

Earth and Straw Bale:
An investigation of their performance and potential
as building materials in New Zealand

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ABSTRACT

Is there a future for 'natural' or 'alternative' building systems in New Zealand? Do they have a role to play in the quest for more sustainable housing solutions? These are the questions that underpin this thesis which looks at the state of earth and straw bale building in New Zealand at the end of the first decade of the twenty-first century, using the Nelson area as a case study.

A database of all the earth and straw bale houses in the region has been compiled, followed by a written survey in the form of a questionnaire of 82% of the owners of these houses. Interviews with eleven experts and house owners provided additional information. This information, and that gleaned from a review of research carried out both in New Zealand and overseas has been collated and analysed to present an overview of the current situation. The way in which both earth and straw bale construction have changed over time is documented and the issues currently being faced for both systems are identified. The thesis concludes that there is a future for these natural building systems in New Zealand and identifies areas for further research that would help facilitate this.

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Note: The opinions expressed in this thesis are those of the author. Although interviewees and survey participants have given their permission to be quoted throughout the thesis, this does not necessarily imply agreement with the author's opinions.

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GLOSSARY

Many of the following terms are also defined in a footnote where they first appear in the body of the thesis.

Adobe bricks: Bricks made from a wet mix of earth and sometimes straw, poured into moulds and then dried in the sun. They are laid up in courses with mortar to form either load bearing walls and/or infill walls between posts and beams.

Building Consent: A Building Consent is the formal approval issued by the relevant Territorial Authority that the proposed building work meets the requirements of the Building Act 2004.

Cinva Ram: A hand operated machine for making soil cement bricks invented in 1952 in Colombia for low cost housing projects.

CO₂-e: Carbon dioxide equivalent. “Greenhouse gases include carbon dioxide, methane, and nitrous oxide; each gas has different physical properties; it’s conventional to express all gas emissions in ‘equivalent amounts of carbon dioxide,’ where ‘equivalent’ means ‘having the same warming effect over a period of 100 years.’” (Climatese, 2011)

Cob: A wet mix of earth and straw and laid directly up into walls in courses approximately 200mm thick. They can either be load bearing or formed as infill to a post and beam structure.

Code Compliance Certificate (CCC): A code compliance certificate is a formal statement, issued by the relevant Territorial Authority under the Building Act 2004, that building work carried out under a building consent complies with that building consent.

DBH: Department of Building and Housing: an agency of the New Zealand Government dealing with building controls and housing.

Determination: A binding decision made by the Department of Building and Housing. It provides a way of solving disputes or questions about the rules that apply to buildings, how buildings are used, building accessibility, and about health and safety.

DIY: An acronym in common usage standing for Do-It-Yourself, and referring to people undertaking work themselves rather than engaging an expert or a professional.

EBANZ: Earth Building Association of New Zealand.

EECA: The Energy Efficiency and Conservation Authority: a New Zealand Government Crown Entity that reports to the Minister of Energy and Resources.

Harakeke: New Zealand's native flax (Phormium Tenax).

HEEP: The Household Energy End-Use Project was a long-term study with the objective to measure and model the way energy is used in New Zealand houses.

HERS: The Home Energy Rating Scheme.

Hygroscopic: A material that will absorb or adsorb water from its surroundings.

Insitu adobe: A system where soil cement bricks are formed in place as the walls are being constructed using either single brick moulds or moulds that allow several bricks to be made at one time. Because of the cement content the bricks do not take long to set and the moulds can be lifted off once the cement goes off.

LCA: Life Cycle Analysis or Life Cycle Assessment.

Licensed Building Practitioner (LBP): A skilled and/or qualified building practitioner who has demonstrated their ability to meet industry consulted competencies in order to obtain the status of being a Licensed Building Practitioner (LBP). The scheme has seven license classes. (DBH, 2011d)

Lifestyle Block: This term refers to a small rural property, rather than a fully fledged farm, which is large enough to allow a level of independence which would be difficult to achieve in an urban environment. Its size can vary, as can its use. In some cases the land is used intensively to grow food either solely for the use of the owners or to supplement their income. In other cases the land is left in its natural state, for instance native forest, while the owners earn their income elsewhere. In this way they are able to enjoy the dual benefits of a rural lifestyle and an urban work environment. Further discussion of this term can be found in a paper by John Paterson (Paterson, 2005) and in a report by Statistics New Zealand (Statistics New Zealand, 2006b).

Light Earth: A system where straw saturated in wet clay is laid up using a light formwork between timber framing. Wood chips and pumice have been used instead of straw but no completed examples of this system have been identified in the research area.

Likert scale: A linear scale used in questionnaires where respondents are asked to evaluate something on a numbered scale which typically might go from ‘strongly disagree’ at one end to ‘strongly agree’ at the other.

MAF: Ministry of Agriculture and Forestry.

Mamaku: A tree fern indigenous to New Zealand, also known as Black Tree Fern (*Cyathea medullaris*).

MfE: Ministry for the Environment.

NCC: Nelson City Council.

NZIA: New Zealand Institute of Architects.

Owner Builder: A person who does building work on their own home, be it building a new home or carrying out alterations and additions to an existing one. Suitably skilled owner-builders do critical and complex work themselves and those who are less skilled often hire builders to assist them. For the purposes of this thesis, to be categorised as an owner-builder, a person must have had consistent involvement in the building process from beginning to completion. The following activities alone do not make an owner an owner-builder: project management, cleaning up after the builders and finishing work such as painting and decorating.

Pākeha: Māori word or name for non-Māori New Zealander, specifically of European descent.

Papakāinga: The term Papakāinga relates to a village or settlement and includes its relationship to the land, the ancestors and the activities that occur within that settlement.

Pivot table: A pivot table is a program tool that allows reorganization and summarization of selected columns and rows of data in a spreadsheet or database table to obtain a desired report (TechTarget, 2003).

Pressed bricks: Bricks formed in a hand operated press using a damp mix of earth with ten percent cement. The bricks are laid up as infill walls between posts and beams. They can be incorporated into a load bearing system but no instances of this have been found in the Nelson area.

Rammed Earth: Walls made from a damp mix of soil and usually ten percent cement in formwork and compacted using a hand or mechanical rammer. Rammed earth walls can either be load bearing or formed as infill to a post and beam structure.

Raupo: A bulrush, indigenous to New Zealand (*Typha angustifolia*).

Scion: The New Zealand Crown Research Institute (CRI) that specialises in research, science and technology development for the forestry, wood product and wood-derived materials and other biomaterial sectors.

SNZ: Standards Association of New Zealand (formerly shortened to SANZ).

Soil cement blocks: Blocks made from a mix of soil with ten percent cement in forms. They are similar to adobe but are usually a larger module size and are load bearing.

Straw: The dried stalks of grains such as wheat and barley. Straw is different to hay which is dried grasses used as stock food.

Straw Bale construction: A system where straw bales are laid up as walls, either load bearing or as infill within a post and beam structure. These are then plastered either directly on to the straw in the case of earth plasters or on to wire netting attached to the straw bales where cement plaster is used.

TA: Territorial Authority, sometimes known as Local Authority, is the local government body for an individual region of New Zealand.

TDC: Tasman District Council.

Wattle and Daub: A system where cob (daub) is plastered on to a woven lattice made out of sticks (wattle) to form walls between timber framing.

Preface

When my father brought home *The First New Zealand Whole Earth Catalogue* in 1972 (Taylor, 1972) I was in my fifth form year at school and trying to decide what career path to follow. At that point my preferred options were either meteorology or architecture. This book sealed it; architecture it was. I was fascinated by all the do-it-yourself ideas about creating shelter, about using local materials and the revival of vernacular traditions in general. In 1975 I enrolled in the first year of the new School of Architecture at Victoria University of Wellington, eager to learn all about it. Sadly for me, the new school had a strong technical bias, and the technology being taught could not have been further removed from the 'low tech' solutions that had inspired my career choice.

But my fascination with what are now referred to as 'natural' or 'alternative' materials remained and when I set up an architectural practice near Nelson in the 1980s I actively pursued projects involving alternative building systems, particularly using earth. Between 1987 and 1999, I designed ten earth buildings and three using straw bale, including one for my family. However these thirteen projects represented less than 5% of the output of my office over that time, and since then I have designed nothing in earth or straw bale. It became economically unviable for the practice to take on these projects, which generally required more time and had smaller budgets. When I decided to take time out from practice to stop producing buildings and start looking at how existing ones were performing, I returned to earth and straw.

I find it frustrating that alternative materials have stayed alternative and never moved into the mainstream. Those in New Zealand who choose to work with them exclusively, operate in the margins of their respective fields, be they architects, designers or builders. Is this because earth and straw bale really do not have a place in a contemporary world? The purpose of this investigation is to see whether they do.

CHAPTER ONE: INTRODUCTION

1.1 OBJECTIVE

Is there a future for 'natural' or 'alternative' building systems in New Zealand? Do they have a role to play in the quest for more sustainable housing solutions? These are the questions that underpin this thesis which looks at earth and straw bale as examples of 'natural' or 'alternative' construction materials. A study of over 100 earth and straw bale houses in the Nelson area built since 1945 provides a context for an investigation into their performance to date, a necessary prerequisite for considering their future. In order to assess the long term sustainability of the materials and the houses that utilise them more research will be necessary. One of the aims of this research is to identify those areas.

1.2 BACKGROUND

The necessity of working towards a sustainable future is well documented and universally accepted but this acceptance is a relatively recent phenomenon. Concern about the unchecked consumption of the earth's finite resources gathered momentum as the industrial revolution continued into the twentieth century. During the 1970s and 1980s it grew from being the concern of a vocal minority, to being a problem recognised by many countries all over the world. In 1983 the United Nations (UN) set up the World Commission on Environment and Development (WCED) which commissioned the 1987 Brundtland Report, otherwise known as *Our Common Future* (WCED, 1987). This report identified global environmental, social and economic issues and was a call for action to address them by all nations of the world. The Rio Earth Summit in 1992 was a response to this call for action and was attended by leaders from 178 countries, including a delegation from New Zealand. Most countries represented at the 1992 Summit, including New Zealand, signed Agenda 21,¹ a plan of action for all countries "*in every area in which humans impact on the environment*" (UN, 1992).

¹ Agenda 21 means literally an agenda for the twenty-first century.

However it was not until after the following Earth Summit, held in Johannesburg in 2002, that the New Zealand Government ventured beyond the rhetoric and took a meaningful stance on sustainability. In 2003 the Ministry for the Environment launched a programme of action for sustainable development which stated that *“Sustainable development must be at the core of all government policy”* (MFE, 2003). Opinions differ about how effective this initiative has been, but there can be no doubt that the concept of sustainability is no longer something that is associated solely with environmental activism on the margins of mainstream activity. In a recent speech, Dr Nick Smith, then Minister for the Environment, stated:

“In the twenty years since the Rio Earth Summit, ground breaking concepts contained in the Rio principles and Agenda 21 have been mainstreamed into our daily lives.” (2012)

Much of modern life is associated with buildings of some description; for living in, for working in, for cultural and sporting activities. The manner in which these buildings are constructed, the materials and processes that are used, and the resources that are required to keep them operating, has consequences for the sustainability of the environment. This has been recognised by the New Zealand Institute of Architects (NZIA) in its Environmental Guidelines:

“The New Zealand Institute of Architects affirms the responsibility of the architectural profession, as a key player in the construction industry, to embrace an integrated approach to ecological, social, cultural and economic sustainability...”

The NZIA recognises that our natural environment is finite and fragile and that we are dependent on enhancing and restoring our naturally and economically productive eco-system to enable us to meet our needs and inhabit this land in perpetuity.” (2011)

Decisions made by those involved in the design and construction of the built environment have effects far beyond the boundaries of individual projects and it is vital that designers, builders, suppliers and building operators are well informed about the products and processes they are using. Building practitioners and owners in New

Zealand are legally bound to take into account the impact of their decisions by the Building Act 2004 which sets out a regulatory framework for building work, a licensing regime for building practitioners and performance standards for buildings. One of the four purposes of the Act is to ensure that:

“buildings are designed, constructed, and able to be used in ways that promote sustainable development.” (NZ Government, 2012, Clause 3(a)(iv))

Issues concerning sustainability have been the subject of much research and have driven significant changes in building design and construction over the last thirty years. Many of the changes have been aimed at improving the energy efficiency of buildings, and the incremental increases in the insulation requirements for floor, wall and roof assemblies that have been occurring in New Zealand since 1978 are a direct result of this (Isaacs, 2007). The correlation between the quality of indoor environments, the health of occupants and the productivity of the work force has also been recognised at government level and is reflected in the policy statements of its key agencies. For instance, in its statement of intent, the Energy Efficiency and Conservation Authority (EECA)² states that one of its desired outcomes is to have:

“Warm, dry, energy efficient homes with improved air quality to reduce ill health and lost productivity.” (2011)

Other changes to the design and construction of buildings have been directed at encouraging more efficient use of building operating systems and of water, increasing the recycling of building materials, using other recycled products to make building materials, and using renewable resources. Homestar™, a joint venture partnership between the Building Research Association of New Zealand (BRANZ) and the New Zealand Green Building Council (NZGBC), aims to encourage the general public to make these changes by providing information about products and processes, and a rating tool to assess the performance of existing and proposed houses (Homestar, 2010). The continued use of locally grown timber as a major component of buildings in New Zealand has been encouraged on the basis of its life cycle credentials: being a

² EECA is a Crown Entity that reports to the Minister of Energy and Resources.

renewable resource and having the capacity to sequester carbon (Alcorn and Donn, 2010). For these reasons, the use of timber for larger scale buildings is also being investigated. For example, the experimental four storey Arts and Media building at the Nelson Marlborough Institute of Technology (NMIT), completed in 2010, uses timber for structural elements which would otherwise have been concrete and steel.

The research that underpins many of the changes aimed at improving the sustainability of buildings has been carried out using materials and systems in common use: timber and steel framing, insulation and concrete in their many forms, and the finishing materials and operating systems associated with them. The NMIT building, for example, has been used to test the research findings of a report written for the Ministry for Agriculture and Forestry (MAF), *Environmental Impacts of Multi-Storey Buildings Using Different Construction Materials* (Buchanan et al., 2008). Most of these commonly used materials and systems have been the subject of ongoing research in universities and research institutions such as BRANZ, the Cement and Concrete Association of New Zealand (CCANZ) and Scion.³ Their properties and performance capabilities are well known, and this information is essential when working with performance based building codes.

Where ‘alternative’ or ‘natural’ materials are concerned (see 1.4), however, there is far less information available. For instance, earth and straw bale houses, which constitute only a small proportion of the total housing stock (see 4.7), can be found scattered throughout New Zealand but very little research has been carried out about them or the materials used in their construction. The Earth Building Standards (SNZ, 1998b) contain valuable information about testing earth based materials and constructing earth walls but, unlike mainstream building methods, there has been very little ongoing research into the material characteristics and capabilities of earth and straw bale in universities and research institutions. The University of Otago’s Department of Physics has carried out research into methods for testing the thermal performance of earth walls, followed by actual testing of the lightweight adobe bricks

³ Scion is the New Zealand Crown Research Institute (CRI) that specialises in research, science and technology development for the forestry, wood product and wood-derived materials and other biomaterial sectors.

discussed in 6.10 (Lloyd, 2008) (Roos and Lloyd, 2003). Similar thermal testing has been carried out at the University of Auckland's School of Engineering on the fibre reinforced rammed earth walls (see 6.13) (Hsen-Han, 2008). Research into the structural performance of straw bales and their resistance to moisture has been carried out by Andrew Alcorn and others (see 6.18) (Alcorn and Worsnop, 2001) (Alcorn et al., 2000). Alcorn's further research at Victoria University of Wellington into the embodied energy of building materials including earth and straw bale confirms their value in this regard (2003).

At a time when the importance of building sustainably is widely accepted it would seem imperative that the potential of systems like these that use renewable resources, are readily available, and have low embodied energy, is further investigated. Currently the lack of knowledge is a barrier to the uptake of earth and straw bale construction and inhibits their construction development.

1.3 SUSTAINABILITY

The widespread, and often indiscriminate, use of the words 'sustainable', 'sustainable development' and 'sustainability' has accelerated over the past two decades, and has had the effect of diluting their meanings, to the point that often they seem meaningless. Nevertheless, their meaning is important.

Twenty-five years ago, the authors of the Brundtland Report provided the following definition of sustainable development:

"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs." (WCED, 1987)

This definition is used by governments in many countries, including New Zealand. New Zealand government agencies such as the Ministry for the Environment (MfE), the Department of Building and Housing (DBH), the Department of Statistics, and Territorial Authorities (TA) throughout the country use this definition. However, the definition is problematic in that, as pointed out by both Brenda and Robert Vale (2009,

p23) and Van der Ryn and Cowan (1996, p5), it fails to define what constitutes a 'need'. The Vales proposed an alternative definition:

"...the only possible definition of sustainability is the ability to be sustained or to continue into the indefinite future." (2009, p7)

This definition does not carry the uncertainty surrounding the interpretation of what constitutes a need and is the definition of sustainability adopted for this thesis. The central question then, is whether houses using alternative materials and construction methods can be sustained into the 'indefinite future'? It is not intended, perhaps it is not even possible, to provide a definitive answer to this question. Rather, this thesis seeks to establish whether these materials and methods have the potential to provide sustainable housing and are therefore worthy of further investigation.

1.4 ALTERNATIVE OR NATURAL MATERIALS

For the purposes of this thesis the terms 'alternative' and 'natural' are used to describe collectively earth and straw bale materials and construction systems. Both terms are in common use, but there are differing opinions about them.

In a global context, the use of the descriptor 'alternative' for earth construction is considered inappropriate by some. Ronald Rael refers to the *"inferiority complex"* that many earth building cultures have in a world where industrial materials are considered superior to traditional ones, and suggests that the term 'alternative' is unhelpful in this regard. In the introduction to his book *Earth Architecture* he states:

"Today the most common building material on the planet is classified as 'alternative' or worse – 'primitive'" (2009, p15).

Within New Zealand there is ongoing discussion around the term. At the Annual General Meeting (AGM) of the Earth Building Association of New Zealand (EBANZ) held on Waiheke Island in October 2010, delegates proposed that the term 'appropriate' be used rather than 'alternative' when referring to earth or straw bale building. They suggested that the term 'alternative' is counterproductive in attempts to make earth and straw bale acceptable as mainstream building materials (Hall, 2010b).

The term 'alternative' also has particular implications in the context of New Zealand's building tradition. As will be discussed in Chapter Two, there was a time when earth was a standard building material in this country; however, only the houses built since earth has moved out of the mainstream are being considered in this thesis. Therefore, for the purposes of this research, the word 'alternative,' when used to describe building materials and methods, simply means that they are alternative to the standard materials and methods currently used for constructing houses in New Zealand. These standard materials and methods are primarily timber or steel framing with a variety of external claddings, reinforced concrete masonry, and precast concrete.

Earth and straw bale are also included under the broad title of 'natural building.' Other natural building systems include cordwood (short lengths of unprocessed timber stacked like masonry and plastered over), solid timber, log building and timber frame construction. In New Zealand timber frame construction is a mainstream method and therefore it is specifically excluded from the definition for the purposes of this research.

When either 'alternative' or 'natural' is used to describe building materials or methods in this thesis, it is referring to those which have one or more of the following properties: they are minimally processed, readily available, renewable, recyclable, or are recycled (Kennedy et al., 2002).

1.5 EARTH AND STRAW BALE HOUSES IN NEW ZEALAND

Buildings constructed of alternative materials can be found scattered throughout New Zealand, mostly in the form of standalone houses. Materials include logs, cordwood, straw bale and earth, with earth being the most common. The different methods of construction, including the various ways of using earth, are described later in this chapter.

Significant pockets of both earth and straw bale houses can be found in Northland, Waiheke Island, the Coromandel, Nelson, Tasman, Marlborough, South Canterbury and Central Otago. The author's understanding of the locations of these pockets is shown

in Figure 1.1. Some of these earth houses date back to early Pākehā⁴ settlement, when earth was still a common construction material, but it is those built after the Second World War (WW2), when earth building was far from common that are the subject of this inquiry. The Nelson and Tasman regions have been chosen as the study area because of the author's personal experience and knowledge of the regions, having lived and worked there as an architect for thirty years. While they are officially two separate regions, the name 'Nelson' is commonly used when referring to the area as a

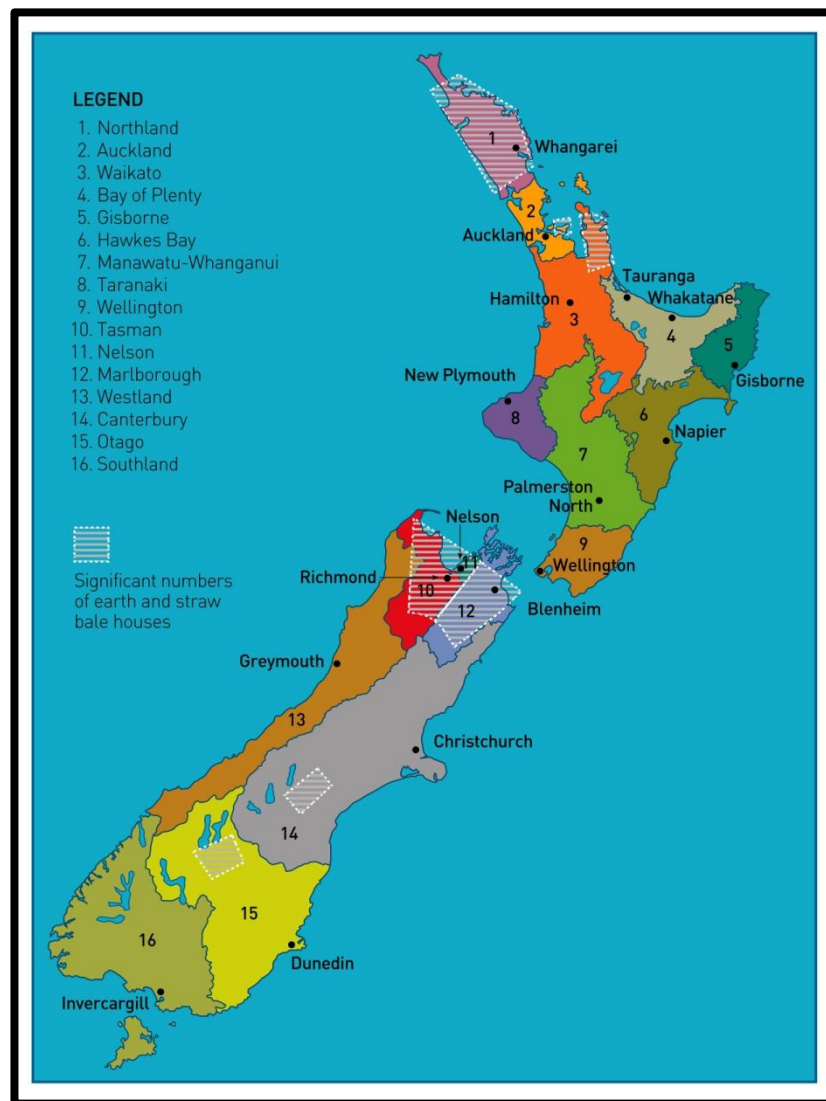


Figure 1.1 Significant Pockets of Earth and Straw Bale Houses in New Zealand

Source: Adapted from New Zealand Map (Ezilon, 2012).

⁴ Māori word or name for non-Māori New Zealander, specifically of European descent.

whole and this common usage is adopted for this thesis. A more detailed description of the area is given in 2.4.

1.6 CONSTRUCTION MATERIALS AND METHODS

A number of different kinds of earth and straw bale construction are used in New Zealand, and most of them are used in the Nelson area:

Adobe bricks are made from a wet mix of earth and sometimes straw, poured into moulds and then dried in the sun. They are laid up in courses with mortar to form either loadbearing walls and/or infill walls between posts and beams.

Cob is made from a wet mix of earth and straw and laid directly up into walls in courses approximately 200mm thick. Walls can either be loadbearing or formed as infill to a post and beam structure.

Insitu Adobe is a system where soil cement bricks are formed in place as the walls are being constructed, using either single brick moulds or moulds that allow several bricks to be made at once. Because of the cement content, the bricks do not take long to set and the moulds can be lifted off once the cement goes off. This method is very common in other parts of New Zealand but no examples have been found in Nelson.

Light Earth is a system where a lightweight material such as straw, wood chips, pumice or vermiculite is saturated in wet clay and laid up between formwork to form walls. In Nelson, only the straw/clay mix has been used. The terms 'straw light clay' and 'straw clay' are also used for this type of system.

Pressed bricks are formed in a hand or machine operated press using a damp mix of earth with ten percent cement. The bricks are laid up as infill walls between posts and beams. They can be incorporated into a loadbearing system but no instances of this have been found in the Nelson area.

Rammed Earth is made in formwork from a damp mix of soil and usually ten percent cement, and compacted using a hand or mechanical rammer. Rammed earth walls can either be loadbearing or formed as infill to a post and beam structure.

Soil cement bricks are made in forms from a mix of soil with up to ten percent cement, and used to form walls in the same manner as adobe bricks.

Straw Bale is a system where straw bales are laid up as walls, either loadbearing or as infill within a post and beam structure. These are then plastered with earth plasters applied directly to the bales, or on to wire netting attached to the bales where cement plaster is used.

Wattle and Daub is a system where cob (daub) is plastered on to a woven lattice made out of sticks (wattle) to form walls between timber framing.

These systems are discussed in more detail in later chapters as appropriate.

1.7 PREVIOUS RESEARCH

An extensive international literature review has been carried out to guide and inform this thesis. Out of this, research from four particular sources provided a starting point and helped define the direction: Ellen Jackson's Master of Architecture thesis, a conference paper by Andrew Alcorn, a second conference paper co-authored by Alcorn and Michael Donn, and Miles Allen's survey of earth buildings in the Nelson and Tasman regions, which provided background material for his Master of Architecture thesis.

Jackson's 2009 Master's thesis *Self Reliance and Earth Building in New Zealand*, investigated the reasons for a lack of uptake of earth construction in New Zealand and involved two surveys. As Jackson states:

"The results suggested that the largest reason why the surveyed population did not want to live in earth buildings was because it was unfamiliar or unknown to them." (2009, p.174)

Some of the perceptions that the general public and earth building experts had about earth buildings identified in Jackson's thesis have been tested in this thesis where information about actual houses and their owners has been analysed. Jackson's background research into the history of earth building in New Zealand which built on Allen's *Out of the Ground, Earth Building in New Zealand* (1997) has also informed this research.

Ongoing research by Alcorn into the energy embodied in materials is also of relevance when considering the contribution that straw bale construction, in particular, can make to a more sustainable housing stock in New Zealand. In his 2010 paper presented at *SB10: New Zealand Sustainable Building Conference* in Wellington, Alcorn argues that bio-based insulation materials have significant opportunities for providing CO₂-e reductions (Alcorn, 2010b). In another paper in the same year written for the *Second International Conference on Construction Materials and Technology* in Ancona, Italy, he and colleague Michael Donn from Victoria University of Wellington, put forward the case for timber and straw bale for reducing CO₂-e emissions:

“By using strawbale [sic] and timber to sequester CO₂, in combination with technologies to reduce the use of grid energy, houses can be made to be net absorbers of CO₂, achieving an essential feature of sustainability.” (2010)

There are some aspects of Alcorn and Donn’s life cycle modelling which may have resulted in exaggerating the role of straw bale in sequestering carbon, and this would require further analysis. For example, straw bales were used as insulation for floors and ceilings as well as for walls; this would be difficult to achieve and is not common practice. There are also a number of items left out of the LCA, such as plumbing, wiring, flooring and furniture, which may affect the results.

In 1990 Allen carried out a survey, *Earth Buildings of the Nelson Tasman Area 1840-1990* (Allen, 1990) as part of the research for his 1992 thesis *A Renaissance of Earth as a Building Material in New Zealand* (Allen, 1992). This survey was a useful starting point for locating houses for the database. Each building was recorded with a photograph, a plan in some cases, a classification of type by use, construction date, names of builder, owner and designer, the type of earth construction and general notes about the physical state of the building and its history (see 4.4).

Other research related to particular materials has been used to inform discussions in Chapter Six about their performance and potential, such as reports on the performance of earth houses following the 2010 and 2011 Canterbury earthquakes, and results from European and North America testing laboratories on the properties of earth and straw bale.

This thesis builds on the research carried out by Allen, Jackson, and Alcorn and Donn. In regard to Allen's work, it updates and significantly broadens the record of earth houses in the Nelson area. Jackson's research focused on the perceptions that the general public have about building with earth in New Zealand, whereas this research focuses on the real life experiences of the owners of houses built out of both earth and straw. Alcorn and Donn used theoretical modelling for their analysis based on assumptions that may not represent actual scenarios; the extensive database of houses created for this thesis can now provide a wider framework for further research in which analysis of the performance of actual houses can be made.

1.8 THESIS STRUCTURE

The goals of this thesis, definitions of terms, the study location, and relevant prior research have been identified in this chapter. The terms and foreign words used in this chapter and throughout the thesis are defined in a footnote on the page where they first occur, or within the text, and are repeated in the Glossary that precedes Chapter One.

The context, in terms of geographical location, the history of earth and straw bale construction globally and nationally, and of housing construction generally in the Nelson area, is set out in Chapter Two. In Chapter Three the methodology applied to the research is described, starting with the compilation of a database of all the earth and straw bale houses in the Nelson area, the carrying out of a survey in the form of a questionnaire of house owners and the sourcing of the additional material required to assist the analysis that followed.

Information from the database, described in Chapter Three, was used as a framework for the history of earth and straw bale houses in the Nelson area from 1945 to 2010 in Chapter Four. In Chapter Five the results of the survey are recorded and summarised and a complete summary of the answers to the questionnaire, in the form of tables and charts, is provided in Appendix 3. Discussions about issues identified in the survey and in the interviews that followed, that characterise earth and straw bale building to date, and which affect their potential as viable systems, take place in Chapter Six. Additional information drawn from local and international sources is used to inform

these discussions, and to place the Nelson condition in a wider context. Finally, the research findings, in relation to the questions central to the thesis, are discussed in Chapter Seven. The thesis concludes that there is a future for natural building systems in New Zealand, and identifies areas for further research that would help facilitate this.

CHAPTER TWO: CONTEXT

2.1 EARTH AND STRAW – A GLOBAL OVERVIEW

Earth and straw have been used as building materials in most parts of the globe for centuries and it is estimated that between one third and one half of the world's population live in houses made of earth (Rael, 2009, p.9). The two materials are closely connected: many kinds of earth construction incorporate straw or other fibrous plant material in the mix, and straw is used as thatched roofing for many earth buildings. Straw and other plant fibre are also used for wall construction. Different techniques and traditions, many of which have been defined in Chapter One, have evolved in different places to suit the material at hand, the culture of the society, developing technologies and the climate.

Although straw has been used as a building material for centuries, the use of straw bale is a relatively recent phenomenon, made possible by new technology. It began in the USA in rural Nebraska in the late 1880s when machines for baling hay and straw were invented.⁵ As Athena Steen has pointed out,

“It took only a slight stretch of the imagination for early homesteaders in the timber-poor region of the Great Plains of North America to think of using bales as oversized bricks” (1994, p.3).

In this thesis it is not intended to provide more of the global history of earth and straw bale than the brief overview above. The focus of the thesis is how the materials have been used in New Zealand. More substantial histories have been written for both materials. For instance, many books devoted to straw bale construction, such as Steen et al's *The Straw Bale House* quoted from above, and Catherine Wanek's *The New Straw Bale Home*, begin with a history of its use (2003). The same is true for earth construction; Rael's (2009) *Earth Architecture* and Paul McHenry's (1996) *The Adobe Story*, also begin with a history of the use of earth materials. There are also many other generously illustrated books that document examples of vernacular earth building

⁵ Hay is cut from grasses for use as a dry stock food. Straw is the dry stalks of grains such as wheat and barley and has no nutrient value.

traditions from all over the world, such as Jean Dethier's (1982) *Down to Earth* and Jean-Louis Bourgeois' (1996) *Spectacular Vernacular: The Adobe Tradition*.

2.2 EARTH AND STRAW – A NEW ZEALAND OUTLINE

Prior to European settlement, Māori used earth as a component of house construction. In *Māori Houses and Food Stores*, W. J. Phillips classified Māori houses under nine types, one of which is “2. *The house with earthed up walls.*” (Phillipps, 1952, p.15). Earth was also used to construct sophisticated fortifications, and for the floors of houses. The Māori lifestyle was mobile, centred around seasonal activities, and as Māori architect Rau Hoskins states:

“Māori have tended not to build long term, the materials and the cultural movements around seasonal food gathering has meant that you built for fifteen or so years and you would rebuild.” (2011).

For this reason the envelope of Maori houses were traditionally built using lightweight fibrous materials such as raupo, harakeke and mamaku⁷, but they did not use straw, which only became available when grain growing was introduced to New Zealand in the nineteenth century.

When European settlers arrived in the nineteenth century they brought their building traditions with them, including a number of earth building techniques. Pompallier House in Russell, one of the oldest surviving earth buildings in the country, was built in 1842 by missionaries from Lyon, a region of France which has a tradition of *pisé de terre* or rammed earth construction (Figure 2.1). Settlers from the United Kingdom brought the techniques of wattle and daub, adobe brick, and cob with them, and adapted the local soils and plant material to suit their new situation. A good example of this is the homestead at Esk Head Station in North Canterbury, which was built in 1863 using earth and red tussock from the site as cob for the walls, and the same tussock to thatch the roof (Figure 2.2).

⁷ Raupo is a bulrush, harakeke a flax and mamaku a tree fern, all indigenous to New Zealand.



Figure 2.1 Pompallier House, Russell, 1842

Photo: Jeremy Salmond



Figure 2.2 Esk Head Homestead, North Canterbury, 1864 and interior showing tussock thatch roofing

Photo: MH 2008

Although hay baling machines are known to have existed in New Zealand from as early as 1902 (Poverty Bay Herald, 1902), there are no known records of hay or straw bales

being used to construct houses at that time, as was the case in the USA. However, the idea of using bales to build animal shelters was recognised from early on as evidenced by an article *Walls of Straw* from the Southland Times in 1902:

“Where a baling machine is available excellent straw shelters can be made by baling the straw and building it up like a brick wall.” (Southland Times, 1902)

Earth, on the other hand, was a common building material in the early years of European settlement. Many of the buildings that have survived were built out of cob, but wattle and daub, and adobe bricks were also used. As sawn timber became more readily available, timber framed houses became the norm, and the use of earth steadily fell out of favour. By the time that WW2 broke out in 1939 it had all but disappeared.

Shortly after the war ended in 1945, in isolated pockets around New Zealand, a new interest emerged in using earth building techniques as an alternative to the now dominant timber framed construction. It was not a nostalgic return to a pioneer tradition that motivated the protagonists of this revival, but rather a combination of factors: exposure to earth buildings overseas, economic necessity, and advancements in the field of soil mechanics. For example, David Jones built a number of rammed earth buildings in and around Whanganui between 1948 and 1992. In his book, *Nga Whare Uku*, he wrote about being impressed with the earth buildings he lived in while stationed in Italy and the Middle East during WW2 (Jones, n.d.p.7).

Ironically, it was a group of pacifists who began the earth building renaissance in the Nelson area. In 1948 they began building in rammed earth at the fledgling Riverside Community at Lower Moutere, thirty kilometres west of Nelson City. It was for pragmatic reasons that they chose to build the first house on their land out of rammed earth (Figure 2.3): they had no money and plenty of clay. They went on to build four more houses over the ensuing ten years in a similar manner. These houses are the earliest in the body of houses being considered in this thesis and are discussed in more detail in later chapters.

An important figure in the return to rammed earth technology in New Zealand was engineer P.J. or Pip Alley. Alley was a lecturer at the University of Canterbury’s School

of Engineering, and designed a number of rammed earth houses in Christchurch during the 1950s and 1960s. Alley's university backed research in soil mechanics, which is discussed in 4.4 in relation to the Nelson houses, gave credibility to the system. This credibility may have helped the Anker brothers in their successful bid to construct six houses for the State Housing Corporation in Wainuiomata in the 1950s (Allen, 1997, p.25).



Figure 2.3 Rammed earth house at Riverside Community, 1948 Photo: MH 2010

The renewed interest in earth got off to a slow start. It was not until the 1970s, when the global counterculture movement reached New Zealand, that interest in alternative building methods gained a stronger foothold. At this point in history, there was a growing awareness of the impact that the prevailing high-tech solutions, requiring ever increasing amounts of fuel to first procure buildings and then operate them, was having on the earth's finite resources. Books from the USA such as *The Whole Earth Catalog* [sic], edited by Stewart Brand (1968) and Lloyd Kahn's (1973) *Shelter* series, together with *The First New Zealand Whole Earth Catalogue*, published by Alister Taylor (1972),⁸ promoted ideas about self-sufficiency and offered insights into simple, often indigenous, building systems, including the use of earth.

⁸ The Second and Third New Zealand Whole Earth Catalogues were published in 1975 and 1977 respectively.

In New Zealand the real renaissance in earth building began in 1971 with a rammed earth house near Whangarei, designed for the potter Yvonne Rust by architect Graeme North with assistance from Alley (Bridge and North, 2000, p97). North has gone on to become a leading authority on earth and straw bale construction in New Zealand. Another rammed earth house was built at Riverside Community in 1975 and a number of houses using pressed bricks were built in Northland, Canterbury and Marlborough during the 1970s and 1980s. Most of the pressed bricks were made using a Cinva Ram press which was invented in 1952 in Colombia for low cost housing initiatives in South America (Rael, 2009, p.157). Fraser Engineering, a Christchurch company, was making these under licence for the Australian market but a few were sold in New Zealand (Allen, 1997, p.26). At this time, the earth building movement in Australia was further advanced, and this had some implications for the way earth building methods developed in New Zealand. This is discussed in more detail in Chapter Four.

Nationally, interest grew in earth building during the last twenty years of the twentieth century. The Earth Building Association of New Zealand (EBANZ) was set up in 1988 to foster interest in earth building and co-ordinate information, education, resources and research. In 1990 the University of Auckland hosted a conference, *Earth Building for the 90s* (University of Auckland, 1990) where national and international speakers presented papers. Expertise was growing both at a hands-on level and professionally as more houses were built. Earth bricks were being manufactured commercially and during the 1990s a group of experts drafted what were to become the Earth Building Standards, published in 1998. The standards comprise three documents: *NZS 4297 Engineering Design of Earth Buildings*, *NZS 4298 Materials and Workmanship for Earth Buildings*, and *NZS 4299 Earth Buildings Not Requiring Specific Design* (SNZ, 1998a, SNZ, 1998b, SNZ, 1998c).

It was also during the 1990s that straw bale construction was introduced to New Zealand, following a resurgence of interest in the method in its country of origin, the USA. After its appearance in the late nineteenth century, the use of straw bale had begun to decline as USA developed and manufactured building materials became readily available. By the mid-twentieth century straw bale construction had virtually ceased, just as earth construction in New Zealand had been largely superseded by

timber framed construction. However, in the late 1970s, interest in straw bale construction was revived, motivated, Wanek suggests, by the counterculture movement and “...the potential for affordable, sustainable shelter” (Wanek, 2003, p1). By the 1990s, the use of straw bale had developed a strong following which spread globally. In 1993 Peter Kundycki, a landscape architect and urban designer,



Figure 2.4 New Zealand's First Straw Bale House, Marlborough, 1995

Photo: MH 2012

began building New Zealand's first straw bale house, a small holiday cottage in Marlborough, after seeing straw bale houses in the USA. The house was completed in 1995. An article written about the house while under construction, published in *New Zealand Home and Garden* in May 1995, sparked so much interest that the magazine followed up with another on the completed house a year later (Hutching, 1995, Stewart, 1996). In the sixteen years since that first house was built, many more have been constructed, 32 of them in Nelson, but in the absence of a national database it is impossible to say how many there are nationwide. Straw bales can be sourced from anywhere that grains are grown; in New Zealand the main area for grain growing is Canterbury where 90% of wheat and 68% of barley is grown (Zydenbos, 2007). Straw from both these grains, which are grown in smaller quantities in Southland, Otago, Manawatu and Wairarapa, are suitable for straw bale construction. However, not all of the straw is baled after the grain heads have been harvested; the rest is burned in the fields (Ibid).

Earth and straw bale houses have continued to be built across New Zealand into the twenty-first century. Whereas earth houses built prior to 1990 generally used raw material directly from their building sites, many of those built since have used material or manufactured earth products that have been transported from elsewhere. The same is true for straw bale houses where the bales have been transported for anywhere between a few kilometres to several hundred from the farms where they are produced. For both materials, methods have changed and are still changing, as a response to developing technology, performance in use, and changes to the New Zealand Building Code (NZBC). Many earth and straw bale houses, both old and new, are located in the Nelson area, making it a suitable region to use as a case study.

2.3 EARTH AND STRAW IN THE NELSON AREA BEFORE 1945

The early history of earth and straw bale housing in the Nelson area is similar to that of the rest of New Zealand. Before the arrival of the first European settlers, Nelson was occupied by Māori and while carbon dating records show occupation since the 1300s (Walrond, 2010), there is no record of them using earth for house construction. Straw as known today was not available before European settlement but other natural fibres were used, as has already been discussed in the national context.

Organised settlement by Europeans began in 1842. Some of the houses built by early settlers out of cob, dating back as early as the 1840s, still function as dwellings in the countryside as well as in Nelson city (Figure 2.5). These surviving cob houses are among the oldest houses in the region (regardless of the materials used to construct them) which is a testament to the durability of the material. However, as with the rest of New Zealand, earth moved from being a mainstream building material to being an outmoded one by the early twentieth century. Timber framed and clad houses became the norm and the increasingly 'old fashioned' earth building techniques became less common.

