FABRIC to FORM

EXPLORING THE RELATIONSHIP BETWEEN HONEYCOMB SMOCKING AND DIAGRID STRUCTURE

2024 \\\ SHARMIN SHIRAZ

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Exploring the Relationship between Honeycomb Smocking and Diagrid Structure

2024

FACULTY OF DESIGN AND CREATIVE TECHNOLOGIES

School of Future Environments

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ABSTRACT

Throughout history, textiles have played a pivotal role in human culture, from the delicate tapestries of ancient civilisations to the high-performance fabrics of today. Similarly, architectural advancements have continuously pushed the boundaries of design and engineering. This research investigates the issue of textile and architectural integration, focusing on the nuanced relationship between the traditional art of honeycomb smocking and the innovative architectural diagrid structure. This exploration aimed to bridge the seemingly disparate domains of textile artistry and architectural innovation, shedding light on how these fields can coexist and enrich one another. With its rich history and decorative appeal, honeycomb smocking offers a unique perspective on flexibility and aesthetics in textile design. Conversely, the diagrid structure, a hallmark of modern architectural efficiency and aesthetics, presents a geometric rigour and structural integrity that challenges traditional building frameworks.

The project has taken a practice-based research approach through a disorderly iterative process of experimenting, synthesising, analysing, examining and evaluating these techniques. Challenging the notion of a rigid design process, both theoretical and practical approaches have been used to answer the questions. This approach sought to uncover the potential of a symbiotic relationship that leveraged the strengths of each discipline, ultimately aiming to inspire a novel approach to design that harmonised the tactile intimacy of textiles with the scale of architectural constructs.

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ATTESTATION OF AUTHORSHIP

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person (except where explicitly defined in the acknowledgements), nor material which to a substantial extent has been submitted for the award of any other degree or diploma of a university or other institution of higher learning. I have used the artificial intelligence tool Grammarly solely for the purposes of grammar checking and proofreading.

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FABRIC TO FORM:

How Can the Gap Between Textile Artistry and Architectural Innovation be Bridged Through the Integration of Honeycomb Smocking and the Diagrid Structure?

> *“Every work is an experiment: … prising an opening and following where it leads. You try things out and see what happens.”*
>
> *[Ingold, 2013, p. 6-7]*

01.

INTRODUCTION

In the evolving discourse of design, the seamless integration of disparate disciplines often yields groundbreaking innovations, nurturing the birth of methodologies and aesthetics that challenge conventional boundaries. The thesis titled “Fabric to Form: How Can the Gap between Textile Artistry and Architectural Innovation be Bridged through the Integration of Honeycomb Smocking and the Diagrid Structure?” embarks on an exploration of the symbiotic relationship between the ancient craft of honeycomb smocking and the contemporary architectural principle of diagrid structure. This research is motivated by a profound curiosity to unravel how the tactile, flexible nature of textiles can inform and transform the rigid, monumental scale of architectural constructs, thereby fostering a novel design approach.

This thesis posits that the integration of honeycomb smocking and diagrid structures can generate a transformative approach to design that harmonises the tactile intimacy of textiles with the structural ingenuity of architecture. By investigating the historical significance, aesthetic appeal, and functional versatility of both techniques, this research aims to illuminate the possibilities that lie at the intersection of textile artistry and architectural innovation. Through an exploration of their theoretical underpinnings and practical applications, this study endeavours to chart a course towards a more holistic and interdisciplinary understanding of design.

The thesis adopts a practice-based research methodology characterised by an iterative disorderly cycle of synthesis, analysis, evaluation, and examination. This approach allows for a dynamic exploration of the interplay between honeycomb smocking and diagrid structures, challenging the rigidity of traditional design processes and encouraging a fluid, discovery-led investigation. Situating this research within the broader context of design and creative technologies seeks to contribute to the evolving narrative of interdisciplinary innovation, advocating for a future where the boundaries between textiles and architecture are not just blurred but beautifully intertwined.

“Fabric to Form” is not merely an academic endeavour but a personal quest to bridge the realms of textile artistry and architectural innovation. Through this thesis, I aspire to uncover new vistas of design thinking, where the delicate intricacies of fabric can inspire the monumental creations of architecture and vice versa. It is a journey of discovery, aiming to redefine the parameters of what is possible when two seemingly disparate worlds converge in harmony.

PERSONAL INTRODUCTION

Growing up surrounded by textiles, I discovered intriguing parallels in my pursuit of a career in architecture. The technique of honeycomb smocking, a traditional hand-sewing method, was prevalent in much of my childhood attire, becoming a familiar language that accompanied me throughout my upbringing. During my architectural studies, I encountered the diagrid structure technique, whose triangular geometric form echoed the diamond pattern inherent in honeycomb smocking, connecting an artistic blend of traditional and innovative features.

As I navigated the realms of textiles and architecture, I found myself at the intersection of two seemingly similar worlds: the honeycomb smocking technique, once a familiar language, now resonated with the precision of diagrid structures. I embarked on an academic exploration within this delicate balance between tradition and innovation. As the two techniques intertwined, discoveries began to bridge the gap between craftsmanship and architectural vision.

02.

LITERATURE REVIEW

To establish a sound foundation for this literature review, it was essential to define the categories of play explored in this research, ensuring a clear understanding. This endeavour streamlined the subsequent exploration and facilitated the distinction of nuances and intersections among the various forms of play examined. The review aimed to provide a structured and thorough analysis by categorising these forms, enabling a more in-depth discussion of each category's unique techniques, characteristics, implications, and contributions to the field. This approach ensured meticulous organisation and facilitated a coherent synthesis of the existing literature, creating a solid research foundation.

2.1.

THE TEXTILE TECHNIQUE OF HONEYCOMB SMOCKING

Smocking is a textile manipulation technique commonly used in garments. The art of smocking involves pleating the fabric to create stretchable three-dimensional surfaces [Figure 5]. It is a hand-sewn technique that uses thread to secure and adjust the folds of pleated fabric, resulting in cellular design patterns [Wolff, 1996]. Smocking offers a variety of patterns, resulting in diverse and decorative gathered forms. The technique serves two primary purposes: decorative function and the ability to maintain a stretchable surface, replacing the need for elasticity [Wolff, 1996]. Additionally, due to the nature of textural fabrication, it acts as insulation and a structural element in garments [Ren, 2024].

Smocking was developed to create practical attire for male agricultural workers during the nineteenth century [Ljungdahl, 2018]. Known as the smock-frock [Figure 1], it was used as protective gear similar to overalls. Honeycomb smocking was employed to create gathers around the body and sleeves of the garment. As work environments began integrating mechanised equipment, the frock became increasingly unsafe to wear in the field. Due to the loose nature of the pattern, it would occasionally get caught in machinery [Toplis, 2018]. This eventually led to the abandonment of the attire, and it transitioned into a fashionable statement, appearing in women's sportswear, gowns, and children's wear typically applied to the bust and waist areas.

Figure 1: Smocking applied on a frock used by male agriculture workers

TECHNIQUE:

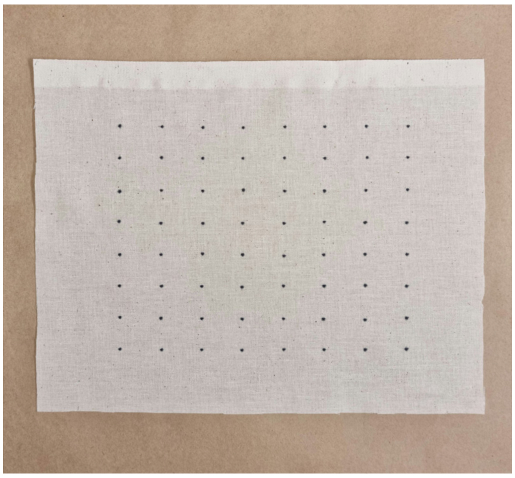


Figure 2: Drafting the honeycomb smocking grid

Across the various types of smocking patterns, this research centres on analysing the honeycomb smocking pattern. The characteristic of this pattern involves pleated fabric connected by threading two pleats to form a node to create diamond sequences [Lind, 2019].

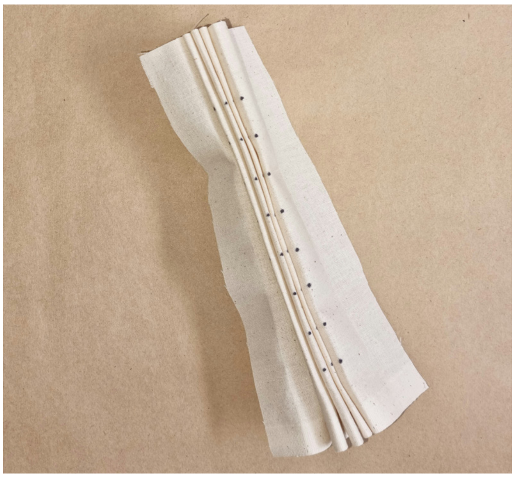


Figure 3: Pleating along the gridlines

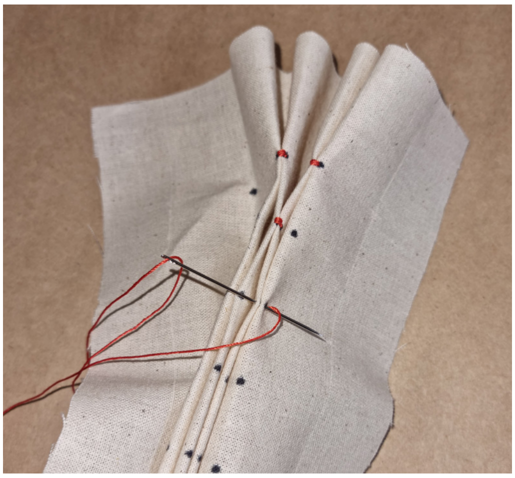


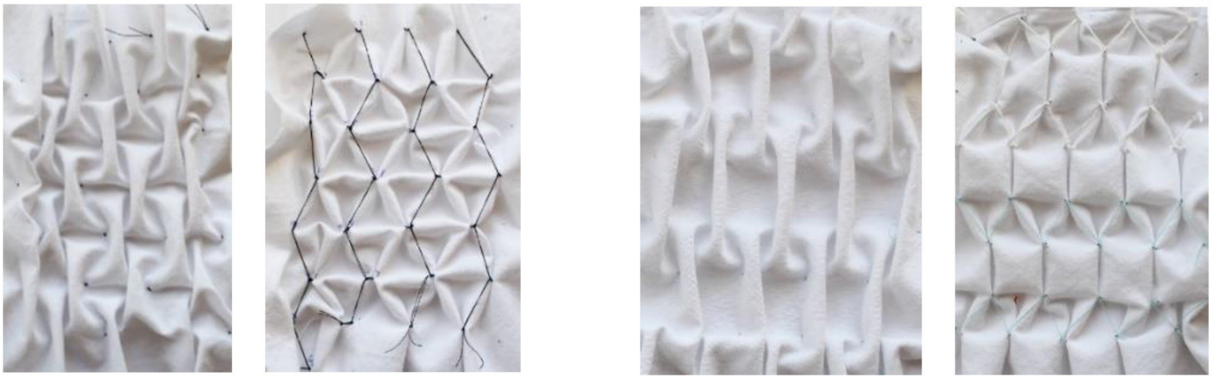
Figure 4: Sewing the nodes along the pleats

Figure 5: Final form of the honeycomb smocking

PRECEDENT REVIEW:

SMOCKING TRANSLATED IN SPATIAL DESIGN

It is rare to see collaborative projects between the textile and architectural environments, especially when they share comparable principles. While the closest interconnection of textiles in architecture is seen in spatial design, there are exciting opportunities for further exploration. One notable initiative is exemplified by the work of Malin Lind from The Swedish School of Textiles. Lind, conducted a project exploring textile techniques. She combined woven jacquard patterns and smocking techniques to explore spatial design contexts. She used jacquard woven fabric to experiment with traditional smocking patterns, including lozenge variant chains, lozenge variant blocks, lattices, and honeycombs [Figure 6]. She applied these techniques to create three-dimensional surfaces from two-dimensional materials, resulting in interior products such as room dividers or sound absorbers.



Lozenge variant 1: *Chain*

Lozenge variant 2: *Block*

Lattice

Honeycombs

Figure 6: Smocking techniques lozenge variant chains, lozenge variant blocks, lattices, and honeycombs applied on jacquard fabric by Malin Lind

The jacquard pattern, woven with two threads that "warp in a vertical line and weft in a horizontal direction" [Lind, 2019, p.], is the foundation for her exploration. She plans to apply the smocking technique to this fabric [Figure 7]. Lind emphasises how textiles can significantly impact space and how scale influences material behaviour and aesthetic experiences.

In her pre-studies, her approach to scaling using smocking as a structural template was found to be fascinating. Her trial-and-error process, involving the lengthening and widening of the smocking pattern, shed light on how form truly impacts function.

Figure 7: Mocked partitions made of Jacquard fabric, Lind, 2019

2.2.

ARCHITECTURAL INNOVATION OF THE DIAGRID STRUCTURE

As its name suggests, the diagrid structure is a diagonal grid structural system that is self-supporting and eliminates the need for internal columns. This system relies heavily on the stability of its triangular configurations and the load distribution at the nodes. Diagrid structures are commonly used in the built environment and are considered "one of the most innovative and adaptable approaches to creating building structures" [Boake, 2014, p.19]. The popularity of this structural system in architecture has risen due to its dual ability to integrate aesthetic and structural elements into buildings. Additionally, the diagrid system relies heavily on prefabrication modular techniques, enhancing its efficiency and precision during construction [Boake, 2014]. Furthermore, the adaptability of the diagrid system allows it to be employed in both linear and curved frameworks.

The structure came to light through the works of the Russian structural engineer Vladimir Shukhov [English, 2005]. He is known for his calculated structural systems, evident in numerous bridges and lightweight roof system designs during the late nineteenth and early twentieth centuries. In the 1880s, he sought a solution to design roof systems that reduced the material and labour required for construction. He encountered the formula for non-Euclidean geometry through his calculated experiments to mitigate these factors. There are two main types of non-Euclidean forms: hyperbolic and spherical. Shukhov applied hyperbolic geometry, where parallel lines can infinitely intersect, forming a quadric shape [Figure 8].

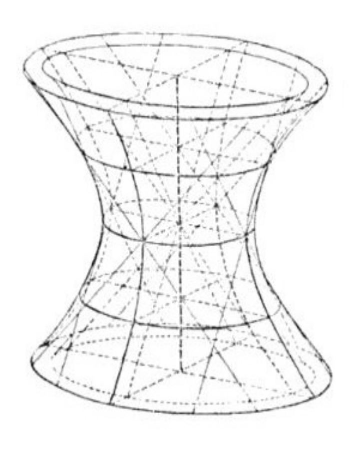


Figure 8: Diagram of a hyperboloid Surface

This birthed the invention of hyperboloid structures, “generally regarded as the first engineering surface structures in which roof membrane and structures form one unit [English, 2005].” The hyperbolic structure employs a grid-like arrangement that can maintain its form without additional support from columns, thus allowing more spacious interiors. Shukhov called these structures “metal lace” [English, 2005] due to their organic form and lightweight construction. While initially applied to roof designs, hyperboloid structures also found applications in other areas. For instance, they provided an efficient and easily constructed solution for taller structures. Shukhov applied the principles of hyperboloid structures to design a tower that used fewer materials through resourceful construction methods.

Shukhov’s exploration extended to over two hundred towers, ranging from 15 to 40 metres in height [English, 2005]. These towers were cinched cylinders, curving out at the top and constructed from diagonal steel or iron grid frameworks. However, Shukhov’s innovation did not stop there. He continued to develop this framework and conceptualised a method for stacking hyperboloid sections to form a tapered top resembling a cone.

One notable example of this approach is the Shabolovka Radio Tower in Moscow [Figure 9], which stands at a height of 150 metres. The tower was prefabricated into six sections, stacked, and assembled on-site. This method remarkably reduced material consumption by 14 times per height unit [Kseniia et al., 2020].

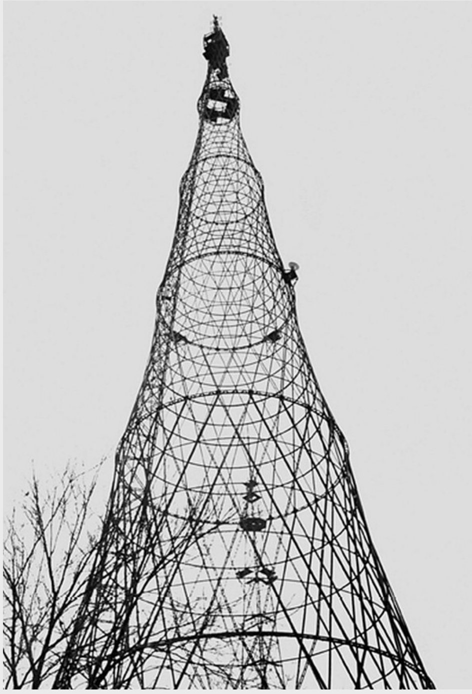


Figure 9: Shabolovka Radio Tower in Moscow, 1922

PRECEDENT REVIEW:

APPLICATION OF DIAGRID STRUCTURE IN ARTISTRY FORM

The hyperboloid structure, now known as the diagrid structure, is widely used in the built environment for all types of projects. Still, it is prevalent in high-rise buildings due to its efficient construction method and ornamental appeal [Kseniia, 2020]. The architect Norman Foster shaped the hyperboloid structure, which played a key role in architectural artistry. One important distinction from traditional hyperboloid structures is that they were hollow. Foster aimed to create a hyperboloid framework capable of supporting loads with multiple floors.

Following Shukhov's work, Foster designed and constructed a high-rise building. While the framework shares some similarities with the hyperboloid structure, it serves a different function. This shift in purpose introduced additional load-bearing factors to consider, such as flooring, service shafts, and programmes. Early collaboration between Foster, engineers, and steel contractors led to the development of the diagrid structure [Boake, 2014]. They explored various configurations, including height-to-width ratios and different angles related to the hyperboloid structure. Their approach involved strategically placing nodes where horizontal and diagonal members of the structure intersect [Figure 10]. These nodes also facilitated prefabrication methods, resulting in module systems seamlessly connecting to form the overall diagrid structure [Figure 11] [Boake, 2014].

