For example, plaster board does not appear in the import statistics until 1936, although it was imported from at least 1923 (Section 6.4.2.2).

Table 37, based on the data used in Section 4.1, provides an analysis of census data for 12 wall constructions and the catch-all *other* category. The top row gives the census date, while the second row is the inter-census total population average annual per cent growth (Statistics New Zealand, 2006b, p. 13). Each cell provides the results of the tests described below for each of the named wall construction type.

As both population and number of dwellings have increased over time, a combined test was used to determine whether the wall construction material continued in use. Firstly was there an increase of 100 or more dwellings with walls of the specified type in that inter-census period? A zero change or decrease would suggest the material had become obsolete. Secondly had the percentage growth in the number of dwellings with that wall construction increased by more than the population increase? Based on the results of these tests, a cell in Table 37 can be one of three colours (white, green or red), as shown in the key.

Table 37: Inter-census Annual Change for Different Wall Constructions

Census	1858	1861	1864	1867	1871	1874	1878	1881	1886	1891	1896	1901	1906	1911	1916	1921	1926	1936	1945	1951	1956	1961	1966	1971	1976	1981
Population Change %/yr							7.3%	5.1%	3.1%	1.5%	2.1%	1.9%	2.8%	2.5%	1.5%	2.3%	2.1%	1.1%	0.8%	2.4%	2.3%	2.1%	2.1%	1.4%	1.8%	0.3%
Asbestos																	42%	3%	1%	157%	7%	15%	5261		13%	
Brick		18%	42%	3%	8%	8%	14%	8%	5%	2%	3%	3%	755	3%		4%	8%	4%	9%	6%	6%	9%	9%	8%	4686	3%
Canvas		55%	26%	7%			44%			5%			265													
Concrete								See Brick								14%	20%	5%	4%	8%	3%	7%	8%	5%	28%	4%
Earth														27%						F					119%	
Iron							9%	6%	4%	2%	3%	3%	3%	3%		F	26%	6%		3%				17%		23%
Raupo				19%																71%						
Roughcast																		8%	13%	12%	20%		9%	16%	9%	
Stone		See Brick					See Brick										3%	F	F	4%		22%	40%		F	
Timber		16%	23%	18%	5%	4%	9%	6%	4%	2%	3%	3%	3%	3%	2%	18842	22531	2%	22443	3%	34944	25886	24291	11719	17040	
Wood, Iron or Lath & Plaster							9%	6%	4%	2%	3%	3%	3%	3%												
Wallboard																		9%	45%			42%				
Other		55%							12%	F			43%		14%	3%		9%	44%	17%			631	48%	10%	

KEY

	White: decrease or no change in number of dwellings
Value	Green: Either the increase in the number of dwellings > 100 OR % annual change > inter-census % annual change
F	Red: Either the absolute number ≤ 100 OR % annual change ≤ inter-census % annual change

A number in a cell in Table 37 indicates there were that number of additional dwellings with the given wall construction, but the growth was less than the inter-census average annual population growth. A percentage value is given in Table 37 when the growth of that construction was greater than the inter-census average annual population growth.

An isolated single white or red cell in Table 37 could be due to a real change in the use of a given wall type or related to a range of possible census errors including the respondent's lack of knowledge. Only one wall material, stone, has two census periods with lower than 100 or less than population percentage increase of new dwellings.

The census does not list stone wall dwellings separately until 1916, and even then the numbers (alone or in combination with other materials) increase from 1,284 in 1916 to just 1,683 forty years later in 1956. To determine an end date for the wide spread use of stone construction, the availability of quarried stone provides assistance. By 1891 there were only nine stone quarries, all in Otago (Section 5.3). It would seem likely that traditional stone wall construction was no longer in wide use by 1891.

Census data on earth wall construction does not appear until 1874, but the number of dwellings continues to fall to 1,714 in 1906 and then increases to 4,019 in 1911, an average increase of 461 dwellings per year. Although earth houses continue to be reported, the numbers still fell through to 1981. It has been assumed that earth construction was no longer in wide use by 1880, although there was new earth construction from the 1950s (Section 5.2.1). Research into earth construction in the Tasman-Nelson district found no earth houses built between 1916 and 1948 (Hall, 2012, p. 22).

Corrugated iron as a separate cladding material first appears in the 1874 census, continues in use throughout the period but is not separately enumerated until 1916. The number of iron walled houses increases in the 1921, 1945, 1956 to 1966 and 1976 censuses, but overall the numbers have fluctuated below 10,000 dwellings. This is different from the use of corrugated iron for roofing, so it has been assumed that overall corrugated iron (or its replacement, long-run roofing) has remained in use for the shell through to the 1980s.

The colour bars in Table 37 provide an overview of changes not only in the use but also the importance of different cladding materials over the 122 years of census data to 1981.

Excluding the 1916 Census (post-WWI), only timber and brick showed growth for 24 of the 25 censuses.

8.2.2 Components

Figure 136 plots the number of techniques by house component. The largest number is associated with walls (26%) followed by floors (17%) and sub-floors (13%). Table 38 gives the count of techniques with the number of components. The majority (72%) are associated with only one component {hollow concrete blocks with walls}, while the rest are with 2 or more components {nails in all components but fenestration}. This explains why the total count in Figure 136 is greater than sixty-four.

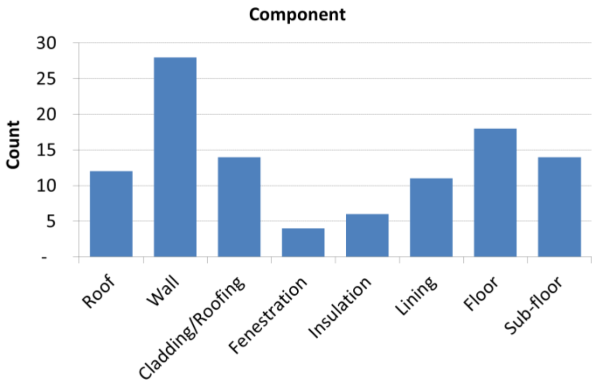


Figure 136: Techniques by Component

Table 38: Count of Techniques by Components

Number of Components	Count	%
1	46	72%
2	9	14%
3	2	3%
4	1	2%
5	3	5%
6	3	5%

8.2.3 Country of Origin

Figure 137 gives the country of origin, defined as the main country from which the specific technique first travelled to New Zealand in significant quantities. A technique can be:

- **Generic**: in use over such a long time that no direct origin can be determined or may have come from any number of possible countries so one single country can be readily identified {air drying of timber}
- **Unknown**: original country is unknown or cannot be determined {fibrous plaster }
- **New Zealand**: invented or patented in New Zealand {Pearse's Patent Concrete Cavity Walls}
- **Australia**: invented in Australia {Camerated Concrete}
- **UK** or **USA**: originated in the relevant country {double-brick cavity wall or polythene DPM on sub-floor earth}

- **Other**: from another identified country {Marseilles terracotta roof tiles from France}

Figure 137 shows similar percentages of techniques trace their origins to the UK (26%) and USA (24%).

Of the 64 techniques, it was not possible to identify a country of origin for 6 (9%). Over two-thirds (69%) could be traced to one single country, while 15 (23%) were generic in origin (Table 39). The country for each technique is given in Table 57.

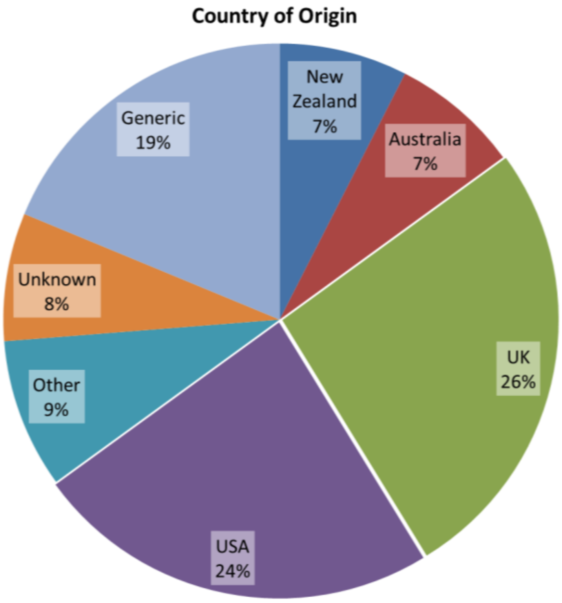


Figure 137: Country of Origin

Table 39: Source of Techniques by Number of Countries

Number of Countries	Count	%
Generic	15	23%
Unknown	6	9%
1	29	45%
2	12	19%
3	2	3%
4		
5		
TOTAL	64	100%

Six techniques were identified as New Zealand in origin or indigenous: modern solid timber walls; Oratonu and Pearse patent concrete constructions; pumice boards; metal roof tiles; and the use of pumice as wall insulation.

Figure 138 plots the countries of origin of the different components. Note that a technique may have more than one country of origin (see Table 39).

Figure 138 shows the comparative importance of USA and UK which are the origins for 50% or more of the techniques for all components. As a nation New Zealand may have considered itself as more British than Britain, (King, 2003, p. 175) but the direct links were to USA not UK. This links with Toomath's identification of an "unexpectedly constant, if clandestine, liaison" with the USA (Toomath, 1996, p. 3) with respect to the development of the appearance of the New Zealand house. It is, however, not as strong as Pevsner's earlier view of New Zealand architects: "Their roots are in Britain, but their eyes are on the United States" (Pevsner, 1959, p. 152).

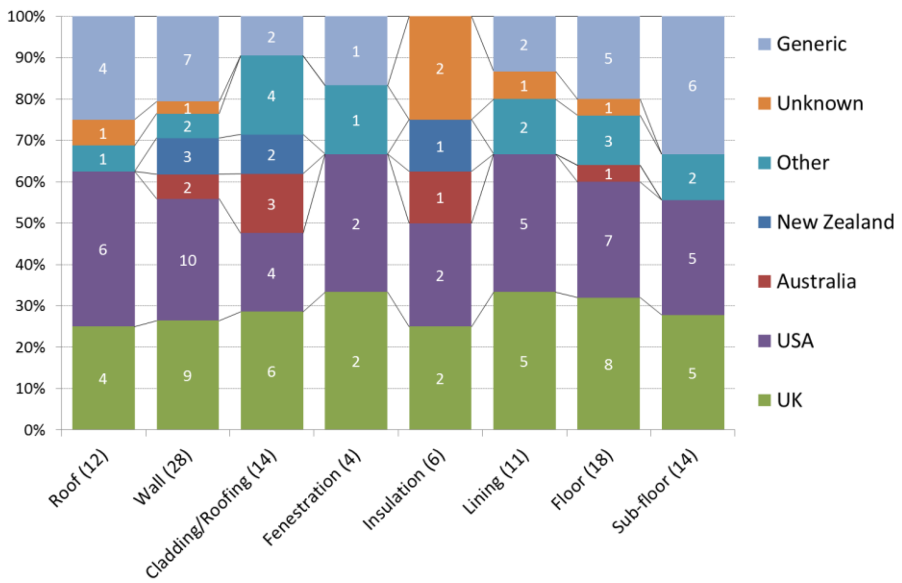


Figure 138: Components by Country of Origin

Figure 139 compares the country of origin with whether the technique was (Yes) or not (No) still being used at the end of the study period. Techniques originating in the UK or USA are nearly twice as likely to be still in use (58%) compared with those not still in use (33%).

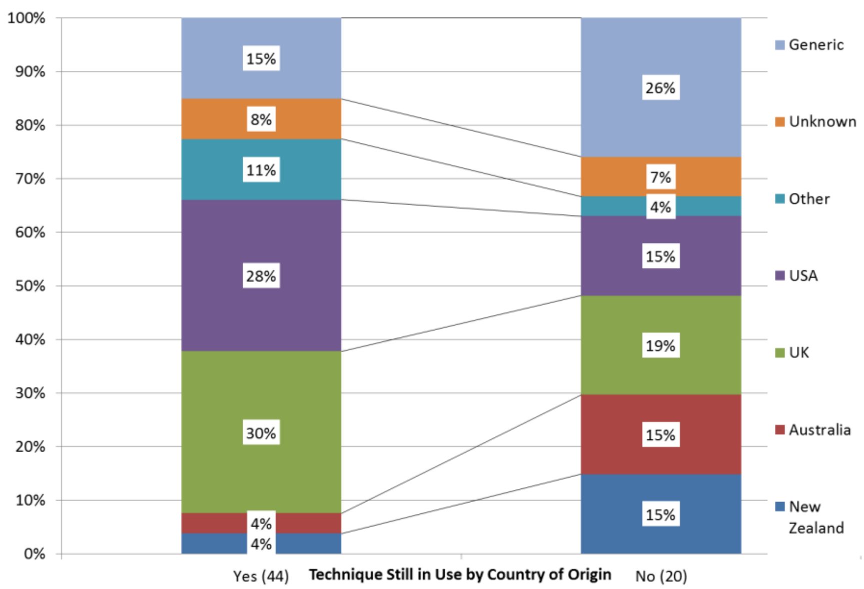


Figure 139: Technique Still in Use by Country of Origin

8.2.4 Arrival and Departure

> "Officials have advised that performance-based regulation is not in itself a flawed philosophy, and is superior to the highly prescriptive 'command and control' system that it replaced. It is the prevailing philosophy internationally in the building area, and has the benefit of encouraging innovation." (Hawkins, 2002, p. 6)

If the 'command and control' system of building controls was as limiting to innovation as was considered to be the case by the 1990s, then it could be expected that comparatively few techniques would have been introduced in the middle of the 20th century. Although this research does not claim to have explored every new technique introduced into the construction industry, it provides a detailed range for investigation. Section 8.2.1 uses census data to examine 13 wall constructions, while this section uses the data from previous chapters to examine the different techniques.

Figure 140 plots the techniques count by start and end decade. The former is the decade in which the technique started in use or manufacture in New Zealand and the latter is either when the technique was no longer mainstream or its use had stopped.

For example, the first evidence of the use of terracotta tiles was in the 1900s, but their local manufacture commenced in the 1910s and ended in the 1950s along with their wider use. They were still imported for replacement roofs. For Figure 140, the use of terracotta tiles is taken as starting in the 1900s and ending in the 1950s.

Nails provide a more complex situation. Nail imports peaked around 1910, falling to very low levels by 1945 as local manufacture took over. However, nails continued to be imported although more for specialist uses (Section 7.1.2). For this research, nail imports are assumed as continuing into the 1980s.

Figure 140 shows there are peaks in the introduction of new techniques in the 1840s and 1950s, with secondary peaks in the 1900s and 1910s.

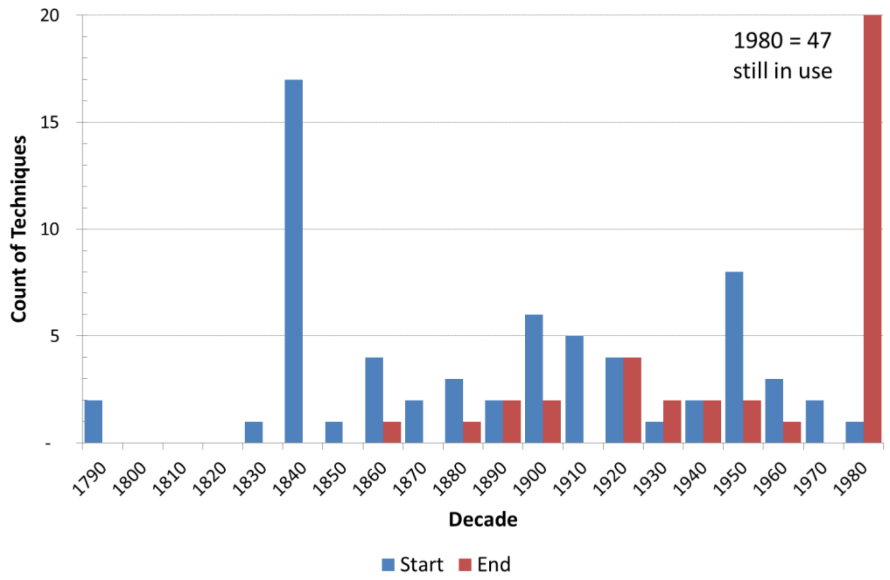


Figure 140: Technique Start or End of Use by Decade

Table 40 tabulates the number of techniques by start and end decades. For example, in the 1860s, use commenced of four techniques {Concrete Slab-on-Grade Floors; Balloon framing; Monolithic Concrete; and Wire Nails}. They all remained in use until the 1940s, when in the next decade one became obsolete {Balloon Framing} while the other three continued.

Table 40: Technique Count End Decade Cross-tabulated by Start Decade

Start Decade	End Decade (end of use or manufacture in NZ)																				% still in use 1980s
	1790	**1800**	**1810**	**1820**	**1830**	**1840**	**1850**	**1860**	**1870**	**1880**	**1890**	**1900**	**1910**	**1920**	**1930**	**1940**	**1950**	**1960**	**1970**	**1980**	
1790	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	50%
1800		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
1810			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
1820				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
1830					1	1	1	1	1	1	1	-	-	-	-	-	-	-	-	-	0%
1840						17	17	17	16	16	15	15	13	13	12	11	11	11	10	10	59%
1850							1	1	1	1	1	1	1	1	1	1	-	-	-	-	0%
1860								4	4	4	4	4	4	4	4	4	3	3	3	3	75%
1870									2	2	2	2	2	2	1	1	1	1	1	1	50%
1880										3	3	3	3	3	3	3	3	3	3	3	100%
1890											2	2	2	2	2	2	2	2	2	2	100%
1900												7	7	7	7	7	7	6	6	6	86%
1910													5	5	3	3	3	2	2	2	40%
1920														4	4	3	3	3	3	3	75%
1930																					
1940																2	2	2	2	2	100%
1950																	8	8	8	8	100%
1960																		3	3	3	100%
1970																			2	2	100%
1980																				1	100%
% start	3%	0%	0%	0%	2%	27%	2%	6%	3%	5%	3%	11%	8%	6%		3%	13%	5%	3%	2%	100%

The far right column gives the percentage of techniques introduced in the given decade that were still in use in the 1980s while the bottom row gives the percentage introduced in the given decade. These are further considered in Table 41.

Figure 141, plots the percentage of the techniques in use by decade based on Table 40. The trend, already shown in Figure 135, was that once techniques became used they continued in use, with few becoming obsolete. A flat period in the 1930s and 1940s reflects the impact of the Great Depression and WWII.

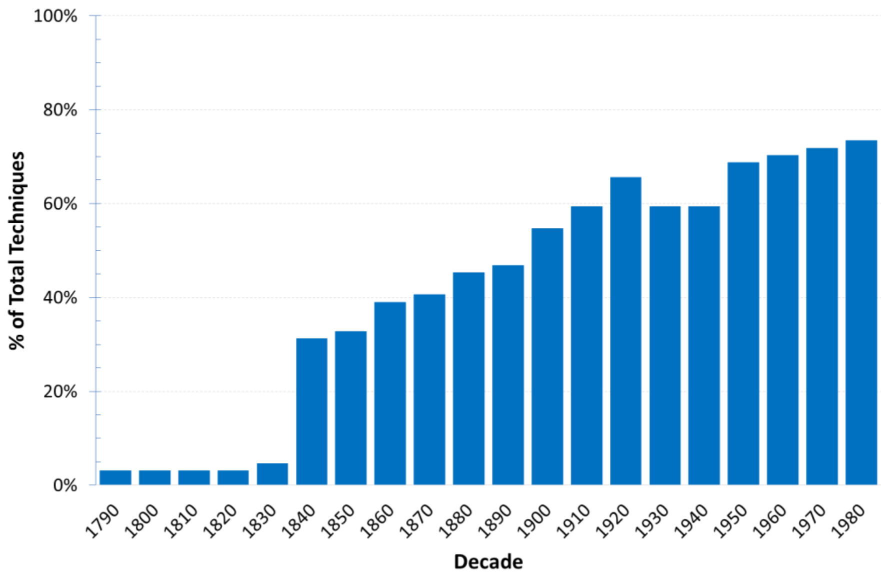


Figure 141: Per cent of Techniques in Use by Decade

Table 41 lists only techniques which were no longer in use in the 1980s. It provides the relevant thesis section, grouping (material or technology), and the decade when either its use, import, or manufacturing started and ended. In some cases the technique was first imported, and then locally manufactured. The last column records if the technique was manufactured in New Zealand.

Where an estimate of the decade has to be made, it is given in ***bold italics***. It has been assumed that use of braced framing overlapped the use of balloon framing for three decades.

Eight of the seventeen techniques no longer in use by the 1980s had originally arrived with early European settlers (1790s – 1850s). These were replaced due to their:

- **higher cost or speed of construction** {Terracotta tiles, Braced framing, Balloon framing, Slates, Pumice Insulation, Hand-made nails, Cut-nails};
- **poor durability** {Earth construction, Timber piles};
- **poor structural or earthquake performance** {Double-wall brick, Stone piles; Strutted rafter roof};
- **poor fire performance** {Shingles}; or
- **poor performance** {Pumice board, Oratonu, Pearse and Camerated concretes}.

Table 41: Techniques That Stopped Being Used Before 1980s

Section	Technique	Group	Start Decade		End Decade		Made in NZ	Replaced due to
			Import /Use	Made	Import /Use	Made		
5.2.1	Earth Construction	Technology	1840		1880			Durability
5.2.2.2	Bricks - Double Wall Construction	Technology	1840		1930			Structural
6.7.4	Fired Earth: Terracotta Roof Tiles	Material	1900	1910	1950	1950	Yes	Cost
5.3	Stone	Material	1830		1890			Structural
6.1.1	Piles - Native Timber, Stone, etc	Material	1840		***1900***			Durability
6.3.1.3	Braced Framing	Technology	***1790***		***1890***			Cost
6.3.1.3	Balloon Framing	Technology	***1860***		***1940***		Yes	Cost
6.3.3.2	Oratonu Patent	Technology	1910		1920		Yes	Performance
6.3.3.3	Pearse Patent	Technology	1920		1930		Yes	Performance
6.5.4	Pumice Boards	Material		1910		1950	Yes	Performance
6.7.1	Structure - Strutted Roof	Technology	1840		1960		Yes	Structural
6.7.2	Slates	Material	1850		1940			Cost
6.7.3	Shingles	Material		1840		1900	Yes	Fire
6.8.2	Pumice Insulation	Material		1870		1920	Yes	Cost
7.1	Nails - Hand made	Technology	1840	1840	***1840***	***1860***	Yes	Cost
7.1	Nails - Cut	Technology	1840		***1920***			Cost
7.3	Camerated Concrete	Technology	1910		1920		Yes	Performance

8.2.5 Local Manufacture

Figure 142 gives the country of origin for the 37 materials and technologies that were made in New Zealand. Almost the same percentage of techniques manufactured in New Zealand trace their origins to the UK (26%) or USA (23%) as for all techniques (Figure 137).

Table 39 shows 5 techniques were generic and it was not possible to identify a country of origin for a further 6. Table 42 shows that the origins of just under half (49%) of the techniques made in New Zealand could be traced to a single country.

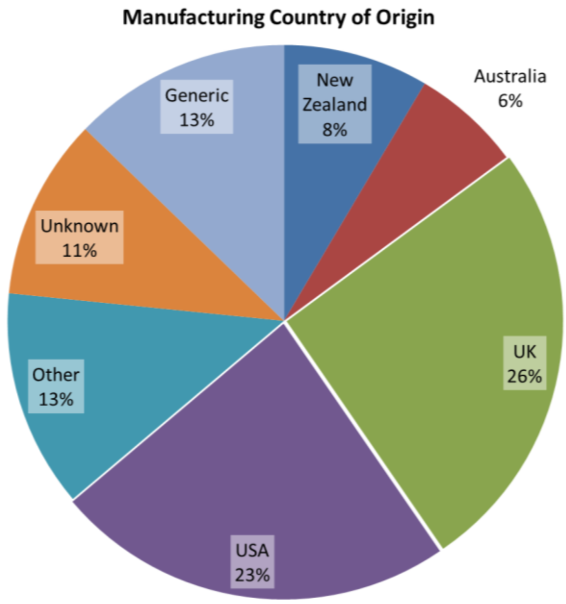


Figure 142: Manufacturing Country of Origin

Table 42: Source of Manufacturing Technique by Number of Countries

Number of Countries	Count	%
Generic	6	16%
Unknown	5	14%
1	18	49%
2	6	16%
3	2	5%
4	-	0%
5	-	0%
TOTAL	37	100%

Figure 143 plots the count of techniques manufactured in New Zealand by start or end decade. Manufacturing is taken as New Zealand mass production of the material or technology. For example the manufacture of New Zealand invented cement pumice boards started in the 1910s and finished in the 1950s. Manufacturing normally commenced some years after the technique was first used {asbestos cement board arrived in the 1900s but manufacture did not occur until the 1940s}, unless the technique was generic or was a New Zealand invention.

Figure 143 shows a reasonably even spread of manufacturing introduction and finishing decades, with peaks in the 1840s, 1910s and 1950s. Apart from around the Great Depression (1930s) new techniques continued to be introduced.

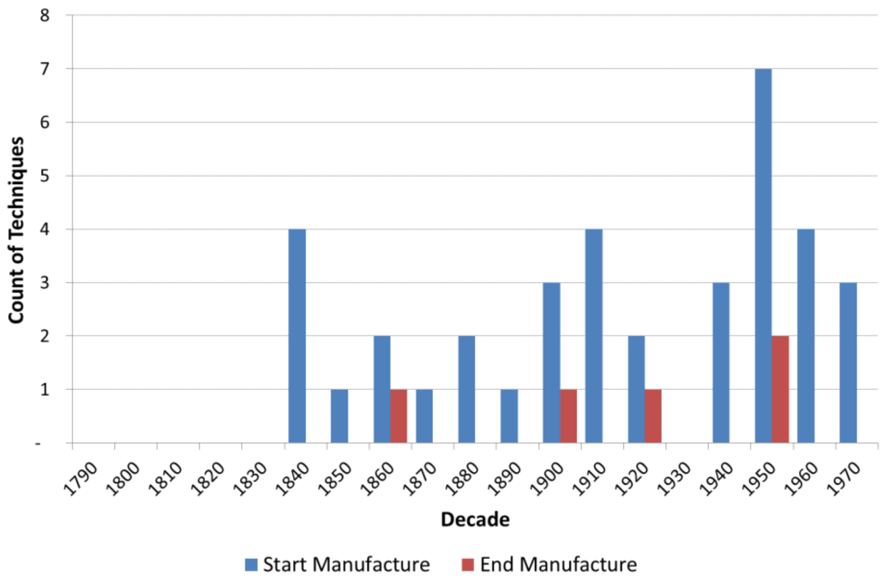


Figure 143: Start or End of Manufacture by Decade

Perhaps unsurprisingly, the largest number of new techniques to be locally manufactured occurred in the first decade after the signing of the Treaty of Waitangi. This was most likely due to the increasing numbers of European settlers, bringing with them not only European style housing but also the associated construction techniques {Bricks, Local Burnt Lime, Slab, Weatherboards, Shingles}.

In the 1910s new techniques arrived from Europe {Terracotta Roof Tiles, Veneer and Plywood, Metal Window Frames} as well as New Zealand and Australian inventions for in-situ {Oratonu Patent, Camerated Concrete} and prefabricated concrete {Pumice Boards}. This decade also saw the results of government policies to improve housing conditions and reduce costs. These included the first state houses to be built under the Workers' Dwellings Act 1905 and loans provided under the Government Advances to Workers Act 1906 (Ferguson, 1994, p. 59).

Following WWII, the 1950s saw the need for housing coupled with international materials shortages spurdevelopments such as manufactured timber products {Glulam; Particle Board; Solid Timber Wall}, metal components {Aluminium roofing, Aluminium Window Frames, Metal Roof Tiles} and thermal insulation {Perlite Insulation, Reflective Foil Insulation}.

Figure 144, using the data in Table 57, compares the origins of the 37 techniques manufactured in New Zealand with the origins of the 27 not manufactured locally. Techniques of unknown origin are less than 5% in both cases There are differences between the local manufacture or non-manufacture of techniques originating from the USA and UK. Figure 145 (based on Table 57) shows that if a technique traced its origins to Australia, UK or was generic in origin, it was more likely not to be made in New Zealand.

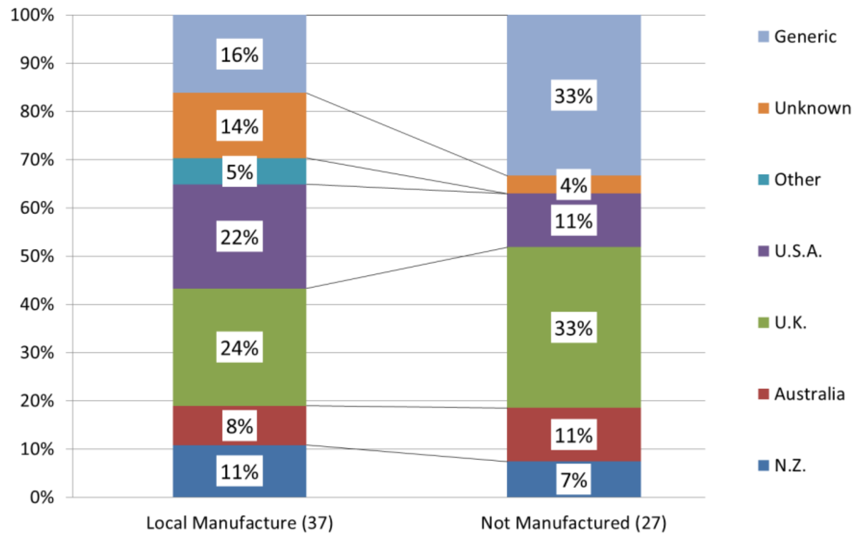


Figure 144: Origins of techniques made or not made in NZ

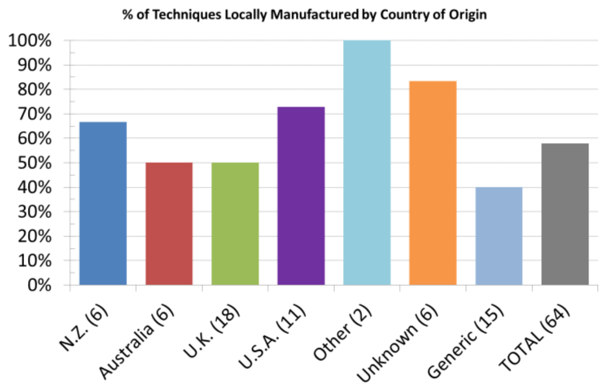


Figure 145: Percent of Techniques Locally Manufactured by Country of Origin

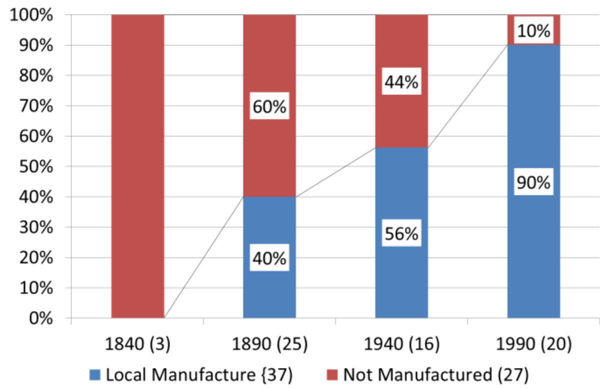


Figure 146: Start period of techniques made or not made in NZ

Figure 146 looks at the time period (50 year blocks labelled by end year) in which the techniques started manufacture or, if not made in New Zealand, started use. The number of techniques introduced in each period are given in brackets (). No local manufacture has been found for overseas techniques that arrived in the fifty years up to 1840 (1790 to 1839), but this is perhaps not surprising given the small numbers of settlers. Local manufacture commenced with techniques that arrived in the next fifty years to 1890, but the following hundred years show an increasingly industrialised country with 90% of the new techniques being locally made in the last half century.

