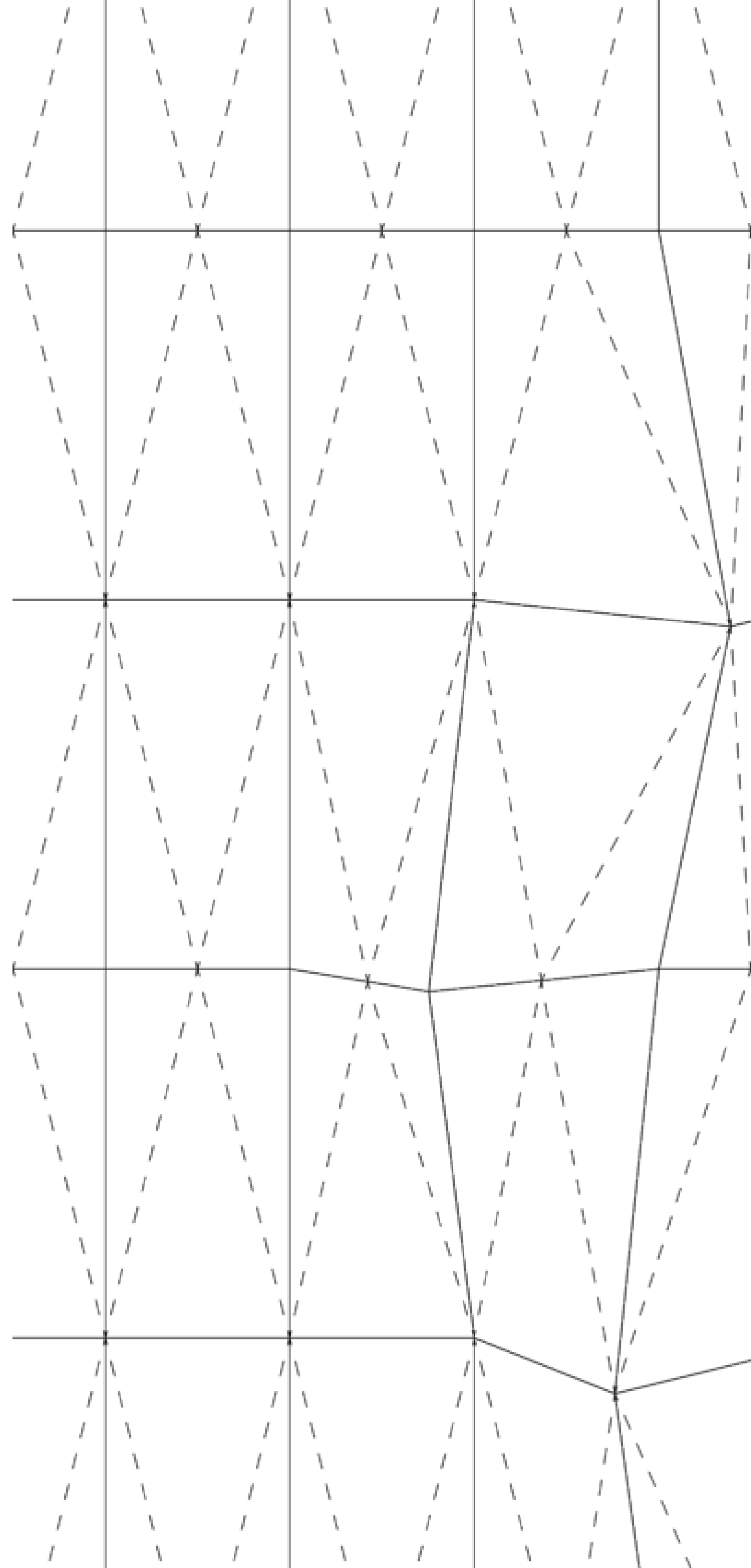
Vertical Folded Plate:
Simulated Architecture with
Mass Timber and Faceted Space

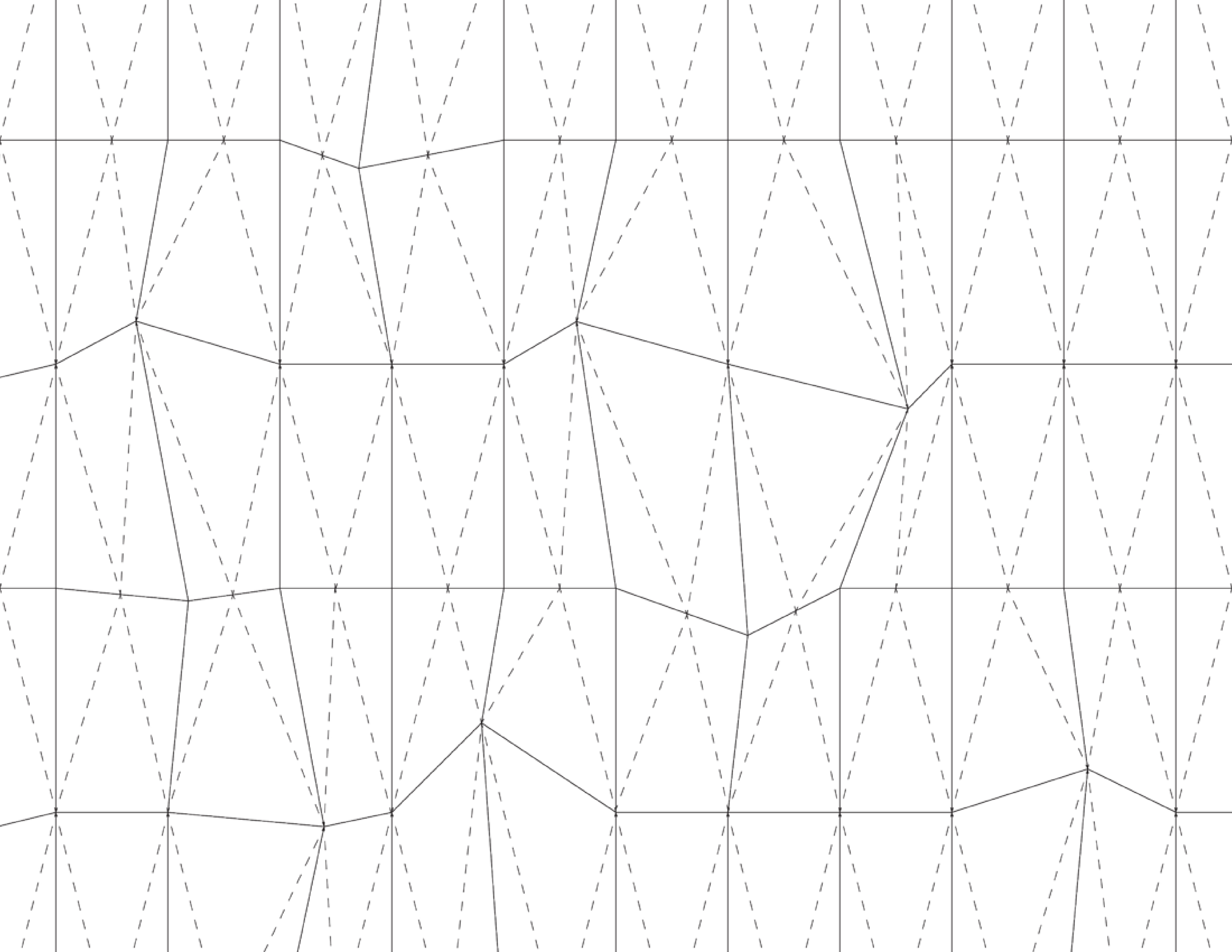
by

Nicholas Peruski

A thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Architecture
in The Lawrence Technological University
2022

Thesis Committee:
Scott Gerald Shall, Chair
Daniel L. Faoro, RA, M.Arch/UD
Aaron Jones, RA, M.Arch





Vertical Folded Plate: Simulated Architecture with Mass Timber and Faceted Space

Nicholas Peruski

1.1 ABSTRACT

Vertical Folded Plate is a historical and technological exploration of folded plate design pushed to its limits. Since 1950s folded plate design and modern mass timber innovation, the collision of these two disciplines reveals scarcely known social and ecological benefits that each would otherwise not reveal on their own. A new design approach to multi-story design can expand on the proven benefits of mass timber as a renewable material. To prototype the synthesis of a space created by folded mass timber plates, the vertical span of a series of humanly occupied, faceted spaces was structurally analyzed to test both precedent and exploratory forms in order to achieve spatially-inspiring spaces.

The study traces folded plate design from Sergio Musmeci's approaches in concrete architecture to Chris Robeller's synthesis of precision routed, integrated joinery. The modern combination calls for a modern visual analysis method. In this study, spaces created with folded plate were analyzed using structural finite element analysis (FEA) to visually represent how folded geometry supports both physical and social forces. Prototyped on a site as context for an architectural work, the approach serves as a catalyst for future innovation in material and form. A comparative study was performed on a non-timber-based structure and revealed sequestered carbon benefits, spatial impacts and structural methodologies. The design of a vertical folded plate-inspired space charts a new expectation for sustainability and tech-driven architecture.

2.1 INTRODUCTION

This thesis both archives and projects the benefits of a specific architectural tectonic as documented from the postwar era to modernity. Tracing the tectonic structural folding approach of Sergio Musmeci (1926-1981) in the design of concrete architecture in postwar Italy to modernity reveals the clarities of folded plate as a structural logic. Just as each era of history charts the materials, technology, innovations and human activity of its time in its built works, today's architecture holds no exception. Today's growing use of mass timber as a viable building material with already over a thousand projects across the States is the notable material innovation of the 21st Century. Currently having no singular comprehensive manual for mass timber as there is for steel or dimensional lumber members, there is similarly a scarcity of resources for a standard guide for folded plate design as there is for engineering design. Although there is a growing case for timber plates to be used for folded horizontal spans, there are rare precedents for mass timber folded plates in the vertical span such as engineered as a shear wall with integrated horizontal spanning members. The responsibility to try mass timber in a plurality of design options not only takes advantage of the material being sustainable through renewability but the structural efficiency and expression of folded forms. Thus, a modern take on a historical approach presents the clarities of mass timber-vertical folded plate as not only a structural logic but also a spatial and ethical one.

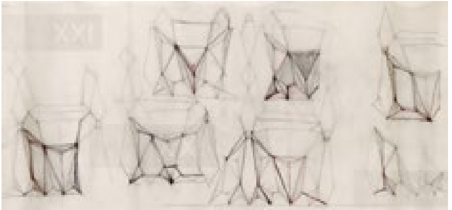


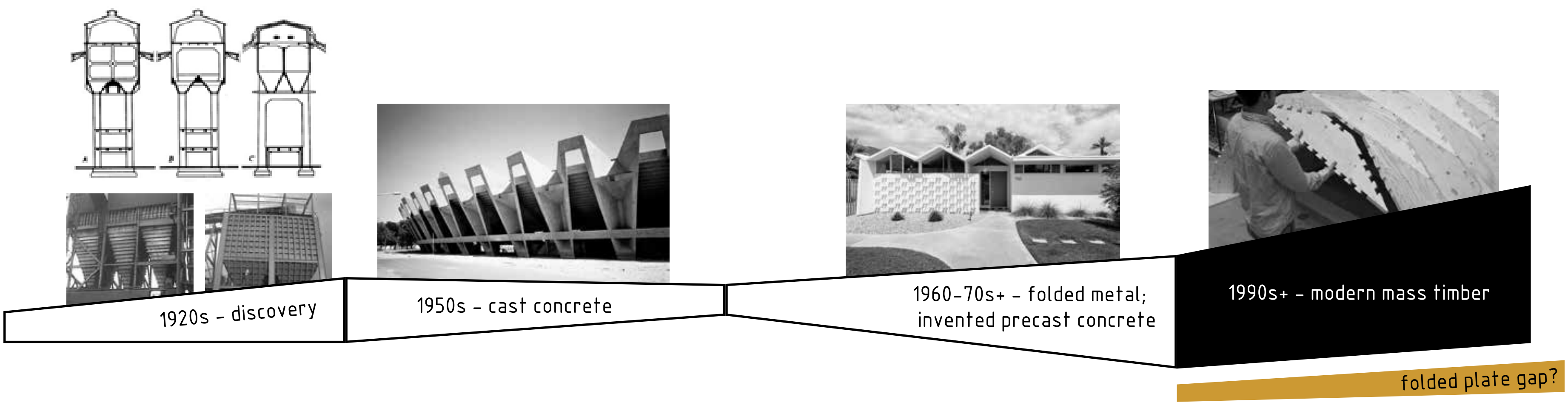
IMAGE 01: Stabilimento Raffo in Pietrasanta (1956), sketch of design variations of the roof plan by Musmeci. By changing the position of the nodes as well as the number and connectivity of the folded edges, the engineer investigates diverse geometric configurations, which imply different structural behaviors for the distribution of the forces within the roof. Source: Archivo MAXXI Musmeci e Zanini.