Figure 10: Diagram of a Diagrid structure

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due to copyright restrictions.

Figure 11: Prefabrication of the modular structure of the Swiss Re Tower, Foster + Partners, 2004

To test and apply this innovative framework, Foster + Partners designed the Swiss Re Tower [Figure 12]. This triangular-framed structure was successfully constructed in 2004, reaching a height of 180 metres with 40 stories [Boake, 2014]. Notably, the structure achieved both structural stiffness and a visually pleasing form. Furthermore, the prefabrication method significantly reduced construction costs [Boake, 2016, p.1].

Figure 12: Swiss Re Tower designed, Foster + Partners, 2004

COMPARISONS:

A widely acknowledged fact in structural engineering is that the triangular shape is the strongest geometric form [Boake, 2014]. This strength arises from the ability of triangles to evenly distribute applied forces along their sides, thereby maintaining their shape under various loads. When a force is applied to a triangle, it is divided into compression and tension forces, efficiently managed by the triangle's sides and base. This inherent stability makes triangles a fundamental element in trusses, bridges, and other architectural structures, where durability and load-bearing capacity are paramount. The use of triangular configurations in construction enhances structural integrity and optimises material usage, contributing to economic and environmental sustainability [Figure 13] [Gordon, 2009].

Likewise, the honeycomb smocking technique leverages the inherent strength of geometric forms, specifically diamonds [Figure 14], to create a structurally sound and aesthetically pleasing design. The diamond configuration in honeycomb smocking allows for an even distribution of stress and strain, similar to the triangular configurations in diagrid structures.

Both diagrid structures and honeycomb smocking utilise geometric configurations to achieve stability and strength. The diagrid structure relies on the triangular shape to distribute loads and eliminate the need for internal columns, while honeycomb smocking uses diamond patterns to enhance tensile strength and flexibility. These techniques improve structural integrity and optimise material usage, contributing to sustainable architectural practices.

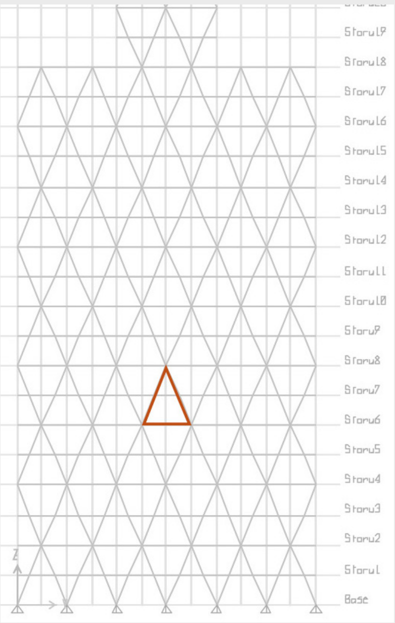

Figure 13: Triangular patterns in diagrid structure

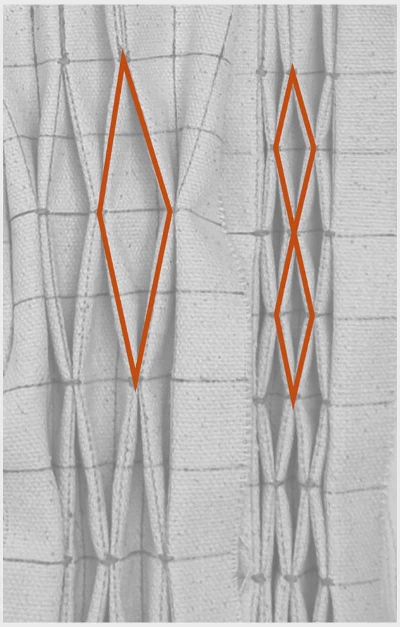

Figure 14: Diamond patterns in honeycomb smocking

INTENTION:

We rarely see cases where the worlds of textile and architecture collide. They share comparable visual and structural principles but restrict themselves within their domains. The patronisation often faced by the textile field, labelled as feminine by society, tends to associate woven elements with softness, fluidity, and flexibility. Yet, it ignores the strength that resides in even the gentlest threads [Goggin, 2017]. Distinctively, the built environment is filled with masculine connotations: rigid, heavy, and calculative, evident in its use of materials and scale. However, it often forgets the innovative approaches that can soften forms [Melhuish, 2006].

A case that breaks this unfounded ideology can be found in the installation designed for the Burning Man festival in 2023. The structure was created by MIT School of Architecture and Planning students. This project aims to showcase textile and architectural techniques' "fluidity, softness, and a dynamic quality" [Munemo, 2023]. The Living Knitwork Pavilion is a modular shelter structure [Figure 15] that employs a 12-sided polygon base and a pyramid-like form (Figure 16) using 3D-knitted live yarn petals as panels [Figure 17]. The result is a large-scale interactive lantern. The base structure "is composed of an asymptotic lattice discretised network of timber elements…tailoring the lattice and joint designs to from curves," ["Living," n.d] attributes comparable to the diagrid structure. The base is designed to hold twelve knitted petals, each constructed from common, photochromic, and luminous yarns. These petals feature custom prints with mesh-like openings, allowing air and light to pass through. Additionally, electrical cabling is inserted to illuminate the structure at night. Remarkably, 60% of the yarn is made from recycled plastic bottles and powered by solar energy ["Living," n.d].

This project materialises the collaborative blending of textile techniques and architectural methods to construct a visually appealing and structurally sound design. While the diagrid structure adheres to a rigid formula, the textile offers a more flexible approach, allowing for greater freedom and stability in design. By highlighting the contrast and similarity between these two techniques, we emphasise the possibility of innovative applications.

Figure 15: The Living Knitwork Pavilion instillation, MIT, 2023

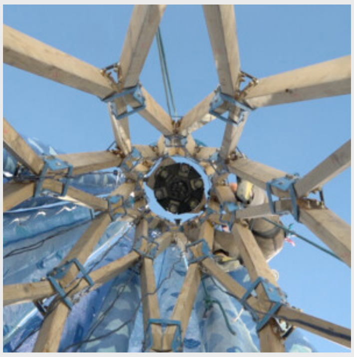

Figure 16: The structural framework of the Living Knitwork Pavilion, MIT, 2023

Figure 17: The petal layer of the Living Knitwork Pavilion, MIT, 2023

03.

METHODOLOGY

The research methodology blends theoretical analysis with practical experimentation to explore the potential of diagrid structures and honeycomb smocking. Following a practice-based design approach through an inquiry-based framework, the investigation aimed to contribute novel insights into these architectural techniques.

This project was organised into six phases of the design process, each encompassing an iterative cycle of theoretical and practical exploration [Figure 18]. Each phase involved an experimental stage, which was analysed based on the findings from the previous stages and further developed through identified constraints and discoveries. This iterative process was applied through the act of making and employing techniques such as drawing, paper-mâché for prototype testing and three-dimensional rendering for conceptual visualisation. These methods enabled a hands-on examination and visual representation of the concepts.

PHASE A:
APPROACHING THE THOUGHT

This phase sets the foundation of the research, building upon leveraging an existing experiment to further its development. It involves studying fabric behaviour, focusing on density and node spacing in fabrics.

PHASE B:
REFINING THE THOUGHT

This phase sets out the findings from Phase A that were utilised to develop conceptual artefacts. It involves synthesising various materials and techniques and examining their impact on the fabrics' elasticity and structural integrity.

PHASE C:
SYNTHESIZING WITH WOOL

Phase C carries out key findings from phase B synthesised to advance the artefact's development while simultaneously exploring wool's potential sustainable benefits and applications.

PHASE D:
DEVELOPING THE THOUGHT

This phase focuses on progressing the artefact developed in Phase C, emphasising the advancements in combining the flexibility of honeycomb patterns with the strength of diagrid structures.

PHASE E:
PROTOTYPING

Phase E involves refining the prototype and conducting experiments with joinery mechanisms. This phase highlights the challenges of assembling modular units at an architectural scale.

PHASE F:
AESTHETICS

The final phase concentrates on integrating structural and aesthetic elements through various forms and techniques, resulting in engaging spatial experiences.

Ultimately, this approach aimed to provide insights into innovative approaches to architectural construction and textile artistry by exploring diagrid systems and honeycomb smocking. It highlighted the integration of theoretical and practical methodologies, pushing the boundaries of conventional architectural practices.

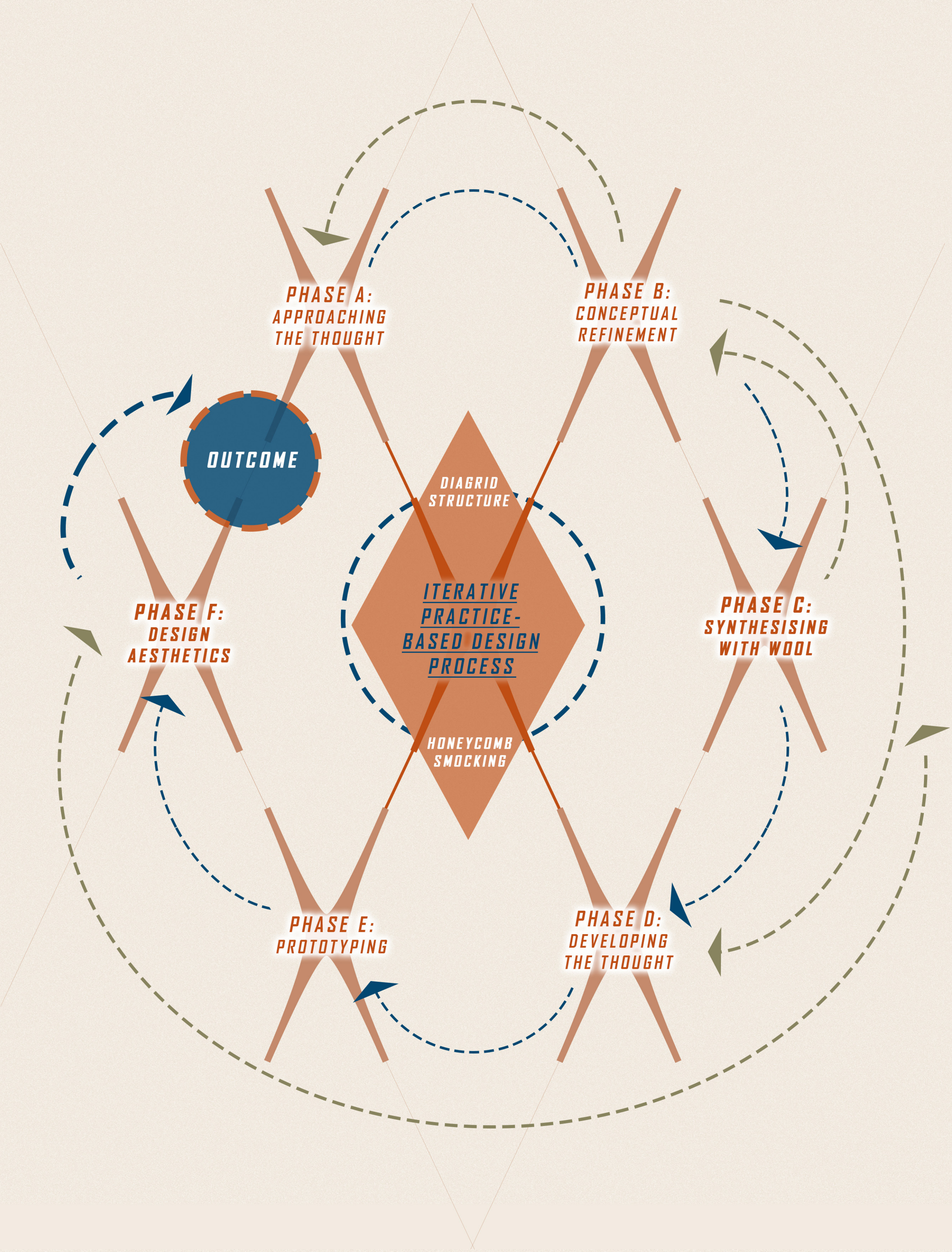

Figure 18: Design research process diagram

04.

DESIGN EXPLORATION

This chapter offers an in-depth description and analysis of the work conducted during the six phases of practical experimentation. It delves into the iterative process of ongoing reflection and the development of key findings that led to the final work. By examining these stages, the chapter highlights the project's design process, the challenges encountered, and the solutions implemented, providing a comprehensive understanding of the development journey from conception to finalisation.

“AN ART OF INQUIRY”

This research addressed the fundamental issue of whether questions must always accompany problems. The belief was held that thoroughly examining a question often surpasses the importance of finding a solution [Lawson, 2005]. The objective was to explore the question and discover findings through inquiry. This study sought to enhance understanding of the basic principles of honeycomb smocking and diagrid structures, without necessarily considering their practical applications in solving specific problems.

The approach treated this research as a thought process, focusing on the shared characteristics of these two innovations and what could be learned from their techniques to unravel possible outcomes. Emphasis was placed on the notion that the research question might not necessarily solve a problem; it could simply be an exploration. Often, the emphasis is on problem-solving, but the essence of research is to gain knowledge and understanding through existing knowledge, potentially creating new outcomes [Western Sydney University, 2023].

Different individuals think and process information in diverse ways. As Ingold [2013] noted, some “make through thinking, and others think through making” [p. 6]. Theorists often apply their thoughts to the physical world, whereas designers are more inclined to use hands-on practice to acquire knowledge, which Ingold referred to as “an art of inquiry” [Ingold, 2013, p. 6]. This research positioned itself between these two approaches; the initial drive often stemmed from using theory as a basis for making while relying on the act of making to drive the theory. This process allowed the act of making to further inform and refine both theoretical and practical understanding.

Fundamentally, “the searching is probably much more important than the finding” [Lawson, 2005]. Exploring these techniques aimed to challenge existing paradigms within their respective fields, altering conventional thinking. Focusing on the thought process suggested that innovation and discovery involve more than just problem-solving; they also encompass exploring diverse ways of thinking and tackling challenges. This approach underscored that the journey to finding solutions can be as important as the solutions themselves, often resulting in unexpected insights and breakthroughs.

The following diagram illustrates the theoretical framework used to approach the research question [Figure 19].

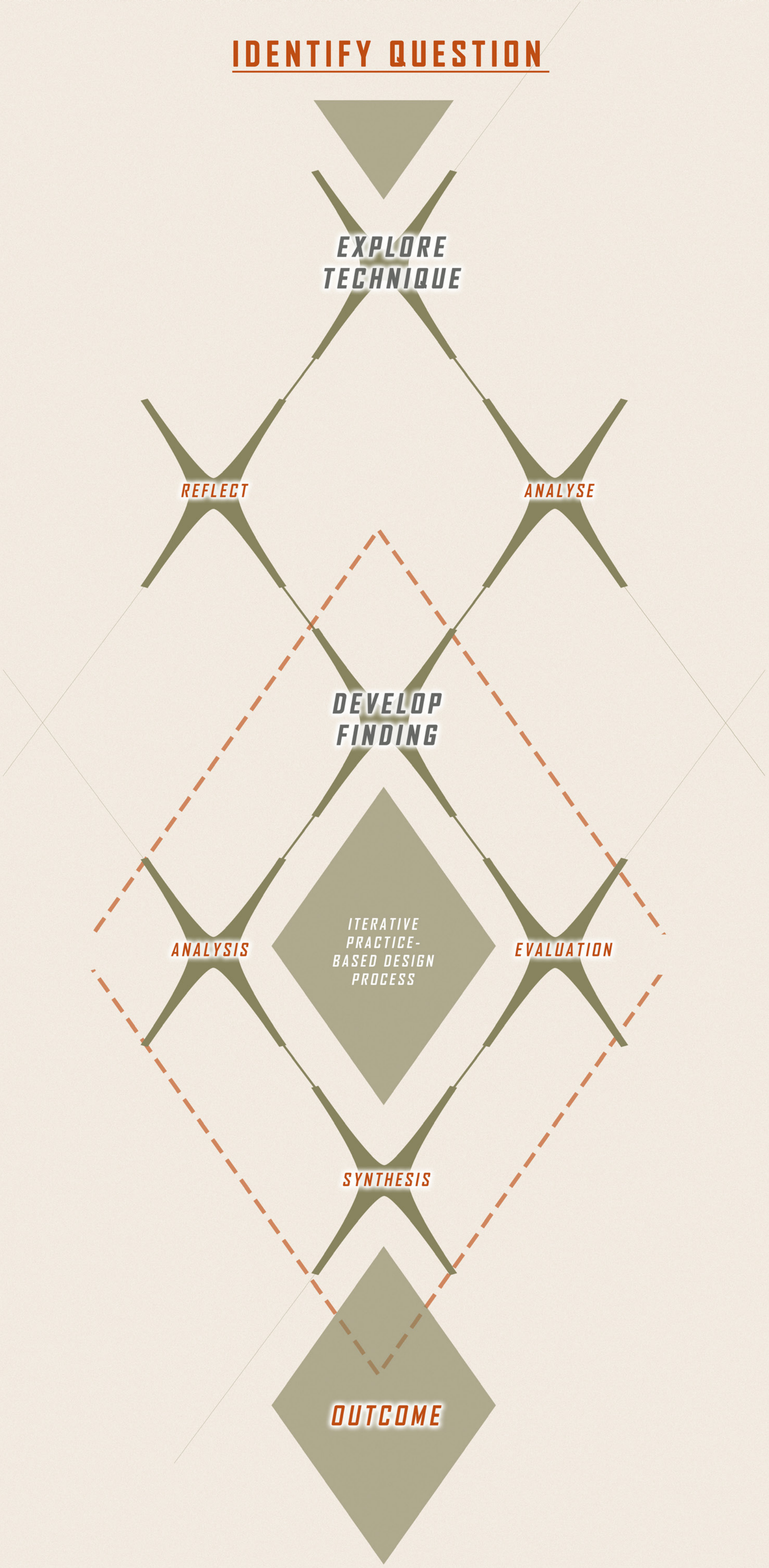

Figure 19: Theoretical framework diagram

THE RESEARCH PROCESS

The transition from a notion to a research process can be approached through various methodological lenses. As a visual learner, a hands-on approach was adopted, leveraging interest and knowledge in creative practices. Ideally, visual and practical making methods were used as foundational tools for the research and its outcomes.