8.2.6 Age of a New Zealand House

The documenting of when different techniques arrived in New Zealand can be used to help establish the age of a house, although this is not true for all techniques. For example, even a specialist would be unlikely to differentiate between imported and locally made general cement without chemical analysis.

The following figures divide the house into the different components to examine the different materials and technologies used by decade. Detailed descriptions have been provided in the relevant sections in Chapters 4, 6 or 7, so only a brief overview is given here.

Figure 147 examines the materials likely to be visible or possibly hidden but still observable in the existing roof. Native plant roofing (including raupo) has not been included (Table 36). Later roofing materials, made from steel, terracotta, slate and fibre-cement stiffened initially by asbestos and then cellulose fibres, were more durable. Apart from the very early years, where raupo and other native plant materials were the only roofing material, there have always been at least three, and up to six, different roofing types available for use.

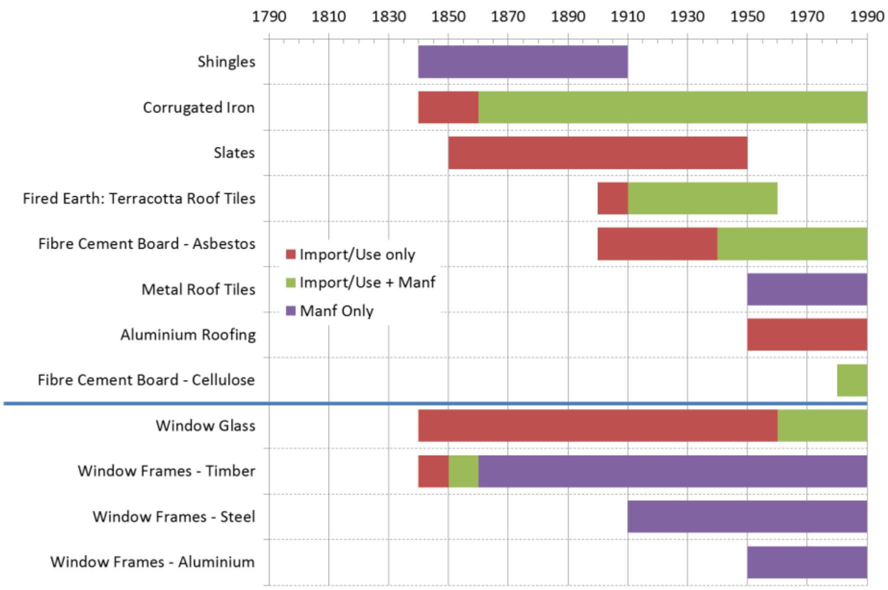


Figure 147: Roofing and Fenestration

Figure 147 also documents the different materials used for fenestration. Glass was imported throughout the period, but local manufacture commenced in the 1960s servicing the general window glass market. While timber-frames were initially imported, local manufacture soon commenced, followed eventually by steel and then aluminium window frames.

Figure 148 provides a timeline for timber-framed wall construction, excluding native plant materials and logs. Interest in USA style log cabins grew in the 1980s, although only small numbers were built. Proprietary solid timber walls commenced manufacture in the 1950s, although initially only in small numbers. Framing styles changed over time, although there were decades of overlap of the three main types of braced framing, balloon and platform framing used, albeit differently, in different parts of the country.

Although building paper was available and advertised from the late 1890s, it was not widely used nationally until mandatorily required in 1964. While slab cladding had limited use, weatherboards, locally made or imported, were widely used. As noted above, the use of corrugated iron for walls had fallen out of favour long before its decline as a roofing material. Asbestos fibre-cement board, brick veneer and eventually cellulose fibre-cement boards started to become more used than weatherboards from the 1920s.

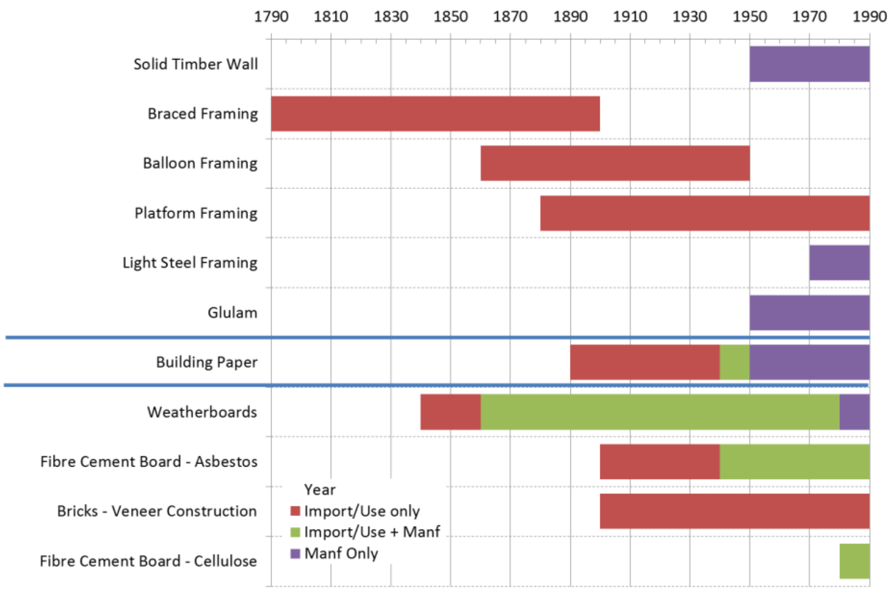


Figure 148: Wall: Timber-frame

Figure 149 is concerned with non-timber-framed wall construction. Stone wall construction was not widely used, and apart from a small rise in the 1961 and 1966 censuses, total numbers were largely unchanged from the 1,540 dwellings reported in the 1871 Census. Dwellings of earth construction increased to 2,389 in the 1901 Census, and then (excluding a rise in 1911) decreased. Local sources are likely to provide the most accurate dating of these types of wall construction. Although bricks were manufactured locally from the 1840s, double wall brick construction was not used after the 1930s. Locally made hollow concrete blocks were used from the 1900s.

Locally manufactured pumice boards were in use from the 1910s to 1950s. Light steel framing, effectively replacing timber with folded steel, came into use in the 1970s.

Although early monolithic concrete dates from the 1880s, it was at least another two decades before reinforced monolithic concrete was in use. The origins and use of three variations of monolithic concrete have also been explored, one from Australia and two from New Zealand.

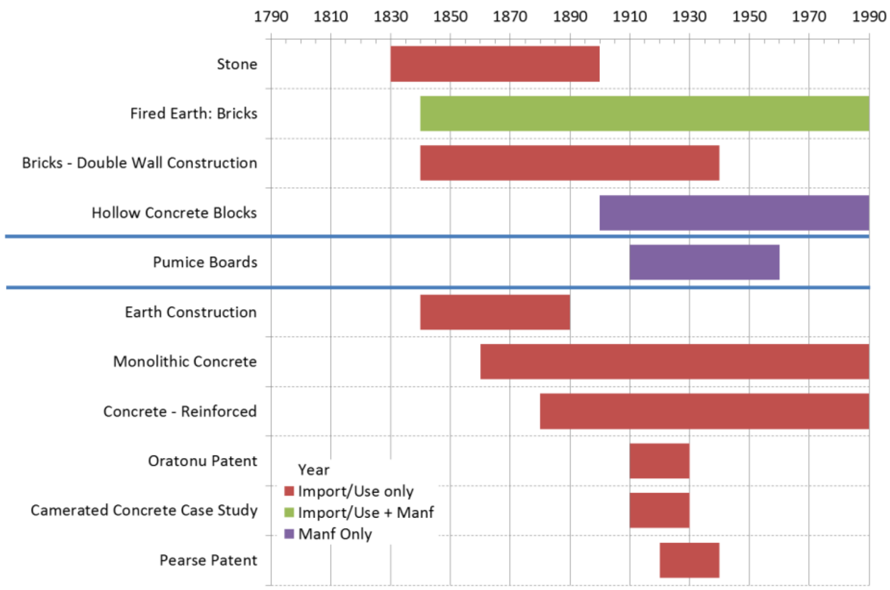


Figure 149: Wall: Non-timber-frame

Floor technologies and materials are plotted in Figure 150. Earth floors had limited use (not plotted) and were soon replaced by suspended timber floors. P.T.&G. floorboards were in use through to the 1980s. Plywood became available in the 1910s although it was not widely used for flooring for some years. Particle board was used for floors from the 1950s. Light steel floor framing was locally manufactured from the 1970s.

Concrete slab-on-grade floors started in the 1860s, while terrazzo was being made from the 1890s.

Cork tiles as a type of insulation were in use from the 1870s. Reflective foil insulation became available in the 1940s, although it was not until the 1970s that it entered wide use due to mandatory thermal insulation requirements.

Figure 150 also plots the nail case study for imports and local manufacture, along with the three main types of nails (hand-made, cut and wire), and later nail plates.

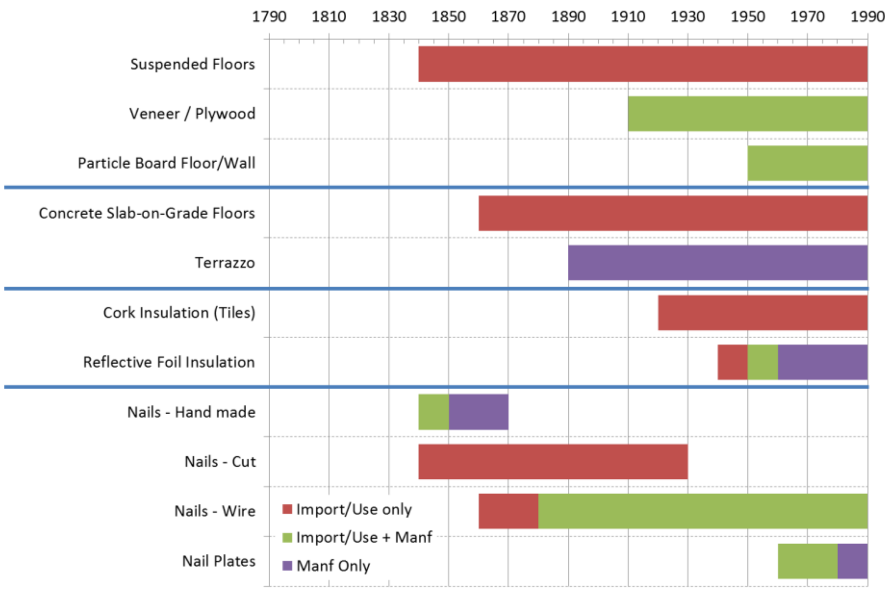


Figure 150: Floor

Figure 151 explores the development of interior linings, timber preservative treatments, and the sub-floor. Wet linings, introduced in the 1840s, were starting to be replaced by the more convenient dry linings in the 1900s although it took some years for the latter to become the majority. Softboard and hardboard were imported from the 1910s and locally manufactured from the 1940s. Timber preservative treatments were largely unnecessary for the appropriate native timbers used in housing but once exotic softwoods became more widely used, they became essential.

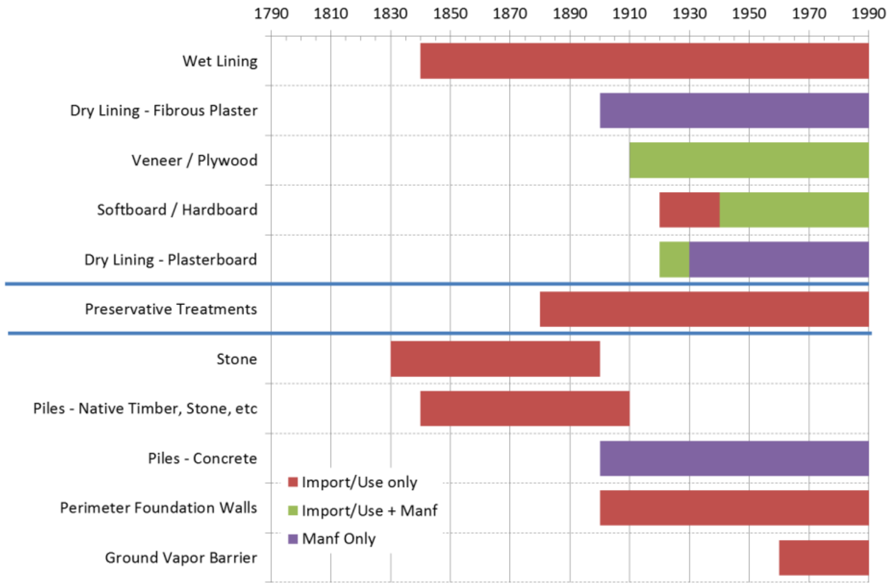
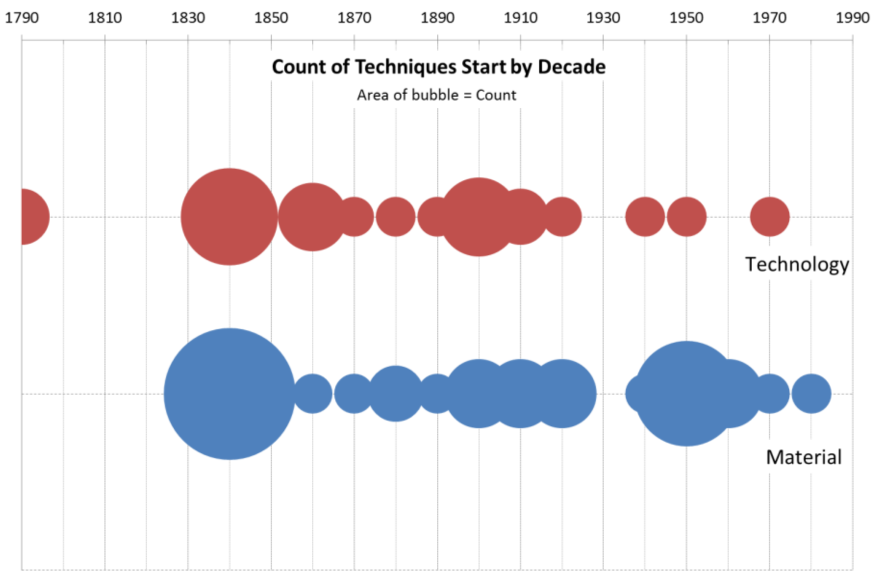


Figure 151: Lining and Sub-floor

Under the suspended floor, piles were first made with the readily available materials and then durable native timbers in the 1840s. Both stone and native timber piles were replaced by the more controllable and durable concrete and brick piles from the 1900s. Perimeter foundation walls were also introduced about the same time. The use of a ground vapour barrier dates from the 1960s.



Start Decade	Material (40)	Technology (24)	Techniques (64)
1790	-	2	2
1800	-	-	-
1810	-	-	-
1820	-	-	-
1830	1	-	1
1840	11	6	17
1850	1	-	1
1860	1	3	4
1870	1	1	2
1880	2	1	3
1890	1	1	2
1900	3	4	7
1910	3	2	5
1920	3	1	4
1930	-	-	-
1940	1	1	2
1950	7	1	8
1960	3	-	3
1970	1	1	2
1980	1	-	1

Figure 152: Count of Techniques Started by Decade

Other approaches can also be used to explore the evolution of these techniques. Figure 152, based on Figure 140 data, provides a bubble plot (left) and a graphic table (right) of the count of a new technique (material or technology) introduced by decade. The bubble area is proportional to the number of techniques. The graphic table provides details by decade.

While Figure 140 provides the count across all the techniques, Figure 152 shows there are peaks in the introduction of both materials and technologies in the 1840s and of materials alone in the 1950s. There are secondary peaks for both technologies and materials in the 1880s and 1900s, and for materials alone in the 1910s.

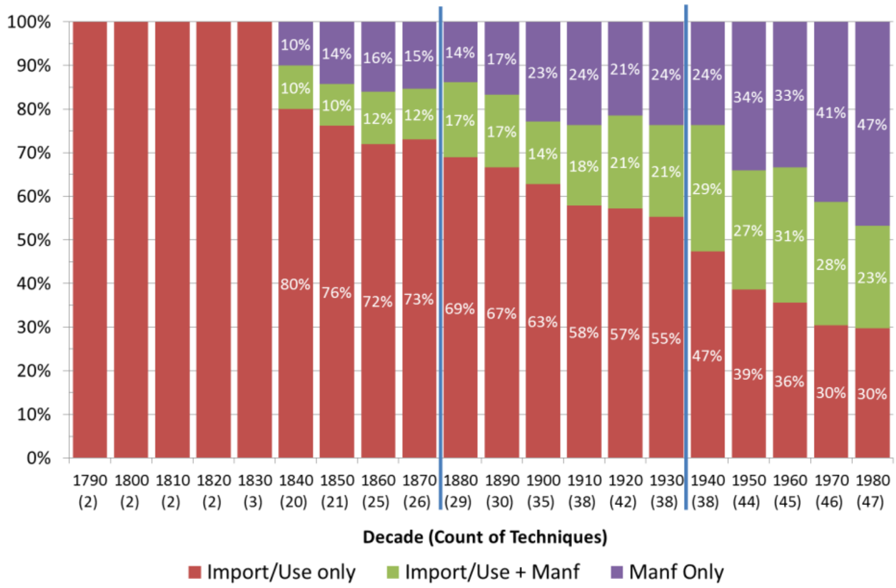


Figure 153: Source of Technologies by Decade

Figure 153 plots the count of techniques by decade whether imported, imported and manufactured, or only manufactured. It can be thought of as a count by decade of Figure 154. The 1790s to 1870s were a period of import with some manufacturing, while the 1880s to 1930s show steadily increasing local manufacture, albeit with imports never falling below 50% of the count. The 1940s to 1980s saw increasing local manufacture.

The data in Figure 152 shows the 1840s European settlement led to the arrival of over a quarter of the materials (28%) and technologies (25%). About one tenth (8% of the materials and 13% of the technologies) arrived in the 1900s. The other peak was in the 1950s, when just 4% of the technologies but 18% of the materials arrived.

Figure 154 plots the start and end times of use, import or manufacture of the technologies and materials discussed in the last section, sorted by start decade. The dates are for the end of the relevant decade. The pattern, indicated by the vertical bluie lines, follows that given in Table 45.

While it may have been possible in 1982 to build a house which closely matched the appearance of a house built any time in the previous 190 years, the underlying techniques underwent important changes. For example, nails while performing the same role, were no longer imported handmade or cut, but were locally manufactured, machine-made wire-nails. Roofing was no longer corrugated wrought iron but corrugated (or other profile) steel.

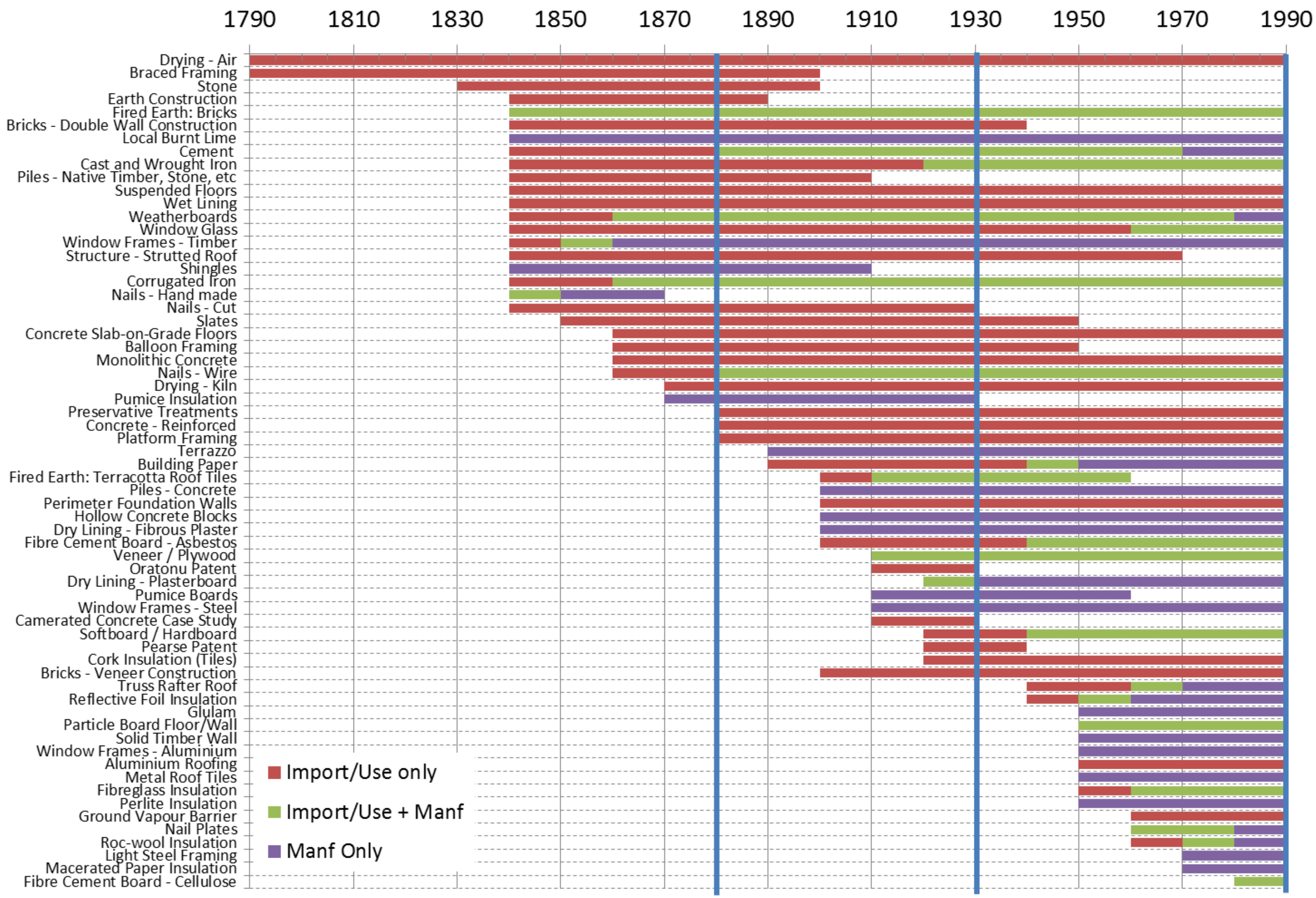


Figure 154: Use, Import and Manufacturing – Time Line

8.3 From Craft to Trade

From the very earliest days of European settlement, the preferred house has been of timber, weatherboard and corrugated iron, as shown by early censuses (Section 4.1.1) and described in early publications:

> "Houses are mostly built of wood in New Zealand, chiefly on account of the rapidity with which they can be constructed, and partly also from the fear of earthquakes." (Fitton, 1856, p. 244)

By the 1880s, the typical New Zealand house was very much as described by Cooney nearly a century later:

> "The traditional NZ house constructed of light timber framing, clad with weather boards, having moderate window openings, and having a steel roof … " (Cooney, 1979, p. 236)

New Zealand poet, Denis Glover described such a house as "perhaps our unique contribution to architecture, although built in wood that won't last more than thirty or forty years" (Glover, 1981, p. 62). European architects quickly recognised this "construction is the usual stud-framing with weatherboard outside and plaster inside"(Plishke, 1947, p. 47).

As has already been noted in Chapter 1, such construction was so common that almost all the designer had to do was to specify construction "according to the best trade practice" ([Martin], 1959, p. 222). Such views fit with a tradition of crafts-driven wooden construction, rather than the engineering analysis that could be expected to accompany steel framing (M. J. O'Brien, 2010, p. 42) or even concrete construction.

The fact that no New Zealand written carpentry book was required until 1944 and even then was designed to train solders returning from WWII, again suggests a craft tradition. When apprenticed craftsmen were not available, formal education offered a faster solution with its larger classes. The drivers for the trade-based textbook published in the late 1950s were to increase the number of trained people available to the building industry and to reduce the costs of construction (Section 3.2). Even from the 1950s, when the census suggested timber construction appeared to be declining, timber framing (structure) was still a significant component of new dwelling construction (Section 4.1.6), and suitably trained people were required.

The shift from craft to trade can also be seen in the details required for construction specification. For example, details of sub-floor ventilation were not specified until 1944, although it had been discussed as early as 1924 (Section 6.2.3). A trained craftsperson would place ventilators following best trade practice, as had been done for many years, but a less experienced person might be expected to require a more detailed specification.

8.4 Changes in Date of First NZ Use

This research has identified a number of cases of materials or techniques being used in NZ earlier than previously recorded. Table 43 provides a summary of these techniques and the relevant section.

Table 43: Changes in NZ Date First Used due to this Research

First example of:	Revised	Former	Difference	Section
Stained glass	1849	1893	-44	6.6
Shift Balloon to Platform framing	1881-86	Early 1890s	-5	7.1.3
Nail manufacture	1887	Mid- to Late- 1800s	-10	7.1
Terrazzo	1897	1927	-30	6.2.2
Terracotta roofing tiles	1899	1901	-2	6.7.4
Hollow concrete block building	1904	1909	-5	7.2.1
Machine made hollow concrete blocks	1904	1938	-34	6.3.4
Plaster board	1923	1925	-2	6.4.2.2
NZ Do-it-yourself home handy man	1939	c1900	+39	3.3

Of the nine cases, the earliest date for four has been shifted to be less than ten years earlier, but of the others, stained glass, hollow concrete block and terrazzo have each been found over thirty years earlier than in previous research. In the case of the do-it-yourself book, the oldest current example listed in the New Zealand Libraries Catalogue, although not in the NZ National Bibliography, has been shown to be English published and written.

8.5 Travelling to New Zealand

> "Yet in the midst of converging cables, shipping, and wireless communication, it [New Zealand] has remained isolated."
> (Beaglehole, 1936, p. 158)

This common view of New Zealand as an isolated, distant country was based on the speed of the return voyage of the sailing, or in later years, steam ships. There could be a year's delay in getting an answer to a letter (Mulgan, 1958, p. 97).

In Australia, Cowan noted that while it took a long time for information to reach Australia, major innovations were frequently adapted to local use within a few years. Corrugated iron, gas light, piped sewerage, hydraulic lifts, and reinforced concrete are all examples of Australian use within a few years of their invention (H. J. Cowan, 1998, p. xiii).

This research shows this was also the case for New Zealand, whether in the 19^{th} or 20^{th} centuries. Examples of where the invention arrived only a few years after its first overseas use are listed below and summarised in Table 44:

- Reinforced concrete was being used within a few years of its first use in Europe;
- Kiln drying of timber was used shortly after its wide spread use in USA;
- Plywood was being made in the same decade as its widespread USA manufacture;
- Sub-floor ventilation requirements were discussed in New Zealand less than a year after they were proposed in the USA in 1923;
- Polythene, although its use as a ground vapour barrier traces to the USA, was being used in the early 1960s at the same time as in the UK;
- Nail plates, used in the USA since about 1956, were used from 1963;
- Hollow concrete blocks, first patented in USA in 1901 were being made in 1904;
- Plasterboard, patented in an early form in the USA in 1890, was being made in the UK in 1917, in New Zealand in 1925 and in France in 1946;
- Building paper, patented in the USA in 1884 was being advertised in 1898;
- Asbestos cement board, invented in Austria and patented in the UK in 1900, was being advertised in 1904, although the Austrian original did not arrive until 1907; and
- Aluminium window frames were introduced in the UK from 1950 and were used in NZ by the end of that decade, while aluminium roofing was available from 1956.

Table 44: Selected Techniques – Origin Decade and NZ Arrival Decade

Technique	Origin – Country and Decade	NZ Arrival
Kiln dried timber	USA 1860s	1870s
Reinforced concrete	France 1878	1883
Building paper	USA 1884	1898
Plasterboard	USA 1890, UK 1917, France 1946	1925
Plywood	USA 1900s	1910
Asbestos cement board	UK 1900	1904
Hollow concrete blocks	USA 1901	1904
Sub-floor ventilation	USA 1923	discussed 1924
Aluminium window frames	UK 1950	late 1950s
Polythene	USA 1954	1960
Nail plates	USA about 1956	from 1963

Although not a random selection, these examples suggest that New Zealand was not isolated in terms of the availability of building techniques. Ideas could travel as fast as the fastest transport from their origin, while materials travelled a little more slowly. It is interesting to note eight of these eleven techniques originated in the USA (Section 8.2.3).

8.6 Technological Evolution

Although a range of time periods have been proposed as an approach for viewing the development of NZ house construction, these do not take into account the changes in construction techniques examined in this research (See Appendix, page 321). Some are based on house design (Garrett, 1954; Harrap, 1981; Salmond, 1989) while others consider both styles and materials (Arden & Bowman, 2004; Bates, 1957).

Based on this research, Table 45 sets out a different time structure for the evolution of building techniques in New Zealand based on the techniques, sources, availability of skills and related environmental changes.

Table 45: Development Periods

Period	Time	Techniques	Source	Skills	Notes
Importation	1790s-1870s	Import + Limited Manufacture	Import	Import	
Industrial Development	1880s-1930s	Import + Manufacture	Import + Local	Training + Limited Import	Focus on increasing employment
Industrialisation	1940s-1980s	Limited Import + Manufacture	Import + Local	Training + Limited Import	Increased specialisation of materials

The 1790s to the end of the 1870s saw the development of a European society in New Zealand. Building materials were largely imported with limited local processing (such as processing a tree to timber) while technologies and skills were largely imported in finished form (including nails, sawmills and carpenters).