Allen recorded 21 earth houses built prior to 1948 in his 1990 survey (1990) and no more have been found for this time period as a result of this research. This suggests that no earth houses built between 1916 and 1948 are still in existence, and it is possible that none were ever built. If this is the case, thirty years is a long time for a



Figure 2.5 Cob house in central Nelson, 1853

Photo: MH 2010

building technique not to be used in a region, long enough for that tradition to be lost. When interest in building with earth was revived after WW2, as already discussed, it was not for using cob.

A detailed history of the period from 1945 to 2010 is provided in Chapter Four, based on information obtained while compiling and analysing the database and survey undertaken for this thesis.

2.4 THE NELSON AREA

Geographically, the Nelson area as defined in this thesis is located at the top of the South Island and includes Golden Bay, Tasman Bay, and the inland areas extending south to the Nelson Lakes (see Figures 1.1 and 3.1). The climate is mild in New Zealand terms. Across the area the average annual rainfall range is 750-2000mm, the average annual temperature range is 12-14 degrees Celsius, and the average annual sunshine hours are 2,200-2,400, some of the highest recorded in the country (NIWA, 2004).

In terms of governance, the area is covered by two Territorial Authorities (TAs): Nelson City Council (NCC) and Tasman District Council (TDC), with Nelson City and Richmond being the urban centres of each TA respectively. The total population stood at 87,500 in the 2006 census, with the numbers split fairly evenly between Nelson and Tasman.

This is just over 2% of the population for the whole country. 12% of Nelson's population identify as Māori (Statistics New Zealand, 2006a). These figures are the most current at the time of writing as the planned 2011 census was put on hold following the Canterbury earthquakes of 2010 and 2011.

Fishing, horticulture, forestry, agriculture and tourism are the predominant industries in the area, which is also well known for its thriving artistic community. The combination of a benign climate, ready access to national parks and beaches, a smaller population and the prevalence of creative people also make it an attractive destination for new immigrants, particularly from Europe and the USA. The same factors also provide an ideal and supportive environment for experimentation with alternative building techniques.

CHAPTER THREE: METHODOLOGY

3.1 INTRODUCTION

Information gathered for this research has been acquired in five main ways: an ongoing literature review, information obtained from TA records, information obtained from records kept by local building professionals and builders associated with earth and straw bale construction, a survey in the form of a written questionnaire of owners of earth and straw bale houses, and finally, interviews with eleven experts and house owners following completion of that survey.

A database of houses in the form of a spreadsheet was set up, and as information came in from existing records and the survey, it was entered for subsequent analysis. Information from the other sources was used to supplement and inform this analysis.

3.2 DATABASE

In order to gather information about the earth and straw bale houses of the Nelson area, it was first necessary to locate them and create a database in which data could be entered for analysis. Allen's 1990 survey provided a starting point (1990). Of the 57 buildings that he identified, 11 were houses built since 1945, which is the starting date for this research. In addition there were 19 already known to the author, including 9 which she had designed. This brought the total of relevant houses to 30.

Locating the other houses was more complex than first envisaged. Like 35% of TAs in New Zealand, NCC and TDC use software developed by Napier Computing Systems (NCS) for their administration systems, including the recording of Building Consent applications (NCS, 2004). Each TA has a Building Consent Enquiry system where the information supplied on Building Consent application forms is recorded. Unfortunately these records do not always include information about the method of construction or the materials used in a building because applicants are not specifically asked to supply this information on the forms. These are based on a template designed by the Department of Building and Housing (DBH) which satisfies the requirements of the Building Act 2004 (DBH, 2011f) and while individual TAs may add to them for the

purposes of gathering additional information this is rarely done. The only place in the form where an applicant can describe the construction system for their proposed house is where they are asked to describe the project:

From the TDC form, Part C 'The Project': *"Description of the building work: (provide sufficient description of building work to enable scope of work to be fully understood; continue on a separate page if necessary, or refer to an attached document setting out the description)." (TDC, 2011)*

From NCC form, 'The Project': *"Description of Building Work: (sufficient to enable scope of work to be fully understood)." (NCC, 2011a)*

The relevant pages of both forms are included in Appendix 7. The kind of description entered is typically very brief. It can be as short as *"erect dwelling"* or *"build new house,"* and very seldom does the description extend beyond the small amount of space offered on the forms to an extra page as suggested in the TDC form (Hall, 2010c). If the construction method and materials are described, then this information is transferred to the TA database and will show up when a Building Consent Enquiry is made.

This means that there is no simple way to locate all the houses built using earth and/or straw bale using the TA records. It would be necessary to go through all the building consent documentation, the drawings and specifications, for all the houses in the area in order to find out which incorporated earth or straw bale. This would be extremely time-consuming and expensive and therefore impractical.

An alternative approach was taken for this research which made use of the author's extensive personal contacts. All the architects, engineers, designers, builders and building inspectors known by the author to have been involved in earth and straw bale house construction were contacted, and asked to provide a list of all the houses built since 1945 of which they were aware. They were also asked to provide additional information for each of the houses under the following headings: location, owner, designer, engineer, builder, type of construction, and dates for consent, occupation and code compliance. A list of the informants is provided in Appendix 4.

Most people were extremely co-operative and eager to assist in the research. They provided lists with as much information as they could. Engineer Richard Walker was particularly helpful as he had carried out the structural design of many earth houses built since 1990 and had kept good records of these.

As the data for each house came in, it was entered into an Excel worksheet. Each house was assigned a three digit number, starting with 001, followed by a single letter suffix, either E for earth or S for straw bale, depending on the predominant building material. Information was entered under the headings listed above. Where information was missing, such as consent dates or names of current owners, enquiries were made through the TAs or by contacting the original owners to update the database.

There are 144 houses on the database which has a cut-off date at 31 December 2010. While there is a possibility that there are still some houses that have not been located in the region, the author's view is that, bearing in mind the methodology employed to collect the data, the 144 houses identified represent the total population of houses for the time period, or very close to that total. A discussion of each heading in the database follows and a sample page can be found in Appendix 6.

3.3 LOCATION

The Nelson/Tasman region comprises a number of sub-regions with no official boundaries other than those separating the two TA areas of governance. Eight sub-regions were identified for recording purposes, with boundaries as indicated in Figure 3.1.

3.4 OWNER, DESIGNER, ENGINEER, BUILDER

The names of both the current owner and the original owner were recorded. In many cases particular houses are commonly known within the earth and straw bale building fraternity by the name of the original owner or occupier. The houses at Riverside Community, for instance, are still referred to by the names of the original occupants, despite having had a number of subsequent occupants over their sixty years of

existence. The first house built in 1948, for example, is still called ‘Barringtons’ after the original inhabitants, although no one by that name still lives there. The names of the designer, the engineer, and the builder of each house were recorded where known, and this information enabled further inquiries to be made regarding particular houses.

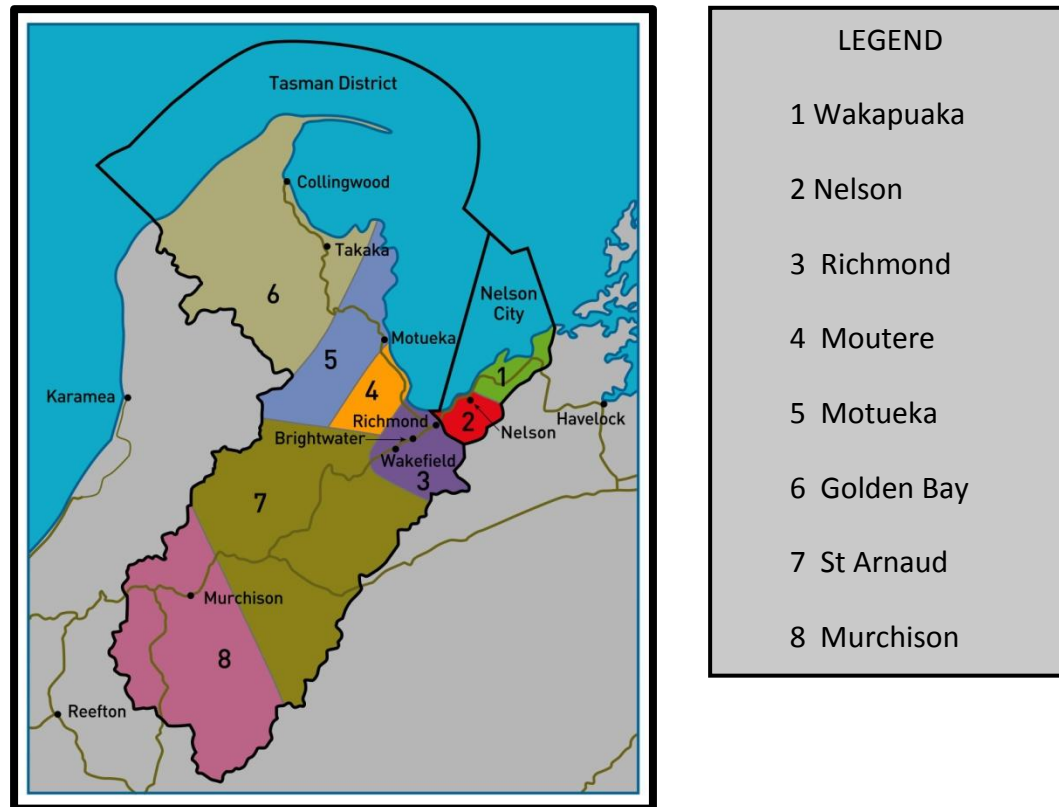


Figure 3.1 Sub-regions of Nelson

Source: Adapted from TDC Management Plan Map

3.5 TYPE OF CONSTRUCTION

The type of construction was recorded for each house, with three tiers of information. The first and most basic tier is simply the letters E or S standing for ‘Earth’ and ‘Straw bale’ respectively, which are the suffixes of the house record number. The second tier information was recorded under nine categories: Adobe, Adobe Interior Veneer, Cob, Light Earth, Rammed Earth, Soil Cement Bricks, Straw Bale, Straw/ Concrete, and Straw Bale/Earth. The category ‘Soil Cement Bricks’ includes both pressed soil cement and poured soil cement bricks. These second tier headings are used in the analysis for this thesis. In order to simplify some discussions (3.11 for example), the nine categories

have been reorganised under three headings: Earth, Straw Bale and Straw Bale/Earth. The third tier is more complex, and identifies specifics such as whether the adobe bricks used in a house were manufactured on or off site, information that may be useful for further research.

3.6 DATES

The aim was to record three dates: the date building consent was issued, the date a certificate of code compliance was issued,⁹ and the date the house was occupied. This was only possible in a few cases. The only date that was consistently available was that of the granting of building consent. Some of the houses do not have a final code compliance certificate, despite having been occupied for a number of years. This is not a situation peculiar to earth and straw bale houses: many people in New Zealand do not bother to obtain code compliance until they are trying to sell their house. The date of occupation was also difficult to clarify in some cases, where current owners either did not know, or could not remember, the specific date. All the houses recorded in the database were both consented and occupied by 31 December 2010.

3.7 SURVEY

Initially, the intention had been to select a small number of houses from the database for in-depth research into a specific aspect, such as owner-building, thermal performance, cost, or ease of obtaining building consent. However, as the database grew, it became clear that a sufficient number of houses had been identified to enable a broader study of all these aspects. It was decided, therefore, to conduct a survey of as many of the house owners as could be contacted using publicly available information and personal inquiry by the author, with the aim of completing the information in the database and obtaining additional information about:

- the demographic of the owners of earth and straw bale houses
- details of the houses' location, servicing, materials, and occupancy

⁹ A Certificate of Code Compliance certifies that the building has been built in accordance with the Building Consent documents and complies with that consent.

- the reasons for buying or building out of earth and/or straw bale
- how easy it was to gain information, finance and consent when using earth or straw bale
- the degree of owner involvement in physically constructing the house
- the performance of the finished house.

The survey was conducted using a written questionnaire. This method was chosen as the most effective means of collecting information from the number of house owners involved, within the time frame of this research. It also had the dual advantages of allowing the respondents sufficient time to think about the questions before answering them, and making it easier to process the information when the questionnaires were completed.

3.8 QUESTIONNAIRE

The questionnaire was designed to provide information in the six areas listed in 3.7 above and was organised into six corresponding sections:

1. Background – Personal
2. Background – House
3. Reasons for building/buying an earth or straw bale house
4. Pre Construction
5. Construction
6. Performance

A copy of the questionnaire can be found in Appendix 2. The questions were designed to be clear for the respondents and also to facilitate straightforward processing of the accumulated data. It is acknowledged that the questionnaire focussed on particular aspects and not on others. For instance, questions about the size of houses, their running costs and where building materials came from were specifically not asked. This information would be useful and necessary if a life cycle analysis were to be undertaken, or if a comparison with conventional housing models was to be made. Instead, the intent of the questions was to acquire information that would help provide an overview of the total body of earth and straw bale houses in the region.

The questions in sections 1, 2 and 5 were designed to gather factual information about the respondents and their houses, and either provided a selection of possible answers with boxes to tick, or required short answers in the spaces provided. Many of the questions in sections 3, 4 and 6 required the participants to make judgement calls and were set up using a likert scale. For instance, in question 3.03 they were asked to rate a series of factors in terms of their importance from one to five, with one being 'not important' to five being 'very important'. In these cases they were asked to circle the appropriate number. The aim of these questions was to find out how important the individual factors were when considered in isolation. Other questions, 3.04 for instance, were designed to find out how important a number of factors were in relation to each other. In these cases respondents were asked to rank those factors in order of importance.

Respondents were asked to provide additional information in a number of places. For instance, in sections 5 and 6 they were asked to elaborate on their previous building experience, additional reasons for choosing to build in this manner, how they felt their house performed and if they were to build again what construction method would they use and why.

3.9 SENDING OUT THE QUESTIONNAIRE

It was decided that the most effective approach was to make personal contact with house owners prior to sending out the questionnaire. Some investigation was necessary to find contact details but ultimately the author was able to communicate by phone or email with all but four of the 144 house owners.

Most people were very interested in the research project and willing to participate. Only two were reluctant but still agreed to receive the questionnaire. Many were keen to talk about their houses and provided valuable anecdotal information during these telephone conversations. Some people mentioned houses that were not in the database and these were added and included in the survey.

Once verbal agreement was given to participate in the survey, the questionnaire, information letter and Human Ethics Committee (HEC) consent form were posted out.

The primary mail-outs occurred during September and October 2010 and additional questionnaires were sent out as information about further houses came to hand. The final questionnaire was sent in March 2011. Completed questionnaires and consent forms were received from late September 2010 to April 2011. Of the 140 questionnaires that were posted out, 116 (83%) were returned with consent forms and these form the basis of this research.

3.10 RECORDING DATA

Prior to the entry of data from the 116 questionnaires, the overall database contained the basic information about the total house population as described in paragraphs 3.2 to 3.6. All questionnaires were read through before processing. This was useful as it highlighted issues with the way some questions were answered and influenced the way the new worksheet to record the survey results was set up. For instance, a number of respondents did not answer question 3.04 as intended (refer Appendix 5), and so a separate column to identify these respondents was provided. This survey worksheet was set up in a manner that would facilitate setting up pivot tables and charts for analysis. The text answers and comments were also entered into the survey worksheet so that all the information from the survey was recorded in one place in digital format. Once all the data from the questionnaires had been entered, information from the overall database of 144 houses pertaining to the 116 survey respondents was added. This stage of the project was carried out during March and April 2011.

3.11 TWO SETS OF DATA

Both sets of information, the overall database for 144 houses and the smaller but more detailed survey worksheets for the 116 houses in the survey, were used for analysis. The overall database forms the basis of discussions in Chapter Four regarding timeline, material type and location. The data from the survey worksheets informs the more detailed analysis of the surveyed houses, their owners, and their performance in Chapters Five and Six.

The two data sets have been used because if the survey results alone were used with regard to timeline and material type, the overall picture of what has actually happened would not be truly represented. Figures 3.2 and 3.3 illustrate the differing results

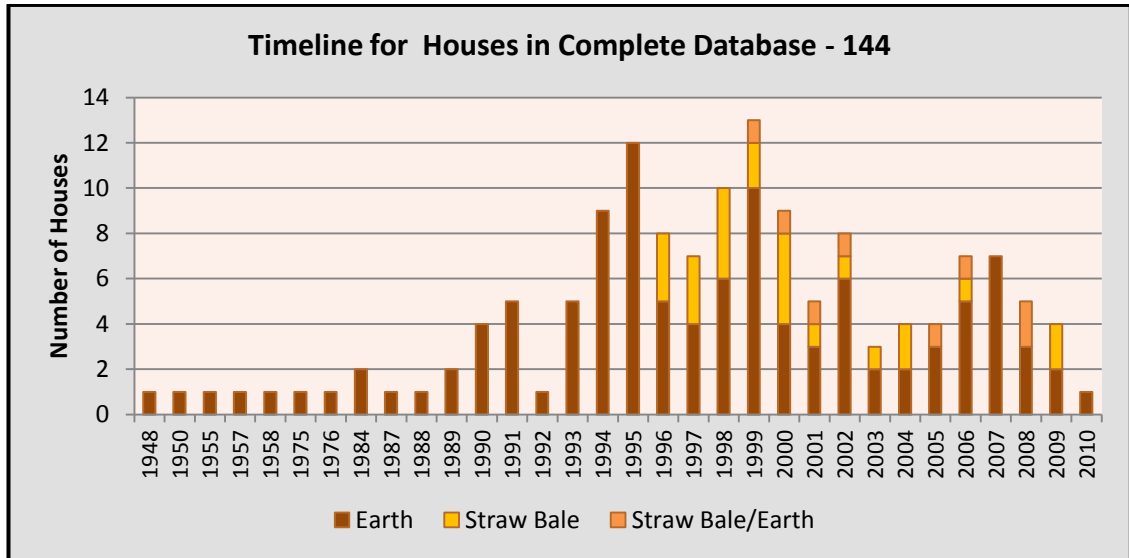


Figure 3.2 Timeline and Material of Houses in Database

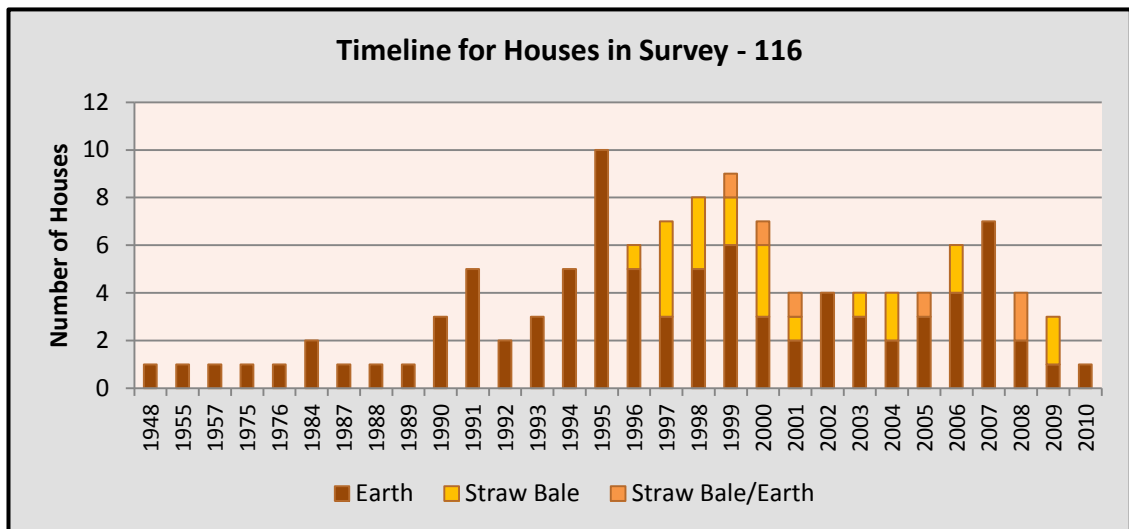


Figure 3.3 Timeline and Material of Houses in Survey

Note: The x axes in Figs.3.2 and 3.3 are non linear: prior to 1987, only the years in which houses were built are shown. From 1987 houses were built every year. (See Figure 4.2 for further analysis)

between the two sets of information. Figure 3.2 shows the timeline and material type for the complete database and Figure 3.3 shows the same for the surveyed houses only. For the complete database the peak year for earth and straw bale houses is 1999

while for the survey population only, it is 1995. This database information, together with the general location of houses, by sub-region (Figure 3.1), is in the public realm and therefore able to be used without HEC consent.

3.12 PREPARATION FOR ANALYSIS

In order to facilitate analysis, tables were set up in the survey worksheet recording the frequencies of the results for each question. These were then used to record the results in the form of charts and tables contained in the summary in Appendix 3. They were also used to cross-tabulate the data by creating the pivot tables used for reporting and analysis in Chapters Four, Five and Six. This process took place between April and December 2011.

3.13 INTERVIEWS

In preparation for the follow-up interviews a simple preliminary analysis of the survey data was made using filters in the worksheet. This, together with information gleaned via the literature review, the conversations with house owners, and the written notes contained in the questionnaires, helped identify what further information was required to assist with the analysis. A list of questions to guide the interviews was developed and this helped inform the choice of candidates. Both the questions and the interviewees are listed in Appendix 4.

The questions were designed to elicit opinions about the performance of the materials, solutions to known problems, changes in house design and materials, and the potential that both earth and straw bale have for community-based housing projects. Interviewees were also invited to bring up any other issues that were not covered in the questions.

Six of the twelve people interviewed had already taken part in the survey and all were owner-builders. Two of these six are also architects (Peter Olorenshaw and Stephan Meijer); one is a builder (Kenny McLennan); one is an engineer (Richard Walker); and one operates an earth brick and plastering business (Verena Maeder). The sixth survey

respondent to be interviewed, Hamish Rush, owns one of the six light earth houses in the region

The remaining five interviewees had not taken part in the survey. Two were from the Nelson region: Mark Fielding is an architectural designer who has designed a number of houses in the survey and Nancy-Jean Bell is an owner-builder whose house was completed after the cut-off date. This house is one of the first in the region to use a new lightweight adobe brick, an important development which is discussed in Chapter Six (6.10).

The other three interview subjects were from outside Nelson and were asked to participate because of their areas of specific knowledge. Architect Graeme North, from Warkworth, north of Auckland, is recognised nationally and internationally as a leading authority on earth and straw bale building in New Zealand. Sarah Johnston has experience as a designer and builder of straw bale houses in New Zealand and the USA. She and her husband Sven are partners in Sol Design which runs hands-on workshops in Geraldine, South Canterbury. Auckland based architect Rau Hoskins has been involved in many Papakāinga¹⁰ projects and was asked questions specifically related to the potential that earth and straw bale might have for rural community housing projects.

The Nelson interviews were carried out in April 2011 and the rest between April and July 2011. The interviews ranged from thirty minutes to one hour long and were recorded and later transcribed. Transcripts were sent to the participants for approval, which they all provided, and these were then used in the analysis and discussions that follow.

3.14 INFORMAL DISCUSSIONS

As well as the formal interviews, there were instances where phone calls and opportune discussions took place in the course of conducting the research that provided valuable information. For instance, while searching the databases and

¹⁰ The Māori term papakāinga relates to a village or settlement and includes its relationship to the land, the ancestors and the activities that occur within that settlement.

building consent records at the TDC and NCC offices, a number of council officers offered insights into the TA processes and their experiences with earth and straw bale building projects. Where this information is reported in the thesis it is referenced as personal communication.

CHAPTER FOUR: EARTH AND STRAW BALE HOUSES, NELSON AREA, 1945-2010

4.1 INTRODUCTION

In this chapter the full database of 144 houses is used to record the location of the existing earth and straw bale house population within the wider Nelson area, and provide a general history of their development since 1945, and their place within the area's total housing stock. Much of the history is previously unrecorded: up until now, it has been held in the memories of those who have been part of it. The history is divided into three periods: The Early Years 1945-1989, The Golden Decade 1990-99, and The New Millennium 2000-2010. The database also reveals trends for the first decade of the twenty-first century which are discussed briefly in this chapter and in more depth in Chapter Six.

4.2 LOCATION

As described in Chapter Three, the surveyed area has been broken down into eight sub-regions. Two of these, Wakapuaka and Nelson, come under the jurisdiction of the NCC and the remaining six under the geographically larger area covered by the TDC. Figure 4.1 shows the numbers of houses in each sub-region with the largest number of houses located in the Moutere sub-region, where the renaissance in earth building began in 1948.

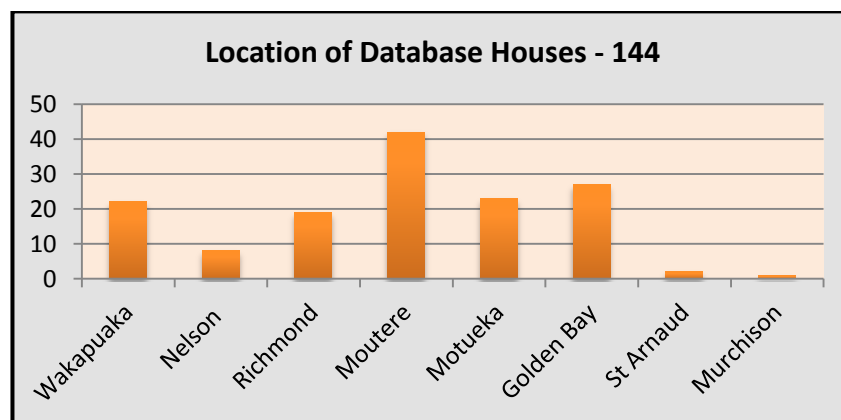


Figure 4.1 Location of houses in Database

4.3 TIMELINE: 1945-2010

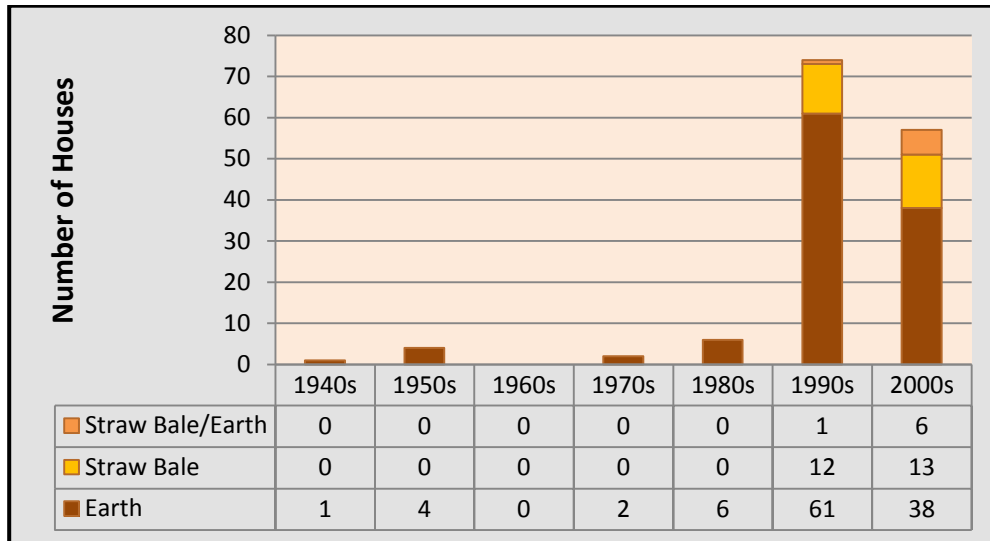


Figure 4.2 Number of Earth and Straw Bale Houses by Decade – 144 houses

Figure 4.2 shows a bar chart for the numbers of houses built using earth, straw bale and hybrids of the two systems, in decades. The final ‘decade’ is in fact eleven years as it includes the year 2010, the cut-off date for this research. The chart clearly illustrates the slow birth of the renaissance in earth building and the subsequent surge in construction in the 1990s. The 1990s is also the decade in which straw bale was introduced to the region. During the following decade the total numbers for earth and straw bale houses fell by 23%. However, at least five houses that were granted building consent between 2008 and 2010 were still under construction at 31 December 2010, and therefore are not included in the database (see 3.6). If five houses are added to the database to adjust for this, the fall in numbers is reduced to 16%. The significance of this decline is discussed in 4.6. When the information is separated into the nine second tier categories in Figure 4.3, more conclusions can be drawn about the development and popularity of the different systems over time.

4.4 TIMELINE AND MATERIALS: THE EARLY YEARS, 1945 -1989

The first house to be built at Riverside Community in 1948 (Figure 2.3) is also the first house in this record of earth and straw bale houses built since 1945. This house, and the four that followed during the 1950s, were built by Riverside community members out of rammed earth, which was a relatively modern technique compared to the cob

tradition of the early New Zealand settlers. Just where the Riverside builders found out about rammed earth is unclear, but there are a number of possibilities.

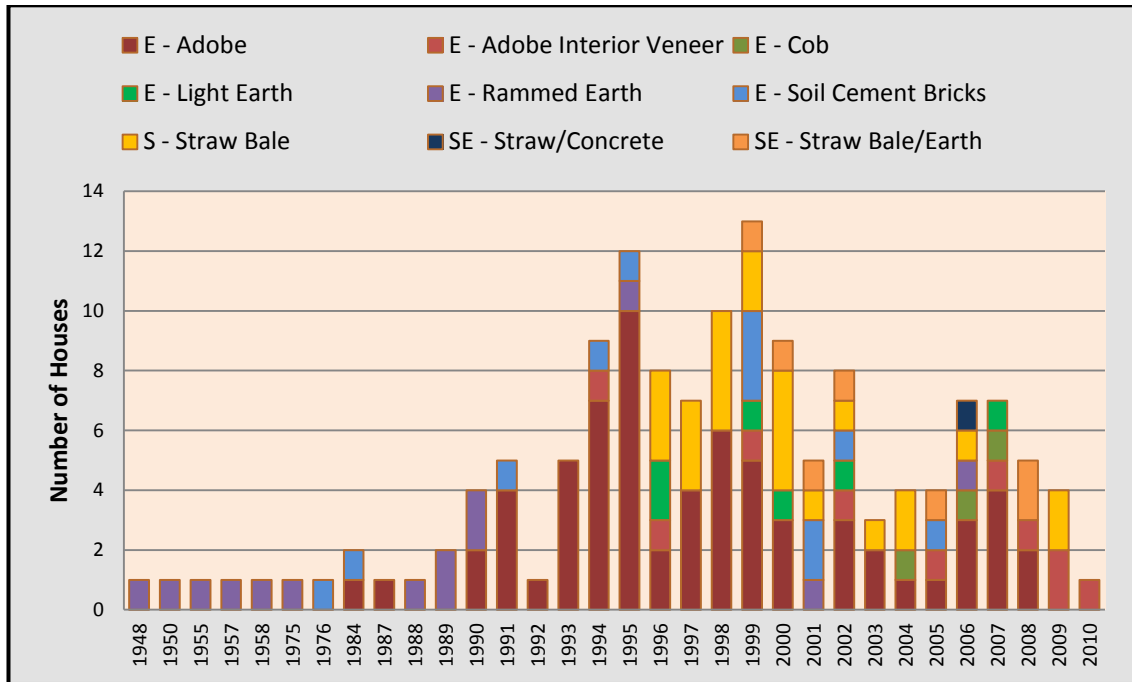


Figure 4.3 Types of Earth and Straw Bale Construction 1948-2010 – 144 Houses

Note: The x axis is non linear - prior to 1987, only the years in which houses were built are shown. From 1987 there are entries for every year.

In *Community: The Story of Riverside 1941-1991*, written on the occasion of Riverside's fiftieth birthday, Lynn Rain refers to an unnamed "*Australian book*" that the members used for guidance (1991, p30). This may have been the New South Wales Government publication, *Build Your House of Earth* (Middleton, 1953). Its author, architect and engineer George Middleton, carried out research into earth wall construction at the Australian Commonwealth Experimental Building Station in New South Wales at the same time as P.J. Alley was doing similar work in New Zealand (Allen, 1997, p.25). For many years Middleton's book, updated in 1976, was the essential Australasian guidebook for those interested in building with earth.

It is also possible that members of the community, many of whom were well read, had seen the article *Buildings from the Earth* by J.R. Marks, which was published in a 1946 edition of the *New Zealand Journal of Agriculture*, two years before their first house was built (1946). Marks concluded his article by referring to the possibilities that the "new science" of soil mechanics, generally associated with road building, could have

for building houses out of earth. Alley's contribution to this new science has been discussed in Chapter Two and it is likely that he had some influence, directly or indirectly, on the building work that was taking place at Riverside.

In his 1990 survey, Miles Allen included the following note in the entry for a house built at Riverside in 1958:

"This house like most of the others was built under the guidance of P.J. (Pip) Alley, Senior Lecturer in engineering at Canterbury University." (1990, NT44)

While it is probable that Alley did visit the community, it is not necessarily the case that he provided direct guidance. The first house was built by foundation member Norm Cole and his brother Jack. As Rain says, *"Jack and Norm learnt as they went along"* (1991, p.31). Norm Cole has no recollection of Alley's direct involvement (Hall, 2010a). However, it is possible that following the construction of the first house in 1948, community members may have read Alley's publications about soil cement: *Soil Cement as a Building Material* (1950) and *Soil Cement House Construction* (1952) before building their subsequent houses between 1950 and 1958. This may have informed their decision to include cement in the mixes as a means of overcoming the problems with cracking that they experienced on their first attempt. Alley's testing of soils from the Moutere region, found them to be *"unsatisfactory"* for building with (1952, p.85), a fact that had not escaped the notice of the Riverside builders as noted by Rain:

"Under the clay soil was a shattered sandstone layer which proved suitable for the rammed earth process. Pure clay was not so good, tending to crack as it dried." (1991, p.31)

This way of learning *"as they went along,"* and not being reliant on expertise, set a tone for building with alternative materials that was to persist into the following decades.

Despite the activity at Riverside, the renewed interest in earth got off to a slow start: there are no records of earth houses built during the 1960s, although during that time Riverside Community built a substantial church and various farm buildings also out of rammed earth. It was not until the 1970s that interest in alternative building methods



Figure 4.4 Riverside Community, the Earth House, 1975 Photo: MH 2010

became more widespread. By this time Riverside was 30 years old and it was the second generation, the children of those earth building pioneers, who were inspired both by the books that were beginning to appear (see 2.2) and by a desire to preserve the skills acquired by their parents, to build another earth house in 1975, (Hall, 2010a). Unlike their parents, who had worked in isolation, this new generation had the moral support of others around them with similar values and interests. One of these was Phillip Woollaston, later to become Minister of Conservation in the Fourth Labour Government in 1989, who built a pressed brick house in Golden Bay in 1976. As a student, Woollaston had worked for Fraser Engineering in Christchurch, who were producing Cinva Ram presses (see 2.2), and this experience led him to first make his own brick-making machine and then build his own house (Woollaston, 2011).

A further six houses were built during the 1980s: two in adobe brick, three in rammed earth and one using pressed soil cement bricks made in a Cinva Ram press. By the end of the decade there were thirteen houses altogether, including nine out of rammed earth, all built by their owners.

It is not difficult to understand why many of these early builders favoured rammed earth. It is a process that involves less handling than brick construction, which requires multiple handling, first to manufacture the bricks and then to construct the walls. With rammed earth, manufacturing the wall material and building the wall are one and the

same process. It does however require more technical skill and this is discussed in 6.13. All these early rammed earth houses are located in the Moutere district with its less than ideal soil, but by adding other materials to the mix, or digging deeper (as was the case at Riverside), the owner-builders were able to modify the soil to suit the process.

The second generation builders are clearer about their sources of information. They had access to literature and the opportunity for hands-on experience (Hall, 2010a). One of the owners described how he had seen the method used in Bendigo, Australia and then used a plywood boxing system that he adapted from one described in an American book, *The Rammed Earth Experience* (Easton, 1981), for his projects (Hall, 2011c).

In 1984 Brian Woodward, who was influential in the continuing development of earth construction in both Australia and New Zealand, ran a hands-on workshop on adobe brick construction in Nelson. Woodward was part of the Earth Construction Research Unit at the University of New South Wales (UNSW) and produced a booklet, *Mud-brick Notes* (Woodward, 1981), around this time, later co-authoring, *Earth-Construction: An Advisory Document*, which documented the development of Middleton's earlier work at the UNSW (1979). The Nelson workshop set the scene for the dissemination of earth building knowledge in the region.

Two adobe brick houses were constructed in the 1980s, both by people who had attended Woodward's workshop. One couple, engineer Richard Walker and his wife Bella, began experimenting with adobe and running workshops on their property near Nelson as they built their own house and outbuildings, Figure 4.5. Walker recognised the suitability of the Moutere clay for adobe bricks, and together with fellow engineer Gary Hodder, developed a structural system which made building loadbearing walls out of adobe bricks in an earthquake environment possible, thereby paving the way for a new wave of earth construction in the Nelson area. Many who attended the Walker workshops in the 1980s went on to build their own adobe brick houses in the following decade.



Figure 4.5 Adobe brick workshop, Walker House, Nelson 1987

Photos: MH 1987

4.5 TIMELINE AND MATERIALS: THE GOLDEN DECADE, 1990-1999

The 1990s was the decade in which earth building gained a real foothold, not only in the Nelson area but also nationwide. Nelson experts, including Walker and Hodder, were instrumental in the development of earth building techniques locally and nationally during this period, by actively participating in research and education. At the 1990 international conference *Earth Building for the 90s*, in Auckland, both Walker and Hodder presented papers as did Ralph Butcher, who was in the process of setting up a commercial adobe brick yard at Appleby, just south of Nelson City (Butcher, 1990). Hodder wrote articles on building with earth that appeared in *Soil and Health* (1992), a magazine likely to have been read by people attracted to building with earth (see 5.14). The Walkers continued to run hands-on workshops and Richard Walker was one of three Nelsonians on the Standards Association of New Zealand (SNZ) committee that drafted the 1998 Earth Building Standards, the others being builder Bob Gilkison and the author (SNZ, 1998).

Butcher's adobe brick making enterprise began operation in 1991 and this meant that those put off by the daunting prospect of first having to make all the bricks for their house before they could start building, could now order them directly from Butcher's yard. The impact this had on the numbers of houses built in this decade is clearly shown in the database. For example, in 1995 earth building reached its peak, with ten



Figure 4.6 Adobe House using Ralph Butcher's bricks, Wakapuaka, 1991

Photo: MH 2000

houses being constructed: see Figure 4.3. Of these ten houses, eight were built with adobe bricks manufactured by Butcher.

In 1995 another small commercial operation began, when Amanda and Grant Devlin set up a design, manufacture and build business using soil cement blocks. These blocks were substantially larger and heavier than the adobe bricks and were not so suitable for owner-builders. They have been used for six houses in the region, four of them built in the 1990s (see Figure 4.7), and a number in other parts of New Zealand.



Figure 4.7 Soil cement brick house, Motueka, 1996 **Photo: MH 2011.**

The significant increase in the numbers of houses being built during the 1990s is also a reflection of a growing skill base, in terms of both construction and design expertise. Some owner-builders went on to assist in constructing houses for others and some held workshops during the construction of their own houses. The structural systems and construction detailing for earth building that were pioneered during the 1980s and developed through the 1990s formed the basis of the Earth Building Standards which came into force in 1998 (1998a, 1998b, 1998c). These systems were already in common use in the Nelson area, which explains why there is no marked rise in earth construction post 1998 when they came into force, see Figure 4.3. More importantly, the existence of the standards gave credibility to earth building and provided TA officials with a means of assessing building consent applications.

The 1990s was also the time that straw bale construction was introduced to New Zealand. In 1996 the first straw bale houses were constructed in the area. Peter Kundycki who had built the first straw bale house in New Zealand the previous year (Figure 2.4), acted as a consultant to the owners or designers for many of the early straw bale buildings in the Nelson area via his company Coyote Design. From 1996 on,



Figure 4.8 Straw bale house Golden Bay, 1997 Photo: MH 2010

straw bale houses made a significant contribution to the numbers of houses built using natural materials each year. People, the author included, were attracted to the idea that straw bales were a by-product of grain production, that they had very good insulative properties, and that the method seemed quicker than constructing out of

earth. All but one of the thirteen straw bale houses built in the 1990s were constructed using a post and beam system with bale infill walls. This means that the roof can be constructed before the walls and provide protection for the moisture sensitive straw bales as they are laid up.

Prior to the new millennium there was no official recognition of straw bale as a valid construction system, but the regulatory environment was generally less stringent then and, in the author's experience, it was easier to gain consent for alternative methods than it is now (see 6.5). Those house owners who engaged Coyote Design used Coyote's specification for the straw bale component of their building consent applications, and those who did not, used information gleaned from books such as *The Straw Bale House* (Steen et al., 1994) and *Buildings of Earth and Straw* (King, 1996) to support their applications.



Figure 4.9 Light Earth House, Motueka, 1996 Photo: MH 2010

Straw bale construction was not the only new method to appear in the 1990s. Light earth and adobe used as internal veneer were also introduced. This growth in diversity of alternative methods may be explained in part by the changes in information technology and use of the internet that occurred in this decade. The internet revolution meant that people no longer had to keep a watchful eye out for new publications in book shops and libraries; instead they could 'surf' the internet and have access to information from a much wider range of sources. Natural building systems

were being explored and developed in the United States and Europe, and information about these was readily available via the internet, as well as from books and magazines like *The Last Straw*, which has been produced quarterly since 1993 (The Last Straw, 1993).

The diversity of methods used also reflects the growing skill base and associated deeper understanding of both the materials and the practicalities of the different construction systems. For example, adobe was used as internal veneer in three conventional timber framed houses to provide thermal mass, see Figure 4.10. In 1999 the first of a number of houses utilising straw bale for exterior walls and adobe brick for the internal ones was built. This solution meant that the excellent insulation properties of straw bale and the thermal mass capabilities of adobe were used to advantage.



Figure 4.10 Adobe brick used as interior veneer, Moutere, 1993

Photo: Derek Smith

In all, 74 houses are recorded in the database for the 1990s. This is half of the total population for the period 1945-2010, and makes the 1990s a golden decade for earth and straw bale building. It was not just that the total stock grew, it also became more diverse. The decade began with only three different systems being used, all of them earth; by the end of it there were seven, including straw bale. Unlike the houses built before 1990, not all of those built in this golden decade were built by the owners. The

incidence of owner-builders was, however, still high at 75% of the total, and is discussed in more detail in 5.9.

