BEYOND THE TENT

THE APPLICATION OF A TOOL BASED APPROACH
TO THE EXPLORATION OF AGGREGATE BUILDING
METHODOLOGIES

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requirements of the degree of Master of Architecture (Professional)
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accomplishment would not have been possible without you.
Thank you.

ABSTRACT

To the detriment of many, the act of building dwellings has become increasingly prohibitive. Materials costs and the cost of labour makes up a significant part of this expense. While this issue is becoming increasingly paramount in the western world where you have population increase (expected to be doubled by 2050), it is the genuinely vulnerable who are the most affected. This design research thesis explores the logic of aggregate assemblages as a potentially low cost, low skills base, rapid assembly (not construction) system that could assist in providing a solution to both post-disaster housing demands or refugee encampments where there is plentiful raw base clays or concreteous material. Aggregate assemblages require neither additives or fixings to bind together instead of relying solely and efficiently on their geometry to create connections. A 2004 internal UNHCR report suggested the average lifespan of a refugee camp was 17 years. Further, while providing little beyond basic shelter, the average lifecycle of a UN family tent is typically three months, hence requiring

constant costly replacement. Additionally, political desires for non-permanent settlement solutions along with the potential for fluctuating landscapes induced by severe weather conditions suggest that space for an agile yet cohesive and robust rapid assembly methodology exists. Thus, this thesis proposes that interlocking aggregate assemblages could provide an alternative solution that would be a valuable addition to the status quo.

The research argues for an interlocking aggregate creation, and assembly method that goes beyond the tent to offer a durable, robust internal environment with high degrees of flexibility and customisation with its human end users in mind – through the following criteria: allows the occupant to stand up and move freely inside; Accommodates the preparation and cooking of meals under shelter; Can respond to a variety of site conditions: Can adapt to reflect cultural customary notions of space; Can increase the sense of safety and security.

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PROBLEM STATEMENT

To the detriment of many, the act of building homes has become increasingly prohibitive. Materials costs and the cost of labour makes up a significant part of this expense. While this issue is becoming more paramount in the western world where you have population increase (expected to be doubled by 2050), it is the genuinely vulnerable who are the most affected.

RESEARCH QUESTION

How can a tool-based approach contribute to the development of a self-build modular aggregate building system?

FRAMEWORK

The main body of this research employs a tool based process. The tool-based approach seeks in the first instance to develop either a tool or method which can then be applied to various applications. This differs substantially from traditional typological concept design, preliminary design, developed design process.

Focusing primarily on the development of the tool/process rather than the end application allows unexpected and unconventional solutions to emerge. The development of these tools or methods of creation were principally fleshed out through the use of physical and digital models.

Additionally, the concurrent nature in which many of the design phases were carried out saw both case studies and learning

born from research revisited, re-read and re-interpreted before being re-drawn.

Subsequent to the production of the physical model's, time was taken to diagram the learning outcome. The process of diagramming was initially conceived simply as a tool that enabled the description of specific behavioural characteristics- learning born out of the physical modelling tests. However, this process became much more significant as it forced a period of questioning and reflection as to what was taking place with the models, enabling considerable learning to take place.

The adoption of this framework saw a series of techniques developed with each building off the last.

PROJECT SCOPE

This thesis sets out to examine the introduction to the creation of use of a tool based process can aggregate assemblies and is benefit the design of an interlocking embodied within and limited aggregate method of assembly that to the first design phase. is able to lend itself to both post-disaster and refugee scenarios. As The second project takes a more a consequence of the often remote speculative approach to engage with locations in which refugee camps are established and subsequently the proposition. Through the body of work assembled within design phases the severe limitations of available two, three, and four, two distinct material from which to build with, methodologies are developed. this design led research seeks to While outside the primary scope develop novel methods of assembly of this research design phase five to leverage these limited materials. further speculates as to how this The scope of this work is research could be applied to a comprised of two projects spread over four design phases. refugee camp scenario. The initial project provides an

PROJECT ONE

DESIGN PHASE ONE

Aim

To explore through physical And digital modelling the geometrical and tectonic qualities of what a solution could look like and then to assess the extent the outcome was fit for purpose.

Method

Equipment:

//Rhinceros // ABS

//Plaster // Harakeke

// Fibre glass

1//Survey existing precedents + Redraw + Fabricated + Assess.

2//Redraw + iterate + reconcile with thermal requirement + Fabricate +access

3//Redraw + iterate vertical requiret

4// Fabriaction studies

Image redacted from digital version

fig.101 Case study module

The research was undertaken both online and also in VUW Libraries database using search terms such as “interlocking bricks”, “interlocking blocks”, “interlocking geometries”, “smart bricks”. A building system designed by Juan Manuel Reyes from Armados Omega and architect Jorge Capistrán stood out as being a good place to initiate further investigations. Their system had been developed as a solution to address a housing affordability issues in Mexico’s most disadvantaged areas and off and as such had been developed with a similar sensibility that which was being pursued. The case study module was modelled in Rhinoceros and fabricated as a 3d print for assessment.

fig.102 Redrawn and printed case study module

On assembling the fabricated case study blocks, gravity promptly illustrated the system did not adequately join more than two blocks in a structurally satisfactory manner. Further, an integrated means to interlock the modules vertically was also absent — the case study module used a steel reinforcing rod to do this. The possibility of using natural material such as bamboo was considered, however addressing the issue with the geometry was deemed preferable in order to limit both materials and the steps required in the building process. This consideration is explored further in future steps.

① **CASE STUDY MODULE**

② **MODULE ADAPTION**

fig.104. Precedent module redrawn

fig.103 Adapted module with thermal solution

1 EXTERNAL RAIN-SCREEN
2 CONTINUOUS RIGID INSULATION

3 INTERNAL STRUCTURAL LAYER
4 BREATHABLE INTERIOR RENDER

fig. 105 Adapted module with thermal solution

Investigations were undertaken to ascertain how the thermal requirement of the proposed building system could most effectively integrate with the adapted case study module.

The double-wall method comprising of insulation sandwiched between a rain screen and a structural wall was assessed to be a viable option, as it:

1. Resulted with minimal thermal bridging
2. Had the ability to accommodate a range insulating mediums including but not limited to XPS, sheep's wool and cellulose.

