BREAK

A post-digital exploration of the cleaving of timber.

Master Thesis
Chalmers school of architecture
Department of Architecture and civil Engineering
Architecture and Urban design, MPARK
Spring 2021

Karl Åhlund

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UNIVERSITY OF TECHNOLOGY

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Abstract

The focus of this thesis lies on the exploration of cleaved timber as a material and the creation of a process of working between the physical and dig-ital. Different methodologies are explored and developed by working with both physical and digital representative models of cleaving. By employing scale tests of cleaved wood, the material is examined, categorized and digitized in a way that allows for further digital exploration. These various forms and shapes influence the design ethos and create the fundamental perspective of materiality and texture for this project.

The initial process is conducted using single scale cleave tests that are an exploration into trying to control the cleaving direction. The process is extrapolated by combining these pieces together and testing a different scale of application. To further explore both the texture and materiality of the cleaved surfaces, a process of digitization was created. Digitization required several iterations before usable 3d meshes could be produced. Using photogrammetry, multiple 3d meshes of the material were created by use of a repeatable method of arranging cleaved wood pieces in various formations. Manipulations of these meshes allowed for the creation of a model that functions as both an analog of a physical model and a way to create architectural representation. Individual pieces of a final design are created digitally with a focus on retaining materiality through this digitization process.

The thesis concludes in two distinct studies of form and representation of a cleaved structure: an open air structure that follows a physical model result, and a chapel made from digitized cleaved surfaces. The investigation examines the material consequence of using cleaved timber as a building material and how a post-digital workflow studies material. The process of working and equivocating physical and digital texture and materiality guides the design and creation of architectural representation in various forms. That workflow stems from the view that by working with textures, both digital and physical, an exploration of materiality is possible that is both new but also linked to the original material and an architects role in creating a built environment.

Student Info

Work

Misc. Studio - *Cofounded*
Gothenburg, Sweden - Spring 2021

Avanto Architects
Helsinki, Finland - Spring 2019

Design-To-Production
Zürich, Switzerland - Fall 2018

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Chalmers University of Technology

Master Studios
- *Material Detail*
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2013-2016 / BSc - Architecture
Chalmers University of Technology

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Thesis Question

How can cleaved wood be used to explore texture and materiality within both the physical and digital domain.

Supplementary questions

Is it possible to control the cleaving of wood through various subtractive manufacturing processes?

How does a method that digitizes complex textures and materials function?

What information is lost through a process of digitization and what is generated?

How effect does the eventual loss of textural information effect our notion of materiality?

Aims

To facilitate testing of various cleaving methods and typologies.

To explore a post-digital workflow through the use of physical and digital models.

To embrace the incidental, to explore alternatives given from the created results post production.

Key Words

Cleave - To split, especially along the grain

Embedded information - Information that is either physically or digitally linked to other information about a system.

Glitch - Remnants of a process or method that had an unexpected outcome or effect.

Subtractive manufacturing - Manufacturing processes based on controlled removal of undesired materials through cutting, drilling or milling to achieve the desired forms.

Pocket - A void in an object created by subtractive manufacturing.

Mesh - A collection of vertices, edges, and faces that

Photogrammetry - A process which photographs are used to create a 3d mesh by use of point triangulation.

Texture (3d rendering) - A series of images that give details to a renderer on how an object reacts and looks.

Retopology - To reduce a high-resolution mesh to a low resolution to allow for easier handling. Also changes the UV mapping of the mesh to be easier to alter.

Introduction

This thesis explores cleaved wood as a design/material element by employing physical testing, digital explorations, and digital manufacturing techniques. Is it possible to design architectural structures and elements in massive wood that are broken on site as the last step of the fabrication process? A step that ensures uniqueness of each piece by following a developed cleave methodology but due to the nature of wood, will always have a different structure.

Traditionally cleaving wood has been done as a way to create planks and straight sections of wood that needed to have high moisture resistance. The act of cleaving exposes the inner structure of the wood grain, parallel fibers that started as a capillary structure to move nutrients up into the canopy. By creating long sections of closed cell structures the wood has a much higher resistance to water ingress than modern sawn timber. This produces a longer lasting wood that is more resistant to rot.

Using a combination of traditional cleaving techniques and digital tools, this thesis aims to put forth a manufacturing and design process for cleaved structures. By modifying individual logs by means of digital tools that are then combined to create a preprogrammed block, a single structure is created only to be broken apart to reveal new volumes. This fabrication methodology challenges our current ideas of prefab elements and creates an artistic touch by cleaving so close to the finished structure. Because the reveal of the final form is done at the building site, the final appearance is hidden until the last moment.

Purpose

The purpose of this thesis is to explore the possibilities of using cleaved wood as both a building material and a design tool. A design methodology is developed during the research phase that utilizes both physical models and their digital equivalents.

Outline & Delimitations

This research was first conducted as a set of scale material tests to explore the ability to control, by shifting or altering, the propagation of a cleaved break. These first tests allowed a creation of different methods and knowledge that are then used to design and explore various scales and the final design proposal.

The use of a post-digital methodology throughout the thesis will be what guides the way to generate data of texture and materiality from the physical realm to the digital. Photogrammetry is used to calculate a digital mesh representation of the physical tests and altered mesh models will be used in the creation of further models and architectural representations.

The findings and developed techniques are by necessity based on scaled-down models and prototypes, and there may be limitations to how well this could be adapted to a full scale scenario. This risk is mitigated by the careful design and chosen test pieces. The use of different scales of wood structure will also have an effect on the texture and further digital representation due to shear scale differences.

Cleaving of wood for boat building

Background

Harvesting material has long been a personal relationship formed by a worker choosing material based on their needs. Trees where chosen based on how their branches split from the trunks to receive strong wood with that shape. Woodlands where even grown and managed in different ways depending on the intended result. This relationship with nature has changed due to industrialization and much of this knowledge has been lost to the ages. The disassociation from material to worker has lead to an altered way of understanding our built environment.

Historically cleaving was used in harvesting of both wood and stone. Before industrialization and the wide scale use of advanced cutting tools and large scale machinery, humans needed a way to break large pieces of material into smaller more manageable sizes. Cleaving was used because by applying force into an object along its natural grain it will break easier then against the grain. Both stone and wood have a grain direction that allows for a clean break between layers. In granite quarries, feathering, a technique where one drills a small hole then induces a pressure into the stone by hammering in a series of wedges, was used to break large chunks of material free from the ground/mountain. Logs of wood where also split along the grain into planks as a way of fabrication. Planks where created in various sizes from small pieces to use as riven clapboards, to planks that where used for the hulls of boats. Only after the industrialization of wood harvesting did we change from a more massive idea of wood buildings using timber to a more material efficient lumber system. These riven planks where typically used as siding or even roofing as shingles. To the right, the image shows a use of the riven boards as a facade material. The offset stacking of the boards helps keep water off of the inner structure of the building.

Riven wood siding example

Discourse

Ignorance and Surprise

The cleaving process is inherently ignorant. Unless extreme measures are taken, the direct path that splits the wood is unknown before the event. This can be mitigated by use of tools designed to slow down the cleave and a knowledge gained only by preforming this action. But is this necessarily a problem from the perspective of architectural materiality? This notion of the unexpected outcome and a willful ignorance of what this entails to a project is defined within sociology and science in Ignorance and Surprise: Science, Society, and Ecological Design by Mattias Gross.

"The idea of experiment (from the Latin: experiri, "to try") will be of pivotal importance to link ignorance and surprises conceptually and to learn from and cope with the unexpected" (Gross, 2010, p. 3) Thus lies the implicit importance of cleaving in my experiments. The experimental nature of this thesis and in the research done into handling cleaving both pre and post event defines its relevance to the current idea of materiality. By including both moments in time, a change to traditional ideals is required.

This experimental approach has been incorporated into the design ethos of the thesis. Many physical and digital tests initially felt inconclusive or wrong. Yet the ability to analyze and reinterpret the tests stems from a welcoming of the unknown, a perspective shift from an old normal.

The unexpected forces one to think on ones feet. Imagine a large wood block, when cleaved, the unexpected happens. A hole is formed between the timber pieces, but it is not where it was intended to be. Does it stay a window? The design is transient, ideas or notions of what should of been are no longer relevant to the material at hand. Could a new entrance, or side exit be more appropriate? This process changes fundamentally the way of design in the modern way, yet yields a look towards discovery as a fundamental part of design.

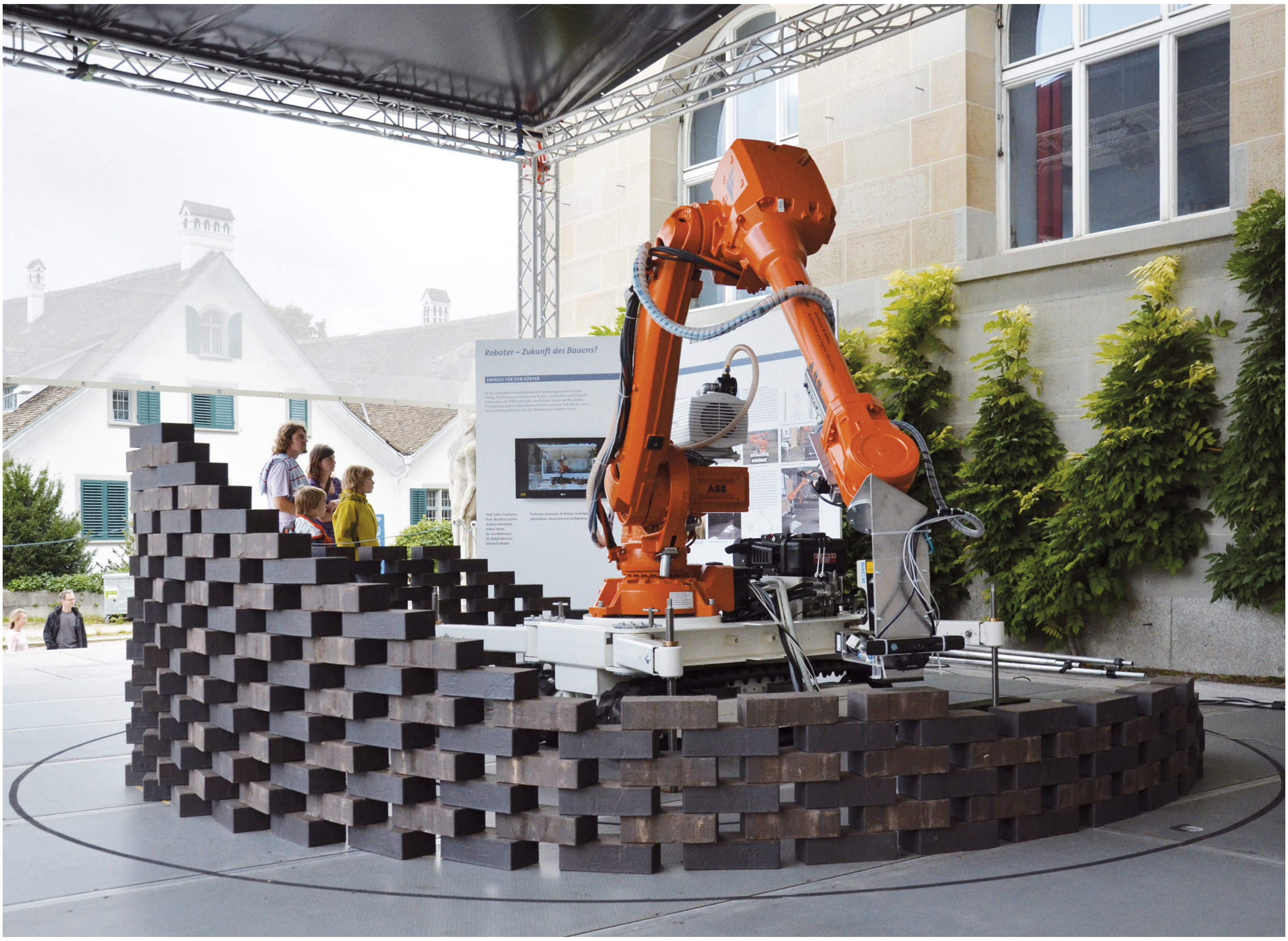
New materialisms

The cleaving of wood helps the material gain agency through its creation process. In a post-digital design landscape, where does this agency come from? *"For Materiality is always something more than "mere" matter: an excess, force, vitality, relationality, or difference that renders matter active, self-creative, productive, unpredictable."* (Coole & Frost, 2013, p.9) This fundamental approach to defining what materiality in an architectural sentiment is, reveals a perception applicable to a method, or process.

This concept of giving agency within materialism to processes does not remove importance from traditional materialism though. The smooth polished base of a Corinthian column is still relevant within this frame of materialism as the process of breaking the stone from the mountain, transported, and finally sculpted is distinctly included not assumed.

As the thesis progressed from physical to a more digital approach, the concept of what a material is and where its value to an architect emerges shifts. Many concepts stay the same but require again a shift of perspective to have the nuanced view of appreciated value.

Further expanding upon this concept yields a revelation of the inference of a digital materialism. Coole & Frost continue to create a discourse of this implied notion of digital currency "Forces, energies, and intensities (rather than substances) and complex, even random, processes (rather than simple, predictable states) have become the new currency." (Coole & Frost, 2013, p.13) Within the post-digital architectural practice, this draws parallels to the creation of a digital practice. Idea's, concepts, images, random number generators all give rise to interpretations of building structures, forms, shapes.



The Endless Wall
Gramazio Kohler Research
(2011)

Digital Grotesque - Grotto 1
Hansmeyer & Dillenburger
(2013)

Discourse

Physical materialisms

Humanistic notions of materiality contribute to our sense of space through the physical characteristics of a material. The current state of revival for natural and relatively lightly processed materials shows the past ideals are still relevant. *"... someone like Kenneth Frampton, Peter Zumthor, or Juhani Pallasmaa, for whom materiality, the concrete, the haptic, and the tactile were ends in themselves. These people were completely skeptical of any form of abstraction."* (Borden & Meredith, 2011, p. 22) Materiality through an older, yet still relevant architectural discourse yields to the absolute. The direct contact, smell, touch of a material is unconditional in the human relation to material. This gives no agency to the process of creation of the material.

"*Computer imaging tends to flatten our magnificent, multi-sensory, simultaneous and synchronic capacities of imagination by turning the design process into a passive visual manipulation, a retinal journey."* (Pallasmaa, 2012, p.28). Pallasmaa gives a candid view on how he interperets the disatvangages to a pedogogical system that is what is currently our everyday. The idea that we are driven by only the visual is relevant in todays post-digital day. The canonization of visual stimuli drives much of the current day architecture. It is not difficult to imagine what Pallasmaa thinks of students raised on the algorithms that drive Pinterest's popularity.

Physical materials give much input to the direction of the method created in the thesis. Two distinctions alter the material, a physical, human man cleaving action, and the digital fabrication method of subtractive manufacturing. Both create physical manifestations of their action upon the material, and method followed highlights these through the design process.

Digital materialisms

"Digital materiality evolves through the interplay between digital and material processes in design and construction. The synthesis of two seemingly distinct worlds – the digital and the material – generates new, self-evident realities. Data and material, programming and construction are interwoven" (*Gramazio and Kohler, 2008, p. 7)* Through Gramazio and Kohlers experiments with fabrication, an integral part of what new materialism is becomes real. Their projects such as Structural Oscillations (2007-08), The endless wall (2011), and Flight Assembled Architecture (2011-12) all examine the role of robotic fabrication in relation to a new materiality. The precision of the stacking of bricks is a detail added to their and the created spaces material expression.

Several physical models has also been produced within the thesis process by means of digital fabrication as well. These processes leave remnants in the individual pieces in the form of ridges that approximate an angled cut. These steps are simply due to the toolpath, and settings chosen based upon knowledge of the material properties and how best to remove material from itself.

In Digital Grotesque - Grotto I, Hansmeyer & Dillenburger use extreme digital manipulations to create an absurd amount of data. They write *"Digital Grotesque is a testament to and celebration of a new kind of architecture that leaves behind traditional paradigms of rationalization and standardization and instead emphasizes the viewer's perception, evoking marvel, curiosity and bewilderment." (2017)* This ornamental nature of more is better within digital materiality can be seen as a peak, an extreme that gives value in showing the current boundary of expression.

Design Research

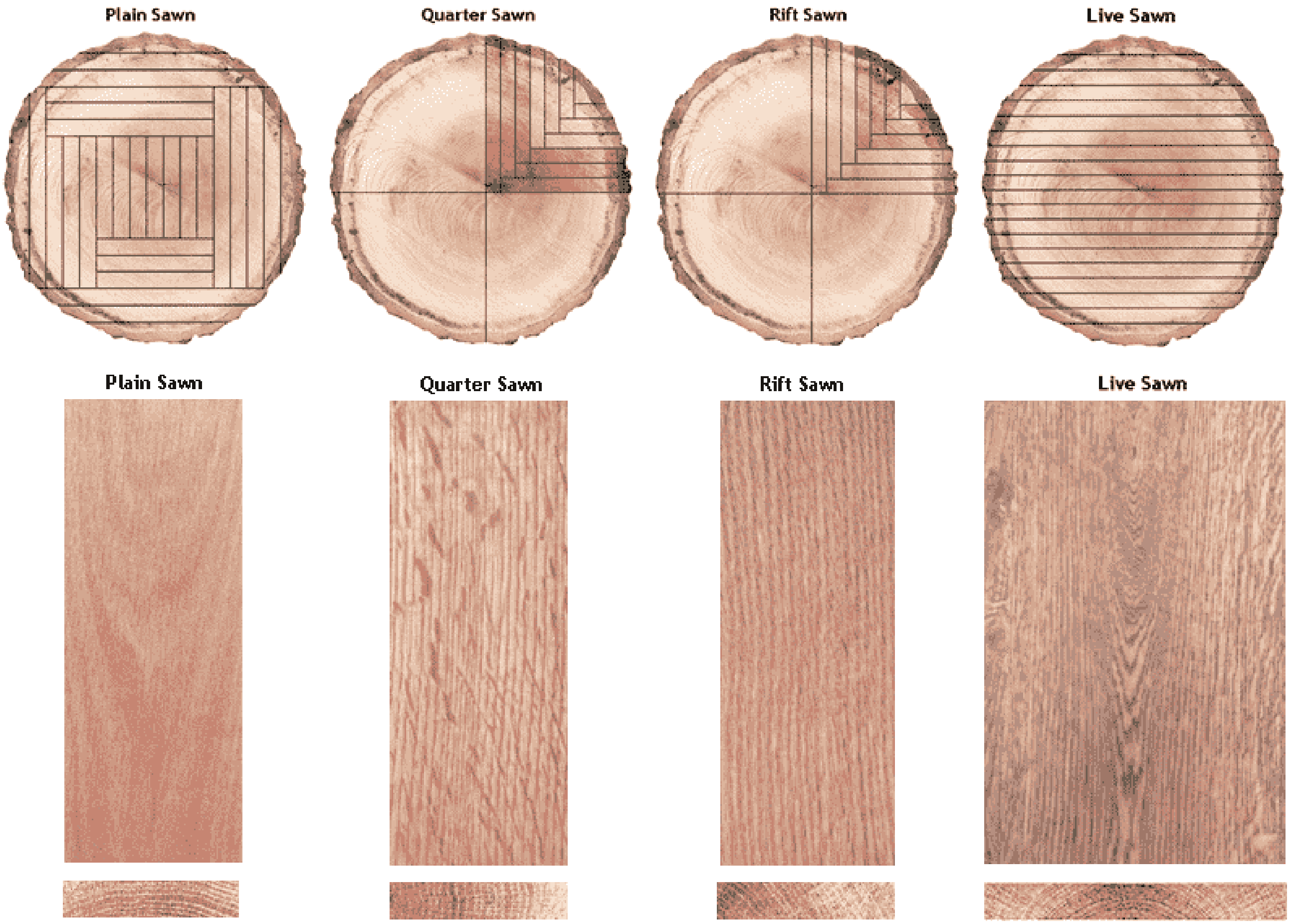


Diagram of various ways to cut lumber

Testing methodology

Finding a suitable scale substitute for a full grain wood log was a difficult task due to limited available resources. Most commercially available logs are impregnated with heavy metals and other poisons to fight rot. This makes the wood dangerous to handle let alone cut into manageable pieces and post process with a CNC machine. They can be so severely compromised that they are considered dangerous goods to ship.

To the right is a cross section of a drying piece of wood. The wood naturally contracts and bends while drying out and creates stress fractures within. These cracks propagate perpendicular to the growth rings and spread radially around the center of growth for the tree. By examining different types of wood and at different humidity levels, a suitable alternative was found in that if the cleave was moving down the length of the piece of wood, simple plain sawn wood could be used. This is a standard cut for lumber which saws the wood in consecutive layers across the length of wood. This creates wooden pieces where the growth rings are roughly perpendicular relative to the outside dimensions. Thus, this allows for the cleaving the piece of wood relatively straight down its grain while still keeping the splitting of the wood from moving to each side.

This lead to the development of a theoretical large sheet of multiple logs attached to each other through various means that could be cleaved to create a large piece. The large sheet could act as large elements similar to CLT or even prefab concrete with the cleaved surface, acting as a large shingle, as a built in exterior material for a building.

A slice of walnut timber, showing a crack propagate through the piece. The shape and direction is based on the grain structure formed when the tree grew, but also allows for a non linear split due to irregularities of a natural material.