However, relying solely on visual and material elements to drive the research can be challenging. Writing analysis was fundamental in comprehensively conveying and analysing the process to bridge this gap. This research approach emphasised synthesis through design practice complemented by written documentation, allowing exploration through making and annotating to describe the process. This methodological approach is known as practice-based design research. Linda Candy explains that creative practitioners work within their comfort zones by using artefacts as research methods to contribute to knowledge, enabling creative individuals to use their strengths to offer broader perspectives [Candy, 2006]. This practice allows a creative individual to explore the research question effectively through innovative processes and methods.

As Lawson [2005] noted, “Designers also tend to work in a very visual way” p. 13]. In exploring the integration of honeycomb smocking techniques and diagrid structures, making was emphasised as a core component. This practice-based design research investigated both techniques’ inherent strengths and limitations, ultimately combining them to yield innovative outcomes. To achieve this, establishing a solid foundation was essential for conducting a design process that fuelled the research. Understanding how designers approach a problem was fundamental. This concept was illustrated through the philosophical underpinnings expressed by Bryan Lawson in his book *How Designers Think* [Lawson, 2005]. Lawson delved into the minds and methods designers naturally use, providing valuable insights into their problem-solving approaches.

In the design field, the design process is often perceived as a structured, step-by-step sequence of research, concept design, developed design, and final product [Lawson, 2005]. However, in practice, this is rarely executed in such a linear fashion [Lawson, 2005]. Each designer has their unique techniques and processes. Lawson challenges the notion of a rigid design process by identifying key attributes of design thinking. He argues that the design process is never a linear, step-by-step procedure. Instead, it is a disorderly, iterative process involving problem identification, analysis, evaluation, synthesis, and solution [Lawson, 2005]. Lawson visualises this iterative approach as a dynamic pathway from problem identification to generating solutions [Figure 20]. By embracing this iterative mindset, designers shift from merely seeking design solutions to engaging in a more research-oriented creative practice. The diagram illustrates that a solution does not always need to start with a problem; it does not have to follow a conventional, orderly manner. Not forming barricades in the design process by restricting oneself to another chain of command allows a natural flow of an individual's methodology.

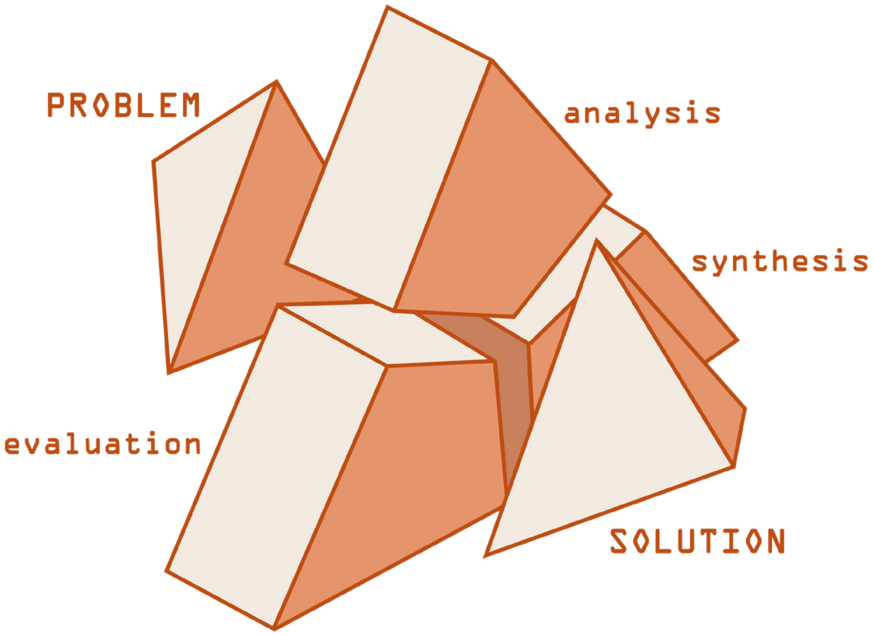

Figure 20: Adapted from [Design process diagram, Lawson, 2005], redrawn by the author

4.1. PHASE A

APPROACHING THE THOUGHT

The initial steps in this investigation aimed to generate inspiration to establish the research foundation. Given that diagrid structures play a key role in reinforcing a building's framework, the investigation commenced with projects exploring the structural components of diagrids. A notable project identified was part of The Third National Conference on Structural Engineering and Construction Management in 2019, which focused on "Sustainable Construction and Design for the Future" [Dasgupta et al., 2019]. The study by Merry James and Neeraja Nair, titled "Seismic Performance Analysis of Vertically Irregular Structures with Diagrids," was particularly relevant. Their research addressed the challenges irregular high-rise buildings face during seismic activity, specifically examining diagrid structures with varying diagrid angles.

James and Nair began their investigation with fixed dimensions for a high-rise building: a 36-metre by 36-metre base and a height of 129.6 metres, with each story measuring 3.6 metres in height [Dasgupta et al., 2019]. They created four diagrid structural templates (Figure 21), gradually increasing the diagonal angle to determine the optimum configuration for seismic performance. Their data revealed a notable finding: as the diagonal angle uniformly increased, the number of diamond frames decreased, leading to structural weakness during seismic tests. Diagrams A and B were successful and remained unimpacted, while C weakened in performance, and diagram D exhibited a drastically unsuccessful outcome [Figure 22] [Dasgupta et al., 2019].

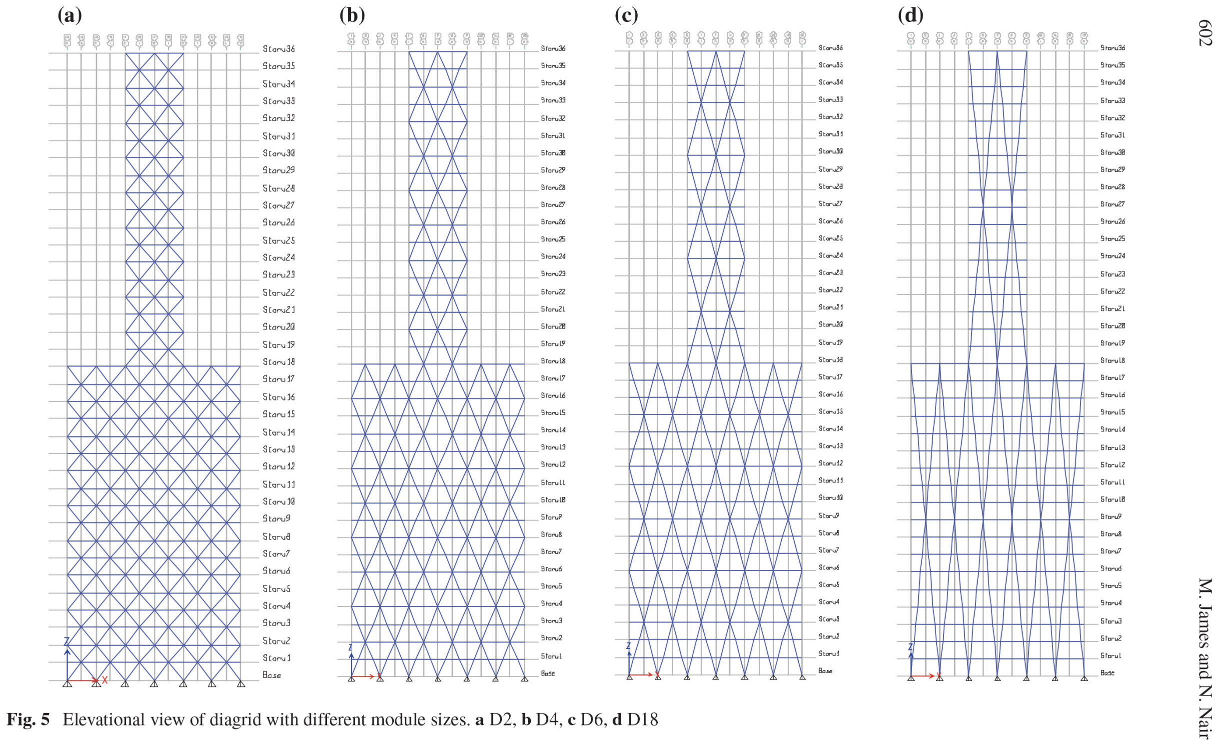

Fig. 5 Elevational view of diagrid with different module sizes. **a** D2, **b** D4, **c** D6, **d** D18

Figure 21: Diagrid Diagram Exploring Diagonal Angles, James & Nair, 2020

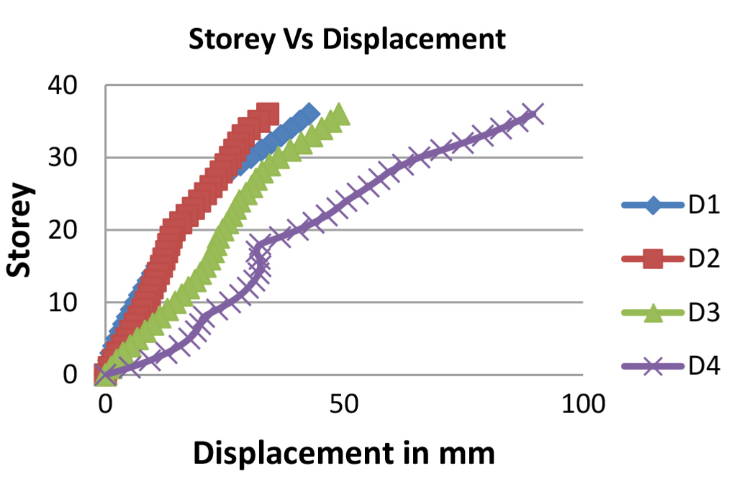

Figure 22: Seismic results of diagrid experiment, James & Nair, 2020

Their investigation identified the significant structural stability that diagrid structures can achieve. Additionally, the importance of diagonal braces in maintaining the form's structural integrity became evident. The four experimental diagrams produced by James and Nair illustrated an exemplary case, providing a valuable template for initiating the design process. Beyond seismic research, the diagrams fabricated for their study demonstrated potential for diverse research applications. These findings underscored the relevance of using their diagrid template to initiate and drive further research.

DEVELOPING THE THROUGH

Drawing from James and Nair's experiments, their diagram was adopted as a foundational template for initiating the research. The goal was to apply the honeycomb smocking technique to their templates, drawing inspiration directly from their work.

The design development and material application process were intuitive, given that fabric is essential in textile design and comes in a diverse range. Textile designers often use calico fabric as their conceptual or mock-up material for experimentation. This choice is due to calico fabric being inexpensive and providing a blank slate to understand the movements created with every fold. Lightweight calico fabric [Figure 23] and heavyweight calico fabric [Figure 24] were employed for the investigations.

Figure 23: Light-weight calico fabric

Figure 24: Heavy-weight calico fabric

INTEGRATION

The integration process involved exploring the interplay between fabric densities through honeycomb smocking. This was conducted at a scale of 1:200 by following the grid patterns of diagrams A, B, C, and D from James and Nair's research, stitching along the nodes where the diagonal lines intersected to create the honeycomb form. This method allowed for a detailed examination of how different fabric densities interacted with the smocking technique, providing insights into each configuration's structural and visual outcomes.

SYNTHESISING

AREFACT A.1.

Artefact A.1 adhered to a 2-by-1 grid structure inspired by James and Nair's diagram. The smocking nodes were sewn on each story in this configuration, two grids apart, creating closely sewn nodes.

OBSERVATION:

LIGHTWEIGHT FABRIC

[Figures 25 & 26]

The lightweight fabric offered a decent amount of flexibility, allowing it to stretch with minimal constraint. However, due to its closely woven nodes, expansion was limited. When stretched vertically from both ends, it expanded horizontally but also reduced in height due to the vertical space aiding in its horizontal expansion.

HEAVYWEIGHT FABRIC

[Figures 27 & 28]

In contrast, the heavyweight fabric was robust but less flexible. Similar to the lightweight fabric, it contracted when released from being stretched. However, stretching this fabric required more force due to the density of the sewn nodes.

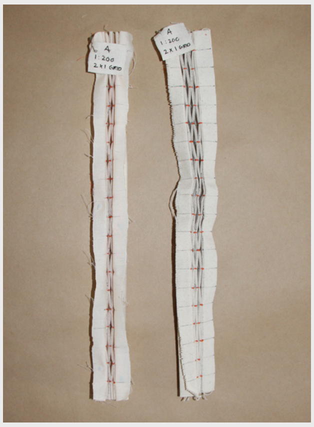

Figure 25 & 27: Artefact A.1 - Light-weight & Heavy-weight calico fabric

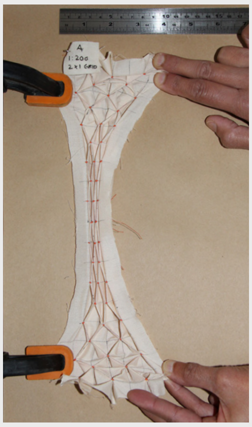

Figure 26: Artefact A.1 - Stretched light-weight calico fabric

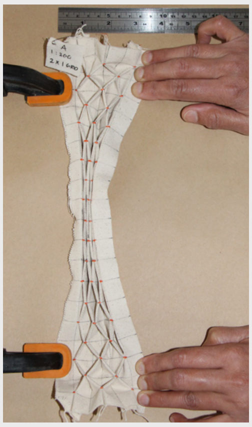

Figure 28: Artefact A.1 - Stretched heavy-weight calico fabric

STRENGTHS:

- Similar characteristics to an elastic fabric: It naturally contracts back to its pleated form if not physically stretched.
- When the heavyweight fabric was stretched, it did not shorten in height, unlike the lightweight fabric.

CONSTRAINTS:

- Minimal elasticity
- Required significant force to expand the structure due to the tightly woven nodes
- Lost the visual elements of the honeycomb smocking due to the density of the nodes.

AREFACT A.2.

Artefact A.2 used a 2-by-2 grid structure from James and Nair's diagram B, which visually displayed the honeycomb smocking pattern without needing to be stretched.

OBSERVATION:

LIGHTWEIGHT FABRIC

[Figures 29 & 30]

The increase in Diagram B's diagonal angle allowed more spacing between the sewn nodes, achieving a more stable and visually pleasing outcome. Both the heavyweight and lightweight fabrics achieved very similar structural and visual traits.

HEAVYWEIGHT FABRIC

[Figures 31 & 32]

Notably, with the heavyweight fabric, when stretched, the diamond forms locked into place. The density of the fabric and the force created when expanding created an additional horizontal fold in the centre of the diamond to lock the shape in place. It adapted to the changes and created its structural element.

Figure 29 & 31: Artefact A.2 - Light-weight & Heavy-weight calico fabric

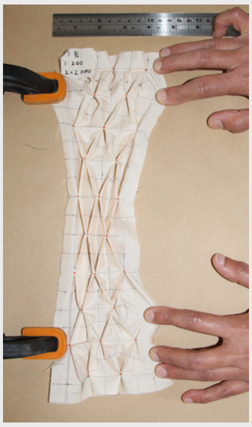

Figure 30: Artefact A.2 - Stretched light-weight calico fabric

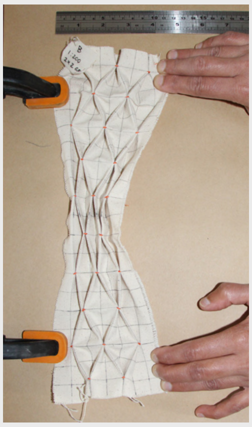

Figure 32: Artefact A.2 - Stretched heavy-weight calico fabric

STRENGTHS:

- In its unstretched form, the honeycomb smocking pattern was clearly visible.
- Allowed both expansion and contraction without losing its form.
- Visually communicated a sound pattern.
- Stabilised itself when expanded structurally

CONSTRAINTS:

- When stretched, its height was reduced as it used the horizontal length to help expand it vertically.

AREFACT A.3.

The 2-by-3 grid pattern from James and Nair's diagram C created a looser form on the calico fabrics. It could visually hold the honeycomb smocking pattern but struggled slightly with the structural element. As the area of the diamond increased, the number of nodes decreased.

OBSERVATION:

LIGHTWEIGHT FABRIC

[Figures 33 & 34]

The lightweight fabric was visually similar to Diagram B but lacked its structural properties. Expanding the lightweight fabric caused it to lose its visual diamond pattern and become distorted, as it required less force to stretch.

HEAVYWEIGHT FABRIC

[Figures 35 & 36]

Similarly, the heavyweight fabric followed a similar path but successfully held a diamond-like pattern. Like Artefact A.2, it also created an additional structural element to lock the stretched form in place.

Figure 33 & 35: Artefact A.3 - Light-weight & Heavy-weight calico fabric

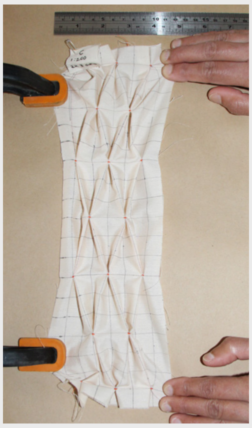

Figure 34: Artefact A.3 - Stretched light-weight calico fabric

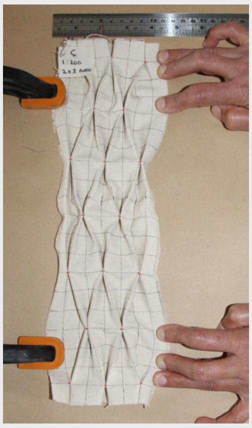

Figure 36: Artefact A.3 - Stretched heavy-weight calico fabric

STRENGTHS:

- Uses fewer node systems, making it flexible and malleable.

CONSTRAINTS:

- When expanded, it lost its critical visual element and reduced horizontal height to adhere to the vertical stretch.
- Decreased in structural rigidity.