LOAD BEARING SURFACE

HORIZONTAL INTERLOCK

VERTICAL INTERLOCK

ANATOMY OF THE BRICK

Through employing an iterative process of drawing, fabricating, testing and redrawing a series of models were created. Undertaken with the view that the double wall methodology that addresses the thermal requirement could be retroactively applied this next series sort to address the requirement for vertical interlocking. On reflection, a criticism of the modules was that the verticle element might be prone to cracking. As such subsequent fabrication studies were embarked on to understand the effectiveness of impregnating the substrate with natural and artifical fibres and whether this could provide suffiecnt reinforcement to the vertical element. These fabrication studies tested the effectiveness of harakeke and fibreglass fibres in a variety of, quantities, lengths and orientations.

fig.107 Vertical interlock series

ORIENTATION: BI-DIRECTIONAL
TYPE: HARAKEKE
QUANTITY: 170
SPACING: 1mm
LENGTH $\times$ *dir.* 100mm
LENGTH $\times$ *dir.* 70mm
FRAGILITY: LOW

ORIENTATION: BI-DIRECTIONAL
TYPE: HARAKEKE
QUANTITY: 85
SPACING: 2mm
LENGTH $\times$ *dir.* 100mm
LENGTH $\times$ *dir.* 70mm
FRAGILITY: LOW

ORIENTATION: BI-DIRECTIONAL
TYPE: HARAKEKE
QUANTITY: 34
SPACING: 5mm
LENGTH $\times$ *dir.* 100mm
LENGTH $\times$ *dir.* 70mm
FRAGILITY: MEDIUM

ORIENTATION: BI-DIRECTIONAL
TYPE: HARAKEKE
QUANTITY: 17
SPACING: 10
LENGTH $\times$ *dir.* 100mm
LENGTH $\times$ *dir.* 70mm
FRAGILITY: MEDIUM

ORIENTATION: BI-DIRECTIONAL
TYPE: HARAKEKE
QUANTITY: 8
SPACING: IRREGULAR
LENGTH $\times$ *dir.* 100mm
LENGTH $\times$ *dir.* 70mm
FRAGILITY: HIGH

ORIENTATION: BI-DIRECTIONAL
TYPE: HARAKEKE
QUANTITY: 8
SPACING: IRREGULAR
LENGTH $\times$ *dir.* 100mm
LENGTH $\times$ *dir.* 70mm
FRAGILITY: HIGH

ORIENTATION: BI-DIRECTIONAL
TYPE: FIBRE GLASS
QUANTITY: 170
SPACING: 1mm
LENGTH $\times$ *dir.* 100mm
LENGTH $\times$ *dir.* 70mm
FRAGILITY: MEDIUM

ORIENTATION: BI-DIRECTIONAL
TYPE: FIBRE GLASS
QUANTITY: 85
SPACING: 2mm
LENGTH $\times$ *dir.* 100mm
LENGTH $\times$ *dir.* 70mm
FRAGILITY: HIGH

ORIENTATION: BI-DIRECTIONAL
TYPE: FIBRE GLASS
QUANTITY: 34
SPACING: 5mm
LENGTH $\times$ *dir.* 100mm
LENGTH $\times$ *dir.* 70mm
FRAGILITY: HIGH

ORIENTATION: BI-DIRECTIONAL
TYPE: FIBRE GLASS
QUANTITY: 17
SPACING: 10mm
LENGTH $\times$ *dir.* 100mm
LENGTH $\times$ *dir.* 70mm
FRAGILITY: MEDIUM

ORIENTATION: BI-DIRECTIONAL
TYPE: FIBRE GLASS
QUANTITY: 8
SPACING: 20mm
LENGTH $\times$ *dir.* 100mm
LENGTH $\times$ *dir.* 70mm
FRAGILITY: LOW

ORIENTATION: IRREGULAR
TYPE: FIBRE GLASS
QUANTITY: 20
SPACING: 2mm
LENGTH $\times$ *dir.* 100mm
LENGTH $\times$ *dir.* 70mm
FRAGILITY: LOW

ORIENTATION: IRREGULAR
TYPE: HARAKEKE
QUANTITY: 5
SPACING: IRREGULAR
LENGTH $\times$ *dir.* 100mm
LENGTH $\times$ *dir.* N/A
FRAGILITY: HIGH

ORIENTATION: IRREGULAR
TYPE: HARAKEKE
QUANTITY: 10
SPACING: IRREGULAR
LENGTH $\times$ *dir.* 100mm
LENGTH $\times$ *dir.* N/A
FRAGILITY: MEDIUM

ORIENTATION: IRREGULAR
TYPE: HARAKEKE
QUANTITY: 20
SPACING: IRREGULAR
LENGTH $\times$ *dir.* 100mm
LENGTH $\times$ *dir.* N/A
FRAGILITY: MEDIUM

ORIENTATION: IRREGULAR
TYPE: HARAKEKE
QUANTITY: 30
SPACING: IRREGULAR
LENGTH $\times$ *dir.* 100mm
LENGTH $\times$ *dir.* N/A
FRAGILITY: LOW

ORIENTATION: IRREGULAR
TYPE: HARAKEKE
QUANTITY: 60
SPACING: IRREGULAR
LENGTH $\times$ *dir.* 100mm
LENGTH $\times$ *dir.* N/A
FRAGILITY: LOW

ORIENTATION: IRREGULAR
TYPE: HARAKEKE
QUANTITY: 80
SPACING: IRREGULAR
LENGTH $\times$ *dir.* 100mm
LENGTH $\times$ *dir.* N/A
FRAGILITY: LOW

ORIENTATION: IRREGULAR
TYPE: FIBRE GLASS
QUANTITY: 5
SPACING: IRREGULAR
LENGTH $\times$ *dir.* 100mm
LENGTH $\times$ *dir.* N/A
FRAGILITY: HIGH

ORIENTATION: IRREGULAR
TYPE: FIBRE GLASS
QUANTITY: 10
SPACING: IRREGULAR
LENGTH $\times$ *dir.* 100mm
LENGTH $\times$ *dir.* N/A
FRAGILITY: MEDIUM

ORIENTATION: IRREGULAR
TYPE: FIBRE GLASS
QUANTITY: 20
SPACING: IRREGULAR
LENGTH $\times$ *dir.* 100mm
LENGTH $\times$ *dir.* N/A
FRAGILITY: MEDIUM