2.2 WHY FOLDED PLATE

Discovered in 1920s Germany, folded plate design originated from the realization that the funnel plates of coal bunkers were self-supporting structures when stripped from additional exterior framing. It was from then on that cast-in-place concrete became the material of choice to fully realize the potential of folded form as a structural system (Robeller [9]). Musmeci and other designers of the midcentury experimented with concrete and metal to create the folds and found that the system was one of integration.

> *Surface-active structure systems are simultaneously the envelope of the internal space and hull of the external Building and consequently determine form and space of the building. Thus, they are the actual substance of the building and criterion of its equality: as a rational-efficient machine, as an aesthetic-significant form. (Engel [4]).*

Folded plate is the best vehicle to perform studies of not only itself but rather of the additional complexity that a material brings to study such a form. In this thesis, mass timber is the material that has rarity in large-scale folded plate design. Designing with mass timber and folded plate means that the material benefits, which will later be described, are revealed simultaneously with a structural system that is altogether many discrete components of the building assembly.



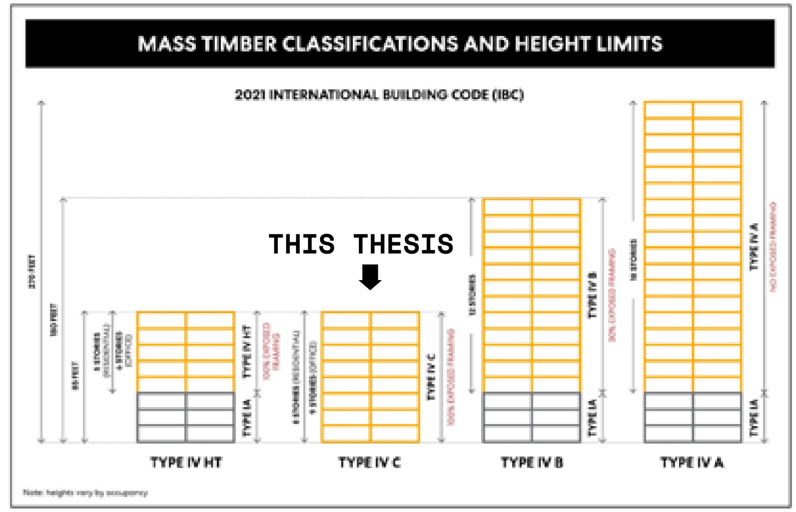
2.3 WHY MASS TIMBER

Mass timber is a relatively new construction material that is comparable to steel and concrete in terms of its strength and span abilities. The earliest known traces of mass timber can be rooted in various 1960s sawmill and lumber yards across North America that adhered layers of dimensional lumber pieces together to create a larger timber piece or product with a mass-ive cross section. Since the 90s, mass timber has been engineered, refined and studied as a material that can be compared on a sustainable measure to conrete or steel.

Sequestration of carbon (carbon in the atmosphere that is absorbed by trees into wood) is the fundamental measure of a sustainable product when paired with sustainable forestry and other ecology considerations. It also requires low embodied emissions to create timber since nature does the heavy lifting of the creation of the woody part of the tree. Dubbed as one of the greatest disruptors of the 21st Century, mass timber can go tall. This thesis uses cross laminated timber (CLT) to explore the folded form and its vertical (tall) potential.

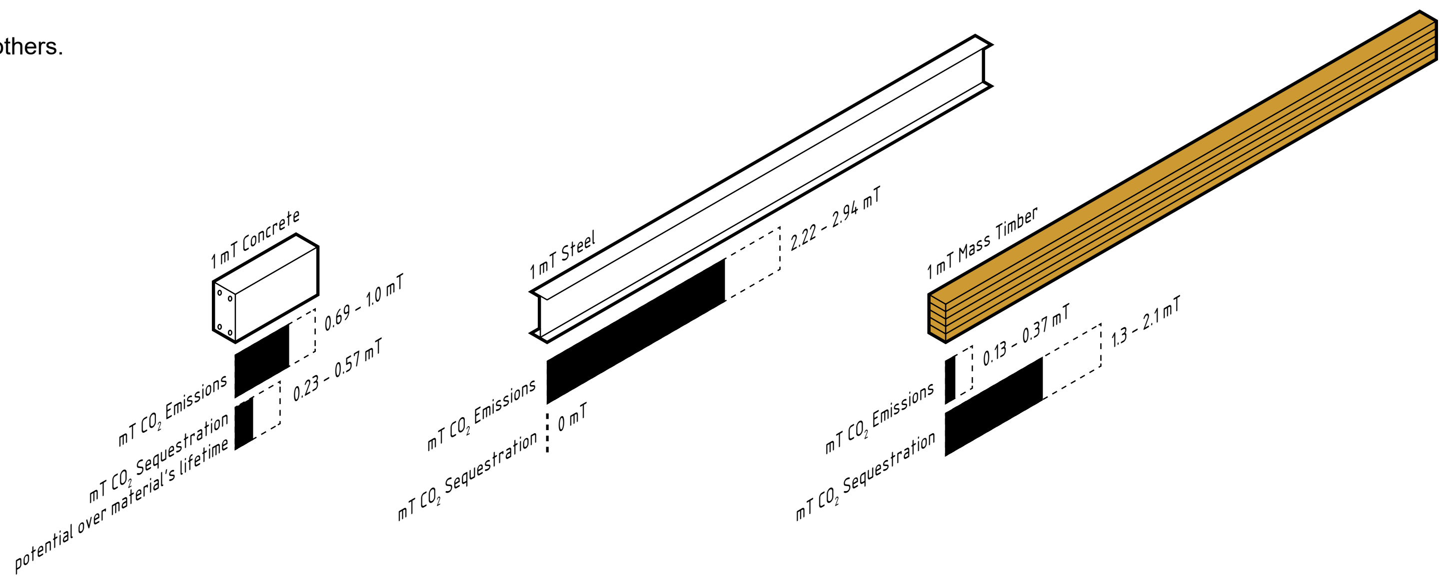
CLT is defined as a prefabricated engineered wood product consisting of not less than three layers of solid-sawn lumber or structural composite lumber where the adjacent layers are cross oriented and bonded with structural adhesive to form a solid wood element.

This “new” wood-based construction material is now included in Type IV construction for use in exterior walls. This thesis tests the verticality potential in the 2021 IBC definition of Type IV C.



Source: Perkins+Will, adapted from ICC

WoodWorks, Structurlam, Thinkwood and others.

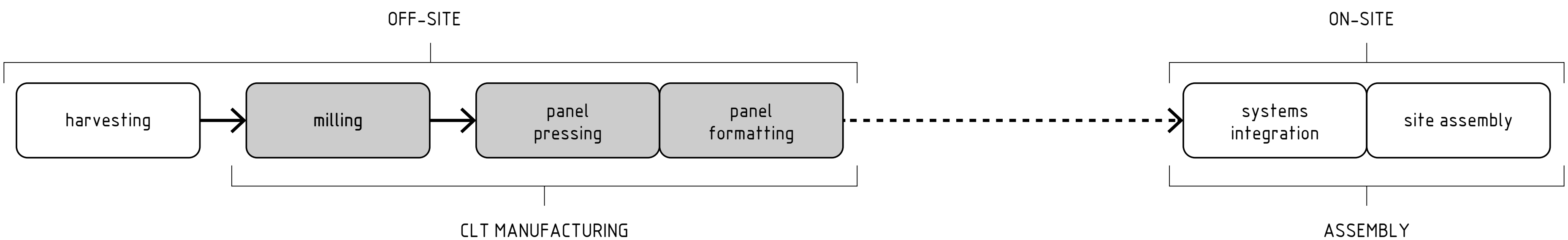


Source: Timber City Research Initiative, Gray Organschi Architecture, timbercity.org

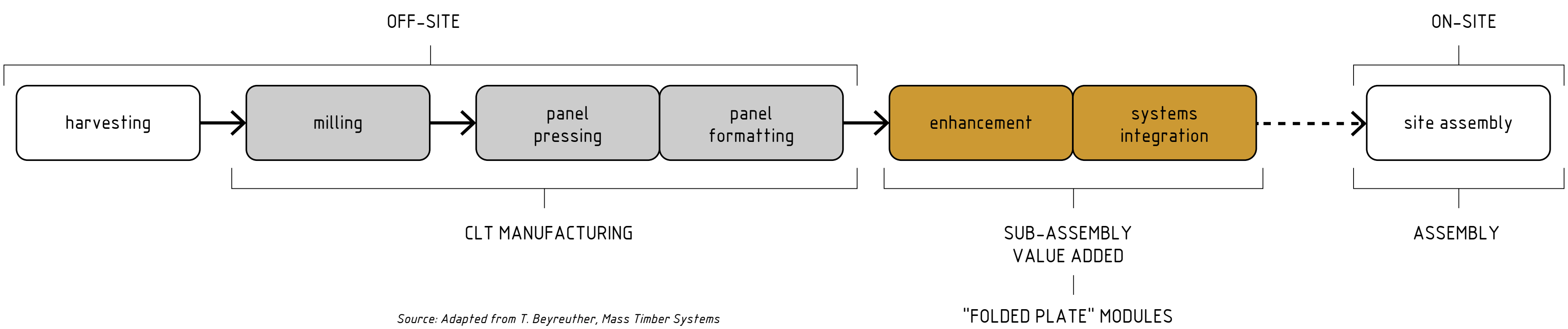
2.4 A NEW PRACTICE

The diagrams below compare how traditional mass timber products are manufactured and assembled versus how this thesis integrates mass timber as a systemed product. Mass timber folded plates can be designed as modules in the “sub-assembly” phase. This means that the integration of folded plate as an envelope and structural component as mentioned previously can also be enhanced with structural add-ons (e.g. post-tensioning) and system integration (e.g. HVAC, lighting).