AREFACT A.4.

Artefact A.4 followed a 2-by-9 pattern from James and Nair's diagram D. The drastic leap of the vertical axis resulted in a distorted form unrecognisable as a honeycomb pattern. The considerable distance between the nodes displaced the visual element and depleted the structural integrity of the form.

OBSERVATION:

LIGHTWEIGHT FABRIC

[Figures 37 & 38]

The form was structurally unstable, but both fabric weights created an illusion, teasing a three-dimensional form. The lightweight fabric acted as if it were returning to its natural two-dimensional form, bringing back the fluidity of the fabric and allowing more free movement with a touch of form.

HEAVYWEIGHT FABRIC

[Figures 39 & 40]

In contrast, due to its natural rigidity, the heavyweight fabric forced the form to bend in half as the centre point was weak, while the top and bottom points held more structural form.

Light-weight | Heavy-weight

Figure 37 & 39: Artefact A.4 - Light-weight & Heavy-weight calico fabric

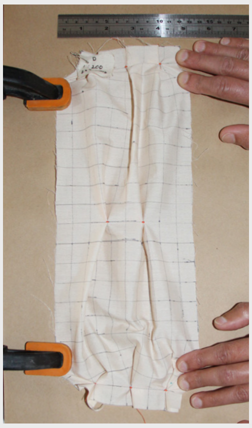

Figure 38: Artefact A.4 - Stretched light-weight calico fabric

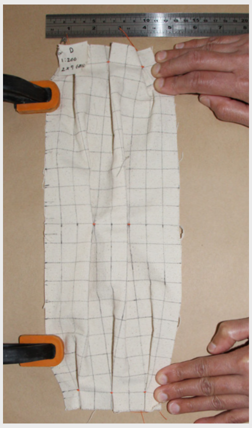

Figure 40: Artefact A.4 - Stretched heavy-weight calico fabric

STRENGTHS:

- The forms were far more mailable

CONSTRAINTS:

- Unstructured and flimsy

PHASE A - ANALYSIS

The experiments highlighted the trade-offs between visual appeal and structural stability in integrating honeycomb smocking and diagrid structures. The findings suggested that carefully considering grid patterns and fabric density was essential to balancing aesthetics and functionality.

Overall, artefact A.2 performed as a well-balanced diamond area and enhanced the flexibility of the form, resulting in a well-rounded structure in terms of pattern, elasticity, and stability.

KEY FINDINGS:

- The distance between the nodes was crucial to the structural properties.
- Fabric density was essential to achieve a particular outcome. Lighter fabrics offered more flexibility but could compromise structural integrity, while heavier fabrics provided more stability but required greater force to stretch.

4.2. PHASE B

CONCEPTUAL REFINEMENT

Reflecting on Phase A, it was noted that the smocking technique of pleating and sewing nodes organically created a structural skeleton [Figure 41] that shaped the honeycomb pattern. Notably, fabric weight also impacted how this skeleton held its form. Lightweight fabric tended to be flimsier while still forming the honeycomb pattern [Figure 42], whereas heavyweight fabric prominently held the pattern and form upright [Figure 43].

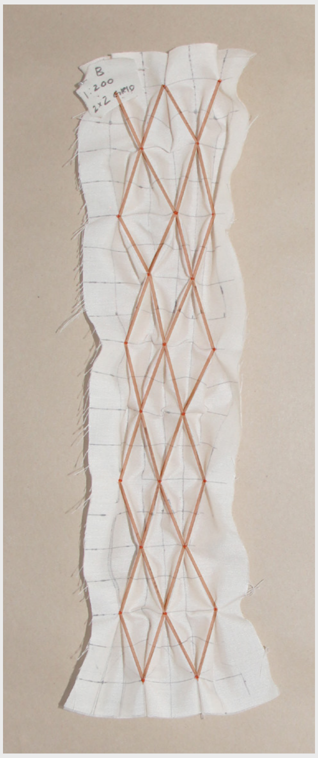

Figure 41: Skeleton of the honeycomb

Figure 42: Testing forms on light-weight honeycomb smocking

Figure 43: Testing forms on heavy-weight honeycomb smocking

AREFACT B.1.

CONTINUOUS WIRE FRAMEWORK

Upon closer analysis of Phase A, I realised that the smocking technique was not solely about elasticity and aesthetics; it also acted as geometric structural moulding, enabling the folds in the fabric to create its structural skeleton. Building on this finding, I experimented with synthesising a structural skeleton integration into the calico fabric to manipulate the fabric and create three-dimensional patterns.

An aluminium-wired framework (1mm diameter) following the artefact A.2 diagonal grid structure was imitated and fused between two sheets of medium-weight calico fabric [Figure 44]. A malleable product was achieved; the wireframe allowed the artefact to be folded at its nodes to create a three-dimensional form that could be flattened back to a flat sheet [Figure 45]. Prominent peaks formed when folded at the nodes, somewhat imitating the honeycomb pattern. Additionally, the wireframe acted as a guide in moulding desired peaks through the nodes, which also served as the support structure to hold the moulded form.

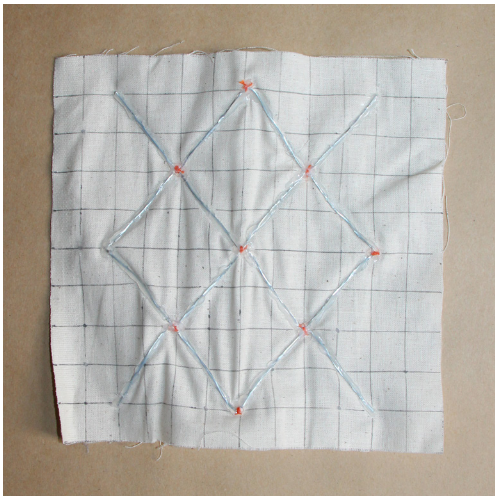

Figure 44: Artefact B.1 - Continuous wire framework

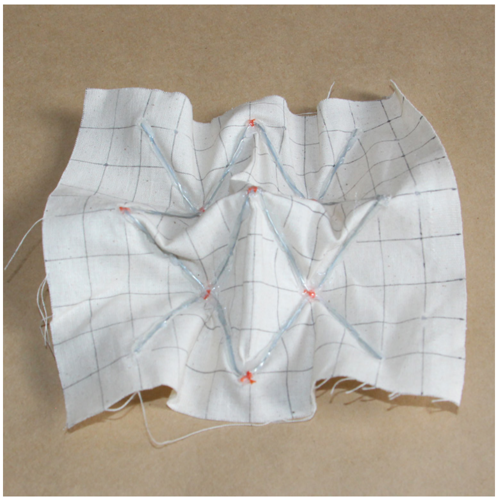

Figure 45: Artefact B.1 - Continuous wire framework – Moulded

AREFACT B.2.

DISCONNECTED WIRE FRAMEWORK

In contrast to artefact B.1, artefact B.2 investigated the idea of using a wireframe that is not connected, with individual wire rods creating the form without nodes connecting at the intersections [Figure 46]. Contrary to the continuous wireframe, this experiment used the calico fabric as the foundation for the wire to bed onto; the wires did not interconnect and hence had no nodes. This allowed it to be moulded but unable to hold the moulded form, retracting it to its flat state [Figure 47].

Figure 46: Artefact B.2 – Disconnected wire framework

Figure 47: Artefact B.2 – Disconnected wire framework - Moulded

AREFACT B.3.

FOLDING TECHNIQUE

The concept of pleating and the expanding and contracting properties of smocking reminded me of the technique of origami. This connection led me to Folding Techniques for Designers by Paul Jackson, where he "establishes folding as a primary design tool" [p.16]. Jackson provided a step-by-step illustrated tutorial on various folding patterns to create three-dimensional patterned forms. The closest pattern found to my research was the "X-form spans" [Jackson, 2022, p.193].

Adhering to the scale 1:200, the pattern from artefact A.2 was drafted to conduct this folding experiment on thick tracing paper [Figure 48]. When folded, the pattern intuitively curved and formed a parabolic shape [Figure 49].

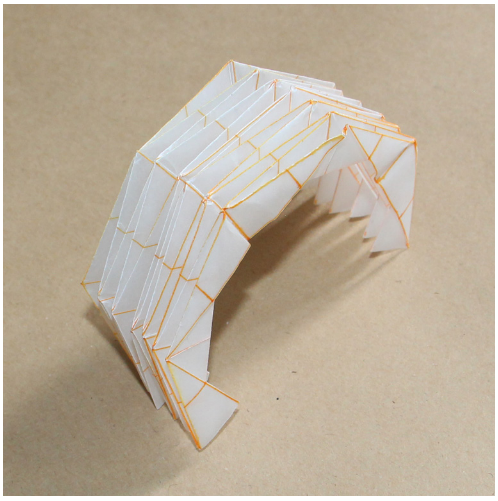

Figure 48: Artefact B.3 – Folding technique

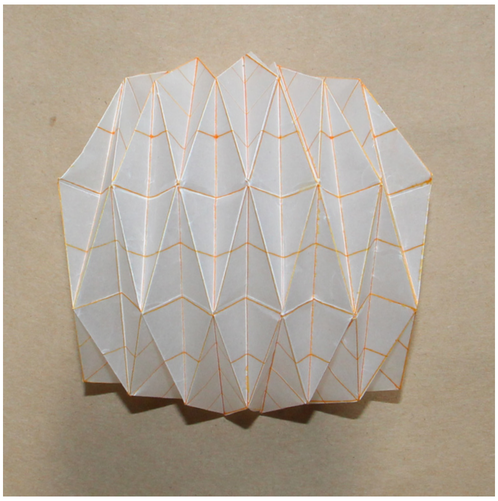

Figure 49: Artefact B.3 – Folding technique – Moulded

AREFACT | B.4.

INFUSED STRUCTURE

From these experiments, it was discovered that a linear framing element was required to create a foundation for the structure. However, I was unsure how would this play if the form itself formed the framing? Returning to the experiment, two layers of calico fabric were used to interpose a thick case board cut into diamond shapes [scaled 1:200 to James and Nair's diagram B]. Thread was used to sew the pieces along the diagrid guidelines to hold them in place [Figure 50].

In synthesising this investigation, critical attributes of structural elements that shape the foundation of a form were effectively identified. This particular experiment was performed in a way similar to the disconnected wireframe experiment. It did not have a wire structure, but the weight and thickness of the case board behaved as its structural framework [Figure 51].

Figure 50: Artefact B.4 – Infused structure

Figure 51: Artefact B.4 – Infused structure – Moulded

AREFACT B.5.

OVERLAY LIGHT-WEIGHT MESH

Based on the findings from artefact B.3, it was noted that weight played a crucial role in shaping and moulding the artefact. An investigation was conducted to understand the impact of using different densities of fabric to layer weighted patterns on. This experiment aimed to analyse the effects of material behaviour with layering.

Fabric mesh was selected as a suitable material due to its diverse compositions. Two densities of mesh fabric were chosen, with the same scale of woven grids but differing in thickness. The lighter polyester net mesh fabric served as the foundation for overlaying the thick diamond-shaped case board. This resulted in an informative artefact [Figure 52]; the lightness of the mesh allowed the product to do away with any rigid structure, with the case board providing the necessary structural element. The product behaved as a malleable form, responding to the structural support of the case board [Figure 53].

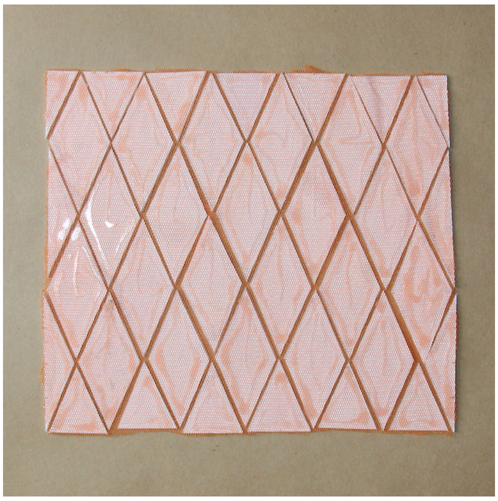

Figure 52: Artefact B.5 – Overlay light-weight mesh

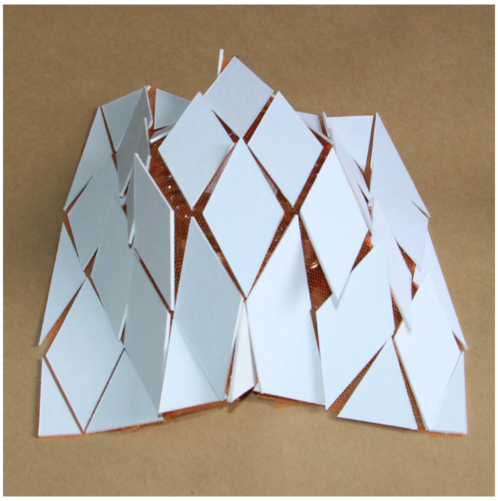

Figure 53: Artefact B.5 – Overlay light-weight mesh – Moulded

AREFACT B.6.

OVERLAY MEDIUM-WEIGHT MESH

Building on the findings from experiment B.5, this experiment utilised a slightly heavier polyester net mesh fabric as the foundation for overlaying the diamond-shaped case board [Figure 54]. The increased density of the mesh resulted in different behaviour compared to the lightweight mesh. The denser mesh provided more structure, and using a structural overlay on a structural base led to rigid movements. The product was limited in its direction of movement, allowing only one direction of fold due to the combined density of the materials [Figure 55].

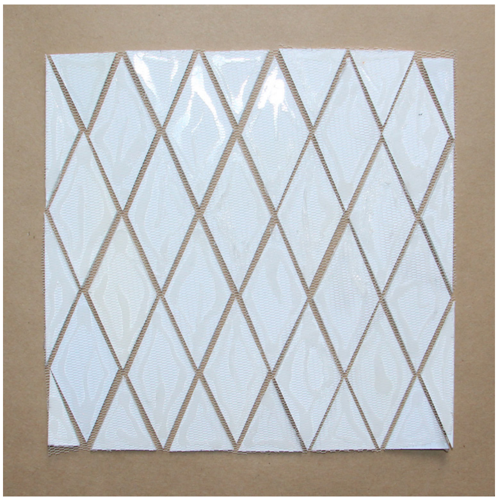

Figure 54: Artefact B.6 – Overlay medium-weight mesh

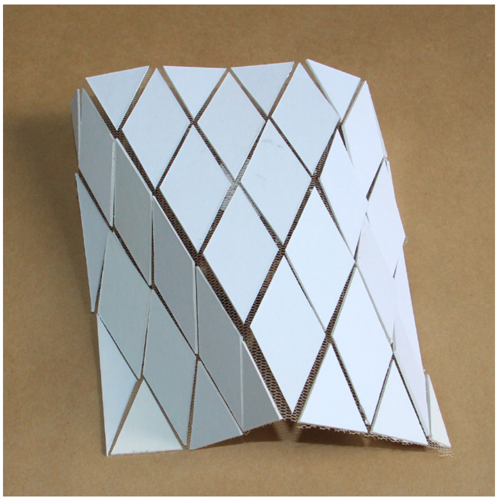

Figure 55: Artefact B.6 – Overlay medium-weight mesh – Moulded

PHASE B - ANALYSIS

The experiments revealed how material properties, such as weight and density, and the use of structural elements influenced the creation and stability of three-dimensional forms—specifically, integrating wireframes or structural elements into fabric created malleable products with desired shapes. It was observed that node connections were crucial for maintaining form stability, and different folding techniques resulted in unique shapes. These insights underscored the importance of carefully considering material properties and shaping the structural supports when designing flexible yet stable three-dimensional forms.

4.3.

FEEDBACK AND REORIENTATION

SOCIAL CLUB:

REFLECTIVE DISCUSSION

While this research adopted an iterative, experimental design approach, it was crucial to consider the possibilities that could arise from the theoretical and practical findings of the work in progress. The developments so far had begun to translate visually into possible outcomes. One common function that emerged was the potential for translating the diagrid structure and using it to design façade or internal wall systems.

A public event at Objectspace [May 16, 2024], organised by the Social Club, provided the opportunity to navigate these possibilities. The Social Club aims to "foster discussions related to a variety of making and applied art practices" [Objectspace, 2016]. This particular event allowed some students from AUT to present their work and receive feedback from architectural practitioners on their progress [Figure 56].

I utilised the opportunity this event presented to address the challenges I was currently facing. I shared my ideas and sought the panel's thoughts on potential design applications for these artefacts. The panel proposed similar areas of application in architecture or interior spaces. Additionally, they appreciated the soft feminine-like features of the honeycomb smocking and, in contrast, the harsh rigidity of the diagrid structure. They encouraged using these soft features to soften the harsh architectural environment [McCabe et al., 2024].

The concept of softening the built environment, where spaces often prioritise function over form and sometimes neglect the comfort and wellbeing of the occupants, was highlighted. Materiality plays a significant role in creating a calmer and more appealing space. Hence, the aim to explore conscious materials that can replicate fabric-like characteristics.

While challenges remained, integrating theoretical and practical approaches opened up innovative design possibilities. The journey focussed on addressing these concerns and leveraging materiality to create sustainable, aesthetically pleasing solutions like wall partitions.

Figure 56: Social club reflection discussion at the Objectspace

MATERIAL EXPLORATION

The challenge during the initial experimental phases was a lack of integration with architectural-based materials. Developing these experimental prototypes into an applicable medium by working with architectural-focused materials was a fundamental component missing from the material outcomes of the first two phases. Materials such as calico, baseboard, and paper were ideal for conceptualisation, but practical considerations such as durability, sustainability, and weather resistance necessitated considering impactful materials suitable at an architectural scale.

The outcome of the next phase of this investigation into materialisation aimed to develop a material that could translate similar fabric characteristics to an architectural scale. In searching for fabric-like materials currently used in architectural environments, several options were highlighted: tensile membrane structures, ETFE foils, polyurethane-coated glass cloth, silicon-coated glass cloth, and PVC-coated polyester fabric [Kuusisto, 2010; Ata, 2009]. However, these materials were deemed less ideal due to unsustainable practices [Kuusisto, 2010]. As a result, the exploration focused on finding a sustainable adaptable material that could meet these needs. Wool emerged as a promising alternative due to its inherent sustainable properties.