ORIENTATION: IRREGULAR
TYPE: FIBRE GLASS
QUANTITY: 30
SPACING: IRREGULAR
LENGTH $\times$ *dir.* 100mm
LENGTH $\times$ *dir.* N/A
FRAGILITY: LOW

ORIENTATION: IRREGULAR
TYPE: FIBRE GLASS
QUANTITY: 60
SPACING: IRREGULAR
LENGTH $\times$ *dir.* 100mm
LENGTH $\times$ *dir.* N/A
FRAGILITY: LOW

ORIENTATION: IRREGULAR
TYPE: FIBRE GLASS
QUANTITY: 80
SPACING: 2mm
LENGTH $\times$ *dir.* 100mm
LENGTH $\times$ *dir.* N/A
FRAGILITY: LOW

Fibre Testing

fibre spacings
fibre direction
fibre length
fibre quantity

ORIENTATION: REGULAR x direction
TYPE: FIBRE GLASS
QUANTITY: 20
SPACING: 20mm
LENGTH x *dir.* 25mm 1/4 standard length
LENGTH y *dir.* N/A
FRAGILITY: LOW

ORIENTATION: REGULAR x direction
TYPE: FIBRE GLASS
QUANTITY: 40
SPACING: 10mm
LENGTH x *dir.* 25mm 1/4 nominal length
LENGTH y *dir.* N/A
FRAGILITY: LOW

ORIENTATION: REGULAR x direction
TYPE: FIBRE GLASS
QUANTITY: 80
SPACING: 5mm
LENGTH x *dir.* 25mm -1/4 nominal length
LENGTH y *dir.* N/A
FRAGILITY: HIGH

ORIENTATION: REGULAR x direction
TYPE: FIBRE GLASS
QUANTITY: 120
SPACING: 3.5mm
LENGTH x *dir.* 25mm -1/4 nominal length
LENGTH y *dir.* N/A
FRAGILITY: HIGH

ORIENTATION: REGULAR x direction
TYPE: FIBRE GLASS
QUANTITY: 160
SPACING: 2.5mm
LENGTH x *dir.* 25mm -1/4 nominal length
LENGTH y *dir.* N/A
FRAGILITY: LOW

ORIENTATION: REGULAR x direction
TYPE: FIBRE GLASS
QUANTITY: 240
SPACING: 1mm
LENGTH x *dir.* 25mm -1/4 nominal length
LENGTH y *dir.* N/A
FRAGILITY: HIGH

ORIENTATION: IRREGULAR
TYPE: FIBRE GLASS
QUANTITY: 10
SPACING: IRREGULAR
LENGTH x *dir.* 50mm -1/2 nominal length
LENGTH y *dir.* N/A
FRAGILITY: MEDIUM

ORIENTATION: IRREGULAR
TYPE: FIBRE GLASS
QUANTITY: 20
SPACING: IRREGULAR
LENGTH x *dir.* 50mm -1/2 nominal length
LENGTH y *dir.* N/A
FRAGILITY: HIGH

ORIENTATION: IRREGULAR
TYPE: FIBRE GLASS
QUANTITY: 40
SPACING: IRREGULAR
LENGTH x *dir.* 50mm -1/2 nominal length
LENGTH y *dir.* N/A
FRAGILITY: HIGH

ORIENTATION: IRREGULAR
TYPE: FIBRE GLASS
QUANTITY: 60
SPACING: 5mm
LENGTH x *dir.* 50mm -1/2 nominal length
LENGTH y *dir.* N/A
FRAGILITY: HIGH

ORIENTATION: IRREGULAR
TYPE: FIBRE GLASS
QUANTITY: 80
SPACING: IRREGULAR
LENGTH x *dir.* 50mm -1/2 nominal length
LENGTH y *dir.* N/A
FRAGILITY: LOW

ORIENTATION: IRREGULAR
TYPE: FIBRE GLASS
QUANTITY: 120
SPACING: 2mm
LENGTH x *dir.* 50mm -1/2 nominal length
LENGTH y *dir.* N/A
FRAGILITY: HIGH

ORIENTATION: REGULAR
TYPE: FIBRE GLASS
QUANTITY: 100
SPACING: 1mm
LENGTH x *dir.* 100mm
LENGTH y *dir.* N/A
FRAGILITY: LOW

ORIENTATION: REGULAR x direction
TYPE: FIBRE GLASS
QUANTITY: 50
SPACING: 2mm
LENGTH x *dir.* 100mm
LENGTH y *dir.* N/A
FRAGILITY: LOW

ORIENTATION: REGULAR x direction
TYPE: FIBRE GLASS
QUANTITY: 20
SPACING: 5mm
LENGTH x *dir.* 100mm
LENGTH y *dir.* N/A
FRAGILITY: HIGH

ORIENTATION: REGULAR x direction
TYPE: FIBRE GLASS
QUANTITY: 10
SPACING: 10mm
LENGTH x *dir.* 100mm
LENGTH y *dir.* N/A
FRAGILITY: HIGH

ORIENTATION: REGULAR x direction
TYPE: FIBRE GLASS
QUANTITY: 5
SPACING: 20mm
LENGTH x *dir.* 100mm
LENGTH y *dir.* N/A
FRAGILITY: LOW

ORIENTATION: IRREGULAR
TYPE: FIBRE GLASS
QUANTITY: 20
SPACING: IRREGULAR
LENGTH x *dir.* 100mm
LENGTH y *dir.* N/A
FRAGILITY: HIGH

ORIENTATION: REGULAR x direction
TYPE: HARAKEKE
QUANTITY: 100
SPACING: 1mm
LENGTH x *dir.* 100mm
LENGTH y *dir.* N/A
FRAGILITY: LOW

ORIENTATION: REGULAR x direction
TYPE: HARAKEKE
QUANTITY: 50
SPACING: 2mm
LENGTH x *dir.* 100mm
LENGTH y *dir.* N/A
FRAGILITY: LOW

ORIENTATION: REGULAR x direction
TYPE: HARAKEKE
QUANTITY: 20
SPACING: 5mm
LENGTH x *dir.* 100mm
LENGTH y *dir.* N/A
FRAGILITY: HIGH

ORIENTATION: REGULAR x direction
TYPE: HARAKEKE
QUANTITY: 10
SPACING: 10mm
LENGTH x *dir.* 100mm
LENGTH y *dir.* N/A
FRAGILITY: LOW