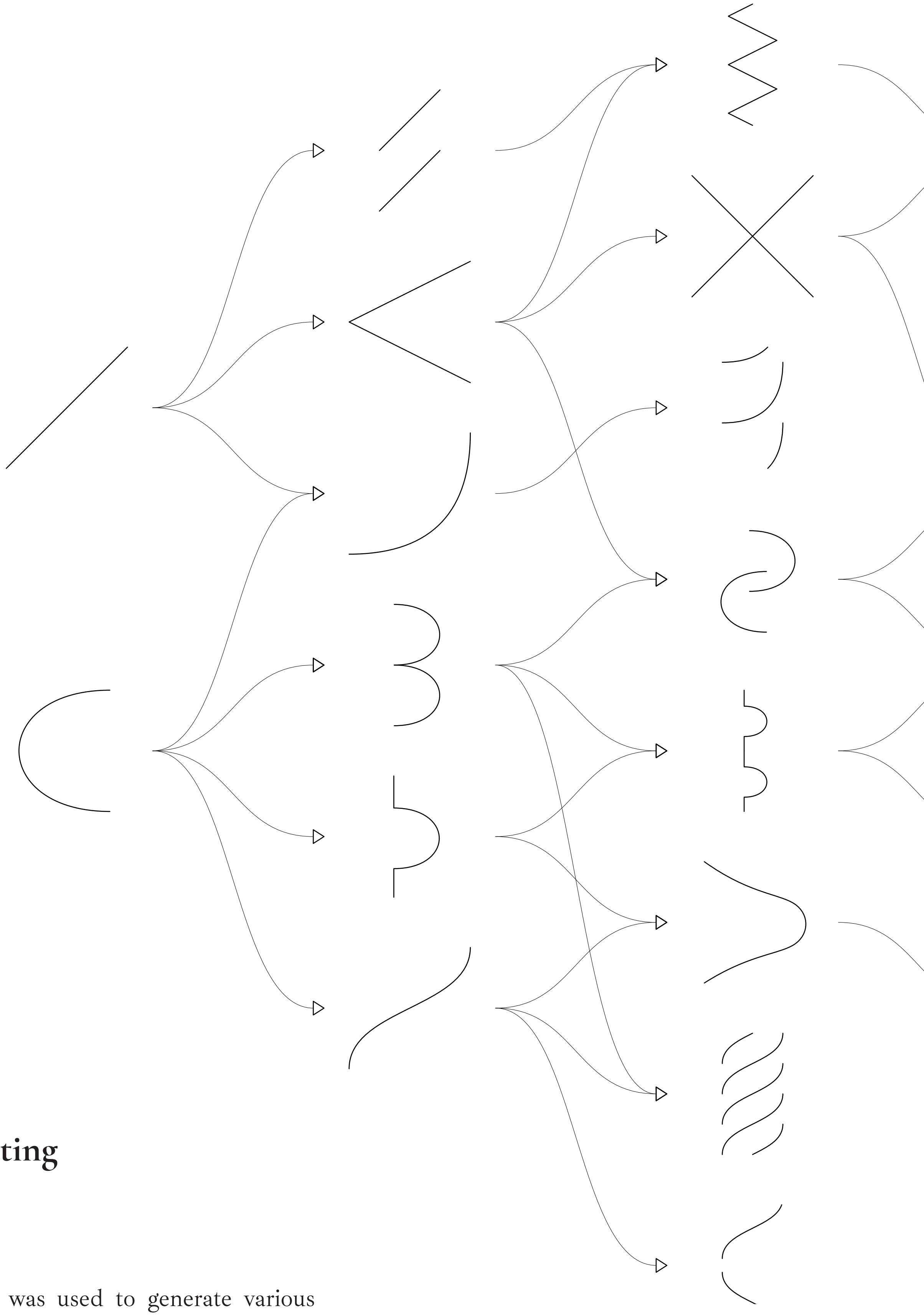
Scale Testing

As previously stated, finding an analog to a full cleaved log would allow the study of larger scales and structures. On the right are two cleaved pieces of wood. The one to the left was a square sawn piece of timber, with a full ring structure, and to the right, a smaller piece of lumber that only included a section of the original ring structure. As the photos show, the resulting texture and materiality of the pieces are fairly similar. The tearing action of wood fibers follows the longitudinal direction of the piece during the cleave in the same way.

The main difference between the two pieces is that of textural fidelity. The fact that the size of the interior ring structure is roughly the same causes an exaggeration of the fibers in the scale piece. Resolution of the texture stays the same independent from the scale of the piece. This is due to the way that the tree grew during its life. As the timer and lumber both come from a quick growing farm-able pine, the amount of growth per year is again similar between the two. Yielding very similar characteristics yet becomes a limiting factor during the recreation of the texture and materiality of the cleaved surface.

The reduced fidelity is accepted and embraced within the thesis process. Thus, the way of creating scale tests and eventual models is integral to the physical and digital nature of the thesis. The resolution shift can draw parallels to both the process of handling the eventual photogrammetry meshes as well as the actual understanding of textures in real life.

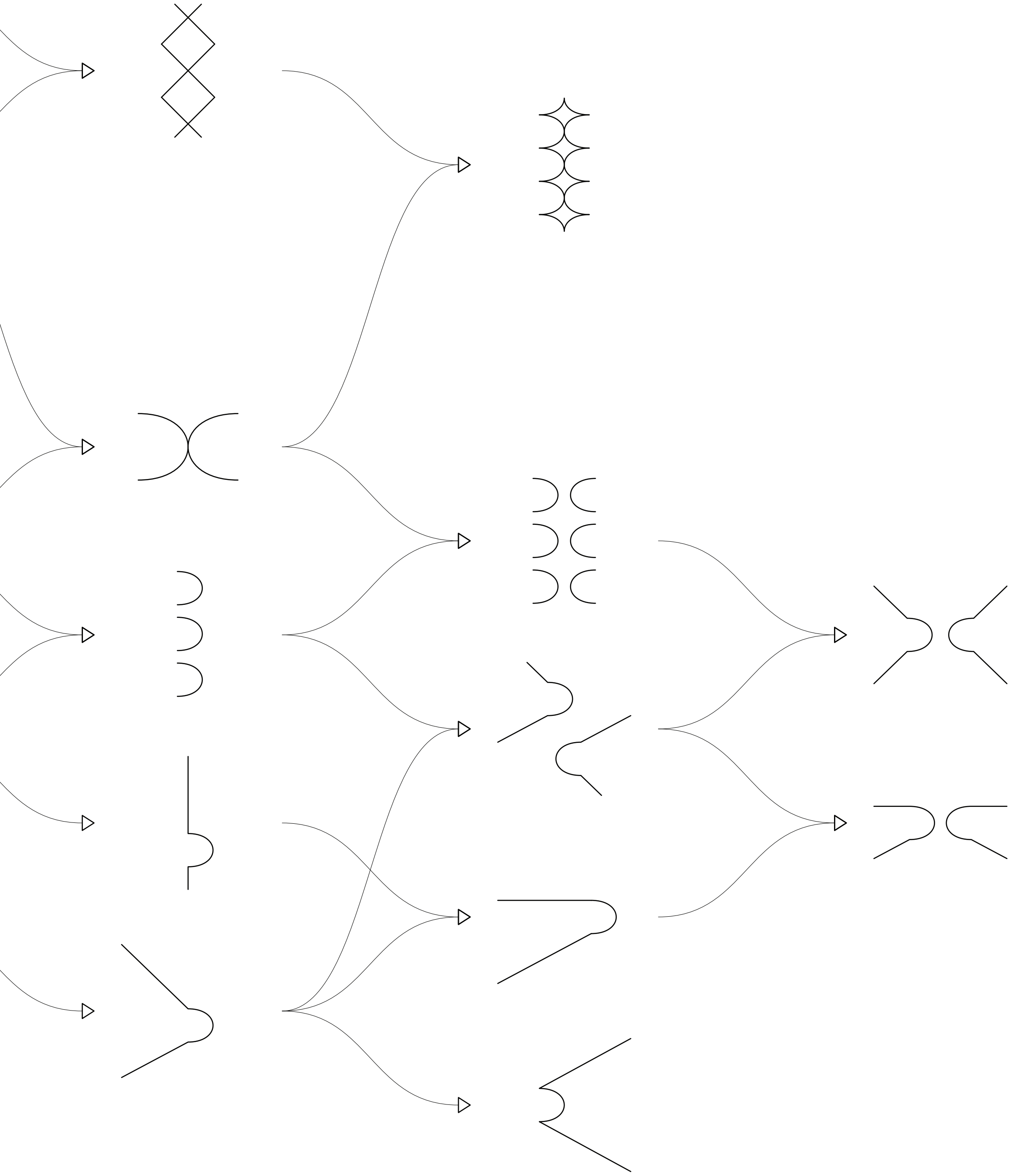
Pictures of two physical cleaving tests. The left from a piece of timber, 200x200mm, and the right a small 22x35mm stick.



Single cleave testing

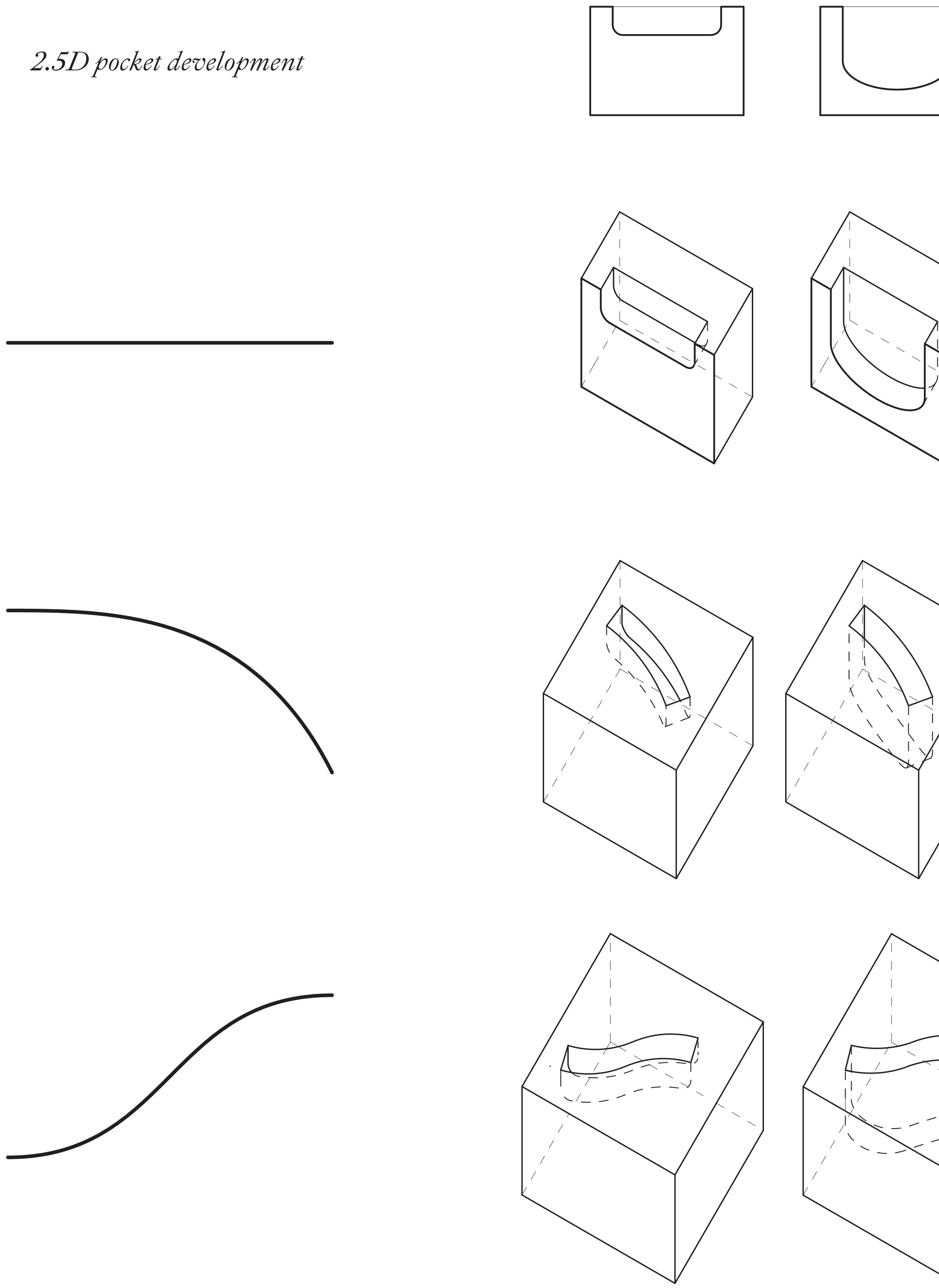
Generation map

A generational format was used to generate various shapes to cut on the single wood test pieces. Allowing an exploration of shape and form of individual curves as a way to control a cleave through a wood test piece. The curves are read left to right and the arrows represent the continuation of certain elements of the curves surviving and moving to the next generation increasing the complexity of curve.



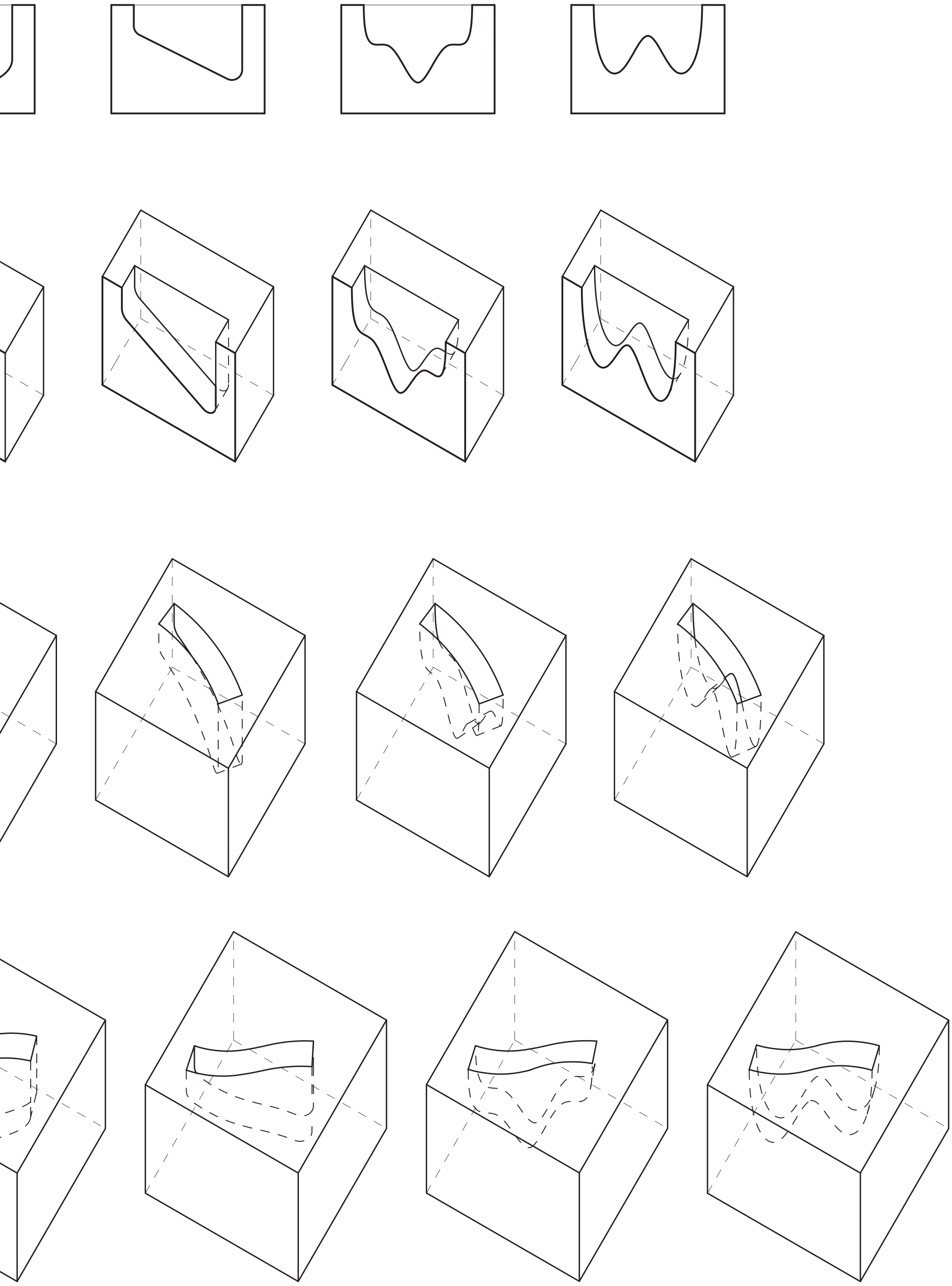
A generational map created to show how various forms influenced each other

2.5D pocket development



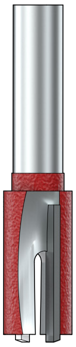
Depth test mapping

A question surrounding the pockets milled into the wood test pieces is how deep do they have to be to affect the cleave. These tests were used to test different types of depths, both 2.5D and 3D as a way to alter the cleave. Unfortunately this process did not lead to any further development as it did not effect the cleave in any noticeable way.

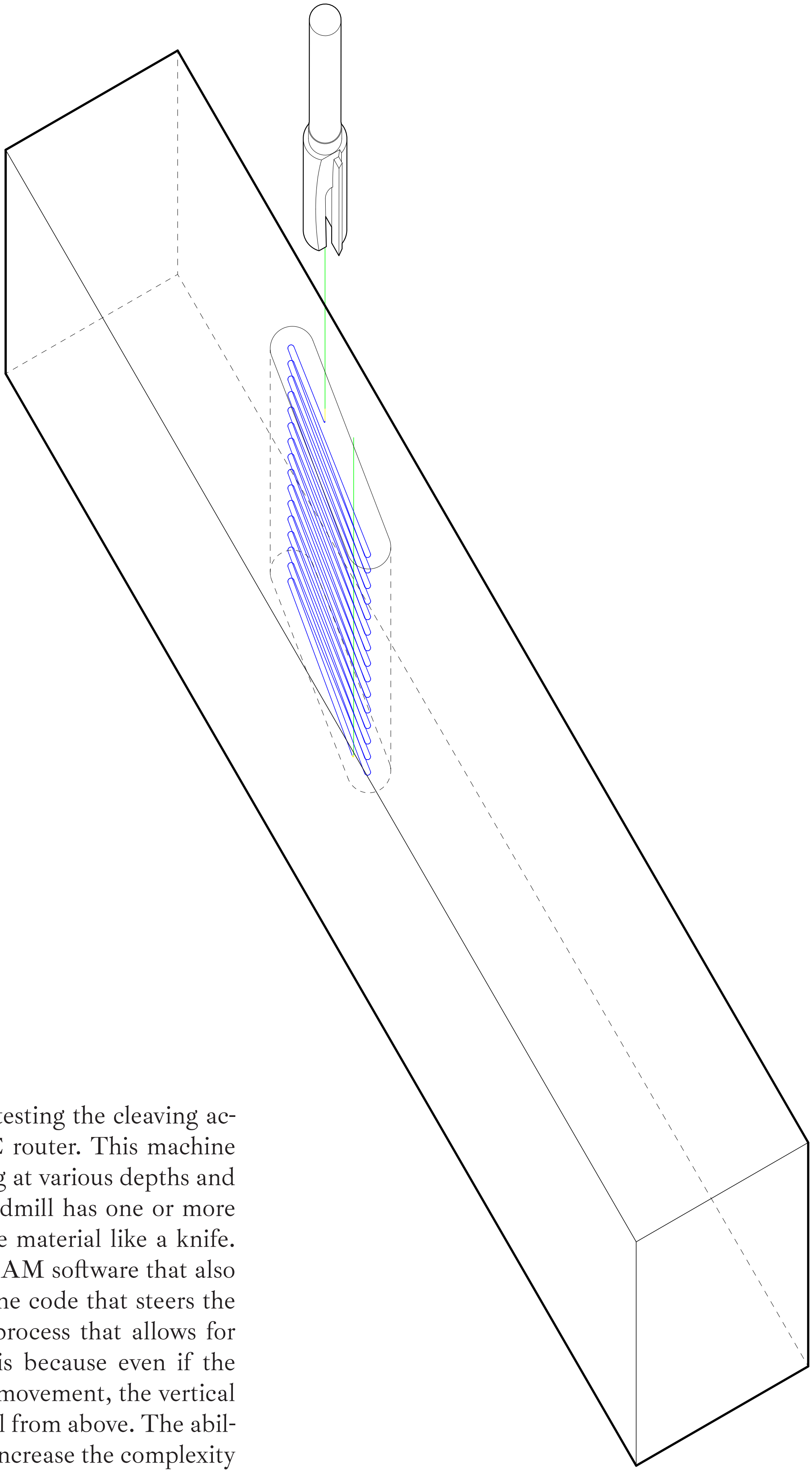


A Diagram that shows the various 3D aspects
of non-through hole pocket design

Design research

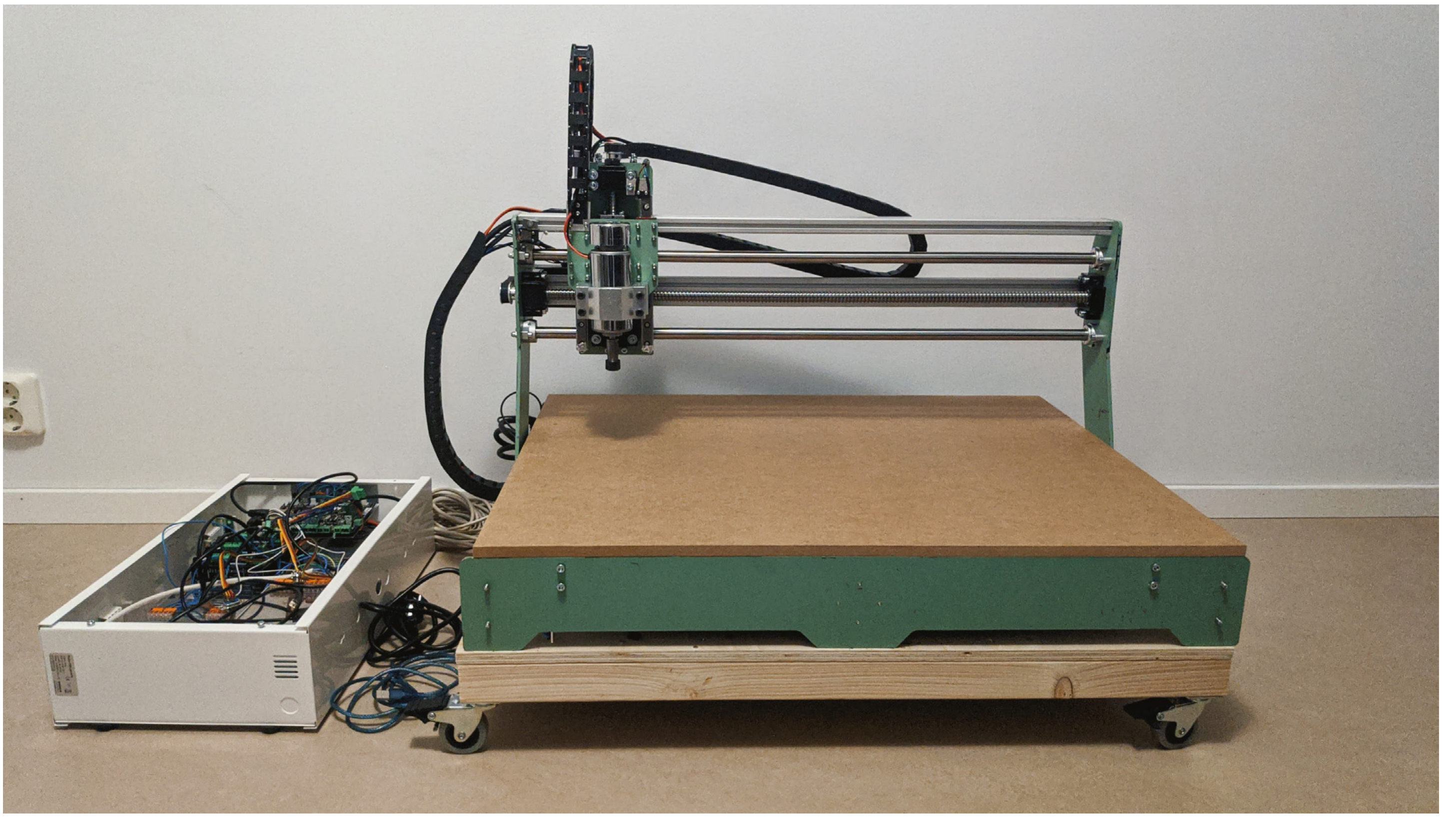


Tool: 8mm Straight shank bit
Cut speed: 2000mm/m
Spindle speed: 12000RPM
Depth of cut: 2mm
Toolpath length: 1167.31MM
Material removed: 9751.67MM/3
Work time: 3m34s



Fabrication process

The creation of the pockets for testing the cleaving action was done by use of a CNC router. This machine removes material through cutting at various depths and speed with an endmill. Each endmill has one or more sharp edges that cut through the material like a knife. The toolpath is created with a CAM software that also translates these lines into machine code that steers the machine. This is a subtractive process that allows for a 2.5 dimensional result. This is because even if the machine used three axises in its movement, the vertical endmill can only remove material from above. The ability to use a CNC router helped increase the complexity in the tests conducted by allowing for a higher precision in the cut as well as repeatability.