From the 1880s to the end of the 1930s a national focus on increasing employment and industrial development led to the emergence of a range of manufacturing industries. Technologies were developed to suit the unique needs of the country and education and training of apprentices was implemented. As nail manufacture commenced, saw mill technology improved and apprentice training legislation was passed.

The 1930s saw changes in response to the damage of the 1931 Napier earthquake. From the 1940s to the 1980s, increased industrialisation helped deal with the ongoing aftermath of WWI and devastation of WWII. By the 1970s it was possible to build a complete house using New Zealand made materials, standards and labour.

8.7 Future Research

Only the shell component of the Duffy model (Table 5) has been investigated in this research. Table 9 provided a starting list of other issues which remain to be explored.

Two materials which have not been investigated in detail but have had an important impact in the later part of the 20th century are plastics and non-ferrous metals.

This research has identified the period immediately after WWII as seeing a change in construction due to a change from well experienced craftspersons to well-educated tradespersons, but has not explored this issue in any detail. Future research might consider issues of trade training, Government policy and the consequences for experienced craftspeople of the Great Depression and WWII.

The *Building Bulletins* published since 1959 by the Building Research Bureau (from 1970 the Building Research Association of NZ) have provided a rich vein for this research, and hold considerable promise for a future researcher to explore the issues that have concerned the building industry from the late 1950s.

Newspapers and selected trade magazines have been used to explore changes in techniques, but as a resource they are limited to what was of interest to the publication, what was considered to be "new" and whether a company had paid for advertising. Further research in trade magazines may provide additional insights, although the history of New Zealand published magazines is far shorter than that of newspapers.

A broader understanding may come from exploration of detailed building permits, but as this would require extensive research investigations, it would need to be undertaken based on specific locations and time periods. One such topic would be the early use of building paper. What was the driver for the earlier users: Cost? Comfort? Wind control? Was there some other benefit? How quickly did the use of building paper spread, and was its early use related to the cost or location of the house? Another topic that may be answered through examination of permits would be a better understanding of the timing and reasons behind the shift of the majority of house construction from balloon to platform framing both on a regional and national basis.

No comprehensive national study of the brick industry has been found, unlike works on timber and concrete constructions and industries. Given the importance of brick in the 19th and early 20th century New Zealand, as well as the consequence of the recent Christchurch earthquakes, this is a topic which holds considerable interest.

The 1970s saw the widespread construction of townhouses, and the 1990s a shift to apartments. The techniques used in these multi-dwelling buildings and their links to earlier techniques have yet to be explored.

This research has focused on how techniques arrived in New Zealand and to a lesser extent, how they were modified to meet local conditions and requirements. This provides a base from which further more detailed investigations could be undertaken in any of the investigated techniques. The question also remains of how New Zealand's modifications, changes and inventions have impacted on the rest of the world.

8.8 Conclusions

While New Zealand could be seen as a ‘taker’ of technologies, the results of this research suggest it has been a selector rather than a taker – selecting techniques that were appropriate within the paradigm of the time. Selection criteria might include price, availability, personal links or government policy, as well as the prevailing philosophy of design or style.

Research Question: Where, why and when did the techniques used in the 1980s New Zealand house shell (exterior and interior) originate? (Section 1.2)

In answering the research question, a systematic investigation of the technological development of the house envelope (exterior and interior) has been undertaken from the earliest European settlement in 1792 through to 1982. The research has documented and constructed timelines for the principal building materials (earth, stone, concrete, timber, and ferrous metals) and those supporting the various house components (foundation, floor, walls, fenestration, and ceiling/roof).

It has been shown that the vernacular buildings of the Maori, based on local plant materials, could not be directly traced through to the New Zealand house of the 1980s, although they played a critical role in the earliest form of European housing.

The New Zealand house of the 1980s owes more to imported techniques, or those invented locally during the research period. The research shows that half of the techniques originated in UK (26%) or USA (24%), over a quarter were either generic (19%) or of unknown (8%) origin while similar numbers were from NZ (7%) or Australia (7%). This suggests a country strongly linked into international trading, both for materials and technologies.

The evidence shows that nationally the basic structure of the typical New Zealand house (light timber frame, timber weatherboard cladding and corrugated iron roof) has been in use, alebit with technological improvements, since at least the 1850s.

From the 1930s there has been a shift away from timber claddings to a wider range of products, including board (asbestos and more recently fibre-cement), but timber has remained as the main structural (framing) material. Documenting these changes has led to a series of charts of the availability of the various techniques against time. Together with the research detail, these provide a unique tool for assessing the age of a New Zealand house as well as tracking the patterns of change. This will be of value to those interested in house preservation, maintenance and renovation, as well as those interested in the use and durability of materials.

The research has shown that there was no shortage of innovation in the New Zealand construction industry from 1792 to 1982. It has been found that the adaption of new techniques has been relatively swift and widespread, whether for hollow concrete blocks or asbestos cement sheets.

When the first European settlers arrived, they used the traditional braced framing already many centuries old. Balloon framing appears to have been adopted in a very similar time period to that used in the rest of the world, based on the increased availability of imported nails. By the mid-1880s, it had been largely replaced by platform framing and was soon associated with local wire nail manufacture. Since then, light timber framing has been refined to meet new economic, legislative and appearance requirements, but the fundamentals remain unchanged.

It has been shown that the use of timber framing has been supported by:

- Extensive exotic forestry plantations and processing, required since the 1950s to replace the depleted native timber resources;
- Importation of new technologies; and
- Manufacture of a range of materials and technologies.

Techniques to replace timber framing did not make significant inroads into construction until the 1960s. Although most often based on international developments, it has been shown that each new technique has been modified to meet the unique New Zealand combination of climate, resources and geography.

The absence of locally developed trade training publications, with the AEWS Carpentry series not published until 1944, suggests that timber-framed house construction was more of a craft than an engineering tradition. Trade training not only equipped the builder with construction skills but also an understanding of "best trade practice". This suggests a different approach might be required for the development of building controls for timber house construction compared to the more professionally-based steel or concrete construction.

A decade after the end of the research period, the building control system was considered to be so prescriptive as to discourage innovation, with the result that a performance based control system was put in place (Government of New Zealand, 1991). Although this research has not explored building controls, a common theme over 190 years has been construction industry innovation. Not all innovations have been successful, but the tracking of individual techniques has shown a steady introduction and removal over the 190 year period. How and why this innovation appears to have stopped in the following decade is a question for another researcher.

Bibliography

The internet has radically altered access to research material. Most importantly newspapers, magazines, journals, books and industry-specific records (including catalogues and advertising) have become available outside the conventional library.

Web addresses, where given, are those at the date of access.

The Zotero referencing system, based on the Firefox web browser, has been used to maintain the reference list (http://www.zotero.org/). References are presented using APA 6th edition.

From 1792 to 2013, few things have remained stable. Newspapers, organisation, businesses and even the legal system have been subject to huge changes. The references use the name given in the source, normally the most recent name.

USA patents and designs have been sourced from the United States Patent and Trademark Office website (www.uspto.gov), at times assisted by Google Patent Search (patent.google.co.nz).

New Zealand newspapers have either been accessed where available through Papers Past (paperspast.natlib.govt.nz) for the dates given in the reference in braces, paper original or microfilm copy.

Adams, T. W. (1915). Article XXIV.—The Species of the Genus Pinus Now Growing in New Zealand, with Some Notes on Their Introduction and Growth. [Originally Read Before the Philosophical Institute of Canterbury, 7th August, 1907]. *Transactions and Proceedings of the Royal Society of New Zealand, 1915 [Electronic Resource]*, *48*, 216–223. Retrieved from http://rsnz.natlib.govt.nz/volume/rsnz_48/rsnz_48_00_002460.html

Addis, B. (2007). *Building: 3000 Years of Design Engineering and Construction*. London & New York: Phaidon Press.

Advanced Energy. (2005). *A Field Study Comparison of the Energy and Moisture Performance Characteristics of Ventilated Versus Sealed Crawl Spaces in the South.* (Technology Assessment Report No. DE-FC26-00NT40995). Raleigh, NC: Advanced Energy. Retrieved from http://www.advancedenergy.org/portal/crawl_spaces/pdfs/Technology%20Assessment%20-%202005.pdf

Aitkens Concrete Ltd. (2009). Aitkens Concrete Ltd - 100 Years in Concrete and the Gisborne Building Industry. *Concrete*, *53*, 8–9.

Allen, D. (1986, July 1). Demolition brick - a load of old cobblers? *New Zealand Engineering*, *41*(6), 10–12.

Allen, M. (1996). Earth Building in New Zealand. In D. Jones (Ed.), *Nga Whare Uku - the Houses of Earth and How to Build Them* (pp. 90–99). Wanganui, NZ: David Jones Publications.

Allen, M. (1997). *Out of the Ground: Earthbuilding in New Zealand*. Palmerston North, NZ: Dunmore Press.

Amalgamated Brick and Pipe Co. Ltd. (1938). *The Construction of Brick Veneer Houses and the Design and Construction of Brick Fireplaces (Produced by E. Satchell, Advertising Consultant)*. Auckland, N.Z: Amalgamated Brick & Pipe Co. Ltd.

A.N.B. (1948, February 28). Home Carpentry. *The Argus*, p. 22. Melbourne, Vic. Retrieved from http://nla.gov.au/nla.news-article22533964

Angus, J. H. (1973). *The Ironmasters: The First One Hundred Years of H. E. Shacklock Limited*. Dunedin, NZ: H. E. Shacklock Ltd.

Annand, J. (1911, April 21). Improvements Relating to Concrete Buildings [NZ Patent 29,425]. Dunedin NZ Retrieved from Archives NZ, Wellington. ABPJ 7396 W3835/166 Patent 29,425

Annand, J. (1912, October 17). Improvements In and Relating to Concrete Buildings [NZ Patent 32,127]. Dunedin NZ Retrieved from Archives NZ, Wellington. ABPJ 7396 W3835/179 Patent 32,127

Annand, J. (1914, June 16). Encasing Wooden Buildings with Concrete [NZ Patent 35,065]. Dunedin NZ Retrieved from Archives NZ, Wellington. ABPJ 7396 W3835/191 Patent 35,065

Anonymous. (1903). Concrete House Building. *Scientific American*, *89*, 148–149. http://doi.org/10.1038/scientificamerican08291903-148

Anonymous. (1915, April 24). Ancient Nails. *The Ironmonger*, 68. Retrieved from http://www.glasgowsteelnail.com/nailnames.htm

Anonymous. (1952). The New Vibrapac Block Plant. *Winstone News*, 8.

Anonymous. (2004). Lightweight Concrete Stands Test of Time. *Concrete*, *48*(4), 3.

Arden, S., & Bowman, I. (2004). *The New Zealand Period House: A Conservation Guide*. Auckland, NZ: Random House.

Armstrong Cork Company - Insulation Department. (1909). *Nonpareil Corkboard Insulation for Cold Storage Warehouses, Abattoirs, Breweries, Ice Plants, Fur Storage Vaults, Dairies, Creameries, Candy Factories, Bakeries, Fish Freezers, Canneries, Refrigerators, Freezing Tanks, and Generally Wherever Refrigeration Is Employed*. Pittsburgh, Pennsylvania: Armstrong Cork Company. Retrieved from http://www.archive.org/details/cu31924004588525

Arthur Cleave & Co. (1898). *Industries of New Zealand (illustrated): An Historical and Commercial Review: Descriptive and Biographical, Facts, Figures and Illustrations: An*

Epitome of Progress: Business Men and Commercial Interests. Auckland, N.Z: Arthur Cleave Publishing Co.

Ashburton Guardian. *Ashburton Guardian [Electronic Version Accessed through: Paperspast.natlib.govt.nz (1887-1921)]*. Ashburton, NZ

Ashford, J. (1994). *The Bungalow in New Zealand*. Auckland, NZ: Viking.

Auckland City. The Auckland City By-laws Nos. 1 & 2 1925 (1925).

Auckland City Council Community Advisory Service. (1972). *Housing in Auckland: renting, buying, building*. Auckland, N.Z: Auckland City Council Community Advisory Service.

Auckland Industrial and Mining Exhibition. (1898). *Auckland Industrial and Mining Exhibition: Opened December 1st, 1898: Official Handbook and Catalogue*. Auckland, N.Z: Geddis and Blomfield.

Auckland Star. *Auckland Star [Electronic Version Accessed through: Paperspast.natlib.govt.nz (1870-1945)]*. Auckland, NZ

Australian Portland Cement Ltd. (1923). *Concrete: How It Is Made, with an Illustrated Description of Its Modern Uses on the Farm.* Melbourne, Victoria. Retrieved from http://handle.slv.vic.gov.au/10381/157816

Auto Machine Manufacturing Co. Ltd. (1909). Auto Machine Manufacturing Company Ltd Directors Minute book (hand written), Auckland. Retrieved from 1474/5/3 (1909)

Auto Machine Manufacturing Co. Ltd. (1941). Auto Machine Manufacturing Co Ltd Amalgamation P.H. Venables Ltd Christchurch December 1939 to December 1941. Retrieved from 1474/2/3 – 35323

Automated Building Components (NZ) Ltd. (1973, June). Superior ‘Gang-Nail’ Constructions - the Low Cost Solution to Distinctive Roof Design. Retrieved from AALF W3202/19 Record 24/15 Part 1

Baber, J. (1872). On the Rate of Growth of Native Trees under Cultivation [Read at 5th meeting of the Auckland Institute, 23 Sept 1872]. *Transactions and Proceedings of the New Zealand Institute 1872. [Electronic Resource]*, *5*, 451–452. Retrieved from http://rsnz.natlib.govt.nz/volume/rsnz_05/rsnz_05_00_003670.pdf

Baber, J. (1885). Art. L.—On the Growth of Transplanted Trees [Read before the Auckland Institute, 29th June, 1885.]. *Transactions and Proceedings of the New Zealand Institute 1885. [Electronic Resource]*, *18*, 311–314. Retrieved from http://rsnz.natlib.govt.nz/volume/rsnz_13/rsnz_13_00_000950.html

Bagnall, A. G., Williams, K. S., & Griffith, P. (1980a). *New Zealand National Bibliography to the Year 1960. Volume 1: to 1889. Part 1: A-M*. Wellington, NZ: Government Printer.

Bagnall, A. G., Williams, K. S., & Griffith, P. (1980b). *New Zealand National Bibliography to the Year 1960, Volume I: to 1889. Part 2: N-Z, indexes*. Wellington, NZ: Government Printer.

Bagnall, L. J. (1886). Art. LXXII - Kahikatea as a Building Timber [Read before the Auckland Institute, 18th October, 1886.]. *Transactions and Proceedings of the New Zealand Institute [Electronic Resource]*, *19*, 577–580. Retrieved from http://rsnz.natlib.govt.nz/volume/rsnz_19/rsnz_19_00_006670.html

Baird, G. (1983). *Energy Cost of Houses and Light Construction Buildings*. Auckland, N.Z: New Zealand Energy Research and Development Committee.

Barber, W. H. (1910, September 5). 103a Coromandel Street, Dwelling.

Barker, L. M. A. (1871). *Station Life in New Zealand*. London: Macmillan & Co. Retrieved from https://archive.org/details/stationlifeinne00broogoog

Barnard, D. (2009). A Half Century of Concrete Masonry. *Concrete*, *53*, 6–7.

Bartel, S., Snell, J., Barr, J., & Barr, M. (1993). *Working Titles: Books That Shaped New Zealand*. Wellington, NZ: National Library of New Zealand.

Bartley, E. (1885). Art. IV - The Building Timbers of Auckland [Read before the Auckland Institute, 30th November, 1885.]. *Transactions and Proceedings of the New Zealand Institute [Electronic Resource]*, *18*, 33–41. Retrieved from http://rsnz.natlib.govt.nz/volume/rsnz_18/rsnz_18_00_000530.html

Barton, J. (1998). James, Esther Marion Pretoria 1900-1990. In C. Orange (Ed.), *The Dictionary of New Zealand Biography. Volume Four, 1921-1940* (p. xxii, 650 p.). Auckland, NZ Wellington, NZ: Auckland University Press and Department of Internal Affairs. Retrieved from http://www.TeAra.govt.nz/en/biographies/4j2/1

Bastings, L. (1955). Heat Losses from Buildings Part III. Reflective Thermal Insulation. *The Journal of the New Zealand Institute of Architects*, *22*(9), 190–2.

Bastings, L., & Clelland, J. (1957). Recent Developments in Permanent Materials for Housing. *The Journal of the New Zealand Institute of Architects*, *24*(2), 41–46.

Bates, H. (1957, December). The Evolution of the Dwelling. *The New Zealand Valuer*, (14), 15–21.

Bay of Plenty Times. *Bay of Plenty Times [Electronic Version Accessed through: Paperspast.natlib.govt.nz (1875-1920)]*. Tauranga, NZ

Beaglehole, J. C. (1936). *New Zealand: a short history*. London England: Allen & Unwin.

Beca Carter Hollings and Ferner Ltd. (1978). *Winstone Limited: Report on Thermal Insulation Investigation* (No. 208963). Auckland NZ: Beca Carter Hollings and Ferner.

Bell, P. (1983). The Balloon Frame Myth. *Journal of Australian Studies*, *7*(12), 53–66.

Best, S. (1998). Early Brickmaking in New Zealand. In M. W. Felgate (Ed.), *His Majesty's Theatre Site Excavations (R11/1624): Final Archaeological Report.* Auckland, N.Z: Bioresearches Consulting Biologists and Archaeologists. Retrieved from http://bickler.co.nz/bricks/history.php

Betteridge, C., Mathias, J., Goldstein, L., Robinson, M., & Leslie, D. (2004). *Draft South Sydney Weatherboard Buildings Study Report* (p. 63). Sydney N.S.W.: South Sydney City Council. Retrieved from http://www.cityofsydney.nsw.gov.au/Development/HeritageInformation/WeatherboardBuildings.asp

Bickler, S. H. (2007). NZ Historic Brick Database. Retrieved 5 September 2014, from http://bickler.co.nz/bricks/

Bishop, C. H. (1929, December 8). Resolution Passed 3 Dec 1926 to go into Voluntary Liquidation - The Cavity Concrete Block Ltd. The Cavity Concrete Block Company.

Blair, W. N. (1870). *Report from W.N. Blair, Esq., C.E.: Addressed to the City Council of Dunedin as to the Dunedin Gas Works, Dunedin, April 21st, 1870*. Dunedin NZ: Coulls & Culling, Printers.

Blair, W. N. (1875). Art. IX.—On the Building Materials of Otago. [Read before the Otago Institute, 13th July and 21st September, 1875]. *Transactions and Proceedings of the New Zealand Institute [Electronic Resource]*, *VIII*, 123–166. Retrieved from http://rsnz.natlib.govt.nz/volume/rsnz_08/rsnz_08_00_000780.html

Blair, W. N. (1876a). Art. IX.—The Building Materials of Otago - Limes, Cements, and Aggregates. [Read before the Otago Institute 5th September, 1876]. *Transactions and Proceedings of the New Zealand Institute [Electronic Resource]*, *IX*, 108–133. Retrieved from http://rsnz.natlib.govt.nz/volume/rsnz_09/rsnz_09_00_000790.html

Blair, W. N. (1876b). Art. X.—The Building Materials of Otago - Timbers. [Read before the Otago Institute, 31st October, 1876]. *Transactions and Proceedings of the New Zealand Institute [Electronic Resource]*, *IX*, 134–181. Retrieved from http://rsnz.natlib.govt.nz/volume/rsnz_09/rsnz_09_00_000950.html

Blair, W. N. (1877a). *Mr Blair's Further Report on Extended Water Supply for the City*. Dunedin, NZ: 'Evening Star' Office.

Blair, W. N. (1877b). *Report on an Additional Water Supply for the City of Dunedin*. Dunedin NZ: 'Evening Star' Office.

Blair, W. N. (1879). *The Building Materials of Otago and South New Zealand Generally*. Dunedin, NZ: J. Wilkie & Co.

Blair, W. N. (1882). *Report on the Silverstream Waterworks*. Dunedin NZ: Jolly, Connor & Co.

Brand, S. (1997). *How Buildings Learn: What Happens After They're Built*. London: Phoenix.

Brocklebank, N., & Greenaway, R. (1979). *Oamaru*. Dunedin, N.Z: J. McIndoe.

Brown, D. (2009). *Māori Architecture: From Fale to Wharenui and Beyond*. Auckland, NZ: Raupo.

Brown, F. D. (1897). Art. VI - The Insulation of Cold-stores. *Transactions and Proceedings of the New Zealand Institute [Electronic Resource]*, *30*, 44–49. Retrieved from http://rsnz.natlib.govt.nz/volume/rsnz_30/rsnz_30_00_000630.html

Bruce Herald. *Bruce Herald [Electronic Version Accessed through: Paperspast.natlib.govt.nz (1865-1905)]*. Milton, NZ

Bryson, B. (1998). *Made in America*. London: Black Swan.

Buchanan, J. (1873). On the Durability of New Zealand Timber, with Suggestions for its Preservation [Abstract & Discussion]. *Transactions and Proceedings of the New Zealand Institute 1873. [Electronic Resource]*, *6*, 390–1. Retrieved from http://rsnz.natlib.govt.nz/volume/rsnz_06/rsnz_06_00_005460.html

Buckett, M. G. (2009, September 12). Interview with Mrs Gwyneth Buckett (wife of the late Mr Roy Buckett, Chief Engineer & former Director, NZ Forest Products Ltd. Lived in Pinedale 1942-1947. Additional handwritten notes also provided.

Building Research Bureau of New Zealand. (1959a). *Aluminium Window Frames*. Wellington NZ: Building Research Bureau of New Zealand (Inc.).

Building Research Bureau of New Zealand. (1959b). *The Use of Radiata Pine in Building Construction*. Wellington NZ: Building Research Bureau of New Zealand (Inc.).
Building Research Bureau of New Zealand. (1960). *Dampness in Building*. Wellington NZ: Building Research Bureau of New Zealand (Inc.).
Building Research Bureau of New Zealand. (1962). *Masonry Veneer Construction*. Wellington NZ: Building Research Bureau of New Zealand (Inc.).
Building Research Bureau of New Zealand. (1966a). *Damp-Proof Courses for Concrete Ground Floors (1st issued Jun 1961. Revised Jun 1966)*. Wellington NZ: Building Research Bureau of New Zealand (Inc.).
Building Research Bureau of New Zealand. (1966b). *Lightweight Concrete - 2. Pumice Concrete*. Wellington NZ: Building Research Bureau of New Zealand (Inc.).
Building Research Bureau of New Zealand. (1966c). *Thermal Insulation for Buildings (1st issued Nov 1960. Revised May 1966)*. Wellington NZ: Building Research Bureau of New Zealand (Inc.).
Building Research Bureau of New Zealand. (1967a). *Lightweight Concrete - 4. Artificial Aggregates - Vermiculite*. Wellington NZ: Building Research Bureau of New Zealand (Inc.).
Building Research Bureau of New Zealand. (1967b). *Lightweight Concrete - 5. Artificial Aggregates - Perlite*. Wellington NZ: Building Research Bureau of New Zealand (Inc.).
Building Research Bureau of New Zealand. (1967c). *Lightweight Concrete - 6. Sawdust Concrete*. Wellington NZ: Building Research Bureau of New Zealand (Inc.).
Building Research Bureau of New Zealand. (1969). *Particle Board Flooring*. Wellington NZ: Building Research Bureau of New Zealand (Inc.).
Burnell, G. R. (1850). *Rudimentary Treatise on Limes, Cements, Mortars, Concretes, Mastics, Plastering, etc*. London: John Weale.
Burn, R. S. (1854). *The Colonist's and Emigrant's Handbook of the Mechanical Arts*. Edinburgh & London: William Blackwood and Sons. Retrieved from http://books.google.co.nz/books?id=Q1gOAAAAYAAJ
Bush Advocate. *Bush Advocate [Electronic Version Accessed through: Paperspast.natlib.govt.nz (1888-1909)]*. Dannevirke, NZ
Callan, L. (1989, March). Looking into glass. *New Zealand Geographic*, (1), 68–84.
Canterbury Provincial Government. Planting of Forest Trees Ordinance (1858).
Carrington, C. G., & Rush, B. L. (Eds.). (1983). *Experiences with Heat Pump Applications in New Zealand: Papers Presented at a Workshop on Large-Scale Applications of Heat-Pumps. Wellington, 25 August, 1982*. Auckland: New Zealand Energy Research and Development Committee.
Carroll, B. (1987). *A Very Good Business: One Hundred Years of James Hardie Industries Limited 1888-1988*. Sydney N.S.W.: James Hardie Industries.
Census and Statistics Department. (1946). *Population Census, 1936. Vol. XIII. Dwellings and Households*. Wellington, NZ: Government Printer.

Census and Statistics Department. (1950). *Statistical Report on Factory Production of New Zealand for the Years 1946-47 and 1947-48 (With a Summary of Building Production for 1947-48)*. Wellington, NZ: Government Printer.

Census and Statistics Department. (1954a). *Population Census, 1951. Vol. VII. Dwellings and Households*. Wellington, NZ: Government Printer.

Census and Statistics Department. (1954b). *Report on the Industrial Production Statistics of New Zealand for the Year 1952-53*. Wellington, NZ: Government Printer.

Census and Statistics Office. (1902). *Results of a Census of the Dominion of New Zealand Taken for the night of 31 March 1901. Part I - Population and Houses*. Wellington, N.Z: Government Printer.

Census and Statistics Office. (1907). *Results of a Census of the Colony of New Zealand, Taken for the Night of the 29th of April, 1906. Part I - Population and Houses*. Wellington, NZ: Government Printer.

Census and Statistics Office. (1922). *Statistical Report on Trade and Shipping of the Dominion of New Zealand for the Year 1921*. Wellington, NZ: Government Printer.

Census and Statistics Office. (1924a). *Results of a Census of the Dominion of New Zealand Taken on the night of 17th April 1921. Part XV Dwellings*. Wellington, NZ: Government Printer.

Census and Statistics Office. (1924b). *Statistical Report on Trade and Shipping in the Dominion of New Zealand for the Year 1923*. Wellington, NZ: Government Printer.

Census and Statistics Office. (1925). *Statistical Report on Trade and Shipping in the Dominion of New Zealand for the Year 1924*. Wellington, NZ: Government Printer.

Census and Statistics Office. (1926). *Statistical Report on Trade and Shipping in the Dominion of New Zealand for the Year 1925. Part I.* Wellington, NZ: Government Printer.

Census and Statistics Office. (1927). *Statistical Report on Trade and Shipping in the Dominion of New Zealand for the Year 1926. Part I.* Wellington, NZ: Government Printer.

Census and Statistics Office. (1931a). *Population Census, 1926. Vol. XIII. Number and Description of Dwellings*. Wellington, NZ: Government Printer.

Census and Statistics Office. (1931b). *Statistical Report on Trade and Shipping in the Dominion of New Zealand for the Year 1930. Part I.* Wellington, NZ: Government Printer.

Census and Statistics Office. (1935). *Statistical Report on Trade and Shipping in the Dominion of New Zealand for the Year 1934. Part I.* Wellington, NZ: Government Printer.

Census and Statistics Office. (1936). *Statistical Report on Trade and Shipping in the Dominion of New Zealand for the Year 1935. Part I.* Wellington, NZ: Government Printer.

Census and Statistics Office. (1937). *Statistical Report on Trade and Shipping in the Dominion of New Zealand for the Year 1936. Part I.* Wellington, NZ: Government Printer.

Census and Statistics Office. (1938). *Statistical Report on Trade and Shipping in the Dominion of New Zealand for the Year 1937. Part I.* Wellington, NZ: Government Printer.

Census and Statistics Office. (1939). *Statistical Report on Trade and Shipping in the Dominion of New Zealand for the Year 1938. Part I.* Wellington, NZ: Government Printer.

Census and Statistics Office. (1942a). *Statistical Report on the Factory and Building Production for the Dominion of New Zealand for the Year 1940-41.* Wellington, NZ: Government Printer.

Census and Statistics Office. (1942b). *Statistical Report on Trade and Shipping in the Dominion of New Zealand for the Year 1940. Part I.* Wellington, NZ: Government Printer.

Census and Statistics Office. (1952a). *Statistical Report on Trade and Shipping of New Zealand for the Years 1945 and 1946. Part I.* Wellington, NZ: Government Printer.

Census and Statistics Office. (1952b). *Statistical Report on Trade and Shipping of New Zealand for the Years 1950 and 1951. Part IB - Imports. Compiled in the Customs Department.* Wellington, NZ: Government Printer.

Ceramco Limited, & David Brett Limited. (1979). *50 Years: Ceramco 1929-1979*. Auckland, N.Z: Ceramco Ltd.

Chambers, J. M. (1917). Art. XXIV.—New Zealand Ironsands: an Historical Account of an Attempt to Smelt Ironsands at Onehunga in 1883. *Transactions and Proceedings of the New Zealand Institute 1917 [Electronic Resource]*, *50*, 223–230. Retrieved from http://rsnz.natlib.govt.nz/volume/rsnz_50/rsnz_50_00_002640.html

Chapman, G. T. (1873). *Chapman's New Zealand Almanac 1873*. Auckland: Geo. T. Chapman, Bookseller. Retrieved from www.enzb.auckland.ac.nz/docs/Chapmans/pdf/chaps2001.pdf

Chapple, G., Maynard, J., Mitchell, D., & Viscoe, W. (1983). *Corrugated Iron in New Zealand*. Wellington NZ: Reed.

Chilton-Young, F. (c1886). *Every man his own mechanic. A complete and comprehensive guide to every description of constructive and decorative work that may be done by the amateur artisan, at home and in the colonies. In three parts ...* (7th ed.). New York & Melbourne: Ward, Lock and Co.

Christie, J. (1996). Improving the Seismic Resistance of Earth Buildings. In *Nga Whare Uku - the Houses of Earth and How to Build Them* (1st ed., Vols. 1–1, p. 80). Wanganui, NZ: David Jones Publications.

Christie, T., Thompson, B., & Brathwaite, B. (2001). *Mineral Commodity Report 21 - Limestone, Marble and Dolomite* (No. 21) (p. 20). Wellington NZ: New Zealand Petroleum and Minerals, Ministry of Economic Development. Retrieved from http://www.nzpam.govt.nz/cms/pdf-library/minerals/publications/Commodity%20Reports/

City Engineer. (1904, June 24). Letter to J.R. Palmer, Town Clerk, Wellington City Council.

Clarke, W., Donaldson, T. L., Gell, W., & Mazois, F. (1832). *Pompeii*. London: Charles Knight.