ORIENTATION: REGULAR x direction
TYPE: HARAKEKE
QUANTITY: 5
SPACING: 20mm
LENGTH x *dir.* 100mm
LENGTH y *dir.* N/A
FRAGILITY: LOW

ORIENTATION: REGULAR x direction
TYPE: HARAKEKE
QUANTITY: 20
SPACING: IRREGULAR
LENGTH x *dir.* 100mm
LENGTH y *dir.* N/A
FRAGILITY: HIGH

REFLECTION

DESIGN PHASE ONE

PROJECT TWO

DESIGN PHASE TWO

Introduction

A significant limitation of the preceding designed outcome was the lack of construction tolerance. This design sort to address that issue. Through researching precedent systems that exhibited larger assembly tolerances, Greg Lynn's Blob Wall project was considered to be fertile ground from which to commence further research. Further, conceived with the view that the modules would be fabricated in field conditions where a reasonable degree of variability between respective modules was likely, a system that featured a more considerable tolerance was thought to be more able to accommodate any irregularities made in the fabrication of the modules and even benefit from these inconsistencies.

Blob Wall was conceived as a research project underpinned by a multitude of motivations. A central motivation was the opportunity to create a response piece to the masonry research carried out by Nader Tehrani and Monica Ponce de Leon at Office dA. Further, it was an opportunity to apply this research to Lynn's longstanding interest in plastics and fibrous composite materials and advanced fabrication methodologies. Lynn's Blob Wall consists of a multitude of plastic rotomolded modules each of which is comprised of 3 nodes. The geometry of the modules is arranged in a manner to allow inter-module nesting to take place as well as providing an element of texture resulting from surfaces with variable degrees of projective depth (projective surfaces being a hallmark of the office dA's practice). The plastic bricks were then arrayed along various designed surfaces and subsequent

overlapping intersections were found. Cutting paths were then sent to a robotic arm which cut out the overlapping geometry at these intersections. In further reference to the work of Office dA the offcuts were ground up before being moulded back into a new module to emulate the slight colour variations that occur between bricks on a masonry wall.

The referenced work of Office dA achieves its projective surface effect through a shift in technique where regular modular bricks are stacked in an irregular way. The work of Lynn furthers this by stacking irregular morphologies in an irregular way. When stacking in this way a change in syntax is also required as Epstein Jones notes the displayed effect is less about the part to the whole relationship as it is about the way in which modules touch, lock together and transfer loads.

Image redacted from
digital version

Image redacted from
digital version

Aim

Employ a tool based methodology to create an interlocking system that allows for a greater construction tolerance and variety of formal outcomes.

Method

Equipment

Table tennis balls

Golf tees

ABS

Various Fabrics

Rhino Grasshopper

1// The design phase commence with a review of existing methods of joining that had been employed to achieve a high level of design tolerance.

2// Physical and digital models were iteratively created assessed and redrawn.

3// Concurrent fabrication studies were undertaken in which methods of construction, patterning was explored with the learning being utilised to inform the redrawing of the models.

fig.204 Array of Fabricated modules

fig.205 sketch models

The phase of study commenced with quick sketch physical models comprising of golftees and table tennis balls. During the creation of the models, the focus had been on the role of the "positive" sphere and the assembly tolerances its inclusion should allow . The sketch models quickly proved considering the "negative + possible receptacle" web was an equally important part of the exercise.

TYPOLOGICAL EXPLORATION

fig.206 Fabricated modules

In order to achieve the dimensional accuracy required of both the ball and web, the model making was taken into the computer with the intent to 3d print selected outcomes. The modelling achieved through the use of via Rhinoceros and Grasshopper. The use of the Grasshopper plugin allowed a series of quick interactive desktop studies to take place with each study interrogating a different variable. The most promising definitions from the desktop study were printed and physically tested. The printing and physical testing process enabled

the intuitive and accurate study of attributes such as material surface friction, gravity and how the module could interlock. Additionally, the physically fabricated modules provided a means through which others were able to interact and create various assemblages. This process of observing how others interpreted and interacted with the modules proved valuable given the self-build premise. This process was repeated with more scripting further exploring the effect of sphere scale, web-scale and other ball and socket derivatives.

A variety of Grasshopper definitions were iteratively created each building on the last and were scripted to explore different variables such as web length, rotation, number of spheres and the arrangement of spheres relative to each other.

fig.207 Grasshopper script

01 INITIAL DEFINITION ONE

02 INITIAL DEFINITION TWO

03

04

05

06

07

THREE NODE TYPOLOGY

WEB LENGTH AND ANGLE EXPLORATION

fig.209, fig. 210 Variation of the 4 node Grasshopper script

i. FOUR NODE DEFINITION 01

ii. FOUR NODE DEFINITION 02

iii. INITIAL DEFINITION 03

ii. INITIAL DEFINITION 03 ITERATION

iii. INITIAL DEFINITION 03 ITERATION

iv INITIAL DEFINITION 03 ITERATION

FOUR NODE TYPOLOGY

WEB LENGTH AND ANGLE EXPLORATION

AGGREGATE INTERLOCKING BEHAVIOUR

fig.212 Assemblages

fig.213 Further assemblage studies

fig.214 Fabricated module assemblage

fig.215 Alternate interlock variation

fig.216 Module assemblage pland and elevation

fig.217 Assemblage front elevation

After the creation of numerous modules an a criteria for assessing the success of the modules was created. The criteria draw on learning from the modelling process as well as how the modules lent themselves to various end applications.

fig.218 Module assessment

NEST- NODE TO WEB

WEAVE- WEB TO WEB

INTERSTITIAL NESTING

HYBRID

Examining the collection of various assemblages created by both the works author and others a study was undertaken to ascertain the various connection typologies successfully exhibited as well those that were less successful. This learning was implemented in the second series of models exploring failed connections, the effect of scale shifts, the range of motion each module was able to obtain and the productive potential this had the possible assemblages.

fig.220 Further typological studies.

FABRICATION

fig.215 Fabricated mould

Concurrent to the development of the second stage of models, fabrication studies were undertaken with the view that this could inform the geometry design process. The first of these fabrication studies focused on casting into 3D printed moulds various pumice and concrete mixes. The 10% cement starting point of these tests referenced the ratio used by the iwi housing provider in the fabrication of their blocks. The quantity of cement was doubled each time with subsequent tests.