4.6 TIMELINE AND MATERIALS: THE NEW MILLENNIUM, 2000-2010

The number of houses built in the first 11 years of the twenty-first century was significantly less than in the preceding decade, 57 houses compared with 74. As illustrated in the pie charts in Figure 4.11, it is not only the total number that is different, but also the way that number breaks down into the different construction types. 62% of houses built in the 1990s were adobe brick. The corresponding percentage for the 2000s is nearly half that, 33%. The combined percentage of straw bale and straw bale/earth hybrids increased from 18% to 32%, and adobe interior veneer increased from 4% to 12%. Three cob houses were built, in contrast none were built in the 1990s, and a further three light earth houses were built, the same number as in the preceding decade. There was one experimental house where straw was sandwiched between two concrete panels in much the same way as polystyrene sheets are used in conjunction with concrete, to form precast insulated wall systems. Taking all these into account, by the end of 2010 there were nine methods of construction being used.

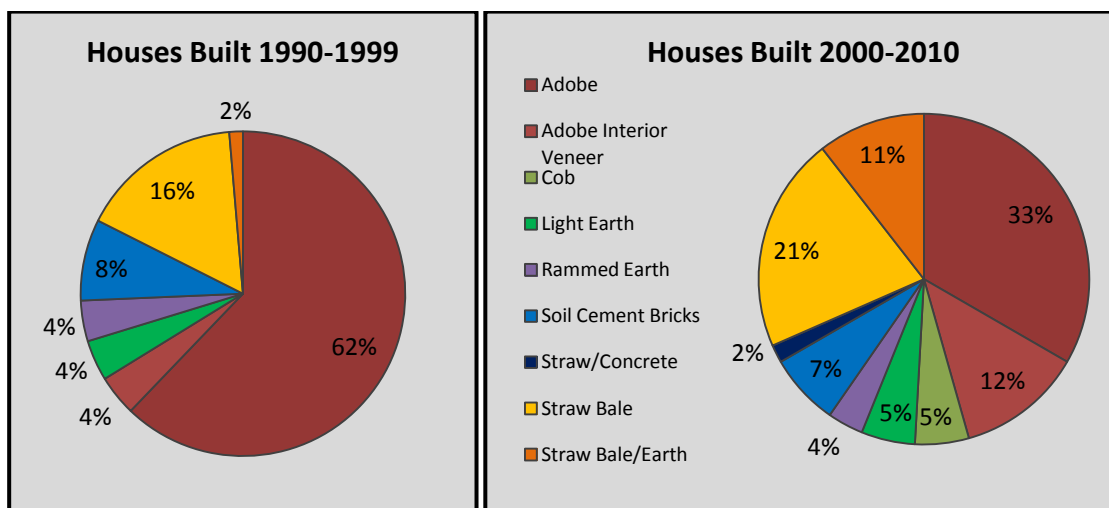


Figure 4.11 Make-up of houses built in 1990s and 2000s

It is difficult to say whether the drop in overall numbers heralds a general decline in the popularity of alternative building methods. During this period the building industry as a whole has undergone a major overhaul in the way that buildings are procured,

spurred on by both the ‘leaky buildings’ crisis and a push towards making more sustainable buildings by increasing the insulation requirements. The former has implications for straw bale and light earth construction and the latter for most types of earth building. Both issues are discussed in Chapter Six. The effect of the Global Financial Crisis (GFC) is also a possible contributing factor to the decline in numbers.

Adobe bricks have been commercially available in Nelson almost continuously since 1991. Butcher’s yard closed in 1996 and shortly after a new commercial yard was set up near Wakapuaka, east of Nelson City. This yard has changed hands twice and is currently owned by Verena Maeder, chairperson of EBANZ, trading under the name Solid Earth: Adobe Buildings Limited. Of the 26 houses built this century that incorporate adobe bricks, either as the complete structure or for internal veneer, there is only one that did not use commercially made bricks. By the end of 2010, Solid Earth Ltd was manufacturing two types of brick as well as providing earth plastering and earth wall building services. These developments and the reasons for them are discussed in Chapter Six (6.8 and 6.10).



Figure 4.12 Solid Earth brick yard, Nelson Photos: Verena Maeder 2009

A further 19 straw bale or straw bale/earth hybrid houses were built in this period, bringing the total in the region to 32. Unlike earth construction, there is still no official standard for straw bale construction in New Zealand although there has now been some recognition of it as a valid method of construction. In 2000 the Building Research Association of New Zealand (BRANZ) produced a bulletin, *Straw Bale Construction*,

which has been recently updated (2010). This provided an introduction to the system, discussed its advantages and disadvantages, and provided references for further information. Another source of information was the EBANZ website (2011). The last straw bale house in the database was consented in 2009. Anecdotal evidence suggests that since then it has become more difficult to obtain building consent for straw bale houses (see 6.5 and 6.15).

There are a number of companies specialising in the design and building of straw bale houses nationally - for example, Sol Design in Geraldine, Strawmark in Wanaka, and Straw Built Homes in Opotiki - but in Nelson there are none that have been able to survive solely by designing and/or building in straw bale.

Although fewer houses were built in the period 2000-2010 than in the previous decade, the numbers were well up on the four that preceded that. The make-up of the house population by construction type has become more diverse and the technologies used have evolved in response to practical, performance and legal issues. These are the subject of in-depth discussion in Chapter Six.

4.7 ALTERNATIVE CONSTRUCTION IN TERMS OF MAINSTREAM TRENDS

In the context of the housing stock in general, houses built using earth and straw bale form a very small part of the whole. This can be illustrated by a comparison between the figures provided by Statistics New Zealand for the total number of dwelling consents issued for the study region from 1991 to 2010 (Statistics New Zealand, 2011), and the consents issued for the same period for earth and straw bale dwellings only, as recorded in the database prepared for this research: see Figures 4.13 and 4.14 respectively. The Statistics New Zealand data is recorded separately for the Nelson and Tasman regions and has been combined to create the graph in Figure 4.13.

The two sets of figures have been compiled from slightly different criteria. The Statistics New Zealand figures include new dwellings, garages and outbuildings, and alterations, which have been granted consent, whether or not the work has actually been carried out. The database figures include consents for new dwellings and substantial alterations, but only where the work has actually been completed.

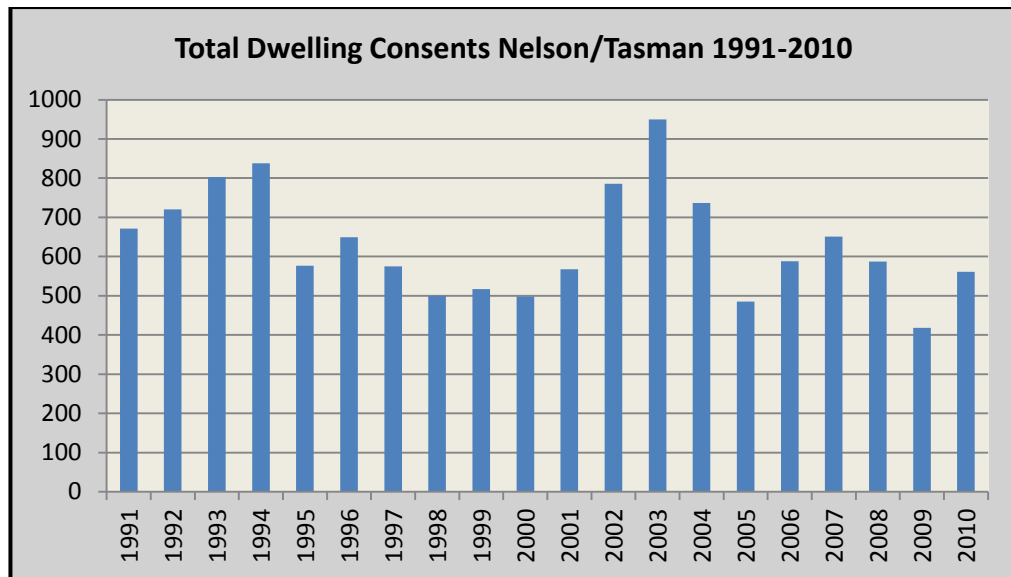


Figure 4.13 Building Consents for New Dwellings, Nelson and Tasman 1991-2010

Source: Statistics New Zealand

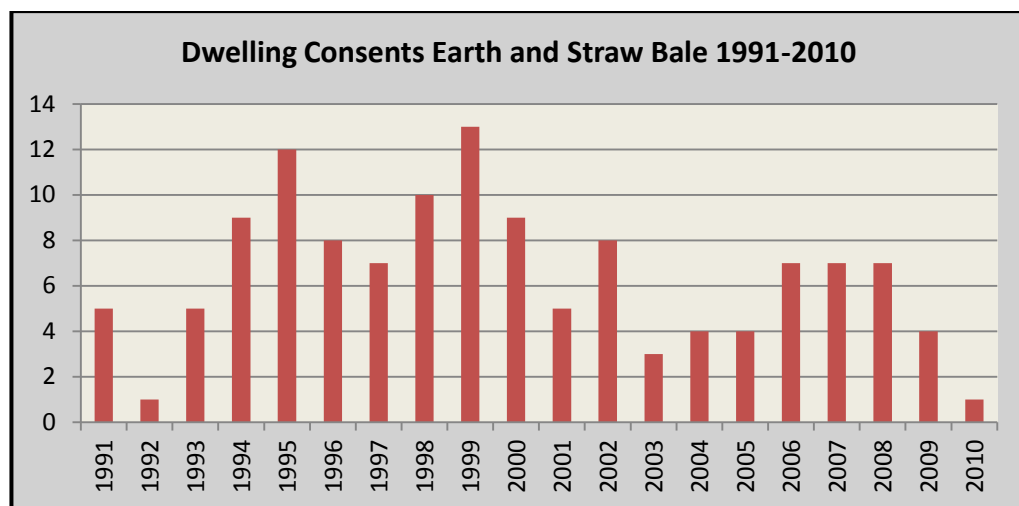


Figure 4.14 Building Consents for Earth and Straw Bale Dwellings, Nelson and Tasman 1991-2010

Moreover, the figures for earth and straw bale houses for 2009 and 2010 do not represent all the houses that were consented in these years, because some of them were not completed by the end of the survey period, 31 December 2010, and the numbers for these two years have therefore been excluded from the analysis below, which covers the period from 1991 to 2008. Further research is therefore required to arrive at an accurate comparison. Nevertheless, despite these disparities, a general sense of the situation can be gained by comparing the two sets of figures.

The vertical axis for the overall figures (Fig.4.13) goes up in hundreds while that for the earth and straw bale house goes up in twos. If the second graph were laid over the first, most of the columns would not even register. In the leanest year for earth and straw bale houses, 1992, they made up 0.1% of the total. In the peak year, 1999, this rose to 2.5%. The average for the 18 year time period from 1991 to 2008 is 1.1%.

Not only do these graphs show what a tiny percentage earth and straw bale houses make up of the annual dwelling consent figures but they also show that trends in the mainstream are not necessarily reflected in the alternative building world. In 1999, the peak year for earth and straw bale, mainstream house construction was experiencing a downturn, and was actually at the bottom of a trough. Conversely, at the peak of a mainstream housing boom in 2003, the figures for earth and straw bale were extremely low. This 'parallel universe' scenario may owe something to the ethics and temperament of those who tend to be attracted to alternative construction, an aspect which is discussed further in 5.14.

CHAPTER FIVE: THE SURVEY RESULTS

5.1 SURVEY RESULTS

The methodology applied in setting up the survey of house owners by way of a written questionnaire has been described in Chapter Three. 116 house owners, 82% of those listed in the database, took part in the survey, and the results are recorded in Appendix 3 in the form of tables and charts. Some of the questions required written answers and these, along with additional notes provided by some respondents, have been recorded in the database worksheets.

In this chapter, the results of the survey are discussed in the order that the questions occurred in the questionnaire (see Appendix 2). All the supporting charts and tables included in this chapter are for the survey population of 116 house owners unless stated otherwise. Information from the interviews that followed the survey is used to inform the discussion, where indicated. The chapter concludes with a commentary on the current body of earth and straw bale houses in the Nelson area based on the survey results and other research sources.

5.2 BACKGROUND: PERSONAL

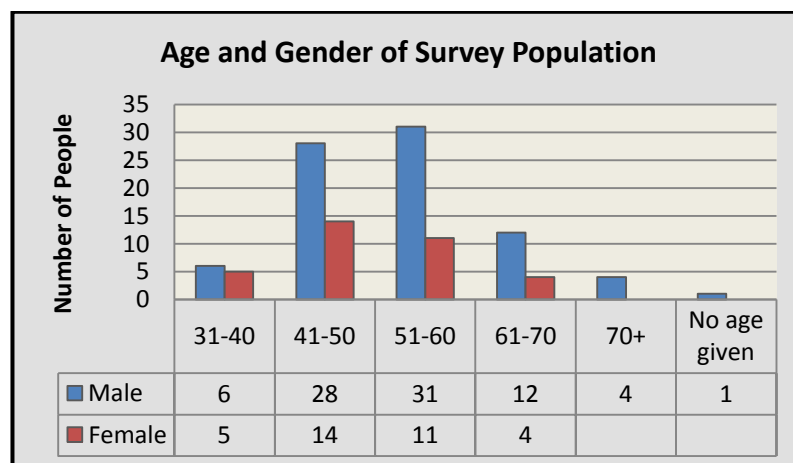


Figure 5.1 Age and Gender of Survey Population

The first section of the questionnaire concerned the make-up of the respondent group: their age, gender, origin, education, and employment status. The majority of respondents were in the 40-60 age group, and 70% were men but this does not

necessarily mean that more men own earth or straw bale houses than women; many of the houses were owned by couples, but only one person answered the questionnaire.

Questions 1.04 to 1.06 were concerned with the origins of the survey group: where they were born, how long they have lived in New Zealand and where else they have lived. The results show that 76% of the respondents were born in New Zealand and 87% have lived here for ten years or more. More than half of the respondents, however, have also lived in other countries, as can be seen in the detailed summary in Appendix 3. While Australia and the western nations of the northern hemisphere figure strongly in these 'other countries', the survey population, as a group, has at some time lived in most parts of the globe. In Section 3 of the survey, a small number of respondents referred to exposure to earth buildings in other countries as being a motivation for trying it themselves in New Zealand.

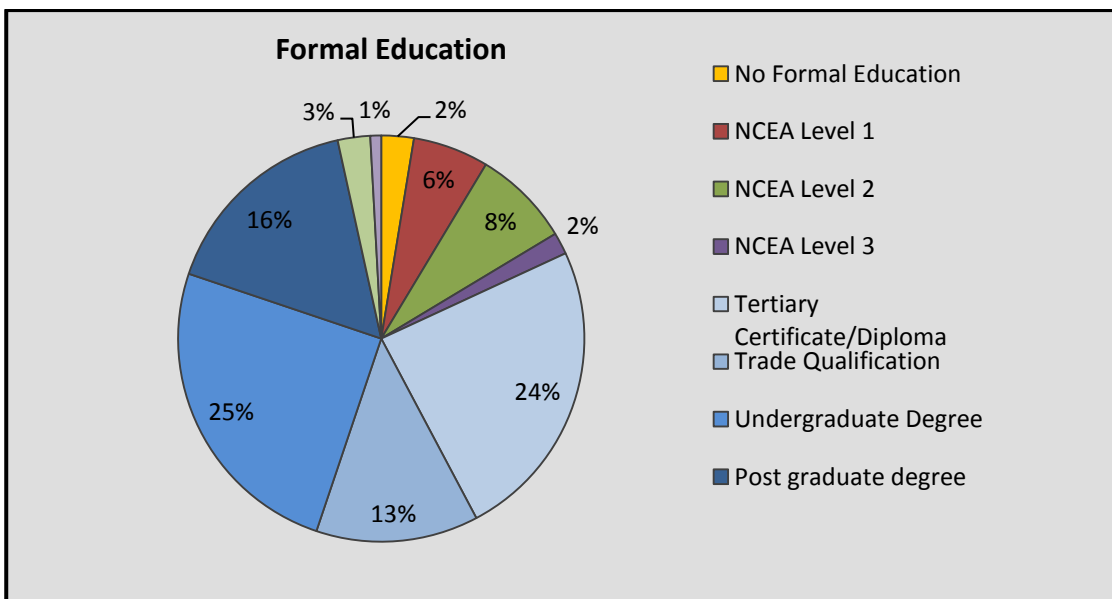


Figure 5.2 Formal Education of Survey Population

As shown by Figure 5.2, 78% of the survey group have had some form of tertiary education, colour coded in varying shades of blue, including trade qualifications. For those currently employed, occupations varied: 78 different answers were given to question 1.09 which asked for the respondent's occupation. The pie chart in Figure 5.3 shows that at least 80% of the respondents were employed full or part time; if those who described themselves as housewives or househusbands are included as being in

employment this brings the total to 84%. Over half the group worked from home (see Figure 5.4), which suggests a level of self-employment or at least ‘independent employment’¹¹ amongst the respondents.

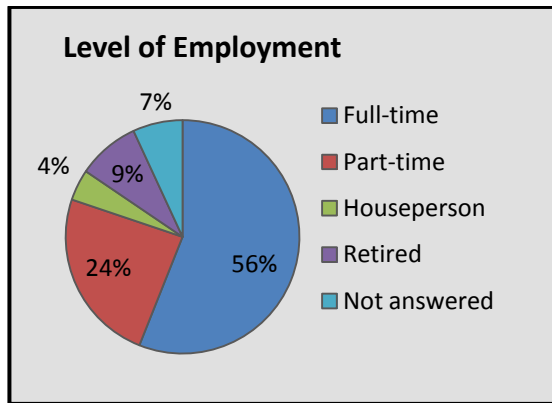


Figure 5.3 Level of Employment

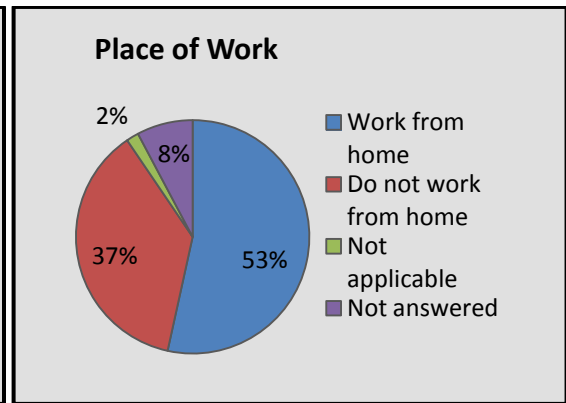


Figure 5.4 Place of Work

5.3 BACKGROUND: HOUSE

The answers to questions in Section 2 of the questionnaire provided information about the houses and the owners’ history of occupation of their houses. Of the 116 respondents, 88 were the original owners and 79 of these, 68% of the survey population, still occupied their houses. The other 9 houses, still owned by their original owners, were rented out. This information emerged during conversations with the owners when they were asked to participate in the survey.

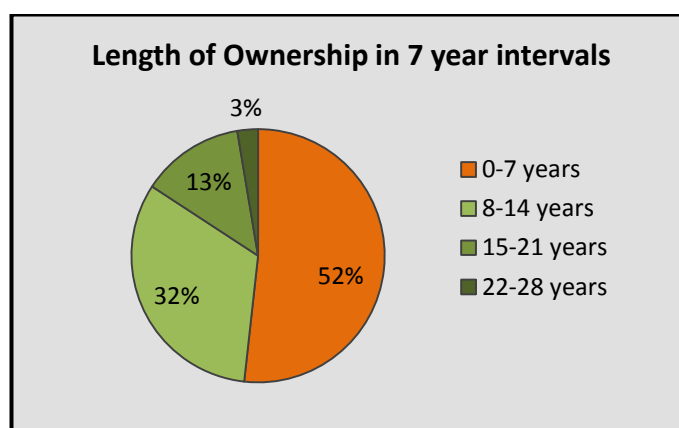


Figure 5.5 Length of House Ownership

¹¹ Meaning being employed by another party but operating from home without on-site supervision.

Figure 5.5 shows that nearly half of the houses have been in the same ownership for more than seven years, which is the approximate national average length of ownership of a house (Mithraratne et al., 2007). Four owners had spent more than 20 years in their houses. 90% of the 116 houses were permanently occupied, with the remaining 10% being either holiday homes, or owned by people who worked part of the year overseas. 50% of the houses were occupied by either one or two people, which corresponds with the fact that over 50% of the home owner group were over 50 years old and therefore less likely to have children still living at home.

Nearly three-quarters of the houses are located on lifestyle blocks. More significantly, out of 116 houses in the survey, only one is located on an inner city section, and only eight in the suburbs or in small towns. This indicates a housing type more likely to be found in rural areas, as illustrated in Figure 5.6, where the four rural property types, as defined in the survey, are shown in different shades of green. When combined, this shows that 89% of the houses are on rural properties. A discussion about the suitability of earth and straw bale construction for urban and rural locations takes place in 6.3.

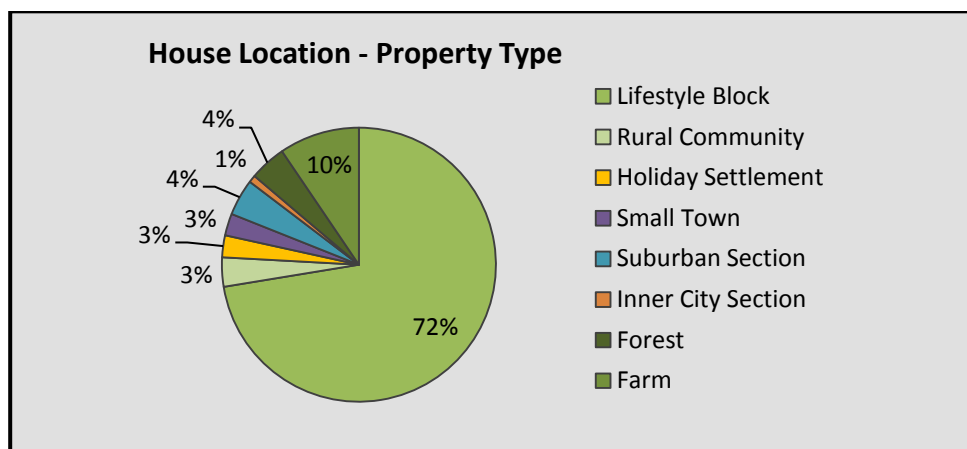


Figure 5.6 House Location by Property Type

Prior to living in their current houses, respondents had lived in houses constructed out of a range of materials including stone, concrete and timber, and a small number had previously lived in earth houses (see Appendix 3). There was a varied response in terms of detail to question 2.08 concerning the main materials used in the construction of the houses: some respondents listed only the earth or straw bale component of their house's construction, while others listed every material and method used. Because of the inconsistency in the level of detail supplied, this

information has not been used. Analysis and discussion of construction type and method has instead been based on the full database of 144 houses, where a consistent categorisation has been applied (4.4-4.6).

5.4 ENERGY SUPPLY AND USE

The answers to questions 2.09 to 2.12 provided information about the sources of electricity, and the space and water heating methods used, for each house. 24 houses out of the 116 surveyed, one fifth, were not connected to the national grid and generated their own electricity. All but one of these independently powered houses used photovoltaic cells, often in combination with micro hydro or wind-powered systems. One house used almost every kind of alternative power source available: solar, hydro, wind and a biodiesel generator (see Figure 5.25).

All the independently powered or ‘off grid’ houses were located in rural areas (see Figure 5.7), and 20 of the 24 were permanently occupied. Gas (not a renewable resource) was the most common power source for heating hot water, closely followed by solar, then wood, and 2 houses used electricity generated on site (see Figure 5.8). All of them used some form of wood-fuelled space heating, sometimes associated with radiators or piped hot water underfloor systems. The 9 houses shown in Figure 5.8,

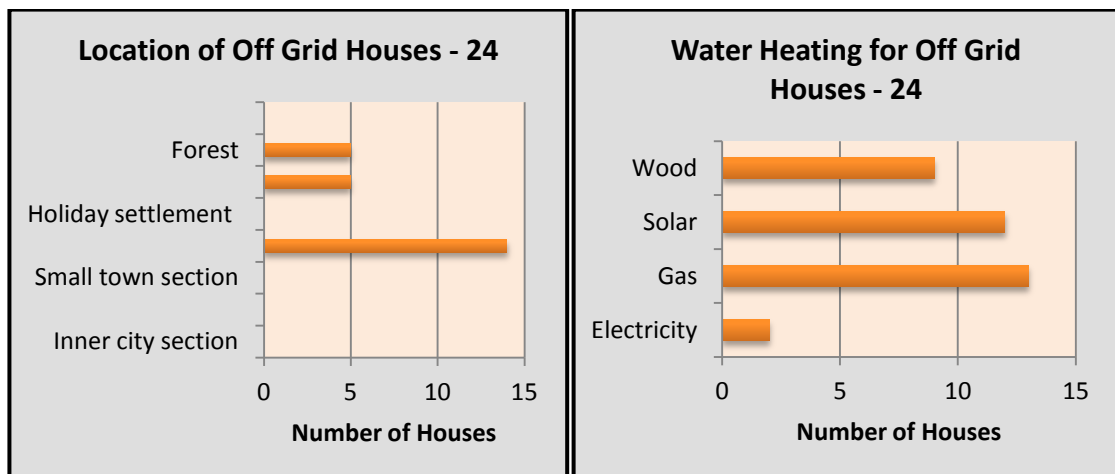


Figure 5.7 Location of 24 Off-Grid Houses

Figure 5.8 Water Heating for 24 Off-Grid Houses

Note: All methods of water heating for each house are listed, so when added the figures exceed 24.

which used wood to heat water also used wood for space heating. The use of gas, a non-renewable resource, for hot water heating seems inconsistent with the ethics of the house owners generally, which are discussed later in this chapter (5.14). However, the decision to use gas may have been driven by cost. A back-up system is generally provided for solar hot water systems to cover the periods when there is not enough solar energy available. It may be that some owners would have liked to install solar but their budget stretched only as far as the back-up system, in this case bottled gas.

For the total survey population of 116 houses, wood-powered heat sources were the most common method of space heating, followed by electricity. Passive solar heating was specifically excluded from the question, see Appendix 2. Typically several forms of heating were used within one house, as shown in Figure 5.9. For water heating, respondents were asked to list all forms used within their houses, so that those who

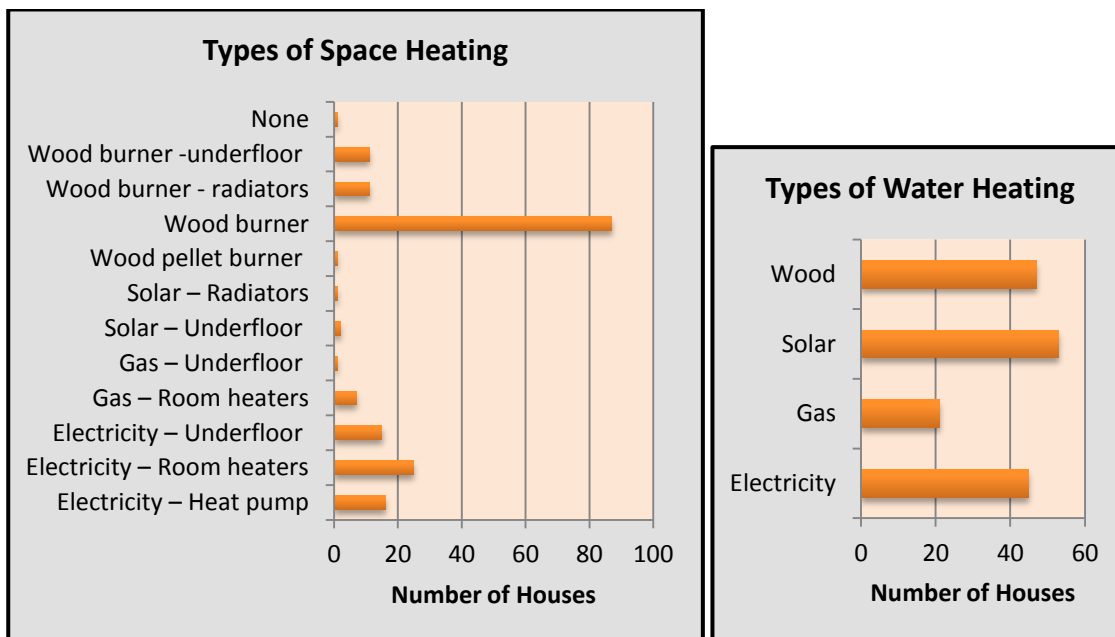


Figure 5.9 Types of Space Heating

Figure 5.10 Types of Water Heating

Note: All methods of heating within one house are listed, so when added the figures exceed 116.

used solar backed up by electricity listed both. The results, Figure 5.10, indicated that nearly half of the houses in the survey used solar hot water heating and many used some form of wood powered hot water heating. It is likely that the same wood powered source was used for both space and water heating.

The high incidence of solar hot water heating in the region is not surprising. The Nelson district experiences very high sunshine hours, some of the highest in the country (NIWA, 2004) and both the NCC and the TDC have actively encouraged people to use solar energy for hot water heating. In 2009 the NCC introduced a targeted rates system, providing low interest loans repayable over a ten year period as part of the rates charged on the particular property (NCC, 2011c). Further encouragement is provided by not charging for the building consent required for the installation of solar hot water systems (NCC, 2011b). The TDC “*subsidises half the cost of building permits for the installation of solar hot water systems from the general rate*” (TDC, 2012).

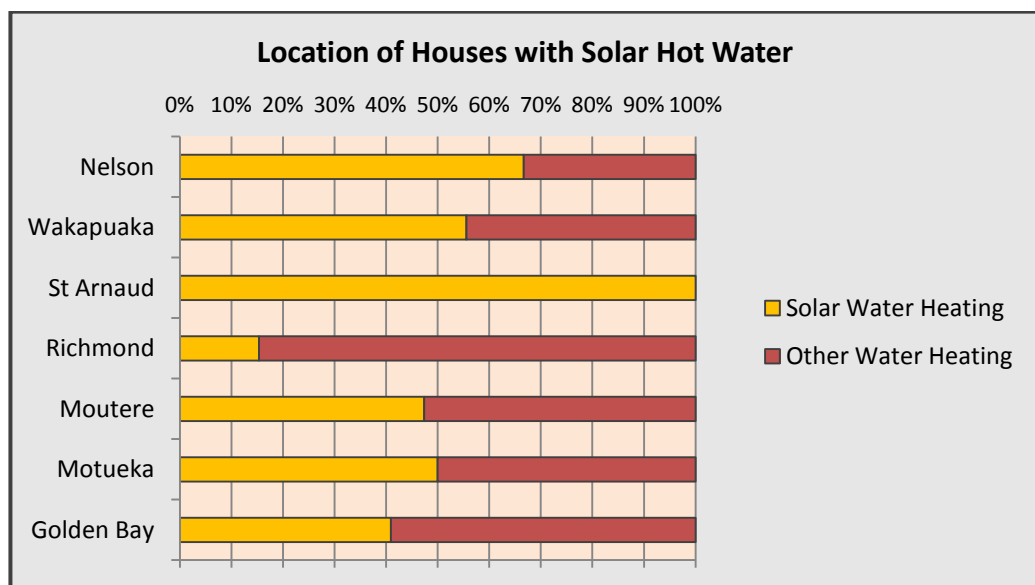


Figure 5.11 Location of Houses with Solar Hot Water Heating

Figure 5.11 shows the percentage of houses using solar hot water heating by sub-region. Nelson and Wakapuaka are governed by the NCC and the other regions by the TDC. Apart from the St Arnaud bar, which represents a single house, the NCC percentage is slightly higher than that for the TDC but overall there is a reasonably consistent uptake across the region. The fact that 53 houses, nearly 50% of the total surveyed, use solar hot water heating indicates a district wide willingness to invest in solar energy, at least amongst those building with natural materials.

5.5 REASONS FOR BUYING OR BUILDING AN EARTH OR STRAW BALE HOUSE

The questions in Section 3 of the questionnaire were set up to find out why people chose to build or buy an earth or straw bale house. The first two questions, 3.01 and 3.02, were directed at the 28 people who had bought, rather than built, their houses, and questions 3.03 and 3.04 were directed at those who were the original owners.

In question 3.01, respondents were asked whether the method of construction was a determining factor in their decision to purchase their house. Annotations on a number of questionnaires suggested that it was the property on which the house was located, rather than the house itself, which was the main reason for buying. However, 12 of the

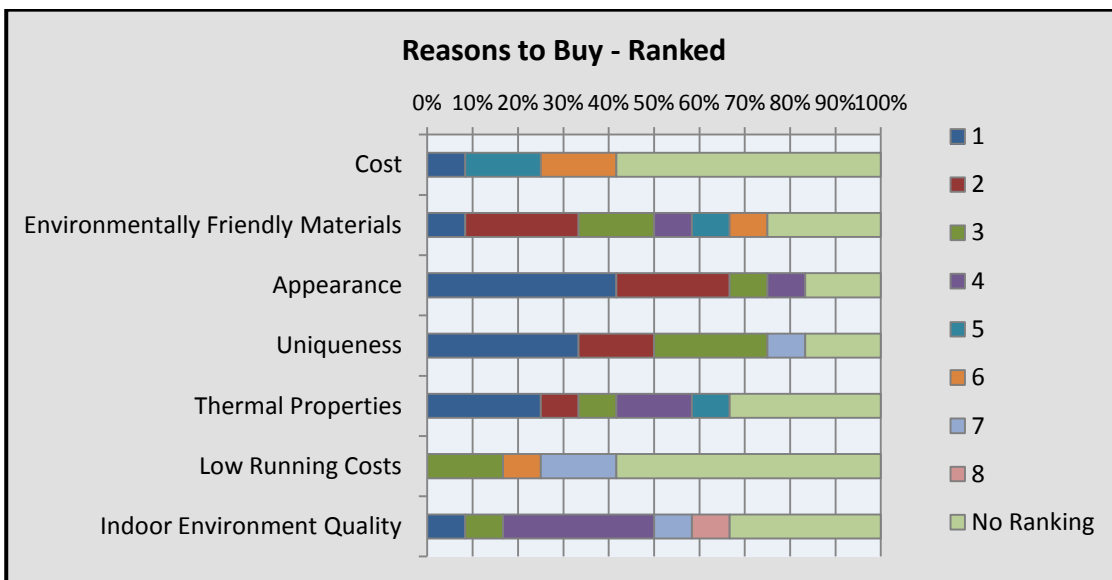


Figure 5.12 Reasons for Buying an Earth or Straw Bale House (n=12) – Ranked in order of importance (1 being the most important, 8 being the least)

28 respondents who were not the original owners reported that the method of construction was a determining factor. These 12 were then asked to rank a number of factors associated with the construction method in order of importance. Figure 5.12 illustrates the results. The most popular factors, those ranked 1 or 2 and coloured dark blue and red respectively in the bar chart, were ‘appearance’ and ‘uniqueness’, followed by ‘thermal properties’ and ‘environmentally friendly materials.’ While it is acknowledged that 12 is too small a number of respondents to be statistically significant, these responses are consistent with those of the 88 original owners when they were asked why they chose to use earth or straw bale.

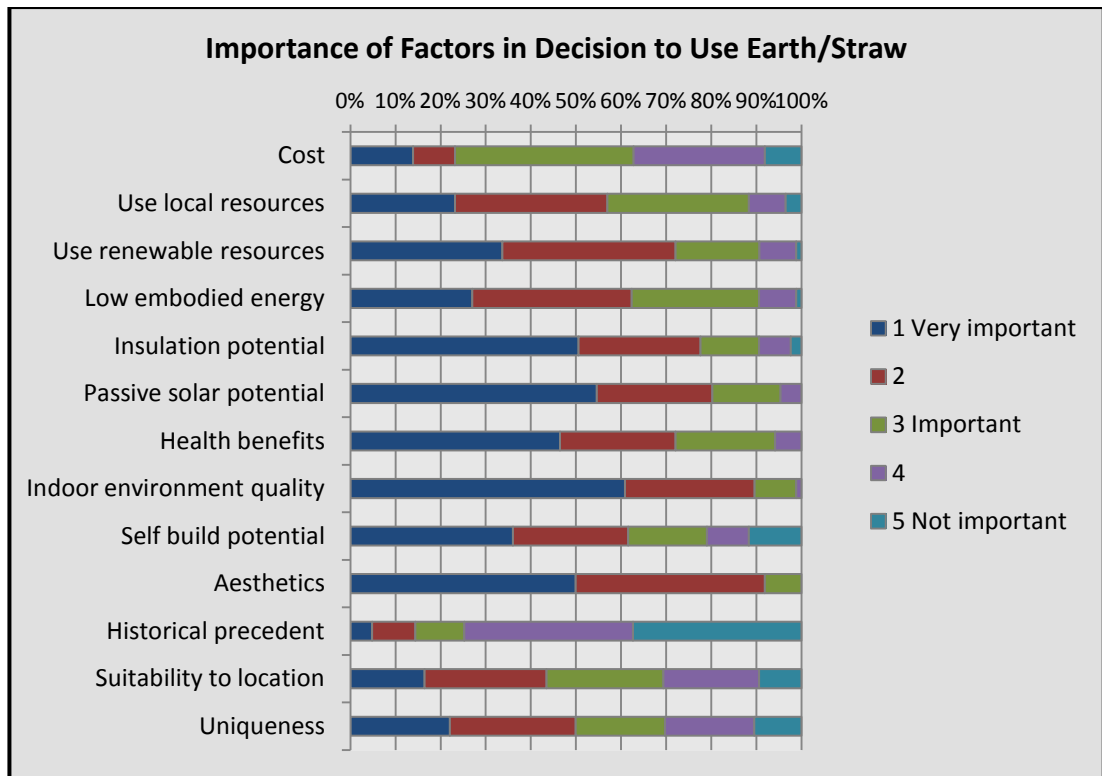


Figure 5.13 Reasons for Building an Earth or Straw Bale House (n=88) – Rated in order of importance

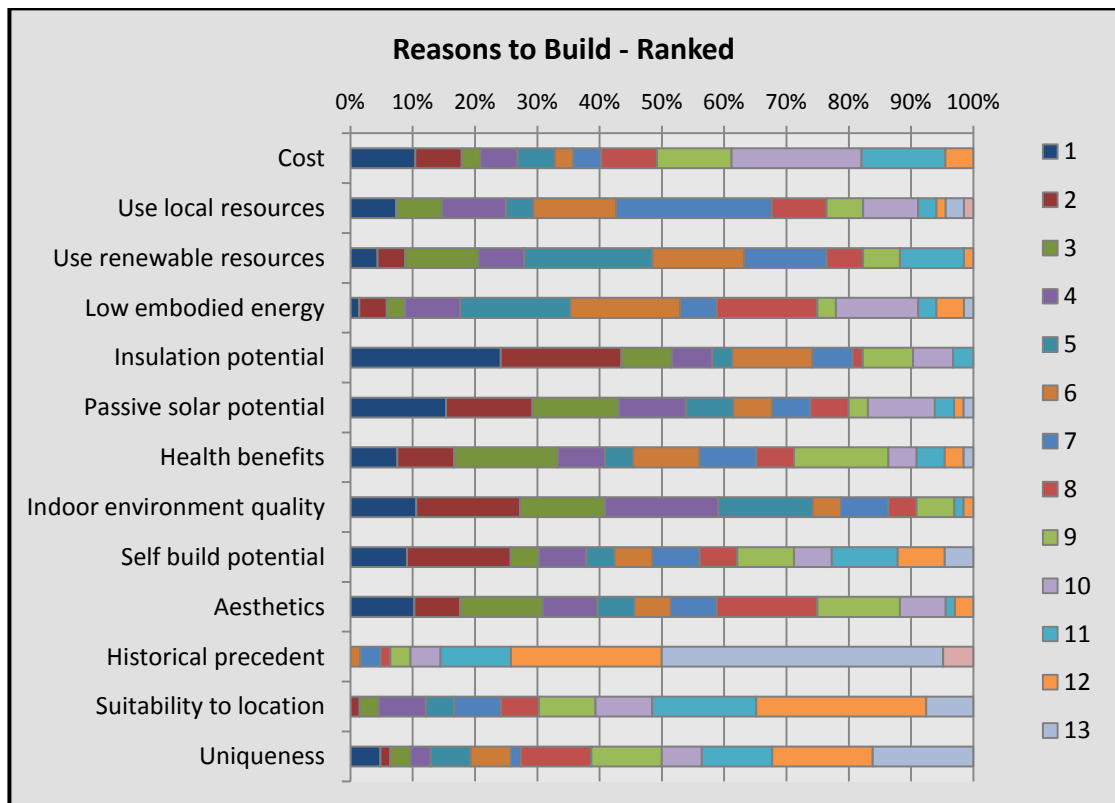


Figure 5.14 Reasons for Building an Earth or Straw Bale House (n=68) – Ranked in order of importance (1 being the most important, 14 being the least)

The questions asked of the 88 original owners were posed slightly differently. Respondents were asked first to rate a number of factors on a likert scale, and then to rank these same factors in order of importance. The results for question 3.03 (see Figure 5.13) show that 'Aesthetics', 'Indoor environment quality', 'Passive solar potential', and 'Insulation potential' were generally rated as being more important than the other factors listed. In contrast, 'Historical precedent' was consistently rated as being unimportant and only a few respondents rated 'Cost' as being very important. The results for question 3.04, where these same factors were ranked against each other, are similar but different: see Figure 5.14. They are similar in that more respondents ranked 'Indoor environment quality', 'Insulation potential', and 'Passive solar potential' as 1 or 2 than for any of the other factors. The major differences are in three areas. 'Self build potential', which had six factors rated higher than it for question 3.03, was ranked 1 or 2 by over 25% of respondents, while 'Aesthetics', which was rated as more than 'important', rating 3, by the highest number of respondents in question 3.03, had less than 20% ranking it 1 or 2 in question 3.04. In contrast the results of question 3.03 suggest that many did not consider 'Cost' to be as important as the other factors; 'Historical precedent' was the only factor rated lower than 'Cost'. Yet in question 3.04, six factors are ranked below 'Cost'.