MASS TIMBER PRODUCTS



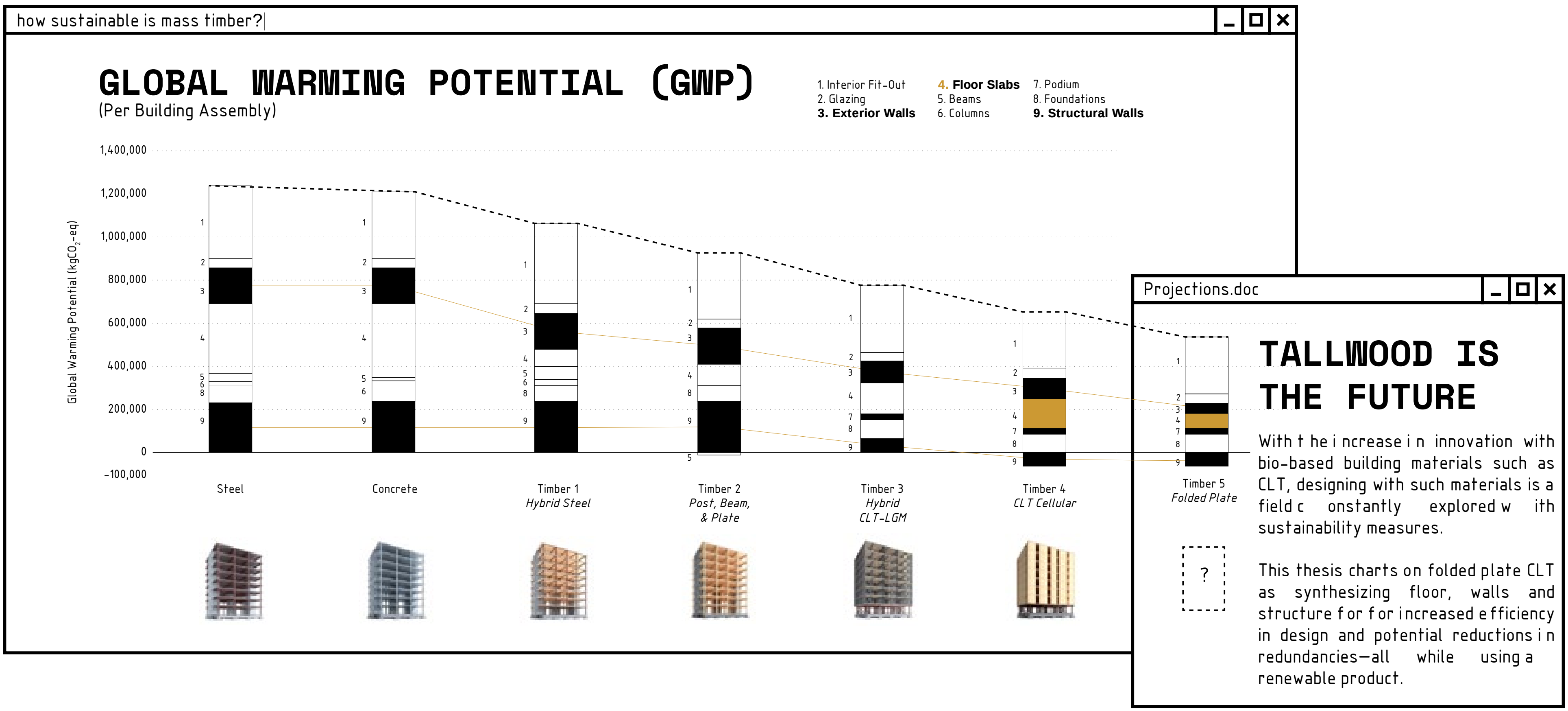
MASS TIMBER SYSTEMS



Source: Adapted from T. Beyreuther, Mass Timber Systems

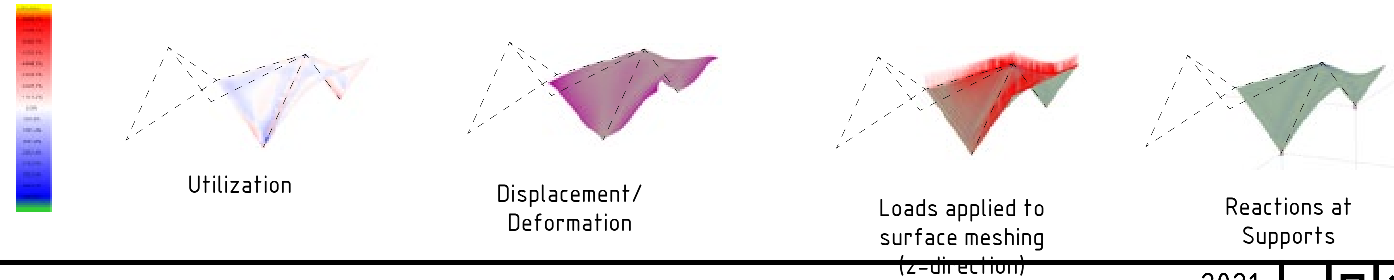
2.5 MEASURING INTEGRATION

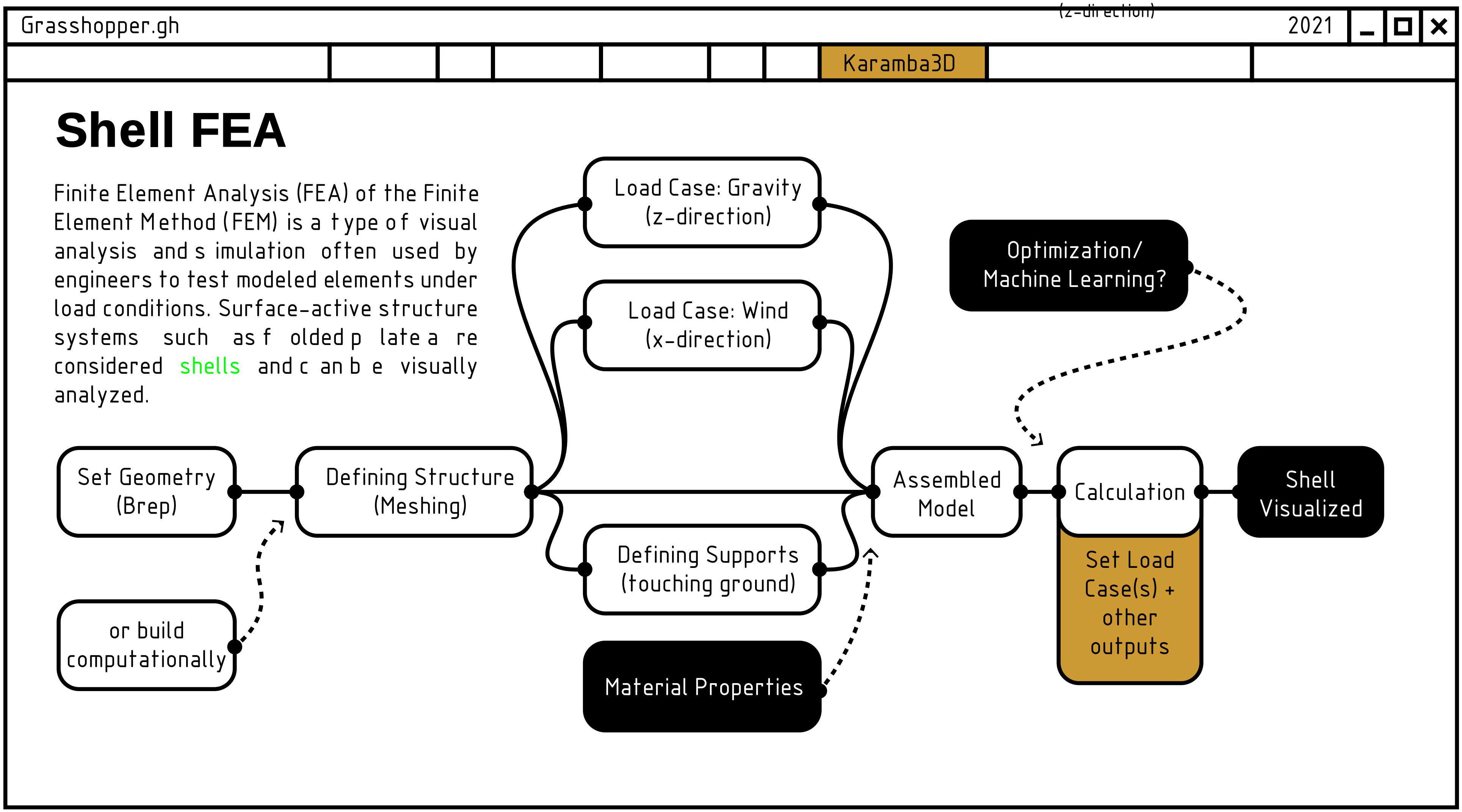
This graph illustrates the GWP broken down by building assembly. The Steel, Concrete and Hybrid Steel design options show a GWP burden for columns and beams due to their steel and concrete members. In the Post, Beam, & Plate option, columns and beams appear as a small negative which in this study equates to positive impact and lower net GWP. THe impact of timber is most evident in the CLT Cellular option, where the CLT of the structural walls also reduces the overall impact of the structural system. It is also evident that the timber options generally indicate savings in the exterior enclosure as their structural systems are also part of their enclosure systems.



2.6 MEASURING STRUCTURAL PERFORMANCE

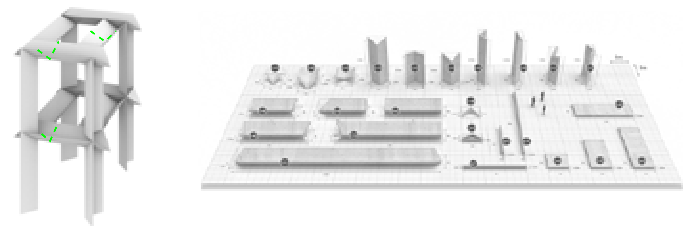
This thesis uses the knowledge of GWP to further economize the impact that structural folds (walls and floors) have on the overall performance of the shell (structure and envelope). Many tests were done on experimental folds to computationally visualize surface conditions across the surface of the plates.



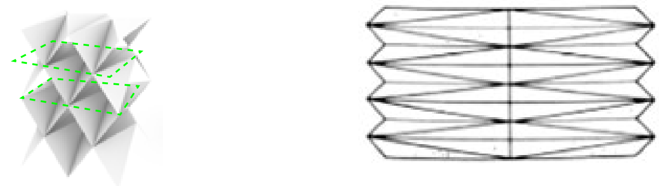


3.1 DESIGN INVESTIGATIONS - PROTOTYPES

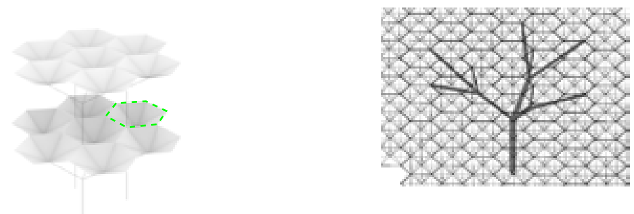
This thesis investigated 5 protoypes of folded geometry that could be constructed vertically. Each have their own approach to their efficiency and tectonic potential. The “hinged folds” prototype was selected to investigate for its greatest potential in long span and vertical span.



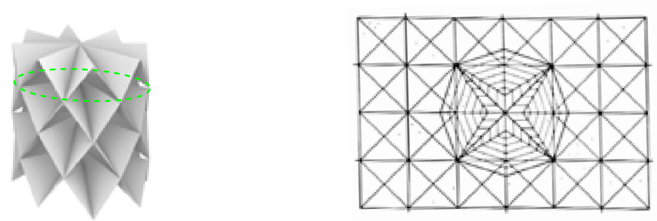
__01 kit-of-parts approach to sub-assemby



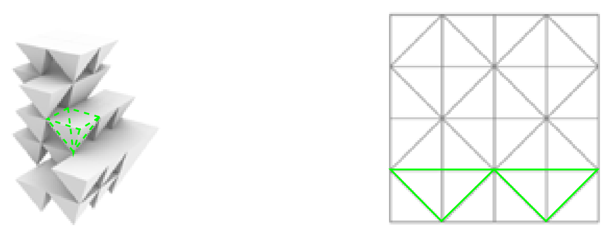
__02 hinged folds



__03 canopy on branches



__04 radial



__05 pyramidal

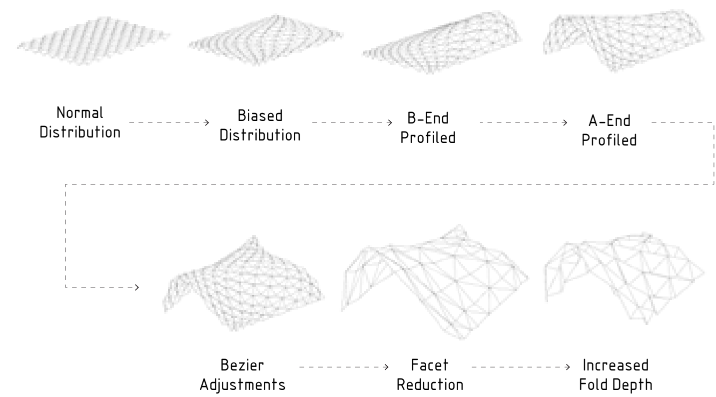
3.2 APPROACHES

The FEA process was tested on Approach B where the volume and mass of an umbrella form can be optimized for its structural and spatial potential.

/approach A

Fold Generation Methods

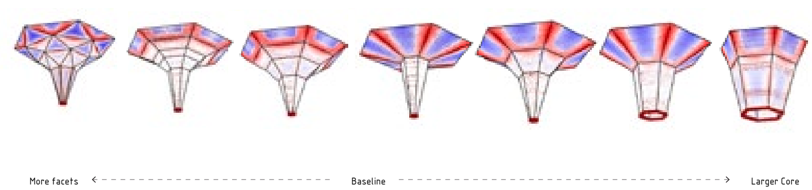
__A polygonal profile designs the general shape in section. The initial accordion folding follows this line and reverses at each inflexion point. All lines reflect on the external angle bisectors of the segments.
__A second profile designs the corrugation of the accordion folding. It defines amplitude and extension of the parallel folds.