The moulds were fabricated in six separate parts as a means to reconcile the size limitations of the printer's bed along the desired scale of the outcome. It was envisioned that the selected scale would be close to 1:1 to take advantage of the benefits of working at this scale would allow.

fig.215 Casting studies

10% CEMENT FILL

20% CEMENT FILL

40% CEMENT FILL

PROCESS
 METHOD:
 BASE MATERIAL:
 BINDING MATERIAL:
 BINDING MATERIAL%: 5% BY WEIGHT

CAST
 PUMICE
 CEMENT

ELEVATION

PROCESS
 METHOD:
 BASE MATERIAL:
 BINDING MATERIAL:
 BINDING MATERIAL%: 10% BY WEIGHT

CAST
 PUMICE
 CEMENT

ELEVATION

PROCESS
 METHOD:
 BASE MATERIAL:
 BINDING MATERIAL:
 BINDING MATERIAL%: 20% BY WEIGHT

CAST
 PUMICE
 CEMENT

ELEVATION

PLAN

PLAN

PLAN

fig. 217 Casting studies

Various cutting patterns were trialled before being assessed on their ability to maintain the form generated from seams acting as lines of control as well as the ease of fabrication. Simple patterns were tested initially before more elaborate patterns were tested with the view that additional seams could increase the lines of control while simultaneously providing a decorative attribute.

fig.218 fabric cutting pattern studies

fig.218 fabric model pattern studies

fig.219 unrolling of patterns

fig.220 unrolling of patterns

10

11

12

13

14

fig.220 fabricate node study

fig. 221 alternate fabriacted node

1 SUBDIVISION OF NURBS MODEL

2 NURBS TO MESH CONVERSION

3 UNROLLED MODEL

PATTERN GENERATION

The previous fabrication studies led to the development of an optimised scheme containing sufficient lines of control while additionally streamlining the fabrication process as much as was feasible.

Unrolling the pattern.

The digital model was converted from Rhinonoers's native NURBS surfaces to a faceted mesh. This translation included limiting the number of surfaces as much as possible while still retaining a resemblance of the intended model. The meshing translation allowed for the digital model to be unrolled within Rhinoceros allowing a cutting template to be created that could be laser cut onto card before being transferred to fabric.

01

02

03

04

05

06

07

08

09

LOOSE SOIL FILL

SOLID CLAY SOIL FILL

PUMICE FILL

fig.223 Module filling procedure

fig.224 Fill type and quantity studies

Consideration was given to materials that lend themselves to be suitable for fabrication. The reuse of hessian sacks used for the distribution of food was investigated. The inclusion of materials such as a sack heavily influences scale as it becomes the determining metric from which the template is made effectively instating a part to whole relationship. To determine an appropriate scale test models were fabricated at a scale from which two modules could be fabricated from one unrolled sack.

Cognisant that modules sitting directly on the ground may experience accelerated degradation methods of mitigating these issues were trialled. Methods included the application of clay to the exterior of the module and alternatively the inclusion of single-use plastic bags on the interior as a liner.

fig.225 Module scale study

fig.226 fabricated module and waterproofing study

Further fabrication studies were undertaken commencing with casting different ratios of cement and pumice. Further, a vacuum bag method was trialled whereby a vacuum bag was inserted into casting mould and filled with a cement and pumice mix before the air was sucked out of the vacuum bag. It was envisioned that the bag mix could then be removed from the mould and allowed to set while a new bag inserted and the next module was made in the same manner. The premise of this method was the bag was lighter, easier to transport and less expensive than the mould and incorporating the use of bags a liner would increase the efficiency of the mould. This method was less successful due to the relatively small scale of the mould in comparison to the thickness of the bag meaning the bag was too thick to conform to the mould. The creation of a larger mould could have remediated this issue. Subsequent test using this method were not carried out due to the less than ideal results from other vacuum bag studies happening concurrently.

CAST METHODOLOGY

VACUUM METHODOLOGY

DISPLACEMENT METHOD

**DRY / WET
FILL**

DRY // WET

DRY

WET

DRY

**FORM
HOLDING
ABILITY 100%
FILL**

POOR // GOOD

POOR

GOOD

GOOD

**FORM
HOLDING
ABILITY 80%
FILL**

POOR // GOOD

POOR

GOOD

POOR

**LEVEL OF
SLUMP
100% FILL**

LITTLE // SOME // A LOT

SOME

LITTLE

LITTLE

**LEVEL OF
SLUMP 80%
FILL**

LITTLE // SOME // A LOT

A LOT

SOME

A LOT

**CASEING
DEGREATION
AFTER 2
WEEKS**

LITTLE // SOME // A LOT

SOME

A LOT

LITTLE

PLAN
TEST GEOMETRY ONE

Reflecting on the work to date, two distinct schemes were used to generate an understanding of the spacial qualities the system could generate. The scale of both schemes was such that they could accommodate visitors. The first scheme was comprised of a simple curved wall and domed roof. The curvature of the wall creating public and private spaces that could provide a desirable separation of men and other family members that can at times be desirable within certain faiths and cultures

fig. 228 fabrication spacial test

PLAN
TEST GEOMETRY ONE

The second scheme was referenced from Rael San Fratello and rescaled. Simultaneously creating moments of relative openness and enclosure the geometry allowed for the study into how less regular spaces may generate public-private spaces.

SECTION
TEST GEOMETRY TWO

fig. 229 fabrication spacial test

REFLECTION

DESIGN PHASE TWO

PROJECT TWO

DESIGN PHASE THREE
FIELD EXPLORATION STUDIES

Image redacted from digital version

Nader Tehrani and Monica Ponce de Leon placed their former practice office dA, between Herzog & deMeuron and Frank Gehry. More specifically they sort to reconcile the techtonic qualities Herzog & deMeuron achieve from the exterior skin of their projects with the formal and spacial qualities Gehrey achieves on the interior. Their key premise is to *resolve the relationship between space and form* which they claim are traditionally dealt with in opposition to each other. Within Tongxian Art Centre surface and space are handled as reciprocal and co-dependent entities. Deviations of the surface coincide with and determine specific spacial deformations. Through a change in technique, patterning and geometry serve as the basis for this resolution.

Aim

1. To broaden the field of exploration in a manner that limits the Imposition of geometrical constraints.
2. To explore the inherent behavioural characteristics of earthen materials.

Method

Materials:

- // plastic bags
- // hesian sacks
- // Clay
- // Plaster
- // Concrete

1// A series of very rudimentary physical modelling processes using earthen materials were carried out whereby verbs were enacted as a means to explore alternate geometries that have interlocking potential.