When collating and analysing the data from Section 3, a number of issues arising from the way the questions were phrased were revealed. Appendix 5 contains a report on these issues and the manner in which they were resolved.

5.6 PRE-CONSTRUCTION: INFORMATION, EXPERTISE AND GAINING CONSENT

Section 4 of the questionnaire concerned the pre-construction phase of the respondents' building projects. It was only relevant to the 88 respondents who were the original owners, and focussed on how they found out about the construction methods, how easy it was to access information and expertise, how easy it was to gain consent and how they obtained finance for their houses.

In question 4.01 respondents were asked to list all their sources of information regarding the construction method. The results show that owners of existing houses,

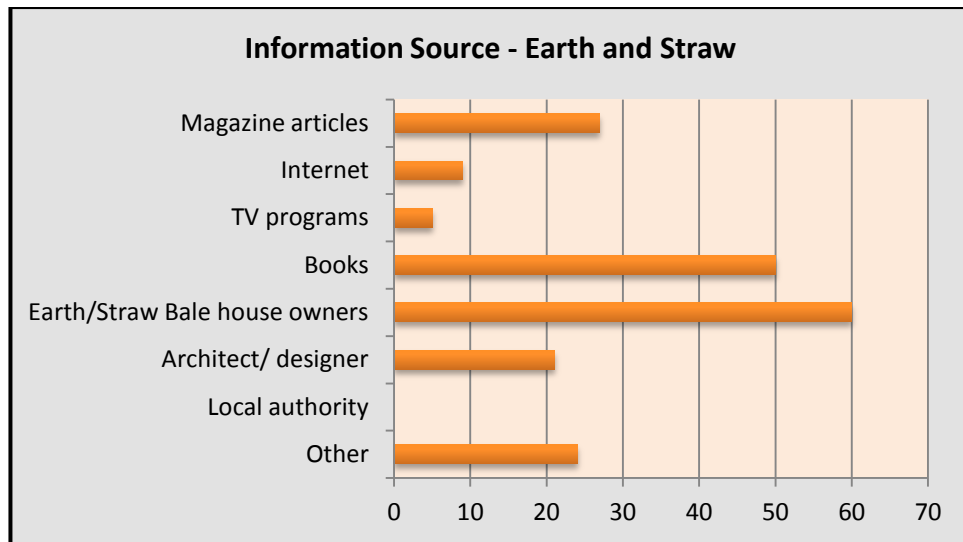


Figure 5.15 Information Sources for Earth and Straw Bale construction (n=88)

and books on the subject, are the most common sources of information. The 24 respondents who included 'other' and then specified what that 'other' was, all specified things that can be classified as being related to the alternative building network, and exposure to older earth buildings in New Zealand or earth building in other countries. Examples that relate to the alternative building network include: *"local adobe manufacturer"*, *"attending a workshop"*, and *"a builder who was keen to try the method"*. No one listed Local Authority staff as being a source of information; perhaps an indication of the lack of knowledge, interest, or both amongst building officials.¹²

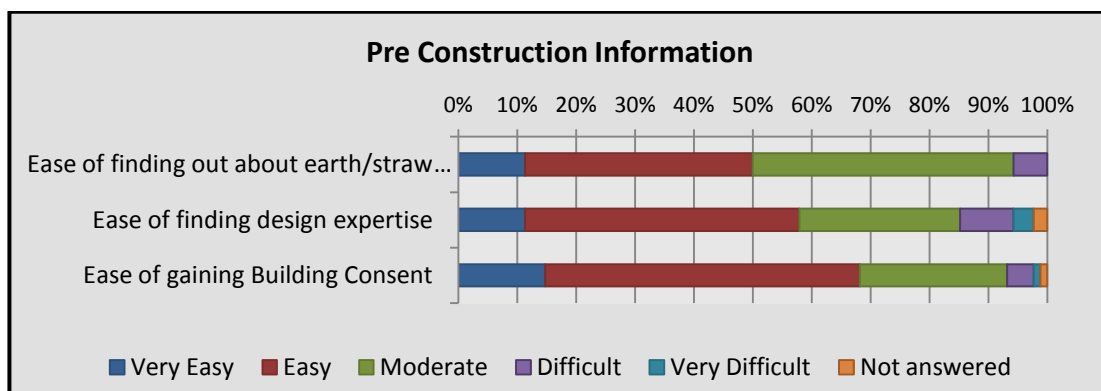


Figure 5.16 Ease of obtaining information, expertise and Building Consent (n=88)

¹² The term 'Local Authority' rather than Territorial Authority was used in the questionnaire because it was considered more widely understood by those not involved in the construction industry.

The results for questions 4.02 to 4.04 about the ease of gaining information, expertise, and building consent are shown in Figure 5.16. Most respondents found it relatively easy to find information and gain consent but a small percentage experienced difficulties.

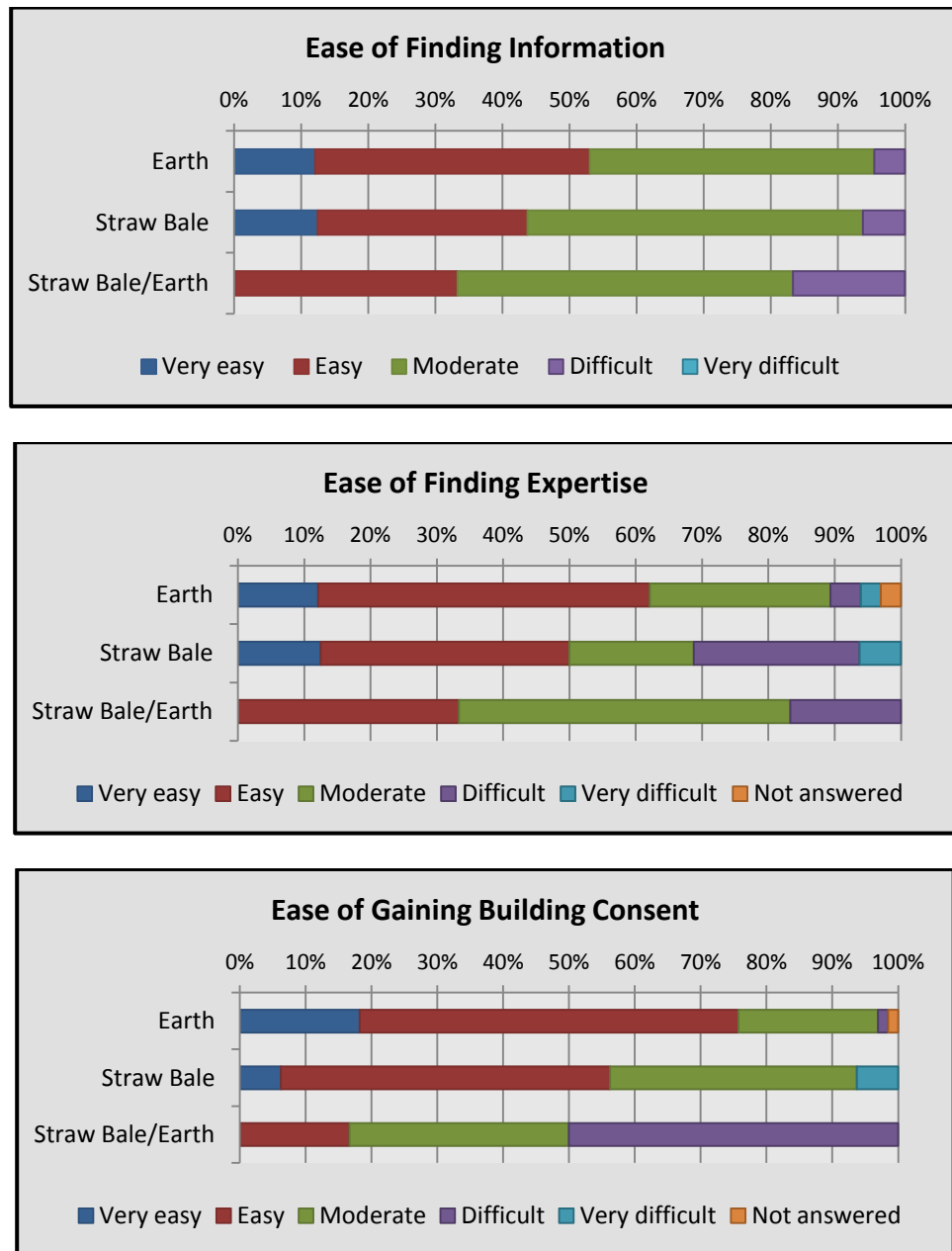


Figure 5.17 Ease of obtaining information, expertise and Building Consent by Construction Method (Earth:n=66, Straw Bale:n=16, Straw Bale/Earth:n=6)

When the survey house population is broken down into the different types of construction, it is clear that a higher proportion of people who built using earth construction of some description found it easier to access information and expertise,

and to gain consent, than those using straw bale (see Figure 5.17). This result has more significance when viewed the opposite way: a higher proportion of the people using straw bale had difficulties than those building with earth. However, given that straw bale construction is more recent, that it is only 16 years since the first house was built in the region, that it is not covered by a building code, and is less familiar to consenting officers, the results are not surprising.

Earth, on the other hand, has a long history and some of the protagonists behind the resurgence of earth building in the 1980s and 1990s are still active in the region:

Richard Walker and/or Gary Hodder are listed as the engineers for 70 of the houses in the database, and they continue to provide engineering services for new houses in Nelson and further afield. Other designers and builders have also built up a body of knowledge through their ongoing involvement in projects locally and nationally. As discussed in 4.5, the Earth Building Standards (SNZ, 1998c) have been significant both for those preparing building consent application for houses involving earth construction, and for the TA officers assessing those applications.

5.7 FINANCING

The last question in Section 4, again directed at the 88 original owners, asked how they funded their building projects and whether they had any problems in doing so. In terms of the source of funding, the answers varied; some were entirely self-funded from savings, or the sale of a previous house, and many were financed through regular lending agencies. No one indicated that they had experienced difficulty in obtaining a loan and many expressly stated that there were no problems. Two people suggested that their bank never even asked what material their house was to be built of. One wrote,

“I’m not sure my bank knew about the adobe construction, but I had an OK banking record, they didn’t ask too many questions from memory.” (Adobe brick house owner, consented 1993)

Many commented that their houses were constructed over a protracted period, as finance became available, and that they were very careful to keep borrowing to a minimum.

The survey results suggest that banks and other lending institutions have not been concerned about the method of construction used, but rather the market value of the complete house and land package.

5.8 CONSTRUCTION

Section 5 was also directed only at those respondents who were the original owners of their current houses. The aim of the questions was to provide information that could be used to assess the suitability of both earth and straw bale construction for unskilled owner-builders. A discussion of this begins later in this chapter, and provides the background for looking at the future possibilities both materials have for low cost and communal housing schemes, discussed further in 6.3. Questions 5.01 and 5.02 concerned the respondents' physical involvement in the building process and were aimed at quantifying the percentage of owner-builders in the survey population. Respondents were asked whether they were actively involved in the construction of their house, and if so to what extent. They were also asked whether they had previous building experience, and if so to elaborate on this. Some of the answers given to question 5.02 revealed levels of involvement which are not regarded as those of an owner-builder as defined in this thesis (see Glossary). These include project

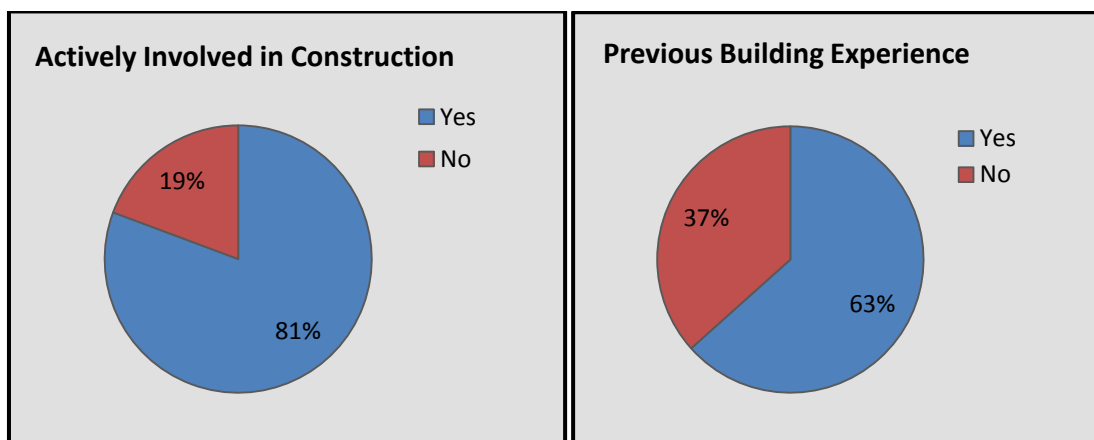


Figure 5.18 Incidence of Owner-Builders (n=88)

Figure 5.19 Incidence of prior Building Experience (n=88)

management only, decorating only, and cleaning up after the builders. Therefore, the affirmative answers given by twelve respondents to question 5.01 have been recorded as ‘no’ in this reporting to give an accurate picture of the incidence of owner-builders. Many of the owner-builders worked alongside an experienced builder from start to finish, while others employed builders to do all the carpentry work while they, the owners, built the earth or straw bale walls on their own.

Figures 5.18 and 5.19 illustrate that 81% of the survey respondents were owner-builders and of these 63% had prior building experience. This experience ranged from paid employment as a builder, to smaller DIY jobs like building a deck or a small shed, to those with much lesser experience like *“built a three legged table at school”* and *“built a picnic table”*.

5.9 INCIDENCE OF OWNER-BUILDERS

Since the origins of all 116 houses in the survey are personally known by the author, it was possible to add owner-builder figures for those houses that have changed hands to the owner-builder figures from the survey results to provide a complete picture. This adjustment results in a slightly smaller percentage of owner-builders, 75%, which is very close to the situation in the North Island as reported by Jackson:

“Engineer Thijs Drupsteen also stated that approximately 70% of the 165 earth building projects he has worked on were owner-built.” (2009, p.132)

Drupsteen is a Consulting Engineer who has worked on many earth house projects and been involved with EBANZ since its inception. Some of the experts interviewed after the survey was completed thought that the incidence of owner-builders has been declining, but this is not borne out by the data when analysed over time. The graph in Figure 5.20 shows that up until 1990 the owners of all the houses were involved in their construction, and since then three out of every four houses have been built this way. When broken down into decades, this percentage is the same for both the 1990s and the 2000s. While there are some years where all the houses had owner-builder involvement, there have been no years where all the houses have been contractor-built only.

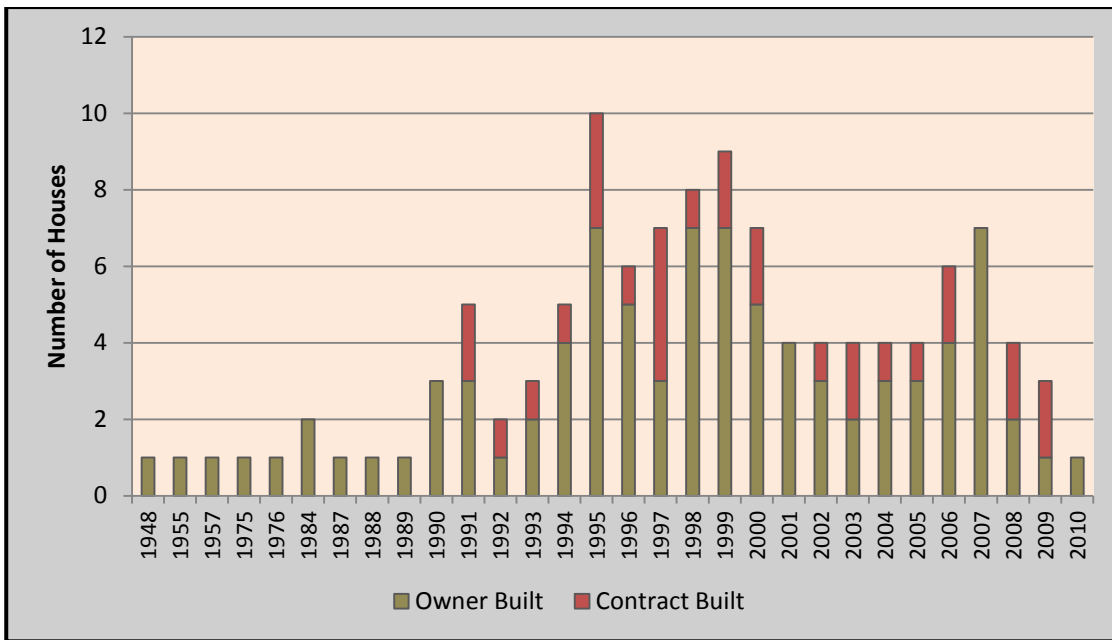


Figure 5.20 Incidence of Owner-Builders over time

In order to find out whether some construction methods are more suited for owner involvement than others, the data has been broken down into the three major construction types (see Figure 5.21). Over 80% of houses that incorporate earth construction and just under 70% of the purely straw bale ones are owner-built. This amounts to nearly three in four houses, whichever construction method is used. There are no comparable figures available for mainstream construction but it is reasonable to assume that the incidence of owner involvement in construction is considerably smaller than when alternative materials are used.

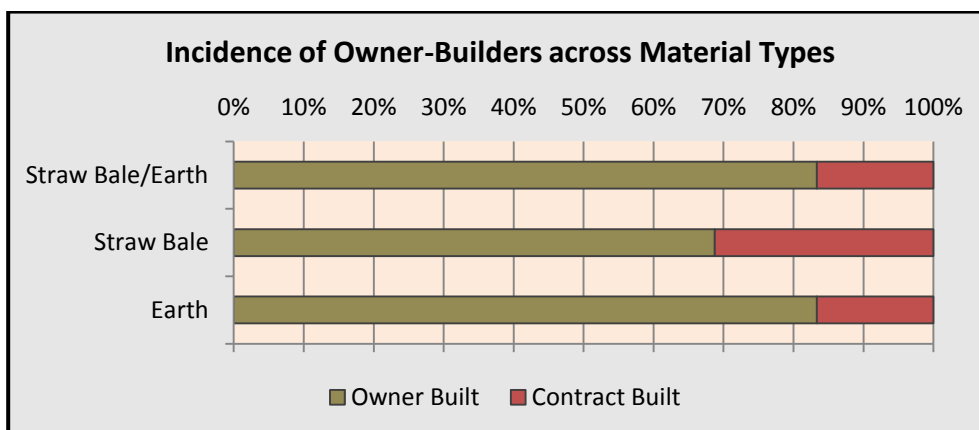


Figure 5.21 Incidence of Owner-Builders across Material Types

All the original owners of houses built out of cob, light earth, and wattle and daub, were involved in their construction. Whilst the numbers are not large enough to draw

reliable conclusions from, these owners were extremely enthusiastic about their respective systems, which are discussed individually in Chapter Six.

5.10 PERFORMANCE

The final section of the questionnaire, Section 6, was primarily concerned with the performance of the houses. The first four questions asked the respondents to rate the performance of their houses in terms of overall performance, thermal comfort, indoor environment quality, and durability on a likert scale. It should be noted that the results of this part of the survey are based on subjective rather than objective data.

The bar chart in Figure 5.22 shows that over 90% of respondents were happy or very happy with the overall performance of their houses. More than 95% were happy with the quality of their indoor environments and 88% were happy with the durability, but only 72% felt the same about the thermal performance. When the data is broken down into the three major construction types, see Figures 6.3, 6.4 and 6.6, it becomes apparent that all the respondents who were unhappy or very unhappy with some aspect of their house's performance are the owners of earth houses. In the worst case, which is 'Thermal Performance,' this amounts to 7 houses, 6% of the population. If those who considered the performance to be moderate are included, the total rises to 31 houses (27%), 28 of which are earth houses.

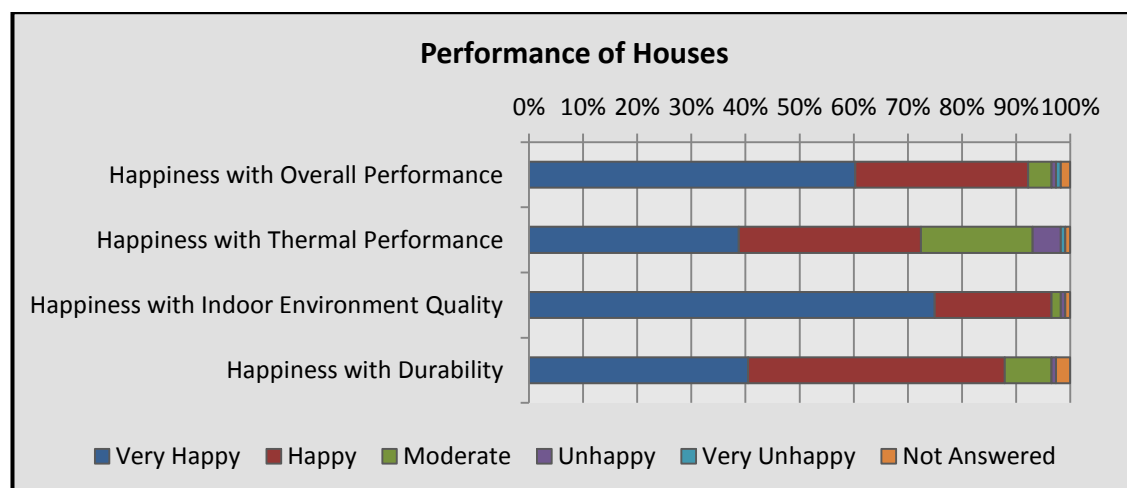


Figure 5.22 Performance of Houses

61 respondents elaborated on their responses to the performance rating questions. Of these responses, 25 concerned thermal performance and the most common concerns

were regrets about not installing insulation under a concrete slab floor, regrets about not installing double glazing, and the poor performance of the earth walls in winter. This last point is illustrated in the following responses:

“The passive solar in my house works very well for two thirds of the year, but when it is needed most i.e. winter my design doesn't work quite so well. I had no experience in designing one of these houses and applied a do it yourself [sic] approach.” (Adobe brick house owner, consented 1993)

“The solid rammed and adobe walls offer no insulation so house tends to be cool in winter.” (Earth house owner, consented 1994)

Many of the elaborated responses were comments about particular aspects of the construction, rather than about the performance of the house. A number wrote about how happy they were with their houses:

“Totally convinced with earth as wall fill medium. Zero maintenance, interior walls are a great heat sink, aesthetically and acoustically gorgeous.”
(Earth house owner, consented 2000)

Nine had concerns about the durability of their earth walls, either in locations exposed to extreme weathering, or in relation to interior walls, where they were experiencing problems with dust. One person mentioned the difficulty of fixing items to straw bale walls, and another the difficulty of retrofitting electrical or plumbing services. Other issues noted were to do with poor workmanship, or performance of building elements other than earth or straw bale.

As well as looking at the results to individual survey questions, a number of responses can be analysed at the same time by cross tabulating the data, as follows. The results from Section 3 of the survey where it was found that nearly 80% of respondents rated ‘insulation potential’ as 1 or 2 on the very important/not important scale in their decision to use earth and/or straw bale have been discussed (see 5.5). The bar chart in Figure 5.23 shows how these same 66 people rated the actual thermal performance of their finished houses. The owners of all the hybrid earth and straw bale houses rated their houses highly: ‘very well’ or ‘well’. Nearly 90% of the straw bale house owners rated their houses highly as did 80% of earth house owners.

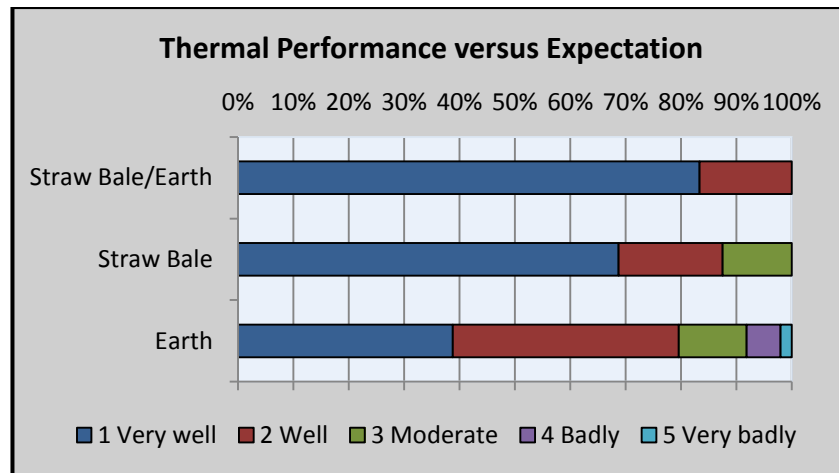


Figure 5.23 Actual Thermal Performance – Ratings by owners who chose to build because of expectations of good thermal performance (n=66)

The results of this section of the survey, including actual performance in relation to initial expectations, the inadequate thermal performance of many forms of earth construction, and responses to this issue are discussed further in Chapter Six (6.6 to 6.9).

5.11 INSURANCE

Respondents were asked whether their houses were insured and whether they had any problems with obtaining insurance cover. 90% of houses were currently insured, and 95% of owners had no problem obtaining insurance cover. Of the six who had problems, two included notes to say that this was because AMI insurance were no longer prepared to insure adobe houses and they had to switch companies. Both these houses are relatively new, having been granted consent in 2007 and 2008. One of the owners wrote:

“Had to change from AMI insurance to State Insurance. AMI does not insure earth houses like ours.” (Adobe brick house, consented 2008)

A telephone inquiry by the author to AMI insurance in Auckland confirmed that the company will no longer insure houses using non-standard construction methods (Hall, 2011e). Earth, straw bale, and log houses all fall into this category, as well as houses with green roofs. The reason given was that the replacement cost for a house built in this way would be more expensive than if it was built using conventional methods. This

explanation is unsatisfactory: higher replacement costs, whatever the construction method, would be covered by having correspondingly higher premiums. It seems very likely that there is another issue influencing AMI's decision which would require further research to uncover. The author made a similar inquiry to State Insurance (Hall, 2011f). The response was that State is happy to insure any house which has a Code Compliance Certificate (CCC) and the company had no problem with insuring either earth or straw bale houses.

5.12 HINDSIGHT

The last questions in the survey were concerned with how the respondents felt about their chosen method of construction with the benefit of hindsight, and whether they would recommend it to others.

Figure 5.24 illustrates the results of question 6.08, which asked respondents whether they felt earth and straw bale construction were cheaper than other methods. Many of the 14% who did not answer the question wrote notes in the margin. Some indicated they just did not know the answer and others indicated that the cost was so dependent on how much the owners were involved in construction that they could not answer the question with a simple 'yes' or 'no'. A number of those who answered 'yes' also noted that they felt this was only true if there was a high level of owner involvement.

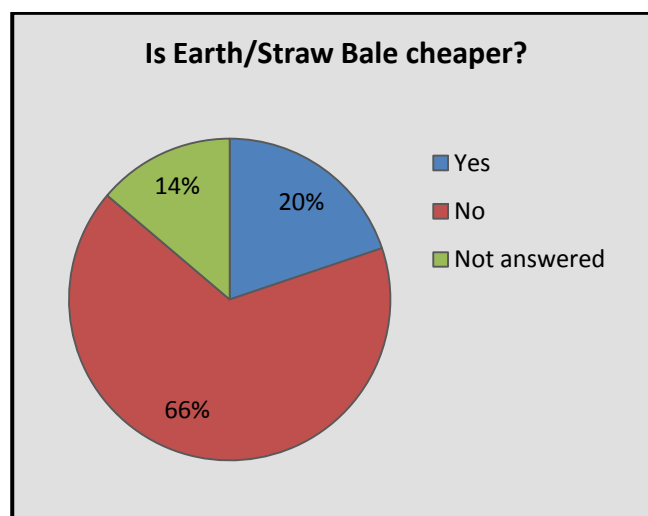


Figure 5.24 *Is Earth/Straw Bale cheaper than other forms of construction?*

88% said they would recommend earth or straw bale construction to others and 87% said they allowed interested people to visit. This result reflects the willingness of house owners to engage with others thinking about using similar materials which has been an important way of disseminating information and which is discussed further in 6.4.

The final question asked respondents to consider what materials and methods they would use if they were to build again, and why. 75% said they would use earth or straw bale, and those who did not want to repeat the experience cited age, expense, the hard work involved, performance concerns and potential consenting issues as reasons for their stance. The following comments illustrate these points:

“At age 77 I do not intend building again but I would not mind constructing a log house if age and arthritis had allowed.” (Rammed earth house owner, consented 1995)

“In NZ I would choose more conventional materials and designs and super insulate using ordinary materials as the cost of doing something less familiar was 2 X [sic] at least what it would have been had I done so. I do love the effect created by straw bale but the costs were hard to justify as were the delays incurred during the building process.” (Straw bale house owner, consented 2008)

“Possibly, it is a lot of work to construct and there are possibly issues with thermal insulation on the south side which receives no sun to warm the adobe.” (Adobe brick house owner, consented 2003)

“Probably would not build/buy earth again. Understand from Building Inspectors/Engineers that regulations, etc, etc, would make the cost prohibitive unless you were really keen and had a large budget for project.” (Rammed earth house owner, consented 2001)

Most people loved their houses, and the factors which influenced their decision to use earth or straw bale for their current houses are still the factors that would influence their decision to use the materials again:

“Would prefer to build in adobe block because of the solid, honest and attractive nature of the material. The stability of the thermal mass would also

be an important reason as our house never gets too cold in winter or overheats in summer.”

(Adobe brick house owner, consented 1994)

“I would build a light earth house again anytime, its warm, absorbs inside humidity, materials are locally sourced and affordable. You can be creative with details and mistakes are easy to fix.” (Light earth house owner, consented 1996)

“Depending on site and local climate I would choose straw bale (post and beam) due to thermal and acoustic properties.” (Straw bale house owner, consented 2000)

5.13 COSTS

The survey results show that 66% of respondents did not think that earth or straw bale were cheaper than other construction methods: Figure 5.24. Many of those who did think it was cheaper, qualified this by saying that it was only true in the case of owner-builders. The author’s experience confirms the accuracy of this view which is also held by other professionals in the earth and straw bale community (North, 2011a, Olorenshaw, 2011, Maeder, 2011).

As a practising architect, the author encountered a number of situations in the 1990s where clients who were keen to build with earth changed their minds because of the estimated cost. These clients were not owner-builders and there were two main reasons for the comparatively high estimates. First, there was the additional cost of the more substantial foundations required to support the heavy walls on other than flat or gently sloping sites, and secondly the building industry’s unfamiliarity with the materials and methods made it impossible to get competitive pricing from builders. Comparative costs were obtained from a quantity surveyor, which showed that the costs of building in adobe brick using a standard building contract and with no client involvement in the construction process ranged from 10-30% more, depending on the site conditions, than the same house using timber framing with plaster or timber cladding.

However, it is not only the construction cost which needs to be considered. When considered in terms of the life of the building the upfront cost has less significance. The length of ownership of the surveyed houses where over 50% of the houses have been in the same ownership for more than seven years supports the view that house owners considered the long term advantages as well as the upfront costs of their houses in deciding to build in earth or straw. Light earth house owner Hamish Rush is one of these. He also believes that the extra initial investment required for long term gain is a reason why many people are not attracted to alternative materials:

“I think that’s another part of why people don’t go for this type of building method because they’ve got to invest more time and money and there’s only a certain percentage of the population who are building a house to live in for 20,30,40 years ... A lot of people don’t want to make that commitment to that upfront cost because they don’t see the potential to get that back over the period of the product.” (2011)

Others took the view that an earth or straw bale house is a much more substantial house than a timber framed one, and has additional benefits in terms of the quality of the interior environment. As expressed by architect Stephan Meijer:

“I mean timber framing is not really a house, it’s just an envelope, I think, a visual envelope. It doesn’t do anything for the interior environment.” (2011)

The findings from section 3 of the questionnaire, where the respondents were asked why they chose to build out of earth or straw bale, were discussed earlier in this chapter, 5.5, and confirm that it was not just the upfront construction cost that was important for the respondents. Figures 5.13 and 5.14 illustrate that whether the different factors were rated or ranked, cost was considered less important than at least four other factors: ‘insulation potential’, ‘passive solar potential’, ‘indoor environment quality’ and ‘self build potential’. The inherent buildability of many forms of earth construction and of straw bale, and the consequent potential for self building that this provides, is the very thing that allows home owners to contribute more to the construction process and hence cut costs. As Richard Walker says:

“I mean with earth a complete novice can be involved in the earth wall construction whereas it would be difficult to have a novice be involved in timber frame construction so the earth wall construction does give an opportunity for the completely inexperienced owner-builder to construct their walls.” (2011)

For Nancy-Jean Bell and Keith Tomlinson this opportunity to be involved in the construction was a major reason why they chose to build in adobe:

“I knew I wanted to have builders to be doing structural things, and maybe getting advice from but I knew that I could do the adobe without going through years of training.” (Bell, 2011)

This ability to play a major role in the construction process had the added advantage of reducing the cost of the house.

While it is generally accepted that the upfront monetary cost of building a house in either earth or straw, using a standard building contract, is more than it would be if conventional materials were used, the opportunity that both materials provide for unskilled owners to be involved in the construction process means costs can be reduced. Many house owners also measured the value of their houses in other ways, such as the ratio of upfront cost to longevity of occupation, the solidity of their houses, and the indoor environment quality.

5.14 WHO BUILDS IN EARTH AND STRAW BALE IN THE NELSON AREA AND WHY?

The results of the survey provide information that can be used to present an overall picture of the earth and straw bale houses in the Nelson area: how they came to be, who has built them and how they have performed. The first houses discussed in this research, those at Riverside Community, were built by a group of people who were seeking an alternative way of living in post-war New Zealand. They were generally well educated and worked at home on their rural property seeking a high degree of self-sufficiency. Sixty years later these characteristics are also typical of the survey respondents.

The survey results show that 78% of respondents have some form of tertiary education and that over half of them work from home, suggesting a high level of independent

employment. 90% live on rural properties and one in five of these properties is not connected to the national electricity supply grid. Three out of four respondents are owner-builders. The house shown in Figure 5.25 illustrates these aspects: it was designed and built by an architect owner who works from home, it is located on a rural property, and is not connected to the national electricity supply grid.



Figure 5.25 Adobe brick house, Nelson, 1996. Photograph: MH 2011.

The answers to the questions about why people chose to build or buy out of earth and/or straw bale show that the respondents placed importance on the environment and their health, the aesthetics of their houses and that they wanted to be actively involved in constructing their houses (see Figures 5.12, 5.13 and 5.14). These results confirm some of the findings in Ellen Jackson's research, which revealed that both the members of the general public and the earth building experts who took part in her surveys had perceptions about earth buildings and those who chose to live in them that are consistent with the findings of this research with regard to environmental, health and aesthetic considerations.

With regard to environmental factors Jackson states:

"The survey results from the general public demonstrate that earth is believed to be a building material that is very good for the environment ... Respondents

who suggested that they would like to live in an earth house were asked why they felt this way. The most common answer was overwhelmingly 'Good for the Environment.'"

And:

"...the great majority (86%) of earth building specialists said that the main reason why they or their clients built with earth was for 'environmental' reasons. Ecological concerns and sustainability is overwhelmingly the main driver for people to build with earth." (2009, p.67)

With regard to health:

"...the earth building specialists generally believed that earth buildings provided an environment which was beneficial towards health." (2009, p.106)

Although the majority of respondents to Jackson's survey of the general public regarded earth buildings as 'ugly' when compared with timber and steel, those who said they would like to live in an earth house also found them attractive (Jackson, 2009, p.85). This is consistent with results of this research which canvassed the views of those who do live in earth or straw bale houses. 65% of people who bought existing houses ranked 'Appearance' as the most important or second most important factor in their decision to buy (see Figure 4.12), and over 90% of the original owners rated 'Aesthetics' as a very important factor in their decision to build with earth or straw bale (see Figure 5.13).

The high incidence of owner-builders amongst the survey respondents is the clearest indicator that most of the population have chosen the building material and method specifically because it has afforded them a level of self-reliance and consequential cost savings that might otherwise have been difficult to achieve. Many of them were relatively unskilled but saw that building out of either earth or straw bale was something they could do.

The conclusions drawn from the survey results inform the wider discussion that follows in Chapter Six, about the current state of earth and straw bale building in New Zealand and the potential contribution both materials have as components of sustainable house building methods.

CHAPTER SIX: ANALYSIS

6.1 INTRODUCTION

In this chapter information drawn from the survey results, supplemented by the interviews and further literature review, is used to investigate the central questions of this thesis, as repeated below.

Is there a future for natural or alternative building systems in New Zealand?

Do these methods and the houses they produce have a role to play in the quest for more sustainable housing solutions?

The database information has been used to provide the general history of earth and straw bale houses, recorded in Chapter Four, which provides a background for the analysis that follows. The survey results discussed in Chapter Five have highlighted a number of factors about the earth and straw bale houses in the Nelson area. There is a high incidence of owner-builders; the houses are predominantly located in rural areas; expertise and information sharing amongst earth and straw bale designers, builders and house owners differs from that for conventional building systems; and most owners were happy with the way their houses performed, although some earth house owners were disappointed with the thermal performance of their houses. These findings are discussed in a national context in 6.2 to 6.9.

The various earth building methods and straw bale construction are discussed separately in 6.10 to 6.15. This is followed in 6.16 by a commentary on their performance under earthquake conditions. 6.17 and 6.18 contain discussions on how designs for both materials have changed over time, issues that need to be addressed to ensure their continued use, and current options for building with earth and straw bale in New Zealand. Finally the possibilities for using both materials in new ways are introduced in 6.19.

6.2 OWNER-BUILDERS AND THE LICENSED BUILDING PRACTITIONER (LBP) SCHEME

New Zealand has a long tradition of DIY (do-it-yourself), stemming from a pioneer heritage where people needed to be self-sufficient ‘masters (or mistresses) of all

trades', in order to establish themselves in a new land. This DIY ethic is still strong and many people continue to do work on their own houses without engaging a professional builder. The survey results show that this is particularly common amongst earth and straw bale house owners, as discussed in Section 5.9. Skills are required to build walls out of earth or straw bale but these skills are easily learned, as voiced by Walker and Bell and quoted in 5.13. Three out of every four earth and straw bale houses in the Nelson area had considerable physical input from their owners during construction, and anecdotal evidence suggests that the situation is similar in other parts of the country (Jackson, 2009, p.132). Some of the owner-builders engaged a qualified builder and limited their own involvement to doing general unskilled work and wall building, often under the guidance of the builder, and others carried out the entire building project themselves.

In 2007, an amendment to the 2004 Building Act was proposed, introducing the concept of a Licensed Building Practitioner regime, which would come into effect on 1 March 2012 (NZ Government, 2012). A Licensed Building Practitioner (LBP) is a skilled and/or qualified building practitioner who meets certain competencies set out by the DBH (DBH, 2011e) and only an LBP can carry out Restricted Building Work (RBW), work that is critical to the integrity of the building (2012, Section 7). The scheme was designed to improve the quality of construction nationwide but many feared that it would seriously limit the ability of owner-builders to construct their own homes (Jackson, 2009, p.132). It was not just earth and straw bale builders who were concerned and after serious lobbying from many quarters, including EBANZ, an amendment to the Act was proposed, which provided an exemption for owner-builders. This exemption came into effect on 13 March 2012 and means that anyone meeting the owner-builder criteria as defined in the Act can construct their own house:

"90B Meaning of owner-builder

(1) An owner-builder, in relation to restricted building work, means a natural person who—

(a) has a relevant interest in the land or the building on which the restricted building work is carried out; and

(b) resides, or intends to reside, in the household unit in relation to which the restricted building work is carried out; and

(c) carries out the restricted building work himself or herself or with the assistance of his or her unpaid friends and family members; and

(d) has not, under the owner-builder exemption, carried out restricted building work in relation to a different household unit within the previous 3 years.”

(2012)

This exemption means that owner-builders of earth and straw bale houses will be able to continue the high level of involvement that has been an important aspect of building with these materials to date, with or without the assistance of a LBP.

6.3 LOCATION: RURAL AND URBAN

As reported in Chapter Five and depicted in the pie chart Figure 5.6, nearly 90% of the houses were located on rural properties. Most of these were lifestyle blocks where many of the owners are committed to a self-sufficient lifestyle, as already discussed. This fact of location is consistent with the perception amongst Jackson’s survey group that earth is a material suited to rural rather than urban environments (2009, p73).

There are two aspects to be discussed here in relation to location. The first is the suitability of earth and straw bale to rural locations and the possibilities this has for other people living rurally to use them to build houses. The second is to consider why earth and straw are not used in more urban settings.

In New Zealand there have been a number of community housing projects in rural areas involving the use of earth as a building material. In the Nelson survey, the Riverside houses and a number of houses in Golden Bay fall into this category and there are other intentional rural communities in other parts of the country that have earth and straw bale houses. Jackson discusses two of these, at Kaiwaka and Waiheke Island, in her thesis (2009, p.49). In the North Island there are three relevant projects involving rural Māori communities: at Opotiki in the Bay of Plenty, at Te Hapua in the Far North and the four Whare Uku houses of which two are in Rotorua, one in South Auckland and one in Ahipara.

The projects at Opotiki and Te Hapua involved communities making soil cement bricks and then building houses with them. According to Jackson:

“The Opotiki scheme ran through the 1980s and 1990s and worked with rural Māori to build 8 or 9 houses.” (2009, p.54)

This scheme is no longer functioning but the Te Hapua project is moving ahead slowly with two houses built to date (Laybourn, 2006).¹³

Whare Uku is a project led by Dr Kepa Morgan at the University of Auckland which uses rammed earth with shredded harakeke fibre added for insulation and reinforcement. The fourth and latest Uku project formed part of John Cheah’s doctoral research and involved building a house in Ahipara, Northland in 2010. The online transcript of an interview with Cheah provides information on the system (2010).