Wool was proposed as a more suitable alternative. It offers a unique combination of softness, flexibility, and strength, making it an excellent material for creating conscious spaces. The exploration of such materials aimed to replicate fabric-like characteristics at an architectural scale, providing innovative design possibilities while addressing practical challenges.

MATERIAL OF CHOICE

Wool is widely recognised and used in the textile industry due to its sustainable and thermal properties. Recently, its application has expanded into product design and spatial design industries, driven by experimental implementation methods. In architecture, wool as a building material could offer numerous benefits and various application methods [Mornu, 2011].

With more attention being paid to regenerative framing practices and low-carbon wool processing technologies, wool products are becoming more efficient to manufacture, use, and eventually recycle compared to synthetic petroleum fibres, resulting in low carbon dioxide emissions over a product life cycle [Nauyital, 2023]. Consequently, increasing the use of wool, which has a low carbon footprint [Figure 57], can help reduce greenhouse gas levels in the atmosphere [Henry, 2012].

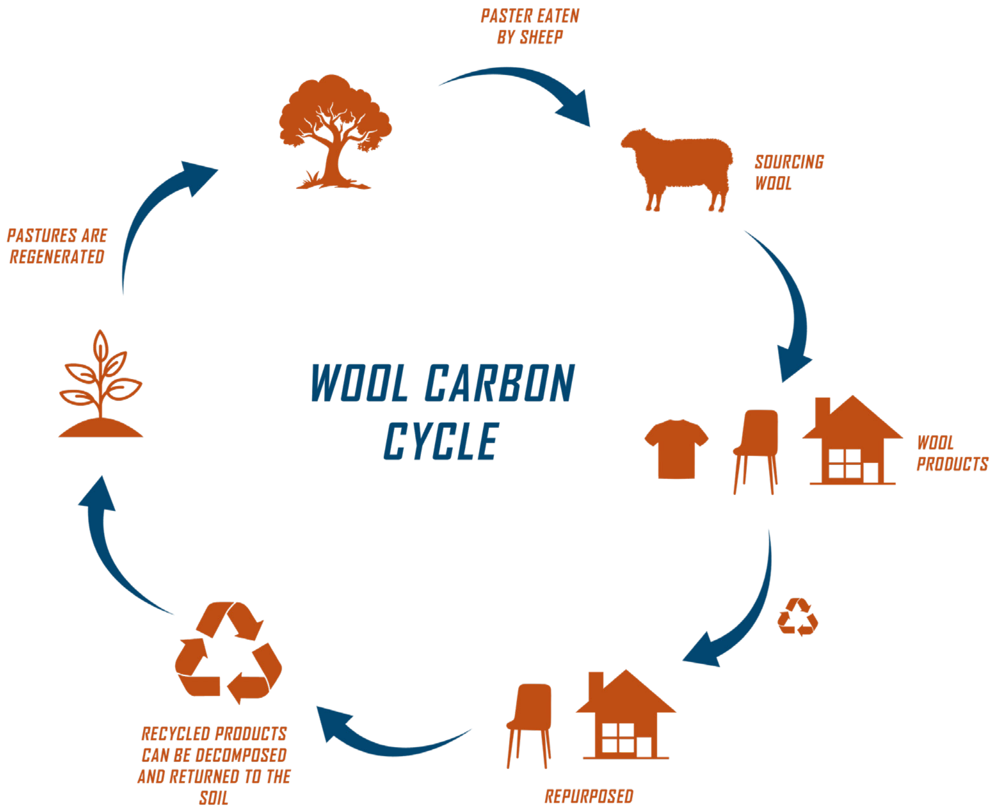

Figure 57: Wool life cycle diagram

HEALTH AND WELLBEING

The built environment produces large amounts of gas emissions, and the extensive use of synthetic materials creates harmful contaminants in the air. Wool can naturally absorb many volatile compounds, thereby improving air quality. Common emissions found in indoor spaces, such as formaldehyde, nitrous oxide, and sulphur dioxide, were effectively captured by wool fibres through a natural chemical process inherent to wool [Cooper, 2023]. This provide a natural and sustainable solution to enhance living environments, contributing to comfort and health.

SOURCING

Well-known types of wool included merino wool and strong wool. Australia produces more merino wool, while Aotearoa holds a significant market share in strong wool [Why, 2023]. Known for its durability and thickness [Perino, 2025], strong wool was ideally suited for products that needed to resist heavy use, such as carpets [Conforte et al., 2011].

Wool's natural properties, such as thermal insulation, moisture regulation, and air purification, make it an ideal material for sustainable building practices. Incorporating wool into architectural and interior spaces enhances occupants' comfort and health while contributing to the regeneration of natural resources.

INDUCTION TO FELTING WITH WOOL

In acquiring a hands-on understanding of application techniques with wool, AUT's Textile Technologies Lab provided a comprehensive exploration into the art of felting and working with wool, highlighting its potential in design applications. During the textile technologies induction, it was learned that forming organic fibres into a material involved the consolidation of fibrous materials by applying heat, moisture, and mechanical action, leading to the interlocking or matting of fibres. Wool, fur, and certain hair fibres can mat together under suitable conditions due to their fibre structure and high degree of crimp. This process allowed for combining various materials to create hybrid textile compositions. Felted textiles are versatile and used in various applications, including accessories, garments, furniture, and industrial uses such as insulation and packaging [Kalyanji & Collings, 2024].

The induction to felting covered two primary techniques: hand needle felting and machine needle felting.

NEEDLE FELTING

[Figure 58]

Needle felting uses barbed needles to interlock wool fibres into a dense fabric by hand. This technique allowed for precise control and was often used to create detailed, three-dimensional shapes and sculptures. The process was relatively straightforward but requires patience due to its labour-intensive nature [Kalyanji & Collings, 2024].

Figure 58: Needle Felting

MACHINE FELTING

[Figure 59]

Machine felting, much like needle felting, but at a manufacturing scale, utilised specialised equipment with a large number of needles agitating and compressing the wool fibres, speeding up the felting process. This method was beneficial for creating large, uniform pieces of felt [Kalyanji & Collings, 2024].

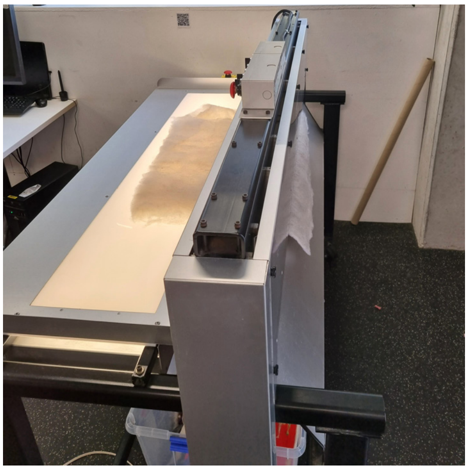

Figure 59: Machine Felting

DESIRED FELTING TECHNIQUE:

Various felting techniques were explored during the induction, including needle and machine felting. Needle felting, although labour-intensive, provided the flexibility to create bespoke forms through the meticulous interlocking of fibres using barbed needles. In contrast, machine felting involved a more straightforward process, where wool was fed into a mechanised system that compressed the fibres into uniform felt sheets. Both methods effectively produced high-quality felt, each with distinct advantages in terms of customisation and efficiency.

However, the objective was to work with a technique that allowed the infusion of wool between a modular structure, similar to artefact B.1[Figures 44 & 45]. Machine felting was deemed unsuitable for this purpose, as feeding a structural element would damage the needles. While needle felting was feasible, it was highly labour-intensive, particularly when scaled up to the industrial manufacturing level. Consequently, wet felting was recommended, a process that would enable the wool to mould around the structure and integrate it into a single cohesive sheet.

WET FELTING - WITH LIZ MITCHELL

▪ WET FELTING

This traditional hand technique uses warm, soapy water to mat and condense wool fibres [Figures 60, 61 & 62]. Layers of wool fibres are arranged in different directions (horizontal, vertical, and diagonal) and then agitated by hand or with tools to create a cohesive fabric. This method is versatile and can produce a variety of textures and thicknesses, making it suitable for both artistic and functional applications [Kalyanji & Collings, 2024].

Instruction was sought from the experienced designer and practitioner Liz Mitchell to gain a comprehensive understanding of the wet felting technique with wool. I had the opportunity to meet with Mitchell at her felting studio. She provided an in-depth overview of the wet felting process and a hands-on tutorial to facilitate practical learning.

Figure 60: Wet Felting – Wool fiber [Liz Mitchell's workshop]

Figure 61: Wet Felting – Applying soapy water [Liz Mitchell's workshop]

Figure 62: We felting – Agitation the fiber [Liz Mitchell's workshop]

The challenges I faced with felting to mould wool around a structural element were discussed. Mitchell indicated that fusing the wool around a structure was achievable with wet felting. It was necessary to continuously agitate the areas where the bottom and top layers of wool met to bind the fibres together, effectively encasing the structure with wool. Furthermore, she suggested using a heated mould, similar to a waffle maker, or an iron as an alternative, particularly at an experimental stage. While the wool was wet, the iron acted as a heated pressure on the fused areas, resulting in a smooth and firm finish.

Additionally, Mitchell introduced me to strong wool and provided a tutorial on carrying out wet felting on the fibre. In contrast to (fine) Merino wool, strong wool has denser fibres and feels harsher to the touch. Availability-wise, Aotearoa produces significantly more strong wool, mainly used for large-scale carpet and insulation manufacturing and focuses on exporting. Merino is more easily available due to its demand in the creative field [Jose et al., 2024]. Furthermore, the introduction to strong wool expanded the scope of materials suitable for wet felting, particularly in applications requiring enhanced durability, such as in the built environment. The material choice also correlates with recent initiatives from organisations like Campaign for Wool New Zealand and Wool Impact Ltd to increase the global market for NZ's strong wool through the development of innovative wool-based architectural and design applications.

4.4. PHASE C

SYNTHESISING WITH WOOL

Building on the insights gained from the workshop with Liz Mitchell, the next phase of the research focused on practical experimentation with wet felting. The objective was to apply the knowledge acquired to create felted structures that integrated seamlessly with modular frameworks. This involved a series of trials in refining the process of agitating the wool fibres and utilising heated moulds or irons to achieve a smooth and firm finish. The following sections detail the experimental procedures, observations, and outcomes derived from artefact B.1.

Given difficulties accessing small quantities of processes strong wool for experimentation and limited personal resources, it was more cost-effective to experiment with merino wool rather than strong wool. Given its superior strength and durability, the intention was to utilise strong wool for experimentation and material testing. However, the affordability and availability of merino wool made it a more feasible option for the initial phases of the research.

AREFACT | C.1.

INTERWOVEN WIRE FRAMEWORK

This section built upon the findings from artefact B.1, where the wired framework was laminated between two layers of calico fabric, effectively fusing the wired structure with the fabric. The subsequent experiment explored the potential of substituting calico fabric with wool.

The experiment involved wet felting on the same wired diagrid geometry structure used on artefact B.1. A vertical layer of loose wool fibres was laid down, followed by a horizontal layer, creating two layers. The wired structure was then placed on top, and the same layers of wool fibres were repeated. Wet felting was applied, agitating the fibres to fuse all the layers of wool.

The result was an infused artefact, where the interwoven wool held the wired frame in place without altering the diagrid pattern [Figure 63]. The artefact was subjected to various manipulations, including folding, pushing, and contracting the wired frame, to evaluate the wool's response to intense agitation [Figure 64]. This experiment revealed the inherent flexibility of wool. The applied tensile stress did not compromise the structural integrity of the wool; it maintained its form and exhibited no tearing at the points of tension [Figure 65]. The wool accommodated the imposed movements, demonstrating behaviour similar to honeycomb smocking.

Figure 63: Artefact C.1 – Interwoven wire framework

Figure 64: Artefact C.1 – Moulded interwoven wire framework

Figure 65: Artefact C.1 – Bent interwoven wire framework

The findings indicated that wool's fabric-like properties made it feasible to replicate the malleable characteristics of fabric. Wool's inherent flexibility and tensile strength allowed it to conform to the wired frame structure effectively, maintaining the desired three-dimensional forms. These promising results suggested that wool could be a viable alternative to traditional fabrics in architectural and interior applications, offering structural integrity and aesthetic versatility.

AREFACT C.2.

3-DIMENSIONAL MOULDING

Building on the concept of an infused structural element but eliminating the wired framework and intending for the wool to form the structure itself, using the same framework form from artefact C.1, the wool was moulded using wet felting to create a three-dimensional silhouette of the structural framework [Figure 66].

This approach yielded an intriguing result: the wool could maintain the moulded forms of the framework [Figure 67]. However, once the wool dried after the wet felting process, it lacked a prominent outline of the framework. The wool tended to spring back, causing the moulded details to become muted [Figure 68].

Figure 66: Artefact C.2 – Three-dimensional – Moulded

Figure 67: Artefact C.2 – Wet felting moulding when wet

Figure 68: Artefact C.2 – Wet felting moulding when dried

PHASE C – ANALYSIS

The studies conducted on using wool as a replacement for fabric successfully demonstrated its adaptability in achieving the desired outcomes for fabric translation. This approach aimed to create a thin, fabric-like sheet using minimal layers of wool fibres.

These experiments underscored wool's potential to replicate the malleable characteristics of fabric while also highlighting the necessity for additional support to maintain precise and stable shapes in architectural applications. The results suggested that with further refinement and the integration of structural elements, wool could serve as a viable and innovative material in architectural design.

MOULDING WOOL - WITH FLOC

The use of wool in architecture is a relatively untapped area. Traditionally, wool had been primarily utilised in construction materials, often concealed and blended with synthetic products like insulation, due to its superior thermal and acoustic properties [Jose et al., 2024]. However, wool has also been effectively used in various spatial design elements such as partitions, wall panels, ceiling panels, and furniture [Jose et al., 2024]. These applications demonstrated wool's versatility and potential for broader use in architectural design, functionality, and aesthetics.

I was introduced to a local business that work with 100% strong wool. Floc specialises in creating sustainable, customisable acoustic panels and other interior projects using 100% Aotearoa-strong wool. Their innovative approach highlighted the potential of wool in contemporary architectural and interior design, focusing on sustainability and performance.

▪ FLOC PANEL [Figure 69]

1.2 x 25 m & 600 x 600mm acoustic panels made by machine felting. These panels are commonly used on walls and ceilings [Floc, 2023].

Figure 69: Floc Panel

▪ FLOC 3D [Figure 70]

500x500mm 3D wall tiles directly fixed to the wall. The Floc 3D comes in various patterns; these panels are 3D moulded square panels which provide both visual and acoustic solutions [Floc, 2023]

Figure 70: Floc 3D panel

▪ FLOC ROLL [Figure 71]

2212 x 1212 mm & 1112 x 112 mm sustainable wall linings for interior spaces that enhance the thermal and acoustic performance [Floc, 2023]

Figure 71: Floc Roll

▪ FLOC CLOUD [Figure 72]

Up to 2.4m acoustic ceiling or wall panel sheets [Floc, 2023]

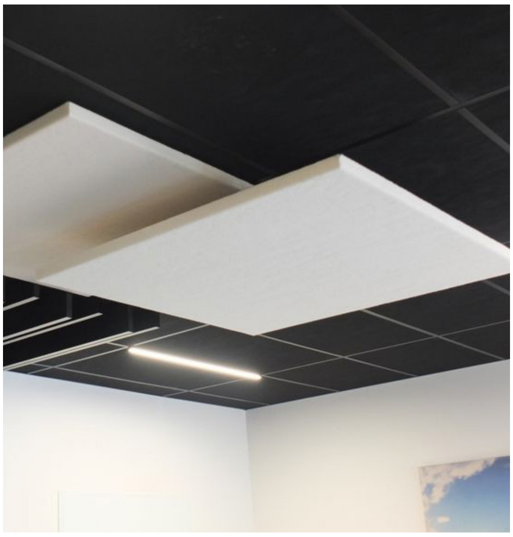

Figure 72: Floc Cloud

The installation of the Floc products uses custom-designed mechanisms and clips [Floc, 2023] [Figure 73]

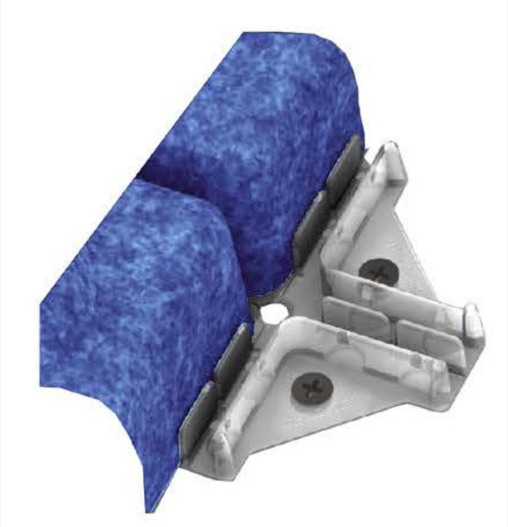

Figure 73: Floc clips

3D WOOL

The analysis of the 3D panels from FLOC provided an excellent example of how organic materials could be utilised in the built environment. Wool's inherent properties highlighted the positive attributes of considering conscious and ethical materials. Further investigation into the 3D panels aimed to uncover the techniques used to manipulate wool to hold the 3D pattern in place. However, limited information was available on the panels' production process.

I was introduced to Tom O'Sullivan, the business development manager for FLOC, to explore additional details about the 3D Floc tiles. The key question revolved around how the 3D panels were shaped. O'Sullivan explained that a small percentage of polyester had been integrated into the wool during the wet felting process to provide the stability required for forming 3D patterns. He also mentioned that they were working on replacing polyester to maintain sustainability and achieve 100% wool products, potentially using a thin layer of metal mesh to aid in holding the moulded form. This exchange underscored that wet felting could be scaled up for larger projects.