“If you think of Brick, you say to Brick, ‘What do you want, Brick?’ And Brick says to you, ‘I like an Arch.’ And if you say to Brick, ‘Look, arches are expensive, and I can use a concrete lintel over you. What do you think of that, Brick?’ Brick says, ‘I like an Arch.’ And it’s important, you see, that you honour the material that you use. ”

Louis Khan

DESIGN PHASE THREE SPATIAL VERBS

A set of descriptive operative spacial verbs were assembled and diagramed. The set consisted of: Carve, compress, extrude, notch, lift, pinch, skew, slide and twist. Using only these words and diagrams as a design generator a series of physical models were iteratively made. Each time the process commenced with mixing up a batch of plaster which was then poured into a single-use plastic bag, and an operative spatial verb was enacted before the plaster set. The second series of models using the process was later redone using a concrete and pumice mixture and hessian bags.

fig.301 spacial verbsl tested

OPERATION	PLASTER MODEL	MODEL TWO	ASSESTMENT : HAS POTENTIAL	ASSESTMENT: HAS LITTLE POTENTIAL	OPERATION	PLASTER MODEL	ASSESTMENT : HAS POTENTIAL	ASSESTMENT: HAS LITTLE POTENTIAL
SLIDE					CARVE

PINCH					COMPRESS

SPLIT					EXTRUDE

SKEW					NOTCH

TWIST					LIFT

fig.301 spacial verbs| testedv

OUTCOME

The viscosity and time limit imposed by the plaster and later concrete mixtures was a crucial factor in determining the outcome of this study. Further, it became very evident from the creation of the first model that unlike the 3D printed modules produced previously in which the author had almost total authorship over the outcome, in the production of these models authorship was shared between author and material. The extent to which the material imposed a degree of authorship resulted from the viscosity of the mix, with the thinner less viscous mixtures imposing more authorship. While the thinner mixtures were significantly more challenging to shape, they did provide the advantage of enabling a larger window of time from when they were mixed to be transferred to a bag and subsequently formed. On multiple occasions, a thicker mix had begun to set before the enactment of the spatial verb could commence.

Reflecting on the outcome of these verb testing

another series of the investigation was undertaken to leverage the larger window of time offered by the weaker mixtures while gaining an increased level of authorship that was more akin to working with the thicker mixtures. The innovation being that here that the replacement of the single-use plastic shopping bag with a vacuum bag could provide additional resistance with which to counteract the natural slump of weak plaster mix. The process was trialled with styrofoam balls which acted as a fluid material while extra plaster was being procured. The process proved to be somewhat successful with an additional level of control being realised. The process was subsequently repeated with various plaster and cement mixtures. These tests were less successful than the styrofoam ball models because the additional weight embodied by the plaster, and concrete mixtures served to pull more air past the bags vacuum value effectively lessening the benefit of the vacuum.

01

02

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fig.301 Vacuum forming method

fig.301 Vacuum formed test models

07

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As a result of the previous testing, the third series of investigations were undertaken to see how the natural fluid behaviour of the mixtures could be leveraged by simply allowing it to do what it naturally wants to do. The reuse of single-use plastic bags was revisited as they offered to be an extremely lightweight, highly transportable and abundant building material. Cognisant of the effect created by the shift in technique presented in the

case study, filled bags were layered over pseudo rocks in a traditional running bond brick pattern, and the bags were allowed to deform naturally.

Previously made concrete models served as rocks with the premise being that on site rocks could be used to elevate the foundational layer off the ground while simultaneously serve as means to introduce variation within the system.

fig.301 Initial plaster stack method
fig.301 Extracted plaster stack modules

REFLECTION

DESIGN PHASE THREE

PROJECT TWO

DESIGN PHASE FOUR
STACKING AND SLUMPING

In his essay, *Multiplicitous and Inorganic Bodies* Greg Lynn uses the language of genetics to suggest a new grammar through which geometry could be rethought. Further, he uses evolutionary theory as a logic to articulate the limitations of Wittkower and Rowe's respective writing on Palladio and human body-centric proportional geometry. Lynn notes "Geometry is no longer a static measure of invariant and unitary characteristics but what Gilles Deleuze and Félix Guattari have referred to as a "plane of consistency" upon which differential transformations and deformations occur. Type itself is never present in a fixed state in an entire species."¹

It is in this context that Lynn's *Embryological house* emerges as he uses evolutionary genetic theory as a method through which to explore mass customisation whereby virtually endless variation can be achieved while still embodying clearly identifiable characteristic parameters.

Harnessing the opportunities offered by vector-based animation and engineering surface software- a spline through a series of 12 control points were created. The parameters assigned to these control points allowed the resultant surfaces to maintain and exhibit a common DNA.

fig.401 Variation of splines through 12 control points

Image redacted from digital version

fig.402 Variation of "Embryological eggs"
with each exhibiting common DNA

Image redacted from digital version

Aim

To further explore the previously identified method of assemblies performative attributes in order to ascertain its suitability for refugee housing.

Integration of surface and structure

Method

Tools:

//Maya

// Rhino.

// Illustrator

Drawing from the process employed by Lynn the use of the animation software Maya was leveraged. This method allowed the simulation of attributes pertaining to force, fill, displacement, and weight. The successive use of Rhinoceros enabled the output of this study to be further distilled, mapped and analysed.

fig.403 Ravoli chair by Greg Lynn for Vitra is comprised of only two parts

Image redacted from digital version

“In the history of the world no one
has ever made something more complex
and been innovative”

- Rolf Fehlbaum - Vitra

Leveraging the nCloth particle simulation functionality within Autodesk Maya, dynamic material behavioural attributes were mapped to a digital model. The material attributes ascribed to the model were then iteratively tuned to replicate the dynamic behaviour exhibited by relevant physical models previously made in design phases two and three.