Above: CNC router that is used for physical testing
Bellow: The actual routing of a pocket for a

Test 1

Test 2

Test 3

Single Tests

Tests were produced based on the generation map and milled into single pieces of quarter sawn wood. The wood used had a ring structure of a quarter circle and that this could effect the cleave. Starting to test different shapes in wood quickly showed some limitations of this single piece testing methodology. The cleave was shown to follow the weakest path through the wood, and sometimes that did not include the path that was intended.

Single tests like this show that by only thinking locally the cleave will only be effected by the wood that is subtracted and the overall size. Thus the wood could cleave as intended until the cleave came to close to the edge it could simply break at that point. The dimensioning of the test pieces also are limited to the material available and the tools used for the milling. Depending of the intended break, sometimes the only change to the cleave was the amount of the wood that was cleaved. It could become that the only part that is altered was the milled section. In tests 8, 10, and 12 where the cleave is aligned vertically and the only change to the form is the part that is milled away. Test 7 shows what happens when natural variables such as a naturally formed knot in the wood, weakens that part of the test piece.

The study helped illustrate why single tests and localized thinking of cleaving does ***not*** work for creating complex and compelling geometries. A single joint could be designed such as in the second case study in the bench/roof joint with this method but to a limited, strict degree. A more integrated method is needed to alter the cleave through subtractive manufacturing. How can these typologies of curves be combined within a larger system to induce greater change while breaking is explored in the compound cleave section?

Test 4

Test 5

Test 6

Test 7

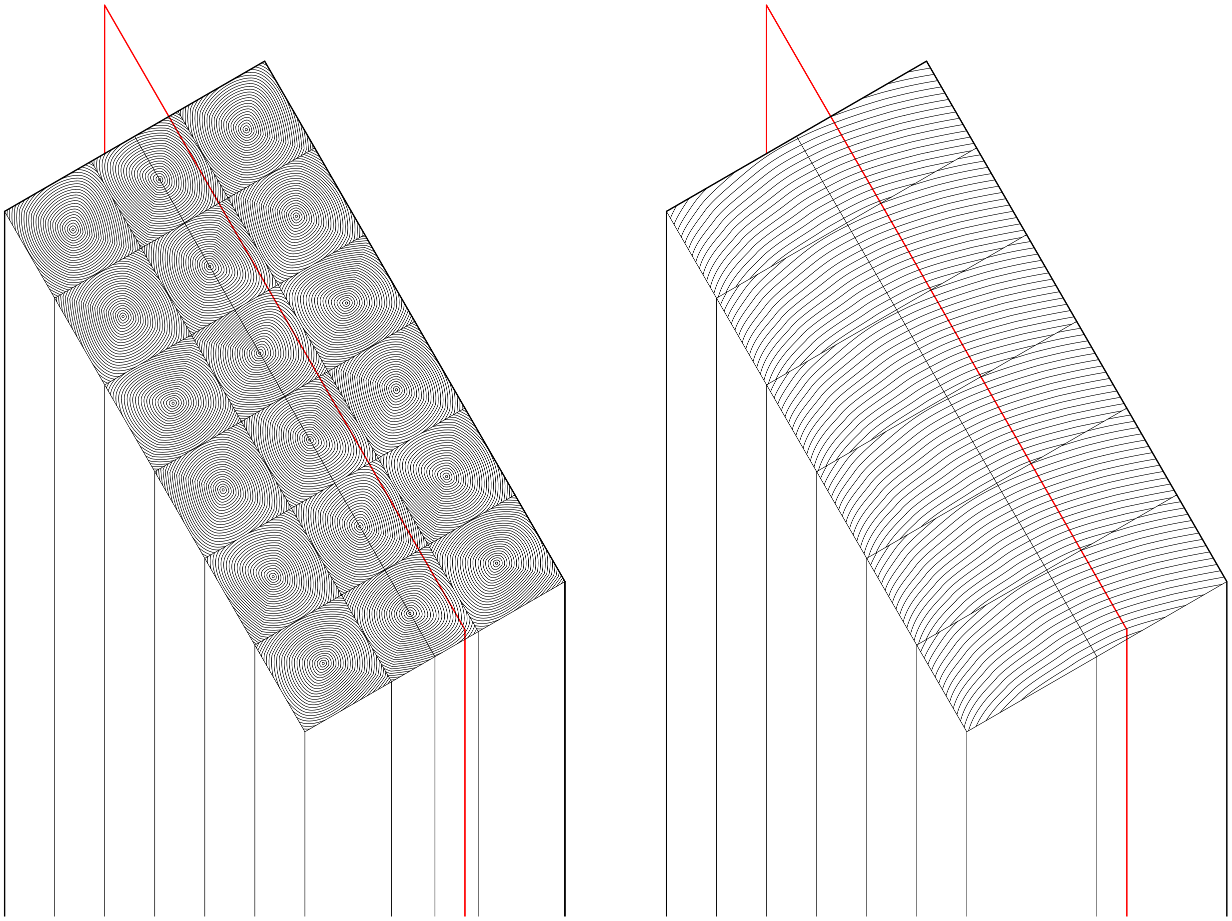
Test 8

Test 9

Test 10

Test 11

Test 12

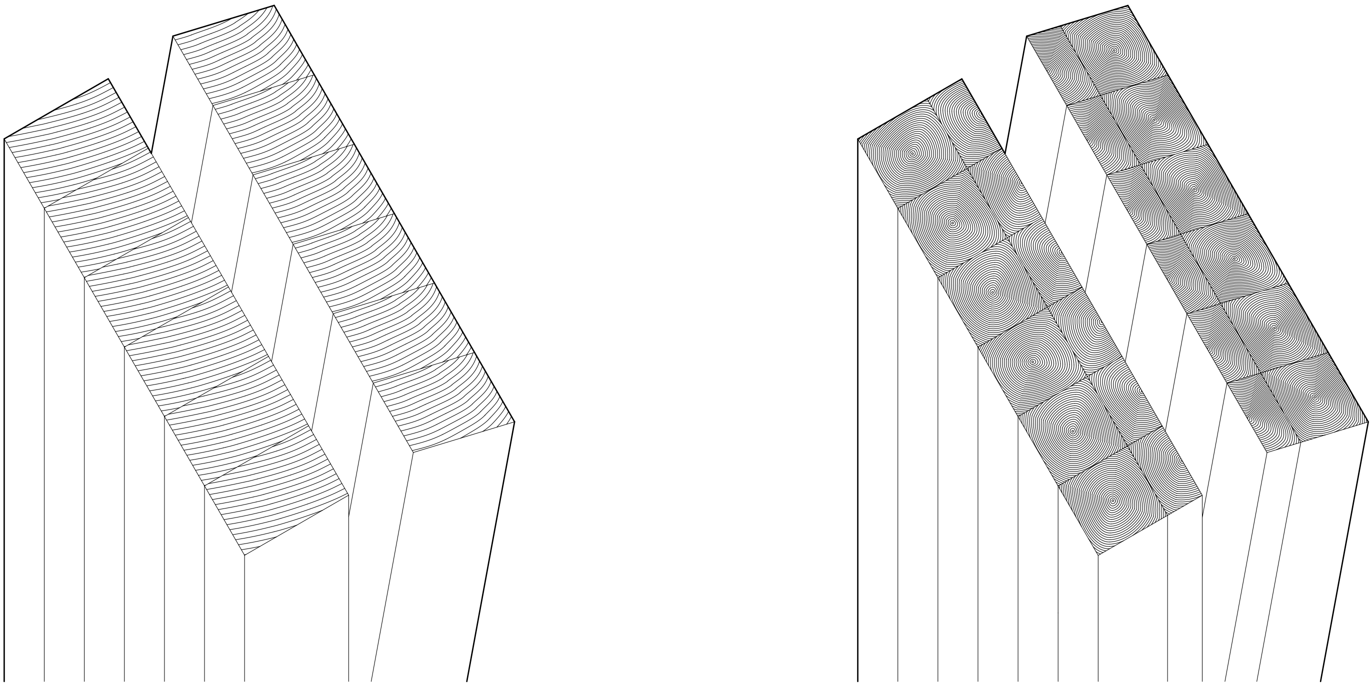


Combined method testing

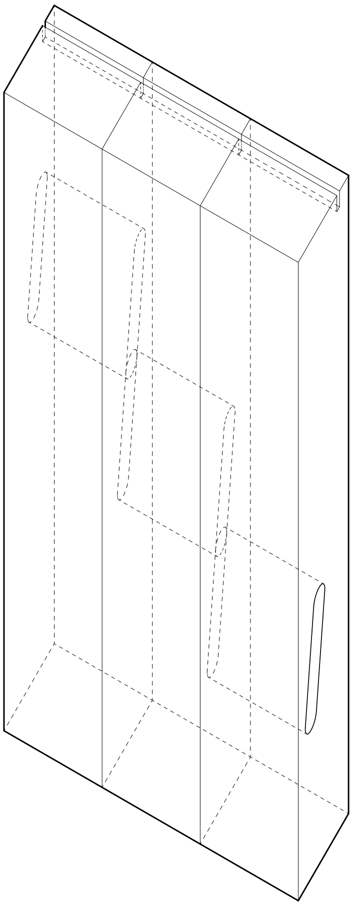
To increase the complexity as well as the possibility of being able to guide the cleave, a combined method was conceived. By stacking multiple pieces of wood, a composite structure was created. This expanded the thought process of both the scale as well as the possibilities of programing more information pre-cleaving.

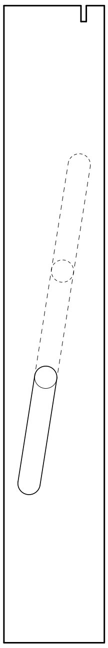
As shown in the diagrams above, the composite structure works similarly as a stack of logs that are split down their centers. By increasing the overall number logs, we introduce more complexity into the system. Every piece of wood, log or lumber is unique. The way the cleave propagates through the wood is also unique. This added complexity is visible in the result post cleave. The wood splits individually but together; showing the slight variance of grain structure among the seemingly identical pieces.

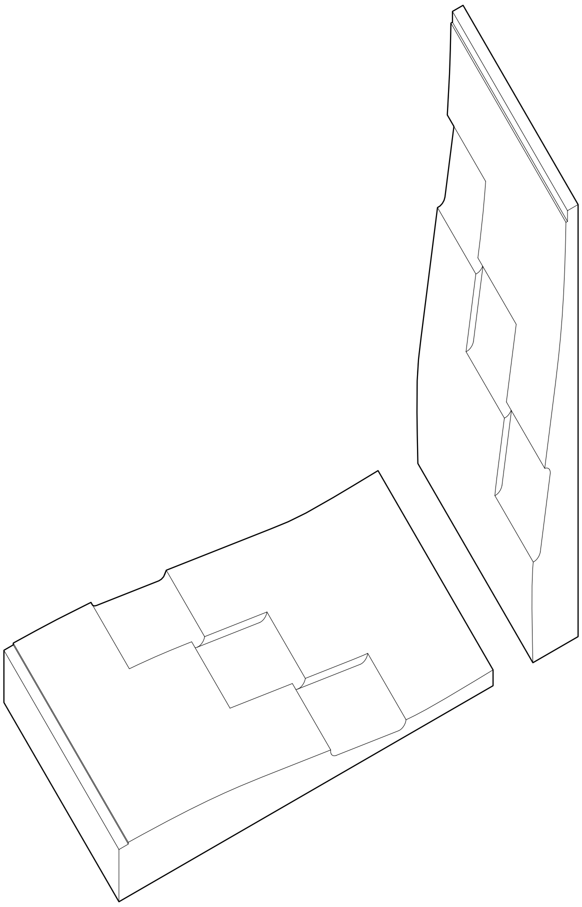
By altering the individual pieces by milling pockets and then stacking them in succession, data of the cleave is programed into the solid block. This allows for the creation of complex composite pieces that have predefined detailing within the structure on a fabrication level lower that what we traditionally tend to imagine. Having detailing physically baked into the production of the structure allows for more thought to go into the actual design and conception of what is possible with massive wooden structures.



Above: Line drawing of the differences but similar structures created by scale model
Bellow: Two models that show the resultant texture of the cleave in scale 1:20







Combined method test

To achieve the desired result of a diagonal break through the material, offset pockets where milled from the three pieces of material. Allowing the force from the cleave impact to follow the path of least resistance in the material, through the pockets. By offsetting the pockets, the total material removed from the wood is reduced. These could be strategically placed throughout a large block to alter the shape of the break.

The model shows the possibility of using a combination of pockets and wood pieces in designing the final architectural element. By being able to alter the path taken by the cleave, complexity can be then programed during production of the individual pieces. By allowing a block to be shipped ready to be cleaved with all the information baked into the overall structure through holes and paths cut into the pieces.

Unfortunately this was the only combined test that actually produced results that showed it was possible to move the direction of the cleave. The toolpath was generated in Fusion360 as a 2d adaptive operation as shown in the *Fabrication process*. The operation is used to cut with only one side of the cutting tool. Producing a cleaner cut and therefore a better finish to the part. It also allows for a constant helical downward movement during the cut which increases the efficiently of the cut and lowers the total work time.

Only successful combination scale test that moved the cleave using pockets

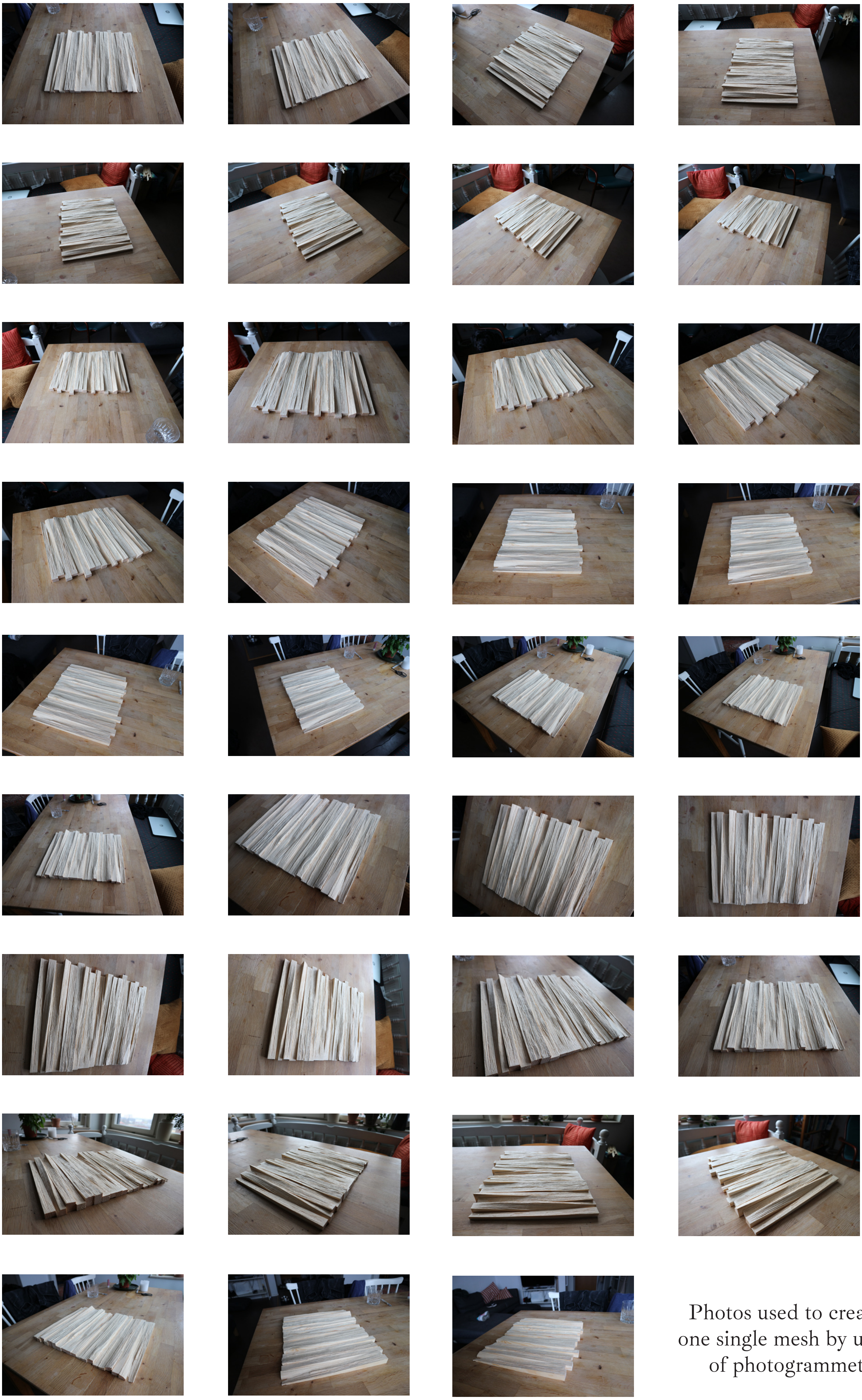
Photogrammetry

Photogrammetry uses computer algorithms to create three dimensional (3D) meshes through point triangulation. By inputting many photos of a stationary object, the software analysis each pixel and finds patterns that can help determine a specific points location in 3D space. Creating a mesh that then has color image applied through texturing. All the photos are merged onto a projected view of the mesh from all the determined camera views. The combined image is applied to the mesh to give a color rendition of the object studied.

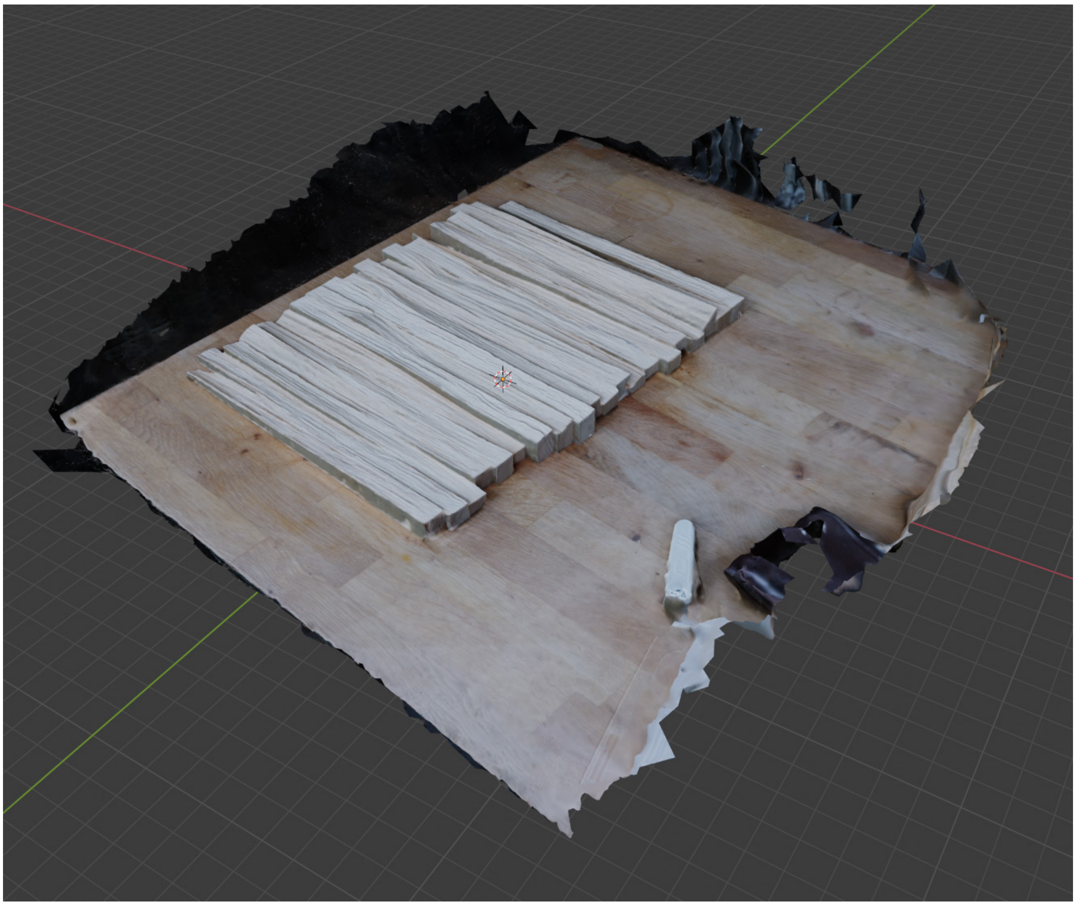
Many details must be taken into consideration while taking the initial photos. Taking good, clear photos with an even light helps by giving a higher fidelity and thus more data for the computer to calculate the points of the mesh. Photos should show the object from all sides as otherwise glitches or holes can appear where the computation could not create meaningful data for that space.