/approach B

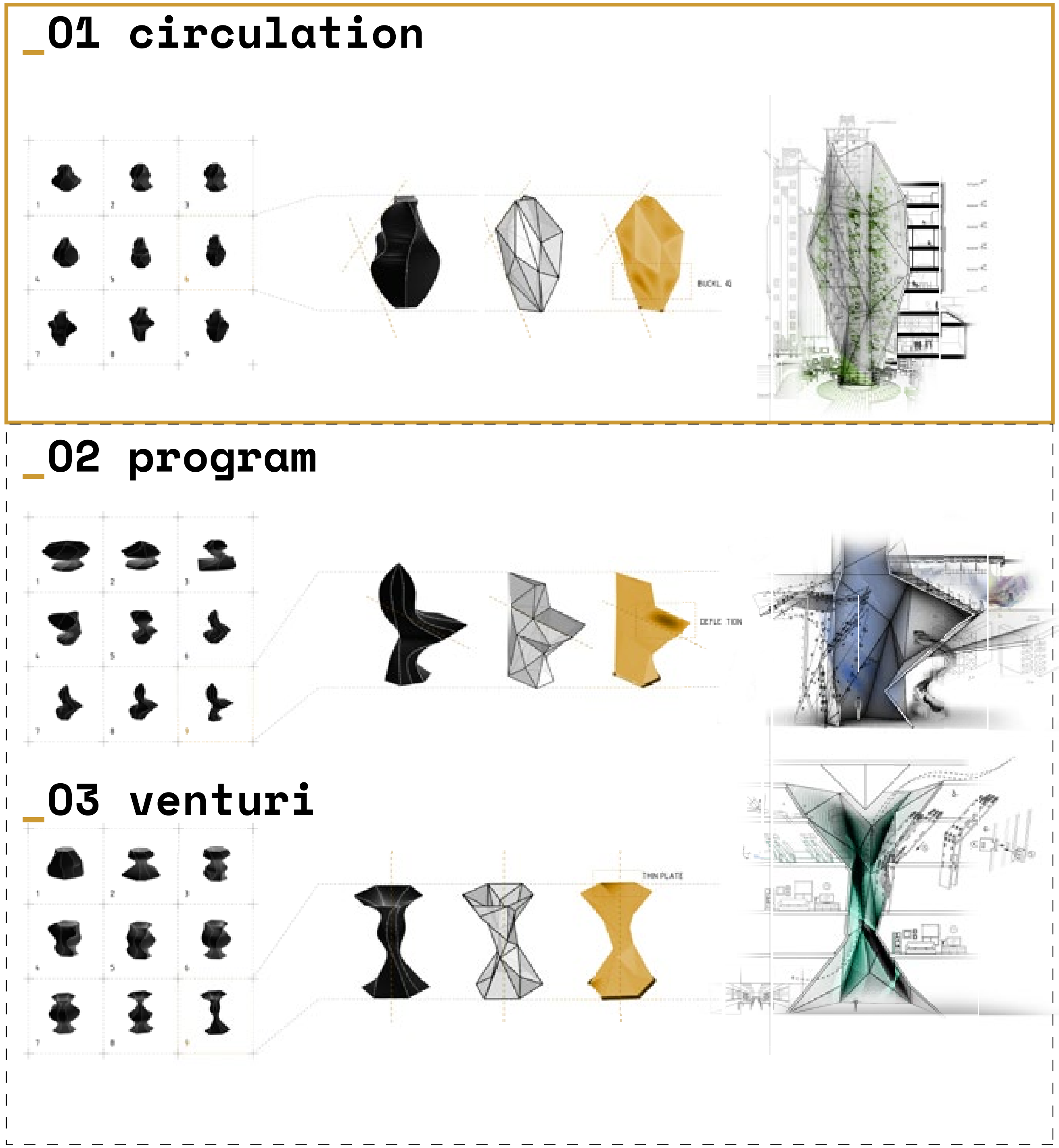
FEM Analysis of an Umbrella Column

__Finite Element Analysis (FEM) of a column is visualized under uniform vertical loads.
__Percent of ridge and surface strength are visualized.



3.3 TRIALS

Then, driven by human occupant needs, the inhabitable, folded space was tested under various formal trials to create spaces dictated by vertical circulation, program-defined parameters and passive concepts such as the venturi wind effect.



3.3 COMPARATIVE ANALYSIS

To test mass timber folded plate in action, a comparative study was done against a Detroit-located project constructed with conventional steel and concrete slab.

MIDTOWN - DETROIT

WOODWARD WEST
3439 Woodward Ave,
Detroit, MI 48201

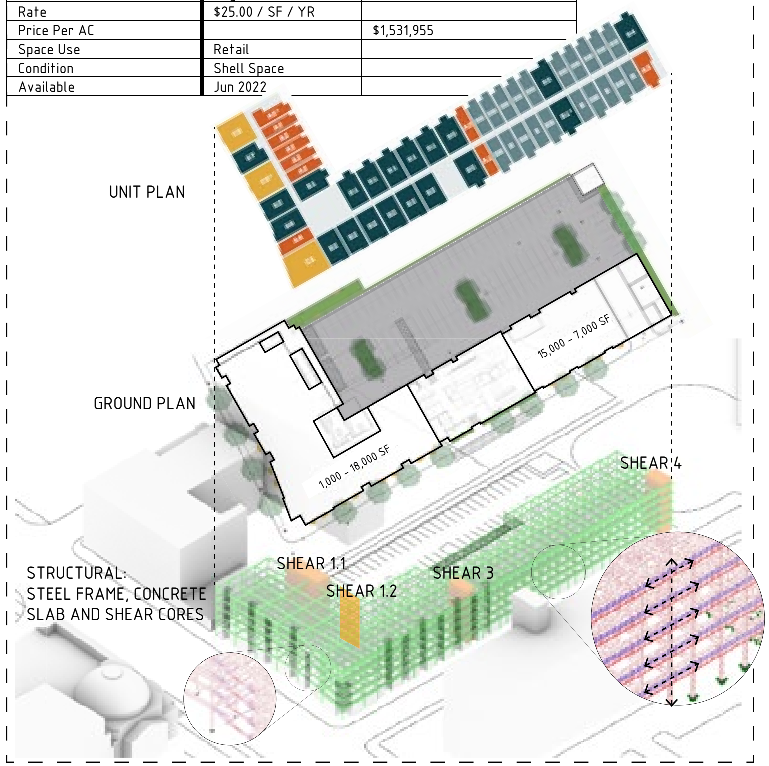
An in-construction 5-story mixed-use development with 200 units and a leasable ground floor

BASELINE_0

MID-RISE BASELINE

PROPERTY BASELINES FOR COMPARISON

PROPERTY FACTS	WOODWARD WEST	BRUSH PARK OPPORTUNITY
Rental Rate	$25.00 / SF / YR	
Price		$380,000
No. Units	204	
Min. Divisible	1,000 SF	
Property Type	Multifamily	Land
Property Subtype	Apartment	Commercial
Apartment Style	Mid Rise	
Building Size	188,000 SF	
Construction Status	Under Construction	Under Contract
Sale Type		Investment
No. Lots		1
Total Lot Size		0.25 AC
Opportunity Zone		Yes
AVAILABLE SPACE / LOT		
Space	1st Floor	
Size	1,000-25,000 SF	0.25 AC (approx. 10,805 SF)
Term	Negotiabe	
Rate	$25.00 / SF / YR	
Price Per AC		$1,531,955
Space Use	Retail	
Condition	Shell Space	
Available	Jun 2022	

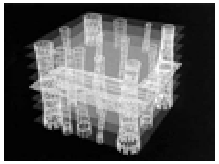


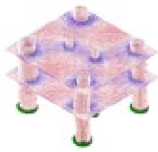
METHOD_1
_MAXIMIZE RENTABLE SPACE AND TIMBER SURFACE EXPERIENCE
_PRIMARY UNIT: AREA (sqft)

OCCUPANT-DRIVEN AREA

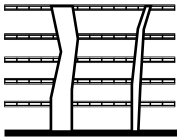
PLATES

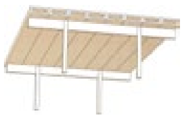
Sendai Mediatheque by Toyo Ito is a basis for occupant-driven floor area with vertical spaces that service all floors.

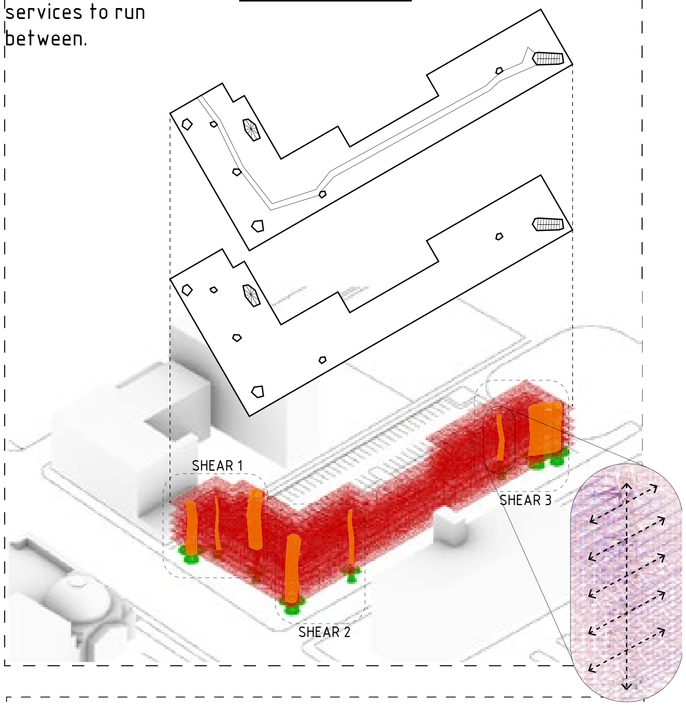




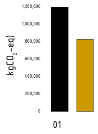
The cassette floor system is a hollow and lightweight system for 'normal' floor spans between spatial columns. It allows services to run between.







GWP



MAX.REVENUE/YR

$4.7M [0] **$5.6M** [2]

Spatial and higher commercial value due to timber material

LIVE LOAD REF.

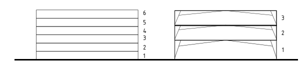
0.4 kip/ft2 (2 kN/m2)	0.4 kip/ft2 (2 kN/m2)
0	1

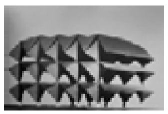
METHOD_2

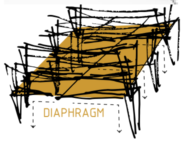
__MAXIMIZE RENEWABLE MATERIALS

__PRIMARY UNIT: GLOBAL WARMING POTENTIAL ($kgCO_2$-eq)

HORIZONTAL DIAPHRAGM

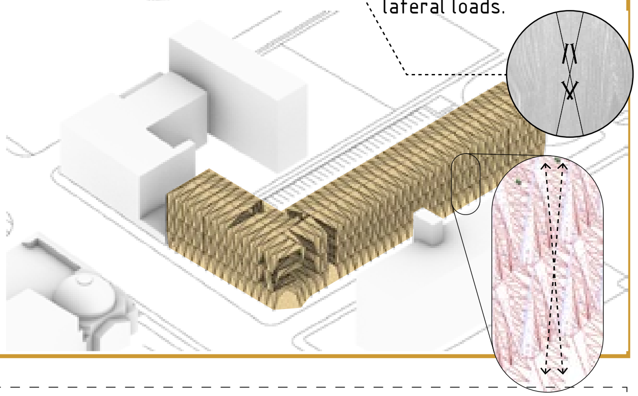


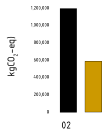




Although seemingly more open-plan compared to Method_1, the floor depth is much larger due to the deeper depth of the folds resulting in an overall building floor area to less to that of a building of similar height.

A diaphragm is a flat structural unit acting like a deep, thin beam. The term 'diaphragm" is usually applied to roofs and floors. A shear wall, however, is a vertical, cantilevered diaphragm. These construction systems can be used when designing a building for wind or seismic lateral loads.