This process enabled the study of morphological deformation that occurred in the modules as imposed by various ground conditions such as the use of rocks as the foundational layer. An additional observation was made of variabilities pertaining to fill material. Additionally, the change in the profile that emerged with the sequential stacking of layers was also studied to ascertain the ramifications that a compounding load had on the interlocking characteristic required of the aggregate system.

fig.403 Maya desktop study

MODULATION + VARIABILITY

5 //

4 //

3 //

2 //

1 //

TWO LAYERS

FOUR LAYERS

FIVE LAYERS

SOFT FILL

MEDIUM FILL

CROSS SECTION MODULE A

CROSS SECTION MODULE B

CROSS SECTION MODULE C

fig.406 Fabricated models extracted from desktop study illustrating variable distortion from fill material- firm material

fig. 407 abricated models extracted from desktop study
illustrating variable distortion from fill material - soft material

GEOMETRY VERTICAL DISPLACEMENT METHOD

Image redacted from digital version

TRADITIONAL BARBED WIRE ASSEMBLY METHOD

REFLECTION

DESIGN PHASE FOUR

PROJECT TWO

DESIGN PHASE FIVE
ENCLOSURE

Introduction

This research to date has been principally carried out with the view of creating an assembly method that is capable of providing a greater sense of security and safety than is currently attainable to a refugee population. The processes undertaken to achieve this have been to create wall systems that are also capable of vaulting in order to provide the necessary closure. To this end two methods have achieved this aim. This research has also indicated that while the additional mass embodied within the respective methods developed can assist with providing a greater sense of security from knife attacks, slashing of tents to gain entry and other acts of violence that happen within the camps, both of the methods of construction developed through this research are labour extensive. To this end a less labour intensive method of assembly that could be suitable for roofs, or other architectural elements that didn't require the mass of the earthen wall to offer a sense of security and protection were investigated. The notion of creating lightweight vaulted structures from site materials such as bamboo or similar was explored.

Aim

To explore less labour intensive methods of assembly suitable for the creation of enclosure.

Method

Tools:
//RhinoVault
// Rhino.

The software plug-in RhinoVault was utilised to provide insight into the feasibility of lightweight vaulted structures and what these could look like.

A desktop study observed and catalogued the availability of naturally occurring and introduced materials available within the context of a selection of self-settled refugee camps. Camps were selected through their geographic location and size with larger camps being favoured as to enable the broadest possible cross-sectional survey of materials.

These materials were redrawn back into a series of drawings exploring what the availability of these means for the creation of refugee camps..

VAULTING ASSEMBLY METHOD

fig.501 Screenshot RhinoVault assessment

RhinoVault, a plugin for Rhinoceros, developed at ETH Zurich was used to explore this method. RhinoVault is a form finding tool that uses a “thrust Network Analysis (TNA) approach to intuitively create and explore compression-only structures”.

The RhinoVault plugin was fully explored to ascertain its capacity to be Informative for the application. Various typologies were drawn each speculating a unique proposition reflecting both the availability of relevant site materials as well as the influence of warm and cool climates and associated ventilation requirements.

The exploration of RhinoVault suggested that simple vaulted structures of various configurations are well within the realm of feasibility considering the constraints imposed by building in remote locations with site materials. Beyond the creation of simple vaulted structures, however, the self-build element of this research serves to render the applicability of software tools of this ilk to be of limited value given the unlikely event that they would be available onsite for consultation.

Following the RhinoVault study an assesment of assembly methodologies explored through this research was undertaken.

	SPEED OF CONSTRUCTION	SKILL LEVEL REQUIRED	VARIETY OF FORMS ACHIEVABLE	ADDITIONAL EQUIPMENT REQUIRED	UNIVERSAL APPLICATION
	SLOWER // FASTER	LITTLE // SOME // A LOT	LITTLE // SOME // A LOT	LITTLE // SOME // A LOT	YES // NO
CAST METHODOLOGY	SLOWER	LITTLE	SOME	SOME	YES
VACUUM METHODOLOGY	SLOWER	LITTLE	LITTLE	SOME	YES
BAG FILL METHOD	SLOWER	LITTLE	A LOT	LITTLE	YES
DISPLACEMENT METHOD	FASTER	SOME	SOME	LITTLE	YES
BRANCH VAULTING METHOD	FASTER	SOME	SOME	LITTLE	NO

fig.502 Assessment of assembly methodologies

MATERIAL SURVEY LOCATION MAP

MISHAMO TANZANIA

POPULATION: 55,380
TYPE: SELF-SETTLED
ESTABLISHED: 2014
POPULATION FROM: BURUNDI

MATERIALS

PLENTIFUL EARTH
TREE BRANCHES
PLASTIC SHEETING

R

Image
redacted

Image
redacted

KATUMBA CAMP TANZANIA

POPULATION: 66,416
TYPE: SELF-SETTLED
ESTABLISHED: 2014
POPULATION FROM: BURUNDI

MATERIALS

PLENTIFUL EARTH
TREE BRANCHES
PLASTIC SHEETING

Image
redacted

Image
redacted

Image
redacted

YIDA CAMP SOUTH SUDAN

POPULATION: 70,331
TYPE: SELF-SETTLED
ESTABLISHED: 2012
POPULATION FROM: SUDAN

MATERIALS

PLENTIFUL EARTH
TREE BRANCHES
HESIAN SACKS
PLASTIC SHEETING

Image
redacted

Image
redacted

Image
redacted

Image
redacted

Image
redacted

fig.504 Material survey

HAGADERA CAMP KENYA

POPULATION: 70,331
TYPE SELF-SETTLED
ESTABLISHED: 2012
POPULATION FROM: SUDAN

MATERIALS

PLENTIFUL EARTH
TREE BRANCHES
PLASTIC SHEETING
LIMITED CORROGATED IRON

Image
redacted

Image
redacted

IFO CAMP KENYA

POPULATION: 70,331
TYPE SELF-SETTLED
ESTABLISHED: 2012
POPULATION FROM: SUDAN

MATERIALS

PLENTIFUL EARTH
EARTHEN BRICK
TREE BRANCHES
PLASTIC SHEETING

Image
redacted

Image
redacted

YEMEN

POPULATION: 70,331
TYPE SELF-SETTLED
ESTABLISHED: 2012
POPULATION FROM: SUDAN

MATERIALS

PLENTIFUL EARTH
TREE BRANCHES
REEDS / THATCHING
PLASTIC SHEETING

Image
redacted

IRAQ

POPULATION: 70,331
TYPE SELF-SETTLED
ESTABLISHED: 2012
POPULATION FROM: SUDAN

MATERIALS

PLENTIFUL EARTH
TREE BRANCHES
REEDS / THATCHING
PLASTIC SHEETING

Image
redacted

Typology Suitability

Climate : Warm + Cool
Material Type: Bamboo
Material Availability: Little Some Plentiful

Typology Suitability

Climate : Warm + Cool
Material Type: Bamboo
Material Availability: ~~Little~~ Some Plentiful

Typology Suitability

Climate : *Cool+ Warm*
Material Type: *Earthen*
Material Availability: *No branch availability*

fig.510 typology study

Typology Suitability

Climate : *Cool*
Material Type: *Short Branches*
Material Availability: *Little Some Plentifull*

Typology Suitability

Climate : *Cool*
Material Type: *Short or long Branches*
Material Availability: *Little Some Plentifull*

fig. 512 typology study

Typology Suitability

Climate : Warm
Material Type: Longer Branches
Material Availability: Little Some Plentifull

PLANNING

While the creation of a master plan falls outside the scope of this research and further does not reconcile with the self build premise central to this line of inquiry a secondary motivation at the outset of this research included;

- 1// Accommodating the preparation and cooking of meals under shelter;
- 2// Can adapt to reflect cultural customary notions of space.