C.M.I. Ltd. (1959). *Consolidated Metal Industries Ltd: a historical survey of the period 1909-1959 supplemented by present day illustrations of properties and equipment associated with the major activities of the C.M.I. Group to commemorate the golden jubilee of the commencement of our organisation*. Auckland NZ: C.M.I. Ltd.

Cochran, C. (1980). *Restoring a New Zealand House*. Wellington, NZ: New Zealand Historic Places Trust: Ministry of Works and Development.

Cochran, C. (1984). *Restoring a New Zealand House*. Wellington, NZ: New Zealand Historic Places Trust: Ministry of Works and Development.

Cochran, C. (1990). Styles of Sham and Genuine Simplicity: Timber Buildings in Wellington to 1880. In D. A. Hamer & R. Nicholls (Eds.), *The Making of Wellington, 1800-1914* (pp. 107–128). Wellington: Victoria University Press.

Cochran, C., & Williams, D. (1991). *Restoring a New Zealand house*. Auckland, NZ: Random Century New Zealand.

Cockayne, L. (1919). Obituary. Thomas William Adams, 1841–1919. *Transactions and Proceedings of the New Zealand Institute, 1919 [Electronic Resource]*, *51*, xi–xii. Retrieved from http://rsnz.natlib.govt.nz/volume/rsnz_51/rsnz_51_00_000060.html

Coles's Book Arcade. (c1900). *Cole's Practical Carpenter, Joiner and General Mechanic : a book for professional and amateur workmen comprising carpentry, turning, fret-sawing, wood-carving, general building - (stone and brick), smiths work, plumbing and gas-fitting, painting and glazing, paper-hanging, etc. With 800 illustrations and working diagrams.* Melbourne: Cole's Book Arcade.

Colorgravure Publications. (1950a). *Australian Picture Handyman - a Practical Guide for Home Craftsmen.* Melbourne: Colorgravure Publications (Herald & Weekly Times).

Colorgravure Publications. (1950b). *New Zealand Picture Handyman - a Practical Guide for Home Craftsmen.* Melbourne: Colorgravure Publications (Herald & Weekly Times).

Commercial Publishing Company of Sydney. (1903). *The New South Wales Annual Review of Shipping and Commerce for 1902*. Sydney, NSW: Commercial Publishing Company of Sydney.

Consumers' Institute of New Zealand. (1972). *Buying or Building a House* (Revised & Enlarged). Wellington NZ: Consumers' Institute of New Zealand.

Consumers' Institute of New Zealand. (1976). *Buying or Building a House*. Wellington NZ: Consumers' Institute of New Zealand.

Consumers' Institute of New Zealand. (1982). *Your Dream House: How to Buy, Build, Improve, Finance and Insure the Home You Have Always Dreamed About.* [Wellington, NZ]: Consumers' Institute of New Zealand.

Cook, C. J. (1893). *Captain Cook's Journal During His First Voyage Round The World Made In H.M. Bark 'Endeavour' 1768-71 - A Literal Transcription Of The Original Mss. With Notes And Introduction.* (C. W. J. L. Wharton, Ed.). London: Elliot Stock. Retrieved from http://www.gutenberg.org/ebooks/8106

Cooke, M. B. (1975). *The Age of Houses Illustrated* (2d enl. ed). Lincoln: Lincoln College, Farm Management and Rural Valuation Dept. (University of Canterbury).

Cooney, R. C. (1979). The Structural Performance of Houses in Earthquakes. *Bulletin of The National Society for Earthquake Engineering*, *12*(3), 223–237. Retrieved from http://www.nzsee.org.nz/db/Bulletin/Archive/12(3)0223.pdf

Cooper, H. S., & Stewart, G. V. (Eds.). (1886). *The New Zealand Year-Book, 1886-1887: Compiled for the Use of Intending Settlers, Tourists, Merchants, and Manufacturers, from Information Furnished by the Works of the Agent-General and the Government of the Colony*. London: Sampson Low, Marston, Searle & Rivington.

Cottrell, W. (2006). *Furniture of the New Zealand Colonial Era: An Illustrated History, 1830-1900*. Auckland NZ: Reed.

Cowan, H. J. (1998). *From Wattle & Daub to Concrete & Steel: The Engineering Heritage of Australia's Buildings*. Carlton South, Vic.: Melbourne University Press.

Cowan, J. (1910). *Official Record of the New Zealand International Exhibition of Arts and Industries Held at Christchurch, 1906-7: A Descriptive and Historical Account*. Wellington, N.Z: Government Printer. Retrieved from http://christchurchcitylibraries.com/Heritage/Publications/1906InternationalExhibition/OfficialRecord/

Cowden, A. B., & Wessel, D. P. (1995). Cast Stone. In T. C. Jester (Ed.), *Twentieth-Century Building Materials: History and Conservation* (pp. 86–93). New York: McGraw-Hill.

Coyte, C. A. (1981). Softwood Plywood - A Contribution Paper to the Session 'Utilisation and Marketing Opportunities'. In *Exotic Forests: Their Importance to New Zealand's Future* (p. 4). Wellington, N.Z: New Zealand Forestry Council.

Cranwell Publishing Ltd. *Cranwells Building Supplies Catalogue*. Auckland NZ: Cranwell Publishing Ltd.

Crawford, R. C. (1868). On Building Materials for New Zealand. *Transactions and Proceedings of the New Zealand Institute [Electronic Resource]*, *1*, 25–27. Retrieved from http://rsnz.natlib.govt.nz/volume/rsnz_01/rsnz_01_00_000420.html

Cresy, E. (1847). *An Encyclopaedia of Civil Engineering, Historical, Theoretical, and Practical*. London: Longman, Brown, Green & Longmans.

Crichton & McKay, Architects. (1904, October 10). 49 The Crescent [Palliser Road] Dwelling (Applicant Niels Nielsen). Wellington City Council Archives.

CSR Viridian New World Glass. (2010, September 14). Manufacturing Float Glass. Retrieved 22 May 2014, from http://glasstalks.com/2010/09/14/manufacturing-float-glass/

Customs Department. (1957a). *Statistical Report on the External Trade of New Zealand for the Years 1955. Exports. Compiled in the Customs Department.* Wellington, NZ: Government Printer.

Customs Department. (1957b). *Statistical Report on the External Trade of New Zealand for the Years 1955. Imports. Compiled in the Customs Department.* Wellington, NZ: Government Printer.

Customs Department. (1962a). *Statistical Report on the External Trade of New Zealand for the Year 1960. Exports. Compiled in the Customs Department.* Wellington, NZ: Government Printer.

Customs Department. (1962b). *Statistical Report on the External Trade of New Zealand for the Year 1960. Imports. Compiled in the Customs Department.* Wellington, NZ: Government Printer.

Cyclopedia Company Limited. (1905). *The Cyclopedia of New Zealand - Otago & Southland* (Vol. 4). Christchurch: The Cyclopedia Company Limited.

Daily Southern Cross. *Daily Southern Cross [Electronic Version Accessed through: Paperspast.natlib.govt.nz (1843-1876)]*. Auckland, NZ

Davis, C. (2009, February). Residential Steel Framing. *Build*, (110), 54–55.

Davis, E. R. (1949). *A Link with the Past*. Auckland NZ: Oswald-Sealy.

Department of Building and Housing. (2011a, April 4). Compliance Document for the New Zealand Building Code: Clause B2 Durability. 2nd Edition [Amendment 7]. Department of Building and Housing.

Department of Building and Housing. (2011b, October 10). Compliance Document for the New Zealand Building Code: Clause H1 Energy Efficiency. 3rd Edition (Amendment 2). Department of Building and Housing.

Department of Industries and Commerce. (1928a, May 14). Visits to Factories - 14 Dec 1928, Lino Nail Company – lead headed roofing nails. Retrieved from AEFN 19294 W715 IC1 390/19/105 Part 1

Department of Industries and Commerce. (1928b, December 11). Visits to Factories - 11 Dec 1928, The Auto Machine Manufacturing Co. Ltd, 232 Thorndon Quay, Wellington. Retrieved from AEFN 19294 W715 IC1 390/19/105 Part 1

Department of Industries and Commerce. (1937, September 29). Briefing Notes Prepared for J.A. Lee, Parliamentary Under Secretary for Industry, 29 Sep 1937 from D.G. Sullivan. Retrieved from AEFN 19294 W715 IC1 390/19/105 Part 1

Department of Industries and Commerce. (1938, August 10). Memo to Minister of Industries 10 Aug 1938. Retrieved from AEFN 19294 W715 IC1 390/19/105 Part 1

Department of Industries and Commerce. (1939, January 26). Memo to Secretary, Department of Industries & Commence 26 Jan 1939. Retrieved from AEFN 19294 W715 IC1 390/19/105 Part 1

Department of Industries and Commerce. (1942). Engineering Hardware - Nails - License to Manufacture - H. Hanson and Company Limited, Wellington 1939-1942. Retrieved from AEFN 19294 W715 IC1 394 / 19/105/9

Department of Statistics. (1957). *Report on the Industrial Production Statistics of New Zealand for the Year 1955-56*. Wellington, NZ: Government Printer.

Department of Statistics. (1967a). *Exports 1965-66. Final Detailed Statistics which replace provisional figures published earlier.* Wellington NZ: Government Printer.

Department of Statistics. (1967b). *Imports Part A Commodity by Country 1965-66. Final Detailed Statistics which replace provisional figures published earlier.* Wellington NZ: Government Printer.

Department of Statistics. (1968). *Statistics of Industrial Production for the Production Year 1965-66*. Wellington NZ: Government Printer.

Department of Statistics. (1973a). *Imports Part A Commodity by Country. 1970-71. Final Detailed Statistics which replace provisional figures published earlier.* Wellington NZ: Government Printer.

Department of Statistics. (1973b). *Statistics of Industrial Production for the Production Year 1970-71*. Wellington NZ: Government Printer.

Department of Statistics. (1978). *External Trade Imports Commodity by Country. 1975-76. Final Detailed Statistics replacing provisional figures and summaries released earlier.* Wellington NZ: Government Printer.

Department of Statistics. (1979). *External Trade Imports. Commodity by Country. Country by Commodity. 1977-78 Final Detailed Statistics replacing provisional figures and summaries released earlier.* Wellington NZ: Government Printer.

Deplazes, A. (Ed.). (2013). *Constructing Architecture: Materials, Processes, Structures: A Handbook* (Third, extended ed). Basel: Birkhäuser.

Director Housing Construction. (1939, November 3). Memorandum for Secretary of Supply from Director of Housing Construction, 3 Nov 1939. Atten. Mr. Dennis. Retrieved from AEFN 19294 W715 IC1 390/19/105 Part 2

Dobson, E. (1849a). *A Rudimentary Treatise on Masonry and Stonecutting ... in Three Sections ... with ... Engravings on Wood; and an Atlas, Etc*. London.

Dobson, E. (1849b). *Rudiments of the Art of Building*. London: John Weale.

Dobson, E. (1850a). *Rudimentary Treatise on Foundations and Concrete Works Containing a Synopsis of the Principal Cases of Foundation Works, With the Usual Modes of Treatment and Practical Remarks on Footings, Timber-Planking, Sand, Concrete, and Béton Pile-Driving, Caissons and Cofferdams; With an Account of the New Mole Executed in Béton at the Harbour of Algiers*. London: John Weale.

Dobson, E. (1850b). *Rudimentary Treatise on the Manufacture of Bricks and Tiles; Containing an Outline of the Principles of Brickmaking and Detailed Accounts of the Various Processes Employed in the Making of Bricks and Tiles in Different Parts of England*. London: John Weale. Retrieved from http://books.google.co.nz/books?id=zJcOAAAAYAAJ&dq=weale%20dobson&pg=PR3#v=onepage&q=weale%20dobson&f=false

Dobson, E. (1866). *Synopsis of a Course of Four Lectures on Foundations: To Be Delivered at the Town Hall, Christchurch, on September 11, 14, 19, and 21, at Half-Past Seven Each Evening.* Christchurch: Ward and Reeves.

Dobson, E. (1868). Art. XX.— On the present state of Applied Science in the Canterbury Province. An Address delivered at the Annual Meeting of the Philosophical Institute of Canterbury, November 5, 1866, *1*, 181–195. Retrieved from http://rsnz.natlib.govt.nz/volume/rsnz_01/rsnz_01_00_001580.pdf

Dobson, E. (1869). Art. LVI.— On a series of Tables for facilitating the Calculations of Altitudes from Barometrical Observations in Mountainous Countries; with explanations, *2*, 223–226. Retrieved from http://rsnz.natlib.govt.nz/volume/rsnz_02/rsnz_02_00_003000.pdf

Dobson, E. (1877). *Pioneer Engineering: A Treatise on the Engineering Operations Connected with the Settlement of Waste Land in New Countries*. London: Crosby Lockwood and Co.

Dobson, E. (1885). *Syllabus of a Course of Twelve Lectures on Building Construction to Be Delivered at the Canterbury College, Christchurch, NZ* Christchurch, NZ

Dobson, E. (1887). *The Function of the Civil Engineer in the Work of Colonization: Being the Substance of an Address Delivered by Mr. Edward Dobson, M. Inst. C.E., July 26th, 1887, on the Occasion of the Opening of the School of Engineering Established in Connection with Canterbury College, Christchurch, New Zealand*. Christchurch NZ: Whitcombe and Tombs.

Dominion. *Dominion [Electronic Version Accessed through: Paperspast.natlib.govt.nz (1907-1920)]*. Wellington NZ

Douglas, J. (1997). The Development of Ground Floor Constructions: Part 1. *Structural Survey*, *15*(3), 109–112. Retrieved from http://proquest.umi.com/pqdweb?did=86923434&Fmt=7&clientId=7511&RQT=309&VName=PQD

Douglas, J. (1998a). The Development of Ground Floor Constructions: Part III (Damp Proofing Materials). *Structural Survey*, *16*(1), 18–22. Retrieved from http://proquest.umi.com/pqdweb?did=86923503&Fmt=7&clientId=7511&RQT=309&VName=PQD

Douglas, J. (1998b). The Development of Ground Floor Constructions: Part IV (Damp Proofing Methods). *Structural Survey*, *16*(2), 76–80. Retrieved from http://proquest.umi.com/pqdweb?did=86923506&Fmt=7&clientId=7511&RQT=309&VName=PQD

Douglas, J. (1999). The Development of Ground Floor Constructions: Part 8 (Review and Summary). *Structural Survey*, *17*(4), 216–220. Retrieved from http://proquest.umi.com/pqdweb?did=86923528&Fmt=7&clientId=7511&RQT=309&VName=PQD

Downer and Company. (1983). *Downer, 50 years, 1933-1983*. Wellington, NZ: Downer and Company.

Drummond, A., & Drummond, L. R. (1967). *At Home in New Zealand: An Illustrated History of Everyday Things before 1865*. Auckland NZ: Blackwood and Janet Paul.

Drysdale, J. (2013, June 20). Early NZ Use of LOSP (Consultant) (E-mail).

Duffy, F. (1990). Measuring Building Performance. *Facilities*, *8*(5), 17–20. http://doi.org/10.1108/eb006518

Dunlap, M. E. (1949). *Condensation Control in Dwelling Construction, by Forest Products Laboratory, Forest Service, U.S. Department of Agriculture, in collaboration with the Division of Standardized Building Codes and Materials, Office of the Administrator, Housing and Home Finance Agency.* (1st ed.). Washington, D.C.: Housing and Home Finance Agency. Retrieved from http://catalog.hathitrust.org/Record/100074362

Dunlap, M. E. (1950). *Condensation Control in Dwelling Construction, by Forest Products Laboratory, Forest Service, U.S. Department of Agriculture, in collaboration with the Division of Standardized Building Codes and Materials, Office of the Administrator,* *Housing and Home Finance Agency.* (2nd ed.). Washington, D.C.: Housing and Home Finance Agency.

Dymock's Book Arcade. (1903). *Dymock's carpenter and builder's handbook: a complete guide to every description of constructive and decorative work, valuable alike to the artisan and amateur workman; ornamental carpentry, joinery, constructive and general building, art and practice &c, &c.* Sydney: William Dymock.

Eclipse Wire Products Ltd. (1941, July 11). Eclipse Wire Products Ltd 11 Jul 1941 letter to Secretary, Bureau of Industry, Wellington. Retrieved from AEFN 19294 W715 IC1 394 / 19/105/8 Part 1

Edgerton, C. E. (1897). The Wire-Nail Association of 1895-96. *Political Science Quarterly*, *12*(2), 246–272.

Eggers, H. W. T. (1949a, November). Preparation for Structural Use. *New Zealand Journal of Agriculture*, *79*(5), 449–459.

Eggers, H. W. T. (1949b, December). The Use of Reinforcing and Boxing. *New Zealand Journal of Agriculture*, *79*(6), 571–576.

Eggers, H. W. T. (1950a, January). The Making of Pre-cast Products. *New Zealand Journal of Agriculture*, *80*(1), 55–62.

Eggers, H. W. T. (1950b, February). The Concreting of Paving and Pressure-resistant Structures. *New Zealand Journal of Agriculture*, *80*(2), 147–150.

Eggers, H. W. T. (1950c, March). The General Uses of Cement and Concrete. *New Zealand Journal of Agriculture*, *80*(3), 233–236.

Eggers, H. W. T. (1952). *Concrete* (1st ed.). Wellington, NZ: NZ Dept. of Agriculture.

Eggers, H. W. T. (1957). *Concrete* (Rev. 1957). Wellington, NZ: NZ Dept. of Agriculture.

Eldred-Grigg, S. (2008). *Diggers, Hatters & Whores: The Story of the New Zealand Gold Rushes*. Auckland, NZ: Random House.

Elkink, A. (2010a). *Renovate - Art Deco*. Porirua, NZ: BRANZ.

Elkink, A. (2010b). *Renovate - Bungalows*. Porirua, NZ: BRANZ.

Elkink, A. (2011a). *Renovate - 1940-1960s*. Porirua, NZ: BRANZ.

Elkink, A. (2011b). *Renovate - 1970s*. Porirua, NZ: BRANZ.

Elliott, C. D. (1992). *Technics and Architecture: The Development of Materials and Systems for Buildings*. Cambridge, Mass.: MIT Press.

Ellis, H. (1833). *The British Museum. Elgin and Phigaleian Marbles.* London: Charles Knight.

Ernst Haberer & Cie, Bern. (1906, August). Berner Stuckfabrik (Bern Stucco Factory). *Heimatschutz = Patrimoine*, *1*(4). Retrieved from http://retro.seals.ch

Evans, D. L. (1965). Gang Nails and Other Plate Fasteners for Roof Trusses. *TDA Bulletin*, *1*(15), 3–4. Retrieved from AALF W3202/19 Record 24/15 Part 1

Evening Post. *Evening Post [Electronic Version Accessed through: Paperspast.natlib.govt.nz (1865-1945)]*. Wellington, New Zealand.

Farmers' Trading Company Ltd. (1927). *Catalogue No. 9 Farmers' Trading Co. Ltd, Auckland*. Auckland NZ: Farmers Trading Co. Ltd.

Fearnley, C. (1975). *Where Have All the Textures Gone?* Dunedin NZ: John McIndoe Ltd.

Ferens, S. (2010). *Building Futures: Hawkins People, Projects, and Stories*. Auckland, NZ: Redit Books.

Ferguson, G. (1994). *Building the New Zealand Dream*. Palmerston North, NZ: Dunmore Press with the assistance of the Historical Branch, Dept. of Internal Affairs.

Ferrar, H. T. (1934). *The Geology of the Dargaville-Rodney Subdivision, Hokianga and Kaipara Division*. Wellington, NZ: Department of Scientific and Industrial Research, Geological Survey Branch.

Fill, B., Mulgan, H., & Davidson, G. (2010). *Riddlers Crescent: A History*. Petone NZ: Petone Historical Society.

Finch, J. (1960, October). Dampness in Buildings. *Construction (Official Journal of NZ Master Builders' Federation, Inc.)*, (61), 32–35.

Findlay Dalziell & Co, Solicitors, Wellington. (1904, September 3). Agreement between Neils Neilsen and A.G. East.

Findlay, M. (2000, c). The House That Thomas Burns Built. Unpublished paper. Staff member University of Otago.

Firth Company. (2008, May). Introducing Firth. Firth, business unit of Fletcher Building Ltd. Retrieved from http://www.firth.co.nz/media/79769/Introducing%20Firth%20Brochure.pdf

Firth, J. C. (1890, April 3). An invention for an insulator, to be called 'Firth's Patent Pumice Insulator' [NZ Patent 4,319]. Retrieved from Archives NZ Wellington. ABPJ W3835 7396 Box 47 4319

Firth, J. C. (1892). Art. VI - Causes of Fires on Shipboard and Elsewhere. *Transactions and Proceedings of the New Zealand Institute [Electronic Resource]*, *25*, 385–395. Retrieved from http://rsnz.natlib.govt.nz/volume/rsnz_25/rsnz_25_00_004720.pdf

Firth, J. C. (1894a, January 12). Drying Pumice [NZ Patent 6,618]. Retrieved from Archives NZ Wellington. ABPJ W3835 7396 Box 47 4319

Firth, J. C. (1894b, October 25). An invention for the application of prepared pumice for insulation for insulating various structures, and for sanitary and other purposes [NZ Patent 7,232]. Retrieved from Archives NZ Wellington. ABPJ W3835 7396 Box 63 7232

Firth, W. T. (1897). Art. LV.—On the Relative Commercial Values of Pumice and Charcoal for Purposes of Insulation. [Read before the Auckland Institute, 6th September, 1897.]. *Transactions and Proceedings of the New Zealand Institute [Electronic Resource]*, *30*, 463–465. Retrieved from http://rsnz.natlib.govt.nz/volume/rsnz_30/rsnz_30_00_007090.html

Fitton, E. B. (1856). *New Zealand Its Present Condition, Prospects and Resources ; Being a Description of the Country and General Mode of Life Among New Zealand Colonists, for the Information of Intending Emigrants [Electronic Resource]*. London: E. Stanford. Retrieved from http://www.enzb.auckland.ac.nz.helicon.vuw.ac.nz/document?wid=1014&action=null

Forbes, R. (1977). An Energy Conserving House. *NZ Environment*, (17), 3–7.
Ford, C. R. (1926). *Earthquakes and Building Construction*. Auckland: Whitcombe & Tombs Limited.
Ford, C. R. (1929). *Brick as a Building Material in Earthquake Areas*. Auckland, NZ: Amalgamated Brick & Pipe Co.
Fraemohs Homes Ltd. (2014). About Fraemohs Homes. Retrieved 7 May 2014, from http://www.fraemohs.co.nz/about-us-2/
Fraemohs Industries Ltd. (1969). Timbo Weekend Batch. Retrieved from AEFN 19294 ICW2680/1 57/9/1
Fraenkel, H. R. (1949, January 1). Revolutionary Building Process - Rubber Moulds Speed Housing Construction. *Democracy: New Zealand's Independent Political and Cultural Review*, *8*(21), 12–13.
Fraser, B., & McLauchlan, G. (1986). *The New Zealand Book of Events*. Auckland NZ: Reed Methuen.
Freeman, M. H., Shupe, T. F., Vlosky, R. P., & Barnes, H. M. (2003). Past, Present, and Future of Preservative-Treated Wood. *Forest Products Journal*, *53*(10), 8–15.
Fricker, J., & Hughes, M. R. (2000). *AIRAH Technical Handbook - 3rd edition* (3rd ed.). Melbourne, Vic.: Australian Institute of Refrigeration, Air Conditioning and Heating (Inc).
Friedman, D. (2010). *Historical Building Construction : Design, Materials & Technology*. New York: W.W. Norton & Co.
F.W. Williams & Co. (1947). *Sisalkraft Handbook of Useful Specifications*. Sydney: F.W. Williams & Co.
Gainsford, J. (2006). *Lockwood: From Innovation to Icon in 50 Years*. Tauranga, NZ: Bay of Plenty Branch Committee, New Zealand Historic Places Trust.
Galer, L. (1981). *More Houses and Homes*. Dunedin, NZ: Allied Press.
Garrett, J. (Ed.). (1954). *Homebuilding, 1814-1954: the new zealand tradition: Catalogue of the Exhibition Group, School of Architecture, Auckland University College*. Auckland, N.Z: Pelorus Press.
Gatley, J. (2008a). *Long Live the Modern: New Zealand's New Architecture, 1904-1984*. Auckland, NZ: Auckland University Press.
Gatley, J. (2008b). The Concrete Block House in 1950s New Zealand. In D. Benyon & U. de Jong (Eds.), *Proceedings of the XXVth International Conference of the Society of Architectural Historians, Australia and New Zealand* (p. 16). Geelong, Australia: Society of Architectural Historians Australia & New Zealand (SAHANZ).
Gillies, T. B. (1879). Art. LIII.—Notes on the Growth of Certain Trees on Scoria Soil Near Mount Eden, Auckland. [read before the Auckland Institute, 30th June, 1879.], *12*, 357–358. Retrieved from http://rsnz.natlib.govt.nz/volume/rsnz_12/rsnz_12_00_003240.html
Gisborne Borough Council. By-Laws of the Gisborne Borough Council. 1st May 1907 (1907).

Glenmore Brick & Tile Manufacturing Coy. (1916). *Brickyards and Quarries Hillsborough Christchurch*. Christchurch, N.Z: Weeks Limited.
Glover, D. (1981). *Hot Water Sailor 1912-1962 & Landlubber Ho! 1963-1980*. Auckland, N.Z: Collins.
Goddard, H. A. (1905, April 26). An improved mode of building in concrete and apparatus therefor [Australian Patent 3018/05]. Concord, Sydney, NSW, Australia.
Goddard, H. A. (1906, January 22). An improved mode of building in concrete and apparatus therefor [NZ Patent 20,638]. Concord, Sydney, NSW, Australia. Retrieved from Archives NZ, Wellington. ABPJ 7396 W3835/133 20638
Goddard, H. A. (1908, August 4). Apparatus for Constructing a Hollow Wall [US Patent 895,255]. Concord, Sydney, NSW, Australia.
Goddard, H. A. (1910, June 9). Improvements relating to box-cores that are used in building hollow concrete walls [NZ Patent 27,851]. Concord, Sydney, NSW, Australia. Retrieved from Archives NZ, Wellington. ABPJ 7396 W3835/159 27851
Government of New Zealand. Raupo Houses Ordinance 1842 (1842).
Government of New Zealand. New Zealand Forests Act (1874).
Government of New Zealand. State Forests Act (1885).
Government of New Zealand. Building Act 1991 (1991). Retrieved from http://www.nzlii.org/cgi-bin/download.cgi/nz/legis/hist_act/ba19911991n150118
Government Printing Office. (1984). Publications: Carpentry in New Zealand. 1960 to 1984. Retrieved from AAUR W3549 8598 Box 42 Part 1
Government Statistician, Registrar-General's Office. (1869). *Statistics of New Zealand for 1868. Compiled from Official Records*. Wellington, NZ: Government Printer.
Government Statistician, Registrar-General's Office. (1870). *Statistics of New Zealand for 1869. Compiled from Official Records*. Wellington, NZ: Government Printer.
Government Statistician, Registrar-General's Office. (1872a). *Results of a Census of New Zealand, Taken for the Night of the 27th February, 1871*. Wellington, NZ: Government Printer.
Government Statistician, Registrar-General's Office. (1872b). *Statistics of New Zealand for 1870. Compiled from Official Records*. Wellington, NZ: Government Printer.
Government Statistician, Registrar-General's Office. (1875). *Results of a Census of the Colony of New Zealand, Taken for the Night of the 1st of March, 1874. Part I - Population and Houses*. Wellington, NZ: Government Printer.
Government Statistician, Registrar-General's Office. (1876). *Statistics of the Colony of New Zealand For the Year 1875: With Abstracts from the Agricultural Statistics of 1876. Compiled from Official Records in the Registrar-General's Office*. Wellington, NZ: Government Printer.
Government Statistician, Registrar-General's Office. (1880). *Results of a Census of the Colony of New Zealand, Taken for the Night of the 3rd of March, 1878. Part I - Population and Houses*. Wellington, NZ: Government Printer.

Government Statistician, Registrar-General's Office. (1881). *Statistics of the Colony of New Zealand For the Year 1880: With Abstracts from the Agricultural Statistics of 1881 Compiled from Official Records in the Registrar-General's Office*. Wellington, NZ: Government Printer.

Government Statistician, Registrar-General's Office. (1882). *Results of a Census of the Colony of New Zealand, Taken for the Night of the 3rd of April, 1881. Part I - Population and Houses*. Wellington, NZ: Government Printer.

Government Statistician, Registrar-General's Office. (1884). *Statistics of the Colony of New Zealand For the Year 1883*. Wellington, NZ: Government Printer.

Government Statistician, Registrar-General's Office. (1885). *Statistics of the Colony of New Zealand For the Year 1884*. Wellington, NZ: Government Printer.

Government Statistician, Registrar-General's Office. (1886). *Statistics of the Colony of New Zealand For the Year 1885: With Abstracts from the Agricultural Statistics of 1886. Compiled from Official Records in the Registrar-General's Office*. Wellington, NZ: Government Printer.

Government Statistician, Registrar-General's Office. (1887a). *Results of a Census of the Colony of New Zealand, Taken for the Night of the 28th of March, 1886. Part I - Population and Houses*. Wellington, NZ: Government Printer.

Government Statistician, Registrar-General's Office. (1887b). *Statistics of the Colony of New Zealand For the Year 1886: With Abstracts from the Agricultural Statistics of 1887. Compiled from Official Records in the Registrar-General's Office*. Wellington, NZ: Government Printer.

Government Statistician, Registrar-General's Office. (1888). *Statistics of the Colony of New Zealand For the Year 1887: With Abstracts from the Agricultural Statistics of 1888. Compiled from Official Records in the Registrar-General's Office*. Wellington, NZ: Government Printer.

Government Statistician, Registrar-General's Office. (1889). *Statistics of the Colony of New Zealand For the Year 1888: With Abstracts from the Agricultural Statistics of 1889. Compiled from Official Records in the Registrar-General's Office*. Wellington, NZ: Government Printer.

Government Statistician, Registrar-General's Office. (1890). *Statistics of the Colony of New Zealand For the Year 1889: With Abstracts from the Agricultural Statistics of 1890. Compiled from Official Records in the Registrar-General's Office*. Wellington, NZ: Government Printer.

Government Statistician, Registrar-General's Office. (1891). *Statistics of the Colony of New Zealand For the Year 1890: With Abstracts from the Agricultural Statistics of 1891. Compiled from Official Records in the Registrar-General's Office*. Wellington, NZ: Government Printer.