The method this thesis utilizes is having the chosen model on a flat table, and walking around taking photos every half step. Making sure to not stand as to cast a shadow over the object. It is a slow and tedious practice but this is necessary to produce a result that can be used in this thesis's scope. Once this is completed several close up photos where taken to try to increase the resolution of the final image textured onto the mesh.

Photogrammetry



Photos used to create one single mesh by use of photogrammetry

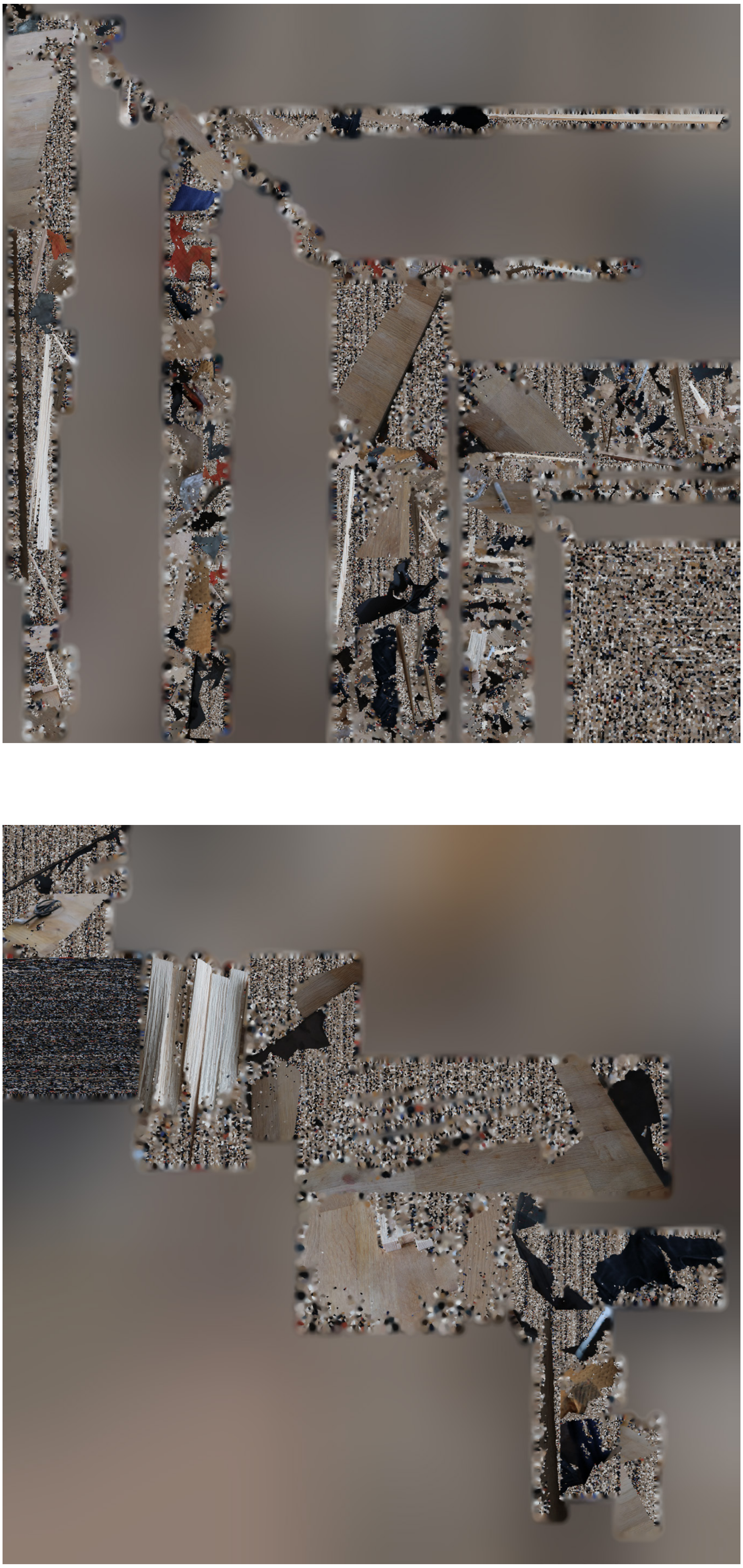


Photogrammetry

The photos are then analyzed by 3DF ZEPHYR, a software that automatically calculates and produces the textured mesh. Above is a screengrab from the software showing the extent of the created model. As can be seen, the software creates more model then is intended. This background is created as the software cannot differentiate the intended model and other objects that are in focus of the photo. Trimming this away is a simple enough process though, so its more of a temporary artifact of the process then a problem.

Ideally a textured mesh should have a resulting image texture that looks roughly similar to a flattened or unrolled surface. As the two images to the right show, this is not the case with the mesh above. Some parts can be compared and found in the mesh, but the extreme majority is a discombobulated mess of random triangles of color in no discernible pattern. Large blurry areas are also found. This is purely excessive information that only adds to the size and difficulty of rendering the mesh. Each image has a size of 8160 x 8160 pixels, but almost 50% is taken up by data that is not used in the resulting render of the mesh.

Two methods are developed in this thesis to better handle the information of the photogrammetry produced mesh. 2D texturing, and 3d retopologizing.



The resultant texture maps direct from the photogrammetry software. 8160 x 8160px in size

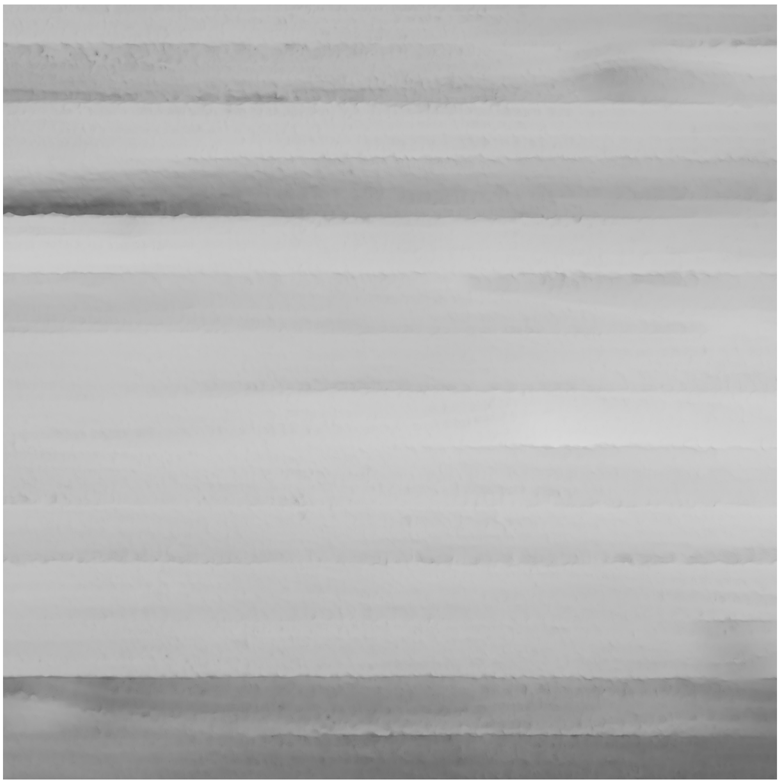
Color map

Texture - 2D

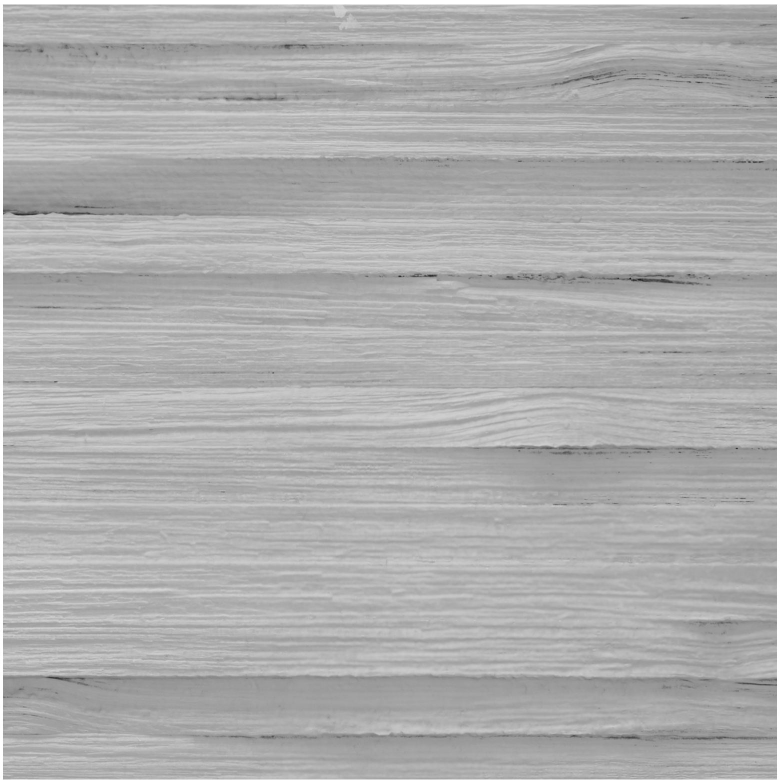
To create photo-realistic digital representation, relying on using textures of materials in a renderer. These are flat images that allow the renderer to recreate materials based on digital information in the form of either a value between 0 and 255, or a value that represents the direction of a vector (Normal map).

The 3d model that was created with photogrammetry to create these textures. The color map above is basically an orthographically render of the mesh itself. If only this was used, a flat surface with no distinguishable features would render out. By changing the render to black and white, a fake roughness map can be produced. A Roughness map gives value to every pixel of how much light it should reflect. This has an effect on the glossiness and overall appearance of the final surface. Causing the render to still be flat, but it would have varying degrees of glossiness and matteness. Finally a displacement map was made by assigning the model a texture that has black as the lowest point in the Z direction and white as the highest. A displacement map of the texture which corresponds to an actual change to the render mesh. The whiter the pixel, the more the mesh is moved in relation to its original plane.

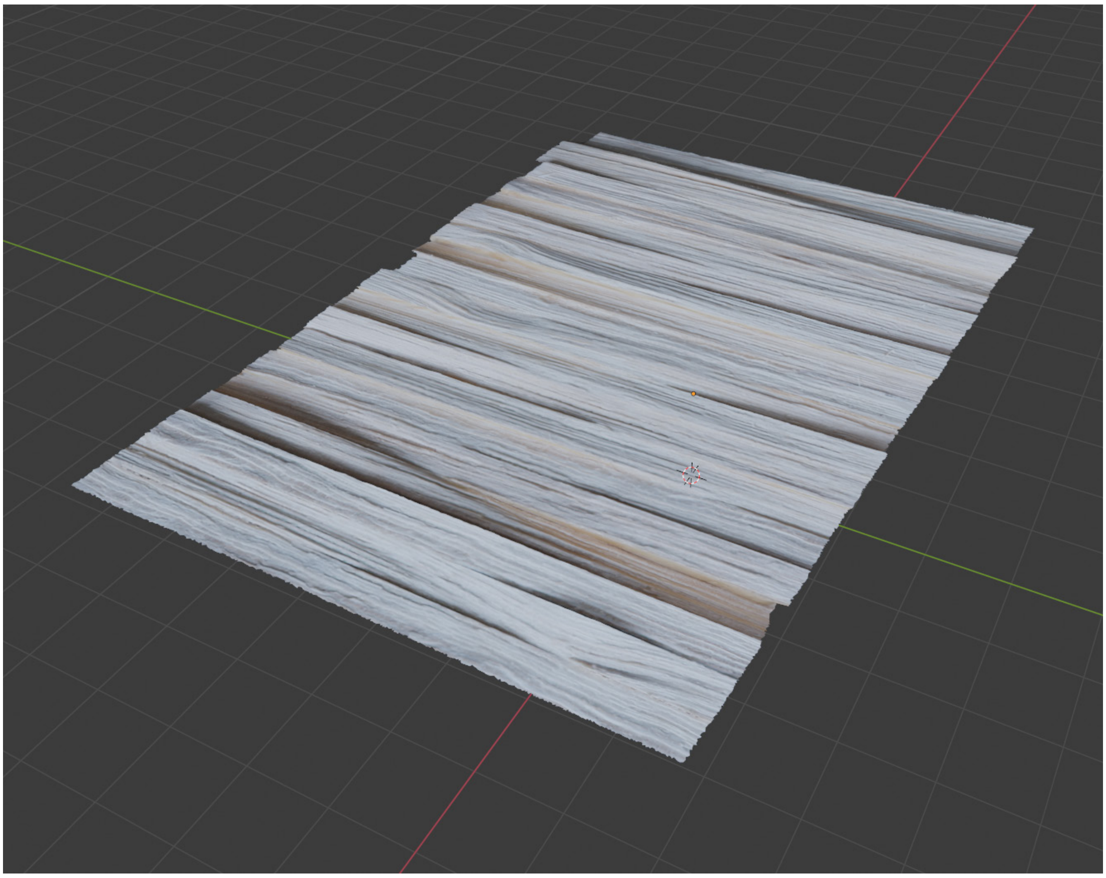
Unfortunately a lot of information from the original mesh is lost during this process. The fine grain and texture of the cleave lose their sharpness, it becomes plastic. This unnatural feeling is hard to overcome with this method, not giving the cleaved wood the fidelity it requires. It is thusly deemed not usable in the thesis.



Displacement map



Roughness map



Screengrab of the finalized texture in blender

Texture - 3D retopologize

Why “fake” a texture? The information is all there. By using a mesh to generate 2d data, then truncating the data generated during the photogrammetry process. Why not just use the mesh?

Meshes can be messy. As shown in the photogrammetry section, a mesh generated by this process typically has its texture which bears little resemblance to the resulting mesh. Thus is it necessary to retopologize and rebake the texture.

By retopologizing the mesh, the mesh veracities are averaged together to give a much lower resolution mesh, but which contains the most important data. This allows a substantial reduction in the number of vertcies which in turn reduces the amount of computing power is required to work with the meshes themselves. After the new mesh is created, the image must be baked (rendered) onto the new surface. This allows for the image to be wrapped in a way that is much more legible to us. The resulting image texture to the right shows the increased legibility of this process.

This method allows for the retention of data with more fidelity than a typical 2d texture. This complexity allows for a more direct representation of a given physical material yet also allows for a computationally light render. By using this method, I was able to recreate a large model with a material and textural fidelity of an actual physical model. Yet still able to use the model in the creation of various forms of architectural representation.

Color map of mesh to the left. Retopologized

Photos of cleave test: 126
Photogammetry scan: 294433 mesh faces
Reduced wireframe mesh: 26589 mesh faces

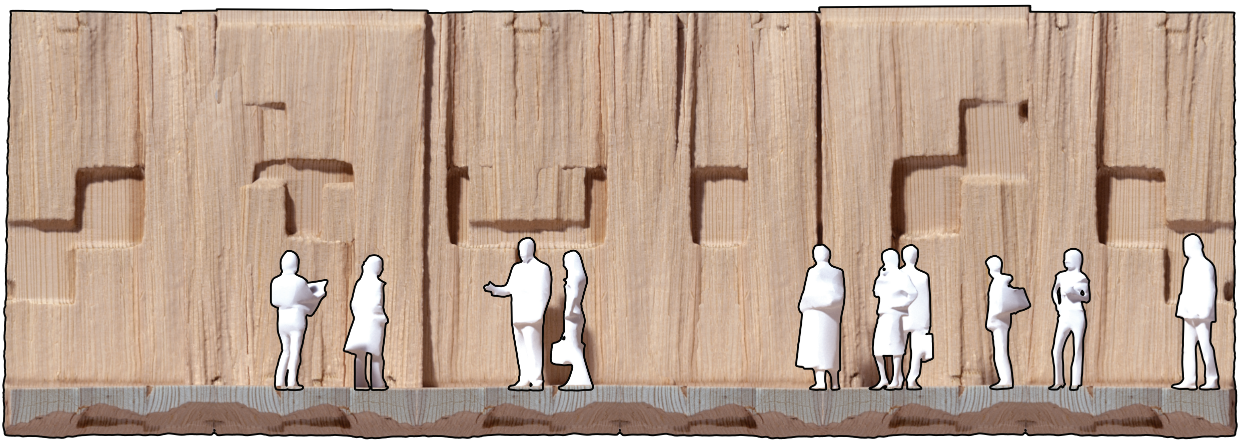
Post-digital workflow

By utilizing photogrammetry as a digitization method, the result of the cleaved tests can be easier utilized to create digital representations. This axonometric view shows a version of the mesh with an overlay of mesh edges that shows the variable density of the model. The amount of data produced is on the order of hundreds of thousands of mesh faces and is reduced to show the varing density over the model. This information also includes countless *glitches* that add a purely digital signature to the model.

Embedded information in the post-digital world is the digital equivalent to the impression of wood found in cast concrete.

By utilizing this model, representations of hallways using a cleaved method are produced. The various pockets that moved the cleaving action are left as remnants of its production. These are then given more data and their use becomes apparent as details in physical space.

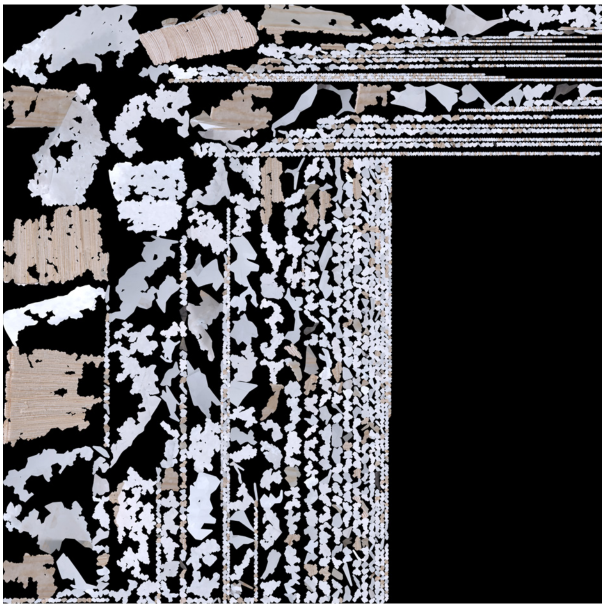
Axonometric view of potential hallway

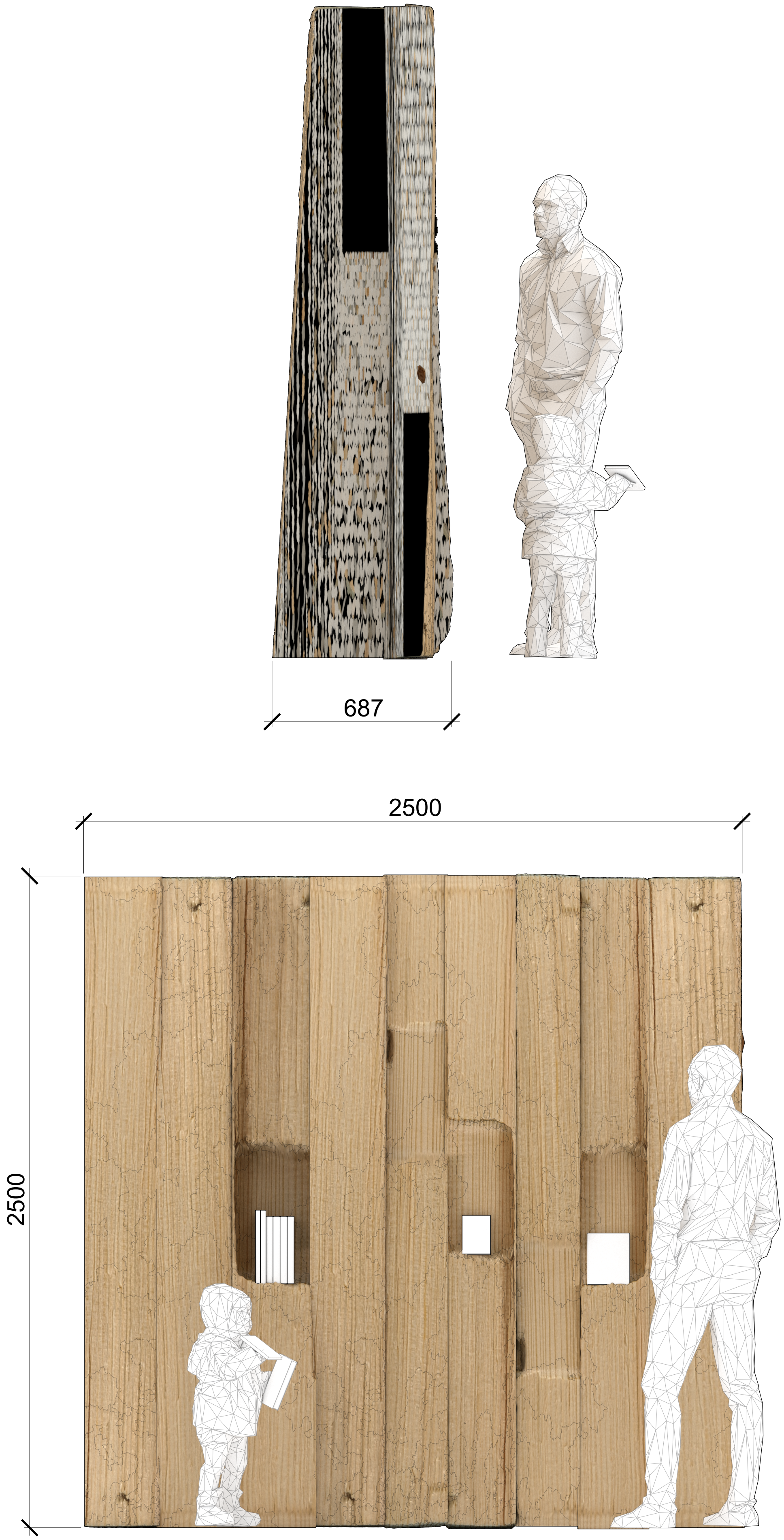


Elevation of potential hallway

Mesh manipulation

Further design studies incorporated the use of photogrammetry produced meshes as a design tool in the digital world. This included scaling, trimming, reduction, and other forms to mesh alterations as tools to create new objects. Careful consideration was needed while altering the meshes as it was easy to destroy the information required for the texturing of the mesh to function properly. This caused errors during the rendering of the object. The information is lost due to the mesh changing and a separate file that stores the texture color data does not correlate anymore with the perceived mesh.