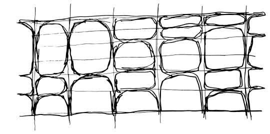
GWP	MAX.REVENUE/YR		LIVE LOAD REF.	
	$4.7M [0]	$2.8M [2]	0.4 kip/ft2 (2 kN/m2) [0]	0.1 kip/ft2 (5 kN/m2) [2]
	Approx. 50% reduction of floor space and with different building use			

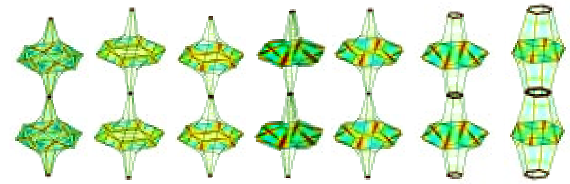
METHOD_3

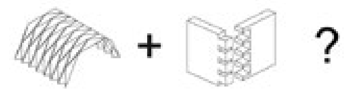
|_MAXIMIZE SPACE POTENTIAL
|_PRIMARY UNIT: NATURAL FORCES (kN)

SPATIAL ECCENTRICITY

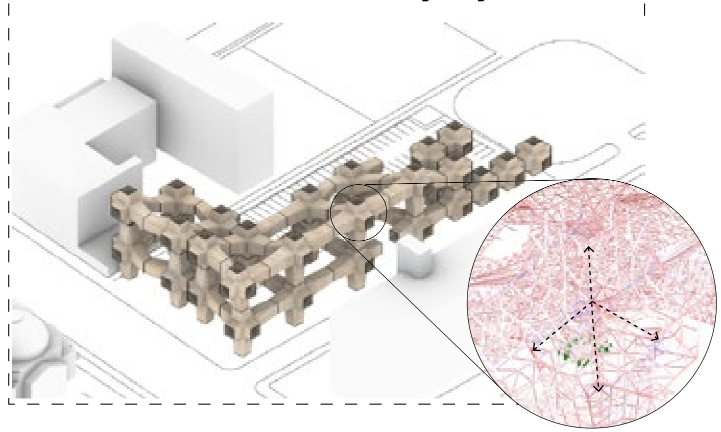
A doubly-inverted umbrella approach creates a unique typology of faceted space. A shell FEA analysis can be unitized/modular.



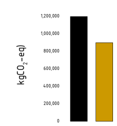




? ntegrated finger-joinery is best for this proposal because eccentric form and space can be simultaneously designed into the engineering of the joinery incl. number of fingers per edge length.



GWP



MAX.REVENUE/YR

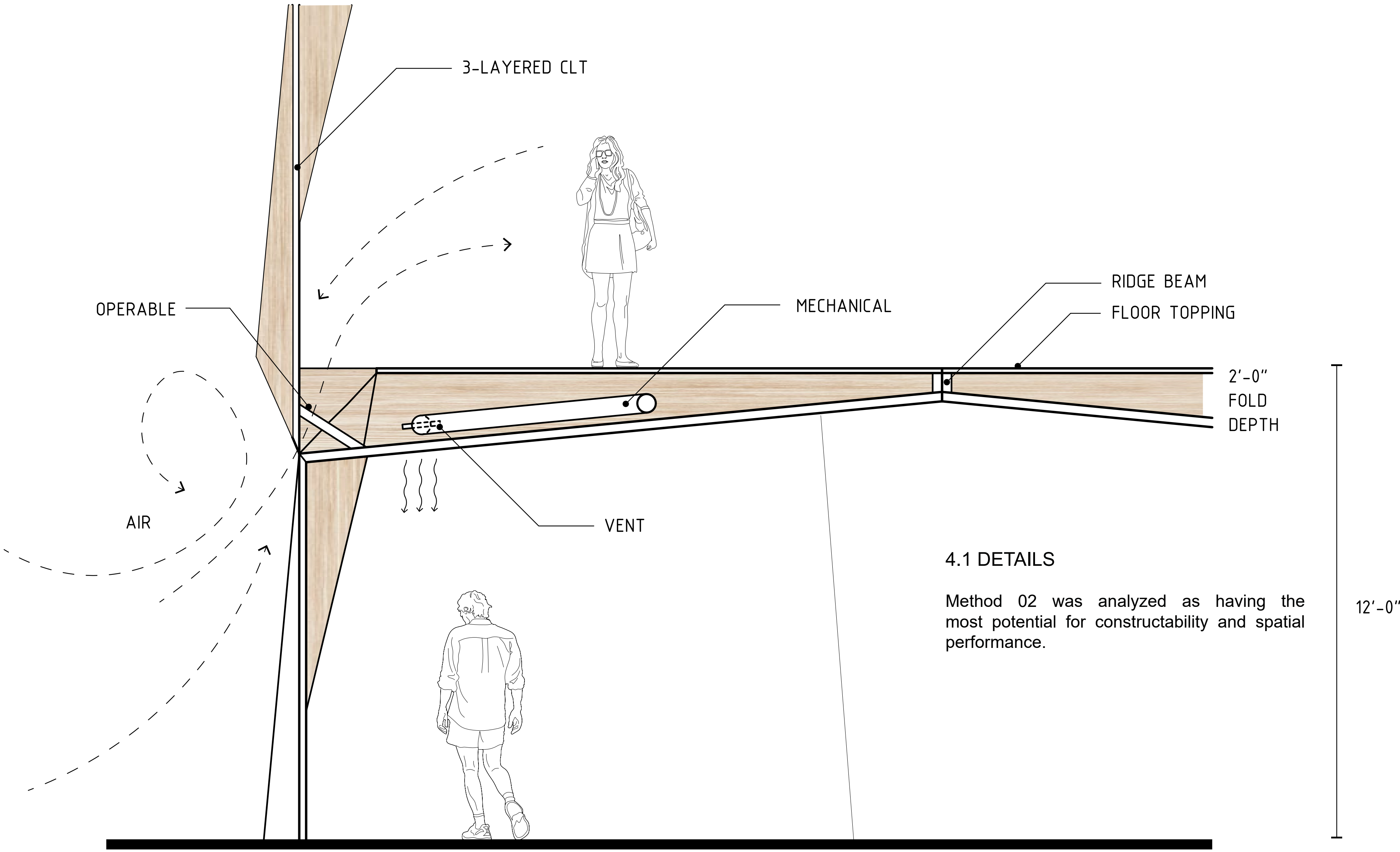
$4.7M 0 **$3.5M** 3

Specialized/ecclectic units

LIVE LOAD REF.

0.4 kip/ft2 (2 kN/m2) 0

0.6 kip/ft2 (3 kN/m2) 3



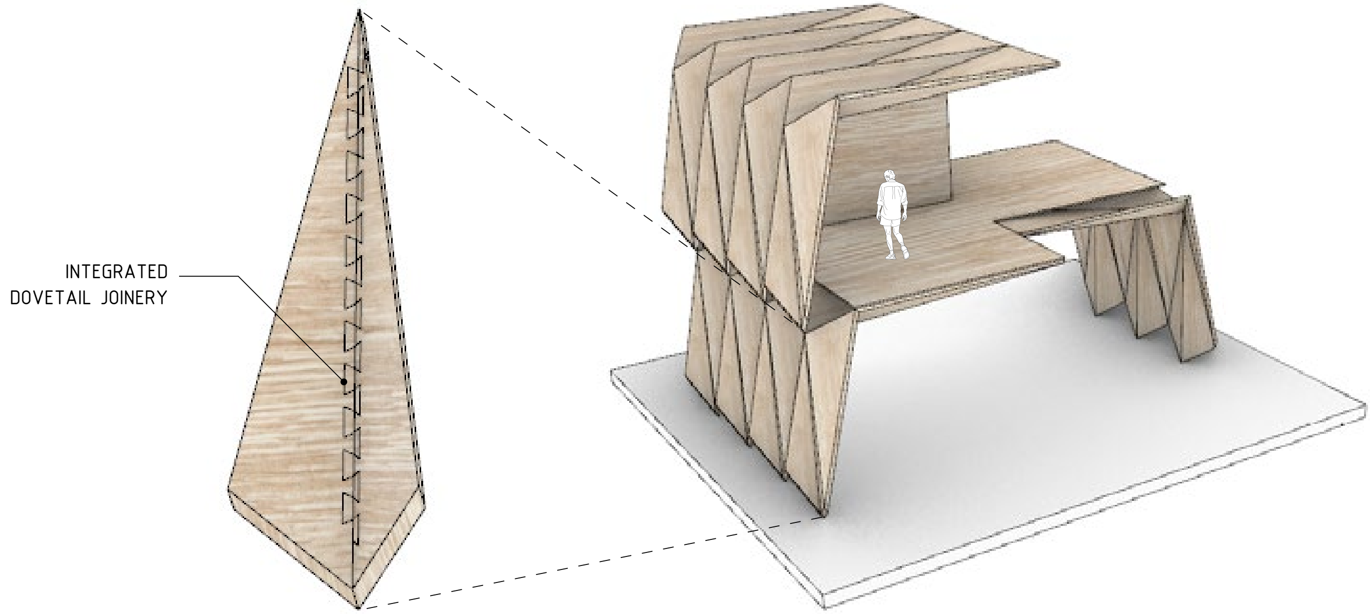
4.1 DETAILS

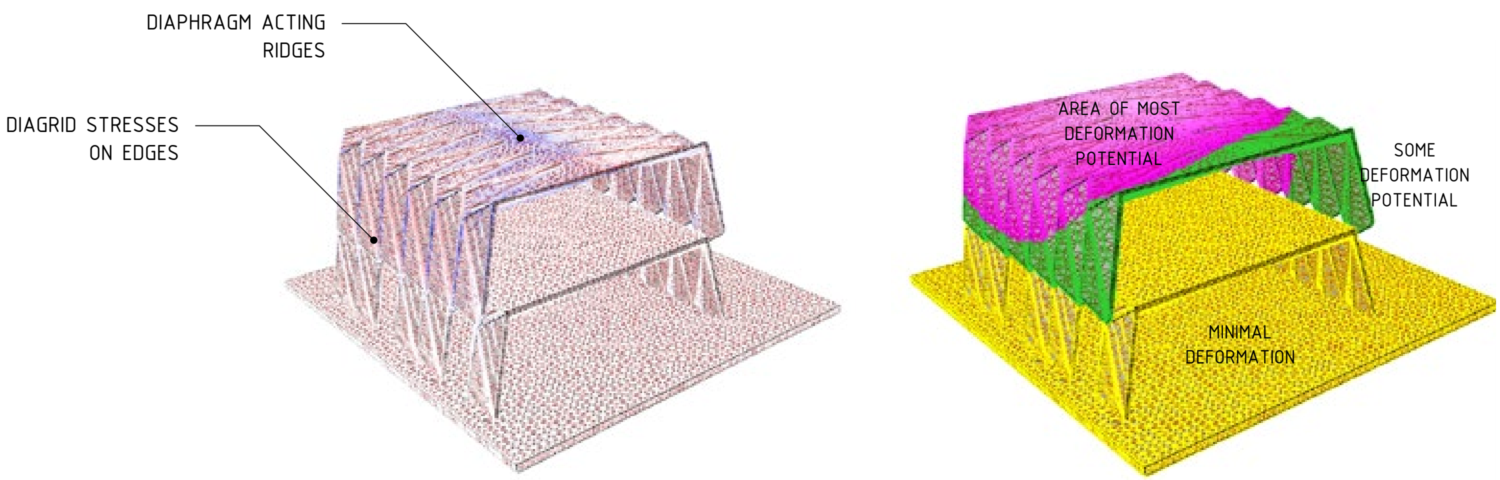
Method 02 was analyzed as having the most potential for constructability and spatial performance.