To this end a self governed, self settled and long established camp in Algeria was studied with the view to extract and distill salient planning attributes in order for these to be redrawn back into a scheme.

CLUSTER TYPOLOGY ONE

- ① KITCHEN
- ② REFRIGERATOR
- ③ COURTYARD
- ④ BEDROOM
- ⑤ STORE
- ⑥ TENT
- ⑦ W.C.
- ⑧ TEA ROOM

CLUSTER TYPOLOGY TWO

- ① KITCHEN
- ② REFRIGERATOR
- ③ COURTYARD
- ④ BEDROOM
- ⑤ STORE
- ⑥ TENT
- ⑦ W.C.
- ⑧ TEA ROOM

- ① KITCHEN
- ② REFRIGERATOR
- ③ COURTYARD
- ④ BEDROOM
- ⑤ STORE
- ⑥ TENT
- ⑦ W.C.
- ⑧ ABLUTIONS
- ⑨ UNDER DEVELOPMENT

CLUSTER TYPOLOGY THREE

On reading the layout of the camp, three clusters stood out as being able to offer greater insight into the mostly organic planning strategy in which the camp had been laid out.

These three clusters were redrawn and distilled. Through the process of redrawing various traits were revealed that are not typical features in a United Nations settled camps. The most generous allocation of space is offered to the interior courtyards and the tent all of which lend themselves to being able to accommodate social interaction. The relative scale of the spaces in comparison to their surrounds is perhaps a sign that these semi-private yet readily accessible areas are highly privileged for the social interaction for which they allow.

**// BUT IN PRACTICE MASTER PLANS FAIL - BECAUSE THEY CREATE
TOTALITARIAN ORDER, NOT ORGANIC ORDER. THEY ARE
TOO RIGID; THEY CANNOT EASILY ADAPT TO THE NATURAL AND
UNPREDICTABLE CHANGES THAT INEVITABLY ARISE IN THE LIFE
OF A COMMUNITY //** .

CHRISTOPHER ALEXANDER

fig.512 speculative cluster plan

INTERSTITIAL SECTION

RAIN CAPTURE METHOD
ROOFING MATERIAL- U.N.H.C.R. PLASTIC SHEET

THATCHED METHOD
ROOFING MATERIAL- LOCALLY SOURCED REEDS

SUN SHELTURE METHOD
ROOFING MATERIAL - DENSELY SPACED FOLIAGE

ROOF ASSEMBLY METHODOLOGIES

Drawing from the clustered approach to planning as observed in the case study a simple cluster plan was created that explores the notion of people coming together under a collective roof. The roof is capable of both providing shelter and harnessing the rainwater which could be shared out amongst the neighbours. There were some issues the creation of the cluster plan sort work through. Working on the premise that multiple dwellings may be assembled in close proximity to each other simultaneously a method of marking out and articulate space was seen as being desirable. It was further recognized as desirable if the process of marking out and articulating space was able to deliver some resemblance in quality of the important interstitial semi-private social space as observed in the case study. As such and given the limitation of materials the cluster explores a strategy whereby a primary planning circle is simply and efficiently scribed on the ground through the use of a large branch, length of string or similar. With the major planning circle marked out, space can be sub-divided and dwellings established as the inhabitants see fit. Further, the inclusion of the circular ring stems from an observation extracted in design phase two, whereby the method of assembly created exhibited a natural tendency to curve and dome.

TYPOLOGICAL DESIGN GUIDE + ASSESMENT

DIGNITY

- + ABILITY TO STAND UP INSIDE
- + ABILITY TO ACCOMODATE PREPARATION + COOKING OF MEALS

IDENTITY

- + ABILITY TO RESPOND TO CULTURAL + FAITH BASED CUSTOMS
- + INCORPERATION OF SOCIAL SPACE

SECURITY

- + DEFENDABLE ENTRANCE
- + STAB + SLASH RESISTANT WALL

SITE

- + ADAPTABLE TO A VARIETY OF SITE CONDITIONS + VARIABLE SHIFTING GROUNDS RESULTING FROM MONSOON RAINS

POLICTIAL

fig. 512 typology study

SPECULATIVE SCHEME PERSPECTIVE

CONCLUSION

The first design project used a "smart brick" designed by Juan Manuel Reyes and Jorge Capistrán as a stepping off point from which it was redrawn and developed further. Through the development of this first project the notion of "smart brick" was brought in to question -how smart is smart if what makes it smart is actually limiting? and more broadly the inherent limit states that are embodied within systems was discussed. Design phase two examined the work of Greg Lynn. Through the process of unpicking this work and understanding that the grammar used to describe the work needed to change from a traditional part to whole relationship to one of touch points and lines of force. This work of Lynn's subsequently gave rise to a series of modules that together with the extensive fabrication studies undertaken produced the first aggregate assembly method targeted for a refugee or disaster relief scenario. Branching out further the third design phase commenced with a spacial verb modelling exercise and through a process of physical modelling methods of negotiating the agency of materials were explored. The work of Lynn returned, this time with the Embryological House- whereby the methods of achieving mass customisation while still retaining a coherence or common DNA was examined and discussed. This case study along with the work undertaken in the previous phase set up the conditions from which Lynn's process of using animation software was leveraged to carry out a dynamic desktop study and another method of assembly emerged.

On reflection when considering the design work of this thesis despite it becoming more capable and less restricted by its own geometry at face value it would appear to have grown consistently dumber and less refined. It is interesting to note that

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