Despite this insight, the precise moulding process for the 3D patterns used by FLOC remained undisclosed. In a previous conversation with Mitchell, she suggested using a moulded heat press to apply the desired pattern [L. Mitchell, personal communication, 2024]; this could be tested in the next phase.

PROSPECTIVE INSIGHTS

Often, interior spaces that experience high foot traffic are constructed using materials that lack sustainability and negatively impact the health of the occupants [Cooper, 2023]. Given the growing concerns around indoor air quality, there is a pressing need to explore and incorporate materials that offered environmental benefits without compromising functionality. Notably, wool has emerged as a promising solution in this context. According to research by Cooper (2023), wool possesses inherent properties that enable it to purify the air by absorbing toxins, thereby significantly improving overall indoor air quality. This revelation opened up new avenues in interior design, advocating for a strategic approach prioritising health and sustainability. By integrating wool into the design of interior spaces, environments could be created that were adaptable to the needs of existing structures and beneficial to the well-being of their users.

4.5. PHASE D

DEVELOPING THE THOUGHT

In encompassing the key findings from artefact B.1, the most prominent attributes were the structural elements facilitating movements for the fabric. Wireframes are typically seen as the rigid support of a structure, unwavering in their movement, and the behaviour of the frame enables it to guide the motion of the artefacts. Drawing from the experiment, a wired frame from a diagrid template is infused between layers of fabric. Once malleable by hand, it could mimic the characteristics of honeycomb smocking in a three-dimensional form. Hence, focusing on forming a structural framework acted as a silhouette to create a foundation for a kinetic system for the fabric to encapsulate.

The most desired attribute of the diagrid structure was its modular components. Due to the nature of the diagonal frames created from the pattern, the structure could be prefabricated and assembled on-site. This prefabrication not only streamlined the construction process but also enhanced the precision and quality of the final build. Additionally, the modularity allowed for greater flexibility in design, enabling architects and engineers to create complex geometries with relative ease [Boake, 2014].

From afar, the diagrid appeared as an indefinite diagonal grid system; closer inspection revealed that it comprised modular components configured to form the overall structure. The Swiss Re Tower, designed by Foster + Partners in 2004, used modular triangular-shaped members assembled at the nodes [Boake, 2014] [Figure 74].

This knowledge was used for architectural innovation to optimise the strength of the triangular form. The diagrid is a structural system that gained stability from triangulation. It was assumed that the nodes in a diagrid system functioned as a hinge or pin connections [Figure 75] [Boake, 2012], which did not resist moments. This implied that the loads on the diagrid members were primarily axial, either in tension or compression and that shear forces were transferred through the nodes. To ensure constructability, adequate stiffness was required in the connections between the nodes and diagrid members to make them self-supporting, thereby reducing the need for temporary bracing during construction [Boake, 2014].

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Figure 74: Swiss Re Tower modular members

Figure 75: Hinge/ pin connection

In summary, while the triangular form provided the essential structural framework, the nodes were vital for connecting these elements and ensuring the system's overall stability and functionality. Both components were interdependent and equally important in the effectiveness of diagrid structures.

AREFACT D.1.

CELLULAR UNITS

Building on this foundational knowledge, the following experiment explored the integration of modular cellular structures similar to the behaviours of the FLOC tiles. Returning to artefact B.1, it utilised a diagonal grid pattern made of aluminium wire, which was then meshed between layers of fabric. The wire, being 1mm in diameter, was relatively thin and did not maintain a rigid hold. However, it allowed the wire to be manipulated, although it lost its shape with slight force. Enhancing this structure and adapting the modular concept of a diagrid by focusing on one area of the grid system of artefact B.1 to aid in forming a pattern to design a cellular unit.

This was conducted by narrowing to a single intersection of the wired framework (Figure 77) from artefact B.1 and upscaling it to resemble the triangular frame of the diagrid modular structure, resulting in an X form. Potential configurations for an X form and its modularity were explored through sketches (Figure 78). Subsequently, the X frame was rendered in a three-dimensional form (Figure 79).

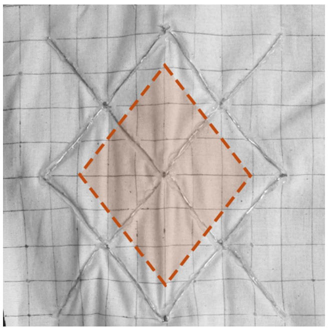

Figure 76: Narrowing the design to a modular form [Drawing over image]

Figure 77: Artefact D.1 – Cellular units

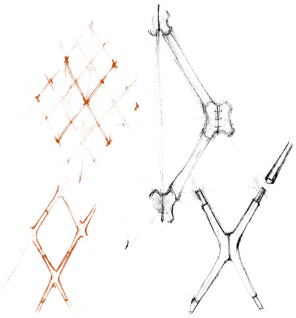

Figure 78: Conceptual drawing of structural formation

Figure 79: Conceptual drawing of a cellular unit

CONFIGURATION

To join these cellular units, the method used in modular diagrid members was employed, where the triangular rods were inserted into the hollow rod units [Boake, 2016]. To test this concept, paper mâché was used to create a modular form [Figure 80], allowing for experimentation and identification of a feasible solution. The artefact resulted in a three-dimensional X modular frame at a scale of 1:100, as continuing to work at a scale of 1:200 became too small to focus on the node systems. The tip of the X form had a hollow opening, while the bottom had a solid end. A copy was made to test the artefact at a modular scale, and it was successfully able to interlock at the opposite ends [Figure 81].

Figure 80: Configuration of cellular units

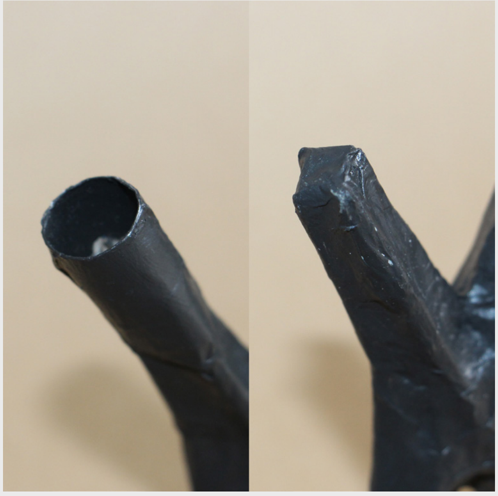

Figure 81: Cellular unit – Hollow to a solid connection

Using an X frame also helped design a modular structure that employed a repetitive pattern consisting of identical units replicated and assembled to form a cohesive whole. This approach leveraged the benefits of standardisation, such as ease of assembly, scalability, and efficiency.

AREFACT D.2.

PLIABLE CELLULAR UNITS

Although this approach to creating a cellular modular structure succeeded, the resulting structure appeared very rigid and lacked character. Therefore, the properties of honeycomb smocking were considered for integration. The joinery of the diagrid structure was examined to understand its assembly and connection.

Honeycomb smocking is known for its elastic character, allowing the fabric to be manipulated to accommodate diverse sizes. Incorporating this adjustable concept could significantly enhance the current artefact. While the diagrid is known for its stable structure and rigid properties, its diagonal framings visually soften the harshness typically associated with vertical and horizontal structures. This raised the question: What happens when a stable structure becomes pliable?

Analysing the structural element of honeycomb smocking revealed that the process of expansion and contraction creates the diamond pattern. Translating this into the X cellular units of Artefact D.1, the X structural units needed to be pleated, which required folding. The joinery techniques used to create flexibility were investigated. Maintaining the industrial touch of the diagrid was seen as essential, as the reliable hardware mechanisms used to assemble these stable structures provided a sense of safety. A straightforward search for common hardware mechanisms that facilitate folding revealed that hinges, commonly used in doors, lids, and other objects requiring rotation, were a suitable solution [Door Controls Direct, 2023].

Hinges allow for rotational movement, which is essential for creating foldable structures. Integrating hinges into the X units could achieve the pleating effect while maintaining the industrial aesthetic and functional reliability of the diagrid and honeycomb smocking. Hinges provided flexibility and stability, ensuring the structure could expand and contract without compromising its integrity.

Applying this finding to the X structural units, the hinge was identified as the component that would act as pleating in the modular structure [Figure 82]. Theoretically, the nodes in a diagrid structure connect and shape the structure. By sectioning the X frame vertically at the intersection and using a common butt hinge mechanism [Figure 83] to reconnect the sectioned pieces, the modular units could fold in and out. Once more units were assembled, they could be expanded and contracted vertically like honeycomb smocking, allowing for customisation.

Figure 82: Artefact D.2 – Pliable cellular units

Figure 83: Artefact D.2 – Hinge joinery mechanism

PHASE D – ANALYSIS

The investigation into diagrid joinery techniques provided a foundation for achieving flexibility within a stable structure. By incorporating hinges, the X structural units achieved the desired pleating effect, maintaining both aesthetic and functional reliability. However, artefact D.2, refined from D.1's X frame, highlighted the need for a more reliable joinery system. The current hollow and solid slide-in connections proved loose and unreliable, underscoring the necessity for a more precise joinery system to ensure secure assembly and structural integrity.

4.6. PHASE E

PROTOTYPING

AREFACT E.1.

PROTOTYPE JOINERY

The assembly process of the diagrid structure in the Swiss Re Tower emphasised custom-designed diagrid structures that were welded and bolted in place [Boake, 2016]. Hence, a question arose in relation to my project: What if the units snapped into place? The joinery technique of a snap-fit joint was used to interlock and secure the units.

Due to the limits and constraints of hand-made models, 3D software was utilised to conceptualise a prototype of the structural X units. The software was used to design a built-in hinge system on the body of the X units [Figure 84]. The hinge was designed to rotate 360 degrees, developing the joinery into a snap-fit joint [Figure 86]. The 3D model was then 3D printed to test the prototype's functionality, ensuring that the hinge rotated, and the units could snap into place.

ANALYSIS

The current snap-fit joint allowed for the easy detachment of components by unauthorised individuals, posing significant safety and security concerns. Therefore, improving the joinery was essential to ensure secure assembly, enhance structural integrity, and mitigate safety risks associated with unauthorised disassembly.

The 3D artefact consisted of a hollow body; two sections connected by a bolt replicating the butt hinge (Figure 85). The built-in hinge had difficulty rotating as the intersection of the X unit was too bulky for the unit to fold into itself. Additionally, the snap-fit joint was deemed effective in locking units in place.

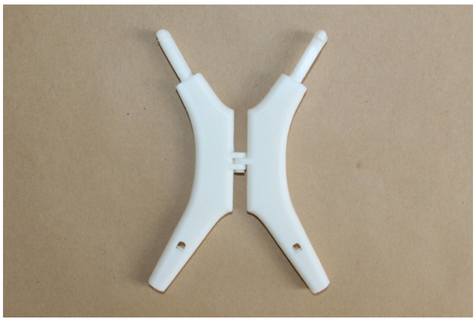

Figure 84: Artefact E.1 – Prototype of the hinge joinery

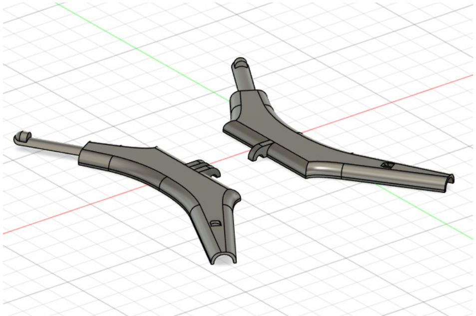

Figure 85: Artefact E.1 – BIM model for 3D printing

Figure 86: Artefact E.1 – Cellular assembling of the units

AREFACT E.2.

PROTOTYPE JOINERY 2

The beauty of diagrid joinery lies in the transparency of its openly displayed joint mechanisms [Boake, 2016]. Similarly, this concept was applied to the assembly of the X units.

Diagrid structures use bolted connections [Boake, 2016] to join the modular members. Employing the same joinery technique, this artefact used bolted connections to connect the cellular units [Figure 87]. It utilised a bolt that runs through both units, locking them in with a nut and finishing off with a nut cap to cover the sharp edges [Figure 88].

After testing the developed mechanism, it was found that this joinery worked better than the snap-fit joint. It locked both units in place with a sound fixture without the risk of disconnection.

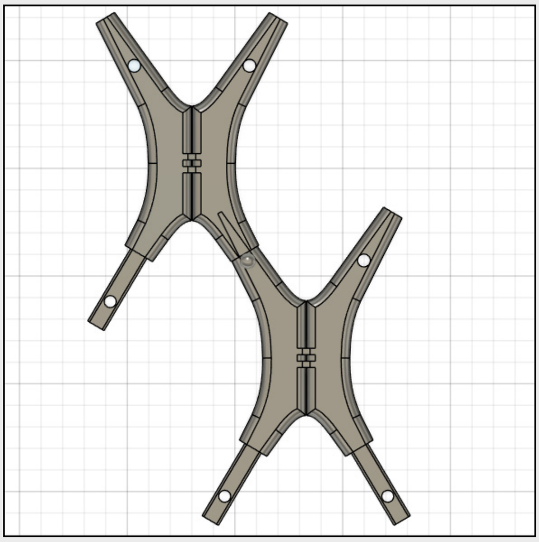

Figure 87: Artefact E.2 – Prototype joinery 2

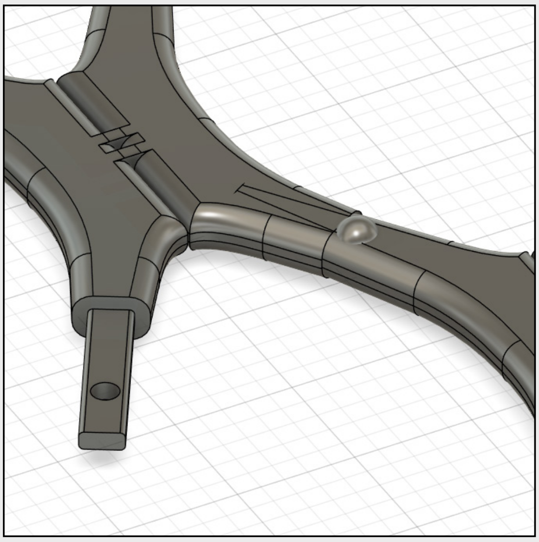

Figure 88: Artefact E.2 – Prototype joinery 2 mechanism

PHASE E – EVALUATION

This phase involved meticulous design and joinery adjustments, ensuring the cellular X units' structural integrity and stability. The snap-fit joint faced challenges due to the X unit's bulkiness, which impeded smooth rotation and raised safety concerns. Bolted connections were developed as a refined solution, providing secure fixtures and preventing disconnection.

Overall, the refined prototype, artefact E.1, successfully addressed the initial challenges. The secure assembly and enhanced structural integrity achieved through bolted connections met the objectives. Satisfaction with the results produced by artefact E.2 was evident, as it not only resolved the identified issues but also upheld the diagrid structure's aesthetic and functional aspirations. The next question to address is how this approach can be scaled up for larger, buildable projects, ensuring the same level of structural integrity and aesthetic appeal.

MATERIALISING THE STRUCTURAL FRAMEWORK

Considering how this modular X could be implemented at a larger scale to function in the built environment, the approach applied to diagrids made of steel (Boake, 2014) could also be used to mould the X members. However, due to the nature of steel, it holds a significant amount of weight. As additional X units are built upon each other, they will eventually outweigh the structure, necessitating additional support structures to hold everything in place.

Reflecting on Floc's joinery systems, they used clip systems that appeared to be made of plastic [Figure 89]. The exact material used to manufacture the clips was not identified, but plastic is generally much lighter and comes in various options.

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Figure 89: Floc clip material

Generally, plastic is not considered the best option for sustainability [Arikan & Ozsoy, 2015]. Can plastic be sustainable? An investigation by Arikan and Ozsoy analysed sustainable plastic production using only renewable biomass sources such as corn, soy, potatoes, and sugars [Arikan & Ozsoy, 2015]. Biodegradable bioplastics are entirely decomposed by microorganisms, leaving no detectable toxic residues. The term "biodegradable" pertains to materials that can naturally disintegrate into biogases and biomass when exposed to microbial environments and moisture, such as those found in soil, thereby mitigating plastic waste.

Bioplastics are particularly promising due to their effective utilisation by microorganisms [Arikan & Ozsoy, 2015]. Polylactic Acid (PLA) is a common bioplastic used in many products, including furniture and architecture [Pathak, 2019].

ARCHITECTURE:

Polylactic Acid (PLA) alone is not suitable for external use, but the composition of additional biomaterials can make it suitable for external use. For example, the Arboskin Pavilion, designed by the Institute of Building Structures and Structural Design in 2013 [Figure 90], used a mixture of PLA, PCL, PHA, Bio-PET, Starch, Bio-PE, Bio-PA, Natural resins, natural waxes, Lignin, Cellulose, natural reinforcing fibres, natural oils, natural fatty acids, and Organic additives to make it suitable for external use [Pathak, 2019].

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Figure 90: Arboskin Pavilion, Institute of Building Structures and Structural Design, 2013

PRODUCT DESIGN:

PLA is becoming a common material used in various areas; the first-ever chair made by injection moulding of PLA was designed by Iratzoki Lizaso in 2015 [Figure 91], and it uses PLA to make the chair [Pathak, 2019]. Additionally, due to its biodegradability and environmental benefits, PLA is the predominant material used in extrusion-based three-dimensional (3D) printing, specifically through fused deposition modelling (FDM). However, its application is constrained by certain drawbacks, including mechanical fragility and water solubility. Nonetheless, it has limitations, such as the mechanical weakness of FDM-produced parts relative to those manufactured through traditional injection and compression moulding methods [Tümer & Erbil, 2021].

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Figure 91: Kuskoa Chair, Iratzoki Lizaso, 2015

EVALUATION

By assessing the properties and compatibility of various materials, despite certain drawbacks, the advantages of using PLA, particularly its biodegradability and environmental benefits, make it a viable material for large-scale projects. Thus, with detailed planning, advanced manufacturing techniques, and sustainable material choices, it is possible to scale artefact E.2 to a larger buildable scale. This understanding highlighted the feasibility of producing the X units in quantities sufficient for practical and interior applications, fulfilling the built environment’s functional and aesthetic requirements.