Government Statistician, Registrar-General's Office. (1892). *Report on the Results of a Census of the Colony of New Zealand, Taken for the Night of the 5th of April, 1891. Part I - Population and Houses*. Wellington, NZ: Government Printer.

Government Statistician, Registrar-General's Office. (1896). *Statistics of the Colony of New Zealand For the Year 1895: With Statistics of Local Governing Bodies for the Year Ended 31st March, 1896. Compiled in the Registrar-General's Office from Official Records.* Wellington, NZ: Government Printer.

Government Statistician, Registrar-General's Office. (1897). *Census 1896 - Results of a Census of the Colony of New Zealand, Taken for the Night of the 12th of April, 1896. Part I - Population and Houses*. Wellington, NZ: Government Printer.

Government Statistician, Registrar-General's Office. (1901). *Statistics of the Colony of New Zealand For the Year 1900: With Statistics of Local Governing Bodies for the Year Ended 31st March, 1901. Compiled in the Registrar-General's Office from Official Records.* Wellington, NZ: Government Printer.

Government Statistician, Registrar-General's Office. (1906). *Statistics of the Colony of New Zealand For the Year 1905: With Statistics of Local Governing Bodies for the Year Ended 31st March, 1906. Compiled in the Registrar-General's Office from Official Records.* Wellington, NZ: Government Printer.

Government Statistician, Registrar-General's Office. (1911). *Statistics of the Colony of New Zealand For the Year 1910: With Statistics of Local Governing Bodies for the Year Ended 31st March, 1911. Compiled by the Government Statistician from Official Records.* Wellington, NZ: Government Printer.

Government Statistician, Registrar-General's Office. (1912a). *Results of a Census of the Dominion of New Zealand Taken for the night of 2nd April 1911. Part I - Population and Dwellings*. Wellington, NZ: Government Printer.

Government Statistician, Registrar-General's Office. (1912b). *Statistics of the Colony of New Zealand For the Year 1911: With Statistics of Local Governing Bodies for the Year Ended 31st March, 1912. Compiled by the Government Statistician from Official Records.* Wellington, NZ: Government Printer.

Government Statistician, Registrar-General's Office. (1913). *Statistics of the Dominion of New Zealand For the Year 1912.* Wellington, NZ: Government Printer.

Government Statistician, Registrar-General's Office. (1914). *Statistics of the Dominion of New Zealand For the Year 1913. In Four Volumes. Volume: II: Trade and Shipping. Compiled from Returns furnished by Customs Department*. Wellington, NZ: Government Printer.

Government Statistician, Registrar-General's Office. (1915). *Statistics of the Dominion of New Zealand For the Year 1914. In Four Volumes. Volume: II: Trade and Shipping. Compiled from Returns furnished by Customs Department*. Wellington, NZ: Government Printer.

Government Statistician, Registrar-General's Office. (1916). *Statistics of the Dominion of New Zealand For the Year 1915. In Four Volumes. Volume: II: Trade and Shipping. Compiled from Returns furnished by Customs Department*. Wellington, NZ: Government Printer.

Government Statistician, Registrar-General's Office. (1917). *Statistics of the Dominion of New Zealand For the Year 1916. In Four Volumes. Volume: III: Production. Finance. Postal and Telegraph*. Wellington, NZ: Government Printer.

Government Statistician, Registrar-General's Office. (1918). *Statistics of the Dominion of New Zealand For the Year 1917. In Four Volumes. Volume: II: Trade and Shipping. Compiled from Returns furnished by Customs Department*. Wellington, NZ: Government Printer.

Government Statistician, Registrar-General's Office. (1919). *Statistics of the Dominion of New Zealand For the Year 1918. In Four Volumes. Volume: II: Trade and Shipping. Compiled from Returns furnished by Customs Department*. Wellington, NZ: Government Printer.

Government Statistician, Registrar-General's Office. (1920). *Statistics of the Dominion of New Zealand For the Year 1919. In Four Volumes. Volume: II: Trade and Shipping. Compiled from Returns furnished by Customs Department*. Wellington, NZ: Government Printer.

Government Statistician, Registrar-General's Office. (1921). *Statistics of the Dominion of New Zealand For the Year 1920. In Four Volumes. Volume: II: Trade and Shipping. Compiled from Returns furnished by Customs Department*. Wellington, NZ: Government Printer.

Grey River Argus. *Grey River Argus [Electronic Version Accessed through: Paperspast.natlib.govt.nz (1866-1920)]*. Greymouth, NZ

Guedes, P. (editor). (1979). *The Macmillan Encyclopedia of Architecture and Technological Change*. London: Macmillan.

Hall, M. (2012). *Earth and Straw Bale: An Investigation of Their Performance and Potential as Building Materials in New Zealand* (Master of Architecture). Victoria University of Wellington, Wellington NZ Retrieved from http://researcharchive.vuw.ac.nz/handle/10063/2529

Hardie, B. G. (1954). *Statistics of New Zealand for the Crown Colony Period, 1840 - 1852*. Auckland, NZ: Dept. of Economics, Auckland University College.

Hardyment, C. (1992). *Home Comfort: A History of Domestic Arrangements*. London: Viking in association with the National Trust.

Harrap, N. (1981). *Buying & Restoring a House*. Wellington, NZ: N. Harrap.

Harris, D. J. (1995). Moisture Beneath Suspended Timber Floors. *Structural Survey*, *13*(3), 11–15.

Harris, J. (1994). *Tohora: the story of Fyffe House, Kai Koura*. Wellington, N.Z: New Zealand Historic Places Trust.

Harris, R. (Ed.). (2002). *Weald & Downland Open Air Museum Guidebook*. Chichester, UK: Weald & Downland Open Air Museum.

Hatschek, L. (1904, August 30). Process of Manufacturing Imitation Stone Plates, Slabs, or Tiles [US Patent 769,078. Reissued 12,594, 15 Jan 1907]. Retrieved from www.uspto.gov

Hatschek, L. (1907, January 15). Manufacture of Imitation-Stone Plates, Slabs, or Tiles [Reissue 12,594 of US Patent 769,078]. Retrieved from www.uspto.gov

Hawera & Normanby Star. *Hawera & Normanby Star [Electronic Version Accessed through: Paperspast.natlib.govt.nz (1880-1924)]*. Hawera, NZ

Hawkins, G. (2002). Submission to the Inquiry into the Weathertightness of Buildings in New Zealand from the Office of the Minister of Internal Affairs. Retrieved from http://www.dia.govt.nz/diawebsite.nsf/Files/SelectCommitteeSubmission/$file/SelectCommitteeSubmission.pdf

Hay, D. (1872). On the Cultivation of Native Trees [read at 5th meeting of the Auckland Institute, 23 Sept 1872]. *Transactions and Proceedings of the New Zealand Institute 1872. [Electronic Resource]*, *5*, 452–455. Retrieved from http://rsnz.natlib.govt.nz/

Hayward, B. W. (1987). *Granite and Marble: A Guide to Building Stones in New Zealand*. Lower Hutt, NZ: Geological Society of New Zealand.

Healy, B. (1982). *A Hundred Million Trees: The Story of NZ Forest Products Ltd*. Auckland NZ: Hodder and Stoughton.

Hegan, C. (1993, November). Prince of Pines. *New Zealand Geographic*, *20*, 88–114.

H. Hanson & Co. Ltd. (1941, July 11). H. Hanson & Co. Ltd 11 Jul 1941 letter to Secretary, Bureau of Industry, Wellington. Retrieved from AEFN 19294 W715 IC1 394 / 19/105/9

Hill, K. M. (1998). *The Development of Metal Tiles in New Zealand: A History*. Auckland, N.Z: AHI Roofing.

Hill, M. (1985). *Restoring with Style: Preserving the Character of New Zealand Houses*. Wellington, NZ: Government Printer.

History Students of Motueka High. (1999). *Back Then - threads from Motueka's past*. (I. Munro, Ed.). Motueka, NZ: Motueka High School.

Humphris, A. (2012, July 27). Nielson Building Permits held by Wellington City Archives (E-mail).

Hutt News. *Hutt News*. Lower Hutt, NZ

Hutt Valley Independent. *Hutt Valley Independent [Electronic Version Accessed through: Paperspast.natlib.govt.nz (1911-1919)]*. Upper Hutt, NZ

Industrial Corporation of New Zealand. (1922). *Exhibition of New Zealand Industries, King Edward's Barracks, Cashel St., Christchurch: official souvenir catalogue*. Christchurch NZ: Industrial Corporation of New Zealand.

Industrial Processors Limited. (2012, June). Perlite [Company]. Retrieved 19 October 2014, from http://www.perlite.co.nz/perlite/

Industries Select Committee. (1919). I- 12 Industries Committee [Report of the] Together with Minutes of Evidence. In *Appendix to the Journals of the House of Representatives — 1919* (Vol. 2). Wellington, NZ: Government Printer.

Inspector of Customs, Auckland. (1908). Outward Letter Book. Archives New Zealand, Auckland.

Inspector of Customs, Wellington. (1908). Outward Letter Book (Aug-Oct). Archives New Zealand, Wellington.

Intellectual Property Office. (2014, February 24). 40671 - Trade Mark - Hollostone Blocks [Government Database]. Retrieved 24 February 2014, from http://www.iponz.govt.nz/app/Extra/IP/Mutual/Browse.aspx?sid=635288537711449815

Internal Affairs. (1899). Niels Nielsen - Naturalisation Papers.

Irvine-Smith, F. L. (Fanny L. (1948). *The Streets of My City: Wellington, New Zealand*. Wellington NZ: A. H. & A.W. Reed.

Isaac, E. C. (1902). *Handwork for Schools: Woodwork.* Wellington: Government Printer.

Isaacs, N. P. (1993). *Thermal Efficiency in New Zealand Buildings - A Historical Overview* Wellington NZ: Centre for Building Performance Research, Victoria University of Wellington.

Isaacs, N. P. (1996). *A Sensible Step to Building Energy Efficiency: 1995 Revision of NZBC Clause H1*. Wellington, NZ: Centre for Building Performance Research, Victoria University of Wellington.

Isaacs, N. P. (2009). Nails in New Zealand 1770 to 1910. *Journal of Construction History*, *24*, 83 – 101.

Isaacs, N. P. (2011). Sydney's First Ice. *Sydney Journal*, *3*(2), 26–35. Retrieved from http://epress.lib.uts.edu.au/ojs/index.php/sydney_journal/index

Isaacs, N. P. (2012). Building Legislation 1840 - 1870. *New Zealand Law Journal*, (June), 179–184.

Isaacs, N. P. (2013). Balloon to Platform Framing: a change of the 1880s? In C. McCarthy (Ed.), *Architectural style spreads its wings: New Zealand Architecture in the 1880s. A one day symposium* (pp. 33–40). Wellington NZ: Centre for Building Performance Research, Victoria University of Wellington.

Isaacs, N. P. (2014). Foundations of Control – New Zealand Building Legislation in the 1840s. In C. McCarthy (Ed.), *'a massive colonial experiment': New Zealand Architecture in the 1840s. A one day symposium* (pp. 58–63). Wellington NZ: Centre for Building Performance Research, Victoria University of Wellington.

Isaacs, N. P. (2015). Hollow Concrete Blocks in New Zealand 1904 – 1910. *Journal of Construction History*, *30*(1), 93–108.

Isaacs, N. P., & Cottrell, W. (2012). 'Nails shipped to any part of the colony' - nails and screws in early New Zealand furniture. In R. Ramsey & Ramsey (Eds.), *Proceedings of the Inaugural New Zealand Furniture History Symposium and Exhibition 8-10 October 2010* (pp. 120–130). Invercargill, NZ: Southland Museum and Art Gallery.

Isaacs, N. P., Lee, J., & Donn, M. R. (1995). *Energy Efficiency in the NZ Building Code: A New Structure*. Wellington, NZ: Centre for Building Performance Research, Victoria University of Wellington.

Isaacs, N. P., & Trethowen, H. A. (Harold A. (1985). *A Survey of House Insulation*. Porirua, NZ: Building Research Association of New Zealand.

James, E. (1965). *Jobbing Along*. Christchurch: Whitcombe & Tombs.
Jaques, R. A. (1998). *Environmental Impacts Associated with New Zealand Cement Manufacture* (No. SR 68). Porirua NZ: BRANZ.
Johnson, J. (2009). Croydon. *Sydney Journal*, *2*(1), 92–97. Retrieved from http://epress.lib.uts.edu.au/ojs/index.php/sydney_journal/index
Jones, R. (2005, Autumn). J.J. Cordes Limited. *TATHS (Tools and Trades History Society) Newsletter*, (90), 23–24.
Jureit, J. C. (1959, May 12). Connector [US Patent 2,885,749]. Retrieved from http://www.google.com/patents/US2885749
Kamesam, S. (1938, February 1). Wood preservative composition [US Patent 2,106,978]. Retrieved from www.uspto.gov
Kelly, S. J. (1995). Aluminum. In T. C. Jester (Ed.), *Twentieth-Century Building Materials: History and Conservation* (pp. 46–51). New York: McGraw-Hill.
Kemp, C. M. (1995). *Henry A. Goddard's Sydney Concrete Houses 1905-1925* (Master Of The Built Environment (Conservation)). University of New South Wales, Sydney N.S.W.
Kemp, C. M. (2014, September 9). Camerated Concrete - John Johnson (E-mail).
Kernohan, D. (2003). *Wairarapa Buildings: Two Centuries of New Zealand Architecture*. Masterton, NZ: Wairarapa Archive.
Kernohan, D., McHaffie, M., Gard'ner, J., Kellaway, T., & Gray, J. (1994). *Wellington's Old Buildings: A Photographic Guide to Old Buildings in Central Wellington*. Wellington NZ: Victoria University Press.
King, M. (2003). *The Penguin History of New Zealand* (1st ed.). Auckland, NZ: Penguin Books.
Kirk, T. (1878). Art. LXXV.–Notes and Suggestions on the Utilization of certain neglected New Zealand Timbers. [Read before the Wellington Philosophical Society, 9th November, 1878]. *Transactions and Proceedings of the New Zealand Institute 1878 [Electronic Resource]*, *11*, 458–463. Retrieved from http://rsnz.natlib.govt.nz/volume/rsnz_11/rsnz_11_00_004720.html
Kirk, T. (1880). Art. XI.—On the Neglected Forest Products of New Zealand. [read before the Auckland Institute, 25th October, 1880]. *Transactions and Proceedings of the New Zealand Institute 1880. [Electronic Resource]*, *13*, 130–142. Retrieved from http://rsnz.natlib.govt.nz/volume/rsnz_13/rsnz_13_00_000950.html
Kirk, T., Balfour, J. M., & Ward, E. W. (Captain). (1875). *Reports on the Durability of New Zealand Timber for Constructive Works, etc., etc*. Wellington NZ: Government Printer.
Knight, B., & Brook, L. (1988). *Building with Logs in New Zealand*. Wellington, N.Z: Grantham House.
La Grouw Corporation Ltd. (2013). About Us and History. Retrieved 7 May 2014, from http://www.lockwood.co.nz/Aboutus.aspx
Lambert, B. (1970). Editorial. *How: New Zealand's Magazine for the Home Handyman*, (July), 1.

Lamb, R. C. (1963). *Early Christchurch: The Beginnings of Municipal Government, 1862-1868: A Study Commemorating the Centenary of the Christchurch City Council*. Christchurch, NZ: Canterbury Public Library.

Lamesch, J. (2005). The World History of Galvanizing. *Revue de Métallurgie*, *102*(02), 119–126. http://doi.org/10.1051/metal:2005113

Lane, E. W. (1837). *An Account of the Manners and Customs of the Modern Egyptians, Written in Egypt During the Years 1833-35, Etc* (Vols. 1–2 vol.). London: Society for the Diffusion of Useful Knowledge.

Lapham, H. (1880). *We Four, and the Stories We Told*. Dunedin NZ: Otago Daily Times. Retrieved from http://nzetc.victoria.ac.nz/tm/scholarly/tei-LapWeFo.html

Larkin, C. P. (1949). *Why I Built an Adobe Cottage, or, Puawananga* (2nd ed.). Whangarei, NZ: Northern Publishing.

Latter, H. B. (1963, June 11). State Advances Corporation. Letter to Dr T.J. Sprott, Carter Merchants Ltd. Re: Gang Nail Construction. 11 June 1963. Retrieved from AALF W3202/19 Record 24/15 Part 1

Lewis, M. (1998). *Australian Building: A Cultural Investigation*. Melbourne, [Vic.]: The author (updated irregularly). Retrieved from http://mileslewis.net/australian-building/

Lewis, M. (2009). Stud and Balloon Frames. In *Proceedings of The Pacific Connection – Trade, Travel & Technology Transfer* (pp. 48–73). Melbourne, Vic.: University of Melbourne.

Leys, T. W. (1883). *Brett's Colonists' Guide and Cyclopaedia of Useful Knowledge: being a compendium of information by practical colonists*. Auckland, NZ: H. Brett.

Leys, T. W. (1897). *Brett's Colonists' Guide and Cyclopaedia of Useful Knowledge: being a compendium of information by practical colonists*. Auckland, NZ: H. Brett.

Leys, T. W. (1902). *Brett's Colonists' Guide and Cyclopaedia of Useful Knowledge: being a compendium of information by practical colonists*. Auckland, NZ: Brett Printing and Publishing.

Lino Products Ltd. (1939, April 28). Lino Products Limited letter 28 April 1939 to Secretary, Bureau of Industry. Retrieved from AEFN 19294 W715 IC1 394 / 19/105/6

Lister, S. (1874). *Findlay and Co.'s Illustrated Catalogue of Cottages, Doors, Sashes, Mouldings, Architraves, and Every Description of Furnishings for Building Purposes. Steam Saw and Planing Mills, Stuart Castle & Cumberland Streets, Dunedin, NZ* Dunedin NZ: Findlay and Co. Retrieved from http://natlib.govt.nz/records/22875468

Littler, I. W. (1969, July). Letter to The Chairman, Industrial Research and Development Grants Advisory Committee re Fraemohs Industries Ltd. Retrieved from AEFN 19294 ICW2680/1 57/9/1

Lloyd, C. (1948). *The Australian Carpenter*. Melbourne, Vic.: Macmillan & Co.

Lloyd-Jenkins, D. (2004). *At Home: A Century of New Zealand Design*. Auckland, NZ: Godwit.

Lloyd Prichard, M. F. (1970). *An Economic History of New Zealand to 1939*. Auckland NZ: Collins.

Loghem, J. J. V., & Grouw, J. L. (1957, May 14). Angle-iron Corner Member to Wooden Structures. [NZ Patent 116,650].

Loveday, A. J. (Jnr). (1983). *The Rise and Decline of the American Cut Nail Industry: A Study of the Interrelationships of Technology, Business Organization, and Management Techniques*. Westport, Conn.: Greenwood Press.

Lundy, J. (2005). *Nine Thousand Bricks a Day: The Hoffman Kiln and the Brickworks of Palmerston North*. Palmerston North, NZ: Manawatu Branch of the New Zealand Historic Places Trust, with the Higgins Charitable Trust.

Lyell, C. S. (1863). *The Geological Evidences of the Antiquity of Man: With Remarks on Theories of the Origin of Species by Variation*. London: John Murray.

Lyttelton Times. *Lyttelton Times [Electronic Version Accessed through: Paperspast.natlib.govt.nz (1851-1869)]*. Lyttelton, NZ

Macarthur, R. S. (1994). *The Cork Oaks and Cork: A New Zealand Perspective*. Picton, NZ: R.S. Macarthur.

MacLeod, A. (1993). Kirk, Thomas. In *The Dictionary of New Zealand Biography. Volume Two, 1870-1900* (p. 260). Retrieved from http://www.teara.govt.nz/en/biographies/2k10/kirk-thomas

Maithel, S., & Greentech Knowledge Solutions Pvt Ltd. (2013, December). Factsheets About Brick Kilns in South and South-East Asia. 7 Tunnel Kiln Technology. UNEP. Retrieved from http://www.unep.org/ccac/Portals/50162/docs/ccac/initiatives/bricks/7%20Tunnel%20Kiln.pdf

Making New Zealand: Pictorial Surveys of a Century. (1940). Wellington NZ: New Zealand Dept. of Internal Affairs.

Manawatu Standard. *Manawatu Standard [Electronic Version Accessed through: Paperspast.natlib.govt.nz (1883-1912)]*. Palmerston North, NZ

Manning, A. (1983). *Walking Tall: The Downer Story, 1933-1983*. Wellington, NZ: Downer and Company.

Margaret Aish. (2013, November 29). Laidlaw Leeds Catalogues (E-mail).

Marlborough Express. *Marlborough Express [Electronic Version Accessed through: Paperspast.natlib.govt.nz (1868-1920)]*. Blenheim, NZ

Marshall, P. (1912). *Geology of New Zealand*. Wellington, NZ: Government Printer.

Marshall, P. (1929). *Building-Stones of New Zealand*. Wellington NZ: NZ Department of Scientific and Industrial Research, Government Printer.

[Martin], L. (1959). Building Industries - New Zealand. *The Architectural Review*, *426*(752), 222, 224.

Martin, W. R. B. (1955). The Iron and Titanium Ores of New Zealand. Occurrence, Composition, Attempts to Use and Status Today with Special Reference to Ironsands. *New Zealand Engineering*, *10*, 317–336.

Marton Borough Council. The Marton Borough General By-laws. 1912 (1912).

Maskell, W. M. (1888). The Late Earthquake (1st September, 1888), and its Bearing on the Architecture of Wellington. *Transactions of the New Zealand Institute*, *21*, 492–8. Retrieved from http://rsnz.natlib.govt.nz/volume/rsnz_21/rsnz_21_00_004060.html

McAloon, J. (1997). *Nelson: a regional history*. Whatamango Bay, N.Z: Cape Catley in association with the Nelson City Council.

McCarthy, C. (2011). Concrete Passions: Anscombe's material politics. In C. McCarthy (Ed.), *'Good Architecture should not be a plaything': New Zealand Architecture in the 1920s. A one day symposium* (pp. 49–55). Wellington NZ: Centre for Building Performance Research, Victoria University of Wellington.

McGrath, R. (1961). *Glass in Architecture and Decoration* (New ed. rev). London: Architectural Press.

McIntosh, K. (2010). *McIntosh Glulam: 50 Years New Zealand: A Pioneering Company & Pioneering Industry*. Auckland, NZ: Timberlam Trust with assistance from PublishMe.

McKelvey, P. (1991). Thomas Kirk in New Zealand Forestry. *New Zealand Forestry*, *35*(4), 16–22. Retrieved from http://www.nzjf.org/contents.php?volume_issue=j35_4

McKelvey, P. (2013, c). Adams, Alfred Albert Thomas William [Web page]. Retrieved 19 March 2013, from http://www.teara.govt.nz/en/biographies/2a1/adams-alfred-albert-thomas-william

McKenzie-Minifie, A. G. Martha. (2007, August 6). Residents Living Near Wood Plant Will Soon Breathe Easy. *New Zealand Herald*. Retrieved from http://www.nzherald.co.nz/nz/news/article.cfm?c_id=1&objectid=10456031

McKinnon, M., Bradley, B., & Kirkpatrick, R. (Eds.). (1997). *Bateman New Zealand Historical Atlas: Ko Papatuanuku E Takoto Nei*. Auckland, NZ: David Bateman in association with Historical Branch, Dept. of Internal Affairs,.

McLean, J. N. (2002). *Pioneer Contractors: The Story of John Mclean and Sons*. Wellington, NZ: J. McLean.

McLintock, A. H. (1939). The Forest. In E. H. McCormick (Ed.), *Making New Zealand: Pictorial Surveys of a Century* (Vol. Vol. 1 No. 9, pp. 12–13). Wellington, NZ: Dept. of Internal Affairs, Centennial Branch.

McLintock, A. H. (Ed.). (1966). *An Encyclopaedia of New Zealand*. Wellington, NZ: Government Printer.

McNab, R. (1909). *Murihiku: A History of the South Island of New Zealand and the Islands Adjacent and Lying to the South, from 1642 to 1835. CHAPTER VII. — First Sealing Gang, 1792*. Wellington: Whitcombe and Tombs Limited. Retrieved from http://www.nzetc.org/tm/scholarly/tei-McNMuri-t1-body-d1-d7.html

Mercury. *Mercury [Electronic Version Accessed through: Trove.nla.gov.au (1860-1954)]*. Hobart, Tasmania, Australia.

Milburn Lime and Cement Company Limited. (1895). *Notes on the Manufacture, Testing, Uses, etc. of Portland Cement*. Dunedin: Milburn Lime and Cement Co. Ltd.

Millen, J. (1984). *Colonial Tears and Sweat: The Working Class in Nineteenth-Century New Zealand*. Wellington NZ: Reed.

Ministry for Primary Industries. (2013, April 24). Production of veneer, plywood, laminated veneer, lumber, particleboard and fibreboard, 1951 to most recent (XLS, 28 KB).

Ministry for Primary Industries. Retrieved from http://www.mpi.govt.nz/news-resources/statistics-forecasting/forestry/annual-panel-statistics.aspx
Ministry of Health. (2013a). *All About Asbestos* (Revised). Wellington, N.Z: Ministry of Health. Retrieved from https://www.healthed.govt.nz/resource/all-about-asbestos
Ministry of Health. (2013b). *Removing Asbestos from the Home* (Revised). Wellington, N.Z: Ministry of Health. Retrieved from https://www.healthed.govt.nz/resource/removing-asbestos-home
Ministry of Works, Architectural Division. (1957). *Inspection of Structural Glued Laminated Timbers*. Ministry of Works, Architectural Division.
Ministry of Works (UK). (1959). *Dampness in Buildings* (1st ed.). London: HMSO.
Ministry of Works (UK). (1973). *Dampness in Buildings* (4th ed.). London: HMSO.
Modern Homes of New Zealand by Architects of Standing. (1917). Auckland, NZ: Keyes, Mann & Co.
Mornement, A., & Holloway, S. (2007). *Corrugated Iron: Building on the Frontier*. London: Frances Lincoln.
Mulgan, A. (1958). *The Making of a New Zealander*. Wellington NZ: A.H. & A.W. Reed.
Mullions, T. C. (1919, February 6). Building Block [NZ Patent 41,240]. Auckland. Retrieved from Archives NZ, Wellington. ABPJ 7396 W3835/216 41240
Nathan, S., & Hayward, B. (2013, July 9). Building stone - Types of building stone [Encyclopedia]. Retrieved 5 March 2014, from http://www.teara.govt.nz/en/diagram/8073/stone-trade-names
National Asbestos Medical Panel. (2006). *Asbestos Exposure in New Zealand 1992 to 2005 [electronic Resource].* Wellington, NZ: Department of Labour. Retrieved from http://www.business.govt.nz/worksafe/information-guidance/all-guidance-items/asbestos-registers-national-annual-reports/asbestos-exposure-annual-report-2005.pdf
National Housing Conference. (1953). *National Housing Conference, 1953: Records of the Conference.* Wellington, NZ: National Housing Conference.
National Machinery Co. (1909, October 9). Letter from National Machinery Co., Tiffen Ohio, USA to Auto Machine Mfg. Co., Auckland, New Zealand. Dated 9 October 1909. Retrieved from 1474-5-3a
Neilson, D. (2011, September 21). Early Concrete Block Manufacture (E-mail).
Nelson Evening Mail. *Nelson Evening Mail [Electronic Version Accessed through: Paperspast.natlib.govt.nz (1866-1918)]*. Nelson NZ
Nelson Examiner and New Zealand Chronicle. *Nelson Examiner and New Zealand Chronicle [Electronic Version Accessed through: Paperspast.natlib.govt.nz (1842-1874)]*. Nelson NZ
Newberry, S. B. (1905a). *Hollow Concrete Block Building Construction*. Chicago, Ill.: Cement and Engineering News. Retrieved from http://hdl.handle.net/2027/wu.89080447865

Newberry, S. B. (1905b, August). Hollow Concrete Block Building Construction. *Cement and Engineering News*, *17*, 148–153. Retrieved from http://hdl.handle.net/2027/mdp.39015086657585

Newberry, S. B. (1905c, September). Hollow Concrete Block Building Construction. *The Cement Age*, *2*(4), 237–250. Retrieved from http://hdl.handle.net/2027/mdp.39015074940746?urlappend=%3Bseq=13

Newberry, S. B. (1906a, May). Hollow Concrete Block Building Construction in the United States. *Concrete and Constructional Engineering*, *1*(2), 118–125.

Newberry, S. B. (1906b, December 1). Hollow Concrete Block Construction - Part 1. *Progress*, *II*(2), 47–48.

Newberry, S. B. (1907a, January 2). Hollow Concrete Block Construction - Part 2. *Progress*, *II*(3), 91.

Newberry, S. B. (1907b, February 1). Hollow Concrete Block Construction - Part 3. *Progress*, *II*(4), 137–138.

New Zealand Census and Statistics Department. (1947). *Population Census 1945. Vol. XI Dwellings and Households*. Wellington, NZ: Census and Statistics Dept.

New Zealand Colonist and Port Nicholson Advertiser. *New Zealand Colonist and Port Nicholson Advertiser [Electronic Version Accessed through: Paperspast.natlib.govt.nz (1842-1843)]*. Wellington, NZ

New Zealand Companies Office. (2014, September 12). New Zealand Companies Office - Companies Register. Retrieved 11 September 2014, from http://www.business.govt.nz/companies/

New Zealand Concrete Research Association. (1984). *The Manufacture of Portland Cement* (Information Bulletin No. IB 002) (p. 12). Porirua NZ: New Zealand Concrete Research Association.

New Zealand Department of Statistics. (1963). *Report on the Industrial Production Statistics of New Zealand for the Year 1961-62*. Wellington, NZ: Government Printer.

New Zealand Department of Statistics. (1964). *Population Census 1961 Vol. IX Dwellings and Households.* Wellington, NZ: Government Printer.

New Zealand Department of Statistics. (1969). *New Zealand Census of Population and Dwellings 1966. Vol. 9A Dwellings*. Wellington, NZ: Department of Statistics.

New Zealand Department of Statistics. (1975). *New Zealand Census of Population and Dwellings 1971. Volume 9 Dwellings*. Wellington NZ: Department of Statistics.

New Zealand Department of Statistics. (1980). *New Zealand Census of Population and Dwellings 1976. Volume 9 Dwellings*. Wellington NZ: Department of Statistics.

New Zealand Department of Statistics. (1981). *Dwelling Questionnaire - New Zealand Census of Population and Dwellings. Tuesday 24 March 1981*. Wellington NZ: NZ Department of Statistics.