Figure 6.1 Whare Uku house nearing completion, Ahipara 2010.

Photo: John Cheah

While it seems clear that both the suitability of a rural location and the potential for unskilled people to be involved in construction are sound reasons for promoting both earth and straw bale as materials for Papakāinga projects, there are some major hurdles to be overcome. One of these is the problem with financing permanent

¹³ Pam Laybourn is the consultant for this project working with the Ngati Kuri Iwi.

heavyweight housing on Māori land, which is communally owned. This is not an issue when financing lightweight timber framed houses which can be easily removed from site should the owner be unable to meet their mortgage repayments. Another difficulty is the need to satisfy the H1 requirements of the NZBC for earth construction discussed later in this chapter (6.8).

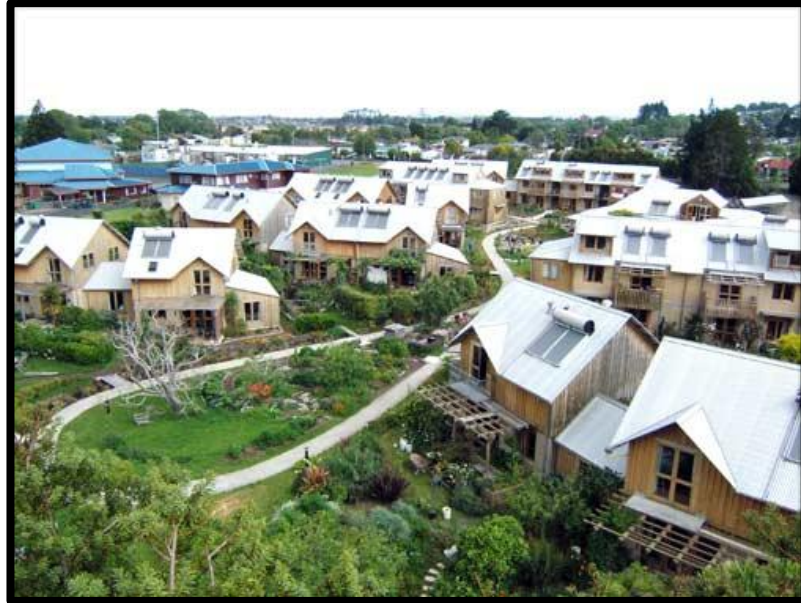


Figure 6.2 Earthsong Eco-Neighbourhood, Ranui, West Auckland.

Photo: Earthsong

The association made between earth and straw bale buildings and rural properties may be a hindrance to more widespread use. The Nelson case study showed that there are fewer earth and straw bale houses built in the inner city, the suburbs and small towns, which is typical for the country as a whole. However, even though the majority of locations are rural, there are few practical reasons why the materials are not suitable for more urban situations, apart from the very smallest of sites where the thicker walls, 300-500mm, take up more space than more conventional materials. While the more urban the scenario the less likely it is that the raw materials, earth or straw bale, can be sourced on site, this is also true for more conventional materials.

The rammed earth houses at Earthsong Eco-Neighbourhood in suburban West Auckland, for example, were built using earth from Muriwai, 30kms from the site. They are the only example of earth construction in a higher density situation in New Zealand. Rammed earth was used to construct the lower storey of the terrace housing

clusters, including the party walls, with timber above. In this case the houses were built under contract by a commercial builder, experienced in rammed earth construction, rather than by residents of the neighbourhood.

There are some examples overseas, where rammed earth has been used for medium density accommodation. For example the Canadian SIREWALL system, where polystyrene insulation is sandwiched between rammed earth panels, has been used in a number of motel and hotel projects (SIREWALL, 2012). This kind of system could have potential in New Zealand, in both rural and urban contexts, and is discussed further in 6.13.

6.4 EXPERTISE AND INFORMATION SHARING

In New Zealand, expertise in particular forms of earth construction and in straw bale has developed in certain areas, and this can often be connected with the microclimate of the area and the resources available there. For instance, in the Nelson area the high sunshine hours which assist drying, and the suitability of the Moutere clays have contributed to the dominance of adobe brick construction over other alternative building methods, with consequent development in design and building expertise. In the Auckland region, the higher rainfall and more granular soils have led to the popularity of stabilised earth construction methods, such as in situ adobe and rammed earth, and the consequent growth of expertise in these areas. For straw bale, expertise has developed more in the dryer grain growing areas of the country, such as Canterbury and Otago, than anywhere else (MAF, 2011).

EBANZ provides the main information sharing forum for both forms of construction, as well as contact details for experts nationwide. It has responded to the interest in straw bale and made a commitment at its 2010 AGM to include other natural building systems as part of its core interest. This is reflected on the EBANZ website where the official name of the association, *The Earth Building Association of New Zealand Inc.* is now subtitled: *Promoting the Art and Science of Earth and Natural Building* (EBANZ, 2010). This is a significant move, as EBANZ provides the only professional forum in the country for experts to share information and for members of the public to seek advice and information. The 2011 EBANZ conference held in Geraldine in South Canterbury

had 'Natural Building' as its theme, and presentations and tours featured earth, straw bale and log buildings.

There is a much closer connection between builders, designers, and home owners engaged in natural building than there is in the conventional building sector, where designers and builders belong to separate organisations which run their own conferences and professional development programmes, and potential home owners rely on the media in the form of books, magazines and television programmes for information. In contrast, EBANZ conferences are attended by owners, builders and designers, and workshops are also attended by all three groups. The most commonly cited source of information for house owners in the survey was owners of existing houses. The sharing of information has been akin to an oral tradition with a direct exchange between individuals via workshops and actual building projects. For example, Sol Design, based in Geraldine, specialises in straw bale construction in several ways: design, building, research and education. Several times a year they run week-long straw bale workshops which are attended mostly by owner-builders, but also by an increasing number of builders and designers (Johnston, 2011). Sometimes both the owner and the builder for a proposed house have participated.

However, the absence of a building code or a national organisation for straw bale building has meant that its development has been more fragmented. Graeme North believes that this stems from the way it was introduced here:

"The earth building scene in New Zealand has really been driven by design professionals, engineers and architects, which added credibility. The straw bale thing was driven more by amateurs ... [they] weren't people really with the design skills or didn't really have the building science knowledge to adapt overseas building methods to New Zealand circumstances." (2011a)

Consequently different straw bale practitioners have used different and sometimes contradictory practices. For example, one company uses straw bale on the inside of standard timber construction with only the exposed surface, the one facing the interior of the house, plastered. The other surface facing into the framed wall is left unplastered. This is contrary to the opinion held by other builders and experts, who maintain that both surfaces must be plastered to ensure the proper performance of

the system thermally, and for fireproofing (King, 2006, p.20). Houses using both systems have gained building consent in the past but it has generally become more difficult to gain consent for straw bale houses since 2010. The lack of agreement amongst straw bale builders and designers, the nervousness of TAs when dealing with a moisture sensitive material like straw, and the absence of an official standard account for this (see 6.5). Further discussion on straw bale construction takes place in 6.15.

Despite the current problems, straw bale houses have been built in many parts of the country over the past sixteen years, and as a consequence there are a number of designers and builders with expertise in the area. This has been supplemented by the arrival of migrant experts from the USA, where the system originated and where there are building codes for straw bale. Sol Design was established in 2004 when Sarah Johnston from Colorado and her New Zealand husband Sven settled in Geraldine. Michael and Spring Thomas, also from the USA, arrived in Golden Bay in 2006 and set up a New Zealand branch of the Sustainable Building Alliance, now based in Invercargill (Thomas, 1992). They too run workshops promoting the use of straw bale and other sustainable building practices. Both these companies have had experience working with building codes in the USA, experience that could prove invaluable if a building code or guidelines were to be developed for New Zealand.

6.5 BUILDING CONSENT

This research is being carried out at a time when those wishing to build with earth or straw bale face new challenges in terms of changes to building codes. The survey was limited to owners of houses that had obtained building consent and that were completed and occupied by 31 December, 2010. Therefore, the results reflect only the ease or otherwise with which consent was obtained. Less than ten percent had difficulty. There is no record of unsuccessful applications but this does not mean there were none. It is likely, however, that many of the participants would have more difficulty gaining consent for their houses if they were applying for them today. There is anecdotal evidence that since 2007, building consents for earth and straw bale houses have become increasingly difficult to obtain both in the Nelson area and

nationally (Hall, 2011a, 2011b). The reasons for this are different for the two material groups. For earth it is the need to comply with the revised H1 requirements of the NZBC, which concern thermal performance, and for straw bale it is the need to comply with the E2 requirements, which relate to external moisture. The specific issues for each material will be discussed later in this chapter (6.10-6.15).

Coupled with these specific issues is the fact that since March 2005, when the 2004 Building Act came into force, requirements for building consent applications and their subsequent processing have been upgraded across the whole building industry making this part of the process more onerous than it had been previously.

The 1998 Earth Building Standards are classified as an 'Acceptable Solution' in terms of the NZBC which means that if they are followed *"a building will automatically comply with the Building Code"* (DBH, 2011c). This means that TA consenting officers have something on which to base their appraisal. Even when an application for an earth house contains aspects that fall outside the scope of the standards, there is at least a starting point for analysis.

Building consent applications for straw bale houses, on the other hand, are made as 'Alternative Solutions', which is a more complicated process. From the DBH website:

"An alternative solution is a building design, of all or part of a building, that demonstrates compliance with the Building Code..."

To obtain a building consent for an alternative solution, a building consent applicant must demonstrate to the building consent authority that a proposed alternative solution will comply with the requirements of the Building Code. Only then will a building consent be issued.

The building owner (or the owner's agent, such as an architect, engineer or builder) needs to provide sufficient evidence that the proposal will meet the provisions of the Building Code." (2011b)

There has been quite a variation between TAs in what has been required to *"provide sufficient evidence"* that the building meets the requirements of the NZBC. In Central Otago, for instance, it has become so difficult to gain building consent that a number of people who wanted to build out of straw bale have changed their minds and settled

for using conventional systems (Hall, 2011a). The ‘leaky buildings’ crisis has understandably created an environment of extreme caution with some TAs (NZ Government, 2002).

There have been a number of instances where straw bale house projects that have either failed to gain building consent, or been refused a code compliance certificate, have been taken to determination.¹⁴ These determinations can be viewed on the DBH website and are significant in that, of the five cases outlined, the TA’s decision not to issue either consent or code compliance were upheld, but the determination outlined what must be done in order for the projects to satisfy the requirements of the Building Act, thus setting a benchmark for future applications (DBH, 2012). At the 2011 EBANZ conference Robert Wright, a former building inspector and now a private consultant, gave a lecture entitled, *The Building Act and the Building Code: Survival Tips for Natural Builders* (2011). He emphasised the importance of presenting well researched and organised applications that made it easy for TA inspectors, unfamiliar with the systems proposed, to navigate the application documents and access supporting information. He also suggested that where TAs are known to be opposed to a particular system that it may be useful to go straight to determination before submitting a building consent application.

In the course of carrying out this research the author has spoken with building inspectors, from both NCC and TDC, who have commented that applications for alternative solutions need to be accompanied by good documentation and that in their experience those wishing to build using alternative materials have researched their chosen materials well and have provided the necessary supporting information (Hall, 2011d). In terms of the viability or sustainability of straw bale as a building system, then, it is possible for those willing to carry out the extra work necessary, or to pay a professional to carry out that work for them, to apply for building consent as an alternative solution, but the complications involved make it too onerous for others and are therefore a barrier to progress.

¹⁴ A determination is a binding decision made by the Department of Building and Housing. It provides a way of solving disputes or questions about the rules that apply to buildings, how buildings are used, building accessibility, health and safety.

6.6 INDOOR ENVIRONMENT QUALITY OF EARTH AND STRAW BALE HOUSES

For the purpose of this research, Indoor Environment Quality (IEQ) refers specifically to the humidity, acoustics, and toxicity inside houses. Thermal performance is treated as a separate category and is discussed in 6.8. 90% of the survey respondents rated IEQ as ‘very important’ when considering building in earth or straw bale, see Figure 5.13. As shown in Figure 5.22, when these respondents rated the actual IEQ of their finished houses most were not disappointed. 95% of respondents thought their house performed well regardless of whether it was built in earth, straw bale or a combination of the two, see Figure 6.3. These results are in line with overseas laboratory research in this area.

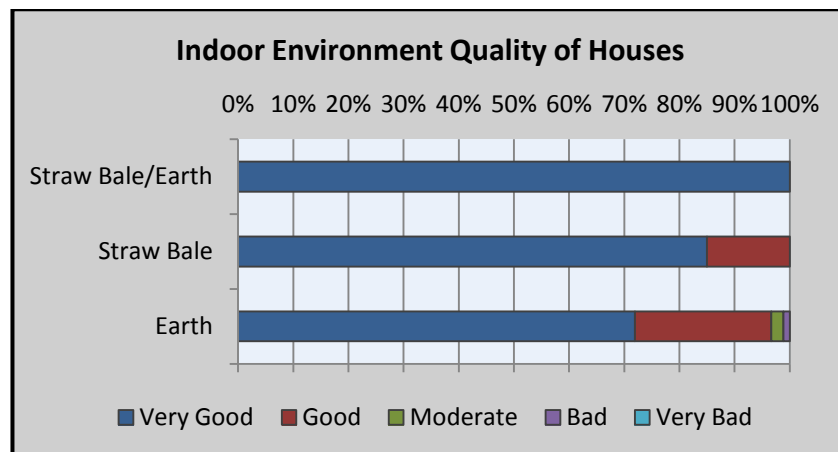


Figure 6.3 Indoor Environment Quality (IEQ) by Material Type

With regard to humidity the hygroscopic qualities of earth and straw bale, which mean that both materials are inherently able to moderate interior environments, are well known. Research guided by Gernot Minke at the University of Kassel in Germany and John Straube at the University of Waterloo in Canada supports the anecdotal evidence:

“Loam [earth] is able to absorb [sic] and desorb humidity faster than any other material, enabling it to balance indoor climate.” (Minke, 2009, p.14)

Straube’s comprehensive report *Building Science for Straw Bale Buildings* (2009) clearly describes how, if built correctly, straw bale walls are able to hold moisture, be it in the form of airborne water vapour, or moisture that has entered the wall system through a penetration, and then allow its subsequent diffusion and/or evaporation. This will be discussed later with regard to watertightness and the problems being experienced

currently in addressing the E2 performance criteria of the NZBC when applying for building consent (6.14). The more recent move to use earth plasters internally for straw bale houses is particularly beneficial in relation to internal humidity control.

Two adobe brick houses designed by the author and included in the survey have performed well acoustically as places for playing and listening to music. The first, completed in 1992, included a practice and performance studio for a professional pianist, and the second, completed in 1995, was for a serious music buff whose sitting room was a dedicated listening space. In both cases the acoustic properties of the earth were known and provided an added reason for choosing the material: the mixture of absorption and reverberation provided by the earth walls creates a lively but not too sharp acoustic. Minke has specifically used earth bricks because of their acoustic properties in a multi-purpose hall in Germany, but the author has been unable to find evidence of testing for these properties (Minke, 2007, p.97).

Straw bale, particularly if earth plasters are used, performs similarly well for playing and listening to music. Research carried out in the Netherlands into the sound insulation qualities of straw bale showed it also performs very well where sound isolation is required. A report on this research by Rene Dalmeijer (2009) is reproduced in *Design of Straw Bale Buildings* edited by Bruce King (2006). A straw bale sleepout designed and owned by the author illustrated this. Located 15m from the main house, when it was used as a practice space for loud acoustic instruments, the sound was barely audible outside.

Over 90% of respondents in the survey rated 'health benefits' as being important or very important and a number of them added comments about this with regard to the non-toxic nature of both the finished product and the way it is manufactured. One adobe house owner of 15 years said, *"Our house never 'smells' which proves the effectiveness that walls do indeed 'breathe'."* He may have been alluding to the claims discussed by Minke that earth walls can remove toxins from the air. Minke observes that although there has been no scientific evidence to date to support the claim that *"earth walls help to clean polluted indoor air"* it is known that earth walls can absorb pollutants dissolved in water (2009, p.15).

The results of the survey and the other research discussed above indicate that the IEQ of earth and straw bale houses is very good. The ability of both materials to moderate humidity within buildings, in particular, is an important attribute at a time when houses are becoming increasingly better sealed as part of the drive to make them perform more efficiently and hence potentially make them more sustainable.

6.7 DURABILITY OF EARTH AND STRAW BALE HOUSES

There are not many materials with better credentials in terms of durability than earth. Some of the oldest surviving buildings in the world are made of earth, and this is also the case in New Zealand where some of the oldest surviving buildings, such as Pompallier House (Figure 2.1), are earth. This inherent longevity is a factor that has attracted many to the material.

Both Rau Hoskins and John Cheah refer to this longevity as an appealing feature for Māori for Papakāinga development. With reference to the fourth Whare Uku house built at Ahipara in 2010 Cheah refers to the iwi's goal: *"Houses that last 6 generations was decided as a good target lifespan towards which to work."* (2010)

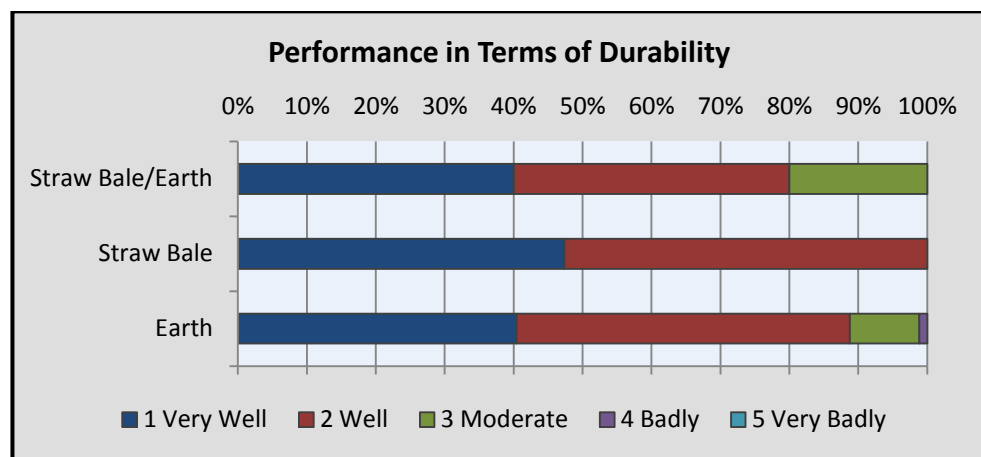


Figure 6.4 Durability of Houses by Material Type

The durability, and hence longevity, of earth is also however dependent on building design, maintenance, and the quality of the materials and workmanship. The Earth Building Standards provide rules and guidelines to facilitate this which may explain why there were very few instances of dissatisfaction amongst the survey respondents with regard to the performance of their houses in terms of durability, see Figure 5.22.

When broken down into the three main materials, as shown in Figure 6.4, there are only slight differences. The only possibly significant factor was that no owners of pure straw bale houses rated them lower than performing ‘well’. None of the houses with a straw bale component was older than fifteen years at the time of the survey so the answers to questions about durability carry less weight. In the USA, however, there are 100 year old straw bale houses still in good condition and still being used (Steen et al., 1994, p.5).

Nine respondents elaborated on their responses to the durability question, all of them with reference to problems they experienced with earth walls. Four talked about problems with dust internally and five were concerned about exterior weathering. One person suggested that the dust problem may be a result of the very dry interior environment. Whatever the cause, the problem is not universal and could be solved by applying a surface coating like casein paint, gypsum plaster, or natural paint. These coatings and others have been used in houses designed by the author and were also recorded by some survey respondents in annotations on their questionnaires.

Of the five respondents who experienced problems with exterior walls weathering, two have applied surface treatments and one, who purchased an existing adobe brick house, has clad over the entire exterior with timber weatherboards both to improve the thermal performance and *“to prevent walls dissolving in the rain.”* This last opinion seems extreme but without knowing more about the house in question the owner’s view must be taken as read.

The interviews with experts that followed the questionnaire revealed some interesting points about the durability of adobe. There have been problems with weathering in exposed locations, but it is difficult to say whether these present a serious threat to the durability of the walls or whether they are merely cosmetic. Peter Olorenshaw has deliberately left an exposed corner of his house to weather and is monitoring the rate of deterioration, Figure 6.5. As he said people are:

“...used to [things] like concrete and fired bricks that don’t weather, so when something weathers they think ugh, its falling apart.” (2011)



Figure 6.5 Exposed corner, Olorenshaw House, Nelson Photo: MH 2011

Verena Maeder also supported the view that the issue is merely cosmetic:

“...it’s a visual thing, it won’t wash away. And it finds a place of equilibrium where it sort of seals itself. It’s just a visual thing. If you want it immaculate then you have to redo it but the actual bricks are not affected and they get wet and dry out again where if you have paint, water gets behind the paint and you have to redo the paint and it starts rotting out the boards. Mud brick doesn’t rot.” (2011)

Maeder went on to talk about her experience with her own house in 2008 when, during a severe storm that brought down trees and closed roads, horizontal driving rain reached the lower part of an adobe brick wall normally protected by a veranda, and caused some erosion.

“The coating, the bagging was stripped away...It took us an hour of re-doing. We just quickly slurried over and that was it, it’s so easy. It’s easier than repainting.” (2011)

In any case, extra protection can be provided for exposed walls. Richard Walker has used lime plaster on the very exposed north facing adobe walls of his ten year old house and is very pleased with their performance. The plaster is coated with a long

lasting silicate paint¹⁵ or lime washed every three or four years (Walker, 2011). In December 2011, after the interviews and survey took place, the Nelson area was hit by serious rains and flooding. Walker reported that despite being subjected to unprecedented and sustained rain to the exposed north walls, the lime plaster performed well and the walls were not damaged (2012). Another adobe brick house in Golden Bay, also included in the survey, was exposed to fast flowing water, followed by being left in standing water 400mm high for four hours, after a stream changed course behind the house in the same weather event. One of the owners, Reto Balzer, reported that the earth walls were unaffected, despite the bottom three courses being submerged for four hours. The lime plaster, which included animal fat, protected the walls and kept them dry (2012).

Even though there have not been any serious problems with earth walls in the Nelson region, there have been some in other parts of the country. The most notable and damaging event involved compressed soil cement bricks manufactured by Excalibur Bricks, which operated out of South Canterbury in the late 1990s. The company manufactured two kinds of brick, one for solid wall construction and one to be used as a veneer. The results of tests carried out by BRANZ and by EBANZ on the bricks intended for solid wall construction only, were used as a means for getting acceptance for both kinds of bricks from TAs and the marketplace. Unfortunately the veneer bricks proved to be of inferior quality and began to disintegrate on a number of houses including 30 located in the Timaru district. The houses have since been reclad using other materials and Excalibur Bricks has closed down (Wright, 2012).

Graeme North has been called in as an expert witness in up to ten cases involving earth building failures. He reports that

“...it’s nearly always involved moisture related problems. The problems nearly always tend to leaking initially and sometimes to failure of materials.” (2011a)

However the great majority of earth buildings have performed satisfactorily in terms of durability and those that have failed have not been built in accordance with the Earth

¹⁵ The paint used is Keim, a German product supplied by Equus Industries. EQUUS (2007) <http://www.equus.co.nz/content/datasheet-pdf/keim-granital.pdf>.

Building Standards. There are also many older earth buildings scattered around New Zealand, built in the nineteenth century, that have survived to this day and which are still in use as discussed in Chapter Two. The other major question concerning durability is the resilience of earth buildings under earthquake loadings which is discussed in 6.16.

6.8 THERMAL PERFORMANCE OF EARTH AND STRAW BALE HOUSES

The earth and straw bale houses in the Nelson survey were built between 1948 and 2010. During this 62 year time frame, expectations of thermal performance and associated legal requirements for thermal insulation have changed dramatically. Prior to 1978 there was no national mandatory requirement for new houses in New Zealand to be insulated, although two South Island TAs introduced insulation bylaws in 1971 and 1972. The minimum insulation requirements introduced in the 1978 legislation were increased in 2000, again in 2004, and most recently in 2007, with the amendment to clause H1 of the NZBC (Isaacs, 2007). Alcorn's research illustrates the extent of these changing insulation requirements. He theoretically modelled a 200m² New Zealand timber framed house from 1970 to 2020 using R values that were typical of their period, including a projection of what they might be in 2020 and found that:

"The average percentage increase in R values from 1970 insulation levels to 2000 levels is 178%, reflecting the low levels of insulation in 1970s houses (and the general New Zealand housing stock). The average R value change from the 2000 to 2010 models is 66%." (2010b, p.3)

The 2007 changes to mandatory insulation requirements do not present a problem when using straw bale walls which have an R value well above the minimum level. The same is not true for most earth walls, however, and many of the existing earth houses in New Zealand would no longer meet the minimum requirements of clause H1 if they were being assessed for building consent today.

The experts interviewed, Peter Olorenshaw, Mark Fielding, Verena Maeder, Richard Walker, Graeme North, and Rau Hoskins, confirmed that solving the issue of poor thermal performance of earth walls is the biggest challenge for their continued use.

The reality is that earth performs well with regard to its thermal mass (its ability to store heat) but not well in its capacity to insulate (to prevent the passage of heat from warm interior spaces to a colder exterior). However, it is not obvious that a significant problem exists on the basis of the survey results, which probably reflect the low level of internal temperatures accepted in New Zealand houses, as borne out in the BRANZ Household Energy End-Use Project (HEEP) (Stocklein et al., 2002).

Figure 6.6 shows a breakdown of the answers to Question 6.02, which asked respondents to rate the thermal performance of their houses, according to material type. 68% of earth house owners considered that their houses performed ‘very well’ or ‘well’ and 7% felt they performed ‘badly’ or ‘very badly’. 85% of straw bale house owners rated their houses highly as did all of the straw bale/earth hybrid house owners, which suggests the owners and or designers had a better understanding of the thermal properties of both materials. This is discussed further in 6.17.

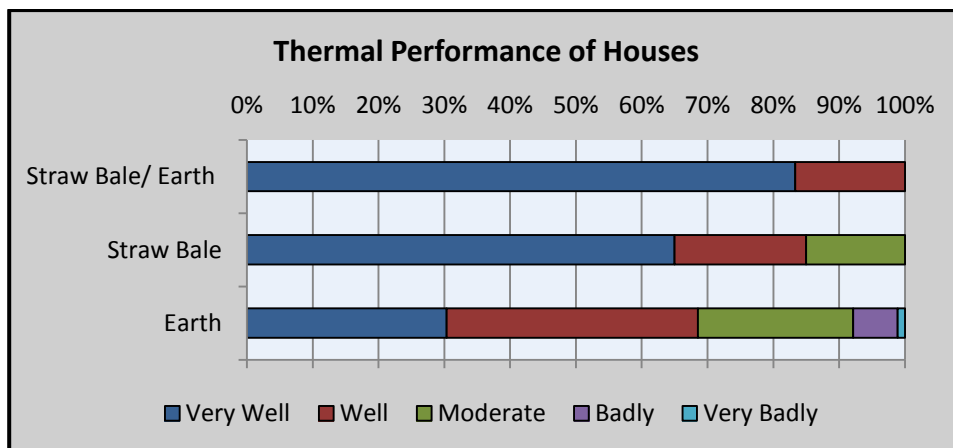


Figure 6.6 Thermal Performance by Material Type

It is clear that two-thirds of the earth house owners did not believe their houses were underperforming thermally, although notes added by some seem contrary to how they rated their houses. For instance one adobe brick house owner, who rated their house as performing ‘very well’ thermally, added this note: *“Southern adobe walls tend to suck heat from the house.”* While it is possible that some house owners were reluctant to acknowledge thermal failings because of the time and money they had invested in their houses, the high ratings may also reflect owners’ relatively low expectations of comfort levels and how they expected to operate their houses. For example, most houses had wood or gas fuelled heating sources which may be kept running

continuously through most of the winter to maintain a comfortable interior temperature, and this may be exactly what their owners expected to happen from the outset. It would also explain why 80% of house owners who had high expectations of thermal performance when they chose to build an earth house rated their houses as performing 'well' or 'very well', see Figure 5.23. In many cases the same heat source was used for heating water and for cooking. Interior walls were usually constructed of earth also and in some cases heat stored in this extra thermal mass may have off set to a degree the poor performance of the exterior walls. For example, where radiators supplied with water heated by a wood burning range were adjacent to earth walls the stored heat in these would continue to warm the room even when the wood burner was no longer running.

The thermal issue for earth houses is not simply a matter of the difficulty in complying with the legal requirements necessary to obtain building consent, but is a very real concern about the thermal comfort experienced within the houses. This is illustrated by the responses of the fourteen owners of earth houses which are not connected to the national electricity supply grid. These houses were not legally required to comply with the H1 requirements, which are concerned with energy efficiency, because they were not reliant on electricity supplied from the national grid (DBH, 2011a). Yet the percentages of satisfaction or not with thermal performance was very similar to those respondents whose electricity was supplied from the national grid: 65% of owners of independently powered houses thought they performed 'well' or 'very well', while 35% rated the performance as 'moderate' or 'badly'.

There are two aspects to discuss in relation to the thermal shortcomings of earth. The first is the thermal resistance of the material itself and the second is the design of the houses.

Earth walls, be they adobe brick, soil cement bricks, cob or rammed earth are typically around 280mm thick. According to the Earth Building Standards walls of this thickness have a thermal resistance rating of R 0.69 (SNZ, 1998a, Clause 3.5.2). This no longer satisfies the code which requires minimum R values, measured in $\text{m}^2\text{C/W}$, ranging from 0.8 in the top of the North Island to 1.2 for the whole of the South Island for solid

earth walls.¹⁶ The NZBC handbook for H1 sets out a verification method for calculating the thermal resistance of the building envelope for solid construction excluding solid timber, H1/VM1. A footnote to the relevant table recognises the difference between reliance on thermal resistance as is the case for timber framed construction and straw bale, and a reliance on thermal mass as is the case for earth:

“Table 2(b) allows buildings of solid construction to have lower R-values than buildings of non-solid construction, due to the benefits of appropriate use of thermal mass. Thermal mass must be used in conjunction with good passive design to increase comfort and reduce energy use. Use of the R-values in table 2(b) requires that the thermal mass is accessible, i.e. inside the insulated building envelope. If additional bulk insulation material is required to achieve the R-values in this table, this insulation must be installed on the outside of the wall.” (DBH, 2011a, p.18)

Changes to earth materials and methods in response to the thermal issue are discussed in 6.10 to 6.13.



Figure 6.7 Adobe brick house, Nelson, 2000

Photo: MH 2011

It is not only the properties of the material which have been responsible for the poor performance of some earth houses; in many cases it has also been the design.

¹⁶ Table 2(b) from Clause H1, NZBC is reproduced in Appendix 8.

Concerns about protecting the earth walls have often led to the creation of large overhangs in the form of verandas, which has meant that the essential principles of passive solar design have not been applied. In other words the large overhangs have prevented sunshine from reaching and warming the thermal mass of the building at crucial times of the year. The veranda in Figure 6.7 creates a sheltered and sunny outdoor living space, but prevents any sun from reaching either the exterior walls or the interior of the house for much of the year. This basic design, with a veranda wrapping around most of the house, follows an Australian model and was popular amongst earth house owners during the 1990s. In most of Australia, the climate is warmer than in New Zealand and the wide verandas are beneficial in that they protect the high thermal mass walls from overheating by overexposure to the sun. This is not an issue in New Zealand and these deep and extensive verandas have had a negative effect. Options for mitigating the negative effects are discussed in 6.9.

Ten houses in the survey used adobe or soil cement bricks as an internal veneer, in a conscious effort on the part of their designers to capitalise on the thermal mass characteristics of the material. 80% of the owners considered their houses performed 'well' or 'very well'. Designer Mark Fielding of Ecotect Limited has used this idea in his Solabodes, two of which are included in the survey. The exterior of the houses are



Figure 6.8 Solabode, Golden Bay, 2010

Photos: Mark Fielding

timber framed, insulated, and clad in profiled metal, while internally they utilise adobe bricks both as veneer and as load bearing walls which has provided thermal mass.

Lawrence McIntyre took the idea a stage further in the Little Greenie in Golden Bay incorporating both passive solar design and passive house design principles (IPHA, 2012). He used super insulation, super sealing and double framing so that the exterior insulative walls are isolated from the thinner interior ones with all their inherent heat leaking penetrations for services. Adobe bricks were used internally for thermal mass. This little house has demonstrated how the thermal mass properties of earth can be used to contribute to excellent thermal performance. In 2009 it received a Home Energy Rating Scheme (HERS) score of 9, the highest for any house in New Zealand (EECA, 2009a).



Figure 6.9 Little Greenie, Golden Bay, 2008

Photo: MH 2011

Light earth is a material that contains a significantly higher straw content than the other earthen materials and therefore has a higher R value. Therefore it is not surprising that five of the six owners of light earth houses in the survey were 'very happy' with their thermal performance. Research funded by the Canadian Mortgage and Housing Corporation (CMHC) carried out by Joshua Thornton, and that carried out by Gernot Minke in Germany, show that light earth walls of the density normally achieved, give a thermal resistance value of $R0.33 \text{ m}^2\text{C/W}$ per 25mm. For a 150mm wall this would give an R value of $1.98\text{m}^2\text{C/W}$ which, if rounded to R2.0, is within the requirements of Clause H1 in the NZBC for all of New Zealand (Thornton, 2004, p.40). The walls in the six houses included in the survey were at least 150mm thick.

Thornton's imperial figures and units have been converted to metric in the calculations.

The owners of straw bale and straw bale/earth hybrid houses were happy with the way their houses performed thermally, see Figure 6.6. This is to be expected given the insulative properties of straw bale are a major reason for its popularity. Testing of full scale walls at the Oak Ridge National Laboratories in the USA and also at the Technical University of Nova Scotia in Canada showed that a conservative estimate for the R value of straw bale walls lies in the range R4.5 to R5.3 m²°C/W which is well above the minimum requirements of H1 (King, 2006, p.193) (Straube, 2009). Not only is it above the minimum requirements it is also higher than that considered 'Best Practice' in New Zealand (Smarter Homes, 2011).

Despite a general satisfaction amongst owners with the thermal performance of earth and straw bale houses in the Nelson survey, the 2007 changes to clause H1 of the NZBC have drawn attention to problems with most forms of earth construction in this respect. This has resulted in changes to the design of new houses, the way materials are used, and the materials themselves. These changes are discussed in 6.10 to 6.13.

6.9 RETROFITTING EARTH HOUSES TO IMPROVE THERMAL PERFORMANCE

In 2009 the EECA estimated that around 900,000 homes in New Zealand had substandard insulation and set up a programme, *Warm Up New Zealand: Heat Smart*, to address the problem (EECA, 2009b). Subsidies are provided for clean heating sources and for house owners to retrofit insulation under their floors and inside their ceiling spaces. The Homestar™ rating scheme discussed in 1.1 also provides encouragement for people to improve the thermal performance of their houses. The *Warm Up New Zealand* scheme does not provide funding for retrofitting insulation to walls, a more complex and costly exercise. However when older timber framed houses are renovated, insulation is often retrofitted behind new interior wall linings and/or exterior cladding.

Just as it is possible to improve the R value of walls in older timber framed houses, it is also possible to do this for earth houses. A good example of this is a house built in



***Figure 6.10 Adobe brick house, Moutere - North and East walls of house
and bank to West***

Photo: MH 2011

1996 in the Moutere sub-region, which is the only one in the survey where its owners rated the thermal performance as ‘very bad.’ Nathan and Jodie Fa’avae bought the house in 2003 and extended it substantially in 2005, using the same adobe brick construction, this time with double glazed windows, and following the same ‘Australian style’ of the rest of the house, with verandas wrapping around all the north and east walls, see Figure 6.10. The house is built close to a high bank to the west which prevents afternoon sun from reaching it. Heating the enlarged house with its greatly increased area of exterior earth walls turned out to be extremely expensive, so much so that the owners chose not to heat it continuously through the winter. In a testimonial on the *Little Greenie* website Nathan Fa’avae describes their experience and engagement of Lawrence McIntyre to retrofit insulation to the south and west walls of the house (McIntyre, 2010). Additional insulation was placed at foundation level and timber framing was added to the outside of the south and west adobe walls with profiled metal cladding and wool insulation, see Figure 6.11. Particular care was taken to seal all openings and additional insulation was added to the ceiling space. Stage 1 was completed before the winter of 2011 and Fa’avae reported that the improvement in the thermal performance was marked (2012). It is intended to complete the retrofit of the north and east walls as Stage 2 of the project.



***Figure 6.11 Retrofitted timber framing, cladding and insulation to
1996 Adobe house in 2010***

Photo: MH 2011

The method described above is not only applicable for adobe brick houses; it could also be used for houses with exterior earth walls of any type. By providing a new exterior envelope the earth walls effectively become interior walls and their inherent value as thermal mass can then be utilised. However, this additional work will add to the overall embodied energy of the walls, somewhat negating the low embodied energy of the earth. This is an area for further research using LCA techniques. Further improvements could be made to the Fa’avae house, and others built with extensive verandas, by replacing some of the veranda roofing material with glass to allow sunlight to reach the interior.

6.10 ADOBE BRICK

In Chapter Four the predominance of adobe brick over other earth materials in the Nelson area was discussed: 70% of earth houses in the database incorporated adobe brick. There is no empirical data available to compare the Nelson situation with the rest of New Zealand but it is unlikely that the percentage of adobe brick houses would be as high elsewhere. In the other areas where significant pockets of earth buildings are found (see Figure 1.1) it is common for the earth material to be stabilised with cement in the form of in situ adobe, soil cement bricks or pressed earth bricks (North, 2011a) (Olorenshaw, 2011).

Building with adobe brick is an accepted and well established construction method in terms of expertise and skill. Completed houses have performed well in terms of IEQ and durability but not thermally, as discussed in 6.8. Prior to the introduction of the revised H1 requirements, earth building proponents were proactive in addressing the issues and experimenting with the material to improve its thermal performance. In Nelson this was instigated by Peter Olorenshaw and Verena Maeder who experimented with a number of additives to adobe brick mixes:

“We tested mixes with pumice, with vermiculite, with straw, with sawdust, with wood chips, and then with paper pulp. And we made mixes with 25, 50 and 75% light aggregates and took them all to the lab and destroyed them. And it was just so obvious that the ones with paper pulp were just superior and stronger.”

(Maeder, 2011)



Figure 6.12 Light Adobe brick and conventional Adobe brick, Solid Earth Yard, Nelson Photo: Verena Maeder

This experimentation led to the manufacture of a new lightweight brick sold under the trade name ‘New Generation’ (Figure 6.12). These bricks were laboratory tested for strength and for thermal resistance at the Department of Physics at University of Otago and the results showed that walls could be built with R values of 1.2 and 1.9 for

walls 280mm and 430mm thick respectively (Lloyd, 2008). This is more than adequate for the whole of New Zealand when applying the H1 verification method discussed in 6.8. Two houses using these New Generation bricks were completed in 2011 (see Figure 6.13) and an equivalent lightweight brick is available in Northland.

The reduced weight of these new bricks, 7kg each, is an added advantage for builders. The standard heavyweight adobe brick used in New Zealand, nominally 300x300x150mm, is the same size as that used in Australia and weighs 12-17kg when dry, depending on the exact dimensions and mix. Bricks of a similar size are also commonly used in the USA and earth building codes in most western nations have been based on these dimensions, further reinforcing the continuing manufacture of



Figure 6.13 House completed 2011 using New Generation bricks, Golden Bay

Photo: MH

bricks of this size. However, while these bricks make sense in terms of their production where machinery can be used to move both the raw material and the finished product, they do have the disadvantage of being heavy to lift when building the walls. Within New Zealand's earth building community people joke about earth builders having elongated arms. One survey respondent commented that he and his partner *"both have arms that drag on the ground – it's a massive effort to build in adobe..."* (Adobe house owner, consented 1998)

In other parts of the world where earth building has been part of a vernacular tradition for centuries the brick dimensions are much smaller. Typically they are 50mm thick as

opposed to 150mm and weigh considerably less. In his book *Ceramic Houses*, Nader Khalili commented on these smaller dimensions:

“Such sizes and dimensions are used all over the world because they are usually easy to handle – small blocks can even be tossed in the air to reach the workers on the roofs.”

And when referring to the larger bricks he had this to say:

“Only strong husky men can handle these blocks – smaller or older men, women and children are out of the picture.” (1986, p71)

There are a number of women in the Nelson region, and in the rest of New Zealand, who have not been daunted by the weight of the bricks and who have taken a very active role in constructing their houses, but it may well have put others off. Peter Olorenshaw made smaller bricks for his own house, 200x400x150mm, which reduced the weight by 2kg per brick. He had been impressed by the smaller bricks shown in the book *Mud Brick and Earth Building the Chinese Way* (Edwards and Wei-Ho, 1994), citing the reduced weight as being a major reason why he chose to make his bricks smaller than the “*man sized bricks*” commonly used in New Zealand (2011). The new insulative adobe bricks reduce the weight even further and will certainly alleviate some of the hard graft involved in earth brick construction.

6.11 IN SITU ADOBE, SOIL CEMENT AND PRESSED EARTH BRICKS

In the Nelson area, houses built using soil cement bricks, including pressed earth bricks, make up only 11% of the total earth house population; there are no known houses built using in situ adobe, which is more common in the North Island. Unlike adobe, it is difficult to add lightweight insulative materials to earth mixes containing cement without compromising the stability and strength of the finished product. This has serious implications for the continued use of in situ adobe, soil cement bricks and pressed earth bricks for exterior walls. Their continued use is more likely to be in the form of interior veneers to timber framed exterior walls or as interior walls only, where their thermal mass characteristics can be utilised.

Some houses built using pressed earth bricks did not perform well in the Canterbury earthquake of February 2011; this is discussed in 6.16.