4.7. PHASE F

DESIGN AESTHETICS

AREFACT | F.1.

VISUAL COMPONENTS

For artefact C.1, which involved binding wool around the structure, the challenge was to understand how this would function in a modular system. Just as the focus was placed on a node in the wired framework, the same composition was used to shape the wool layer. This resulted in a manually cut diamond sheet of wet felted wool [Figure 92]. However, the issue remained: how to attach this to the X units.

Both diagrid and honeycomb smocking rely on visual components [Boake, 2014; Wolff, 1996], and “designers also tend to work in a very visual way” [Lawson, 2005, p. 13]. While artefact C.1 was functional, its aesthetic tied the piece together. It was crucial not to obscure the structural element by covering it up, as seen in diagrid and honeycomb smocking characteristics exhibiting their structural workings. While, artefact B.4 required a straight stitch to hold the diamond forms in place. Similarly, the most recent artefact E.2 faced challenges in moulding the wool to the structure.

Figure 92: Artefact F.1 – X unit wedged between wet welted wool

AREFACT F.1.1.

[FIGURE 93]

The thread was hand-sewn snugly around the silhouette of the X unit, helping achieve the moulded form initially intended for artefact F.1. Visually, this added the character and element of textile techniques that were previously lacking. However, this approach constrained attempts to connect the modular pieces, as it was too snug and limited the space needed to locate the joint system for the bolt mechanism.

Figure 93: Artefact F.1.1

AREFACT F.1.2.

[FIGURE 94]

Nodes played a significant role in this design process, leading to sewing vertically and horizontally across the nodes of the X unit to lock the wool sheet in place. Due to the lack of sewn structuration, the fabric had too much freedom in movement.

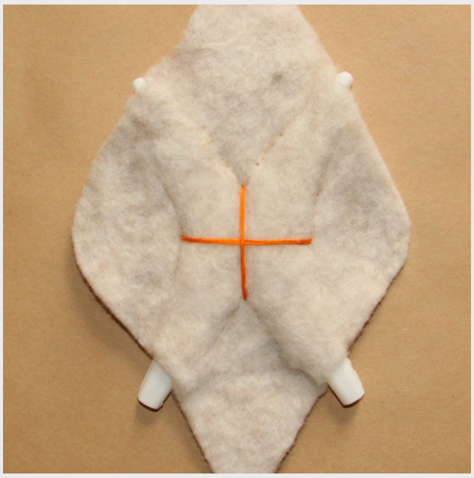


Figure 94: Artefact F.1.2

AREFACT F.1.3.

[FIGURE 95]

Combining both aspects from the above artefacts, the sewing technique used in artefact F.1.1 was applied. However, only to half the diameter around the node of the X unit, similar to artefact F.1.2. This approach added a visual element that fixed the wool sheet to the X frame and created movement within the structural unit. Consequently, as users moved around the space and air drafts interacted with the wool sheets, the X units were slightly exposed, enhancing the dynamic interaction between the installation and its environment. This method effectively demonstrated the potential for integrating structural and aesthetic elements to create engaging spatial experiences.

Figure 95: Artefact F.1.3

AREFACT F.1.4.

[FIGURE 96]

ARTEFACT F.1.4
[Figure 96]

Practically sewing on the felted wool felt constrictive and did not allow the freedom to customise the wool envelopes. Just as Floc uses its custom clips to attach its panels, this method employed clips that mimicked the visual elements of sewn thread, locking into place.

Figure 96: Artefact F.1.4 – BIM model of thread clip

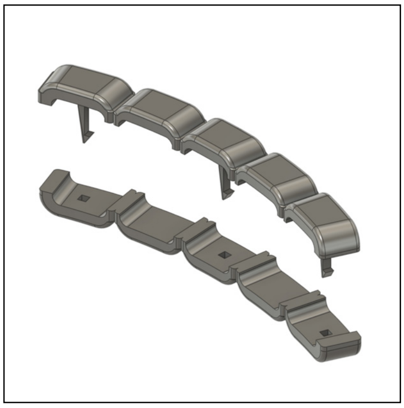


Figure 97: Artefact F.1.4 – BIM model of thread clip unconnected

The clip prototypes were designed using 3D software and made using PLA filament through 3D printing [Figure 97]. They were visually appealing and functionally satisfactory. This added element allowed consumers to customise the wool sheets and easily replace them after their lifecycle.

AREFACT F.2.

REFINING AND SCALING [FIGURE 98]

To test artefact F.1.3 at a realistic scale, it was necessary to see how it would perform at a 1:1 scale. The current artefact was at a scale of 1:100. Building it at a scale of 1:1 helped to understand the practical scale of the design. Due to cost and timeframe constraints, going through a manufacturer was not successful; hence, it was 3D printed. Unfortunately, 3D printing has its limitations in size; the bed only caters to 220mm in length, 220mm in width, and 280mm in height. Therefore, the X units had to be sectioned and assembled together. This approach faced constraints due to the segmentation but practically helped understand the scale. Despite these challenges, the results provided valuable insights into the feasibility and functionality of artefact F.1.3 at a larger scale.

Figure 98: Artefact F.2 1:1 scale

Additionally, a minor issue encountered with wet felting wool was the presence of loose fibres [Figure 99] as well as the labour-intensive nature of the process. Revisiting the machine felting process showed that it achieved a cohesive flat sheet [Figure 100] and was less time-consuming. Aesthetically, the machine-felted wool had a pleasing, professional finish, shortened manufacturing time, and did not require waiting for the felt to dry.

Figure 99: Wet felted wool sheet

Figure 100: Machine needle felted wool sheet

Overall, the artefact successfully integrated structural and aesthetic elements, creating engaging spatial experiences while addressing practical manufacturing concerns. The machine-felted wool offered a viable solution for producing professional-quality, structurally sound components.

4.8.

DESIGN PROCESS OUTCOME

The outcome resulted in a cellular configured structural product [Figure 101]. Its cellular and pliable properties made it a custom piece, adaptable to diverse surroundings and easily transportable. The pliable nature of the product allowed the structure to hold itself upright while the wool panels fluttered gracefully in response to movements in the environment, such as people walking by or a gentle breeze, adding a dynamic element to the design and visually elevating the space. Additionally, the product infused conscious materials that mitigated air quality issues in interior spaces and enhanced the living environment.

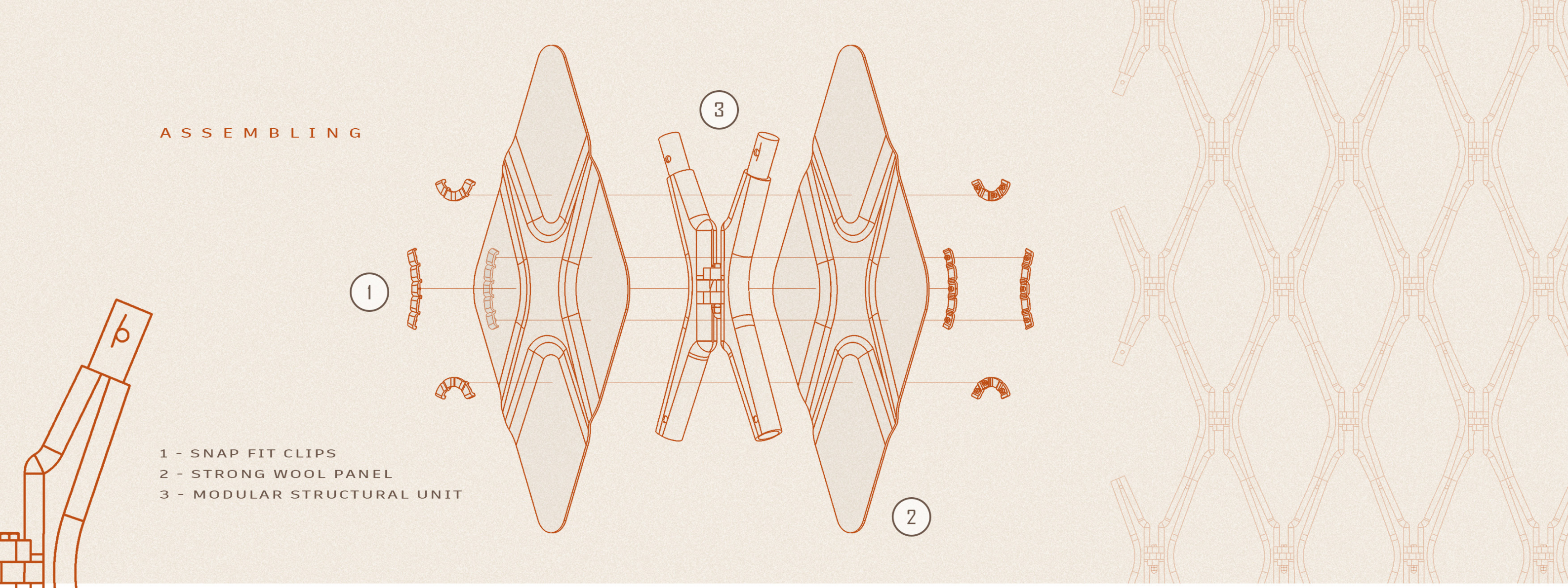
Additionally, it functions as a flat-pack item, designed to be easily disassembled and reassembled. This feature not only facilitates easy transportation but also allows the structure to be compactly stored when not in use. The product's aesthetic appeal and fluid, graceful movements further contributed to its innovative design and functionality, providing a harmonious blend of form, function, and environmental benefits.

RESEARCH CONSTRAINTS

- The intention was to experiment with strong wool; however, it was deemed too costly and more challenging to source. This limitation restricted the choice of materials to merino wool, for this prototyping which was more accessible.

- Manufacturing and Cost: Contacting manufacturers regarding the production of the product provided a rough estimate of around $3,000 for the injection moulding of the cellular X units. The estimated timeframe for manufacturing ranged from 2 to 3 months. Additionally, manufacturers did not accommodate one-off productions but rather offered wholesale options, as custom moulds needed to be created for the process. Due to time and cost constraints, a 1:1 installation model was not achieved.

ASSEMBLING



1 - SNAP FIT CLIPS
2 - STRONG WOOL PANEL
3 - MODULAR STRUCTURAL UNIT

Figure 101: Design outcome

05.

CONCLUSION

This research set out to answer whether the worlds of textile artistry and architectural innovation can be bridged through the integration of honeycomb smocking and the diagrid structure. Through a systematic investigation that included both theoretical inquiry and practical experimentation, this research has demonstrates that the fusion of these two domains not only is possible but also offers a number of benefits. Honeycomb smocking, with its flexibility and aesthetic appeal, when combined with the structural integrity and efficiency of diagrid structures, paves the way for new architectural solutions that are both functional and visually compelling.

The iterative, practice-based research approach adopted in this study has underscored the importance of a symbiotic relationship between textiles and architecture. It has shown that by challenging function-oriented design processes and embracing a more intuitive, experimental approach, a space was created where innovation could flourish.

The final outcome of this research resulted in a cellular-configured structural product. Its cellular and pliable properties make it a customiable piece that can caters to diverse surroundings and is easily transportable. Additionally, the product infuses conscious materials that mitigate air quality issues in interior spaces and enhance the living environment. In addition it has some inferent (although yet untested) acoustic properties. The aesthetic appeal and dynamic movements this creates further contribute to its innovative design, functionality and appeal, providing a harmonious blend of form, function, and environmental benefits. This product exemplifies how the integration of honeycomb smocking and diagrid structures can yield practical, aesthetically pleasing, and environmentally conscious solutions in the realm of architectural design.

Additionally, further studies could investigate the scalability of the proposed solutions, additional acoustic and moisture-regulating properties and their adaptability to different environmental and cultural contexts. By synthesising the tactile intimacy of textiles with the scale of architectural constructs, this research contributes to a novel approach to design. It invites architects and designers to reconsider the materials and methodologies they employ, encouraging a more integrated and innovative perspective on building design. Ultimately, this thesis not only bridges the gap between textile artistry and architectural innovation but also opens up new avenues for creative and functional design solutions in the built environment.

5.1.

FUTURE DIRECTIONS

The findings of this research have not only demonstrated the potential for textiles and architecture to enrich one another but have also set the groundwork for future explorations in this interdisciplinary field. Future directions of this research could include:

AREFACT 4.1.1.

HIGH-TRAFFIC INTERIOR SPACES

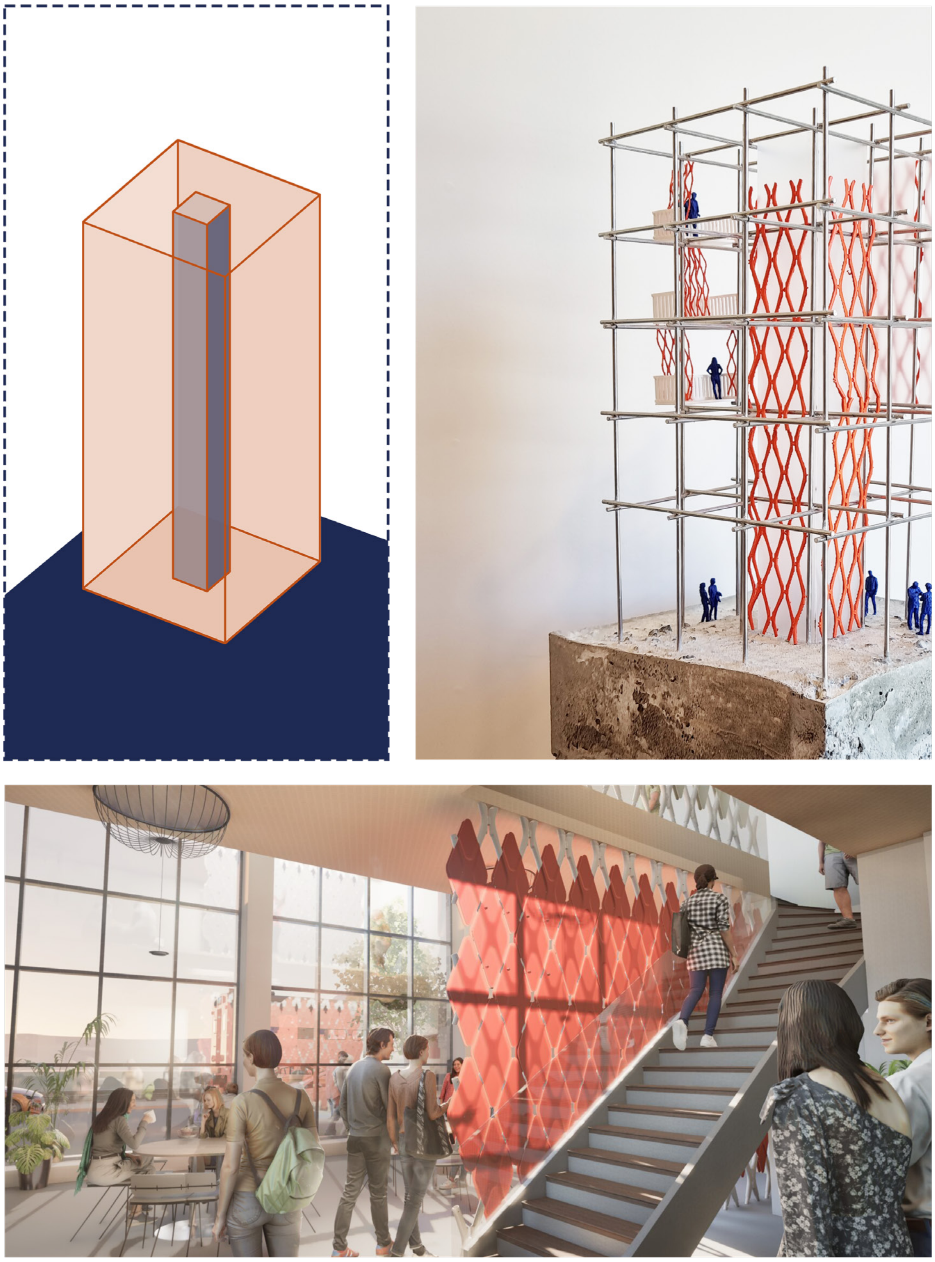


Figure 102 : Artefact 4.1.1 – High-Traffic interior spaces

Areas such as stairways and shafts, typically located in the centre of buildings, often lack ventilation and are visually neglected. Installing cellular units in these spaces could filter the air and elevate the aesthetics. Further exploration into mechanisms to stabilise the product on a larger scale and offering customisable colour options would enhance its applicability.

AREFACT

4.1.2.