New Zealand Department of Statistics. (1983). *New Zealand Census of Population and Dwellings 1981. Volume 9 Dwellings*. Wellington NZ: Department of Statistics.

New Zealand Department of Statistics. (1985). *New Zealand Census of Population and Dwellings 1981. Volume 12 Population Perspectives 81: General Report*. Wellington NZ: Department of Statistics.

New Zealand Department of Statistics. (1988). *1986 New Zealand Census of Population and Dwellings. Range and Availability of Statistics 1986*. Wellington, N.Z: Department of Statistics.

New Zealand Department of Statistics. *New Zealand Official Yearbook*. Wellington, NZ: Government Printer.

New Zealander. *New Zealander [Electronic Version Accessed through: Paperspast.natlib.govt.nz (1845-1852)]*. Auckland, NZ

New Zealand Free Lance. *New Zealand Free Lance [Electronic Version Accessed through: Paperspast.natlib.govt.nz (1900-1920)]*. Wellington, New Zealand.

New Zealand Gazette and Wellington Spectator. *New Zealand Gazette and Wellington Spectator [Electronic Version Accessed through: Paperspast.natlib.govt.nz (1839-1844)]*. Wellington, NZ

New Zealand Government. *New Zealand Gazette [Electronic Version 1841 to 2008]*. Wellington, NZ: Department of Internal Affairs.

New Zealand Herald. *New Zealand Herald [Electronic Version Accessed through: Paperspast.natlib.govt.nz (1863-1945)]*. Auckland, NZ

New Zealand Parliament. (1874). H-25 Durability of New Zealand Timbers. Report by Mr. Thomas Kirk) with Papers 'On the Best Season for Falling Timber in New Zealand; and 'On the New Zealand Teredo". In *Appendix to the Journals of the House of Representatives - 1874 Session 1* (Vol. 2). Wellington NZ: Government Printer. Retrieved from http://natlib.govt.nz/records/20333812

New Zealand Parliament. (1880). H-22 Colonial Industries Commission (Report of the). In *Appendix to the Journals of the House of Representatives — 1880 Session I* (Vol. 2). Wellington NZ: Government Printer. Retrieved from http://atojs.natlib.govt.nz/cgi-bin/atojs?a=d&d=AJHR1880-I.2.2.3.44&e=-------10--1------0--

New Zealand Parliament. (1895). H-2 Tariff Commission (Report of The). In *Appendix to the Journals of the House of Representatives — 1895* (Vol. 3). Wellington NZ: Government Printer. Retrieved from http://atojs.natlib.govt.nz/

New Zealand Registrar-General's Office. (1862). *General Statistics of the Colony of New Zealand, for 1861*. Auckland, NZ: Printed by W.C. Wilson for the New Zealand Government.

New Zealand Registrar-General's Office. (1865). *General Statistics of the Colony of New Zealand, for 1864*. Auckland, NZ: Printed by W.C. Wilson for the New Zealand Government.

New Zealand Registrar-General's Office. (1866). *General Statistics of the Colony of New Zealand, for 1865*. Auckland, NZ: Printed by W.C. Wilson for the New Zealand Government.

New Zealand Registrar-General's Office. (1868). *General Statistics of the Colony of New Zealand, for 1867*. Auckland, NZ: Printed by W.C. Wilson for the New Zealand Government.

New Zealand Spectator and Cook's Strait Guardian. *New Zealand Spectator and Cook's Strait Guardian [Electronic Version Accessed through: Paperspast.natlib.govt.nz (1844-1865)]*. Wellington, NZ

New Zealand Standards Institute. (1936). *NZSS 95-1936. New Zealand Standard Model Building By-law. Sections I-X*. Wellington NZ: New Zealand Standards Institute.

New Zealand Standards Institute. (1944). *NZSS 95 New Zealand Standard Model Building Bylaw. Part IX: Light Timber Construction*. Wellington NZ: New Zealand Standards Institute.

New Zealand Standards Institute. (1948). *NZSS 495 New Zealand Standard Specification for Weatherboards, Flooring and Matchlining*. Wellington NZ: New Zealand Standards Institute.

New Zealand Standards Institute. (1950). *NZSS 632:1950 Code of Practice for the Kiln Drying of Timber*. Wellington NZ: New Zealand Standards Institute.

New Zealand Standards Institute. (1953a). *NZSS CP2 New Zealand Standard Code of Practice for the Use in Building of Pinus Radiata and Other Pinus Species*. Wellington NZ: New Zealand Standards Institute.

New Zealand Standards Institute. (1953b). *NZSS CP4 New Zealand Standard Code of Practice For Timber Preservation.* Wellington NZ: New Zealand Standards Institute.

New Zealand Standards Institute. (1956). *Glossary of Building Terminology. NZS.S. 1245* (Reprinted 1961). Wellington NZ: New Zealand Standards Institute.

New Zealand Standards Institute. (1956). *NZSS 95 Standard Code of Building By-laws Part IX - Light Timber Construction – Amendment 3*. Wellington NZ: New Zealand Standards Institute.

New Zealand Standards Institute. (1958). *NZSS 632:1958 New Zealand Standard Specification for the Kiln Drying of Timber*. Wellington NZ: New Zealand Standards Institute.

New Zealand Standards Institute. (1964). *NZSS 1900 New Zealand Standard Model Building Bylaw: Chapter 6.1:1964 Construction Requirements for Timber Buildings Not Requiring Specific Design*. Wellington NZ: New Zealand Standards Institute.

New Zealand Standards Institute. (1967). *NZSS 632:1967 New Zealand Standard Specification Kiln Drying of Timber*. Wellington NZ: Standards Association of New Zealand.

New Zealand State Forest Service. (1924a). *Model Building by-Law for the Economic Construction of Wooden Buildings. (Pre-conference draft)*. Wellington NZ: New Zealand State Forest Service. Retrieved from Archives NZ Wellington. (ADSQ 17639 F1 W3129/368 SP 03.01)

New Zealand State Forest Service. (1924b). *Recommendations of Building Conference Relating to the Use of Timber in Building-construction.* (Vol. 14). Wellington NZ: Government Printer.

New Zealand Tablet. *New Zealand Tablet [Electronic Version Accessed through: Paperspast.natlib.govt.nz (1873-1909)]*. Dunedin NZ

New Zealand Technical Correspondence Institute. (1977). *Carpentry*. Wellington: Government Printer.

New Zealand Technical Correspondence Institute. (1980). *Carpentry*. Wellington: Government Printer.

New Zealand Technical Correspondence Institute. (1987). *Carpentry*. Wellington: Government Printer.

New Zealand Technical Correspondence School. (1951, 1974). Education By Correspondence - New Zealand Technical Correspondence Institute - Production of Textbooks - Carpentry and Joinery.

New Zealand Technical Correspondence School. (1955, to 1964). Education By Correspondence - New Zealand Technical Correspondence Institute - Production of Textbooks - Plumbing.

New Zealand Window Glass. (1982, May 10). Price List 10 May 1982. New Zealand Window Glass.

New Zealand Window Glass Company. (1965). *Glass A New Industry of the Nation*. Whangarei, NZ: New Zealand Window Glass Company.

New Zealand Window Glass Ltd. (1981). *New Zealand Window Glass Limited - Report to Employees 1981*. Whangarei, NZ: New Zealand Window Glass Ltd.

Nicholson, P. (1797). *The Carpenter and Joiner's Assistant*. London: L. and J. Taylor.

Nicholson, P. (1837). *The New and Improved Practical Builder: Masonry, Bricklaying, Plastering* (Vol. II). London: Thomas Kelly.

Nielsen and Atkinson. (1904, May 11). Thompson Street, Retaining Wall (for Mr. S. Arcus).

Nielsen, N. (1904, June 15). Letter to J.R. Palmer, Town Clerk, Wellington City Council and associated annotations in response.

Nielsen, N. (1905a, October 28). Improvements in Blocks for Building Purposes [NZ Patent 18,666]. Retrieved from Archives NZ Wellington. ABPJ W3835 7396 Box 125 18666

Nielsen, N. (1905b, December 11). 216 Queens Drive [Para Crescent].

Nielsen, N. (1906, February 20). Improvements in Roofing Tiles [NZ Patent 20,773]. Retrieved from Archives NZ Wellington. ABPJ W3835 7396 Box 133 20773

Nielsen, N. (1907a, January 17). Specification the Addition to Mrs Kilfoy's Property, Maranui. Wellington City Council Archives.

Nielsen, N. (1907b, March 27). Specification Mr Cowie's House, Maranui. Wellington City Council Archives.

Nielsen, N. (1907c, August 6). Specification the work required to be done and of the material to be used in the erection of a residence in [Mariri Road] Kelburne [sic] for C.W. Nielsen, Esq. Wellington City Council Archives.

Nielsen, N., & Palmer, H. S. (1905, February 6). Improved Machine for Moulding Hollow Concrete Building Blocks [NZ Patent 19,038]. Retrieved from Archives NZ Wellington. ABPJ W3835 7396 Box 127 / 19038

Nippon Sheet Glass Co. Ltd. (2010). Pilkington and the Flat Glass Industry 2010. Nippon Sheet Glass Co. Ltd. Retrieved from http://www.pilkington.com/resources/pfgi2010.pdf

Northcote-Bade, S. (1958). Early Housing in New Zealand — With particular reference to Nelson and Cook Strait Area. *Nelson Historical Society Journal [Electronic Resource Accessed through NZ Electronic Text Centre]*, *1*(3), 2–7. Retrieved from http://nzetc.victoria.ac.nz/tm/scholarly/tei-NHSJ01_03-t1-body1-d1.html

Northcote-Bade, S. (1971). *Colonial Furniture in New Zealand*. Wellington NZ: Reed.

Northern Advocate. *Northern Advocate [Electronic Version Accessed through: Paperspast.natlib.govt.nz (1887-1925)]*. Whangarei, NZ

North Otago Times. *North Otago Times [Electronic Version Accessed through: Paperspast.natlib.govt.nz (1864-1918)]*. Oamaru, NZ

NZ Forest Products Ltd. (1979). Overseas Know How Shapes Mineral Fibre Plant (News Release). *NZ Architect*, (2), 47–49.

NZ Hollow Concrete Building Block Company. (1906, March 9). Summary of Capital and Shares for the New Zealand Hollow Concrete Building Block Company made up to the 9th day of March 1906.

NZ Hollow Concrete Building Block Company Ltd. (1904, October 14). Prospectus of the New Zealand Hollow Concrete Building Block Company Ltd. NZ Hollow Concrete Building Block Company Ltd.

NZ Nail Industries Ltd. (2000). *Know Your Nails - Training Manual*. Auckland NZ: NZ Nail Industries Ltd.

NZ Patent Office. (1911). Register of Applications for Letters Patent, No. 2 (Applications 23,224 to 30,533. 1907-1911).

NZ Truth. *NZ Truth [Electronic Version Accessed through: Paperspast.natlib.govt.nz (1906-1930)]*. Wellington NZ

Oamaru Mail. *Oamaru Mail [Electronic Version Accessed through: Paperspast.natlib.govt.nz (1876-1920]*. Oamaru, NZ

O’Brien, G. (1975). *Foil Insulation of Timber Floors* (No. R6). Wellington NZ: BRANZ.

O’Brien, M. J. (2010). Hybrids on the Way to the Western Platform Frame: Two Structures in Western Virginia. *Preservation Education & Research*, *3*, 37–52. Retrieved from http://ncpe.us/wp-content/uploads/2012/07/Obrien.pdf

O’Brien, M. J. (2013). Load-bearing, single-wall constructions from Shanties to Structural Insulated Panels. *Construction History*, *28*(1), 49–64.

Observer. *Observer [Electronic Version Accessed through: Paperspast.natlib.govt.nz (1880-1920)]*. Auckland NZ

Ohinemuri Gazette. *Ohinemuri Gazette [Electronic Version Accessed through: Paperspast.natlib.govt.nz (1891-1921)]*. Paeroa NZ

O'Keeffe, M. (2014, August 31). Pumice Charcoal Holder (E-mail).
Oliver, J. (2006). *John Oliver's Brick Book: A Guide to Designing and Building in Brick* (2nd ed). Auckland, N.Z: Lifetime Books.
Oruawharo Homestead Ltd. (2014, October 5). The History of Oruawharo Homestead [Company]. Retrieved 19 October 2014, from http://www.oruawharo.com/history.html
Otago Daily Times. *Otago Daily Times [Electronic Version Accessed through: Paperspast.natlib.govt.nz (1861-1920)]*. Dunedin NZ
Otago Witness. *Otago Witness [Electronic Version Accessed through: Paperspast.natlib.govt.nz (1851-1909)]*. Dunedin NZ
Oxford English Dictionary. (2014, May 16). ''weatherboard, n.'. Retrieved 16 May 2014, from http://www.oed.com/view/Entry/226647?rskey=4lrxhX&result=2&isAdvanced=false
Oxley Conservation. (2012). *Energy Efficiency and Historic Buildings. Insulating solid ground floors.* Swindon, UK: English Heritage. Retrieved from http://www.english-heritage.org.uk/publications/eehb-insulating-solid-ground-floors/eehb-insulating-solid-ground-floors.pdf
Page, I. (2014, March 24). HCS Flooring Types (E-mail).
Page, I., & Fung, J. (2008). *Housing Typologies – Current Stock Prevalence.* (No. EN6570/8) (p. 47). Auckland NZ: Beacon Pathway Ltd. Retrieved from http://www.beaconpathway.co.nz/images/uploads/Final_Report_EN6570%288%29_Housing_Typologies_Current_Stock_Prevalence.pdf
Palmer, A. (2010, July 20). History of Steel Framing (Market Analyst. New Zealand Steel - BlueScope Steel Limited) (E-mail).
Palmer, H. S. (1887, December 27). Machine for Moulding Building-Blocks [US Patent 375,377]. Retrieved from www.uspto.gov
Palmer, H. S. (1899, April 25). Machine for Moulding Hollow Concrete Building Blocks [US Patent 623,686]. Retrieved from www.uspto.gov
Palmer, H. S. (1901, May 28). Concrete Wall For Buildings [US Patent 674,874]. Retrieved from www.uspto.gov
Palmer, H. S. (1903, May 5). Machine for Moulding Hollow Concrete Building Blocks [US Patent 727,427]. Retrieved from www.uspto.gov
Palmer, H. S. (1906, August 14). Machine for Making Concrete Blocks [US Patent 828,767]. Retrieved from www.uspto.gov
Papakura, M. (Makereti). (1938). *The Old-Time Maori*. (T. K. Penniman, Ed.). London: Victor Gollancz [New Zealand Electronic Text Centre]. Retrieved from http://nzetc.victoria.ac.nz/tm/scholarly/tei-MakOldT.html
Parker, J. H. (1875). *Classic Dictionary of Architecture. A Concise Glossary of Terms Used in Grecian, Roman Italian, and Gothic Architecture* (4th Ed. revised (Facsimile Edition 1986)). Oxford : London: Parker.
Paterson and Barr. (1897, May 19). Letter to Official Assignee, Dunedin. 19 May 1897.

Patterson, R., & Naylor Love Construction Limited. (2010). *A Bob Both Ways: Celebrating 100 Years of Naylor Love*. Dunedin NZ: Advertising & Art.

Pearce, G. L. (1982). *The Pioneer Craftsmen of New Zealand*. Auckland NZ: Collins.

Pearce, T. J., & Beardsley, M. W. (1886a, March 30). Mixed Paint [US Patent 338,868]. Retrieved from www.uspto.gov

Pearce, T. J., & Beardsley, M. W. (1886b, September 14). Paper and Products and Manufacture Thereof [US Patent 348,995]. Retrieved from www.uspto.gov

Pearse, W. (1920, August 11). Pearse Patent Monolithic Concrete System [US Patent 44,437]. Fielding. Retrieved from Archives NZ, Wellington. ABPJ 7396 W3835/230 44437

Pearson, Knowles, Ryland Bros NZ Ltd. (1941, May 7). Pearson, Knowles, Ryland Bros NZ Ltd letter 7 May 1941 to Secretary, Bureau of Industry. Retrieved from AEFN 19294 W715 IC1 394 / 19/105/7 Part 1

Pearson, Knowles & Rylands Bros. NZ Ltd. (1938, August 2). Pearson, Knowles & Rylands Bros. NZ Ltd, Rylands Building, 50-52 High St, Auckland C1. – letter to Minister for Industries & Commerce, dated 2 August 1938. Retrieved from AEFN 19294 W715 IC1 390/19/105 Part 1

Petty-John Company. (1909, April 1). The Petty-John Company, Manufacturers of Concrete Moulding Machinery, Terre Haute, Ind. USA. *Progress*, *IV*(6), 184.

Pevsner, N. (1959). Commonwealth I. *The Architectural Review*, *426*(752), 149–152.

Phillipps, W. J. (1952). *Māori houses and food stores*. Wellington NZ: Government Printer.

Phillips, J., & Maclean, C. (1983). *In the Light of the Past: Stained Glass Windows in New Zealand Houses*. Auckland, NZ: Oxford University Press.

Plishke, E. A. (1947). *Design and Living*. Wellington, N.Z: Army Education Welfare Service.

Porter, F. (Ed.). (1979). *Historic Buildings of New Zealand: North Island*. Auckland: Cassell New Zealand.

Porter, F. (Ed.). (1983). *Historic Buildings of New Zealand: South Island*. Auckland, N.Z: Methuen Publications (NZ) Ltd.

Poverty Bay Herald. *Poverty Bay Herald [Electronic Version Accessed through: Paperspast.natlib.govt.nz (1879-1920)]*. Gisborne, NZ

Powell, F. E. (Ed.). (1919). *Concrete Information: A Practical Handbook for All Classes of Concrete Users*. Christchurch NZ: Whitcombe & Tombs for the Proprietors of The Cement Manufacturers of New Zealand.

Priess, P. (1973). Wire Nails in North America. *Bulletin of the Association for Preservation Technology*, *5*(4), 87–92.

Pringle, T. (2010). *Renovate - Villas*. Porirua, NZ: BRANZ.

Private Drainage Connection Application Plans. 9 & 11 Webb Street. (1896).

Progress. *Progress [Electronic Version Accessed through: Paperspast.natlib.govt.nz (1905-1910)]*. Wellington, NZ

Provincial Government of the Province of Auckland. City of Auckland Building Act 1854 (1854).

Raven, W. (1914). Extract from the Journal of a Voyage from England to Port Jackson, New So. Wales in the Years 1792, 1793, 1794, and 1795, in the Ship Britannia,. In R. McNab (Ed.), *Historical Records of New Zealand* (1st ed., Vol. II). Wellington: John MacKay. Retrieved from http://nzetc.victoria.ac.nz/tm/scholarly/tei-McN02Hist-t1-body-d1-d25-d1.html

Reed, A. H. (1964). *The New Story of the Kauri* (3rd ed. rev. and reset, with new illustrations). Wellington: Reed.

Reed, A. W. (2002). *The Reed Dictionary of New Zealand Place Names* (2002 ed). Auckland NZ: Reed.

Reid, H. (1877). *The Science and Art of the Manufacture of Portland Cement, Etc.* London: E. & F.N. Spon.

Reid, J. S. (1950). *Building Timbers in New Zealand*. Wellington NZ: New Zealand Forest Service.

Reid, J. S. (1956). *New Zealand Building Timbers: How, Where, and When to Use Them*. Wellington, NZ: New Zealand Forest Service.

Reid, J. S. (1961). *New Zealand Building Timbers: How, Where, and When to Use Them*. Wellington, NZ: New Zealand Forest Service.

Reynolds, P., Hansen, J., & Salmond, J. (2009). *Villa: From Heritage to Contemporary*. Auckland, N.Z: Godwit (Random House New Zealand).

Reynolds, P., & Stock, N. (2014). *Bungalow: From Heritage to Contemporary*. Auckland, New Zealand: Godwit (Random House New Zealand).

Rice, H. H., & Torrance, W. M. (1906). *The Manufacture of Concrete Blocks and Their Use in Building Construction*. New York: The Engineering News Publishing Company. Retrieved from http://openlibrary.org/books/OL6970443M/The_manufacture_of_concrete_blocks_and_their_use_in_building_construction

Richards, N. (2010, February 15). History of Thermal Insulation Manufacture in NZ (E-mail).

R.J. Stark & Co. (c1900). *Stark's Practical Carpenter, Joiner and General Mechanic : a book for professional and amateur workmen comprising carpentry, turning, fret-sawing, wood-carving, general building - (stone and brick), smiths work, plumbing and gas-fitting, painting and glazing, paper-hanging, etc. With 800 illustrations and working diagrams.* Dunedin: J. Stark & Co., Booksellers & Stationers, 56 Princes St.

Robb, A., & Stokes, W. (1884). Cup-Headed, Self-Adjusting Tinned-Wire Roofing-Nail Requiring No Washer. [NZ Patent 1,152]. Christchurch. Retrieved from Archives NZ Wellington. ABPJ 7396 W3835 Box 20 Patent 1152

Robert Holt & Sons Ltd. (1963). *Holts Catalogue - for everything building. To build, renovate, decorate and home appliances* (1st ed.). Napier N.Z: Robert Holt & Sons Ltd.

Robert Holt & Sons Ltd. (1965). *Holts Catalogue - for building, renovating and decorating and home appliances. Everything for building.* (2nd ed.). Napier N.Z: Robert Holt & Sons Ltd.

Rosenfeld, M. (1971). *Holiday Homes and Town Houses* (12th ed.). Auckland NZ: New Zealand House Design Publications Ltd.

Rose, W. B. (1994). A Review of the Regulatory and Technical Literature Related to Crawl Space Moisture Control. In *ASHRAE Transactions 1994 Part I*. New Orleans, LA: ASHRAE.

Rosier, L. (1990). Crawford, James Coutts. In W. H. Oliver (Ed.), *The Dictionary of New Zealand Biography. Volume One, 1769-1869* (p. 93). Wellington NZ: Bridget Williams Books and Department of Internal Affairs.

Rowley, F. W. (1919). The Housing Problem: Homes for Worker. In *Official Volume of Proceedings of the First New Zealand Town-Planning Conference And Exhibition. Wellington 20th to 23rd May, 1919* (pp. 207–212). Wellington, New Zealand: Government Printer. Retrieved from http://www.archive.org/stream/officialvolumeof00newzrich

Royal Commission for the Exhibition of 1851. (1852). *Reports by the Juries on the Subjects in the Thirty Classes into Which the Exhibition Was Divided*. London: William Clowes & Sons.

Royal Commission into Ballantyne's Fire. (1947). H-47 Report of Royal Commission Appointed by His Excellency the Governor-General on the 10th Day of December, 1947, to Inquire into and Report Upon Matters Concerning the Fire at the Premises of Messrs. J. Ballantyne and Co., Ltd., City of Christchurch, on the 18th Day of November, 1947. In *Appendix to the Journals of the House of Representatives — 1948 Session I* (Vol. 5). Wellington, NZ: Government Printer. Retrieved from http://atojs.natlib.govt.nz/cgi-bin/atojs?a=d&cl=search&d=AJHR1948-I.2.5.2.15&srpos=15&e=-------50--1---bySH---0-AJHR_1948_I_HZz-I-

Ryan, V., Burgess, G., & Easton, L. (2008). *New Zealand House Typologies to Inform Energy Retrofits* (No. EN6570/9) (p. 92). Auckland NZ: Beacon Pathway Ltd. Retrieved from http://www.beaconpathway.co.nz/images/uploads/Final_Report_EN6570(9)_NZ_House_Typologies_to_Inform_Energy_Retrofits.pdf

Sackett, A. (1880a, April 13). Process of Coating Paper and Cloth [US Patent 226,459]. Retrieved from www.uspto.gov

Sackett, A. (1880b, August 24). Process for Coating Paper and Cloth [US Patent 231,450]. Retrieved from www.uspto.gov

Sackett, A. (1884, January 8). Roofing Felt and Mechanism for Making the Same [US Patent 291,628]. Retrieved from www.uspto.gov

Sackett, A. (1894, May 22). Inside-Wall Covering [US Patent 520,123]. Retrieved from www.uspto.gov

Salmond, J. (1989). *Old New Zealand houses, 1800-1940*. Auckland NZ: Heinemann Reed.

Saville-Smith, K., Jowett, J. H., Jones, M. S., Buckett, N. R., & Marston, N. J. (2011). *Preliminary BRANZ 2010 House Condition Survey Report*. Porirua, NZ: BRANZ. Retrieved from

http://www.branz.co.nz/cms_show_download.php?id=52d66a0ef26d13cbf2c4878a413d939223e792ea
Schrader, B., & Birkinshaw, V. (2005). *We Call It Home: A History of State Housing in New Zealand*. Auckland NZ: Reed Pub.
Scie Construction Ltd. (2014). A Brief History of Flat Roofing in New Zealand [Company]. Retrieved 16 November 2014, from http://www.scieroofing.com/retro.htm
Scott, D. (1979). *Fire on the Clay: The Pakeha Comes to West Auckland*. Auckland NZ: Southern Cross Books.
Scott, W. H. (1897, May 12). Invoice to David Nicolson dated 12 May 1897.
Scrope, G. P. (1858). *Geology and Extinct Volcanos of Central France*. [S.l.]: Murray.
Sear, A. L. (1967, October 5). A.L. Sear, Housing Division. Memo to District Supervisors Auckland, Hamilton, Palmerston North, Wellington and Christchurch. Retrieved from AALF W3202/19 Record 24/15 Part 1
Sears, Roebuck and Company. (1971). *1908 Catalogue No. 117: The Great Price Maker*. (J. J. Schroeder, Ed.). Northfield, Ill.: DBI Books, Inc.
Secretary & Collector of Customs, Wellington. (1908, September 29). W T Glasgow, Secretary and Inspector, Customs Department, Wellington to Collector of Customs, Auckland.
Secretary, Department of Industries and Commerce. (1923, May 29). Letter from Secretary, Department of Industries & Commerce, to Napier Harbour Board dated 29 May 1923. Retrieved from AEFN 19294 W715 IC1 390/19/105 Part 1
Secretary & Inspector of Customs, Wellington. (1908, August 22). Collector of Customs, Wellington to Collector of Customs, Westport. (Customs Outwards Letterbook, August-October 1908, p. 82).
Seed, E. M. (1954). *The History of the Brick, Tile and Pottery Industries in Otago: [Thesis Presented for the Degree of M.A. in History]*. Dunedin, N.Z: University of Otago.
Shaw, H. W. (1912, February 24). Improved means for building concrete walls [NZ Patent 30,933]. Upper Hutt, Wellington. Retrieved from Archives NZ, Wellington. ABPJ 7396 W3835/173 30933
Shaw, H. W. (1913, February 7). Core For Building Concrete Walls [NZ Patent 32,595]. Upper Hutt, Wellington. Retrieved from Archives NZ, Wellington. ABPJ 7396 W3835/181 32595
Shaw, H. W. (1914a, February 25). Reinforcing Medium For Concrete-Work [NZ Patent 34,450]. Upper Hutt, Wellington. Retrieved from Archives NZ, Wellington. ABPJ 7396 W3835/188 34450
Shaw, H. W. (1914b, April 22). Concrete - Construction [NZ Patent 34,761]. Upper Hutt, Wellington. Retrieved from Archives NZ, Wellington. ABPJ 7396 W3835/190 34,761
Shaw, P. (1995). *Whitestone Oamaru: A Victorian Architectural Heritage*. Nelson, N.Z: Craig Potton Publishing.
Shaw, P. (2009). *Pride of Place: A History of the Fletcher Construction Company*. Auckland, NZ: Fletcher Construction Company Ltd.

Shaw, P., Morrison, R., & McCredie, P. (2003). *A History of New Zealand Architecture*. Auckland, NZ: Hodder Moa Beckett.

Shearer, G. J. (1961). Wood Particle Board. *New Zealand Engineering*, *16*(4), 115. Retrieved from http://search.informit.com.au/documentSummary;dn=196586088979020;res=IELENG

Shelton, R. (2007). *Engineering Basis of NZS 3604* (No. SR 168). Porirua NZ: BRANZ Ltd.

Simpson, F. A. (1965). *The First Century: A Centenary Review of Winstone Limited*. Auckland, NZ: Winstone Ltd.

Simpson, P. H. (1989). Cheap, Quick, and Easy: The Early History of Rockfaced Concrete Block Building. *Perspectives in Vernacular Architecture*, *3*, 108–118. Retrieved from http://www.jstor.org/stable/3514298

Simpson, P. H. (1999a). *Cheap, Quick, & Easy: Imitative Architectural Materials, 1870-1930* (1st ed). Knoxville: University of Tennessee Press.

Simpson, P. H. (1999b). Comfortable, Durable, and Decorative: Linoleum's Rise and Fall from Grace. *APT Bulletin*, *30*(2/3), pp. 17–24. Retrieved from http://www.jstor.org/stable/1504636

Simpson, P. H., Hunderman, H. J., & Slaton, D. (1995). Concrete Block. In T. C. Jester (Ed.), *Twentieth-Century Building Materials: History and Conservation* (pp. 80–85). New York: McGraw-Hill.

Skinner, R. (2008). The Whare in the Bush. Unpacking a Twentieth Century Tradition. *Fabrications*, *18*(1), 56–73.

Smith, J. (2009). *No Job Too Big: A History of Fletcher Construction. Volume I, 1909-40*. Wellington, NZ: Steele Roberts.

Smith, J. H., & Carr, D. R. (1950). *Principles of Wood Preservation - Their Application under New Zealand Conditions*. Wellington NZ: Government Printer.

Smith, N. (2001). *Heritage of Industry: Discovering New Zealand's Industrial History*. Auckland NZ: Reed.

Smith, R. H. (1944a). *Carpentry: Study Course*. Wellington NZ: Army Education Welfare Service.

Smith, R. H. (1944b). *Drawing for Carpenters and Joiners: Study Course*. Wellington NZ: Army Education Welfare Service.

Smith, T. G., & Vitruvius Pollio. (2003). *Vitruvius on Architecture*. New York: Monacelli Press.

Southland Times. *Southland Times [Electronic Version Accessed through: Paperspast.natlib.govt.nz (1862-1902)]*. Invercargill, NZ

Speight, R. (1927a). Building Stones of New Zealand. *Board and Council: New Zealand Local Authorities' Review.*, *5*, 783.

Speight, R. (1927b). Building Stones of New Zealand (concluded). *Board and Council: New Zealand Local Authorities' Review.*, *5*, 819.

Sprague, P. E. (1981). The Origin of Balloon Framing. *The Journal of the Society of Architectural Historians*, *40*(4), 311–319.