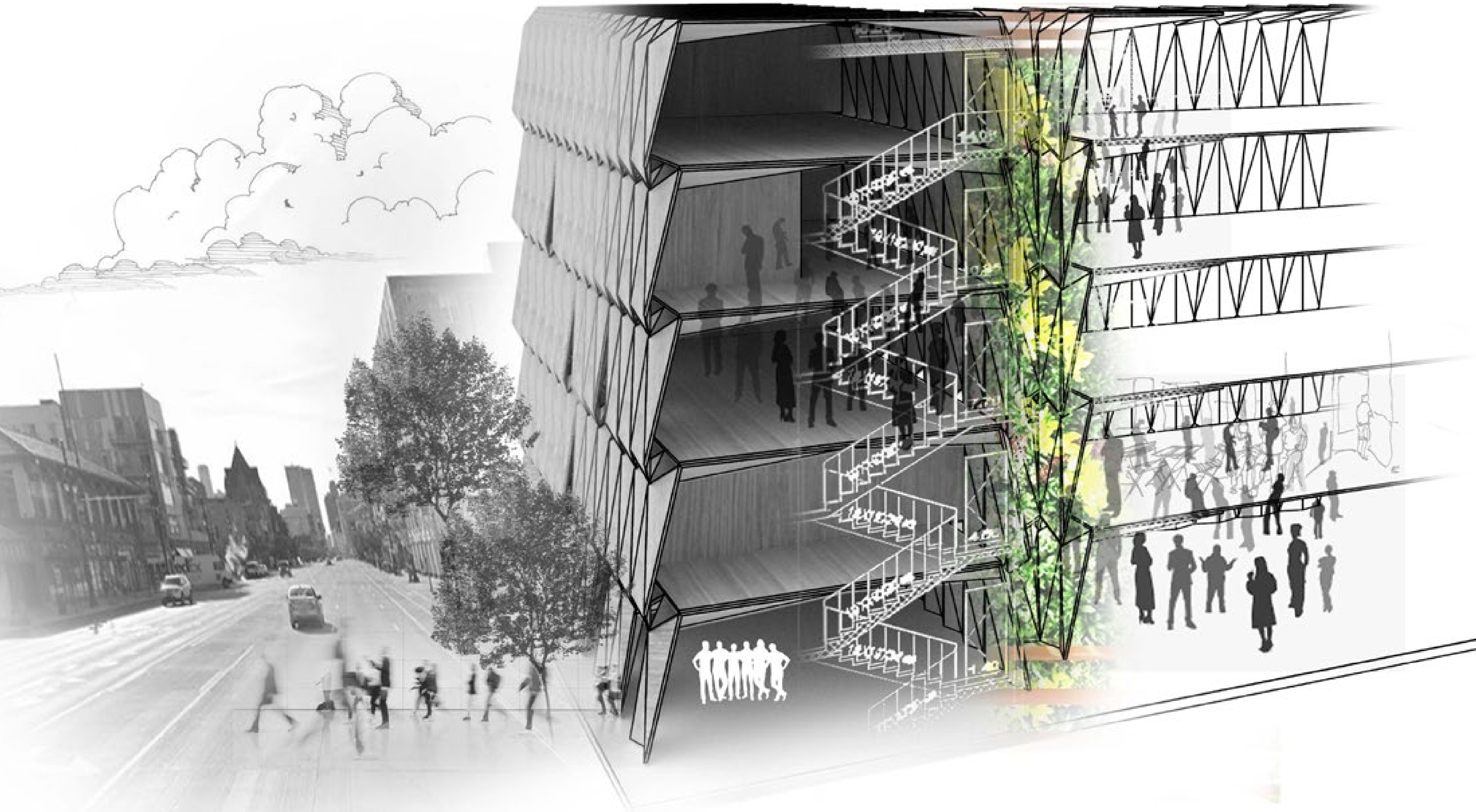
IMAGE 01 (page xx): Explanation and Citation (Author, Date)

4.2 INTEGRATED JOINERY

Integrated joinery methods (the dovetail connection) was implemented into each edge in order to provide continuity and the precision tolerance needed for structural integrity.







5.1 CONCLUSIONS

Any of the Methods chosen for study may have been applicable to a real constructable project. However, each tends to use expectedly large amounts of timber for its shell enclosure due to its representation.

The thesis negates the enclosure of windows and apertures beyond those naturally formed with the exclusion of plates at select grids.

The FEA approach is successful in its reading of forces along the surface of folds.

5.2 FURTHER WORK

The Future Work of this thesis explores the reduction of CLT plate in the surface as informed by the FEA. This will accomodate services needed for the human experience that the building envelope can integrate.

Appendix: Literature Review

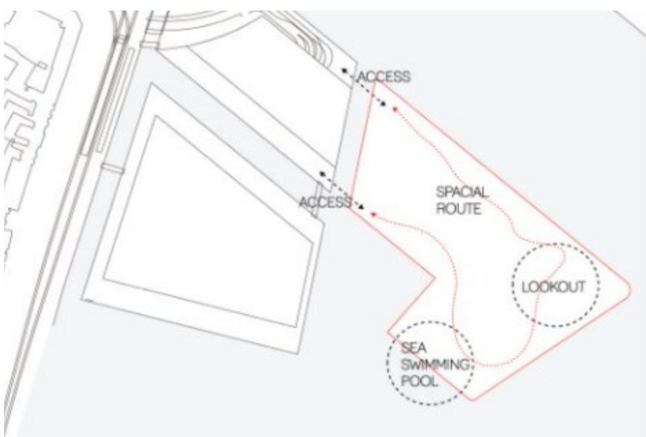
Aarhus School of Architecture. Folded Structures: Digital Physical Workshop. Blurb, 2012.

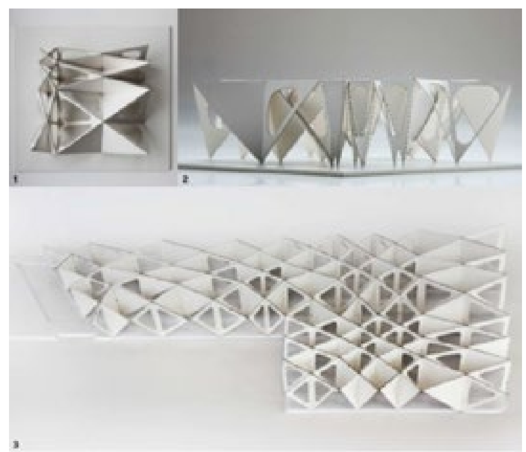
From this workshop, I am studying the work of folded geometry that is modeled to represent a large scale or mesh across an urban landscape. The studio explores the digital fabrication of folded forms on the Aarhus harbor in Denmark. The design of folded plate through computational means are realized at a scale that allows a speculative argument for folded form as infinitely many metaphors on the seaside pier.

I am studying this because the relationship between folded form and social meaning is grounded in its contextualized urban program. This provides insight into how to perform an architectural prototype with a site context and program considerations.

This helps me understand the consequences and benefits that folded form have on space and its relationship to the ground and form footprint (or building footprint). In some cases, the form meets the ground at a point, and in others, it meets with an edge. Some images from the workshop show the removal of the surface plane (the removal of material) to create an opening. This may represent an opportunity to allow structural folding along an edge without full surface-active structural performance. This removal of surface will be explored in Further Work.

> *Folded Structures examines this connection between a part and the whole by converting the basic elements of the architectural geometry into parametrics: points, lines and surfaces.*





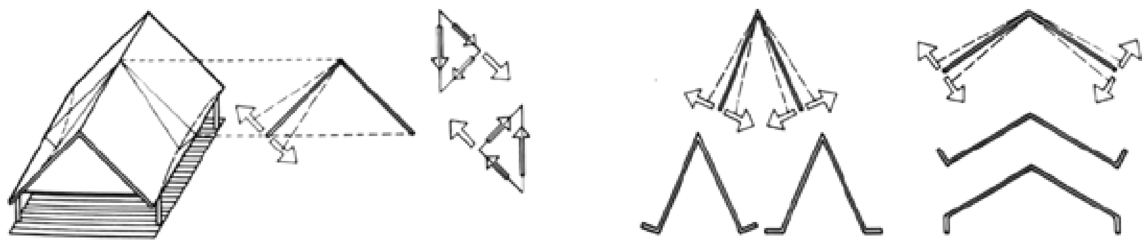
Engel, Heinrich. Structure Systems. Praeger, 1968.

I am studying Engel’s Chapter 4 on Surface-active Structure Systems where he defines folded plate during the period of its first popularity, as surface and form – two prerequisites that today’s designers may preserve as common to all design but which are deliberate mechanisms for folded plates as surface-active structures.

I am studying this because Engel’s definition of surface-active structure systems is paramount to any understanding of the folded plate approach. He diagrams slab force action and the schemes of the influence of slab thickness and fold rationalization.

His definition reinforces the thesis’ main reason for using the form to test significancy – a system that is altogether the structural system, the envelope and the space-creator. This is a critical synthesis in the work.

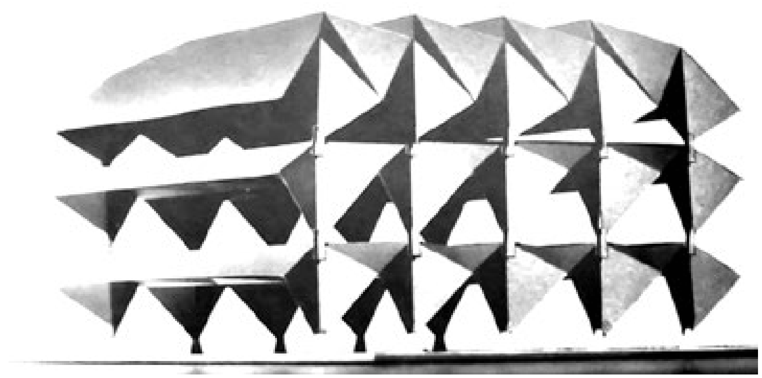
> *Surface-active structure systems are simultaneously the envelope of the internal space and hull of the external Building and consequently determine form and space of the building. Thus, they are the actual substance of the building and criterion of its equality: as a rational-efficient machine, as an aesthetic-significant form.*



Verformung aufgrund von Kraftkomponenten senkrecht zur Ebene
deformation due to component stresses normal to plane

Randversteifung für steile Faltung
edge beam for steep folding

für flache Faltung
for shallow folding



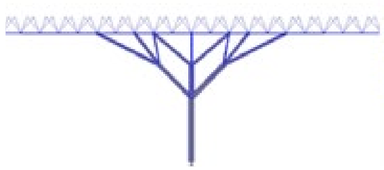
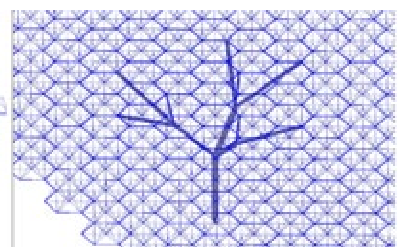
Falk, Andreas, et al. Folded plate assemblies with branching column supports – interaction and control of overall shape. Proceedings of the International Association for Shell and Spacial Structures (IASS) Symposium, 2010.

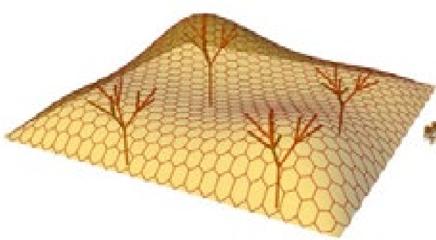
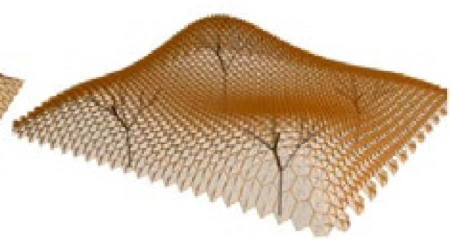
I am studying this IASS paper which uses the background of CLT folded structures to act as a structural sub-system on top of supporting branch-like columns. The hex-based form tessellates to create a complex array of folds to create a canopy.

I am studying this because this specific approach to folded design not only is experiential but responds to the issue of needed moisture control on the interior spaces of exposed CLT. This design intends to use the canopy as an envelope that addresses moisture and ventilation concerns of indoor air.

This helps me understand the performative measures of folded form and timber as a material as a building envelope.

> *In context geometry is a key factor, not only for the aimed at space-related utility/function/perception for the end-user, but also for the material-related performance of the building, since geometry affects air-flows in the enclosed volume and thereby ventilation, the exposure of roof areas to direct sunlight, the flow of light and heat through the building and the climatic interplay between indoor air and roof and wall surfaces.*

Falk, Andreas, et al. Form Exploration of Timber-based Folded Plate Domes. Proceedings of the International Association for Shell and Spacial Structures (IASS) Symposium, 2015.

I am studying this approach to using folded geometry to create interior space that is designed in response to daylight. The typologies of domes in folded form allow for openings in the structural shell to allow light and apertures.