6.12 COB

Cob was the earliest method of constructing earth houses in the Nelson area. Settlers from the UK brought the techniques with them and adapted these to suit the materials at hand. It is interesting then, that no cob houses were recorded in the area between 1945 and 2004 when one was built in Golden Bay. There are a total of three in the survey, all recent (see Figure 6.14), and a further two are known to be under construction. Cob was not included in the Earth Building Standards, and this may be a reason for the low uptake. Despite the fact that some of the oldest surviving earth buildings are built with loadbearing cob walls and that many of them have survived significant earthquakes in the past one hundred years (see Figure 2.2), loadbearing cob walls are difficult to quantify structurally. The recent cob houses all incorporate post and beam structures and the walls serve as infill; they are quite different structurally from their predecessors.



Figure 6.14 Cob house with Post and Beam structure, Nelson, 2006

Photo: Richard Walker

Cob is a more fluid medium than other earth building methods and one survey respondent referred to this in response to the last question in the survey, 6.11: *“If you were to build or buy a house again what material or construction method would you chose and why?”*:

“... will build the next one in cob fashion as found adobe block very time consuming and restricted as far as artistic design goes” (Adobe house owner, consented 2000)

If the earth material on site is suitable and close to the building area, then the advantage of a one step process of mixing and lifting straight on to the wall is clear and if owner builders have more time available than money, the cob process means they do not have to purchase the bricks. However there are some disadvantages. As Maeder pointed out, *“...it’s quite hard work because you’re actually lifting wet weight”* (2011). Richard Walker, who was the engineer for all the new cob houses, was positive about the material but highlighted some construction issues:

“Cob is fine because it’s basically structurally the same as adobe. But generally with cob in the New Zealand climate, I think it’s best if you put up a post and beam structure first because cob construction takes a lot longer and with the roof on there’s really no issue with it, whereas with adobe you can put the walls up for your house in two or three weeks. So I think cob is a great form of construction but it’s a little more critical in terms of time and weather protection.” (2011)

Walker also suggested that if a machine for making the mix was devised a lot of the hard work could be avoided; such machines are used overseas.

As with other earth materials, it is still difficult to satisfy the H1 requirements for thermal insulation. The wall thickness required for cob to achieve an R value of 1.2, as required for houses in Climate Zone 3, which covers all of the South Island and central North Island, is 530mm (SNZ, 1998a, Clause 3.5.2). The large amount of extra material required, for the reinforced foundations and the walls, and the consequent cost of this, makes the use of walls at these widths untenable. Ironically, earlier nineteenth century cob houses typically had walls over 500mm thick and would have satisfied the H1 requirements. There has been some experimentation with adding lightweight materials to cob mixes in Northland, using similar materials as those used for the lightweight adobe bricks (North, 2011a). This is a more practical way of addressing the insulation issue and has the added advantage of making the mix lighter and therefore easier to handle.

Seeking to use age old techniques in a modern regulated context raises an additional problem. As Joshua Thornton states in the introduction to his research paper *Initial Material Characterisation of Straw Light Clay*:

“One of the most definitive characteristics of current building practice is the need to adhere to building codes and standards. These codes are often based upon evidence gathered from laboratory analysis of materials characteristics. Therefore, placing natural building materials in a contemporary context requires testing which demonstrate [sic] basic material properties.” (2004)

However, materials like earth and straw are not supplied or supported by the wider construction industry and therefore there is no incentive for businesses and agencies to supply funding for the testing required.

6.13 RAMMED EARTH

Rammed earth has not been a common technique in the Nelson area largely because no one has set up a business specialising in it. Perhaps if someone had done that in 1990, when Ralph Butcher began producing adobe bricks commercially, the make-up of housing types in the region would have been quite different. Ironically, this someone could have been Butcher himself. In the paper he presented at *Earth Building for the '90s* in Auckland in 1990 he wrote:

“My preference initially was for rammed earth construction...After seeing Richard and Bella’s [Walker’s] house, Richard succeeded in converting me to adobe bricks as a construction method.” (1990)

Building rammed earth walls is more complex than building adobe brick walls. Boxing is required and it is more difficult to maintain consistency when ramming the soil mix, so it is not so well suited to the unskilled owner builder. Regardless of this, of the thirteen rammed earth houses on the database, eleven were built by their owners. The owner of the house shown in Figure 6.15 worked consistently on the project under the guidance of a qualified builder.

The rammed earth technique is very similar to building in situ concrete walls, and in fact it was the forerunner of the latter (Rael, 2009, p.10). Building in situ concrete is a

technique that most commercial builders are familiar with and there are a few in New Zealand who specialise in rammed earth building, such as those in Northland and Central Otago. Houses built out of rammed earth have performed well under earthquake loading. Nine of these, built between 1950 and 1980, were included in the EBANZ survey following the Canterbury Earthquake in February 2011. All were built before the Earth Building Standards and all of them performed well with only minor damage in the form of superficial cracking. One older rammed earth house, built in 1925, suffered more serious damage and will require remedial work. The EBANZ survey is discussed further in 6.16 (Morris et al., 2011).



Figure 6.15 Rammed Earth house, Moutere, 2001

Photo: MH 2011

The insulation problem is even more of an issue with rammed earth. The dense nature of rammed walls means that their thermal resistance is less than that for adobe and makes using them for housing in the colder parts of New Zealand, those in Climate Zone 3, difficult. The Whare Uku project, discussed in 6.3, is the only known New Zealand example of an attempt to improve the thermal resistance of rammed earth walls. Although the introduction of shredded harakeke fibre to the mix improves the R value of the wall system, it is still well short of the minimum value required (Cheah, 2012).

The poor thermal performance of rammed earth walls is not a problem peculiar to New Zealand. The patented Canadian SIREWALL system, discussed in 6.3, uses Stabilised Insulated Rammed Earth (SIRE) walls to achieve R values in excess of R

5m²°C/W (SIREWALL, 2012). Private houses and commercial buildings have been built using this system, the most publicised project being the Nk'Mip Desert Interpretive Centre in British Columbia built in 2006 (Rael, 2009, p.104). The solution is a high tech one requiring significant amounts of reinforced concrete for the foundations, steel reinforcing in the walls and polystyrene panels for the insulative core. None of these materials rate well from an embodied energy point of view (Alcorn, 2003), although this does not take total life cycle energy of the building into account. In addition, the contemporary nature of the finished product may make it more appealing to a wider range of people, including architects.

Many architects, spoken to by the author, who have not worked with earth materials were excited about rammed earth as a material but were not at all keen on adobe, cob or other methods. The texture and solidity of the rammed walls are qualities that appealed to them. Ronald Rael noted this in Chapter One of *Earth Architecture*:

“As evidenced by the number and variety of projects in this chapter, from housing to religious and cultural buildings, rammed earth has emerged as the most popular earth-building technique in contemporary architecture culture.”
(2009, p.19)

However, in terms of built houses, rammed earth has not been as popular as other earth building methods in New Zealand and this may be due to it being less suited to owner-builders, who currently make up over half of the earth house owners. For it to be used more widely a satisfactory solution to its thermal performance must first be found.

6.14 LIGHT EARTH

Light earth, as defined in 1.5, is a system where earth is mixed with straw or other lightweight materials such as pumice or wood chips to form walls. In North America the name 'straw light clay' is used for light earth systems incorporating straw which is the material used for the six light earth houses in the Nelson survey. It is a material which could fit into either of the broad categories of earth or straw construction. Thornton describes it as *“a contemporary variant”* of much older earth building

techniques. Although the word ‘straw’ does not feature in the name commonly used in New Zealand, the straw content of light earth is much higher than in other earth systems and indeed it has more straw in it than clay by volume. This straw content is what gives it a higher R value than other earth materials as discussed in 6.8. Thornton describes it thus:

“Straw light clay (SLC) is prepared by coating a straw aggregate with a clay binder. This creates a versatile non-structural and insulative infill material with a very low embodied energy. Applications include exterior walls as well as interior partition walls.” (2004)

Hamish Rush, owner of one of the light earth houses in the survey, described it as being like making a salad where a ‘dressing’ of a creamy clay mix is drizzled over the straw ‘salad’ before placing it between boxing to form the walls (2011).

Light earth is a system well suited to owner-builders. Five of the six light earth houses owners in the survey were owner-builders, and no owners had difficulty obtaining building consent. By using timber framing for the structure of their houses and using the light earth as infill, the construction system fell within the scope of NZS 3604, meaning that additional engineering input, which is required for some of the other systems, was not required to gain consent.

In the USA, architect Paula Baker-Laporte and builder Robert Laporte have developed a system incorporating a traditional timber post and beam framework with light earth walls on the outside of this, a system they call ‘outsulation’. In this way the thermal bridging that occurs where the walls are infilled between frames is avoided. The system, along with examples of completed projects, is outlined in the Laportes’ book *Econest* (2005).

The uptake for light earth is very low both in Nelson and nationally and it is difficult to see why this is so. Architect Stephan Meijer was the only expert interviewed who had firsthand experience of light earth. He used it in his own house and was very positive about its performance (2011). Perhaps the low uptake is because light earth is not included in the Earth Building Standards and is not widely known, but its relatively high

insulation value, coupled with the opportunity it provides for a high degree of owner involvement, makes it worthy of further research.

6.15 STRAW BALE

The time period this research covers, 1945 to the present day, includes the entire period of straw bale construction in New Zealand. In the seventeen years since the first straw bale house was built in Marlborough in 1995, much has been learned and processes have been developed and refined. The attributes of straw bale, its high insulation value, its utilisation of a waste product, its inherent buildability, and its low embodied energy are the reasons cited for using the system, as discussed in Chapter Five, and the results of the survey indicate that the 27 straw bale or straw bale/earth house owners were very happy with the overall performance of their houses (see 6.6-6.8).

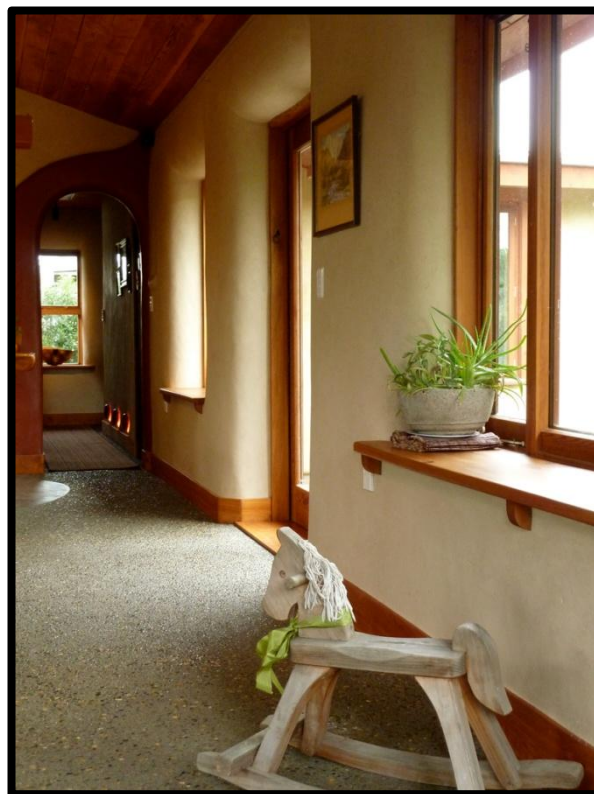


Figure 6.16 Straw Bale house with Earth Plaster, 2010

Photo: S Johnston

Plastering systems for straw bale have developed since 1995. Initially cement plaster on steel wire mesh, or stucco, was used both externally and internally for most straw bale houses in New Zealand, and there are still many built in this way. Over time,

however, the skills and techniques for using earth and lime plasters have been developed and high quality finishes using these products can now be achieved, see Figure 6.16. Earth plasters have other advantages: at 50 to 70mm thick they provide some thermal mass; they provide an absorbent surface acoustically; and they also improve the capability of the complete wall system to moderate humidity.

Wire mesh is still used where there are changes in materials, for instance where a straw bale wall abuts a timber wall or a timber component such as a window or door frame, but it is no longer necessary to use cement, or to completely cover the straw bale walls with wire mesh. This is a significant advantage, as the use of these materials with their high embodied energy compromises the otherwise very low embodied energy content of the complete wall system. Alcorn's research, based on simulation of a New Zealand house, suggests, the CO₂ emitted by building materials is second only to that emitted from hot water heating and more than that emitted from space heating (Alcorn, 2010b). The use of straw bale and timber provide very real opportunities to reduce this through their ability to sequester carbon. Straw bale has an added advantage:

"Super insulation (beyond R5) using conventional insulation materials is often assumed to reduce total energy use, but (at least in the NZ climate) this is incorrect. Strawbale [sic] insulation, however, does provide increased CO₂ benefits as more is used." (Alcorn and Donn, 2010)

The incidence of owner-builders amongst straw bale house owners is high (see 5.9) and currently this is what makes straw bale affordable to many. However the perceived requirement that owners participate directly in the actual construction, may be a hindrance to more widespread acceptance of straw bale as a building system.

The major impediment to the future of straw bale building in New Zealand is the lack of official acceptance: the absence of a national standard, and the reluctance of some TAs to accept it as a valid construction method. In 1993 a code for straw bale was adopted in New Mexico and by 2006 sixteen counties across the USA had codes, guidelines or mandates in place (King, 2006, Ch.11). Belarus and Germany were the only other countries to have codes while in Australia, as in New Zealand, there is no code and building consent applications are processed as 'alternative solutions' (see

6.5). Despite the lack of a code, there has been some recognition of straw bale as a valid construction method in New Zealand, best illustrated by the fact that there are 32 houses in the Nelson database that have been granted building consent, as alternative solutions, between 1996 and 2009. In 2000 BRANZ issued a bulletin, updated in 2010 as *Bulletin 530 Straw Bale Construction* (2010), and this together with North's paper *Strawbale [sic] Building Guidelines for Wet and Humid Climates (Such as New Zealand's)* (2002) provides some guidance for construction. Most of the supporting information required for consent applications, however, has come from North American sources. Prior to 2000, books such as *The Straw Bale House* (Steen et al., 1994) and magazine articles from *The Last Straw* (1993) were used, and since then more recent publications have been used such as *Building with Straw* by Gernot Minke (2005), a number of scientific papers by John Straube (2000, 2009) and Bruce King's definitive book *Design for Straw Bale Buildings* (2006). These recent publications contain well researched information about the building science of the material and the structural and construction systems required.

The main problem area for building consent applications for straw bale houses is when they are assessed for compliance with clause E2, External Moisture, of the NZBC. There is no 'official' method for deciding whether straw bale walls require a drainage cavity to mitigate moisture penetration. Straw bale is outside the scope of the risk matrix which is used to assess timber framed houses, including those with light earth infill walls, and TA assessment of applications has been inconsistent (DBH, 2005). For instance, a recent straw bale house under the jurisdiction of the TDC, that is not complete at the time of writing, was subjected to a more rigorous application of the requirements of E2 when its building consent application was assessed in 2011, than that applied to previous applications. Whereas a house consented by the same TA in 2008, but by a different consenting officer, with two storey (5.5m) high straw bale walls was not required to have a drainage cavity on the exterior walls, the one consented in 2011 which is single storey with walls up to 4m high and with similar roof overhangs, was required to have one. A conversation with the TA inspector who processed the 2011 application revealed that, as recommended by North (2002), the guidelines for roof overhangs for earth buildings contained in NZS 4299 were used to

assess whether the straw bale walls were required to have a cavity (SNZ, 1998c, Clause 2.10) (Hall, 2011b). In this case the roof overhang in relation to the wall height was less than that recommended in NZS 4299, and a cavity was required. If the 2008 house had been assessed using a similar method it too would have required a cavity.

Undoubtedly there are situations where drainage cavities are advisable, as expressed by Straube in his 2009 paper:

“For strawbale [sic] walls exposed to high rain exposures (tall houses with little overhangs) a drained system is recommended: on the exterior of a typical plastered strawbale [sic] assembly, a small drainage gap and an external finish can be provided. This drainage gap need only be 1/16” or even less and can be formed by special creped housewrap, or strips of wood. The exterior finish can be a plaster, siding, wood, or any other lightweight system.” (2009, p.11)

This does however, end up making the system very expensive, as the hidden exterior face of the straw bale still needs to be plastered to ensure the integrity of the system thermally and from a fire risk perspective. Anecdotal evidence suggests that the situation cited in Nelson is being repeated in Central Otago where straw bale buildings, regardless of their wall height to roof overhang ratio, are either being declined consent or are required to have a cavity (Hall, 2011a).

This inconsistency amongst individual TAs and amongst consenting officers within a particular TA is a frustration for straw bale proponents because as Straube says:

“In summary there are no real technical obstacles to the use of strawbales [sic] in a manner that meets the intent of all building codes. The practical experience with thousands of such buildings provides more than sufficient confidence in the conclusions of this technical review.” (2009, p.12)

The final chapter of King’s book is written by Martin Hammer and entitled *Building Codes and Standards*. Besides providing a record of countries and states within countries which have building codes, standards or guidelines, Hammer discusses the merits and otherwise of having a straw bale building code:

“Building codes are a double edged sword for any material or method of construction because they allow and legitimise everything that is codified, but

they also tend to restrict practice to only that which is codified.” (King, 2006, p.236)

For an evolving system, like straw bale, Hammer’s point is particularly pertinent. If a straw bale code had been introduced before now in New Zealand then plasters that do not require a steel mesh backing, such as earth and lime plasters, may not have been included and the development of the system as a whole may have been restricted. Nevertheless, as Hammer concludes, gaining acceptance by way of building codes should be the goal for straw bale building in all countries:

“Otherwise there will continue to be unnecessary duplication of effort, lack of uniformity where it is needed, and confusion or conflict” (2006, p.240).

6.16 EARTHQUAKES

In New Zealand earth and straw bale houses must be able to perform satisfactorily under earthquake loading to have a future here. The Canterbury earthquakes of 2010 and 2011 have provided real life testing for houses built using both materials, but while post earthquake surveys have been made of earth houses, none have been any carried out for straw bale houses. There are also no known reports of straw bale houses having performed badly. Straw bale buildings in New Zealand and overseas are, of course, designed to withstand expected seismic loading. For example tests have been carried out at the University of Nevada, under the auspices of the Network for Earthquake Engineering Simulation (NEES), on an experimental straw bale house designed for northern Pakistan in an area severely affected by the devastating earthquake in 2005 with favourable results (NEES, 2009). No such tests have been carried out in New Zealand and this is an area where further research would be beneficial.

The Canterbury earthquakes not only provided real life testing of earth houses but also of the Earth Building Standards, presenting the opportunity to compare houses built according to the standards with those built prior to their promulgation in 1998. After the earthquake of 4 September 2010 a team from EBANZ, comprising engineers Hugh Morris, Richard Walker and Thijs Drupsteen, carried out a survey of 14 earth walled

buildings that suffered damage, varying from very little to significant. After the earthquake on 22 February 2011 they were joined by architect Graeme North for a second survey which included more buildings. Their findings were presented at the *Pacific Conference on Earthquake Engineering* held in Auckland in April 2011 where they reported on the performance of four houses.

“The September event was the first major earthquake where modern reinforced earth buildings have been tested. Damage was minor in most of the modern buildings surveyed and able to be understood in all cases with most of the more serious damage to modern buildings due to differential ground movement. The specific examples considered in this paper were a rammed earth building with thick unreinforced walls [built in 1925] that suffered moderate damage that would have been significantly reduced if the reinforced concrete bond beam had been properly attached to the unreinforced walls. The three adobe buildings all used modern detailing and where properly applied, confirmed the requirements of the New Zealand earth building standards as detailed in NZS 4299. Full height continuous vertical reinforcement is critical, timber ceiling diaphragms work well, and a minimum length of return walls and stiff cross walls need to be provided.” (Morris et al., 2011)

The damage caused by the February event was reported to be similar, except for houses built out of pressed soil cement bricks, which performed badly in some cases, see Figure 6.17. Whilst there was no loss of life or serious injury resulting from these failures, largely due to the fact that the walls in question were infill to a post and beam structure and therefore were not loadbearing, the loss to property was significant. Morris et al. made a number of recommendations as a result of what they observed:

“The February earthquake caused comparable patterns of damage to the September event except for pressed earth brick buildings. Unreinforced earth walls thinner than 200mm, without any lateral support from timber framing, should be dismantled or strengthened by providing additional lateral support to the walls, this should also apply to existing NZ houses in higher seismic zones. The same recommendation applies to unreinforced double skin earth masonry walls with a cavity. Although none of the damaged pressed brick walls complied

with the New Zealand earth buildings standards, modification to the pressed earth brick section of the standards will be required.” (2011)



Figure 6.17 Damage to Pressed Earth Brick house, Canterbury, following the February 2011 earthquake Photo: Thijs Drupsteen

Graeme North has also written a discussion paper which places the future of earth building following the earthquakes in the context of earth building in New Zealand generally. This is particularly significant as a review of the Earth Building Standards is currently underway. In his paper, North refers to the general move towards lighter weight earth building materials for both thermal and structural reasons and observes that pure adobe brick seemed to performed better in the Canterbury earthquakes than bricks with cement added:

“In my opinion the future use of higher density earth building materials – ie greater than 1600 kg/cub - is diminishing apart from specialist applications such as dense thermal mass walls in specific locations, or possibly when used for sound transmission attenuation. This trend may lead to a reduction in the use of pressed earth bricks and possibly rammed earth too, unless low-density aggregates that can withstand high manufacturing pressures are further developed.

It appears to me that less brittle materials such as natural mud brick seemed to survive better than more brittle materials such as cement stabilised pressed

earth bricks, all things being equal, although direct comparisons were difficult to make.” (2011b)

North confirms the view expressed by the engineers with regard to unreinforced earth walls but puts it a little more bluntly:

“Unreinforced earth walls have no place in the future in NZ earth building. The risks are too high, even in low risk areas such as Northland. Partially reinforced walls may still have some future but only in lower seismic risk areas.” (2011b)

It is useful to put the performance of these earth houses in earthquakes in the context of how other conventional housing performed. Unreinforced brick work performed badly while the performance of timber framed houses, with or without brick veneer, varied and was more dependent on the underlying ground conditions than the building method. Earth walled houses built in accordance with the Earth Building Standards performed well, as did some built prior to the standards, but all of the houses that performed badly were not built in accordance with the standards. This would suggest that the standards are a good benchmark for building with earth in terms of ensuring their structural resilience under seismic loading.

6.17 DESIGN CHANGES AND IMPLICATIONS FOR EARTH BUILDING

Over the 65 year time frame covered by this research, the design of earth houses has changed. The first houses at Riverside Community were designed with economy in mind. There was an urgent need for shelter and not much money with which to provide it. They were not designed by architects, yet their simple footprints and low gabled or mono pitched roofs were not dissimilar to those being used at the same time by the outspoken Group Architects in the North Island. Julia Gatley and Bill Mackay suggest that the Group’s houses were consciously presented as *“unpretentious, straightforward solutions to everyday life”*, a description that could apply equally to the pragmatic aspirations of the Riverside Community members (Gatley, 2010, p.40). Most of the Riverside houses had wide eaves, see Figure 6.18, something which was recommended in the Earth Building Standards when they came into effect 40 years

later, but they did not have the deep verandas that were to become a feature of many houses built during the 1990s (see Figure 6.7).



Figure 6.18 House at Riverside Community built in 1957 Photo: MH 2010

It is fair to say that at the time, when the Earth Building Standards were being developed, the emphasis was on protecting the walls from erosion; on creating a structurally sound and weather tight building envelope. The wide verandas were a wonderful solution in this regard. Not only were the verandas deep, however, but often they were also low, which exacerbated the negative effect they had on solar gain and the corresponding thermal performance of the houses (see 6.8).

Not all earth houses were built with these continuous wide verandas and as their implications became more widely understood, house designs changed accordingly with more glazing in north facing walls, see Figure 6.19.

Engineer Richard Walker has developed a hybrid post and beam system for earth wall construction, where the vertical loads are taken by the posts and beams, and the horizontal loads are taken by the infill walls. The major advantage of this system is that the roof is erected before the walls, and therefore it is possible to keep building the walls in all weather conditions (Walker, 2011). An added advantage is that the system makes it possible to include more glass and less solid wall to the north, thus maximising the solar gain, the major requirement for passive solar design.



Figure 6.19 Adobe House from the North, Motueka 2007 **Photo: MH 2011**

The changes to building regulations and advances in the technology of earth construction over the past 65 years have contributed to the current situation, where those wishing to build houses out of earth in New Zealand can choose from a number of options that meet the requirements of the NZBC.

Lightweight adobe bricks can be used for all the exterior walls, either completely loadbearing or as the wall components of a hybrid post and beam system. The traditional heavyweight earth bricks, poured earth, cob and rammed earth can also be used for exterior walls, so long as the walls are thick enough. They need to be considerably thicker than those typically built between 1945 and 2007, when the new H1 requirements came into effect. Prior to this, typical wall thicknesses ranged from 140mm to 280mm. If the formula for calculating R value provided in the Earth Building Standards is used the wall thickness required ranges from 340mm to 530mm, depending on the climate zone: see Appendix 8 (DBH, 2011a).

$$R(\text{m}^2 \cdot ^\circ\text{C}/\text{W}) = (2.04 \times \text{wall thickness}(\text{m})) - 0.12 \text{ (SNZ, 1998a, Clause 3.5.2)}$$

Increases in wall thickness also mean increases in the amount of other materials required to support them; concrete and steel for the foundations and for wall reinforcement, which increases the embodied energy of the complete system as discussed by Alcorn and Donn (2010).

Another option is to use the heavier weight earth walls in the interior only, and use conventional insulated timber framing for the exterior with a variety of cladding

options. In this case, the earth is treated more as a building component rather than a building system.

Light earth and lightweight cob, used as infill walls, have the advantages of improved thermal characteristics and provide the opportunity for owner involvement in their construction. Experimentation with lightweight cob is relatively new and there are few examples in New Zealand but the performance of houses built using light earth, both in Nelson and in other parts of New Zealand, are a positive indication of the potential of the system.

6.18 DESIGN CHANGES AND IMPLICATIONS FOR STRAW BALE BUILDING

Straw bale is a much newer system than most kinds of earth construction and changes in design are not as apparent as they are for earth houses. The introduction of straw bale in the New Zealand building scene in the 1990s coincided with the popularity of the 'Santa Fe style' where the solid, whitewashed, adobe walls of traditional buildings in Southern California were mimicked using timber framed walls with a stucco finish. Typically, Santa Fe style houses also had roofs with minimal overhangs, sometimes none at all. When straw bale is plastered, it gives the appearance of being a solid masonry wall and some saw it as being ideally suited to the 'Santa Fe style.' In reality, the properties of straw bale make it distinctly unsuitable; the straw within the walls is full of air and susceptible to failure if moisture is able to penetrate beyond the plastered surface, and the minimal eaves leave the walls vulnerable and completely reliant on their coating system. There were no houses like this in the Nelson sample, but the appearance of a number of straw bale houses with minimal or no eaves prompted Alcorn and others to carry out laboratory tests on a number of straw bale wall assemblies for air and moisture penetration in 2000. Their subsequent report concludes by saying:

"The chances of a straw bale wall suffering a rain and wind event lasting long enough to damage the straw sometime in the life of the building is high. In countries like New Zealand that experience simultaneous wind and rain conditions regularly, exposed plastered straw bale walls can be expected to exceed a safe moisture level in a single event. Some means other than plaster

on straw, such as verandahs of generous proportions, very big eaves or rain screen claddings, is needed to keep rain away from straw bale walls under all weather conditions in the challenging New Zealand climate.” (Alcorn et al., 2000)

It is now widely recognised that straw bale walls need to be protected with generous roof overhangs; if these cannot be achieved then drainage cavities need to be installed just as they are for timber framed houses with insufficient eaves. Without further research it is not possible to determine exactly what the extra cost of this is but anecdotal evidence suggests that it is a reason why a number of people have changed their minds about building with the material (Hall, 2011a). If the guidelines provided by and referred to in BRANZ Bulletin 530 (2010) are followed it is possible to design houses that are appropriate for the material by providing adequate protection for the walls and still allowing for passive solar design.

There have also been developments to the structural system with a combination of loadbearing straw bale walls and posts and beams within one house, in a similar manner to the hybrid post and beam system used for earth. Sol Design, in Geraldine, have moved to using straw bales stacked on their edge, rather than on the flat, meaning that fewer bales are required and the wall thickness is reduced from 500mm to 350mm. Surprisingly this does not reduce the R value of the wall. Scientists at the Oakridge National Laboratories in the USA:

“...found the R-value per inch to be higher for bales laid on edge, in which the general orientation of straw fibers [sic] was perpendicular, not parallel, to the direction of heat flow. The net result was that a 24-inch-wide bale wall with bales laid flat has about the same net R- value as a 16-inch-wide wall with bales laid on edge.” (King, 2006, p.187)

Sol Design have also been experimenting with prefabricated straw bale wall panels which they demonstrated at the EBANZ conference in 2011. The advantage of prefabrication is that the time consuming process of applying the first plaster coat to the bales can be carried out in controlled conditions before transporting the wall panels to site.

6.19 FUTURE PROSPECTS

By providing a record of the development of earth and straw bale building over the last 65 years, an understanding of the current situation is made possible. A house designed and built out of earth even 30 years ago is likely to be different from that same house designed and built today. Similarly, a straw bale house constructed today will be different from those designed 15 years ago. This is because the growing understanding of the characteristics and properties of the materials has led to changes in design and construction that takes this experience into account in order to produce healthy, comfortable and energy efficient houses that can be sustained for the indefinite future.

New houses can be built using lightweight earth materials and existing houses which do not perform adequately from a thermal point of view can be retrofitted with insulation. The denser earth materials can be used internally to capitalise on their thermal mass capabilities within a more conventional exterior envelope.

Straw bale houses have performed well and as long as New Zealand farmers continue to grow grains, there is every reason to continue exploring the potential for straw bale as a construction material. Currently development is hampered by the lack of a nationally recognised set of guidelines or building standard. The experimentation with prefabricated straw bale wall panels could lead to more widespread use of straw bale as a building component. The recently completed Gateway Building at the University of Nottingham in the UK incorporated prefabricated straw bale wall components, combining timber and straw bale, on a large scale (MAKE, 2012). This concept could have potential in New Zealand's housing market. Straw has also been used overseas in other forms to produce building components such as wall and ceiling panels and this concept also has potential in New Zealand. The Australian product, Durra Panel, produced by Ortech Industries is an example of this (2012).

The emergence of hybrid materials and hybrid designs, where the differing properties of earth and straw are capitalised within one house is an indication of the future direction for the use of both materials. Light earth, or straw clay, is a good example of the properties of both raw materials being exploited within one building product. This

method also lends itself to off-site prefabrication, where wall and ceiling panels could be made in a controlled environment and transported to site, in a similar manner to the straw based Durra Panels.

The hybrid houses in the Nelson survey incorporated straw, with its high insulation value for exterior walls, and earth as thermal mass for internal ones. Their owners rated the IEQ and thermal performance of their houses more highly than the owners of pure straw bale or pure earth houses (see Figures 6.3 and 6.6) and this real life comparison is a clear indication of the growth in understanding of how best to use both materials.

The continued evolution of the use of both earth and straw, in their raw form and as processed products is an indication of the willingness of the people committed to exploring the potential of alternative or natural materials to embrace change when this is required. However, the full potential of both earth and straw bale will never be realised if this potential continues to rely on the enthusiasm of a few committed individuals. New Zealand based research into the properties of both materials, and officially accepted building standards or guidelines for straw bale, are necessary before these materials can make a significant contribution to the production of a more sustainable housing stock.

CHAPTER SEVEN: CONCLUSION

7.1 OBJECTIVE

The goal of this research was to ascertain first whether alternative or natural building materials and methods have a future in New Zealand and, secondly, whether they have a role to play in establishing more sustainable housing solutions. The earth and straw bale houses of the Nelson area built since 1945 have been used as a case study and a survey of the owners of these houses has provided much of the data that informs the research. Analysis of the survey data and information from the ensuing interviews, supplemented by further research conclude that earth and straw bale do have a future in New Zealand, and could be valuable components of a sustainable housing stock.

7.2 THE RESEARCH

Acquiring the body of information that was necessary in order to carry out this research was a project in its own right. Before a survey of house owners could be conducted, a database was compiled of all the houses built of earth and straw bale in the Nelson region since 1945 which were still occupied in 2010. Information from this database of 144 houses provided the background to the history of earth and straw bale housing in Nelson between 1945 and 2010 recorded in Chapter Four – a history which until now, has been largely held in the memories of those who were part of it. The fact that there are 144 houses, some of which have now been lived in continuously for more than 60 years after construction, alone indicates that earth and straw bale construction methods are viable ways of making houses in New Zealand.

The survey results showed that three out of every four house owners were also owner-builders. This level of independence, or self-sufficiency, is further illustrated by the fact that one in every five houses in the survey was not connected to the national electricity supply grid. An independent streak amongst owners, coupled with an association with a rural locale is synonymous with the use of alternative building materials in New Zealand. Paradoxically these aspects are both a reason for their

continued use and a reason why they have not been used more widely. The statistics for the Nelson area, discussed in Chapter Four, show that not only do houses built with alternative materials make up a very small proportion of the total house population, but they are also relatively immune to fluctuations experienced in the wider construction industry. This makes for a sustainable housing model but not necessarily one that will ever have a wider appeal than it currently does.

Both earth and straw bales are readily available in New Zealand, and the processing required to turn them into building products is minimal. With earth, varying amounts of cement and reinforcing steel are required, depending on the system used, and this reduces the material's sustainability when measured in terms of reducing CO₂-e and energy embodied in the material. Using the same criteria, straw bale, in association with timber structural elements, has the potential to perform better than most other known construction methods available in New Zealand.

The owners of earth and straw bale houses were generally very happy with the performance of their houses in terms of the IEQ and durability, and this result confirms existing building science knowledge of both materials, as discussed in Chapter Six. In terms of durability and resilience, the Canterbury earthquakes of 2010 and 2011 and the Nelson rainstorms of 2011, have put houses built out of both materials through real life testing, and proven their physical integrity, if built according to best practice.

The excellent thermal properties of straw bale were endorsed by the owners of houses built using this material, while the shortcomings of earth in this regard were recognised by some. These shortcomings have been addressed by experts within the earth building fraternity in New Zealand and internationally, resulting in changes to products, development of new products and changes to the way earth products are used within a building. Ways have been found to rectify existing poorly performing houses, and newer houses incorporate lightweight earth material with better insulative properties, or are designed in ways that capitalise on the original material's positive thermal attribute, thermal mass. This has been done by using earth for interior walls or as an internal veneer to timber framed and insulated exterior walls, and not using earth alone for exterior walls, where its inadequate insulative properties have a detrimental effect on the thermal comfort within. This ability to respond to problems

and adapt the material and how it is used, illustrated by the way the thermal issue has been addressed, is a vital attribute for a building model that can be sustained into the indefinite future.

7.3 FUTURE RESEARCH

This thesis provides data and information about a substantive body of houses built out of earth and straw bale in the Nelson area of New Zealand. This resource now provides the background for further research into particular aspects of the performance and potential of both materials and can also be used as a model for further research in other parts of the country, or for investigating different building methods.

Smaller groups of houses could be selected for in depth study of the IEQ, including thermal performance, by using instruments to record temperature, humidity and air quality. In a similar manner, before and after studies could be made of earth houses retrofitted to improve their thermal performance. Life cycle impact studies could also be carried out as well as investigation into life cycle and upfront costs.

One group of houses that could benefit from such a study would be the five rammed earth houses at Riverside Community built prior to 1960, the earliest houses included in this research. They are important historically, being the first houses built for the oldest intentional community in New Zealand (Jones, 2011, p.176). They are also the first earth houses built in Nelson since the material ceased to be commonplace, and are some of the earliest stabilised rammed earth houses built in the country. Lessons learned from a project designed to upgrade these houses in order to improve their IEQ could be applied to other earth houses around New Zealand with similar performance issues.

Another group of houses that would be useful to study are the 24 off-grid houses. They provide an opportunity to assess 'real life' sustainability using the methodology developed and described by Alcorn in his thesis *Global Sustainability and the New Zealand House* (2010a).

Straw bale construction is a relatively new method, but it has quickly gained popularity both in New Zealand and overseas. Further research into developing technologies

utilising straw, building codes for straw bale, and affordable housing applications overseas could have benefits for New Zealand. The potential for light earth and other lightweight earth based materials for walls are other areas that would benefit from further research.

The Nelson area data could also be used as a starting point for a history of earth and/or straw bale building, or alternative building generally in New Zealand. It could also inform a study of self help or DIY building in New Zealand.

7.4 EARTH AND STRAW BALE IN NEW ZEALAND INTO THE FUTURE

The use of earth and straw bale for building houses has increased over the past 60 years with the most rapid development happening in the last 20 years. The 144 houses in the Nelson area, and many more nationwide, represent only a small portion of the total housing stock in New Zealand, but they add to its diversity and contribute to its robustness. It is important to develop and then maintain the skills involved in building with sustainable materials: those that are close at hand, require minimal processing, and empower owners to be involved with building their own houses. The ongoing building of earth and straw bale houses and the presence of the designers, engineers and builders who make them happen, ensures that the expertise and skills that have developed over the last 60 years can be passed on as the technologies continue to evolve.

The presence of the Earth Building Standards has given earth building credibility in New Zealand and it is unlikely that so many earth houses would have been built if those standards were not in place. In order for the same credibility to be afforded to straw bale, building standards or officially accepted guidelines need to be developed. This seems unlikely in the current economic climate where research funding in many areas has been significantly reduced, but the existence of official standards overseas offers some hope that eventually straw bale standards will be developed, or even adapted, for New Zealand.

Now that the properties of both materials are better understood, designs have changed and will continue to evolve to make best use of this knowledge. Hybrid

houses with straw bale exterior walls and heavier interior earth walls for thermal mass have been built. Hybrid materials such as light earth combine the advantageous properties of both straw and earth into one wall material which, when used in association with a timber structure, provides a sustainable building system using home grown materials. Alcorn's research showed that the use of locally grown and minimally processed timber and straw as building materials is significant in terms of the materials' embodied energy and ability to sequester carbon (Alcorn and Donn, 2010). By choosing materials that are available within New Zealand, it is also possible to know the complete story behind their origin. This is more difficult to achieve when sourcing materials from other countries, for example ensuring rain forest timber comes from a sustainable supply chain. It is also likely that, if properly managed, these natural materials will continue to be available into the indefinite future, an essential requirement for sustainability.

In a country whose economy is strongly based in the agricultural sector there is a unique opportunity to take a holistic approach and link a by-product of agricultural production, which currently literally goes up in smoke, with the housing and construction sectors. Straw, timber and earth are all natural materials that are readily available in New Zealand, and which, when combined, have the necessary material characteristics to produce enduring, healthy houses on a sustainable basis.

APPENDIX 1: HUMAN ETHICS COMMITTEE APPROVAL



MEMORANDUM

Phone 0-4-463 5676

Fax 0-4-463 5209

Email Allison.kirkman@vuw.ac.nz

TO	Margot (Min) Hall
COPY TO	Brenda Vale
FROM	Dr Allison Kirkman, Convener, Human Ethics Committee
DATE	04 September 2010
PAGES	1
SUBJECT	Ethics Approval: No 17951 Alternative construction methods in New Zealand: an investigation of existing houses that incorporate earth and straw bale construction and an analysis of their performance and potential in terms of the advancement of sustainable building practices.

Thank you for your applications for ethical approval, which have now been considered by the Standing Committee of the Human Ethics Committee.

Your applications have been approved from the above date and this approval continues until 30 April 2012. If your data collection is not completed by this date you should apply to the Human Ethics Committee for an extension to this approval.

Best wishes with the research.

Allison Kirkman

Convener

APPENDIX 2: QUESTIONNAIRE

QUESTIONNAIRE FOR HOUSE OWNERS

Background - Personal

1.01 What is your name:.....

1.02 What age group do you fit in? ☐ 16-20 ☐ 21-30 ☐ 31-40 ☐ 41-50 ☐ 51-60 ☐ 61-70
☐ 70+

1.03 Are you male or female? ☐ Male ☐ Female

1.04 Were you born in New Zealand? ☐ Yes ☐ No

1.05 How long have you lived in New Zealand?

- ☐ All your life
- ☐ 20+ years
- ☐ 10-19 years
- ☐ 5-9 years
- ☐ 0-4 years

1.06 If you have not lived in New Zealand all your life where else have you lived?

.....

1.07 What is your highest level of formal education?

- ☐ No formal education
- ☐ School Certificate, NCEA Level 1 or equivalent qualification
- ☐ Sixth Form Certificate, NCEA Level 2 or equivalent qualification
- ☐ University Bursary, NCEA Level 3 or equivalent qualification
- ☐ Tertiary Certificate or Diploma or equivalent qualification
- ☐ Trade Qualification

- ☐ Undergraduate Degree
- ☐ Postgraduate Degree
- ☐ Other (Please state.....)

1.08 Please tick which of the following applies to you.

I am:

- ☐ in full-time employment
- ☐ in part-time employment
- ☐ a housewife/husband
- ☐ retired

1.09 If you are in paid employment what is your occupation?

.....

1.10 Do you work from home? ☐ Yes ☐ No

Background - House

2.01 Are you the first owner of your house? ☐ Yes ☐ No

2.02 How long have you lived in your current house?.....years

2.03 Is your house permanently occupied? ☐ Yes ☐ No

2.04 If you have answered 'no' above please estimate the number of weeks per year the house is occupied:.....

2.05 How many people normally live in the house when it is occupied?.....

2.06 What kind of property is your house located on?

- ☐ Inner city section

- ☐ Suburban section
- ☐ Small town section
- ☐ Life style block/small holding
- ☐ Holiday settlement section
- ☐ Farm
- ☐ Forest

2.07 Prior to your current house what kind of house/s (type of construction) have you lived in before?

- ☐ Timber framed with brick cladding
- ☐ Timber framed with sheet cladding
- ☐ Timber framed with timber cladding
- ☐ Solid timber
- ☐ Concrete masonry
- ☐ Concrete
- ☐ Steel
- ☐ Stone
- ☐ Earth (If so what type?).....
- ☐ Straw bale
- ☐ Other (If so what type?).....