Sprott, T. J. (1963, May 27). Dr T.J. Sprott, Carter Merchants Ltd. Letter to State Advances Corporation Re: Gang Nail Construction. 27 May 1963. Retrieved from AALF W3202/19 Record 24/15 Part 1

Stacpoole, J. (1976). *Colonial Architecture in New Zealand*. Wellington: Reed.

Standards Association of New Zealand. (1977). *NZS 4218P Minimum Thermal Insulation Requirements for Residential Buildings*. Wellington NZ: Standards Association of New Zealand.

Standards Association of New Zealand. (1978). *NZS 3604 Construction Requirements for Timber Buildings Not Requiring Specific Design*. Wellington NZ: Standards Association of New Zealand.

Standards Australia. (1974). *AS 1538-1974 Cold-formed Steel Structures Code*. Sydney N.S.W.: Standards Association of Australia.

Standards Australia. (1988). *AS 1538-1988 Cold-formed Steel Structures Code*. Sydney N.S.W.: Standards Association of Australia.

Standards New Zealand. (1979). *NZS 3617: 1979. Specification for Profiles of Weatherboards, Fascia Boards, and Flooring*. Wellington NZ: Standards Association of New Zealand.

Standards New Zealand. (1996). *NZS 4218 Energy Efficiency - Housing and Small Building Envelope*. Wellington NZ: Standards New Zealand.

Stanley, C. C. (1986). *Highlights in the History of Concrete* (Reprint). Slough, England: Cement and Concrete Association.

Star. *Star [Electronic Version Accessed through: Paperspast.natlib.govt.nz (1868-1909)]*. Christchurch NZ

Starky, S. (1993). Dobson, Edward. In W. H. Oliver (Ed.), *The Dictionary of New Zealand Biography. Volume One, 1769-1869* (pp. 108–9). Wellington: Bridget Williams Books and Department of Internal Affairs. Retrieved from http://www.TeAra.govt.nz/en/biographies/1d14/1

Statistics New Zealand. (1997). *1996 Census of Population and Dwellings. An Introduction to the Census*. Wellington NZ: Statistics New Zealand.

Statistics New Zealand. (2004). *Statistical Publications, 1840 - 2000*. Wellington, NZ: Statistics New Zealand.

Statistics New Zealand. (2005). Long-Term Data Series - Statistics New Zealand. Retrieved 4 July 2014, from http://www.stats.govt.nz/browse_for_stats/economic_indicators/NationalAccounts/long-term-data-series.aspx

Statistics New Zealand. (2006a). *2006 Census of Population and Dwellings. Introduction to the Census*. Wellington NZ: Statistics New Zealand.

Statistics New Zealand. (2006b). *Demographic Trends 2005*. Wellington NZ: Statistics New Zealand. Retrieved from http://www.stats.govt.nz/~/media/Statistics/browse-categories/population/estimates-projections/demographic-trends/2005/full-report.pdf

Statistics New Zealand. (2006c). *Dwelling Schedule Questionnaires - 1906 to 2006 (PDF Scanned copies)*. Wellington NZ: Statistics New Zealand. Retrieved from http://www.stats.govt.nz/Census/about-2006-census/2006-census-definitions-questionnaires/forms.aspx

Statistics New Zealand. (2013, August 28). Overseas Merchandise Trade. Retrieved 17 June 2014, from http://datainfoplus.stats.govt.nz/Item/nz.govt.stats/6ed114da-3571-40d4-a89f-932068a4c753

Stephens, M., & Stephens, N. (1981). *Mud in Our Eyes: The Construction of the Mud Hut, During the Period 1951-54 and Other Detail*. Christchurch, N.Z: Mud Hut Press.

Stewart, D. (1992). *The New Zealand Villa: Past and Present*. Auckland, NZ: Viking Pacific.

Stone, J. *Stone's Otago & Southland Commercial Municipal & General Directory*. Dunedin NZ: Stone, Son & Co.

Sunday Times. *Sunday Times [Electronic Version Accessed through: Trove.nla.gov.au (1895 - 1930)]*. Sydney N.S.W.

Sutcliffe, G. L. (Ed.). (1905). *The Modern Carpenter, Joiner and Cabinet-Maker: A Complete Guide to Current Practice.* (Vols. 1–8). London: Gresham Publishing Co.

Taranaki Herald. *Taranaki Herald [Electronic Version Accessed through: Paperspast.natlib.govt.nz (1852-1909)]*. New Plymouth, NZ

Taylor, A. (1966). *The Maori Builds: Life, Art and Architecture from Moahunter Days*. Christchurch NZ: Whitcombe and Tombs.

Taylor, A., McCormack, D., & Gruar, W. (Eds.). (1977). *The Third New Zealand Whole Earth Catalogue*. Martinborough, N.Z: Alister Taylor.

Taylor, R., & Smith, I. W. G. (1997). *The State of New Zealand's Environment, 1997*. Wellington, NZ: Ministry for the Environment.

Technical Correspondence School. (1958). *Carpentry in New Zealand*. Wellington, New Zealand: Government Printer.

Technical Correspondence School (New Zealand). (1966). *Carpentry in New Zealand*. Wellington, NZ: Govt. Printer.

Technical Correspondence School (New Zealand). (1973). *Carpentry in New Zealand*. Wellington,: A. R. Shearer, Govt. printer.

Tennent, J. E. S. (1860). *Ceylon: An Account of the Island, Physical, Historical and Topographical: With Notices of Its Natural History, Antiquities and Productions*. London: Longman, Green, Longman and Roberts.

TenWolde, A., & Glass, S. V. (2013). Moisture in Crawl Spaces. *Wood Design Focus - A Journal of Contemporary Wood Engineering*, *23*(3), 11–17. Retrieved from http://www.forestprod.org/assets/images/wdf/Wood%20Design%20Focus%20Volume%2023,%20Number%203.pdf

The Auckland Industrial Agricultural and Mining Exhibition: Official Catalogue and Guide. (1913). Auckland, NZ: Goldfinch System.

The Cavity Concrete Block Ltd. (1919, November 29). Memorandum of Association of The Cavity Concrete Block Ltd. The Cavity Concrete Block Company.

The Colac Herald. *The Colac Herald [Electronic Version Accessed through: Trove.nla.gov.au (1875-1918)]*. Colac, Victoria, Australia.

The Colonist. *The Colonist [Electronic Version Accessed through: Paperspast.natlib.govt.nz (1857-1920)]*. Nelson NZ

The Farmers' Christchurch. (1956). *The Farmers' Home of Today 1956. At the Industries Fair April 27 - May 19*. Christchurch NZ: The Farmers' Christchurch.

The Fletcher Merchants Ltd. (1970, May). Builders' Price List May 1970. The Fletcher Merchants Ltd, Christchurch.

The Monopolies Commission (Great Britain). (1973). *Asbestos and Certain Asbestos Products: A Report on the Supply of Asbestos and Certain Asbestos Products*. London: H.M.S.O. Retrieved from http://www.competition-commission.org.uk/rep_pub/reports/1970_1975/fulltext/066c01.pdf

The News (Westport). *The News (Westport)*. Westport, NZ

The NZ Dairy Produce Exporter Newspaper Co. (1939). *Do It Yourself: Practical Ideas and Simple Instructions for Making Improvements to the Home, with Many Illustrations: Also Hundreds of Money and Labour-Saving Hints on Housework, Cooking and Sewing*. Wellington, NZ: The NZ Dairy Produce Exporter Newspaper Co.

The NZ Dairy Produce Exporter Newspaper Co. (1941). *Do It Yourself: A Complete, Concise Manual, Containing Hundreds of Practical Ideas and Simple Instructions for Making Improvements to the Home, Carrying Out Repair Jobs of All Descriptions, and Making Indoor and Outdoor Furniture*. Wellington, NZ: The NZ Dairy Produce Exporter Newspaper Co. Ltd.

The NZ Dairy Produce Exporter Newspaper Co. (1942). *Do It Yourself: A Complete, Concise Manual, Containing Hundreds of Practical Ideas and Simple Instructions for Making Improvements to the Home, Carrying Out Repair Jobs of All Descriptions, and Making Indoor and Outdoor Furniture, and Erecting Buildings About the Home.* Wellington, NZ: The NZ Dairy Produce Exporter Newspaper Co. Ltd.

The Press. *The Press [Electronic Version Accessed through: Paperspast.natlib.govt.nz (1861-1920)]*. Christchurch NZ

The Times. *The Times [Accessed through The Times Digital Archive (1785-1985)]*. London England.

Thomas, P. E. (1928). *Cork Insulation; a Complete Illustrated Textbook on Cork Insulation--the Origin of Cork and History of Its Use for Insulation--the Study of Heat and Determination of the Heat Conductivity of Various Materials--Complete Specifications and Directions for the Proper Application of Cork Insulation in Ice and Cold Storage Plants and Other Refrigeration Installations--the Insulation of Household Refrigerators, Ice Cream Cabinets and Soda Fountains*. Chicago: Nickerson & Collins Co.

Thompson, G. E. (1927). *Official record of the New Zealand and South Seas International Exhibition, Dunedin, 1925-1926*. Dunedin, NZ: Coulls Somerville Wilkie for Otago Master Printers Association.

Thomson, A. D. (1996). Cockayne, Leonard. In C. Orange (Ed.), *The Dictionary of New Zealand Biography. Volume Three, 1901-1920* (pp. 107–109). Wellington: Bridget Williams Books and Department of Internal Affairs. Retrieved from http://www.TeAra.govt.nz/en/biographies/3c25/cockayne-leonard

Thomson, S. (2005). *Wrinkly Tin: The Story of Corrugated Iron in New Zealand*. Wellington, NZ: Steele Roberts.

Thornton, G. G. (1982). *New Zealand's Industrial Heritage*. Wellington NZ: Reed.

Thornton, G. G. (1996). *Cast in Concrete: Concrete Construction in New Zealand, 1850-1939*. Auckland NZ: Reed.

Thornton, G. G. (2001). *Bridging the Gap: Early Bridges in New Zealand 1830-1939*. Auckland, NZ: Reed.

Tiemann, H. D. (1920). *Kiln Drying of Lumber* (3rd ed). Philadelphia: Lippincott.

Timaru Herald. *Timaru Herald [Electronic Version Accessed through: Paperspast.natlib.govt.nz (1864-1920)]*. Timaru, NZ

Timber Preservation Authority. (1958). *Timber Preservation in New Zealand: The Functions of The Timber Preservation Authority of New Zealand*. Wellington NZ: Department of Industries and Commerce.

Timber Preservation Authority. (1963). *Timber Preservation in New Zealand. The Preservative Treatment of Timber - Introduction and Specifications. Under the Authority of the Timber Preservation Regulations 1955.* Wellington NZ: Government Printer.

Tomlinson, C. (1854). *Cyclopædia of Useful Arts, Mechanical and Chemical, Manufactures, Mining, and Engineering. Vol. 1 Abattoir to Hair-Pencils. Vol. 2 Hammer to Zirconium*. London and New York: G. Virtue & Co.

Toomath, W. (1996). *Built in New Zealand: The Houses We Live In*. Auckland, NZ: HarperCollins.

Torrance, W. M. (1906). Types of Hollow Concrete Blocks Used in the States and their Patents. *Concrete and Constructional Engineering*, *1*(3), 206–212.

Torres, F., Emeric, F., & Guilhem, Y. de. (2006). *A History of Lafarge Gypsum*. Paris: Editions de Monza.

Trethowen, H. A. (1987). *A Survey of Subfloor Evaporation Rates* (Study Report No. SR 13). Judgeford, NZ: BRANZ.

Trethowen, H. A. (1988). *A Survey of Moisture Damage in Southern New Zealand Buildings* (No. SR 7). Judgeford, NZ: BRANZ.

Trethowen, H. A. (1994). Three Surveys of Subfloor Moisture in New Zealand. In *ASHRAE Transactions 1994 Part I* (pp. 1427–1438). New Orleans, LA: ASHRAE.

Trethowen, H. A. (1995). Further Comment on Fibrous Insulant Materials. *Journal of Building Physics*, *19*, 89–92.

Turnbull, T. (1888). On Earthquakes and Architecture. *Transactions of the New Zealand Institute*, *21*, 498–502. Retrieved from http://rsnz.natlib.govt.nz/volume/rsnz_21/rsnz_21_00_004110.html

Tutton, M., Hirst, E., & Pearce, J. (Eds.). (2007). *Windows: History, Repair, and Conservation*. Shaftesbury: Donhead Publishing.

van Oss, H. G. (2006). *Background Facts and Issues Concerning Cement and Cement Data* (1.2 ed.). U.S. Geological Survey. Retrieved from http://pubs.usgs.gov/of/2005/1152/

Varman, R. V. J. (1993). *Bricks and Nails Building Materials as Criteria for Dating in Sydney and Environs from 1788 ; a Documentary Survey and Assessment of Dating Potential*. University of Sydney, Sydney N.S.W. Retrieved from http://hdl.handle.net/2123/1205

Venables, P. H. (1941, May 22). P.H. Venables Ltd 22 May 1941 letter to Department of Industries and Commerce, Christchurch. Retrieved from AEFN 19294 W715 IC1 394 / 19/105/5

Venesta Limited. (1903, April 10). For Partitions and Panels Use Venesta Boards. *British Architect*, iv. Retrieved from http://search.proquest.com.helicon.vuw.ac.nz/docview/6786733/fulltext/1?accountid=14782

Vercoe, J. (1867). *Descriptive Schedule to Accompany Map of the City of Auckland*. Auckland, N.Z: W.C. Wilson, Lithographic and General Printer, 'Herald' Office.

Vercoe, J., & Harding, E. W. (1866). City of Auckland, New Zealand, from Actual Survey. Auckland NZ: Vercoe and Harding. Retrieved from www.aucklandlibraries.govt.nz

Vitruvius Pollio, Morgan, M. H. (Morris H., & Warren, H. L. (1914). *Vitruvius: The Ten Books on Architecture*. Cambridge, Mass.: Harvard University Press (Dover Publications Ltd).

Waikato Coalfields Museum. (2006). *Huntly Brick: The Brickworks and the Buildings*. Huntly, NZ: Waikato Coalfields Museum.

Waikato Times. *Waikato Times [Electronic Version Accessed through: Paperspast.natlib.govt.nz (1872-1895)]*. Hamilton, NZ

Wairarapa Daily Times. *Wairarapa Daily Times [Electronic Version Accessed through: Paperspast.natlib.govt.nz (1879-1919)]*. Greytown NZ

Wakefield, E. J. (1845). *Adventure in New Zealand, from 1839 to 1844; With Some Account of the Beginning of the British Colonization of the Islands. Vol. 2*. London : J. Murray. Retrieved from http://archive.org/details/adventureinnewze02wakeiala

Wakefield, E. J. (1908). *Adventure in New Zealand from 1839 to 1844: With Some Account of the Beginning of the British Colonization of the Islands*. (R. Stout, Ed.). Christchurch, N.Z: Whitcombe and Tombs.

Walker, C. C. (1876). Art. XIII.—On State Forestry: Its Aim and Object. [Read before the Otago Philosophical Society, December 21, 1876.]. *Transactions and Proceedings of the New Zealand Institute 1876 [electronic Resource]*, *9*, 187–203. Retrieved from http://rsnz.natlib.govt.nz/volume/rsnz_09/rsnz_09_00_001180.html

Walker, C. C. (1877). The Climatic and Financial Aspect of Forest Conservancy as Applicable to New Zealand. [A Lecture Delivered in Connection with the New Zealand Institute at the Colonial Museum, 19th March, 1877]. *Transactions and Proceedings of the*

New Zealand Institute 1876 [electronic Resource], *9*, xxvii–xlix. Retrieved from http://rsnz.natlib.govt.nz/volume/rsnz_09/rsnz_09_00_008300.html

Wanganui Chronicle. *Wanganui Chronicle [Electronic Version Accessed through: Paperspast.natlib.govt.nz (1874-1919)]*. Wanganui, NZ

Wanganui Herald. *Wanganui Herald [Electronic Version Accessed through: Paperspast.natlib.govt.nz (1867-1909)]*. Wanganui, NZ

Ward, L. E. (1929). *Early Wellington*. Auckland: Whitcombe & Tombs.

Ward, W. C. (1967). *Fifty Years [1917-1967]-- a History [of the Dominion Sawmillers' Federation Incorporated]*. Wellington: Dominion Sawmillers' Federation.

Warren, J. H., Kember, A., & Haas, A. (Eds.). (1983). *How to Heat Your Home. A Consumer Guide for New Zealanders.* Wellington NZ: Ministry of Energy and Asia Pacific Economic News.

Warren & Mahoney Architects. (1989). *Warren & Mahoney Architects, 1958-1989*. Christchurch NZ: The Architects.

Warwick, M. L. (1996). *Hurricane Wire Products: The First Sixty Years: 1932-1992: A Short History of Hurricane Wire Products Limited, with Updating Comment on Events to December 1996*. Christchurch, N.Z: Hurricane Wire Products.

Washbourn, E. (1970). *Courage and Camp Ovens: Five Generations at Golden Bay*. Wellington: Reed.

Watkinson, P. J., & Bennett, A. F. (1987). *Adhesives and the NZ Building Industry (1985-1986)* (No. SR 5). Porirua NZ: BRANZ.

Wellington Independent. *Wellington Independent [Electronic Version Accessed through: Paperspast.natlib.govt.nz (1845-1874)]*. Wellington NZ

Wells, A. G. (1970). *History of the Building Research Bureau*. Wellington NZ: Building Research Association of New Zealand.

Wells, R. E. (1946). *J. Pullman building at Sandy Bay*. Retrieved from http://natlib.govt.nz/records/22818040

West Coast Times. *West Coast Times [Electronic Version Accessed through: Paperspast.natlib.govt.nz (1865-1909]*. Hokitika, NZ

West, D. (2008, April 24). Penrose Hardboard Plant.

W.G. Bassett. (c1920). *W.G. Bassett, Sash & Door Manufacturer & Timber Merchant, 95, Upper Wilson Street, Wanganui, NZ* Wanganui NZ: W.G. Bassett.

White, J. (1863). Return of authorities given by J. White Esq. R.M. Central Whanganui {sic} for the Purchase of Ironmongery by Friendly Natives. Part of 'Papers relating to the sale of arms to Maoris'. Retrieved from MS-Papers-0075-032

Whyte, P. (2001). *Solid Concrete: a History of Firth Industries*. Auckland, New Zealand: Published by Whyte & Mclean on behalf of Firth Industries.

Wilkes, O., Chapple, J., List, D., Shadbolt, T., Admore, A., & Pettigrew, J. (Eds.). (1972). *The First New Zealand Whole Earth Catalogue*. Wellington, N.Z: Alister Taylor Publishing Ltd.

Wilkins, F. (1968). *Woodwork: For Student, Apprentice and Handyman* (1st ed). Christchurch NZ: Whitcombe and Tombs.

Wilkins, F. (1973). *Woodwork: For Student, Apprentice and Handyman* (Rev. metric ed). Christchurch NZ: Whitcombe and Tombs.

Wilkins, F. (1981). *Woodwork: For Student, Apprentice and Handyman* (3rd ed). Christchurch, NZ & London: Whitcoulls.

Williams, A. (1907). *How It Is Made: Describing in Simple Language How Various Machines and Many Articles in Common Use Are Manufactured from the Raw Materials*. London: Nelson.

Williams, G. J., & McKee, T. J. (1974). *Economic Geology of New Zealand : The T. J. McKee Memorial Volume*. Parkville, Australia: Australasian Institute of Mining and Metallurgy.

Williams, T. (1993). Blair, William Newsham. In W. H. Oliver (Ed.), *The Dictionary of New Zealand Biography. Volume Two, 1870-1900* (p. 45). Wellington: Bridget Williams Books and Department of Internal Affairs. Retrieved from http://www.TeAra.govt.nz/en/biographies/2b27/1

Williams, W. W. (1964, September 24). W.W. Williams, Automated Building Components (NZ) Ltd. Letter to State Advances Corporation. 24 Sep 1964. Retrieved from AALF W3202/19 Record 24/15 Part 1

Williams, W. W. (1965, January 25). W.W. Williams, Automated Building Components (NZ) Ltd. Letter to State Advances Corporation. 25 Jan 1965. Retrieved from AALF W3202/19 Record 24/15 Part 1

Wilson, D. (Ed.). (2004). *New Zealand Electoral Roll 1893 (CD)*. Auckland, NZ: New Zealand Society of Genealogists.

Wilson, G. (1981). *Home Sweet Home - A New Zealand Guide to Buying and Selling a House*. Wellington NZ: A.H. & A.W. Reed.

Wilson, R., & Snodgrass, K. (2008). *Early 20th-century Building Materials: Siding and Roofing*. United States Dept. of Agriculture, Forest Service, Technology & Development Program. Retrieved from http://www.fs.fed.us/t-d/pubs/pdfpubs/pdf08732308/pdf08732308dpi72.pdf

Wright, Stephenson & Co. Ltd. (1950, January 16). Simplicity Moulds (Advertisement). *NZ Journal of Agriculture*, *80*(1), 33.

Young, D. (2005). Treasure Islands c.1300-1642. In B. Dalley & G. McLean (Eds.), *Frontier of Dreams: The Story of New Zealand*. Auckland, NZ: Hodder Moa Beckett.

Appendix

This section provides additional supporting material

Approaches to Time Classification

The following tables set out the different classification periods, and where available brief descriptions, as used in selected NZ publications.

Table 46: Historical Survey of NZ Domestic Building 1814-1954

Period	Description
1350 – 1840	Maoris
1820 – 1860	Pioneering – Simplicity
1820 – 1860	Pioneering Elegance
1850 – 1900	Victorian Age
1895 – 1920	Arts and Crafts Period
1981 – 1952	Age of Anxiety
1940 – 1950	New Pioneers

Source: "*Home Building 1814 – 1954 the New Zealand tradition*" (Garrett, 1954)

Table 47: NZ House Type Identification 1890-1940

Period	**Description**
1890 – 1900	Transition of cottage to villa
1860 – 1890	Single gable cottage
1890 – 1910	Villa or square house, verandah and 4 rooms
1920 – 1930	Bungalow
1890 – 1910	House. Hip roof, one room wide
1860 – 1890	Cottage, simple verandah
1890 – 1910	House. Stair behind front door
1920 – 1940	California bungalow. Casement windows
1890 – 1910	Bay villa, large bay window, ornate decoration
1860 – 1890	Double Gable Cottage

Source: "*Buying & Restoring a House*" (Harrap, 1981, pp. 8–9)

Table 48: NZ House Construction Periods 800 – 1940

Period	**Chapter Heading (Description)**
800 – 1769	Maori Houses
1792 – 1840	First European Arrivals
1840 – 1860	Houses for Settlers
1860 – 1910	Victorian Villas and Cottages
1910 – 1940	The Bungalow and Beyond

Source: "*Old New Zealand Houses 1800 – 1940*" (Salmond, 1989)

Table 49: NZ House Styles & Materials

Date	Worker class	Middle Class	Affluent Class
1820s- 50s	Barracks, tents, 'V' huts, Maori-built huts, Poorest self-build.	Builder-designed & -built, Maori labour, house imports from NZ & overseas	Regency, Georgian, English/Australian architect-designed, overseas prefab
1850s- 90s	Self-built, builder- constructed, Georgian box cottages, company settlements	Builder-designed & built, prefab, plain villas, colonists' design guides	Local & English architect-designed, cottage orné, Elizabethan, Tudor styles
1890s- 1915	Terrace housing, 1st state housing Petone, railway cottages	Spec housing, bay & corner villas, catalogues, pre-made joinery & details	Arts & Crafts, half-timber-framed, American styles, Queen Anne
1915- 20s	Transitional villas, Californian bungalow, 1919 Housing Act 'English bungalow'	Spec housing, Californian bungalow, Spanish Mission	Georgian style in Wellington, English Domestic revival
1920s-40	State housing from 1935, English Domestic revival	Spec housing, Art Deco, Moderne, late bungalow, Villas modified	Neo-Georgian, 1st Modern Movement
1940s- 60s	State housing, Star Flats. War years constraints	Council housing, built-in furniture	Modern Movement, international styles
1960s- 80s	State housing	Spec imitations, Colonial styles	Postmodern style
1980s -	Little or no state housing with right-wing government	Copies of old styles, e.g. half-timber, villa, Georgian	Repetition of Modern Movement
	Materials		
1820s- 50s	Readily available: cob, mud & stud, slab, adzed & pit-sawn timber, raupo, bark	Imported timber sashes, doors, handmade bricks, sawn timber, shingles	Imported timber sashes, doors, glass etc, stone & timber, corrugated steel
1850s- 90s	Handmade brick, shiplap weatherboard, machined timber, stone, corrugated steel	Catalogues, rusticated weatherboards, Marseilles tiles	Concrete, imported slates, pressed metal, encaustic floor tiles, plain roof tiles, cast & wrought iron
1890s- 1915	Concrete, asbestos sheet	Machine-made decoration, coloured glass	Arts & Crafts hand-adzed timber, leaded windows
1915- 20s	Roughcast stucco	Bevelled glass, 'off the shelf' plaster decoration, creosote	Fibrous plaster sheet
1920s- 40		Softboard, plywood	Glass blocks
1940s- 60s			Concrete block, steel window & door, aluminium roofing
1960s- 80s		Asbestos cement sheet & roof, pre-cut gang-nail framing, 'clinker brick', exposed beams, pressed metal tiles	Pre-cast elements
1980s -		Monolithic sheet material with plaster & paint systems	Exterior plywood

Source: "*The New Zealand Period House: A Conservation Guide*" (Arden & Bowman, 2004, pp. 13–14)

Table 50: Evolution of the Auckland Dwelling (1860s – 1950s)

Date	Planning	External	Interior	Construction
1860-70	Simple plans, central passage, front verandah, no built-in features, few conveniences; outside laundry & E.C.	Plain design, short span gables, pitched roofs, centre parallel gutter, back lean-to, flush eaves & gables.	Rough lining & scrim, horizontal 9 x 1” beaded T. & G. linings, ceiling match lined or board & battens plain, trim simple mould, doors 4 panel bed mould.	Puriri blocks, low floors, no vermin plates, weatherboards random butted, no scribers. Verandah roofs board & batten or flat iron with raised seams.
1870-80	Little change during except two-storey cottages to fit narrow sections. Generally one-room wide with entrance hall. Trend for better & larger houses but construction, design & finish were same as in the previous period.			
1880-90	Simple plan. Sometimes no hall or front verandah, generally 4 rooms with back lean-to scullery; outside washhouse & W.C.	Plain design, front lean-to verandah. Lean-to back. Short pitched roofs over main rooms; flush eaves, narrow barges; rusticated weatherboard. Outside washhouse	Interior rough lined, scrim & paper, some horizontal 9” T.G. & B. linings; ceiling T.G. & B. or board & battened; sashes D.H. & divided into small panes. Fuel range and sink	Puriri blocks, weatherboards, rusticated long lengths & random butted & butted to angle piece; generally no vermin plates; studs tenoned to plates; floors 9” x 1” P.T.G.; cut rails in general use.
1890-1900	Planning, design, construction improved. Fuel range, open fire, sink & perhaps a cupboard. Early villa cottage giving way to flat-roofed bay & true bay villa	Exterior with lean-to front verandah, hipped roof, boxed eaves with O.G. spoutings & bed moulds, moulded brackets & fretwork, turned balustrades, moulded handrails, rusticated weatherboards.	Interior rough lined, scrim & paper; ceilings moulded battens & board; moulded architraves & trim; 4 panel doors bed moulded, rim locks, etc.; double-hung windows, 2 panes. Fuel range, open fire, sink & perhaps a cupboard.	First class timbers. Puriri blocks often to plate; generally all heart kauri timbers; weatherboards mostly rusticated & full length; 4” x 4” cut out angle stops & 1” scribers. Cut nails went out of use about 1900; wire nails taking their place.
1900-10	**The Bay Villa Era** Simple orthodox plans with hall down the middle & bathroom at the end; uniform width rooms, front verandah, back lean-to; 10 to 12ft. stud, bay window.	Roof gabled over bay & hipped boxed eaves. O.G. spouting bed moulded & brackets; moulded frieze boards; moulded & fancy barge boards; bullnose verandah roofs; ornamental & turned spindle ornaments; moulded caps & fretwork brackets to posts; turned balusters, moulded handrails; double hung sashes; single panes, moulded trim.	Rough lined, scrim & paper; moulded, battened & board ceilings; moulded cornices, architraves & skirtings; doors 4 panel bed moulded. Some ceilings were "Wonderleth" pressed steel, galvanised or zinc moulded & ornamental panels, etc. Kitchens, pantries & bathrooms generally, P.T. & G. match lined; gas & fuel cooking, gas caliphont.	Construction generally good, Puriri blocks (all brick foundations not uncommon); weatherboard bases, or vertical T. & G.; rusticated & lapped weatherboards; iron roofs but some in slate & imported Marseilles clay tiles; angle boxes cut out of the solid 4” x 4” & later 4” x 1” with scribers. Generally all Kauri. Mouldings, joinery fretwork, & brackets from K.T.C. Catalogue.
1905-10	**Semi-Villa or Semi-Bungalow** Transition period with gradual change from the bay-villa to bungalow & in consequence the two types have characteristics common to both. Ceilings changing from board & moulded batten to fibrous plaster with moulded cornices. Architraves & skirtings becoming plainer. Casement windows becoming more common. About 1910 sawn totara blocks & some glazed octagonal earthenware house blocks were fairly common.			