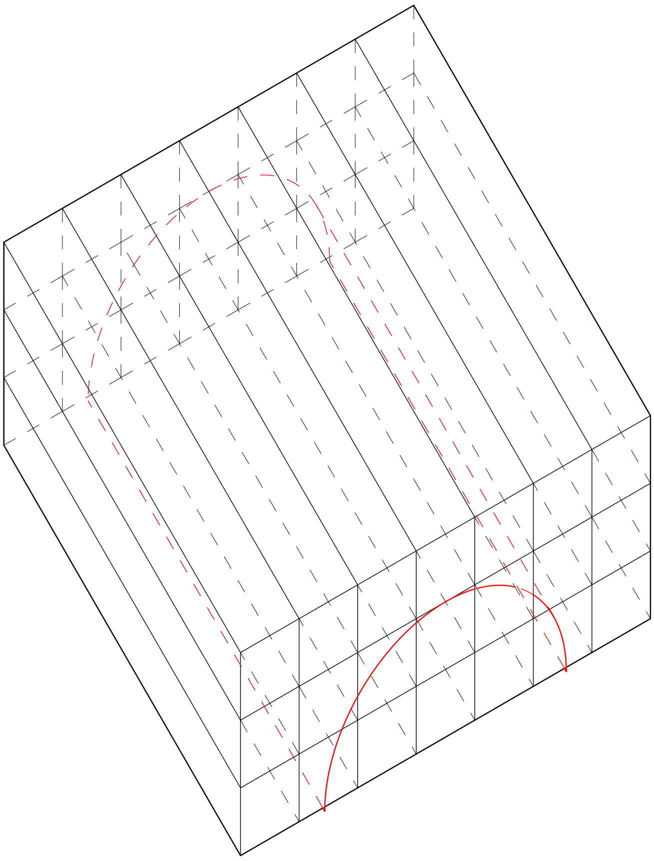
Elevation studies of a cleaved bookshelf

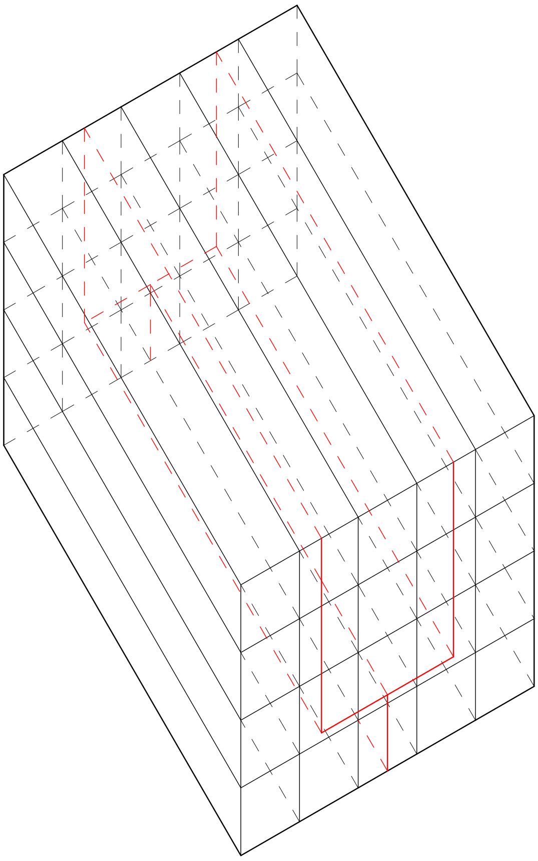
Mesh manipulation

Design research

Mesh manipulation

A podium and a bench to be used in the second design application . Both created by manipulating a raw photogrammetry mesh.





Case study 1.1
Human-material scale

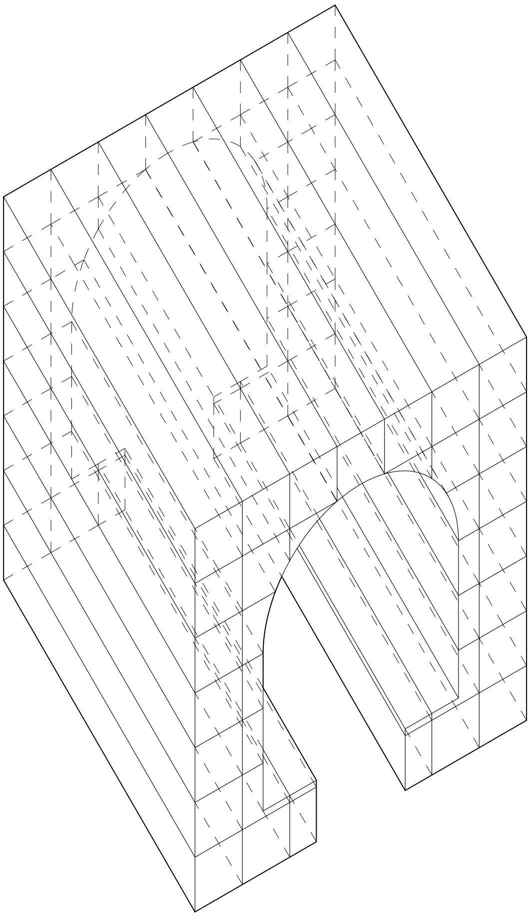
This case study looks at the human+material interaction as well as the interior scale detailing required for construction. Can this fabrication technique be useful as a way to create interesting interiors and experiences where texture is held in very high regard? A fake digital cleave representation was also tested as a way to create a comparison from these digital renders and those of earlier tests. This noisy displacement map attempted to create the subtitles of a cleaved surface but further pushes the point of using photogrammetry as a method of capturing this texture

The three chosen architectural objects are:

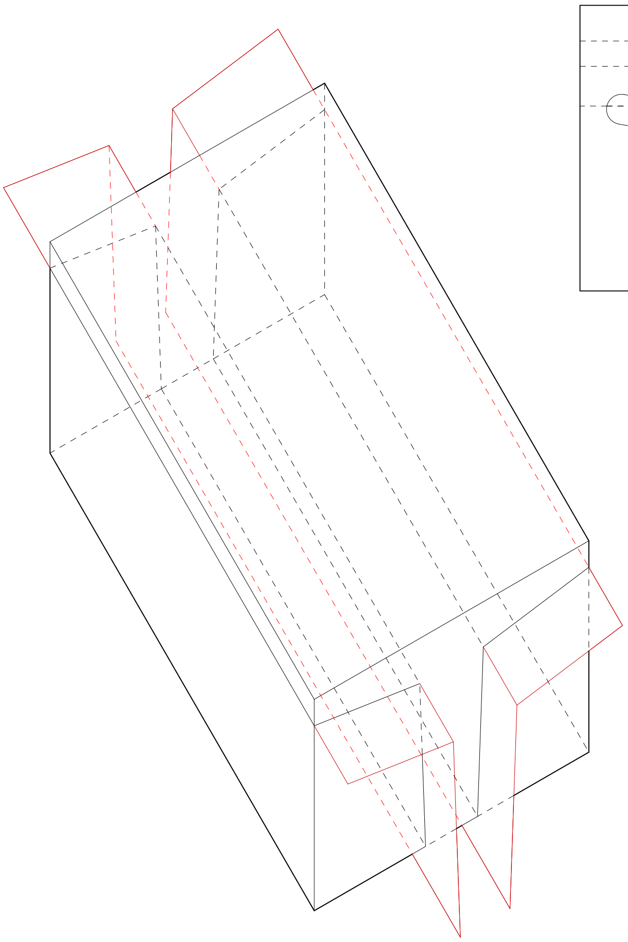
Seating booth
Chair and table set
Bar

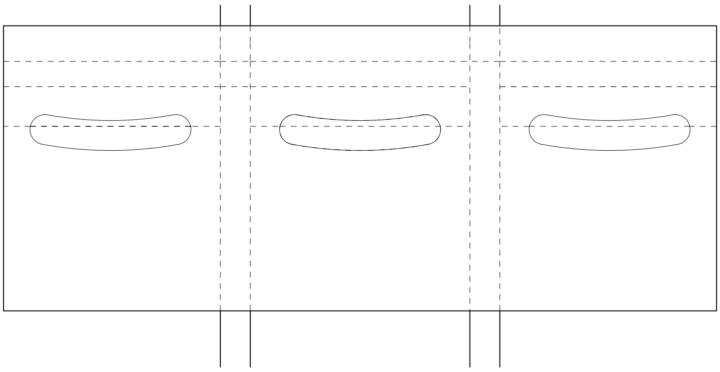
Goals:

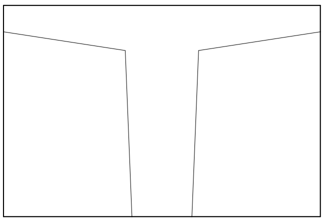
Human+Material Interaction
High precision detail fabrication

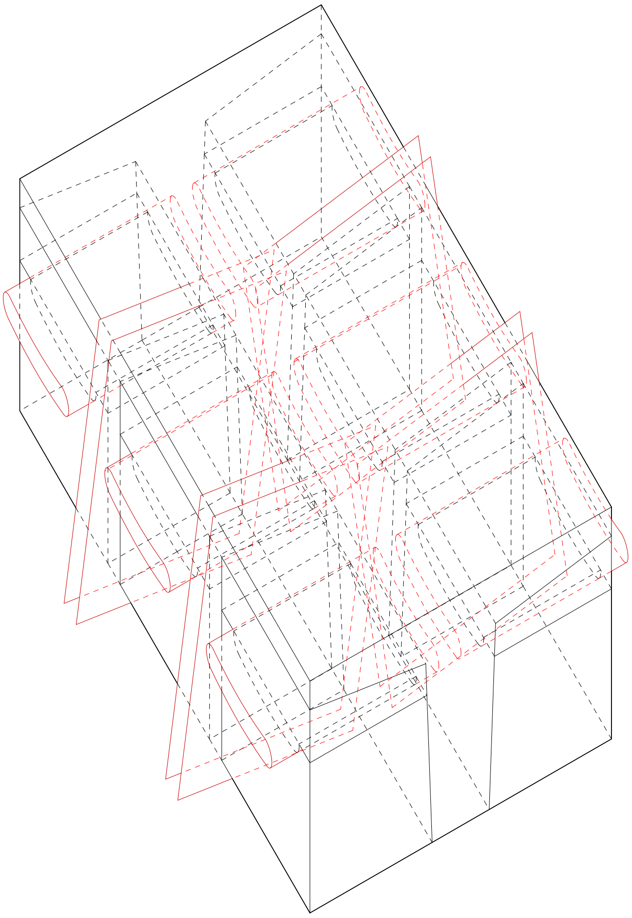


Render over the seating booth in cast study 1.1





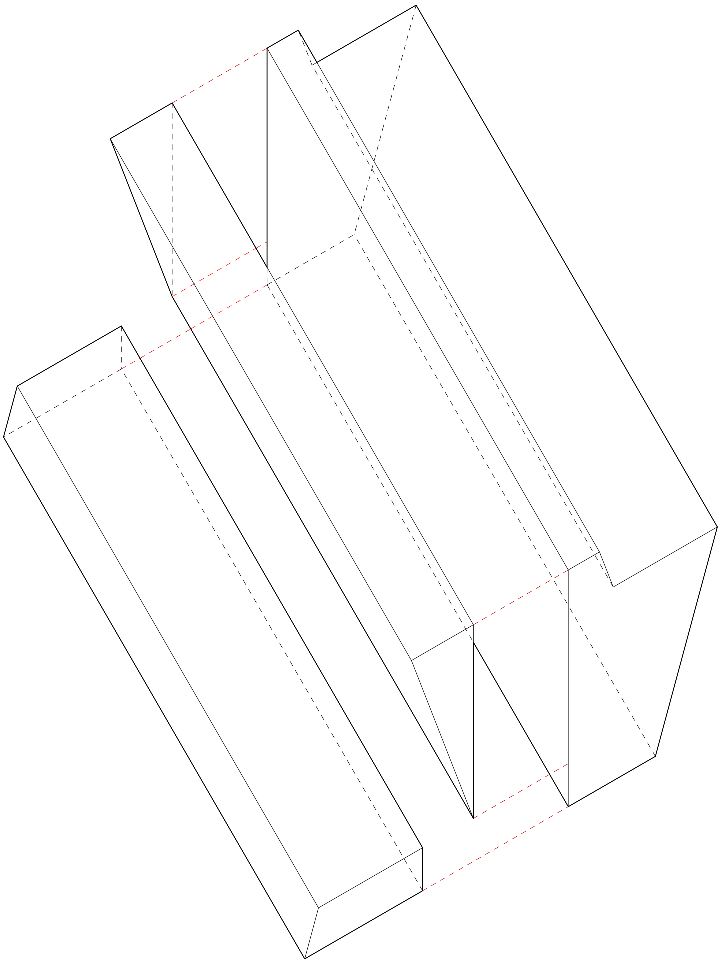


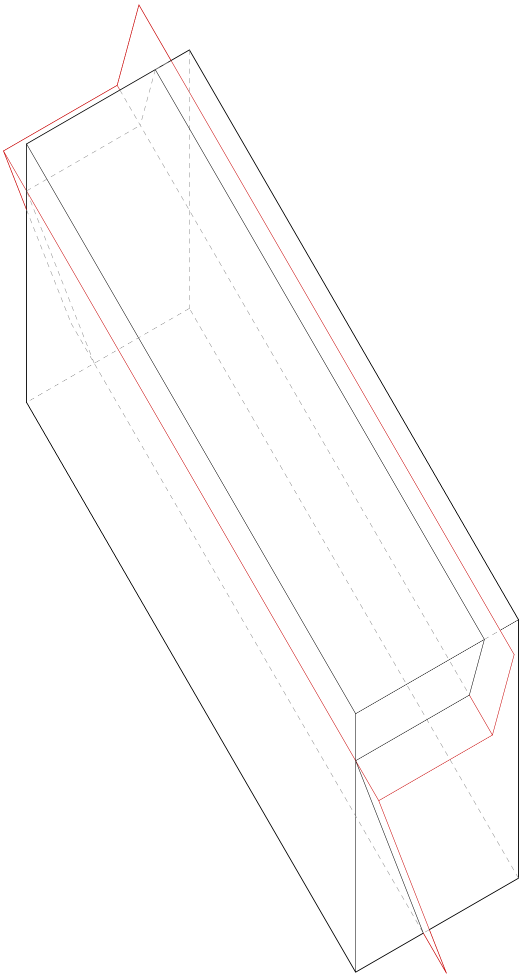


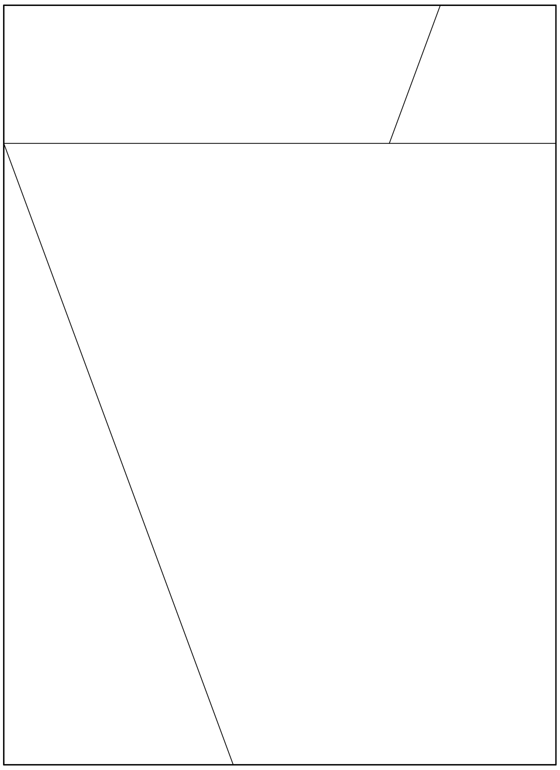
Case study 1.2
Human-material scale

The booth and the chair and table set show little in common in their fabrication processes. The booth is fairly straight forward with only the attempt of a curved inner roof that gives any indication of programed alterations of the cleave. The chair and table set are more interesting as the human interface with the chair is milled. This gives a third possible texture to the rest of the table and increases the complexity of the pre-cleaved part.

Render over the seating group in cast study 1.2



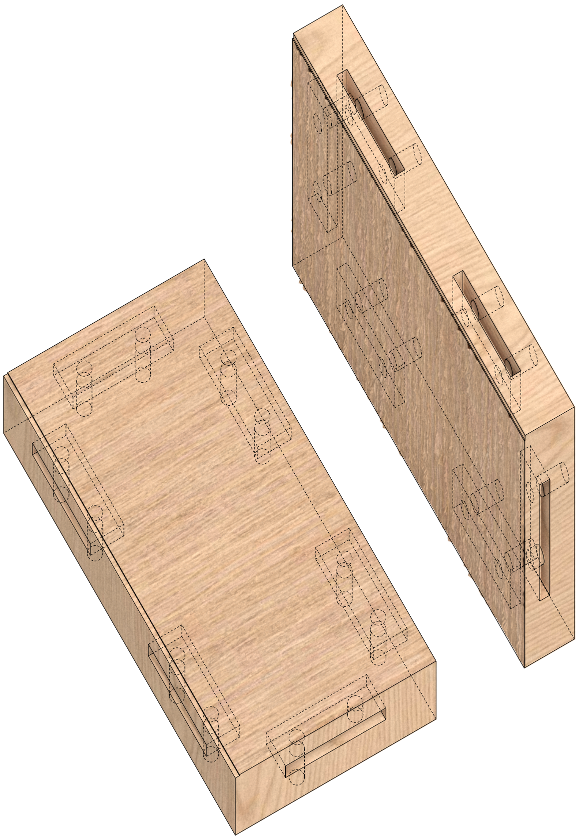


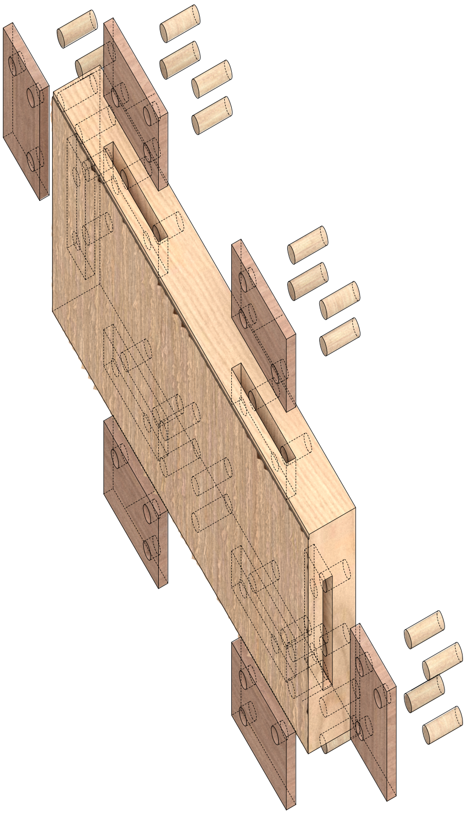


Case study 1.3
Human-material scale

The bar shows promise as this is where there would be a high level of interaction between the patrons of the bar and the cleaved texture. The tactility of the cleaved surface would be reinforced by the slanted surface which would be riddled with pockets similar in the composite cleave test. These pockets could be used for many things such as lighting accents, storage for the patrons, and footholds while sitting. It would be interesting to further study the possibility of pre-fabricating such elements as plumping and electrical work pre-cleaving event.