I am studying this because the approach uses the surface of the facets to analyze potential beyond structurally. DIVA daylight analysis provides a Daylight Factor (DF) of inputs of the folded gridshell including material properties and light distribution in the room.

This helps me understand the need for a merging of all materials at play in a building envelope beyond just the mass timber (CLT). This may come at a future study if structural integration is the farthest study performed.

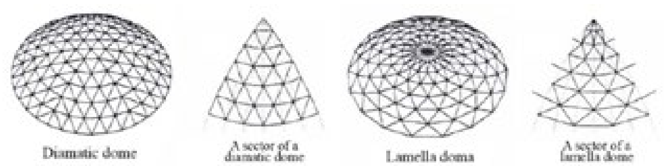
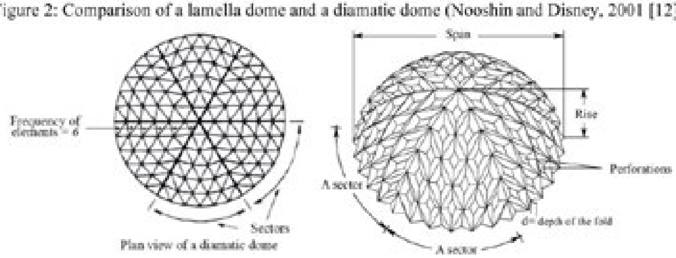


Figure 2: Comparison of a lamella dome and a diamatic dome (Nooshin and Disney, 2001 [12]).



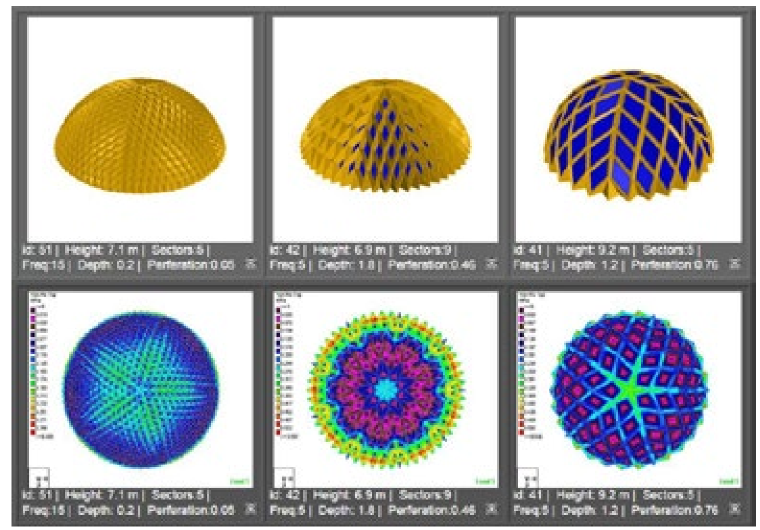


Table 2: Definitions and effects of different Daylight Factors.

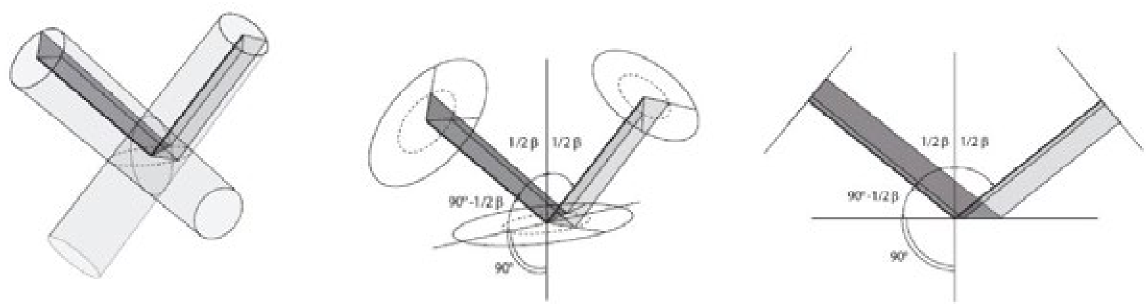
DF and appearance, thermal performance		
Average DF	Appearance	Energy implications
< 2%	The room looks gloomy	Artificial lighting is required
2% to 5%	The room looks lit, but supplementary artificial lighting is needed.	Artificial lighting may be required for some times.
> 5%	The room appears strongly lit	Daytime artificial lighting rarely needed, but glare and solar gain may cause problems due to overheating in summer and heat losses in winter.

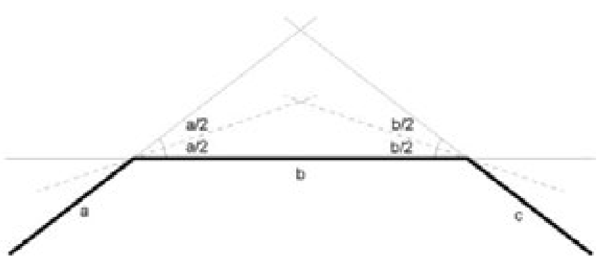
Buri, Hani, and Yves Weinand. “Origami—Geometry of Folded Plate Structures.” Structures & Architecture, 2008, doi:10.1201/b10428-90.

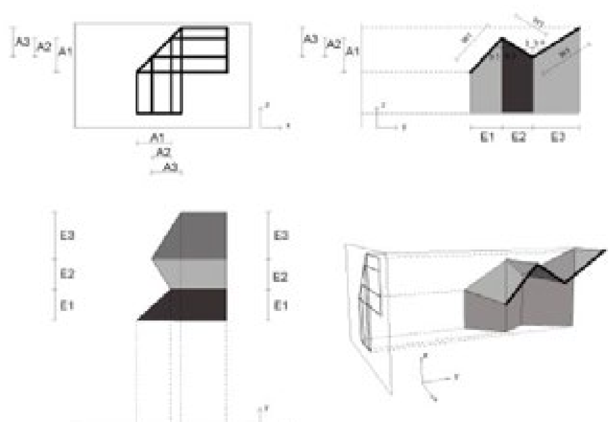
I am studying this to reveal the potential of folded plate as realized through Origami-rationalized, mathematical investigations of the form-finding process and CNC-milling of CLT. This approach strictly analyzes edge conditions of folded forms even though actual continuity of material cannot be achieved through such an assembly of CLT plates.

I am studying this because just like there is a typology of folded form, there is a typology of folds as in Origami art. In this case, parallel reverse folds were deployed as a base then infintiely varied based on multiple conditions such as amplitude of corrugation.

This helps me understand the potential of prototyping a reverse fold and the design sequence to achieve a free-standing structure created from a linearly arrayed series of folds.





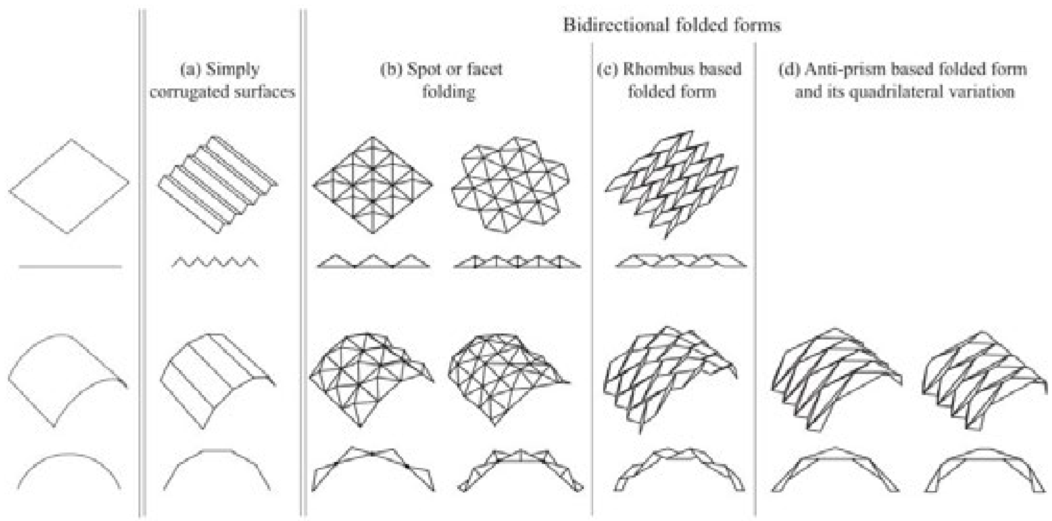


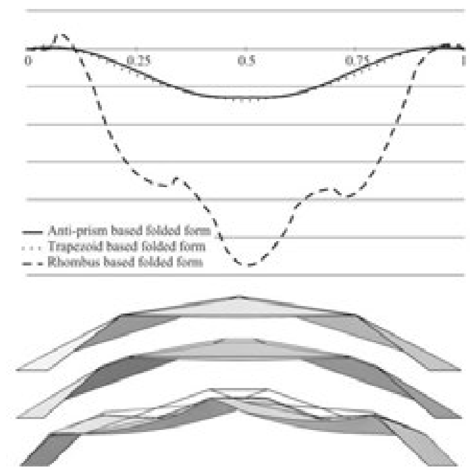
Stitic, Andrea, and Yves Weinand. “Timber Folded Plate Structures – Topological and Structural Considerations.” International Journal of Space Structures, vol. 30, no. 2, 2015, pp. 169–177., doi:10.1260/0266-3511.30.2.169.

I am studying the edgewise conditions of folded plate that are performance-maximized to achieve lightweight structure. By intensely presenting the force comparisons and performance of the classifications of folded plates, the case is made for using the structures on a building scale.

I am studying this because this research is presented to those who would do similar calculations for the types of specific joinery on the edge condition to where this research focuses on the gravitational implications of the edge between panels.

This helps me understand that by designing such prefabricated systems with intentional load bearing considerations, the construction of the system are projected into ecological and sustainable advantages of a long-span system.





The above classified bidirectional folded forms are further compared according to their utilization of the folding principle, making them more or less feasible for structural application in timber folded surface structures.

Heimsath, Clovis B. The Aesthetics of Folded Plates. Dept. of Architecture, Rice University, 1964.

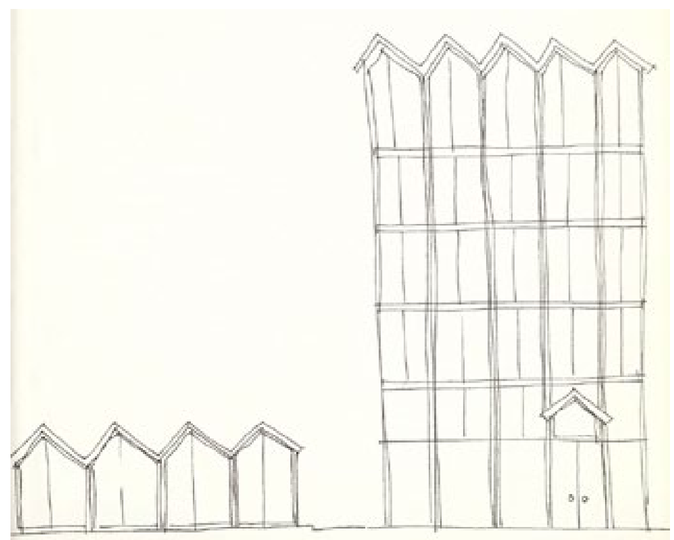
This 1964 “rulebook” of the aesthetics of folded plate reveal the context of the system within architectural history and Gestalt psychology. Such includes that humans have survived by judging and measuring their environments and that there is a natural self-entity, just like domes, of folded plate.

This is a mid-century foundational (almost primitive) look at the typology and application of folded plate from its repetitional nature to its context within the integration of other systems such as structure and daylighting.

> *Certain situations ripe for ugliness and misuse are common to most applications of the folded plate. First of all, the folded plate, as other exposed structural forms, is an entity in itself. It merges with other forms only at great peril.*

This idea is challenged. Folded plate can be an integral structural system that expresses edge-wise tectonics and may not be a self-entity form.