2.08 What are the main materials/construction methods used in the construction of your house?

- ☐ Timber frame
- ☐ Timber Post and Beam
- ☐ Concrete Post and Beam
- ☐ Steel Post and Beam
- ☐ Concrete masonry
- ☐ Steel reinforcing
- ☐ Earth- Rammed Earth
- ☐ Earth- Cob
- ☐ Earth- Adobe bricks

- ☐ Earth- Soil cement bricks
- ☐ Earth- Sand cement bricks
- ☐ Earth- Light Earth
- ☐ Straw bale
- ☐ Other (If so what type?).....

2.09 Do you have a reticulated power supply? ☐ Yes ☐ No

2.10 If you have answered 'no' above what type of electrical supply do you have?

.....

2.11 Please tick all forms of space heating – excluding passive solar systems - you use in your house?

- ☐ Diesel powered – Radiators/Underfloor (Hydronic)
- ☐ Electricity – Heat pump
- ☐ Electricity – Room heaters
- ☐ Electricity – Underfloor heating
- ☐ Gas – Room heaters
- ☐ Gas – Underfloor heating
- ☐ Gas – Forced air central heating
- ☐ Solar – Underfloor heating
- ☐ Solar – Radiators
- ☐ Wood pellet burner
- ☐ Wood range/burner
- ☐ Wood range/burner with radiators
- ☐ Wood range/burner with under floor heating
- ☐ Other
- ☐ None

2.10 What main form of water heating do you use in your house?

- ☐ Diesel

- ☐ Electricity
- ☐ Gas
- ☐ Heat exchange
- ☐ Solar
- ☐ Wood

Reasons for building/buying an earth or straw bale house

3.01 If you are the original owner of your house please go to question 3.03.

If you are not the original owner of your house was the method of construction a determining factor in your decision to buy? ☐ Yes ☐ No

3.02 If you have answered 'yes' above please rate the following factors which may have influenced your decision in order of importance with 1 being the most important:

- ☐ Cost of the house
- ☐ Having a house that uses environmentally friendly materials
- ☐ Appearance
- ☐ Uniqueness
- ☐ Thermal characteristics of the house
- ☐ Low running costs
- ☐ Indoor environment quality – Humidity/Acoustics/Non toxic
- ☐ Other (State).....
- ☐ Other (State).....

Please now go to question 6.01

3.03 There are probably a number of factors which influenced your decision to build a house using earth/straw bale construction rather than a more conventional house. Using the scale below please circle how important the following factors were in your decision to build in an alternative way:

1	2	3	4	5
NOT IMPORTANT		IMPORTANT		VERY IMPORTANT

Cost	1	2	3	4	5
Opportunity to use local resources	1	2	3	4	5
Opportunity to use renewable resources	1	2	3	4	5
Opportunity to use materials with a low embodied energy content	1	2	3	4	5
Insulation potential	1	2	3	4	5
Passive solar potential	1	2	3	4	5
Health benefits	1	2	3	4	5
Indoor environment quality – Humidity/Acoustics/Non toxic	1	2	3	4	5
Opportunity for self build	1	2	3	4	5
Aesthetics	1	2	3	4	5
Historical precedent	1	2	3	4	5
Suitability to geographical location	1	2	3	4	5
Uniqueness	1	2	3	4	5

3.04 Please rate the same factors in order of importance with 1 being the most important:

- ☐ Cost
- ☐ Opportunity to use local resources
- ☐ Opportunity to use renewable resources
- ☐ Opportunity to use materials with a low embodied energy content
- ☐ Insulation potential
- ☐ Passive solar potential
- ☐ Health benefits
- ☐ Indoor environment quality – Humidity/Acoustics/Non toxic
- ☐ Opportunity for self build
- ☐ Aesthetics
- ☐ Historical precedent
- ☐ Suitability to geographical location
- ☐ Uniqueness
- ☐ Other (State).....
- ☐ Other (State).....

Pre Construction

4.01 How did you find out about earth/straw bale construction?

- ☐ Magazine articles
- ☐ Internet
- ☐ Television programmes
- ☐ Books
- ☐ People who own or have built in earth/straw bale
- ☐ Architect/Designer
- ☐ Local Authority staff
- ☐ Other (Please specify).....

4.02 On a scale of 1-5 how easy was it to find out about earth/straw bale construction?

Please circle

1	2	3	4	5
very difficult	difficult	moderate	easy	very easy

4.03 On a scale of 1-5 how easy was it to find people with the relevant design expertise to help you?

1	2	3	4	5
very difficult	difficult	moderate	easy	very easy

4.04 On a scale of 1-5 how easy was it to gain consent for your house?

1	2	3	4	5
very difficult	difficult	moderate	easy	very easy

4.05 How did you obtain finance for your house project and did you have any difficulties with this?

.....

.....

.....

.....

.....

Construction

5.01 Were you actively involved in the construction of your house? ☐ Yes ☐ No

5.02 If so, to what extent ? e.g. was your involvement continuous? Did you act as the main contractor?

.....

.....

.....

.....

5.03 Had you had prior building experience? ☐ Yes ☐ No

5.04 If you have answered 'yes' above please give brief details of this experience:

.....

.....

.....

.....

Performance

6.01 On a scale of 1-5 how happy/unhappy are you with the overall performance of your house? Please circle

1	2	3	4	5
very unhappy	unhappy	moderate	happy	very happy

6.02 On a scale of 1-5 how do you think your house performs thermally? Please circle

1	2	3	4	5
very badly	badly	moderate	well	very well

6.03 On a scale of 1-5 how do you rate the indoor environment quality (humidity/acoustics/toxicity) of your house? Please circle

1	2	3	4	5
very bad	bad	moderate	good	very good

6.04 On a scale of 1-5 how well do you think your house performs in terms of durability? Please circle

1	2	3	4	5
very badly	badly	moderate	well	very well

6.05 If you are unhappy with any aspects covered by questions 6.01-6.04 please elaborate:

.....

.....

.....

.....

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.....

6.06 Is your house insured? ☐ Yes ☐ No

6.07 Did you have any problems getting insurance cover? ☐ Yes ☐ No

6.08 Do you believe earth/straw bale construction is cheaper than other forms of construction?

☐ Yes ☐ No

6.09 Would you recommend this form of construction to others? ☐ Yes ☐ No

6.10 Do you allow people interested in building out of earth/straw bale to visit your house?

☐ Yes ☐ No

6.11 If you were to build or buy a house again what material or construction method would you chose and why?

.....

.....

.....

.....

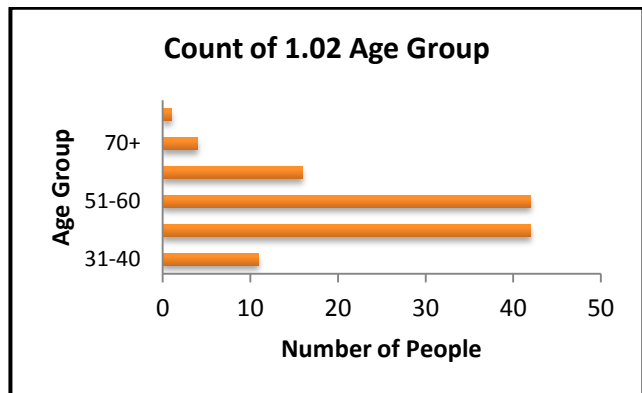
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of..... 2010

APPENDIX 3: SUMMARY OF HOUSE OWNER QUESTIONNAIRE RESULTS

SUMMARIES FOR SECTION 1. Background - Personal

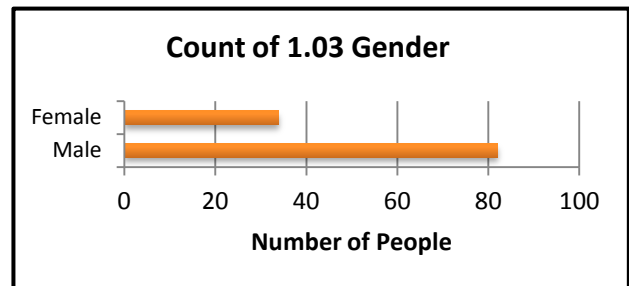
1.02: What age group do you fit in?

1.02 Age	Total
31-40	11
41-50	42
51-60	42
61-70	16
70+	4
Not answered	1
Grand Total	116



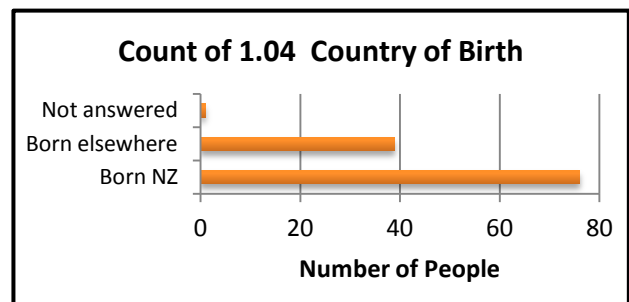
1.03: Are you male or female?

1.03 Gender	Total
Male	82
Female	34
Grand Total	116



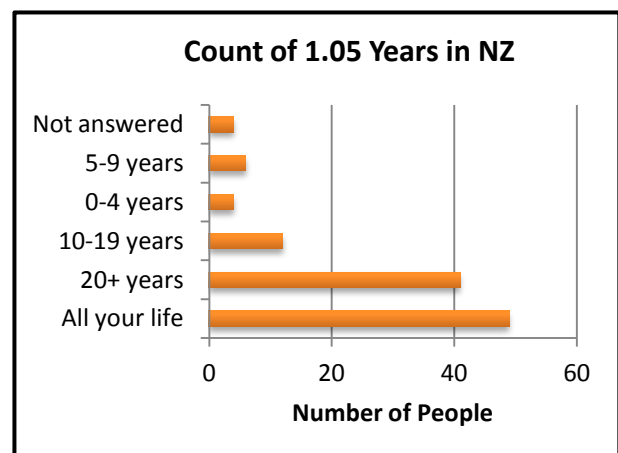
1.04: Were you born in New Zealand?

1.04 NZ Born	Total
Born NZ	76
Born elsewhere	39
Not answered	1
Grand Total	116



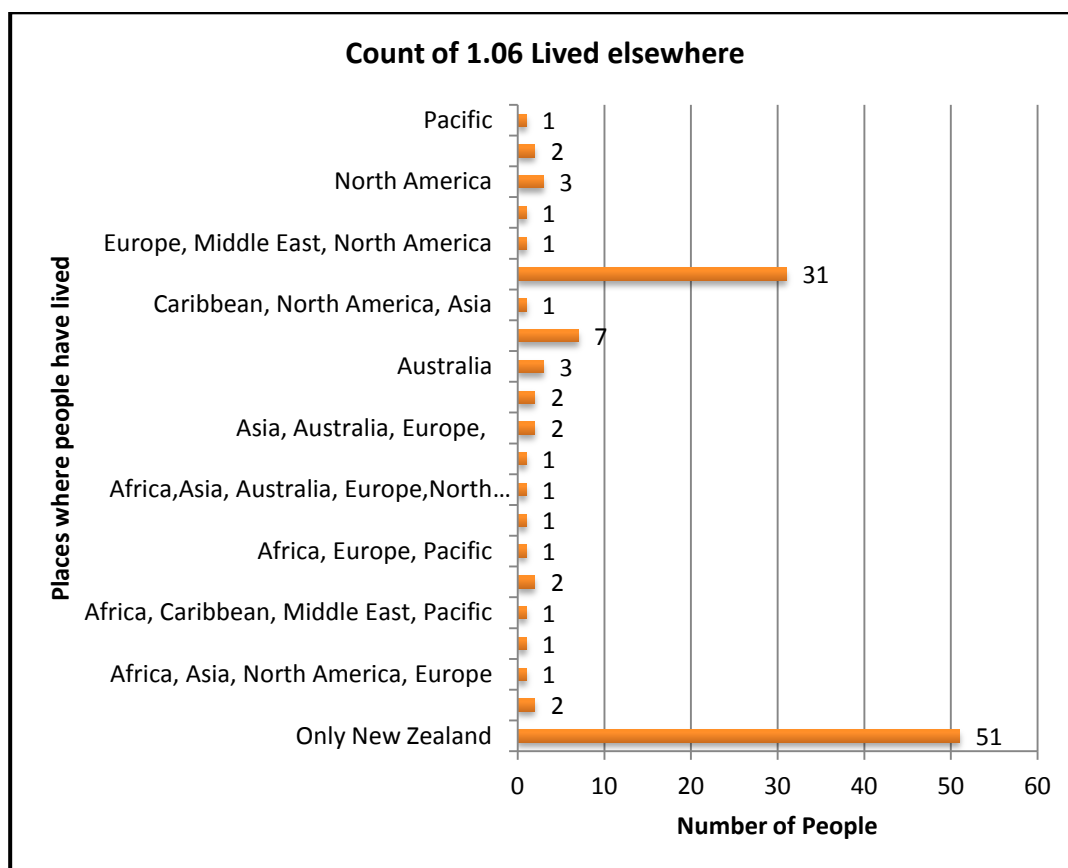
1.05: How long have you lived in NZ?

1.05 Years in NZ	Total
All your life	49
20+ years	41
10-19 years	12
0-4 years	4
5-9 years	6
Not answered	4
Grand Total	116



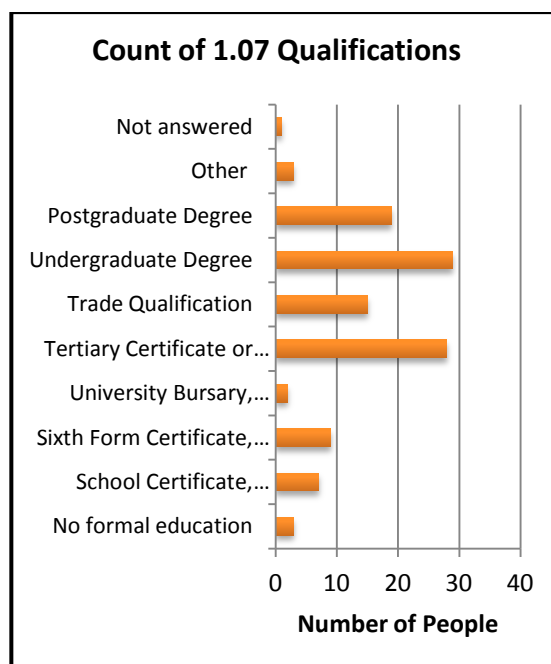
1.06: If you have not lived in New Zealand all your life where else have you lived?

Note: The answers to Question 1.06 have been summarised into broad geographical areas. Some respondents have lived in many countries.



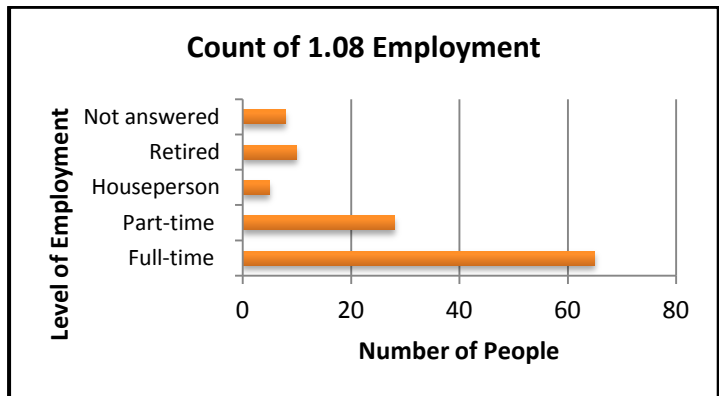
1.07: What is your highest level of formal education?

1.07 Highest qualifications	Total
No formal education	3
School Certificate, NCEA Level 1 or equivalent	7
Sixth Form Certificate, NCEA Level 2 or equivalent	9
University Bursary, NCEA Level 3 or equivalent	2
Tertiary Certificate or Diploma or equivalent	28
Trade Qualification	15
Undergraduate Degree	29
Postgraduate Degree	19
Other	3
Not answered	1
Grand Total	116



1.08: Employment

1.08 Employment	Total
Full-time	65
Part-time	28
Houseperson	5
Retired	10
Not answered	8
Grand Total	116

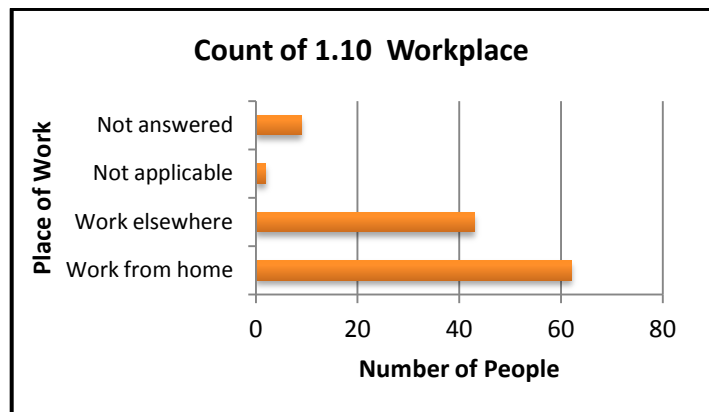


1.09: If you are in paid employment what is your occupation?

Note: There were 78 different occupations given for this question

1.10: Do you work from home?

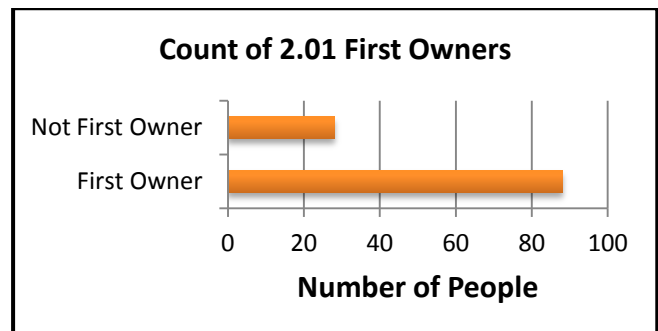
1.10 Workplace	Total
Work from home	62
Work elsewhere	43
Not applicable	2
Not answered	9
Grand Total	116



SUMMARIES FOR SECTION 2. Background - House

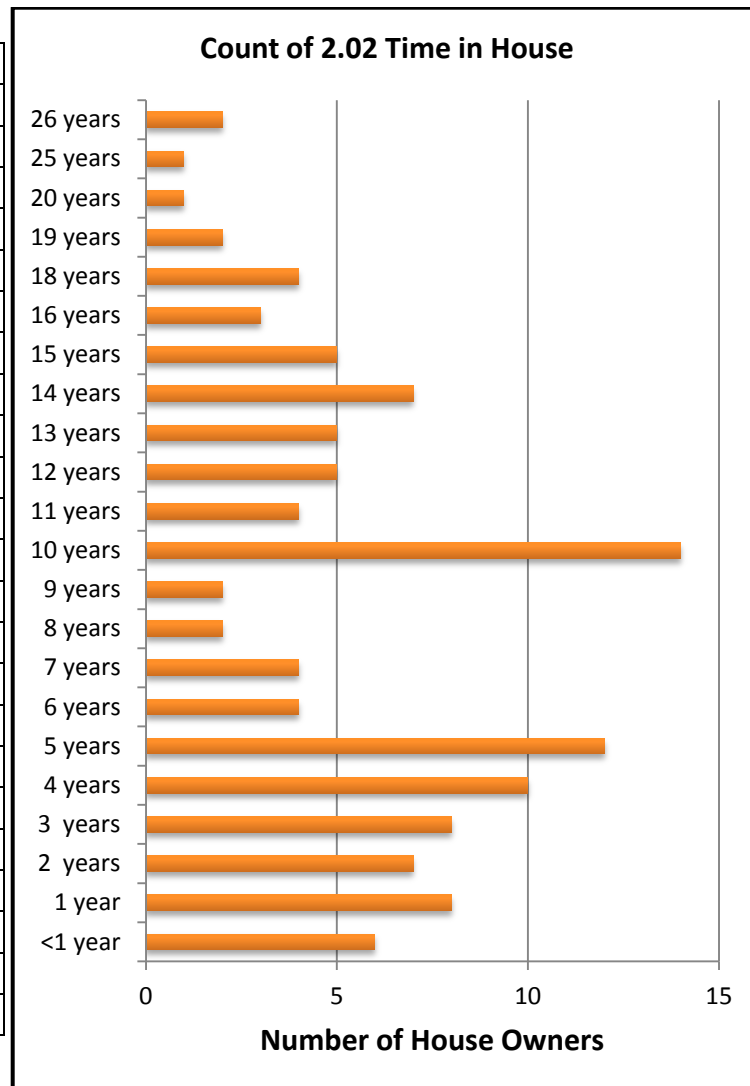
2.01: Are you the first owner of your house?

2.01 First Owner	Total
First Owner	88
Not First Owner	28
Grand Total	116



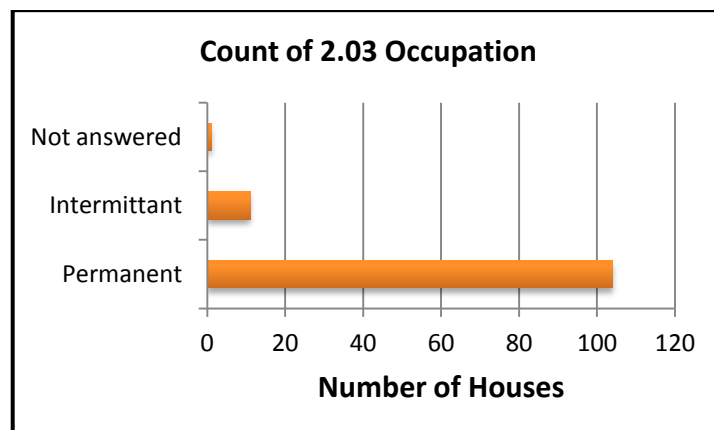
2.02: How long have you lived in your current house?

2.02 Time -years	Total
less than 1 year	6
1	8
2	7
3	8
4	10
5	12
6	4
7	4
8	2
9	2
10	14
11	4
12	5
13	5
14	7
15	5
16	3
18	4
19	2
20	1
25	1
26	2
Grand Total	116



2.03: Is your house permanently occupied?

2.03 Occupation	Total
Permanent	104
Intermittant	11
Not answered	1
Grand Total	116



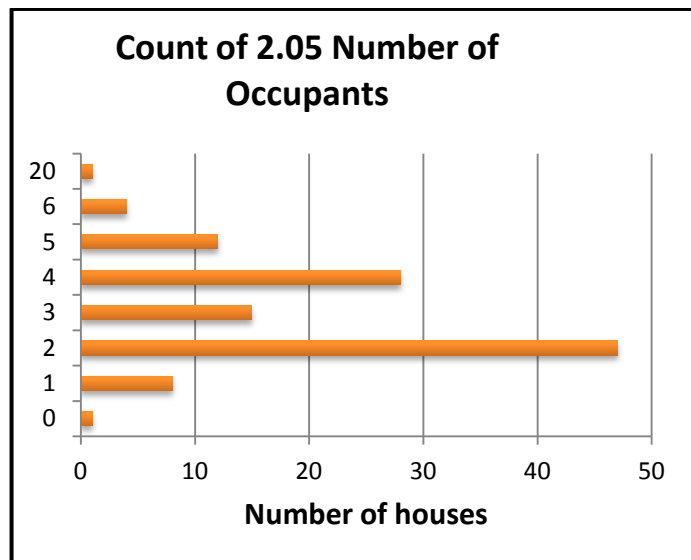
2.04: If your house is not permanently occupied please estimate the number of weeks per year it is occupied?

2.04 Weeks	Total
No answer	107
12	1
20	1
25	1
26	2
28	1
30	1
40	1
40 to 50	1

2.05: How many people normally live in the house when it is occupied?

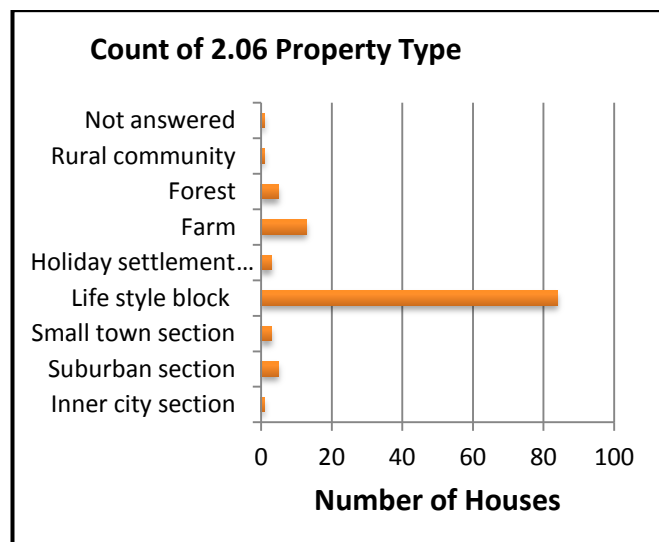
Where respondents gave a range of occupancy, an average figure has been applied.

2.05 Occupants	Total
0	1
1	8
2	47
3	15
4	28
5	12
6	4
20	1
Grand Total	116



2.06: What kind of property is your house located on?

2.06 Property type	Total
Inner city section	1
Suburban section	5
Small town section	3
Life style block	84
Holiday settlement section	3
Farm	13
Forest	5
Rural community	1
Not answered	1
Grand Total	116



2.07: Prior to your current house what kind of house/s (type of construction) have you lived in?

2.07 Previous House Types	Total
Timber framed - brick cladding	20
Timber framed - sheet cladding	32
Timber framed -timber cladding	78
Solid timber	5
Concrete masonry	18
Concrete	5
Steel	0
Stone	9
Earth	7
Straw bale	0
Other	16

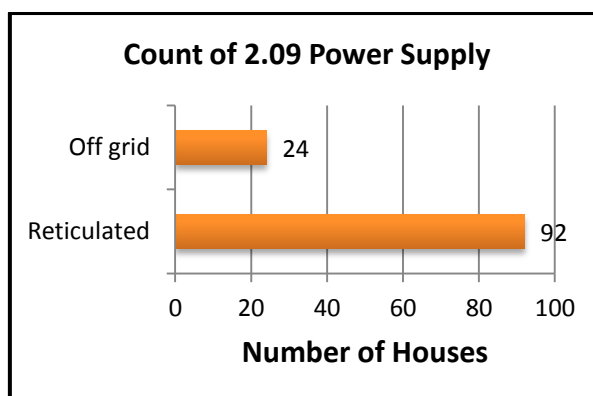
2.08: What are the main materials/construction methods used in the construction of your house?

Note: Answers to this question ranged from providing one material to providing multiple materials.

2.08 Current House Construction	Total
Timber frame	34
Timber Post and Beam	36
Concrete Post and Beam	1
Steel Post and Beam	2
Concrete masonry	9
Steel reinforcing	7
Earth- Rammed Earth	13
Earth- Cob	5
Earth- Adobe bricks	66
Earth- Soil cement bricks	7
Earth- Sand cement bricks	2
Earth- Light Earth	6
Straw bale	27
Other	4

2.09: Do you have a reticulated power supply?

2.09 Reticulated power	Total
Reticulated	92
Off grid	24
Grand Total	116

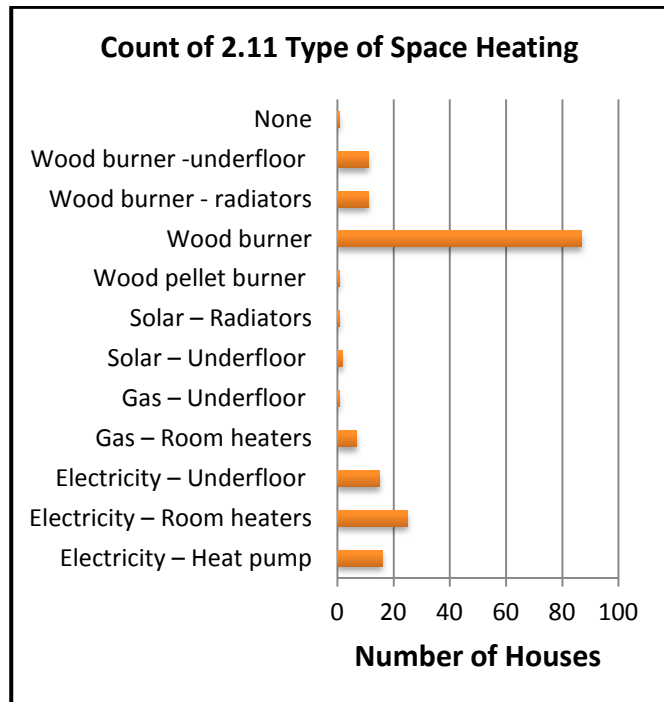


2.10: If you do not have a reticulated power supply what kind do you have?

2.10 Type electrical supply	Total
Micro Hydro	1
Micro Hydro,Solar	6
Solar	11
Solar, Micro Hydro, Wind, and Biodiesel generator	1
Solar, wind	5
Grand Total	24

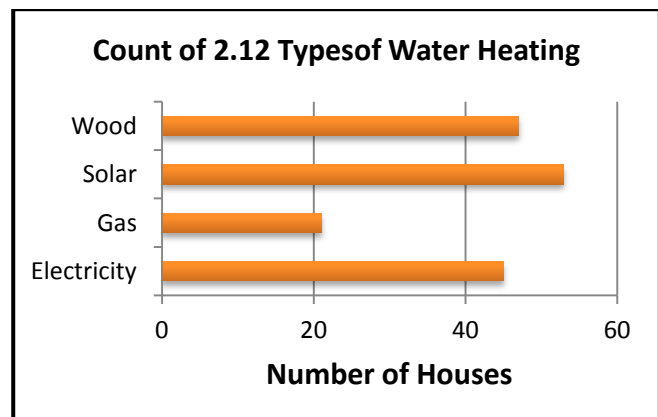
2.11: What kind of space heating do you use – excluding passive solar?

2.11 Type of space heating	Total
Electricity – Heat pump	16
Electricity – Room heaters	25
Electricity – Underfloor	15
Gas – Room heaters	7
Gas – Underfloor	1
Solar – Underfloor	2
Solar – Radiators	1
Wood pellet burner	1
Wood burner	87
Wood burner - radiators	11
Wood burner -underfloor	11
None	1



2.12: What main form of water heating do you use in your house?

2.12 Water Heating	Total
Electricity	45
Gas	21
Solar	53
Wood - Wetback	47



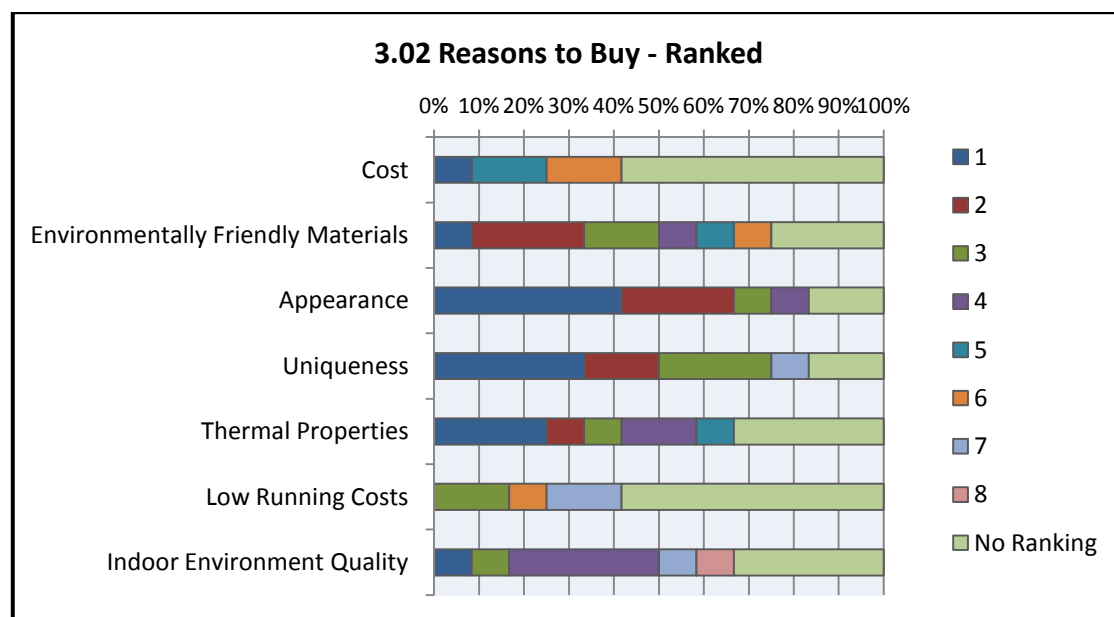
SUMMARIES FOR SECTION 3: Reasons for building/buying an earth or straw bale house

3.01: If you are not the original owner of your house, was the method of construction a determining factor in your decision to buy?

3.01 Decision to Buy	Total
Yes	12
No	13
Not answered	3
Original Owner	88
Grand Total	116

3.02: If you have answered 'yes' above please rate the following factors which may have influenced your decision in order of importance with 1 being the most important.

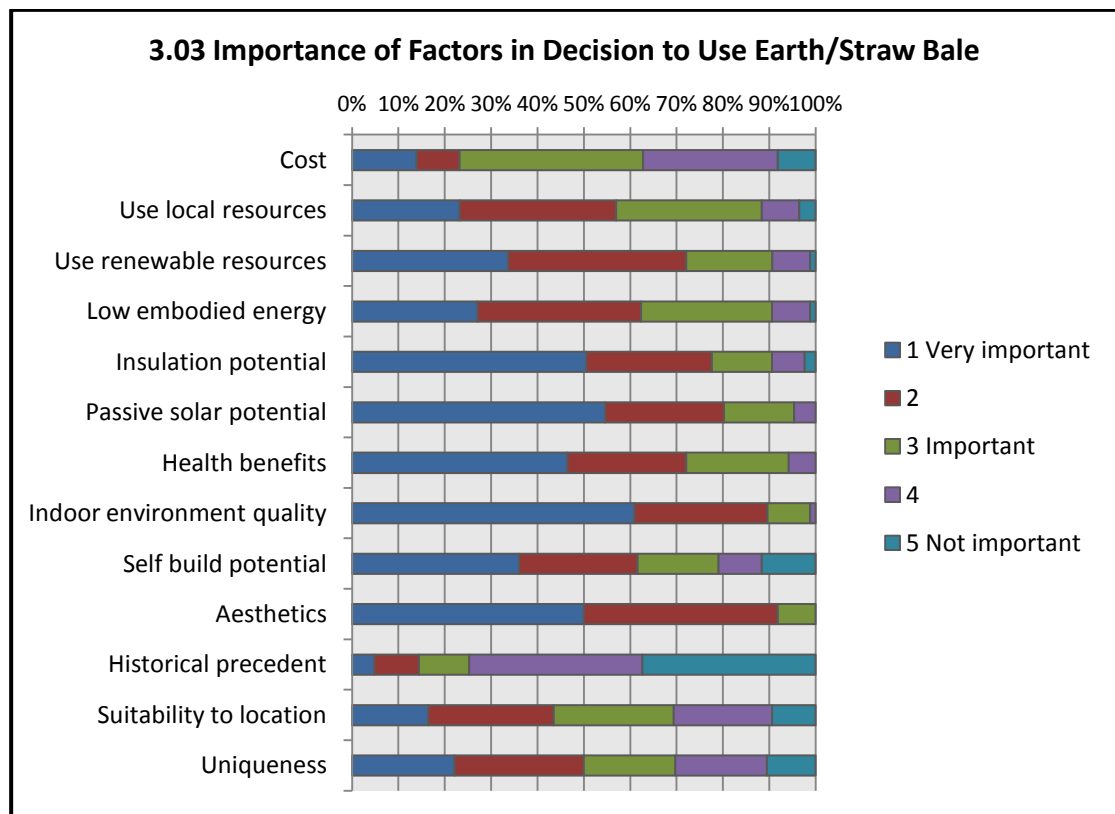
3.02	1	2	3	4	5	6	7	8	No Ranking
Cost	1				2	2			7
Environmentally Friendly Materials	1	3	2	1	1	1			3
Appearance	5	3	1	1					2
Uniqueness	4	2	3				1		2
Thermal Properties	3	1	1	2	1				4
Low Running Costs			2			1	2		7
Indoor Environment Quality	1		1	4			1	1	4



3.03: Using the scale below please rate how important the following factors were in your decision to build in an alternative way.

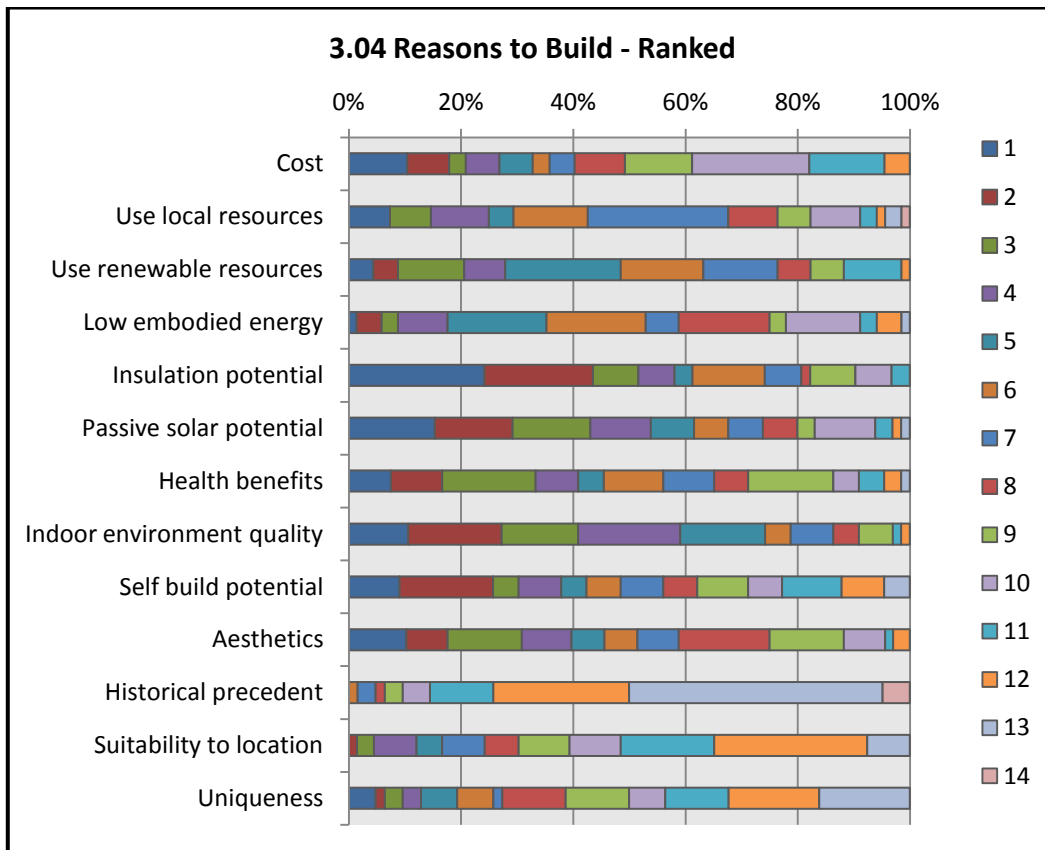
Note: The data numbering has been reversed from that used in the Questionnaire. The number 1 now represents 'Very Important' and the number 5 represents 'Not Important'. The reason for this is to facilitate ease of comparison and is explained in depth in Appendix 5.

3.03	1 Very important	2	3 Important	4	5 Not important
Cost	12	8	34	25	7
Use local resources	20	29	27	7	3
Use renewable resources	29	33	16	7	1
Low embodied energy	23	30	24	7	1
Insulation potential	43	23	11	6	2
Passive solar potential	47	22	13	4	0
Health benefits	40	22	19	5	0
Indoor environment quality	53	25	8	1	0
Self build potential	31	22	15	8	10
Aesthetics	43	36	7	0	0
Historical precedent	4	8	9	31	31
Suitability to location	14	23	22	18	8
Uniqueness	19	24	17	17	9



3.04: Please rank the same factors in order of importance with 1 being the most important.

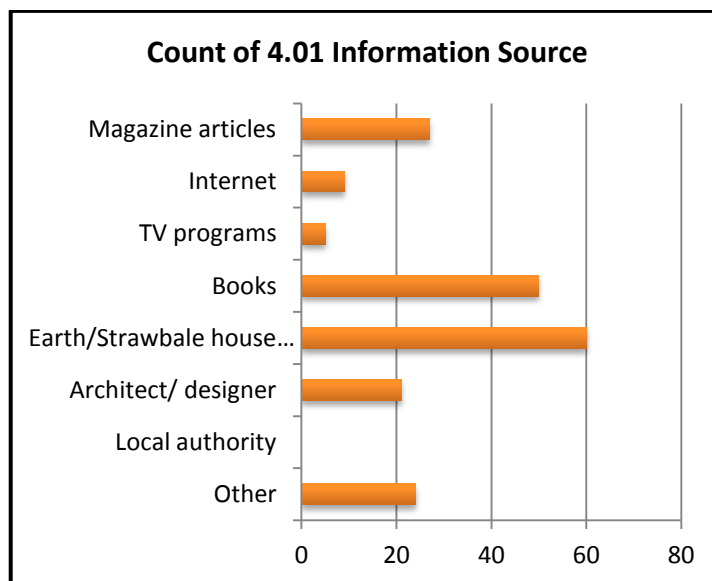
Note: See Appendix 5 for further analysis of the responses to this question.



SUMMARIES FOR SECTION 4: Pre Construction

4.01: How did you find out about earth/straw bale construction?