Render over the bar in cast study 1.3



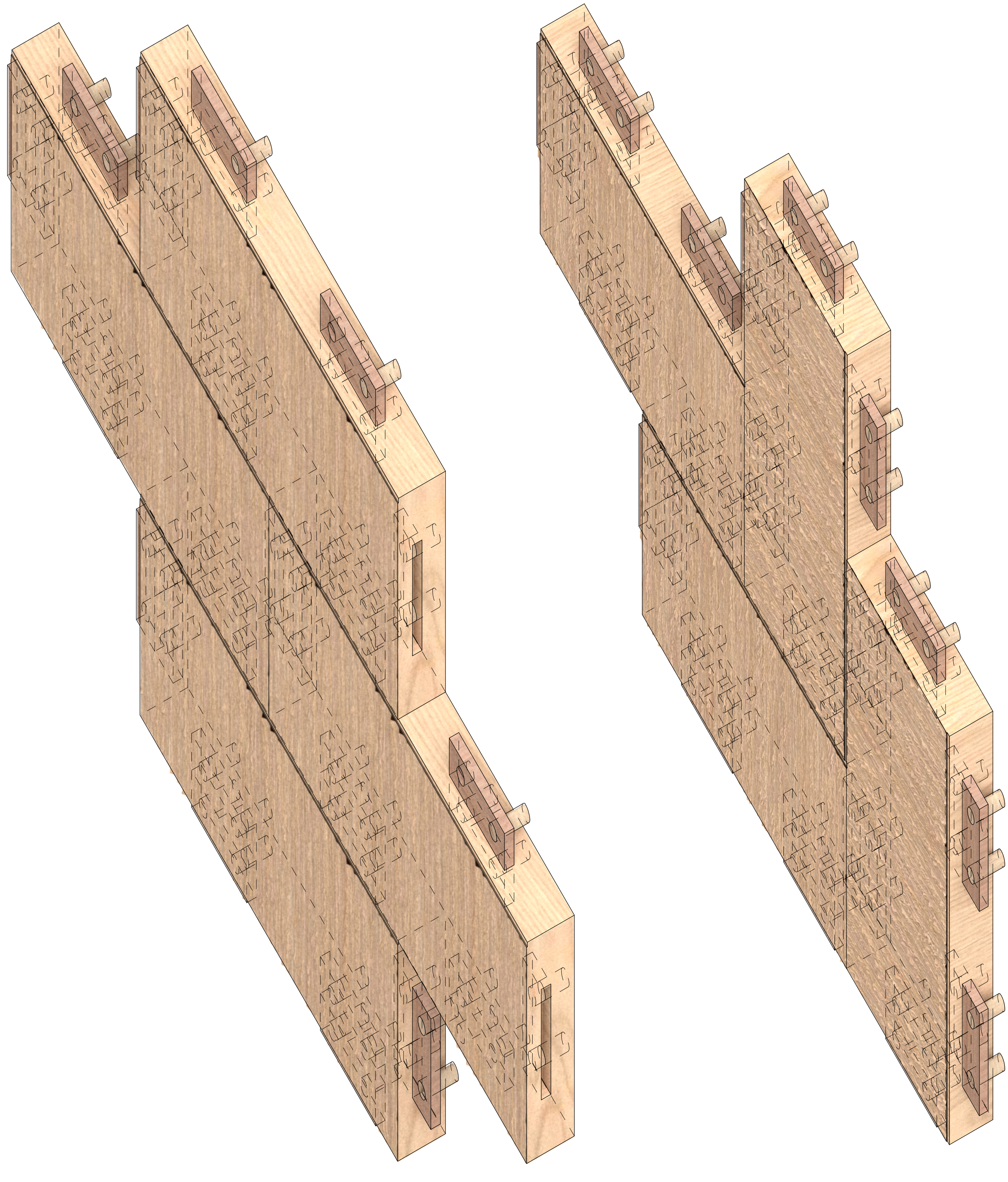


Modular system design

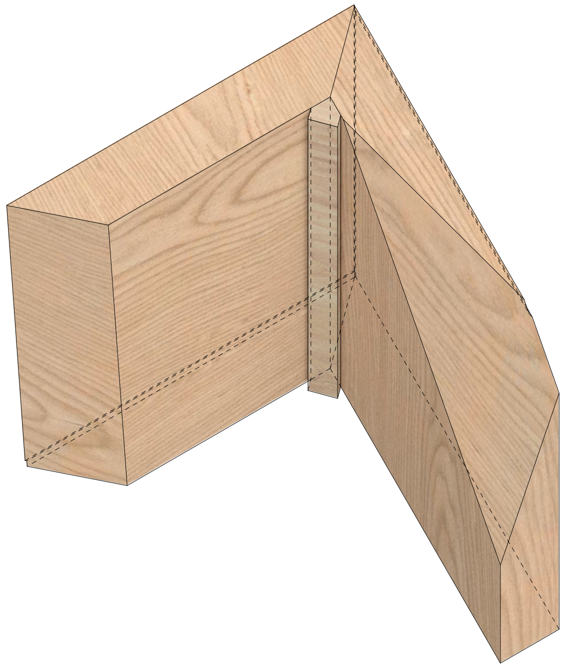
One likeness that emerged from the design process is the way that blocks of precleaved wood could be similar to precast concrete elements. The idea of building efficiently with the use of prefabricated elements is not new to the current building practice.

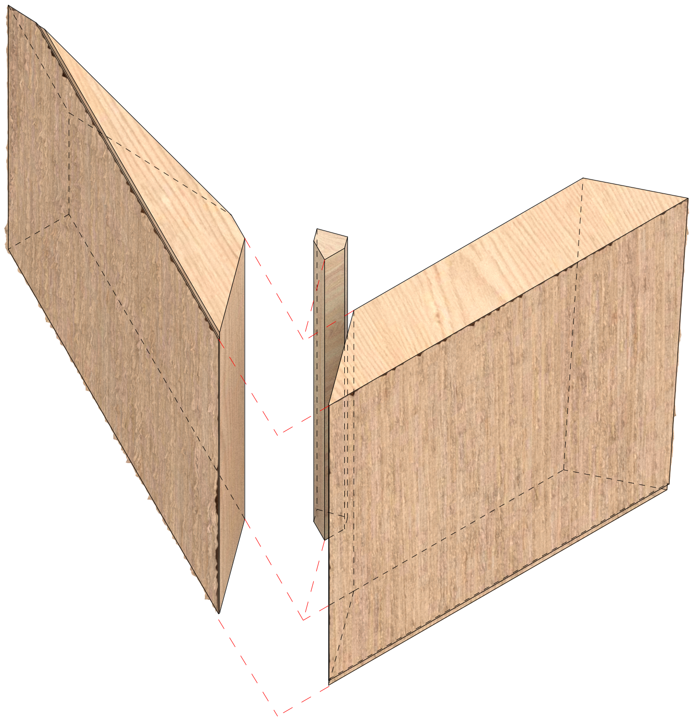
By envisioning a system of blocks, their size limited by standard logistical dimensions. These elements would be brought on site, cleaved and lifted by crane to be constructed into a building. Elements such as doorways, windows, and architectural details could be programed into the block of wood before its construction. By having a modular system, different ways of exposing the texture could be made. A hearing bone pattern found in wood floors is one such way, the alternating strips of cleaved texture would undulate across a facade diverting rain water in different directions.

The plugs and brackets used to connect the elements could be altered for different structural needs. By using different types of wood, varying structural needs could be met, these could include strength, rotational forces, and moisture inside the wood.



A peg and biscuit system used to connect larger walls of cleaved timber. Could be used as a prefab facade system.





Angular system design

To increase the complexity in a modular system, different ways to attaching the cleaved pieces together. By altering the shape by use of subtractive manufacturing, angles of future joints are programed into the wooden block. In the image to the right, we see the red lines which indicate cutplanes that could be used to slice away material from the block. The pieces could then be cleaved down the middle, and fastened together using a separate piece of wood. By allowing for a way of creating complex geometries in a bigger system. It could also be used to alter the direction of the cleaved wood when they are combined. An ability to change the direction and orientation of the cleaved wood could have physical as well as artist merit within the buildings facade.

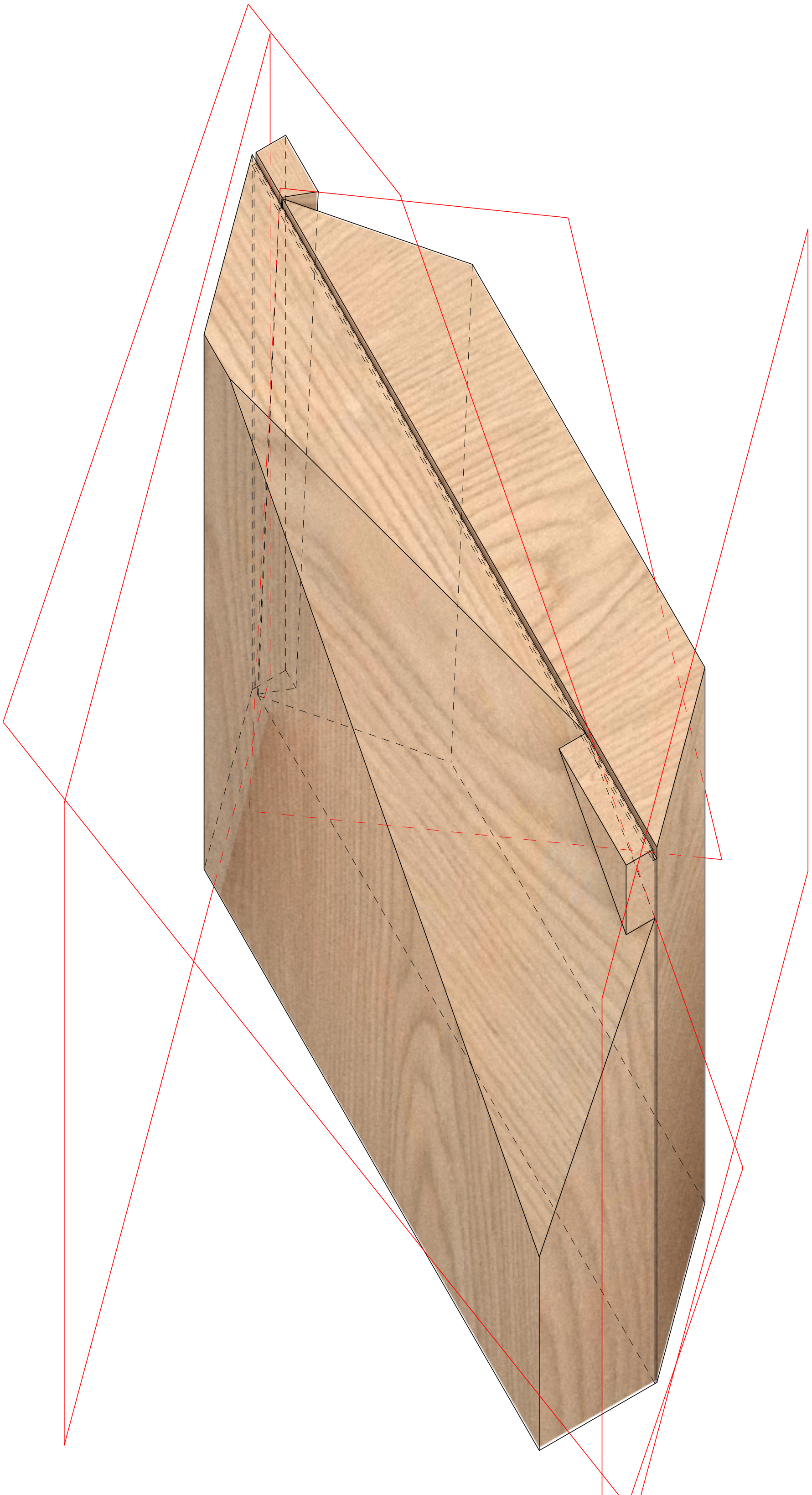
Joints

Parallel jointing between wood pieces to form the block:
To solve this issue in the test models, plugs and glue where used as the main joint build up. Creating a strong, solid joint that survives the breaking action. The method can be easily automated while the pieces are being milled.

Perpendicular joints between crossed pieces that build up the block:
While designing the large block it is inevitable that some perpendicular joints between wood pieces will happen. The method used in the preliminary testing has been to weaken the piece by removing material to allow for a break perpendicular to the cleaving action. This could be much more refined but does open possibilities to be designed in such a way that they could work as the construction joints

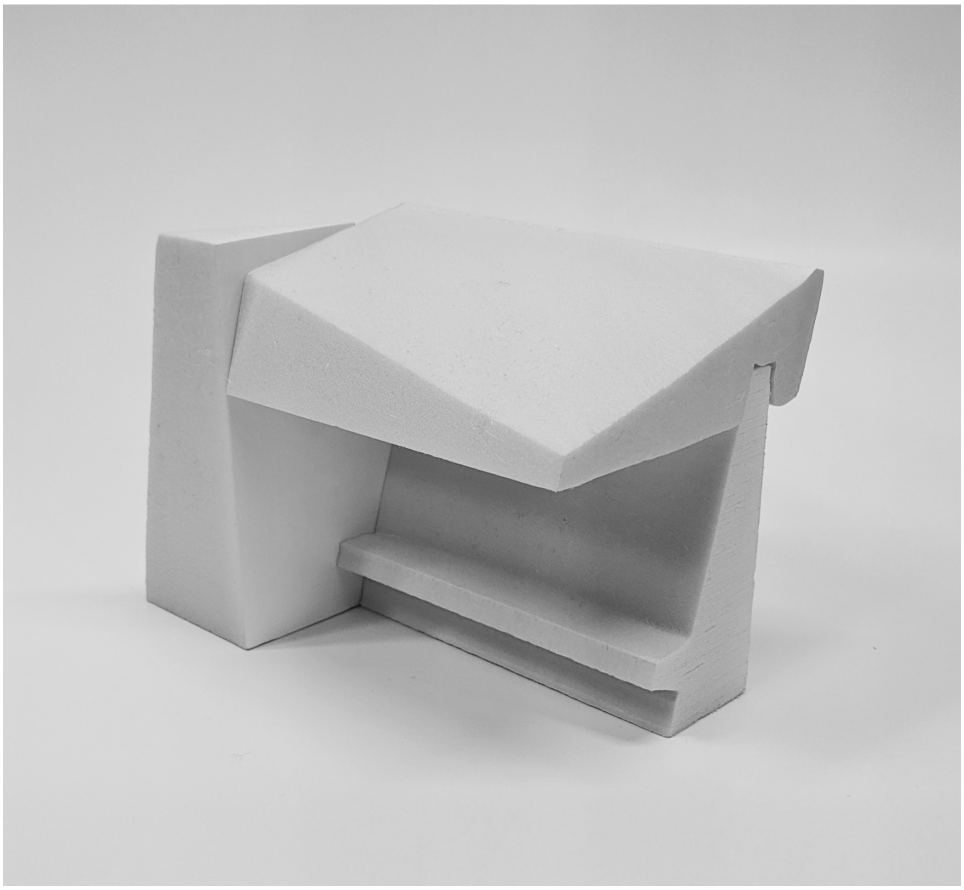
Construction Joints
The joints are structural in nature and deal with the meeting of the final cleaved pieces. They have yet to be developed but many styles of joints exist in the CLT-fabrication world. Various locking joints will be examined and tested but for vertical loads, conical joints allow for a precise and strong hold. The conical shape is similar to how CNC machines are able to change tools quickly and precisely.

How would one treat the inevitable end grain that still will exist?
Depending on the orientation of the end grain, various methods can be explored. For downward facing end grain, nothing is needed other then space to allow for adequate ventilation. For cuts into the wood, there are several current options. Burning or charring the wood can act as a barrier to moisture, as well as a sealing liquid can be used for this method. Design considerations will have to be developed to handle these and more issues for this method.



Angular cuts that show the ability of prefabrication techniques for creating individual pieces from one larger piece of timber

Design Application



Design application 1
Open air structure scale

The design study focuses on a small open air structure that studies a specific joint. The joint, a tapered meeting between a wall and roof structure will use a combination wooden structure comprised of four square logs that are milled separately then joined and cleaved. The idea is that the bench shape is milled and the negative piece will be designed to fit over the top of the wall piece. The design will also look at the one block, one structure idea as a means of fabrication and logistical challenges, as well as physical material properties of water resistance of the roof and wall.

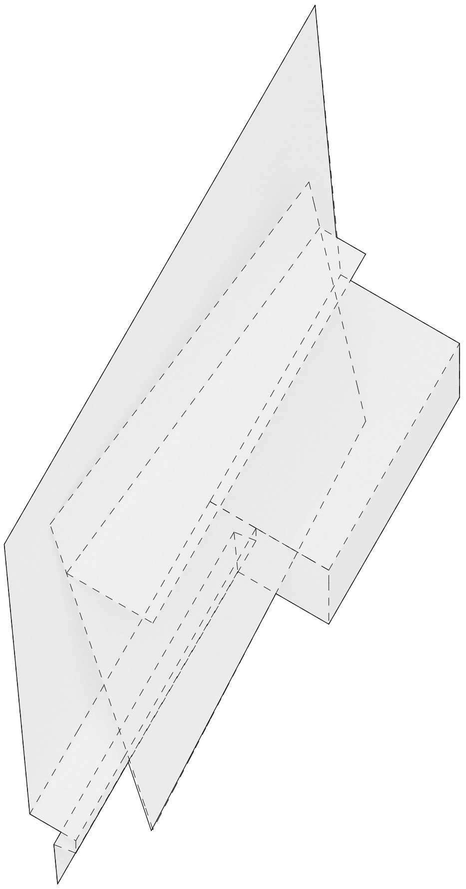
The bus stop was designed over several iterations of model testing. Foam models quickly allowed me to generate a volume analog of both the intended final design as well as the cutplanes needed to generate said shape.

The basis for the bus stop design was a joint that creates a positive and negative shape during the cleaving process. Creating the shape of the seat, as well as the negative shape in the roof piece that allows it to join with the seat/wall structure.

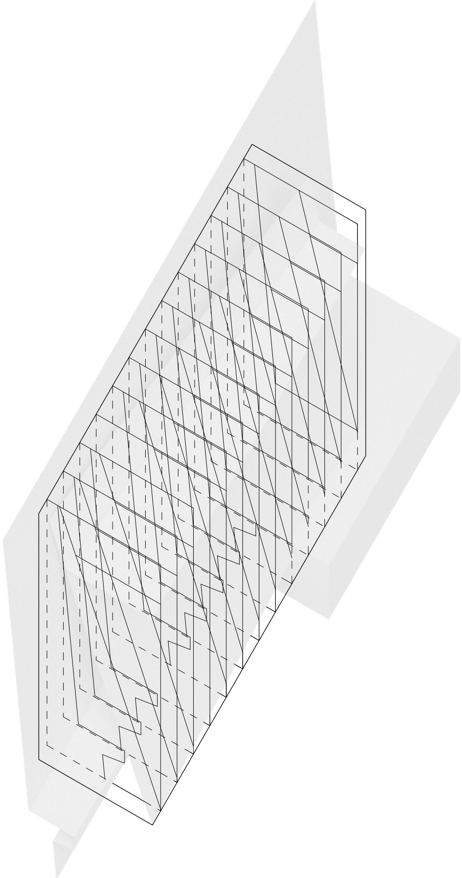
To generate the pockets used to create these diagonal cleaves, the cutplanes where intersected with a plane that represents the center of each wooden piece. Lines are then used to align a pocket within the segmented wooden block.

Goals:
Look at joint/interlocking pieces as a means of construction.

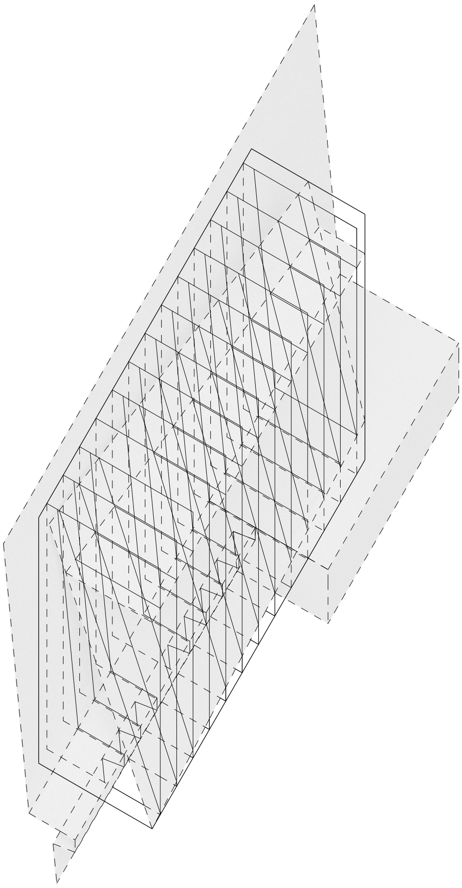
Study the resulting texture created by the cleaving process in combination of several pieces.



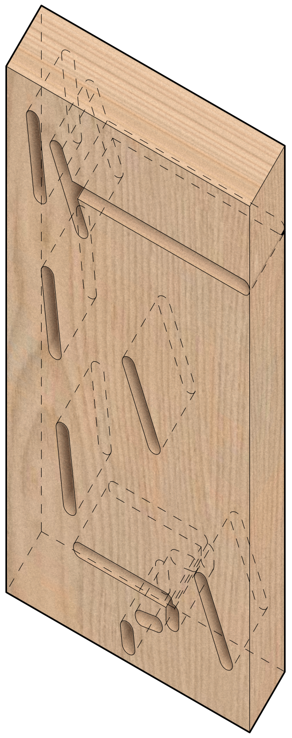
Cutplanes for the bus stop

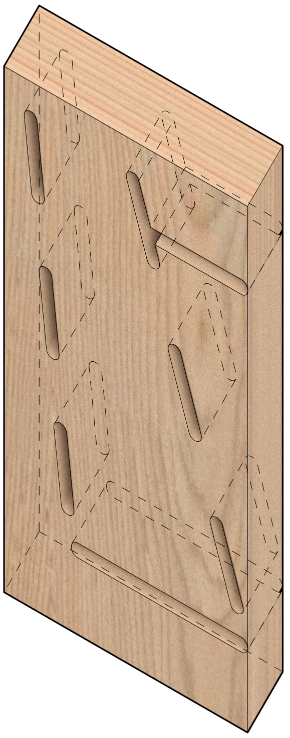


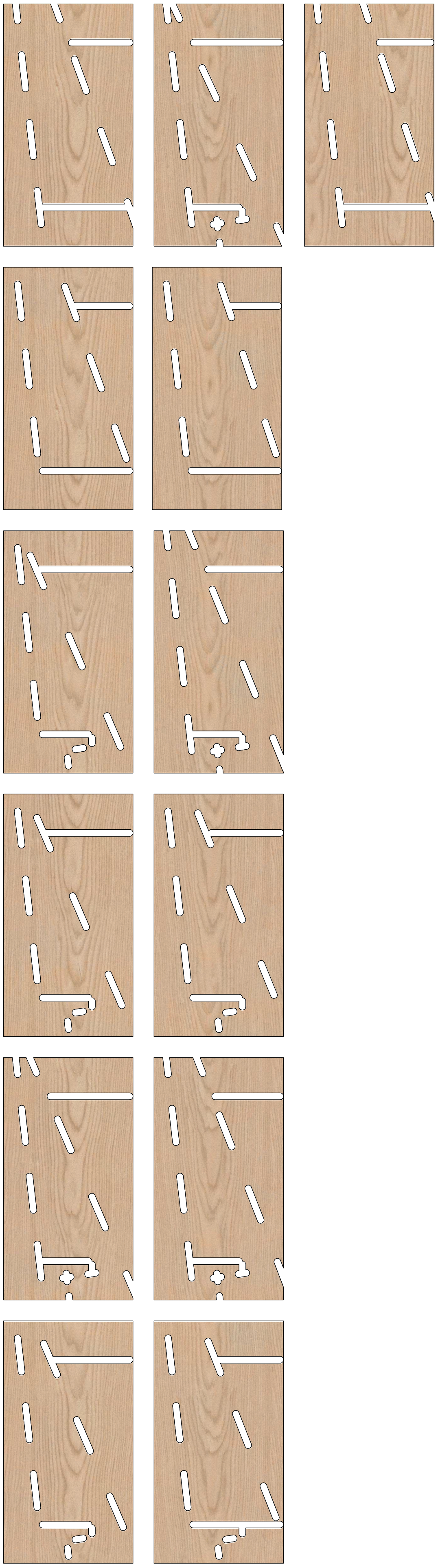
Intersection of wood pieces and cutplanes