FAÇADE SYSTEM

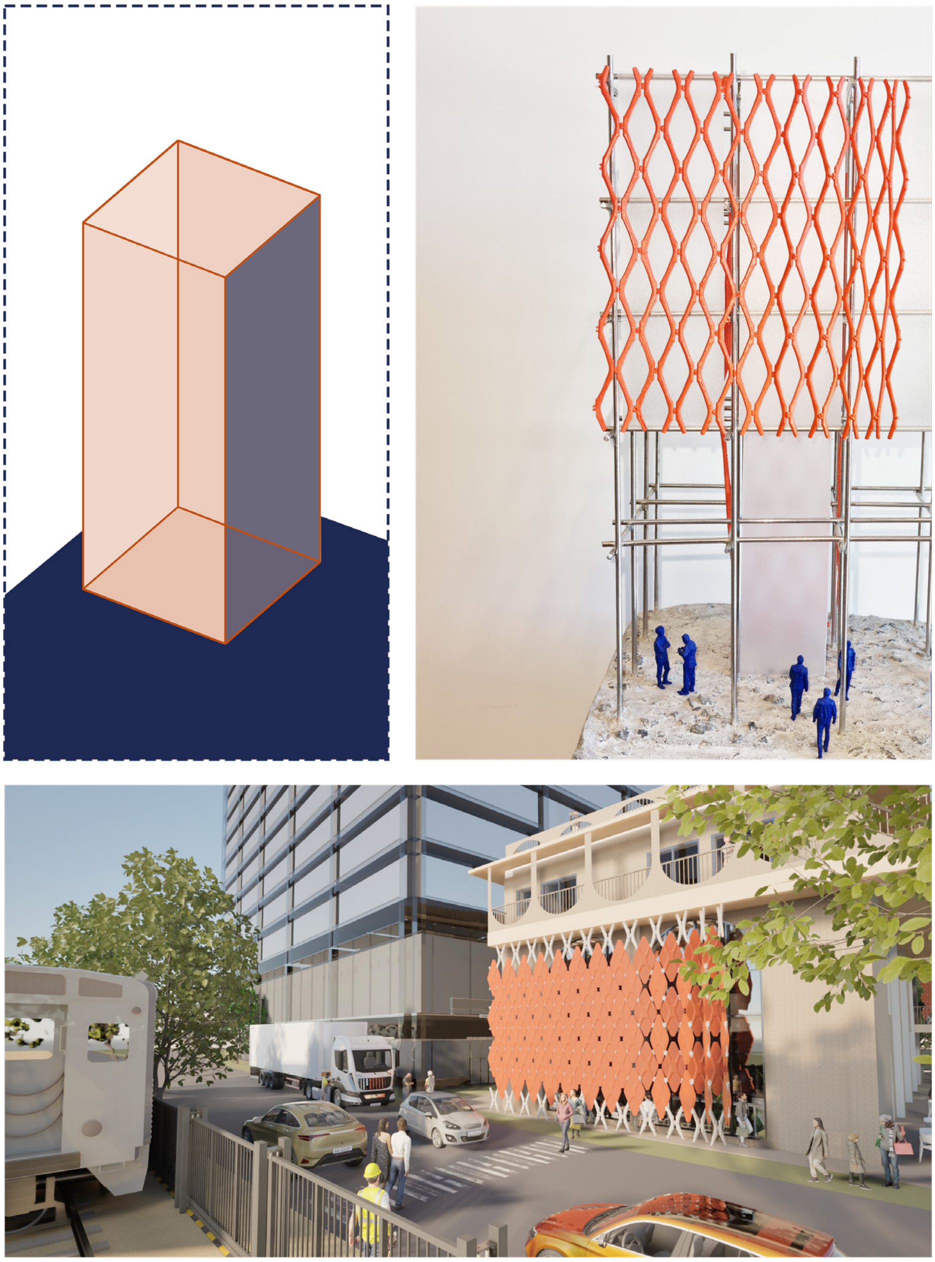
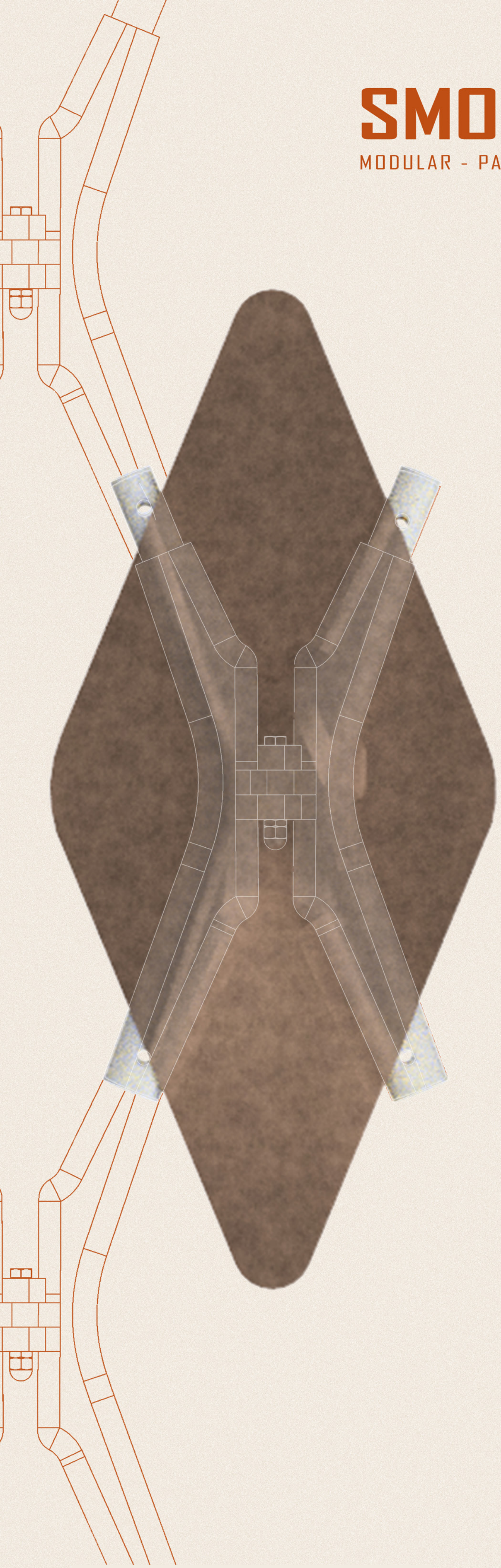


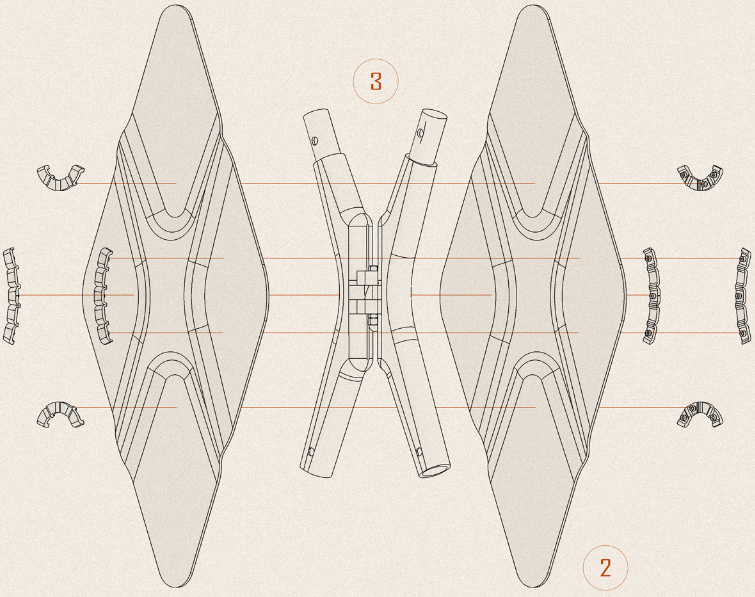
Figure 103: Artefact 4.1.2 – Façade system

The outcome demonstrates significant potential for use in façade systems. In environments surrounded by high foot traffic and vehicle emissions, cellular units can mitigate air pollution, creating healthier spaces for users and the environment.

SMOCK-GRID

MODULAR - PARTITION / FACADE SYSTEM





1. SNAP CLIPS
2. STRONG WOOL PANEL
3. MODULAR STRUCTURAL UNIT

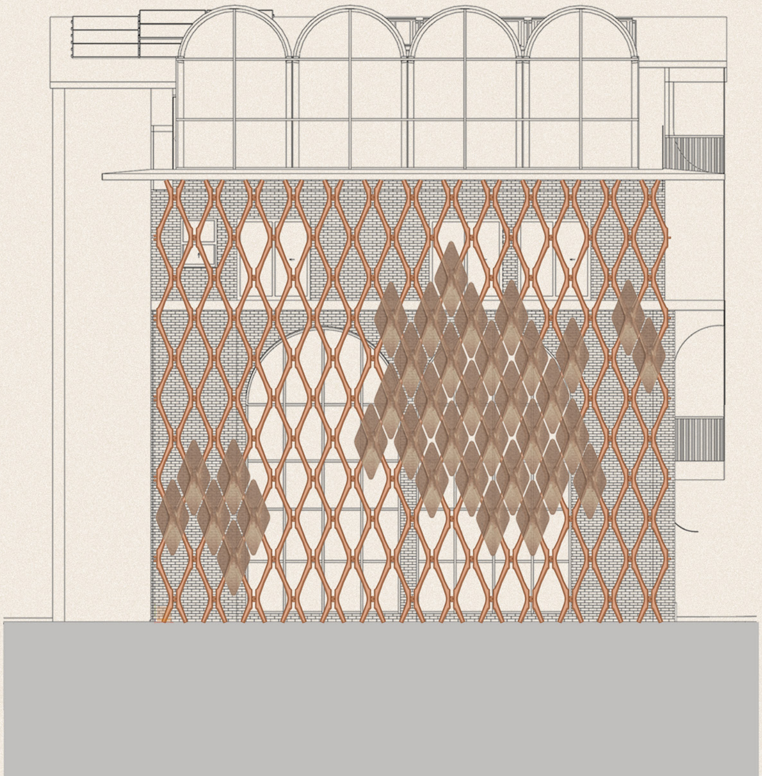


Figure 104: Facade System Product Design

AREFACT 4.1.3.

BALCONIES

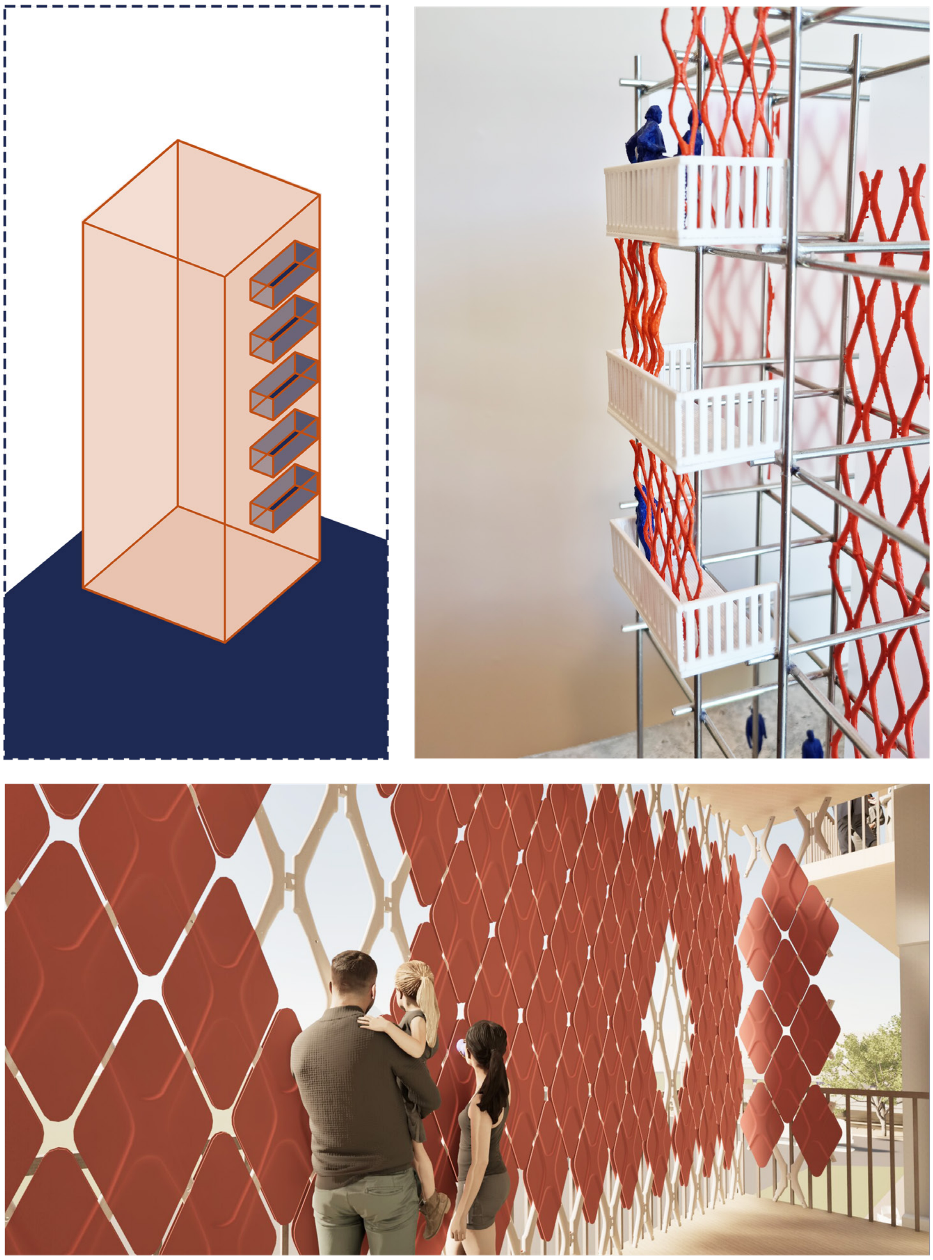


Figure 105: Artefact 4.1.3 – Balconies

With the increasing demand for housing and the growth of high-rise apartment complexes in compact cities, air quality often suffers from carbon emissions. Cellular units could be used to filter polluted air, improving living conditions for residents, and providing greater privacy.

These future directions highlight the versatility and adaptability of cellular units across different applications. Further research is required to refine these concepts and develop practical solutions, ensuring that these innovative products can be effectively integrated into various environments.

LIST OF FIGURES

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Figure 10: Figure 3. Fundamental diagrid geometrical features: (a) diagrid module. . . (n.d.). ResearchGate. https://www.researchgate.net/figure/Fundamental-diagrid-geometrical-features-a-diagrid-module-and-basic-triangular_fig10_342040305

Figure 11: (n.d.). https://blog.naver.com/k_bg/80066669750

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Figure 15: The Living Knitwork Pavilion instillation, MIT, 2023 Living Knitwork Pavilion – MIT Media Lab. (n.d.-b). MIT Media Lab; Irmandy Wicaksono. https://www.media.mit.edu/projects/living-knitwork/overview/

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Figure 20: Lawson, B. (2005).WhatDesigners Think: Thedesign process demystified. United Kingdom: Taylor & Francis. (Adapted by Shiraz, S., 2024).

Figure 21: National Conference on Structural Engineering and Construction ManagementKerala, India, Dasgupta, K., Sajith, A. S., Kartha, G. U., Joseph, A., Kavitha, P. E., &Praseeda, K. I. (2020). Proceedings of SECON'19: Structural Engineering and Construction Management /Kaustubh Dasgupta, A. S. Sajith, G. Unni Kartha, Asha Joseph, P. E. Kavitha, K.I. Praseeda, editors. Springer.

Figure 22: National Conference on Structural Engineering and Construction ManagementKerala, India, Dasgupta, K., Sajith, A. S., Kartha, G. U., Joseph, A., Kavitha, P. E., &Praseeda, K. I. (2020). Proceedings of SECON'19: Structural Engineering and Construction Management /Kaustubh Dasgupta, A. S. Sajith, G. Unni Kartha, Asha Joseph, P. E. Kavitha, K.I. Praseeda, editors. Springer.

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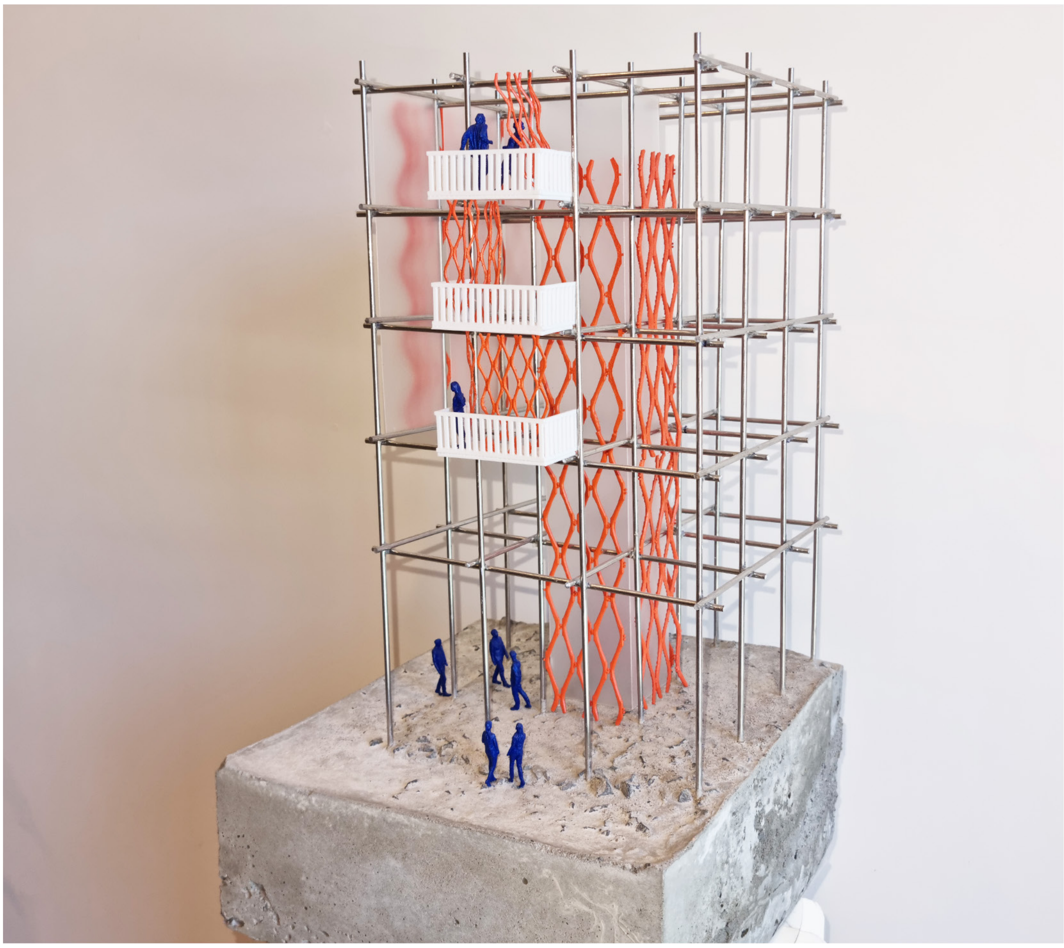
APPENDIX 1

DOCUMENTATION OF THE DESIGN OUTCOME



APPENDIX 2

DOCUMENTATION OF FINAL DISPLAY OF DESIGN WORK

Bridging the Gap between Textile Artistry and Architectural Innovation through the Integration of Honeycomb Smocking and the Diagrid Structure?