Date	Planning	External	Interior	Construction
1910-20	**Bungalow Type** Advance in planning, grouping & more flexibility in size & shape of rooms. No longer conform to the standard linoleum widths. Angles, nooks & bays of various shapes & sizes appeared.	Generally gabled in front & hipped brackets often under gables; open eaves with exposed rafter ends, & match lined on top of eaves rafters; fancy ends to barge boards, gables; shingled half-timbered effect or narrow weatherboards; bellcast effect at ceiling lines, bracketed or dentils; casement windows, leadlight fans.	Rough lining & scrim in general use; ceilings panelled, moulded fibrous plaster, wood battens or beams, & some steel ceilings being general. Trim generally plain with some bevelled architraves & skirtings; more built-in cupboards in kitchens, cabinets, wardrobes, gas caliphonts & stoves; laundry under one roof.	Sawn totara blocks in general use, also some glazed earthenware blocks; lapped weatherboards, bevelled, etc., angles 4” x 1” boxed 1” scribes & plasters under windows; base boards, vertical spaced; bays· with bases shingled & hoods; bungalow lower pitched roofs, galvanised iron, Marseilles tiles & Rosemary tiles.
1920 - 30	**Closed-Eaves Type** Greater consideration given to planning, communications & conveniences. More thought given in planning to the site, sun, view, etc.- all under one roof. More attention paid to kitchen layout & equipment	More freedom, but less fussy; general striving for simplicity, bays became fewer, fanlights & leadlights were less numerous; gables & hips; eaves were wide & lined, generally panelled. "Konka" board (pumice hardbacking for stucco) early in the period. "Steeltex," imported reinforcing mesh with waterproof paper backing later in the period & extensively used as a soft backing for stucco finish.	Wallboards first appeared in 1920 & became general, both "Giproc" core & pulpboard. Ceilings, wallboard & fibrous plaster; panelled or beam ceilings; trim, chamfered or simple moulded edges, mitred, doors, greater variety; more built-in fittings & equipment, wardrobes, cupboards, linen, kitchen cupboards, etc. Electric stoves & hot water systems became general from about 1925.	Concrete house blocks first appeared about 1920 & rapidly became common practice; weatherboards to ground or 6” x 1” spaced; angle boxed 4” x 1” & scribers or galvanised zinc or copper soakers; bays, some shingle bases & gables; bays & porches flat roofs; stud height showing tendency to be lowered even to 8ft. Locally-made Marseilles tiles appeared in 1924 & "Gibraltar" board in 1927.
1930-40	Similar to the previous period but even greater consideration & thought given to communication & planning. Prolific new designs. Parapet-roofed ~1936 & overhanging lean-to roof type ~1939. Ornamental shutters disappearing.	More varied with acceptance of new materials, "Steeltex," "Bishopric" & “Konka" board. Semi-solid & solid backings for stucco became general about 1930, allowing greater variety of textures & coloured finish. Shutters, plain & fancy, window boxes used as ornamental features. Tiled roofs becoming more general, particularly in the better class homes. Fanlights & shutters disappearing. Bay windows (a feature in previous period) simplified & reduced in number.	Interiors becoming plain more flush finishing. Towards the end of the period all flush finish to doors, cupboards & ceilings were general. Terrazzo & some stainless steel sink benches replaced wood, "Fama," tile & other materials. "Celotex,"" Donnaconna" & other pulp insulating boards appeared early in the period & were used fairly extensively for both linings & ceilings. "Mastertile"' hollow earthenware block, early 1930s. "Hollostone," blue stone chip hollow concrete block late 1930s. Hard-pressed ⅛” boards, about same time as soft insulating lining boards, "Celotex" & "Donnaconna"	Even with the greater variety of external treatment (stucco on hard, soft or semi-soft backings, brick veneers), there was little change in the orthodox methods of construction except that continuous concrete footings became general. Weatherboards were various widths & lengths & generally mitred at angles with butts in line under windows with metal soakers. There was a general strengthening of the framework with noggings, flush & cut in braces, etc., brought about by the introduction of soft linings.

Date	Planning	External	Interior	Construction
1940-50	Planning & external treatment in design, fenestration, etc., changing the appearance of dwellings creating a "new look" Planning similar to the previous period but with greater freedom & variety. Latter part of the period open plan began to appear-fewer partitions & the use of fittings as screens. Out-door living considered ideal, with garden linked to living-room by floor to ceiling glazing. Reduced availability of native timbers – some timber imported, Pinus radiata being more used.	Greater variety of external design & materials but hipped level eaves held its own; the parapet type declining in popularity & losing appeal about end of period. Mid-1940s "Defiant Board' & "Reincrete Board," steel reinforced sheathing for stucco. About 1943 Durock sidings, asbestos cement shingle. "Fibrolite," locally-made asbestos ·cement sheet for external sheathing, battened & stucco backing. About 1942 galvanised iron replaced by corrugated fibrolite. Fibrolite ridges, barge & cover boards, spouting & downpipes introduced. Wood spouting & downpipes used extensively to replace galvanised iron during WWII 1939-45	All flush-finish to the interiors; flush plywood doors; coreboard cupboards; narrow architraves & skirtings; small scotia mould to flush ceilings; a stream-lined effect with few projections; greater emphasis by the end of the period being placed on contrasting colours & materials, etc. "Pinex," a pine wood pulp insulating wall & ceiling board, made its appearance about 1942.	General advance in the variety & use of materials in construction. Continuous concrete footings from early period as did brick & concrete block veneers, sheathing, solid & soft backings for stucco. Latter backing generally disappearing towards end of period.
1950-60	Greater consideration given to open plan. Varied from a square plan of about 30ft. x 30ft. with living space, dining space, kitchen space, etc., around a central tower with sleeping spaces in a loft, to a long lean-to type 62ft. x 17ft. Experimental plans of great variety & curiousness in design were being tried out possibly to combat the high cost of construction but with inconspicuous results. Greater use of the module system on both large & small projects. Pinus radiata became used fairly generally for construction	Followed new trends in planning. External designs over simplified & gaunt, with flat roofs or low-pitched lean-to roofs. Structural sashes with fixed glazing from floor to ceiling fairly frequent & external design feature with opening section top hung & sometimes wood flaps only above doorheads for ventilation. Various forms of external panelling were often used such as RB. plys, metal finished plywood, ship lap, vertical T. & G., etc. Anodised aluminium moulded roof tiles 1954.	Interiors plain with small skirtings & architraves & if level ceilings, scotia moulded; coreboard cupboard & flush doors; pine shiplap used as an internal decorative feature; also pine sarking & ceiling rafters, etc., waxed & oiled finish; contrasting pattern in the materials used, finish & colours appeared to be a general trend. Pinex flameproof “Albi-R” ½” board 1956.	Different methods & systems tried with little effect on the older methods & probably no cheaper. During 1952 1 or 2 houses built using mill construction system with indifferent results. (Used in North America - wood pier & beam 18ft to 10ft apart & with 2” P.T. & G. flooring & with 2” ditto for flat roof). Pre-stressed concrete used on some local bridges & a three-storey building designed. Plywood, resin bonded, used structurally, & as panels.

Source: based on *The Evolution of the Dwelling* (Bates, 1957, pp. 16–21)

Table 51: Early NZ Use of Hollow Concrete Block Trade Names

Date	Location	Name	Reference
26 Apr 1904	Thompson St, Wellington (retaining wall)	Palmers Hollow Building Blocks (*USA)	(Nielsen and Atkinson, 1904)
7 Jun 1904	Wellington Hollow Concrete Block Co.	Palmers Hollow Building Blocks (USA)	(Evening Post, p. 1, 7 Jun 1904)
12 Jan 1906	Timaru	Palmers Hollow Building Block (USA)	(Wanganui Herald, p. 5, 12 Jan 1906)
1 Nov 1906	C.A. Hamlin & Co advertisement for Auckland & Christchurch Exhibitions	Miracle Concrete Building Blocks (*USA)	(Progress, p. 34, 1 Nov 1906)
1 Nov 1907	Mr. E.J. Ible (Wellington) & Wilson's Portland Cement (Auckland)	Miracle Concrete Building Blocks (*USA)	(Progress, p. 32, 1 Nov 1907)
29 Nov 1907	Auckland Show	Pearson's hollow concrete blocks	(Auckland Star, p. 5, 29 Nov 1907)
10 Jun 1908	Otago A & P Show (Milburn Lime & Cement)	Miracle concrete building blocks (USA)	(Otago Witness, p. 27, 10 Jun 1908)
25 Sep 1908	J.A. Sutton for Winstones Ltd import duty	Pioneer hollow concrete block (*UK)	(Inspector of Customs, Wellington, 1908, p. 199, 25 Sep 1908 Ref 1908/1749) (Ohinemuri Gazette, p. 2, 12 Oct 1908)
Early 1909	108 Derby St, Westport	Singley (?)	Historic Place Register 7191
1 Apr 1909	Wm J. Alexander advertisement	Petty John Co. (*USA)	(Progress, p. 184, 1 Apr 1909)
15 Oct 1913	M.W.S. Lane	Hobbs' Concrete Block Machine (USA)	(Auckland Star, p. 12, 15 Oct 1913)
27 Oct 1917	McMillan Ltd, Herbert St (Wanted to sell)	Miles Hollow Concrete Block (?)	(Evening Post, p. 1, 27 Oct 1917)
25 May 1920	"Homes for Workers" article	OK Dry Wall system (*NZ)	(Evening Post, p. 8, 25 May 1920)
15 Jan 1921	Inventor Albert E Brooks, Lower Hutt.	Brooks System (*NZ)	(Evening Post, p. 7, 15 Jan 1921)
14 May 1921	Cavity Concrete Block Ltd advertisement	Cavity Concrete Building Blocks (*NZ)	(New Zealand Herald, p. 11, 14 May 1921)
23 Feb 1922	Lamport & Co. advertisement	Helm Concrete Blocks (*USA)	(New Zealand Herald, p. 12, 23 Feb 1922)
13 Mar 1922	Winget Concrete Block Co., Wellington	Winget Concrete Block (*UK)	(Evening Post, p. 2, 13 Mar 1922)
7 Jul 1922	Cavity Concrete Block Ltd advertorial	Fallwell Concrete Blocks (*NZ)	(New Zealand Herald, p. 9, 7 Jul 1922)
8 Jul 1922	B.B. Hollow Block Ltd, Hamilton	B.B. Hollow Block (?)	(Auckland Star, p. 5, 8 Jul 1922)
17 Feb 1923	D. Cleary, Licensed Drainage Contractor	Milwaukee Universal (*USA)	(Northern Advocate, p. 8, 17 Feb 1923)
7 Nov 1923	Tong Limited, Hawera	Winget Concrete Block (*UK)	(Hawera & Normanby Star, p. 1, 7 Nov 1923)
29 Aug 1925	British Building Block Company (Auckland), Ltd, advertorial	Lean cavity concrete blocks (*UK)	(Auckland Star, p. 10, 29 Aug 1925)
6 Jun 1928	Invicta Concrete Block Co., Auckland	Invicta Concrete Block (?)	(Auckland Star, p. 3, 6 Jun 1928)
10 Nov 1932	Concrete Block and Tile Co. Ltd	Trianco Building Blocks (*UK)	(Auckland Star, p. 24, 10 Nov 1932)
1937	Firth Industries, Rangiriri	Rockcrete (?)	(Whyte, 2001, p. 20)
11 Feb 1944	For Sale advertisement	Lightning (?)	(Auckland Star, p. 2, 11 Feb 1944)
1946	Firth Industries, Hastings	Columbia (*USA)	(Whyte, 2001, pp. 31–32)
16 Jan 1950	Wright, Stephenson & Co. Ltd	Simplicity Moulds (?)	(Wright, Stephenson & Co. Ltd, 1950)
1950	Pyramid Concrete, Rotorua	(*Italy)	(Whyte, 2001, p. 27)
1951	Universal Block Co., Christchurch	Trianco (English)	Fletcher Trust Archives
1953	Winstone, Auckland	Besser Vibrapac (USA)	(F. A. Simpson, 1965, p. 65)
1958	Vibrapac (Otago)	Besser Vibrapac (USA)	(Otago Daily Times, p. 5, 1 Dec 1958)
1958-9	Firth Industries, Hamilton, Hastings, Rotorua	Columbia (USA)	(Whyte, 2001, p. 27)

Table 52: Count of Inhabited Permanent Private Dwellings by Main Wall Materials

Census Year	Wood		Masonry (inc. Concrete)		Other Wall Material		TOTAL	
	Count	+ or -/yr	Count	+ or -/yr	Count	+ or -/yr	Count	+ or -/yr
1858	10,179		307		2,326		12,812	
1861	15,769	1,863	477	57	6,152	1,275	22,398	3,195
1864	26,022	3,418	1,082	202	10,892	1,580	37,996	5,199
1867	39,714	4,564	1,182	33	13,119	742	54,015	5,340
1871	46,710	1,749	1,540	90	8,932	-1,047	57,182	792
1874	51,575	1,622	1,901	120	7,880	-351	61,356	1,391
1878	69,224	4,412	3,001	275	10,363	621	82,588	5,308
1881	81,687	4,154	3,752	250	10,311	-17	95,750	4,387
1886	97,952	3,253	4,749	199	9,270	-208	111,971	3,244
1891	108,546	2,119	5,241	98	10,064	159	123,851	2,376
1896	126,879	3,667	6,155	183	8,305	-352	141,339	3,498
1901	143,681	3,360	7,194	208	8,023	-56	158,898	3,512
1906	167,781	4,820	7,949	151	8,727	141	184,457	5,112
1911	196,027	5,649	9,135	237	10,263	307	215,425	6,194
1916	223,010	5,397	10,026	178	5,030	-1,047	238,066	4,528
1921	242,381	3,874	12,693	533	5,155	25	260,229	4,433
1926	266,566	4,837	18,543	1,170	1,291	-773	286,400	5,234
1936	337,608	7,104	10,049	-849	2,248	96	349,905	6,351
1945	383,725	5,124	13,247	355	6,362	457	403,334	5,937
1951	463,723	13,333	19,479	1,039	10,810	741	494,012	15,113
1956	532,398	13,735	21,846	473	8,808	-400	563,052	13,808
1961	600,037	13,528	31,039	1,839	2,631	-1,235	633,707	14,131
1966	664,424	12,877	48,270	3,446	3,410	156	716,104	16,479
1971	735,152	14,146	49,912	328	16,622	2,642	801,686	17,116
1976	787,446	10,459	116,940	13,406	18,871	450	923,257	24,314
1981	853,740	13,259	136,794	3,971	12,570	-1,260	1,003,104	15,969

Table 53: Cost per unit of nail imports 1871 to 1965

Year	Cost per unit weight of imports (£ NZ/cwt)					
	UK	Australia	USA	Canada	Other - all	Average
1871	£1.37	£1.44	£0.96		£0.61	£1.38
1875	£1.20	£1.47	£2.40			£1.24
1880	£0.98	£1.40	£3.86		£2.00	£1.11
1885	£0.68	£0.88	£3.12		£2.17	£0.78
1890	£0.65	£1.38	£2.80		£0.79	£0.76
1895	£0.54	£0.70	£2.97		£0.52	£0.64
1900	£0.77	£1.59	£0.64	£1.00	£0.68	£0.69
1905	£0.72	£1.76	£0.54	£0.53	£0.58	£0.62
1910	£0.64	£1.31	£0.54	£0.50	£0.68	£0.77
1915	£0.88	£1.33	£0.60	£0.58	£4.29	£0.95
1920	£2.78	£2.19	£1.58	£1.41	£3.29	£3.12
1926	£1.12	£2.27	£1.90	£0.98	£1.27	£2.53
1930	£0.97	£2.08	£3.65	£1.13	£1.48	£1.52
1935	£1.62	£2.14	£2.57	£1.35	£2.81	£2.35
1940	£4.66	£3.06	£1.90	£2.81	£3.39	£4.60
1945	£6.46	£6.52	£6.86	£3.53		£7.87
1950	£6.54	£9.76	£39.38	£7.02	£4.73	£8.38
1955	£6.46	£5.73				£5.77
1960	£9.02	£8.74	£32.30	£12.30	£29.43	£18.12
1965	£17.58	£28.75	£18.93	£15.50	£28.09	£25.70

Table 54: Timeline - Niels Nielsen and NZ Hollow Concrete Building Block Co.

Date	Patent	Activities or Patents	Reference
1873		Niels Nielsen born in "Danmark"	(Internal Affairs, 1899)
1896		Niels Nielsen arrives NZ (Naturalisation) (c 22 yr. old)	(Internal Affairs, 1899)
29 Jan 1896		S.S. Tongariro arrived from London with a Mr 'Nielsen' in steerage for Wellington	(Evening Post, p. 2, 30 Jan 1896)
10 Jun 1899		Niels Nielsen Naturalisation Memorial (Carpenter, 26 yrs. of age, born "Danmark", resides Wellington, in NZ 4 yrs.)	(Internal Affairs, 1899)
5 Jul 1899		Niels Nielsen naturalisation	(New Zealand Government, p. 1313, 13 Jul 1899)
10 Mar 1904		Building Permit for shed, Lyall Bay, Nielsen & Atkinson	(Humphris, 2012).
11 Mar 1904	17649	A new or improved construction of stone or blocks for building purposes (Nielsen & Atkinson for Palmer)	(New Zealand Government, p. 961, 31 Mar 1904)
26 Apr 1904		Building Permit for Retaining Wall, Thompson St (Nielsen & Atkinson)	(Nielsen and Atkinson, 1904)
27 Apr 1904		Building Permit for house, Lyall Bay (Nielsen & Atkinson)	(Humphris, 2012).
7 Jun 1904		Wellington Hollow Building Block Company 1st advertise	(Evening Post, p. 1, 7 Jun 1904)
10 Oct 1904		Building Permit, Roseneath House	(Crichton & McKay, Architects, 1904)
14 Oct 1904		Prospectus issued for New Zealand Hollow Concrete Building Block Co Ltd (Company number 1904/44)	(NZ Hollow Concrete Building Block Company Ltd, 1904).
28 Oct 1904	18666	Improvements in blocks for building purposes (Original title "Improvements in blocks for building purposes and apparatus for construction of same") Paperwork dated 27 Oct 1904 for C.W. Nielsen, Registered Patent Agent to act as agent	(New Zealand Government, p. 2058, 24 Aug 1905) (New Zealand Government, p. 2739, 10 Nov 1904) (Nielsen, 1905a)
12 Jan 1905	*17649*	Application for letter patent abandoned (i.e. complete specifications not filed)	(New Zealand Government, p. 64, 12 Jan 1905)
6 Feb 1905	19038	Improved machine for moulding hollow concrete building blocks (Nielsen for Palmer)	(New Zealand Government, p. 1171, 18 May 1905) (Nielsen & Palmer, 1905)
15 May 1905	19474	Improvements in roofing tiles (Provisional – 19474 not found in Archive NZ files, but part of 20773 paperwork)	(New Zealand Government, p. 1414, 1 Jun 1905)
11 Dec 1905		Building Permit, Holiday House	(Nielsen, 1905b)
20 Feb 1906	20773	Improvements in roofing tiles	(New Zealand Government, p. 1335, 17 May 1906) (Nielsen, 1906)
20 Mar 1906		Liquidation meeting for New Zealand Hollow Concrete Building Block Co Ltd	(New Zealand Government, p. 1137, 26 Apr 1906)
13 Aug 1906		Moore and Varlow, 20 Customhouse Quay '*Agents for the Hollow Concrete Blocks, for walls, etc.*'	(Evening Post, p. 8, 13 Aug 1906)
17 Jan 1907		Building Permit, new timber house next to Holiday House	(Nielsen, 1907a)
27 Mar 1907		Building Permit, new timber house near Holiday House	(Nielsen, 1907b)
27 Aug 1907		Building Permit, timber house for C.W. Nielsen	(Nielsen, 1907c)
29 May 1934		Wind up NZ Hollow Concrete Building Block Co Ltd	(New Zealand Government, p. 1660, 31 May 1934)

Statistics Data Sources

Table 55 lists for each census report the relevant page and/or table number for walls (left column) and roofs and roof/wall combinations (right column). Table 56 provides this for import statistics. Individual page numbers are not given as the reports are in alphabetical or classification order. Where required these are given as references in the relevant places.

Table 55: Census Data Sources: Walls, Roofs and Roof/Wall Combinations

Census	Walls	Roofs, Roof/Wall Combinations
1858	(New Zealand Registrar-General's Office, 1862 Table 6)	
1861	(New Zealand Registrar-General's Office, 1862 Table 6)	
1864	(New Zealand Registrar-General's Office, 1865 Part I, Census. Table 6)	
1867	(New Zealand Registrar-General's Office, 1868 Part I, Census. Table 5)	
1871	(Government Statistician, Registrar-General's Office, 1872a Table 5)	
1874	(Government Statistician, Registrar-General's Office, 1875, p. 11 Table XV)	
1878	(Government Statistician, Registrar-General's Office, 1880, p. 9 Table XV)	
1881	(Government Statistician, Registrar-General's Office, 1882, p. 10, Table XV)	
1886	(Government Statistician, Registrar-General's Office, 1887a, p. 8 Table XIV)	
1891	(Government Statistician, Registrar-General's Office, 1892, p. 9 Table XIV)	
1896	(Government Statistician, Registrar-General's Office, 1897, p. 8 Table XIV)	
1901	(Census and Statistics Office, 1902, p. 8 Table XV)	
1906	(Census and Statistics Office, 1907, p. 10 Table XV)	
1911	(Government Statistician, Registrar-General's Office, 1912a, p. 12 Table XIV)	
1916	(Census and Statistics Office, 1924a, p. 8)	
1921	(Census and Statistics Office, 1924a, p. 8)	
1926	(Census and Statistics Office, 1931a, p. 62 Table 25)	
1936	(Census and Statistics Department, 1946 Table 20)	
1945	(New Zealand Census and Statistics Department., 1947 Table 18)	
1951	(Census and Statistics Department, 1954a, p. 10)	
1956	(New Zealand Department of Statistics, 1964, p. 101 Table 22)	
1961	(New Zealand Department of Statistics, 1964, p. 101 Table 22)	(New Zealand Department of Statistics, 1964, p. 101 Table 23)
1966	(New Zealand Department of Statistics, 1969, p. 77 Table 18)	(New Zealand Department of Statistics, 1969, p. 77 Table 19)
1971	(New Zealand Department of Statistics, 1975, p. 103 Table 18)	(New Zealand Department of Statistics, 1975, p. 103 Table 19)
1976	(New Zealand Department of Statistics, 1980, p. 152 Table 21)	(New Zealand Department of Statistics, 1980, p. 152 Table 22)
1981	(New Zealand Department of Statistics, 1983, p. 23 Table 18)	(New Zealand Department of Statistics, 1983, p. 24 Table 19)

Table 56: Import Statistics Data Sources

Year	Publication
1868	(Government Statistician, Registrar-General's Office, 1869)
1869	(Government Statistician, Registrar-General's Office, 1870)
1870	(Government Statistician, Registrar-General's Office, 1872b)
1875	(Government Statistician, Registrar-General's Office, 1876)
1880	(Government Statistician, Registrar-General's Office, 1881)
1885	(Government Statistician, Registrar-General's Office, 1886)
1886	(Government Statistician, Registrar-General's Office, 1887b)
1887	(Government Statistician, Registrar-General's Office, 1888)
1888	(Government Statistician, Registrar-General's Office, 1889)
1889	(Government Statistician, Registrar-General's Office, 1890)
1890	(Government Statistician, Registrar-General's Office, 1891)
1895	(Government Statistician, Registrar-General's Office, 1896)
1900	(Government Statistician, Registrar-General's Office, 1901)
1905	(Government Statistician, Registrar-General's Office, 1906)
1910	(Government Statistician, Registrar-General's Office, 1911)
1911	(Government Statistician, Registrar-General's Office, 1912b)
1912	(Government Statistician, Registrar-General's Office, 1913)
1913	(Government Statistician, Registrar-General's Office, 1914)
1914	(Government Statistician, Registrar-General's Office, 1915)
1915	(Government Statistician, Registrar-General's Office, 1916)
1916	(Government Statistician, Registrar-General's Office, 1917)
1917	(Government Statistician, Registrar-General's Office, 1918)
1918	(Government Statistician, Registrar-General's Office, 1919)
1919	(Government Statistician, Registrar-General's Office, 1920)
1920	(Government Statistician, Registrar-General's Office, 1921)
1921	(Census and Statistics Office, 1922)
1922	(Census and Statistics Office, 1922)
1923	(Census and Statistics Office, 1924b)
1924	(Census and Statistics Office, 1925)
1925	(Census and Statistics Office, 1926)
1926	(Census and Statistics Office, 1927)
1930	(Census and Statistics Office, 1931b)
1934	(Census and Statistics Office, 1935)
1935	(Census and Statistics Office, 1936)
1936	(Census and Statistics Office, 1937)
1937	(Census and Statistics Office, 1938)
1939	(Census and Statistics Office, 1939)
1940	(Census and Statistics Office, 1942b)
1945	(Census and Statistics Office, 1952a)
1950	(Census and Statistics Office, 1952b)
1955	(Customs Department, 1957b)
1960	(Customs Department, 1962b)
1965	(Department of Statistics, 1967b)
1970	(Department of Statistics, 1973a)
1975	(Department of Statistics, 1978)

Investigated Techniques

Table 57: Summary of Investigated Techniques

Technique	Start Decade		End Decade			Component								Technique			Country of Origin								
	Import /Use	Made	Import /Use	Made	Made in NZ	Roof (Structure)	Wall (Structure)	Cladding / Roofing	Fenestration	Insulation	Lining	Floor	Sub-floor	Material	Technology	Still used?	New Zealand	Australia	UK	USA	Other	Unknown	Generic	Possible Origin (if Other)	Timber Frame Wall
Earth Construction	*1840*		1880				x								x	Yes							x		No
Fired Earth: Bricks	*1840*	1840	1980	1980	Yes		x							x		Yes			x						No
Bricks - Double Wall Construction	1840		1930				x								x	No			x						No
Bricks - Veneer Construction	1900		1980					x							x	Yes		x							Yes
Fired Earth: Terracotta Roof Tiles	1900	1910	1950	1950	Yes			x						x		Yes					x			France	No
Stone	1830		1890				x						x	x		No							x		No
Drying - Air	1790		1980			x	x				x	x	x		x	Yes							x		Yes
Drying - Kiln	1870		1980			x	x				x	x	x		x	Yes			x	x					Yes
Preservative Treatments	1880		1980			x	x				x	x	x	x		Yes			x						Yes
Veneer / Plywood	1910	1910	1980	1980	Yes						x	x		x		Yes			x						Yes
Glulam		1950		1980	Yes	x	x							x		Yes			x	x					Yes
Softboard / Hardboard	1920	1940	1980	1980	Yes			x			x			x		Yes				x	x			Sweden	Yes
Particle Board Floor/Wall	1950	1950	1980	1980	Yes							x		x		Yes					x				Yes
Local Burnt Lime		1840		1980	Yes		x					x		x		No							x		No
Cement	1840	1880	1960	1980	Yes		x					x	x	x		Yes			x						No
Concrete - Reinforced	1880		1980				x					x	x	x		Yes			x		x			France?	No
Cast and Wrought Iron	1840	1920	1980	1980	Yes		x							x		Yes			x						No
Piles - Native Timber, Stone, etc	1840		1900										x	x		No							x		No
Piles - Concrete		1900		1980	Yes								x		x	Yes							x		No
Perimeter Foundation Walls	1900		1980										x		x	Yes							x		No
Suspended Floors	1840		1980									x			x	Yes							x		No
Ground Vapour Barrier	1960		1980										x	x		Yes				x					No
Concrete Slab-on-Grade Floors	1860		1980									x			x	Yes							x		No

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Technique	Start Decade		End Decade			Component								Technique			Country of Origin								
	Import /Use	Made	Import /Use	Made	Made in NZ	Roof (Structure)	Wall (Structure)	Cladding / Roofing	Fenestration	Insulation	Lining	Floor	Sub-floor	Material	Technology	Still used?	New Zealand	Australia	UK	USA	Other	Unknown	Generic	Possible Origin (if Other)	Timber Frame Wall
Terrazzo		1890		1980	Yes							x			x	Yes						x		Italy?	No
Solid Timber Wall		1950		1980	Yes		x								x	Yes	x								Yes
Braced Framing	1790		1890			x	x								x	No							x		Yes
Balloon Framing	*1860*		*1940*				x								x	No		x		x					Yes
Platform Framing	*1880*		*1980*				x								x	Yes				x					Yes
Nail Plates	1960	1960	1970	1980	Yes	x	x					x	x	x		Yes				x					Yes
Light Steel Framing		1970		1980	Yes		x					x			x	Yes				x					No
Monolithic Concrete	1860		1980				x							x		Yes						x			No
Oratonu Patent	1910		1920				x								x	No	x								No
Pearse Patent	1920		1930				x								x	No	x								No
Hollow Concrete Blocks		1900		1980	Yes		x								x	Yes				x					No
Wet Lining	1840		1980								x			x		Yes			x						Yes
Dry Lining - Fibrous Plaster		*1900*		1980	Yes						x			x		No						x			Yes
Dry Lining - Plasterboard	1920	1920	1920	1980							x			x		Yes				x					Yes
Weatherboards	1840	1860	1970	1980	Yes		x							x		Yes							x		Yes
Building Paper	1890	*1940*	*1940*	1980	Yes	x	x							x		Yes				x					Yes
Fibre Cement Board - Asbestos	1900	1940	1980	1980	Yes			x						x		No		x	x		x			Austria	Yes
Fibre Cement Board - Cellulose	1980	1980	1980	1980	Yes			x						x		Yes		x							Yes
Pumice Boards		1910		1950	Yes			x						x		No	x								No
Window Glass	1840	1960	1980	1980	Yes				x					x		Yes			x	x					No
Window Frames - Timber	1840	1850	1850	1980	Yes				x					x		Yes							x		No
Window Frames - Steel		1910		1980	Yes				x					x		Yes			x		x			France, Germany	No
Win[illegible]Frames																									

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Technique	Start Decade		End Decade			Component								Technique			Country of Origin								
	Import /Use	Made	Import /Use	Made	Made in NZ	Roof (Structure)	Wall (Structure)	Cladding / Roofing	Fenestration	Insulation	Lining	Floor	Sub-floor	Material	Technology	Still used?	New Zealand	Australia	UK	USA	Other	Unknown	Generic	Possible Origin (if Other)	Timber Frame Wall
Corrugated Iron	1840	1860	1980	1980	Yes			x						x		Yes			x						Yes
Aluminium Roofing	1950		1980					x						x		No			x	x					No
Metal Roof Tiles		1950		1980	Yes			x						x		Yes	x		x						No
Cork Insulation (Tiles)	1920		1980									x		x		Yes			x	x					No
Fibreglass Insulation	1950	1960	1980	1980	Yes					x				x		Yes				x					Yes
Roc-wool Insulation	1960	1970	1970	1980	Yes					x				x		Yes			x						Yes
Pumice Insulation		1870		1920	Yes					x				x		No	x								No
Perlite Insulation		1950		1980	Yes					x				x		No						x			No
Macerated Paper Insulation		1970		1980	Yes					x				x		Yes						x			Yes
Reflective Foil Insulation	1940	1950	1950	1980	Yes					x		x		x		No		x	x	x					Yes
Nails - Hand made	1840	1840	1840	1860	Yes	x	x	x			x	x	x		x	No							x		Yes
Nails - Cut	1840		1920			x	x	x			x	x	x		x	No			x	x					Yes
Nails - Wire	1860	1880	1980	1980	Yes	x	x	x			x	x	x		x	Yes				x	x			France	Yes
Camerated Concrete Case Study	1910		1920				x								x	No		x							No