Combined drawing showing all information







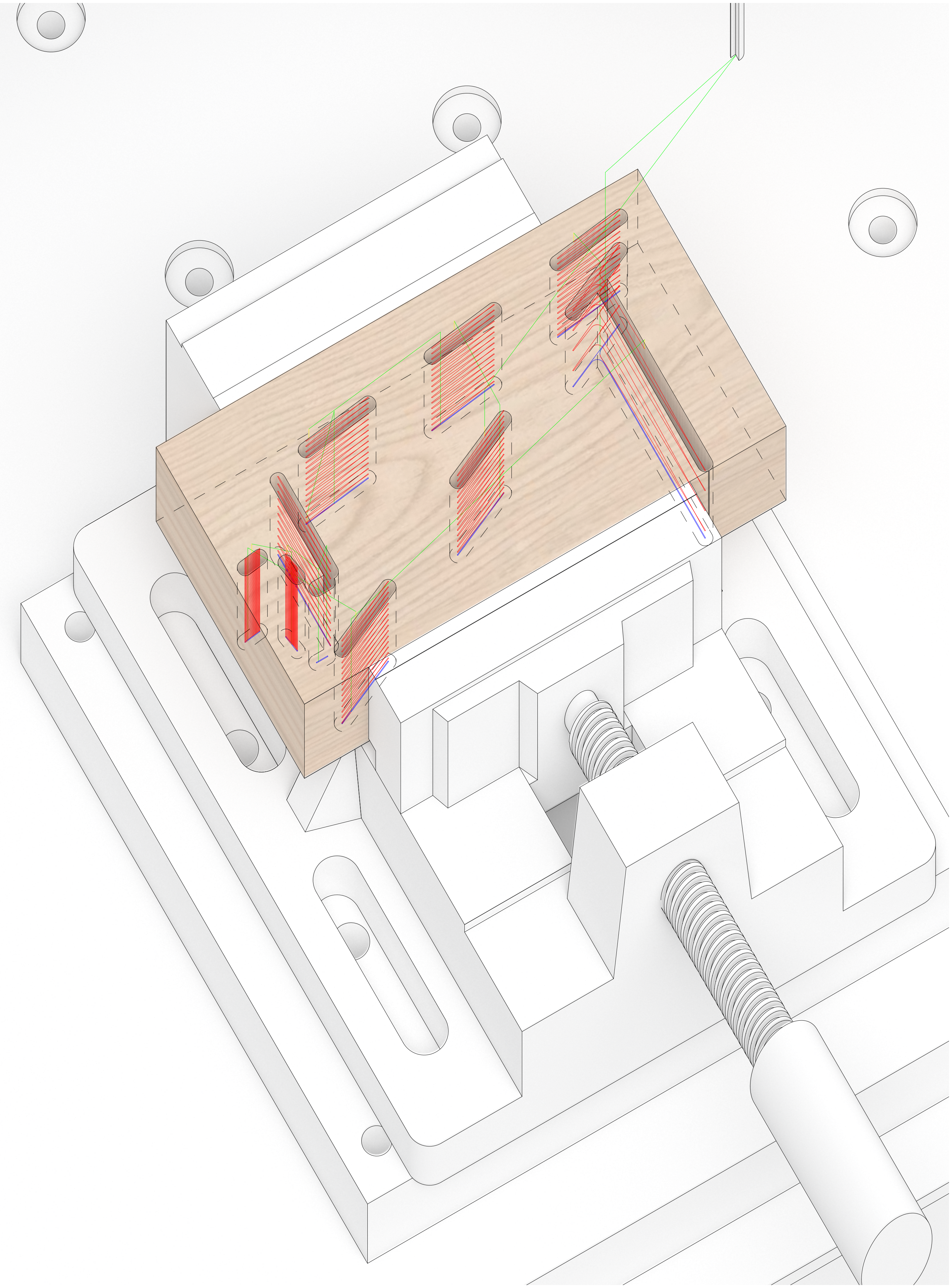
Design application

Design application 1
Open air structure scale
Model fabrication

To create the fabrication model a general method for visualizing and generating geometries needed to be created. By using planes that signify the direction of the cleaving action, they are intersected with each of the sub pieces of the large block. The resulting curves are then used as a base for the creation of pockets that are offset depending on whether the sub piece was located in an odd or even position within the large block. Allowing for a versatile system that allows for the creation of offset pockets such as in the first combined method test.

Scripts where applied to all cutplanes and the resulting geometries to the left are formed. Toolpaths are then generated for each piece and they are milled on the CNC router in a repeatable fixture. Comprised of a small vice and a stop piece that allows for the indexing of all wood pieces quickly and precisely.

Toolpath



Axonometric view of the toolpath for piece 1

Design application 1
Open air structure scale
Cleaving action

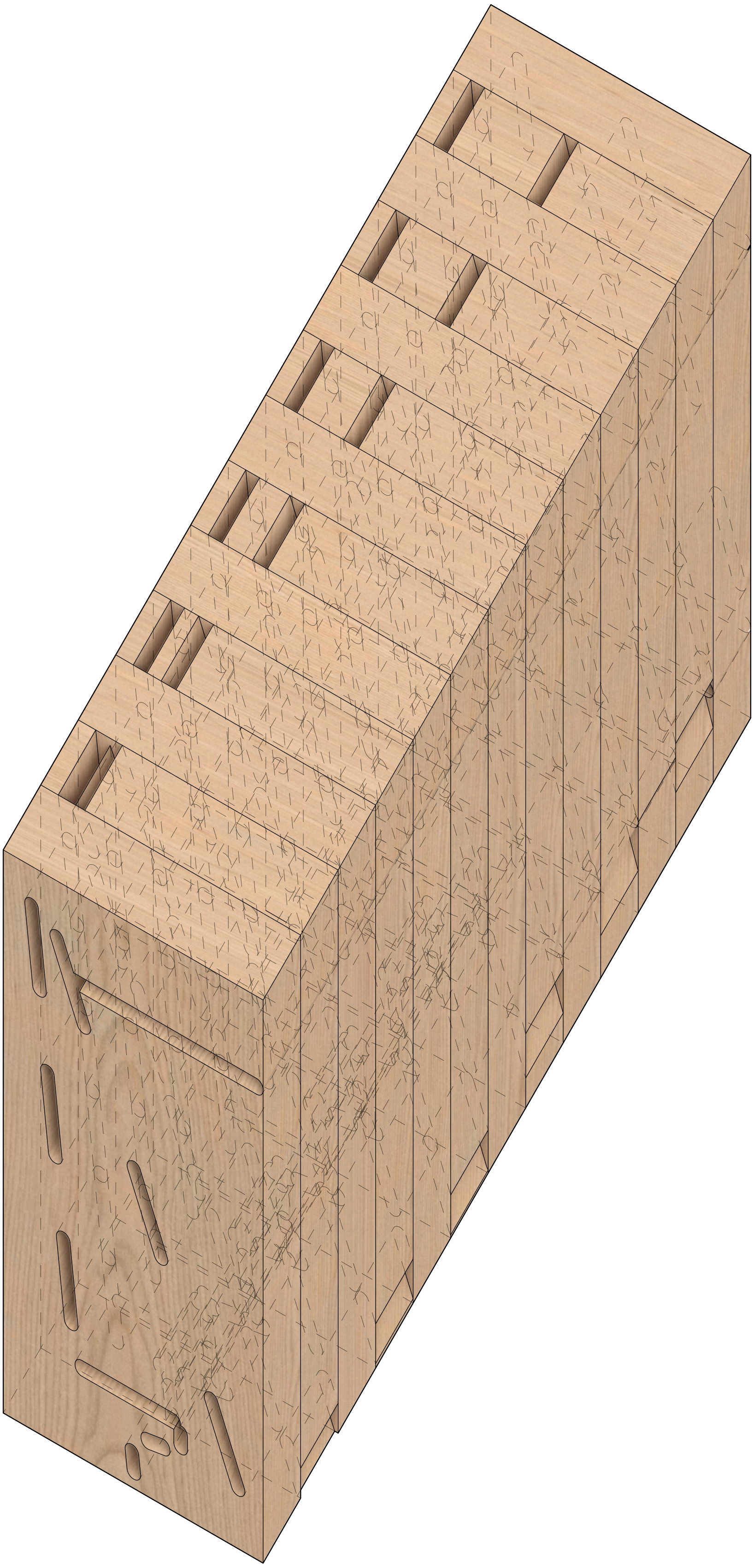
The cleaving process did not go as planned with this bus stop model.

The first piece was cleaved cleanly according to the design but that is where the idea of the cleaved surfaces stopped working. The piece that was supposed to become th vertical marker of the buss stop did not cleave as intended. It cleaved vertically through the grain through what was supposed to be the roof structure. It broke the bench and split the entire test in two.

These errors accumulated during the process and did not allow for the original intention to be completed. Though disheartening, this test helped guide the rest of my design thinking by informing of the complexities of multi part cleaves.

The test was not all for naught as the exposed cleaved surfaces allowed a thorough study of the interaction of textures. The separate pieces where studied in various positions and documented to examine the interplay off smooth and cleaved wood. The scale figures helped bring a sense of scale to the texture and overall structure that was able to be constructed.

Overall this test is integral to my understanding of the cleaving process. After this test, my ideas of controlling the cleave lessened and my design ideas started to think about texture and the possibilities of larger pieces than smaller more detailed structures.



Axonometric view of the initial precleved piece of wood

Cleave 1

Cleave 2

Issue of failure to cleave becoming apparent.

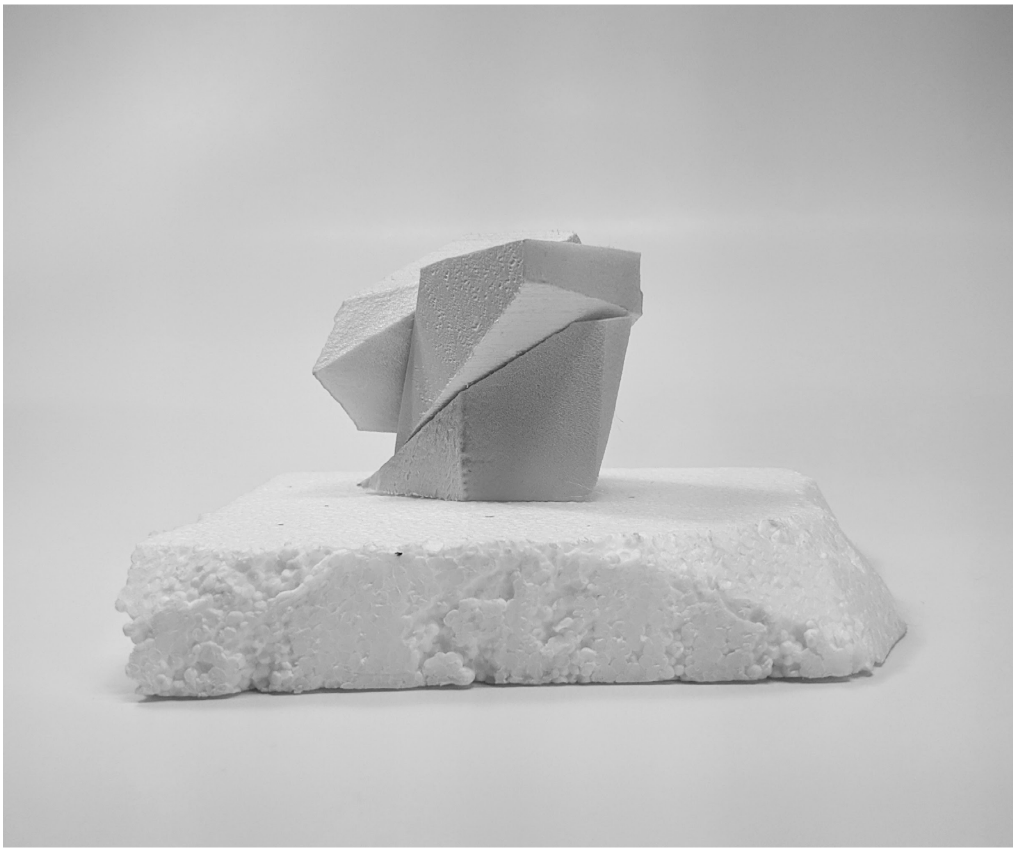
Design application 1
Open air structure scale
Reflection

The fundamental moment of this design application came during the cleaving of the scale model. So much time and work had be spent to try to make the a scale model that would cleave in a predictable manner. Special care had been taken during the cleaving process as well, many small shims to split the wood evenly along many pieces where utilized. This did not go to plan.

But was this a problem? It is a question that is faced many times during the testing and cleaving the models. Again the intended result and the idea that this is the only correct solution to the action is put into question. Yet, there is a result on the table, and the way we approach it forms our understanding.

How does this ambiguity effect the notion of a new materialism? Is it within the realm of possibility that one could be at a construction site, ready to cleave, and the unknown happens? The cleaving action forms its own material identity and how that is handled is the fundamental exploration of the process.

The final model, a result of the difficult cleaving system

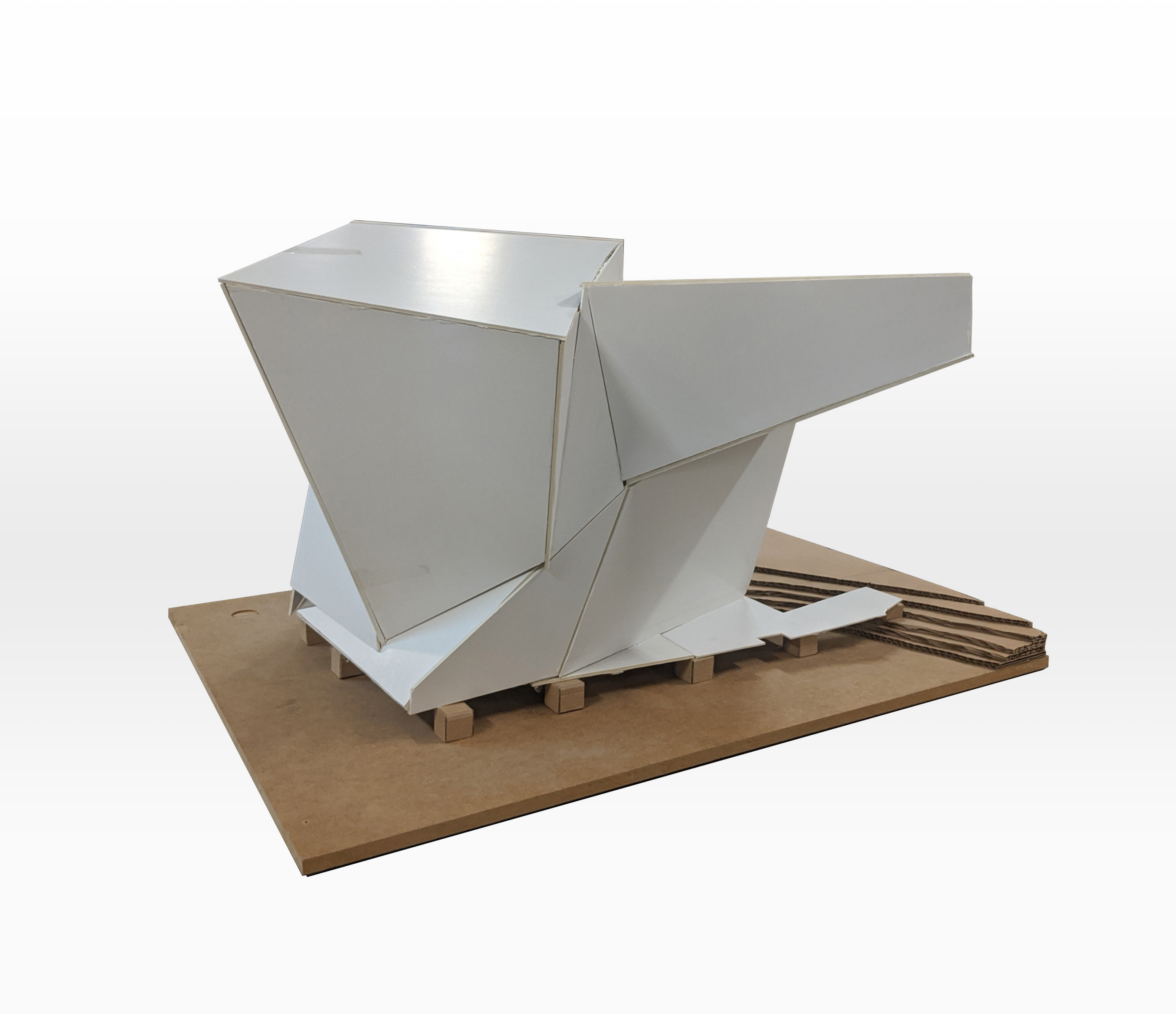


Design application 2
Chapel
Digital materiality

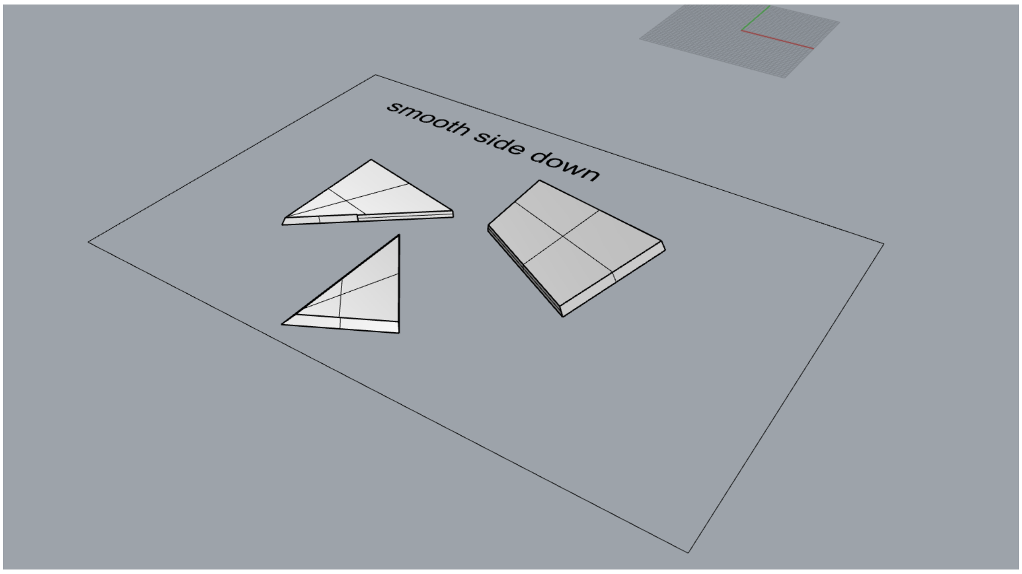
For the second design application a larger structure was proposed. A chapel in the harbor, a dynamic structure of massive timber. Each piece split forming a distinct material expression. The final material test of a cleaved structure focuses on both architectural material expression and a distinct methodology created through the earlier tests. The overhanging structure and folded plate structure was used to express the massive sheet material created from earlier combination tests. The method developed looks at the multiple steps taken to study materialism and its transient nature between the physical and digital.

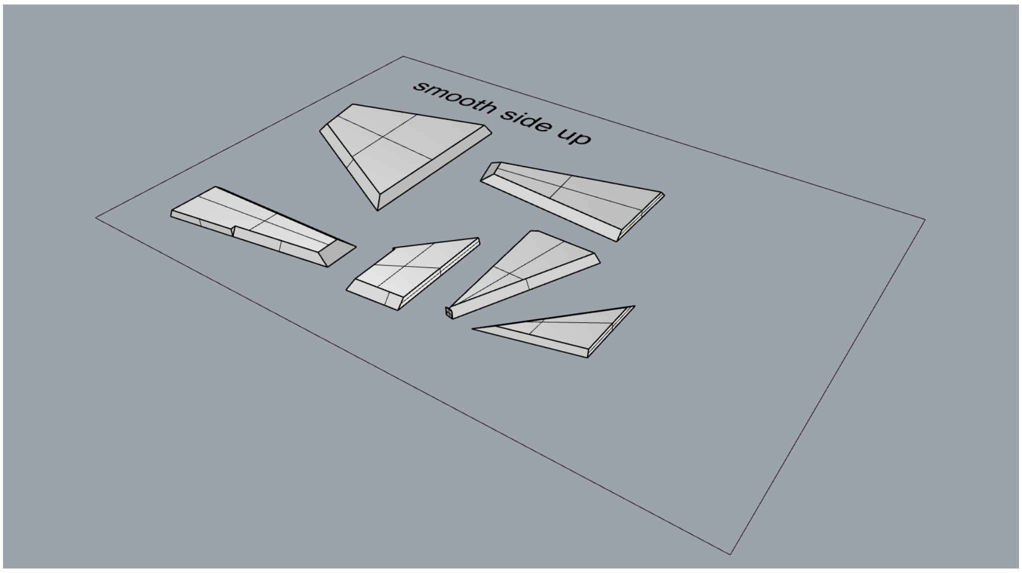
A looping method was developed for this design application in the hope that this continual experimental process would generate information in a perpetual loop. To explore a new materialism, moving freely between the physical and digital realms was a necessity. The link between models was key to both understanding but also the application and study of a cleaved material.

The looping process forces little change on a global level. The overall shape and tectonics was determined already in the second sketch model. What does change is the fidelity of material, which happened in parallel with the cleaving texture. By digitizing the material and trying to understand it, yet creating new information in the process, a nuanced view on what representation can be is formed. The ideal of equating a digital model with a physical one is drawn to an extreme with this process. The glitchy, chaotic meshes formed are in theoretical parallel with a equally dynamic cleaved surface. Information is lost, but it is created in troves as digital nuance.



1:20 scale sketch model that the initial digital model is based upon.