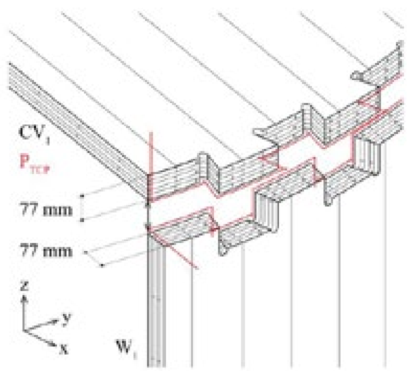
> *Of all the aforementioned problems, none is more controversial than that of folded plates used on multi-story buildings. A folded plate is a long span structure. If the program calls for a series of floors of uninterrupted spaces, then theoretically it is possible to stack folded plate floors and infilling the folds on all but the roof. However, in the majority of multi-story buildings, the floors are on a standard framing system. Can this be aesthetically justified?*

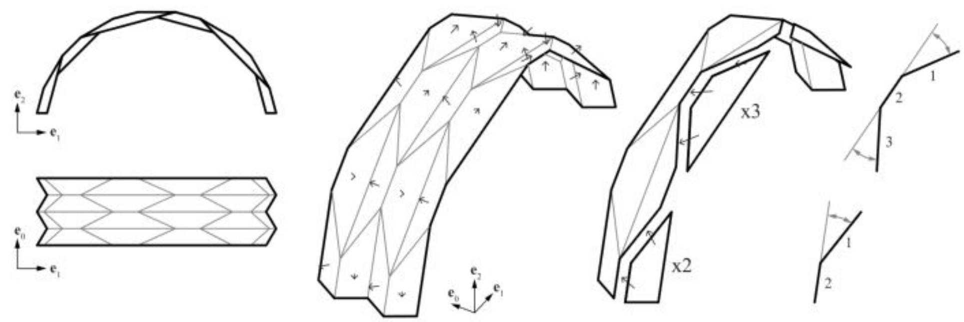


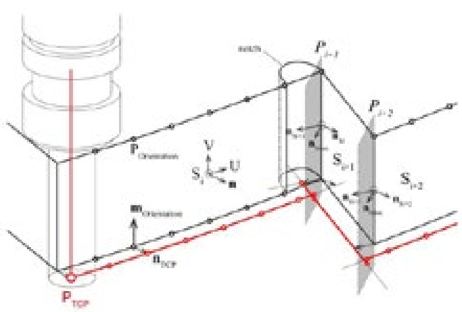
Robeller, Christopher. (2015). Integral Mechanical Attachment for Timber Folded Plate Structures. 10.5075/ epfl-thesis-6564.

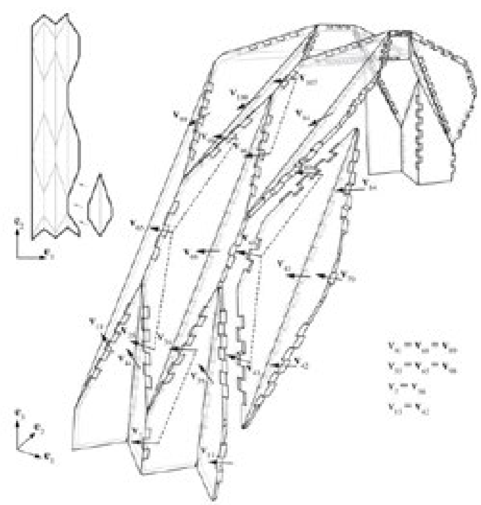
This source is the most reliant grounding for this thesis which not only poses real theories on folded geometry but uses 21st century tool methods to connect the benefits of integrated joinery to the benefits of CLT mass timber. This source will be studied more in Future Work.

Robeller comprehensively presents how timber plates can be fastened not with mass-produced mechanical fasteners but with ones that are integral to the plates themselves. For those also inspired by European and Asian joinery (in both building and object applications) the automated manufacturing process allows for the same rationalization. Innovation with CLT plates is headed toward having their connections automatically designed during the primary process rather than as a secondary process. This is integral to the prefabrication and automated design disciplines.









Oxman, R., & Oxman, R. (2010). New structuralism: Design, engineering and Architectural Technologies. Architectural Design, 80(4), 80–83. https://doi.org/10.1002/ad.1101

Re: Variable Property Fabrication (VPF)

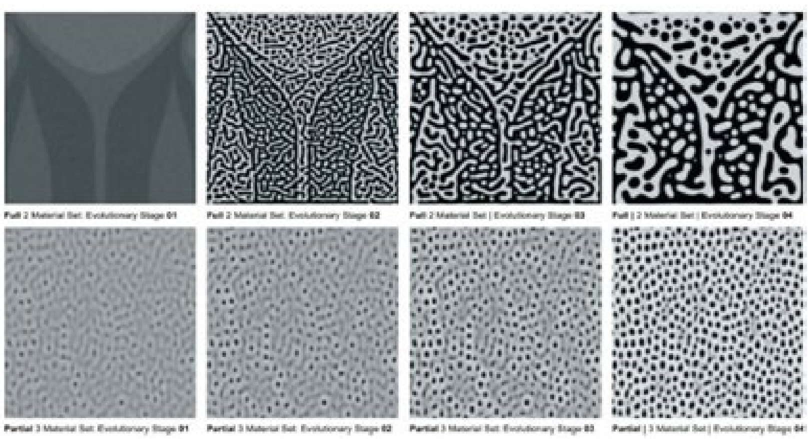
> *Variable property fabrication aims at introducing a novel material deposition 3-D printing technology which offers gradation control of multiple materials within one print to save weight and material quantity while reducing energy inputs. The result is a continuous gradient material structure, highly optimized to fit its structural performance with an efficient use of materials, reduction of waste and the production of highly customized features with added functionality.*

This description of fabricated materiality is almost universal no matter which material is used in the effort to perform with minimal waste. In the case of mass timber, there is a quantity of its form that can be fabricated to have the qualities as Oxman describes of the carpal skin model.

Re: Materials are the New Software

> *The work presented here calls for a shift from a geometric-centric to a material-based approach in computationally enabled form-generation.*

When weighing the balance between this thesis being about both (1) folded plate and (2) mass timber, while the thesis starts out as a folded plate-centric exploration, ultimately the thesis is about the material-based approach. This maximizes any questions posed on mass timber as a material that form alone cannot.



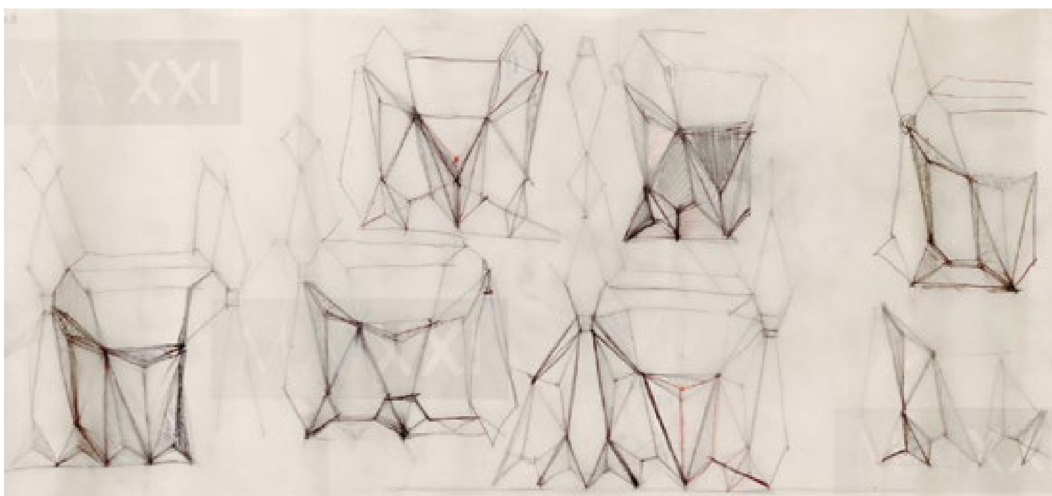
Neri Oxman, Carpal Skin: Prototype for a Carpel Tunnel Syndrome Splint, Museum of Science, Boston, Massachusetts, 2009
left: Physical model of prototype. Material distribution charts illustrating a range of potential solutions informed by size, scale, direction and ratio between soft and stiff materials. The charts are computed on top of an optimised unfolded representation of the frontal and dorsal planes of the patient's hand and refolded following material assignment to construct the 3-D glove.

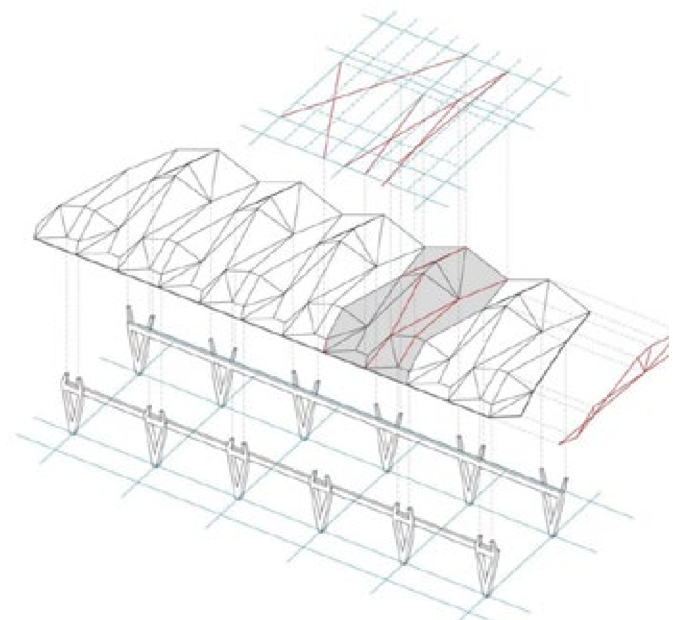
D'Acunto, P., & Ingold, L. (2016). The Approach of Sergio Musmeci to Structural Folding. Proceedings of the IASS Annual Symposium 2016.

> *The approach of Musmeci is integral to this thesis because it gives a clear basis to the reason of the folded approach as not just a form but a logic. Studied with concrete, his projects sometimes had to be built with a low budget, and thus the folds had to be designed with efficiency.*

The employment of structural folding, like in the work of Sergio Musmeci, is a result of this process. One of the most peculiar properties of folded structures is their ability to resist the external applied load through their form. A folded system has a clear structural logic, which relies on the relationship between the flow of the forces within the system and its overall geometry. It is because of its inherent potential that structural folding has been investigated during the 1950s, especially in Italy."

> *'In reinforced concrete the tensile stresses are channelled into the main reinforcement bars, and considering that these stresses tend to be confined to specific edges, it is natural to try to keep them as straight and continuous as possible. These edges are the ones that should connect geometrically the different parts of the structure, likewise a rigid truss. The intuition that along them tensile stresses run contributes to fix the form of the vault, moving away from any sense of arbitrariness. Compressive stresses have always been kept in large sections of the slab in order to facilitate their diffusion and, again, with the intention of expressing this characteristic structural behaviour in the form' (Musmeci S., Copertura pieghettata per un'industria a Pietrasanta. L'Architettura,1960; 52;710-713.)*





References

[1] Aarhus School of Architecture. Folded Structures: Digital Physical Workshop. Blurb, 2012.

[2] Buri, Hani, and Yves Weinand. “Origami—Geometry of Folded Plate Structures.” Structures & Architecture, 2008, doi:10.1201/b10428-90.

[3] D’Acunto, P., & Ingold, L. (2016). The Approach of Sergio Musmeci to Structural Folding. Proceedings of the IASS Annual Symposium 2016.

[4] Engel, Heinrich. Structure Systems. Praeger, 1968.

[5] Falk, Andreas, et al. Folded plate assemblies with branching column supports – interaction and control of overall shape. Proceedings of the International Association for Shell and Spacial Structures (IASS) Symposium, 2010.

[6] Falk, Andreas, et al. Form Exploration of Timber-based Folded Plate Domes. Proceedings of the International Association for Shell and Spacial Structures (IASS) Symposium, 2015.

[7] Heimsath, Clovis B. The Aesthetics of Folded Plates. Dept. of Architecture, Rice University, 1964.

[8] Oxman, R., & Oxman, R. (2010). New structuralism: Design, engineering and Architectural Technologies. Architectural Design, 80(4), 80–83. https://doi.org/10.1002/ad.1101

[9] Robeller, Christopher. (2015). Integral Mechanical Attachment for Timber Folded Plate Structures. 10.5075/epfl-thesis-6564.

[10] Stitic, Andrea, and Yves Weinand. “Timber Folded Plate Structures – Topological and Structural Considerations.” International Journal of Space Structures, vol. 30, no. 2, 2015, pp. 169–177., doi:10.1260/0266-3511.30.2.169.