Information Source	Total
Magazine articles	27
Internet	9
TV programs	5
Books	50
Earth house owners	60
Architect/ designer	21
Local authority	0
Other	24



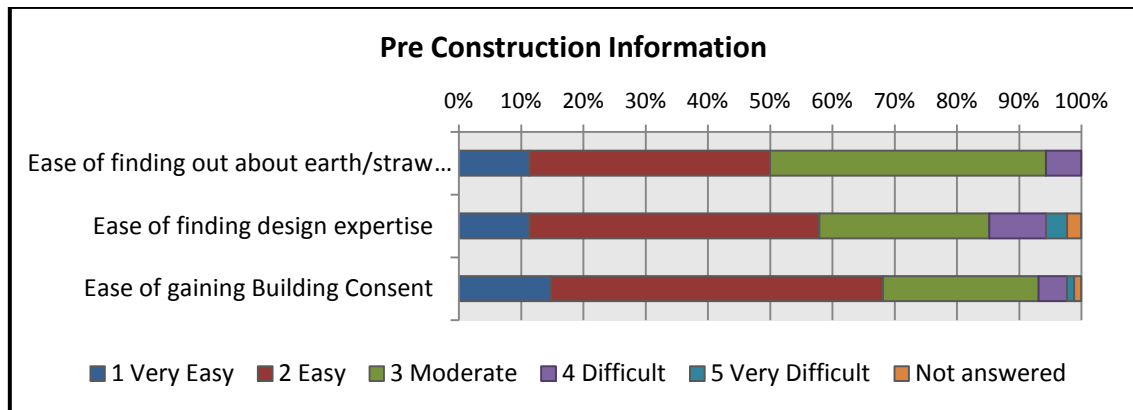
4.02: How easy was it to find out about earth/straw bale construction?

4.03: How easy was it to find people with the relevant design expertise to help you?

4.04: How easy was it to gain consent for your house?

Note: As for 3.03 the results have been rearranged to facilitate ease of comparison as outlined in Chapter 3.

Questions 4.02 – 4.04	Very Easy	Easy	Moderate	Difficult	Very Difficult	No answer
4.02: Ease of finding out about earth/straw construction	10	34	39	5	0	0
4.03: Ease of finding design expertise	10	41	24	8	3	2
4.04: Ease of gaining Building Consent	13	47	22	4	1	1



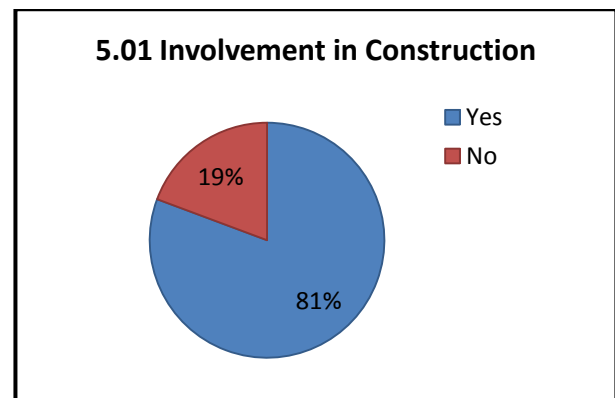
4.05: How did you obtain finance for you house project and did you have difficulties with this?

There were many different answers to this question as to sources of funding. No one expressed difficulty in obtaining a loan for their project.

SUMMARIES FOR SECTION 5: Construction

5.01: Were you actively involved in the construction of your house? (For original owners only)

5.01 Actively involved in construction	Total
Yes	71
No	17
Grand Total	88

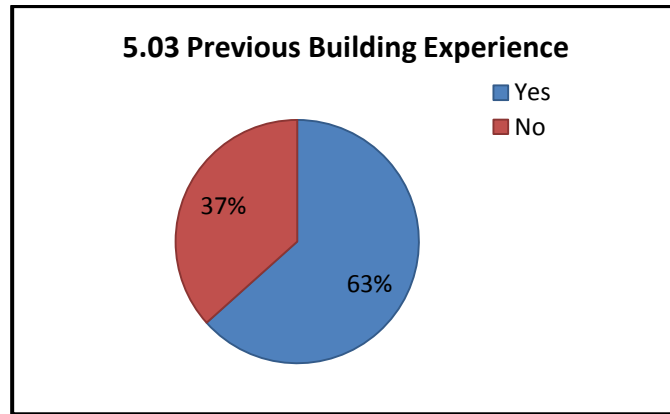


5.02: Is, to what extent? E.g. was your involvement continuous? Did you act as the main contractor?

The answers to this question are reported on in Chapter 3.

5.03 Had you had prior building experience?

5.03 Prior building experience?	Total
Yes	45
No	26
Grand Total	71



5.04: If you have answered 'yes' above please give brief details of this experience?

The answers to this question are reported on in Chapter Five.

SUMMARIES FOR SECTION 6: Performance

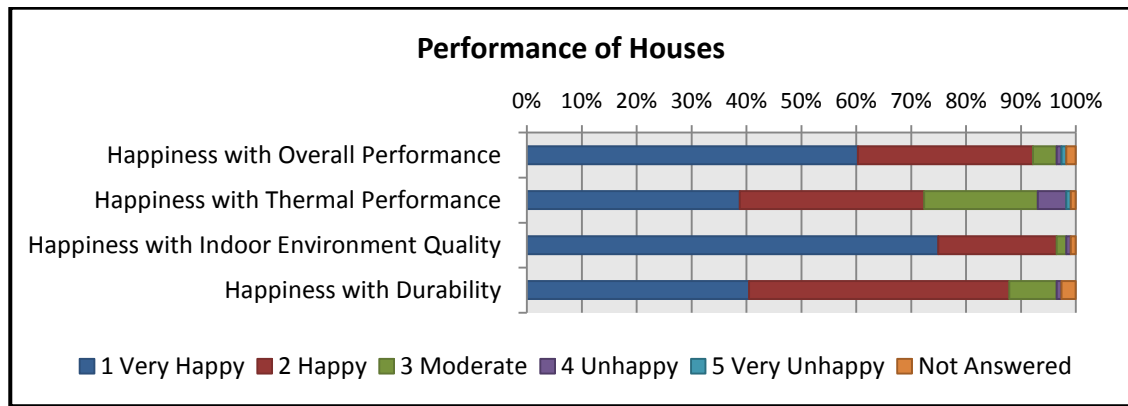
6.01: How happy/unhappy are you with the overall performance of your house?

6.02: How do you think your house performs thermally?

6.03: How do you rate the indoor environment quality (humidity/acoustics/toxicity) of your house?

6.04: How well do you think your house performs in terms of durability?

Questions 6.01-6.04	Very Happy	Happy	Moderate	Unhappy	Very Unhappy	No Answer
6.01: Overall Performance	70	37	5	1	1	2
6.02: Thermal Performance	45	39	24	6	1	1
6.03: Indoor Environment Quality	87	25	2	1	0	1
6.04: Durability	47	55	10	1	0	3

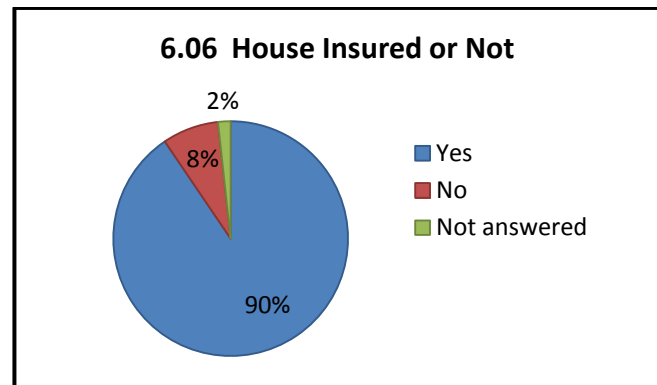


6.05: If you are unhappy with any aspects covered by questions 6.01-04 please elaborate.

The answers to this question are many and varied and are discussed in Chapters Five and Six.

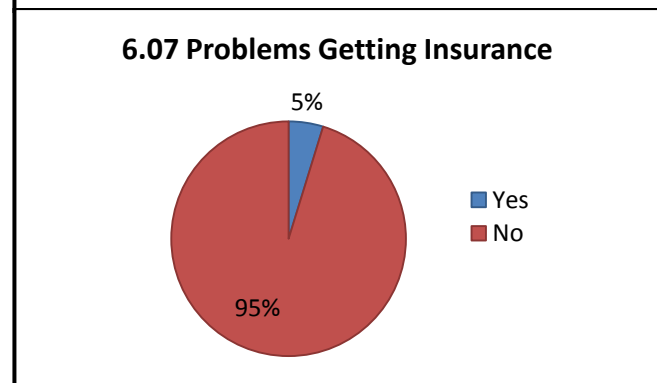
6.06: Is your house insured?

6.06 House Insured?	Total
Yes	105
No	9
Not answered	2
Grand Total	116



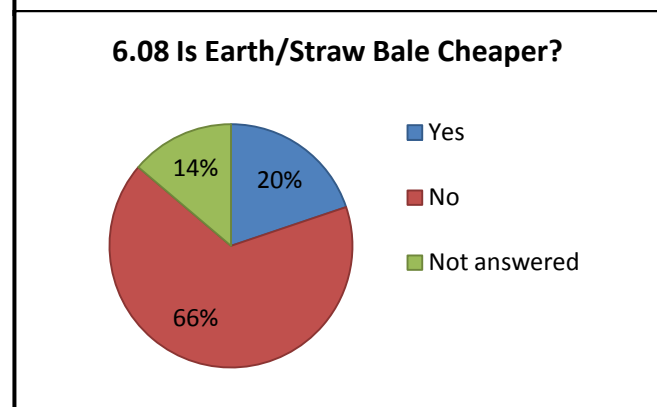
6.07: Did you have any problems getting insurance cover?

6.07 Insurance Problems?	Total
Yes	5
No	100
Grand Total	105



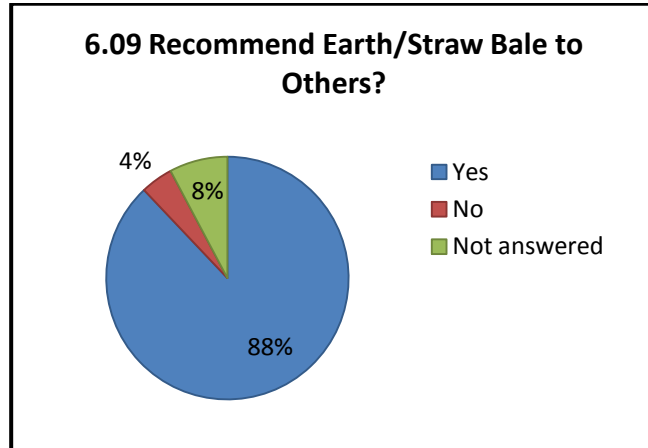
6.08: Do you believe earth/straw bale construction is cheaper than other forms of construction?

6.08 Is earth/straw bale cheaper?	Total
Yes	23
No	77
Not answered	16
Grand Total	116



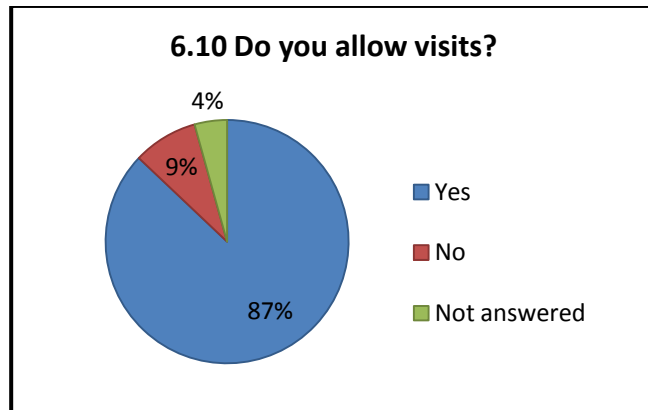
6.09: Would you recommend this form of construction to others?

6.09 Recommend earth/straw bale to others?	Total
Yes	102
No	5
Not answered	9
Grand Total	116



6.10: Do you allow people interested in building out of earth/straw bale to visit your house?

6.10 Do you allow visits?	Total
Yes	101
No	10
Not answered	5
Grand Total	116



6.11: if you were to build or buy a house again what material or construction method would you chose and why?

There were 116 different answers to this question which are discussed in Chapter Five.

APPENDIX 4: INFORMANTS, INTERVIEWEES, AND INTERVIEW QUESTIONS

A4.1 INFORMANTS: People who assisted with identifying and locating earth and straw bale houses in the Nelson area (see 3.3).

Danny Beattie (TDC)

David Davies

Mark Fielding

Jon Fraser

Gerald Gaskell

Gary Hodder

Kelly Isles (NCC)

David Kinloch

Verena Maeder

Linda Mitchell (TDC)

Peter Olorenshaw

Philip Osborne

Richard Popenhagen (NCC)

Aiden Pykett

Ken Robinson

Richard Walker

Chip Williams

A4.2 INTERVIEWEES

Nancy-Jean Bell

Mark Feilding

Rau Hoskins

Sarah Johnston

Kenny McLennan

Verena Maeder

Stephan Meijer

Graeme North

Peter Olorenshaw

Hamish Rush

Richard Walker

A4.3 INTERVIEW QUESTIONS

FOR EXPERTS –VM, PO, GN, MF, RW, SM, SJ, JC, RH, KM

Where is design heading – where do you think it should be heading?

Are there improvements to materials that you think should be made?

Is it getting harder to get consents?

Are there as many owner builders?

Do you think owners really understand thermal characteristics of earth/straw?

What are your thoughts about the light earth method?

Can you tell me about the New Generation Bricks – their history, testing, performance?

What are your thoughts about cob as a method and its performance?

Why do you think there is no in situ adobe or poured earth in Nelson?

What are your thoughts about straw bale construction and the inclusion of drainage cavities?

After seeing how buildings have performed in the Canterbury earthquakes are there any changes you think should be made to the earth building standards?

How viable are existing earth and straw building companies?

Do you think there is the potential for new industries producing building products and specialising in construction utilising earth and/or straw?

Do you think this method of construction lends itself to community housing schemes?

FOR OWNER BUILDERS – VM, PO, RW, SM, KM, HR, NB

Why did you choose to build your house yourself? Why was it important?

How did you support yourself financially while building your house?

How many square metres is your house?

How much did your house cost to build?

Do you think this method of construction lends itself to community housing schemes?

FOR HOME OWNERS WITH PERFORMANCE ISSUES – RW, PO, SM

What aspects of your house's performance are you unhappy with?

Do you have plans to address these issues? If so what are they?

Do you believe it is possible to avoid these problems if you were starting again?

APPENDIX 5: LIKERT SCALE QUESTIONS and QUESTIONS 3.03-3.04

A5.1: LIKERT SCALE QUESTIONS

The survey questions which asked respondents to rate factors on a likert scale were set up with 1 being 'Not important', 'Very difficult', 'Very unhappy' and so on and 5 being 'Very important', 'Very easy', 'Very happy' and so on. When it came to analysing the data, particularly for Section 3, it became clear that if the numbering had been the other way around, with 1 being 'Very Important' and so on and 5 being 'Not Important' and so on, it would have been simpler. It would facilitate a straight forward comparison between the rating questions, such as 3.03, and the ranking questions, such as 3.04. In this way number 1 would always represent the most important factor and all graphs would read from left to right in order of importance. Therefore the data has been rearranged to facilitate this in the summary, Appendix 3, and the thesis chapters. For all graphs the colours dark blue and dark red always stand for ranking or ratings of 1 and 2 respectively.

A5.2: ANALYSIS OF RESPONSES TO QUESTIONS 3.03 AND 3.04 FROM THE QUESTIONNAIRE (Appendix 2)

The answers to the questions directed at the 88 original owners regarding their reasons for choosing to build in earth or straw bale provided the information sought but also highlighted some issues with the way the questions were asked. With the benefit of hindsight, it may have made the intention of the question clearer if the word 'rank' had been used for this question rather than 'rate'. The following analysis was made by Nellie Hall, (M.Maths) Manager, Housing Analysis and Research at Housing New South Wales in the NSW Government's Department of Family and Community Services. The likert scale numbering used in the questionnaire has been reversed for the reasons described above in A5.1 and the figures prepared by the author for the thesis have been used to support Nellie Hall's analysis.

INTRODUCTION

Section 3 of the questionnaire asked those respondents who were the original owners to rank 13 factors in terms of their importance. This was done in two ways.

1) Question 3.03: Respondents were asked to rate each factor on a scale of 1 'Very Important' to 5 'Not important'.

2) Question 3.04: Respondents were asked to rate each of the factors relative to the other 12 factors. They were asked to rate each factor in order of importance with 1 being the most important and 13 being the least important. The intention was that respondents would assign a rank between 1 and 13 to each of the 13 factors.

Whilst nearly all respondents answered question 3.03 using the scales provided, not all respondents answered question 3.04 correctly. Of the 88 original owners, 68 answered question 3.04 correctly rating the factors from 1 to 13. A further 17 answered the question using a condensed rating scale (e.g. one respondent rated 3 of the factors as 1, 5 factors as 2 and 5 factors as 3). The remaining 3 respondents did not answer the question at all.

ANALYSIS

The intention of these questions was to establish which factors were most important to the home owners in their decision to build an earth/straw bale house rather than a more conventional house. Because of the issue with question 3.04, the analysis was done separately for the 68 respondents who answered the question as intended and for the 17 who answered using a condensed scale. The results below show that regardless of the rating scales used, the same factors keep coming up as being the most important to the respondents.

Q3.03 (Analysis is for all 88 original owners)

For each of the 13 factors, Table A5.1 shows the number of respondents who rated the factor as 1, 2, 3, 4 or 5 (very important to not important).

Figure A5.1 shows that the two factors that are consistently rated as 4 or 5 (very important and nearly very important) are indoor environmental quality (89%) and

aesthetics (90%). The next most highly rated factors were passive solar potential (78%), insulation potential (75%), health benefits (70%) and the opportunity to use renewable resources (70%). The factors rated as being the least important were the historical precedent (14%) and the cost (23%).

	1 Very important	2	3 Important	4	5 Not important
Cost	11	7	25	19	6
Use local resources	17	22	21	6	2
Use renewable resources	25	23	13	6	1
Low embodied energy	20	22	20	4	1
Insulation potential	30	23	8	4	2
Passive solar potential	32	20	12	3	0
Health benefits	31	19	12	5	0
Indoor environment quality	41	21	5	1	0
Self build potential	22	19	12	7	8
Aesthetics	33	28	7	0	0
Historical precedent	3	7	6	26	23
Suitability to location	11	19	19	10	8
Uniqueness	15	20	15	11	7

Table A5.1: Q3.03 Answers (n=88)

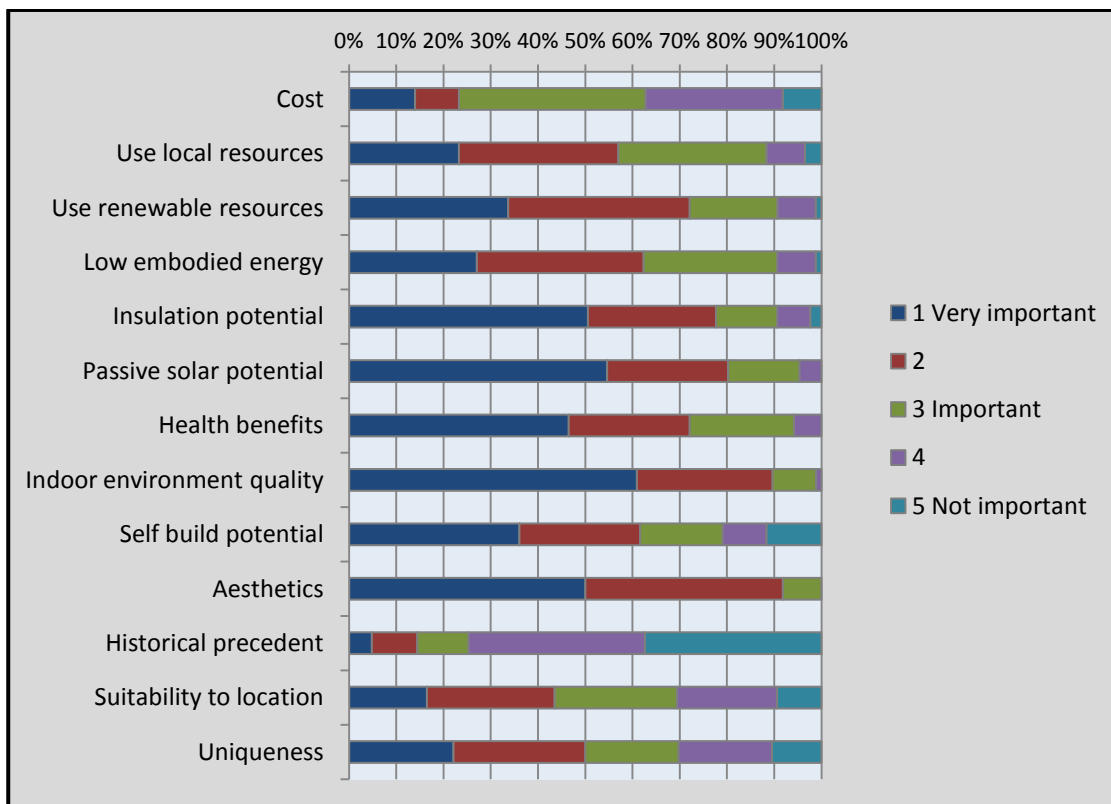


Figure A5.1: Importance of Factors in Decision to Use Earth or Straw Bale (n=88)

Q3.04 (Analysis for the 68 respondents who answered correctly, unless otherwise indicated)

RANK	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Cost	7	5	2	4	4	2	3	6	8	14	9	3	0	0
Use local resources	5	0	5	7	3	9	17	6	4	6	2	1	2	1
Use renewable resources	3	3	8	5	14	10	9	4	4	0	7	1	0	0
Low embodied energy	1	3	2	6	12	12	4	11	2	9	2	3	1	0
Insulation potential	15	12	5	4	2	8	4	1	5	4	2	0	0	0
Passive solar potential	10	9	9	7	5	4	4	4	2	7	2	1	1	0
Health benefits	5	6	11	5	3	7	6	4	10	3	3	2	1	0
Indoor environment quality	7	11	9	12	10	3	5	3	4	0	1	1	0	0
Self build potential	6	11	3	5	3	4	5	4	6	4	7	5	3	0
Aesthetics	7	5	9	6	4	4	5	11	9	5	1	2	0	0
Historical precedent	0	0	0	0	0	1	2	1	2	3	7	15	28	3
Suitability to location	0	1	2	5	3	0	5	4	6	6	11	18	5	0
Uniqueness	3	1	2	2	4	4	1	7	7	4	7	10	10	0

Table A5.2: Ranking of Factors in Decision to Use Earth or Straw Bale (n=68)

	Ranked as 1 or 2
1 Insulation potential	27
2 Passive solar potential	19
3 Indoor environment quality	18
4 Self build potential	17
5= Cost	12
5= Aesthetics	12
7 Health benefits	11
8 Use renewable resources	6
9 Use local resources	5
10= Uniqueness	4
10= Low embodied energy	4
12 Suitability to location	1
13 Historical precedent	0

Table A5.3 Factors in order of importance 1 (n=68)

Table A5.2 shows the number of times respondents rated a factor as rank 1 or 2 or 3 etc up to number 13. One way to view this information is to consider the number of times a factor was rated as either the most important (1) or second most important factor, and then to rank the 13 factors on this basis. Using this methodology the results in Table A5.3 indicate the most important factors in order of importance.

Another way to make sense of the ratings is to sum them for each factor. To ensure that a rating of 1 is assigned the highest value, a ranking of 1 received 14 points, a ranking of 2 got 13 points, and so on down to a ranking of 14 which received 1 point (occasionally a factor was rated as 14 when a respondent added an additional factor which was important to them in making their decision to build in earth/straw bale).

The points for each of the 13 factors were summed and factors ranked on the basis of the points totals. So for example the cost factor got a total of 518 points. Using this methodology the most important factors in order of importance were (Table A5.4):

	Total points
1 Indoor environment quality	700
2 Insulation potential	659
3 Passive solar potential	648
4 Aesthetics	619
5 Use renewable resources	617
6 Health benefits	599
7 Use local resources	566
8 Self build potential	557
9 Low embodied energy	556
10 Cost	518
11 Uniqueness	374
12 Suitability to location	364
13 Historical precedent	191

Table A5.4 Factors in order of importance 2 (n=68)

There are now three ways of viewing the results for questions 3.03 and 3.04. To summarise, Table A5.5 shows the ranking of each factor using the three methods described above. These are graphically displayed in Figure A5.2. (Note that the data presented in Table A5.5 and Figure A5.2 for Q3.03 (importance 1 or 2) relates only to the 68 respondents who answered Q3.04 correctly. Hence it is marginally different to the earlier analysis of Q3.03 which was based on all 88 respondents).

	Ranks 1 or 2 (Q3.04)	Total points (Q3.04)	Importance 1 or 2 (Q3.03)
Cost	5	10	12
Use local resources	9	7	9
Use renewable resources	8	5	6
Low embodied energy	10	9	7
Insulation potential	1	2	3
Passive solar potential	2	3	4
Health benefits	7	6	5
Indoor environment quality	3	1	1
Self build potential	4	8	8
Aesthetics	5	4	2
Historical precedent	13	13	13
Suitability to location	12	12	11
Uniqueness	10	11	10

Table A5.5 Summary of Three Ranking Methods (n=68)

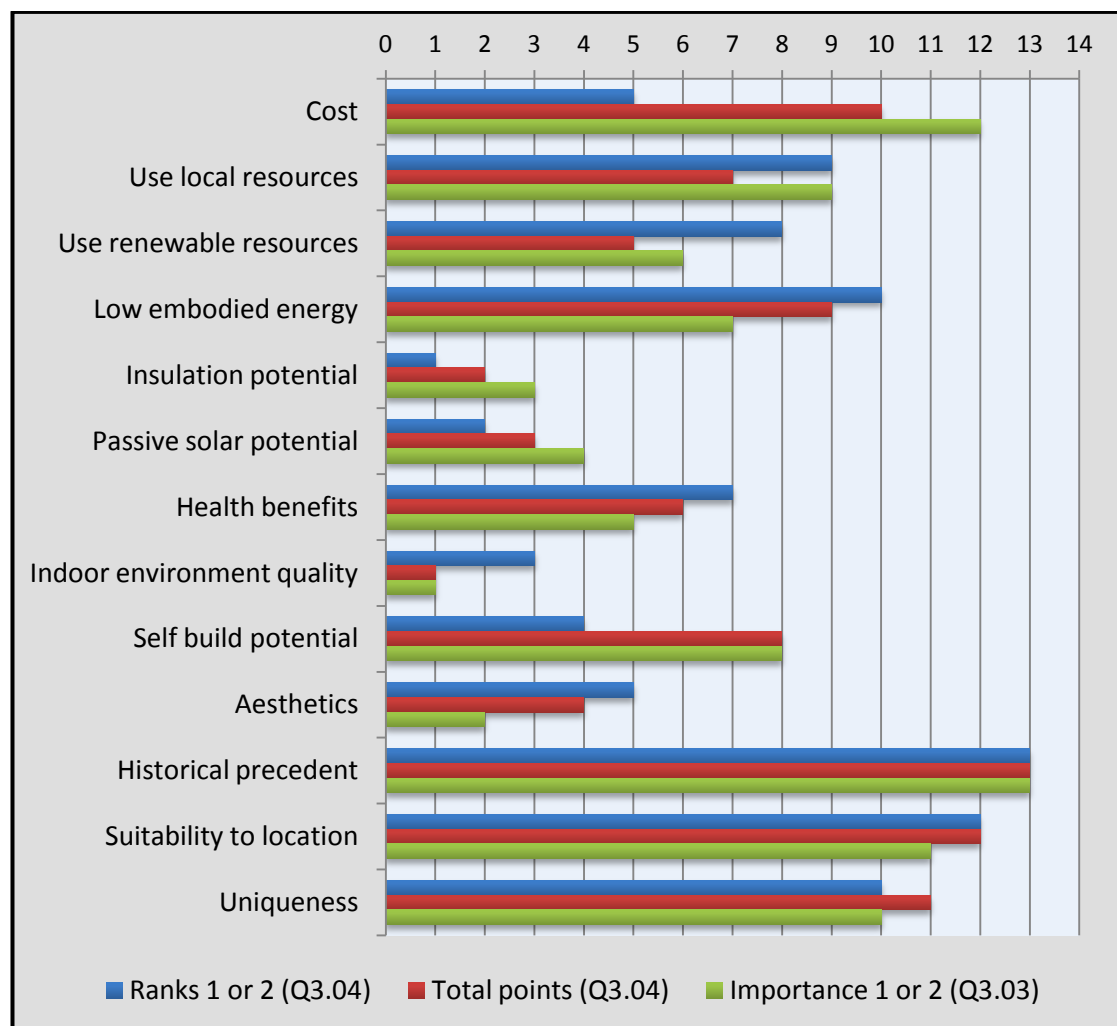


Figure A5.2 Summary of Three Ranking Methods (n=68)

It is clear from Table A5.5 and Figure A5.2 that insulation potential, passive solar potential and indoor environment quality, were considered the most important factors, regardless of the way the rankings are analysed. All three ranked between 1 and 4 under each of the analysis techniques. Aesthetics also consistently rated well, while 3 factors: historical precedent, suitability to location and uniqueness consistently ranked at the bottom.

The only factor that is difficult to fathom in terms of giving quite different results for each of the three analysis techniques is the cost. Whilst in Q3.03 it was not rated as being that important, in comparison to other factors it was rated highly (ranked 1 or 2 in Q3.04) by a substantial number of respondents.

Q3.04 Results for the 17 home owners who used a modified rating scale for question 17.

	Ranks 1 or 2 (Q3.04)	Total points (Q3.04)	Importance 1 or 2 (Q3.03)
Cost	8	5	12
Use local resources	8	10	9
Use renewable resources	8	9	5
Low embodied energy	7	8	7
Insulation potential	3	3	4
Passive solar potential	1	2	3
Health benefits	5	4	5
Indoor environment quality	1	1	2
Self build potential	4	5	7
Aesthetics	5	7	1
Historical precedent	12	13	13
Suitability to location	12	11	11
Uniqueness	8	11	10

Table A5.6 Summary of Three Ranking Methods (n=17)

The following analysis demonstrates that even though these respondents used different ranking scales for question 3.04, the same conclusions can be drawn about which factors were most important in their decision to build in earth / straw bale rather than conventional building methods.

Table A5.6 shows the ranking of each factor using the three methods described above but for the 17 home owners who used a modified rating scale for Q3.04.

As was the case for the 68 respondents who answered Q3.04 as intended, the three factors that were consistently ranked as 1, 2, 3 or 4 by the 17 respondents were insulation potential, passive solar potential and indoor environmental quality. As with the larger group, aesthetics also ranked highly.

Apart from two instances, the ranks of the 68 respondents differed from the ranks of the 17 respondents by no more than 3, for any of the three different ranking analyses conducted.

APPENDIX 6: SAMPLE PAGE FROM DATABASE OF 144 EARTH AND STRAW BALE HOUSES IN THE NELSON AREA

Note: Street addresses have not been included in the sample page.

Number	Name	Location	Material	Consent	Designer	Engineer	Builder
049S	Lord/ Watson (formerly Brabant)	Golden Bay	Strawbale	1998	M.Hall	B. Andrew	G.Gaskell
050E	McIntyre, L and A (Little Greenie)	Golden Bay	Adobe Int.Veneer	2008	M.Rogers	R.Walker	L.McIntyre
051E	McKenzie Holmes	Motueka	Soil Cement Bricks	2005	G.Deplazes		
052E	Mosey/Reid	Wakapuaka	Adobe	2004	I.Marriott		M.Rose
053E	Johnston (The Mud Castle)	Moutere	Adobe	1991	G.Hodder	G.Hodder	K.Johnston
054E	Newton/Squire House	Moutere	Adobe	1994	B.Gilkison	K.Forsman	I.Newton
055E	Olorenshaw/Jones House	Nelson	Adobe	1993	P.Olorenshaw	G.Hodder	Olorenshaw
056S	Reilly House	Moutere	Strawbale	2006	P.Olorenshaw		N.Marar
057S	O'Neill/Stevens House	Nelson	Strawbale	2003	A.Walters	Andrew/Hodder	
058E	McLennan Marshall House	Motueka	Adobe	2007	J.Fraser	R.Walker	K. MacLennan
059E	Gordon/ Moon (formerly Mitchell)	Moutere	Adobe	1995	J.Fraser	G.Hodder	Gilkison/Davies
060E	R.Taylor House	Moutere	Adobe	1997	R.Taylor	G.Hodder	Bolwell/Davies
061S	Rodgers House	Moutere	Strawbale	1996	B.Gilkison	R.Walker	Gilkison/Davies
062E	Isherwood (formerly Postles)	Richmond	Rammed Earth	1990	G.Postles	G.Hodder	G.Postles
063E	Isherwood (formerly Postles)	Richmond	Rammed Earth	1989	G.Postles	R.Walker	G.Postles
064E	Shapiro/Walker House	Motueka	Adobe	2008	M.Fielding	R.Walker	K.MacLennan
065E	Smith House	Moutere	Adobe	2007	S.Hunt	R.Walker	L.Smith
066E	Riverside - Barringtons	Moutere	Rammed Earth	1948	Riverside		Riverside
067E	Riverside - Hylands	Moutere	Rammed Earth	1950	Riverside		Riverside
068E	Riverside - Browns	Moutere	Rammed Earth	1957	Riverside		Riverside
069E	Riverside	Moutere	Rammed Earth	1958	Riverside		Riverside
070E	Riverside - Coles	Moutere	Rammed Earth	1955	Riverside		Riverside
071E	Riverside - The Earth House	Moutere	Rammed Earth	1975	Riverside		Riverside
072E	Manssen Morante	Moutere	Adobe	2002	P.Olorenshaw		G.Gaskell
073E	Kaye-Wood Van Der Koelen	Moutere	Adobe	1995	J.Kaye-Wood	R.O'Hara	P.Hay
074E	Brookes (formerly Parr)	Richmond	Rammed Earth	1988	I.Jack	K.Norgate	T. Parr/G Perry
075E	Parr	Richmond	Rammed Earth	2006			
076E	Petyt	Golden Bay	Adobe	1991	B.Gilkison	K.Forsman	B.Gilkison
077E	C. Taylor	Richmond	Adobe	2006	I. Marriott	R.Walker	N.Perram

APPENDIX 7: PAGES FROM NCC AND TDC BUILDING CONSENT APPLICATION FORMS.

A7.1 NCC Building Consent Application Form: Page 2

APPLICATION																	
Have you applied for a PIM regarding this proposal <input type="checkbox"/> Yes (if yes state number and date): _____ / ____ / ____ <input type="checkbox"/> No																	
I request that a: <input type="checkbox"/> Building Consent including Project Information Memorandum (PIM) <input type="checkbox"/> Building Consent only: be issued for the Building Work Described in this Application																	
I agree to pay all fees applicable to this application SIGNATURE: Owner _____ or Agent _____ <div style="text-align: right; margin-right: 50px;">On behalf of and with the authority of the owner</div> <div style="text-align: right;">Date _____</div> <p><i>Note: if acting "for and on behalf", please read the following declaration before signing:- "I hereby declare that I am authorised to act as Agent of the Applicant".</i></p>																	
<div style="text-align: center; border-bottom: 1px solid black; margin-bottom: 5px;">THE PROJECT</div> Description of Building Work: <i>(sufficient to enable scope of work to be fully understood)</i> <input type="checkbox"/> New <input type="checkbox"/> Alteration <input type="checkbox"/> Relocation <input type="checkbox"/> Extension <input type="checkbox"/> Demolition Details: <div style="border: 1px solid black; height: 150px; margin-top: 5px;"></div>	<div style="text-align: center; border-bottom: 1px solid black; margin-bottom: 5px;">PROJECT INFORMATION MEMORANDUM</div> <p>Note: This section must be completed if you are applying for a PIM with your Building Consent.</p> <p>The following matters are involved in the project: <i>(provide relevant information on plans/documentation)</i></p> <div style="display: flex; flex-wrap: wrap;"> <div style="width: 50%;"> <input type="checkbox"/> Subdivision Application No: _____ </div> <div style="width: 50%;"> <input type="checkbox"/> Resource Consent Application No: _____ </div> </div> <div style="margin-top: 5px;"> <input type="checkbox"/> Alterations to land contours <input type="checkbox"/> New or altered connections to public utilities <input type="checkbox"/> New or altered locations and/or external dimensions of buildings <input type="checkbox"/> New or altered access for vehicles <input type="checkbox"/> Building work over or adjacent to any road or public place <input type="checkbox"/> Disposal of stormwater and wastewater <input type="checkbox"/> Building work over any existing drains or sewers or in close proximity to wells or water mains <input type="checkbox"/> Other matters known to the applicant that may require authorisations from the Territorial Authority <i>(Eg. Planning Approvals, other licenses)</i> </div> <div style="margin-top: 10px;"> <i>(Specify):</i> _____ <div style="border: 1px solid black; height: 100px; margin-top: 5px;"></div> </div>																
Will the building work result in a change of use of the building? No <input type="checkbox"/> Yes <input type="checkbox"/> If 'Yes', give details: <div style="border: 1px solid black; height: 40px; margin-top: 5px;"></div>																	
Intended life of the building (if < 50 years): _____ Estimated value of the building work on which the building levy will be calculated (including GST) <i>(State estimated value as defined in section 7 of the Building Act 2004)</i> \$ _____																	
List building consents previously issued for this project: <i>(i.e. is this project being constructed in stages? Is this consent for a relocated or transportable building)</i> <table border="1" style="width: 100%; border-collapse: collapse; margin-top: 5px;"> <thead> <tr> <th style="width: 30%;">Issued by</th> <th style="width: 30%;">Date of issue</th> <th style="width: 40%;">Consent number</th> </tr> </thead> <tbody> <tr><td> </td><td> </td><td> </td></tr> <tr><td> </td><td> </td><td> </td></tr> <tr><td> </td><td> </td><td> </td></tr> <tr><td> </td><td> </td><td> </td></tr> </tbody> </table>			Issued by	Date of issue	Consent number												
Issued by	Date of issue	Consent number															

A7.2 TDC Building Consent Application Form: Page 3

PART B**Project Information Memorandum** *supporting information (to be completed unless a PIM has already been provided)*The following matters are involved in the project: *(tick the matters relevant to the project)*

- ☐ Subdivision application no. _____
- ☐ Resource Consent application no. _____
- ☐ Alterations to land contours
- ☐ New or altered connections to public utilities
- ☐ New or altered locations and/or external dimensions of buildings
- ☐ New or altered access for vehicles
- ☐ Building work over or adjacent to any road or public place
- ☐ Disposal of stormwater and wastewater
- ☐ Building work over any existing drains or sewers, or in close proximity to wells or water mains
- ☐ Other matters known to the applicant that may require authorisation from the territorial authority: *(specify)*

PART C**The Project**Description of the building work: *(provide sufficient description of building work to enable scope of work to be fully understood; continue on a separate page if necessary, or refer to an attached document setting out the description)*

- ☐ New
- ☐ Alteration
- ☐ Relocation

Will the building work result in a change of use of the building? ☐ Yes ☐ No

If Yes, provide details of the new use: _____

Intended life of the building if less than 50 years: *(number of years)* _____List building consents previously issued for this project *(if any):*
(list who issued the consent, the date of issue and the consent number)

Issued By	Date Issued	Consent No.	Issued By	Date Issued	Consent No.

Estimated value of the building work on which the building levy will be calculated \$ _____
(including goods and services tax): (state estimated value as defined in Section 7 of the Building Act 2004)

APPENDIX 8: TABLE 2(b) p.18 H1/VM1 NZBC

Replacement Table 2(b):	Solid construction (excluding solid timber) – alternative minimum R-values for schedule method (only where area of glazing is 30% or less of total wall area)					
Building thermal envelope component	Minimum R-values (m ² °C/W)					
	Climate zone 1		Climate zone 2		Climate zone 3	
	Option 1a	Option 1b	Option 2a	Option 2b	Option 3a	Option 3b
Roof	R 3.5	R 3.5	R 3.5	R 3.5	R 3.5	R 3.5
Wall	R 0.8	R 0.8	R 1.0	R 0.9	R 1.2	R 1.0
Floor	R 1.5	R 1.3	R 1.5	R 1.3	R 1.5	R 1.3
Glazing (vertical)	R 0.26	R 0.31	R 0.26	R 0.31	R 0.26	R 0.31
Glazing (skylights)	R 0.26	R 0.31	R 0.26	R 0.31	R 0.31	R 0.31

NOTE:

- (1) The R-values given in this table are those applicable to the reference building as described in this Standard (NZS 4218).
- (2) Climate zone boundaries are shown in Appendix B (of NZS 4218).
- (3) If the sum of the area of glazing on the East, South and West facing walls (see Appendix H of NZS 4218) is more than 30% of the total wall area of all of these walls, then the calculation or modelling method shall be used.
- (4) Carpets or floor coverings are not included in the floor R-value. The floor R-value is met by concrete slab-on-ground and suspended floors with continuous closed perimeter with 100 mm draped foil. Exposed floors will require additional treatment (e.g. pole houses).
- (5) The R-values for glazing refer to whole window R-values (glass and frame). The values in this table are for a standard WERS window (Appendix G of NZS 4218). Any proposed area of glazing shall be considered to have an R-value as given in Appendix G (of NZS 4218).
- (6) There are no R-value requirements for the opaque parts of a door or a door set.
- (7) Total area of skylights must be no more than 1.2 m². The calculation or modelling methods must be used for designs where the total area of skylights is more than 1.2 m².
- (8) An R-value of 0.26 m² °C/W may be used for traditional leadlight glass when the total area of leadlight glass is no greater than 2.6 m² and either the schedule method or calculation method is used.
- (9) The R-values specified in Option 1b, 2b and 3b may only be used in the schedule method, i.e. shall not be used in the calculation or modelling methods.
- (10) When using R-values for either Options a or b, all R-values for that option shall be used, i.e. roof, wall, floor and glazing. The R-values for a single building component shall not be substituted from one option to another.
- (11) Table 2(b) allows buildings of solid construction to have lower R-values than buildings of non-solid construction, due to the benefits of appropriate use of thermal mass. Thermal mass must be used in conjunction with good passive design to increase comfort and reduce energy use. Use of the R-values in table 2(b) requires that the thermal mass is accessible, i.e. inside the insulated building envelope. If additional bulk insulation material is required to achieve the R-values in this table, this insulation must be installed on the outside of the wall.

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