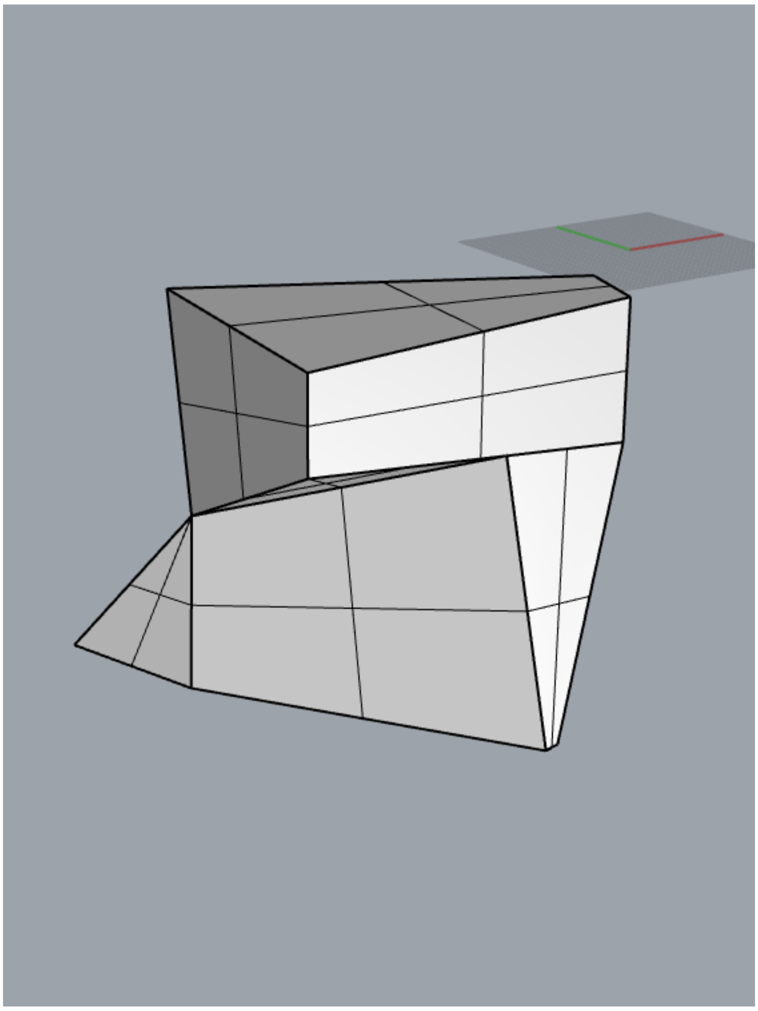


Digital to physical

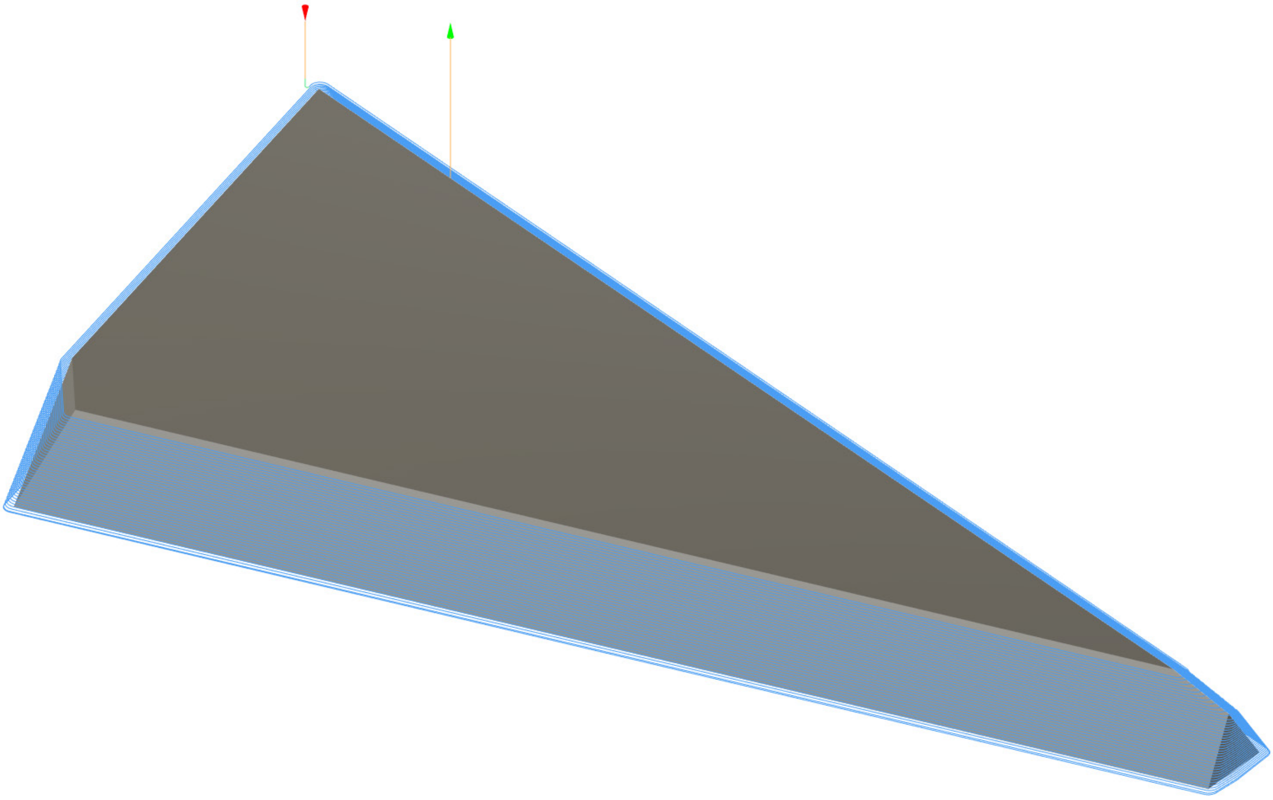
After the generation of a digital model of the second sketch model, a section of the structure was chosen to create a physical model. The front part of the structure was selected because it showed a large variance of textures, different angles between adjacent pieces, and an interesting structural form. The facing direction of each piece became a challenge to handle. The piece had to be designed as a whole, looking at the cleaving characteristics and physical properties of the material it creates.

Each piece was arranged digitally to decide how and in which order the fabrication processes would be conducted. The slope of the side angles had to be taken into consideration as the subtractive manufacturing method only works in a vertical direction. Plates with sides that had different angles would be solved by having two operations. One to cut the angles facing up. Then the whole workpiece is flipped and the other angles are milled.

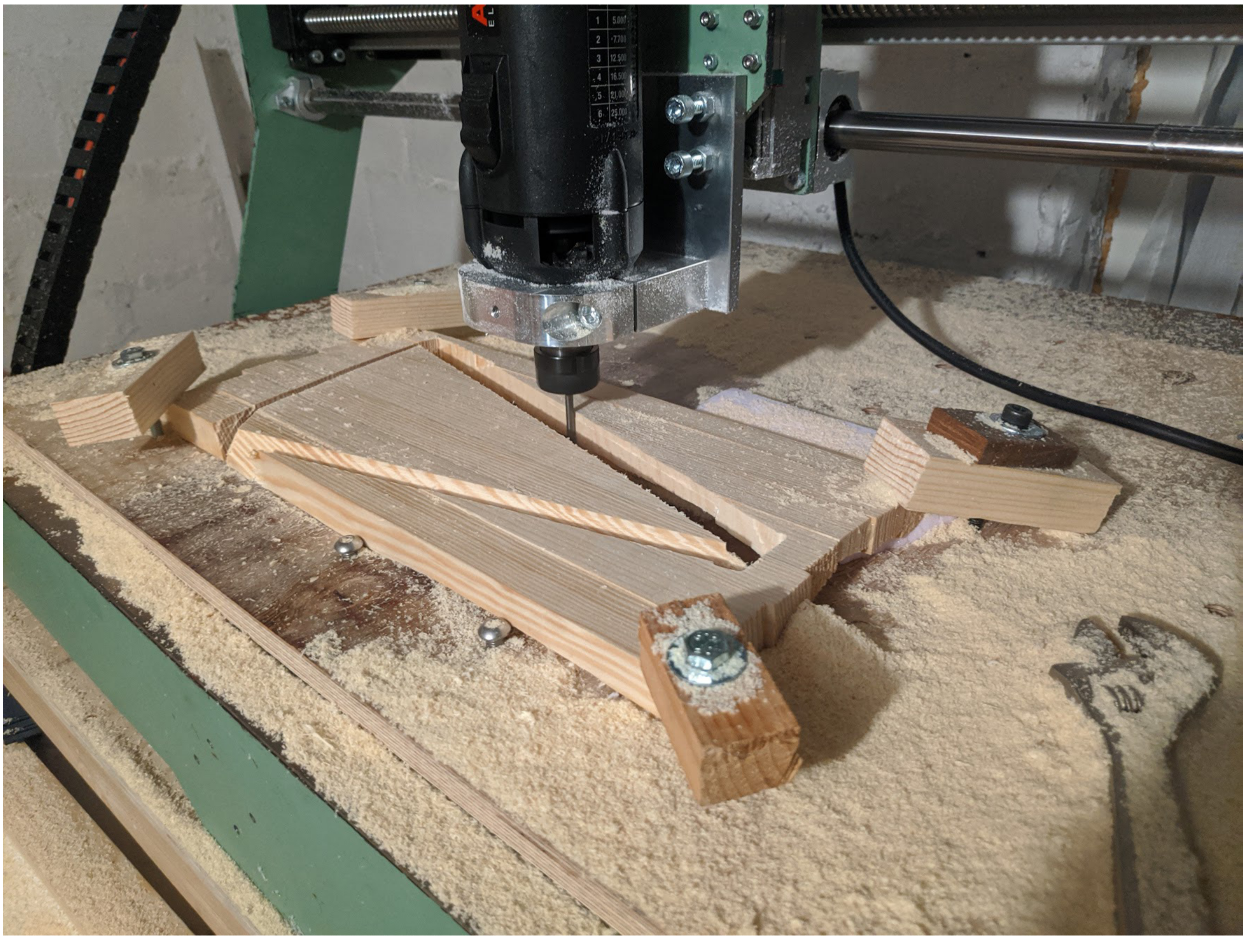
The tool path generated is a fairly simple ramp. The endmill is always cutting the desired depth of cut. The tool follows a continuous contour around the plate. In this case a 1mm cut was chosen as this increased the fidelity of the angled sides as they are a slope approximation of many steps.



1:20 scale sketch model that the initial digital model is based upon.



Toolpath for a single piece.
1mm Stepdown per layer



A typical setup for fabricating the pieces. There are four clamps and a foam shim visible in the back.

Physical model fabrication

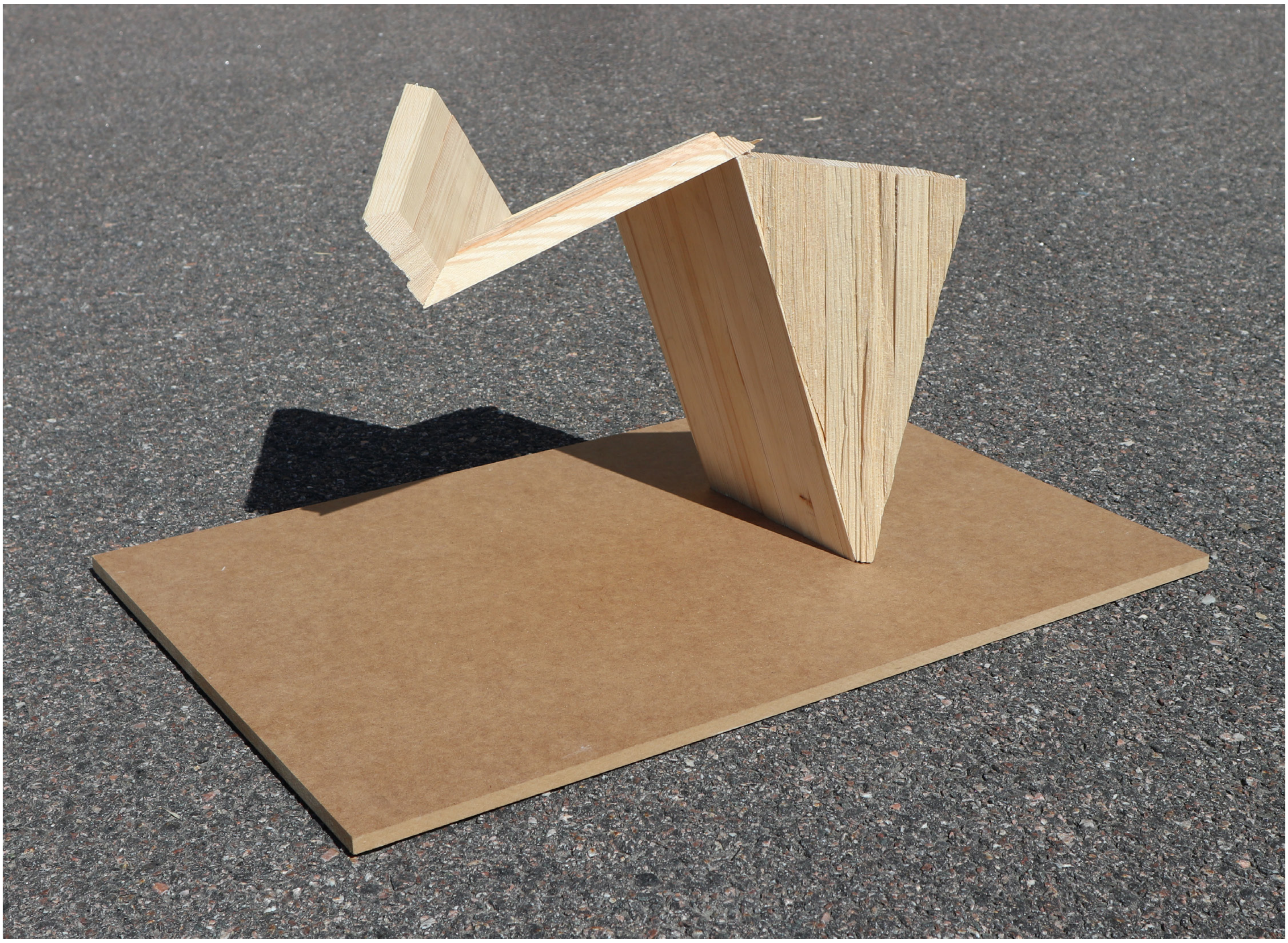
To create the polygonal shapes from the scale cleaved material, subtractive manufacturing was utilized. A CNC router cut away layers of wood 1mm deep at a time. Due to the limitations of a lightweight, home built machine, small cuts needed to be taken to create the precise edges and angles required in the final model. The machine was able to keep a speed of roughly 2500mm per minute which gave each piece a fabrication time of roughly 2 hours.

The actual fabrication of each in individual piece required tailored solutions each time. First, the pieces needed to be affixed the work table of the machine. This was done using clamps bolted into inset threaded nuts that allow holding the material only by the corners, such as in the first image above. For pieces that had the cleaved texture facing downwards, shims where placed under the model to approximate a top surface perpendicular to the endmill. Insulation foam was used as it could be crushed by the clamping force, greatly increasing the holding ability of the clamps.

Some pieces required a second operation. If the piece had angled edges of both slanting upwards and downwards, the modeled needed to be flipped and milled on the opposite side. This was done approximately by the endmill to a corner that was known in the digital model, then moved to the next know corner. Tracing the polygonal shape and adjusting the alignment of the piece each time until it was deemed satisfactory in its relation to the machine and thus the digital model used in generating a toolpath.

A macro photo of the ridges left by the approximation of a angled surface by a straight endmill.

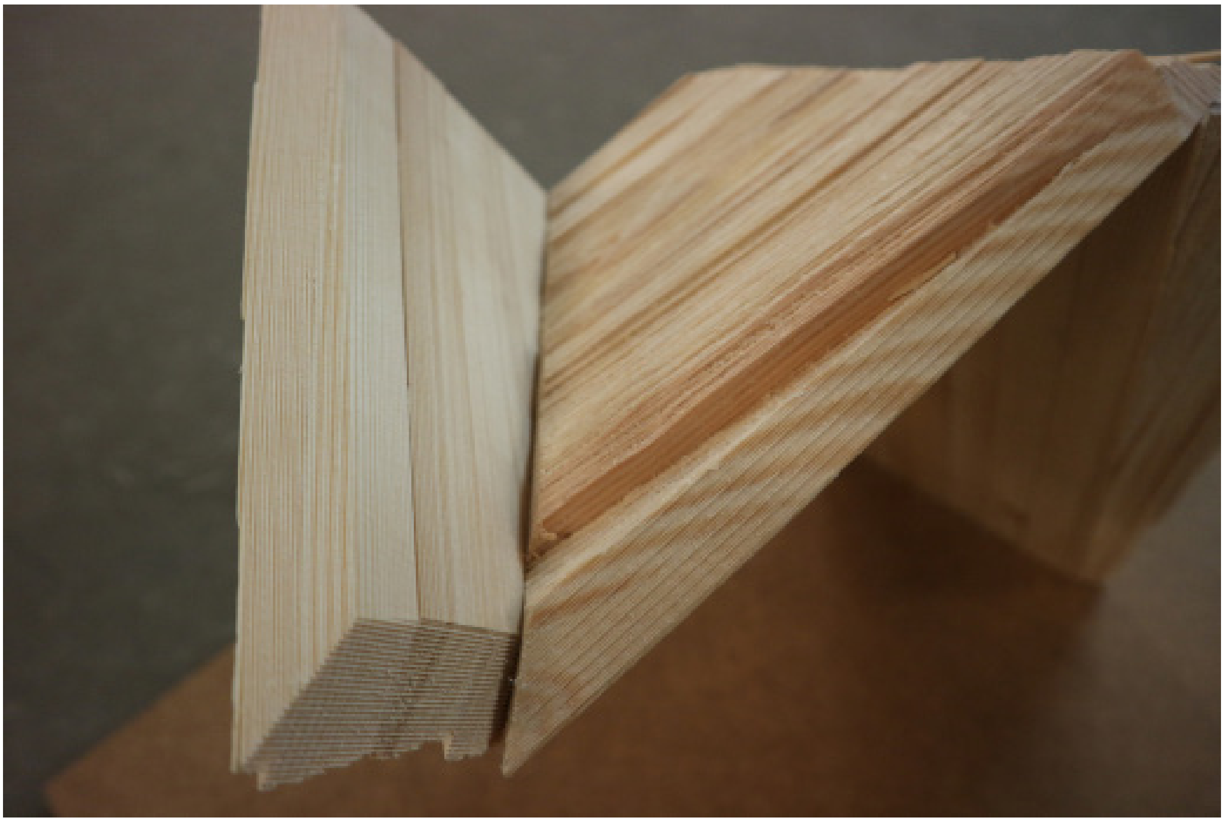
When the pieces are placed together the intended texture is finally revealed. The angle of which each piece was milled greatly influences the visual texture.

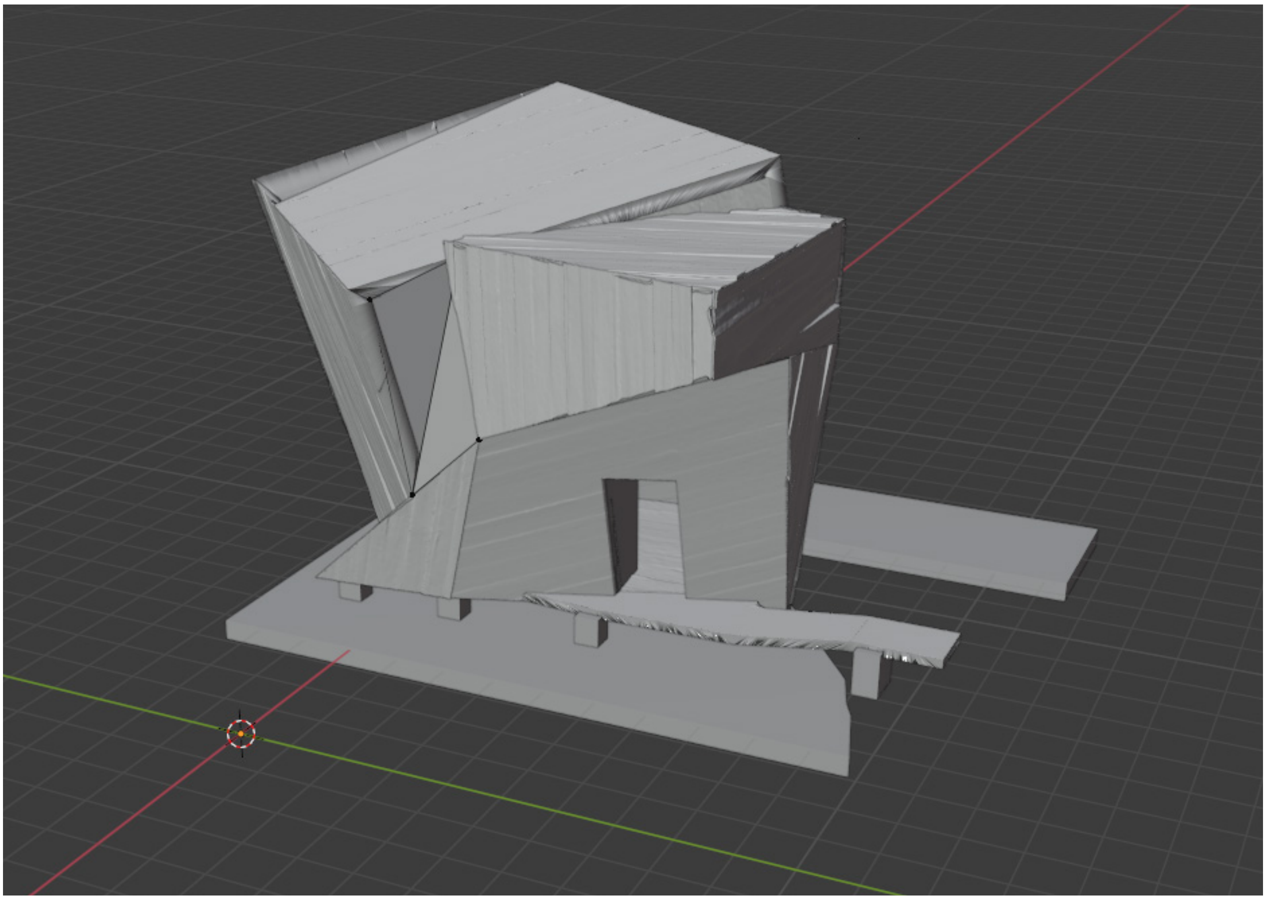


Physical model

Many different strategies and techniques had to be combined to make it possible to build. Putting the pieces together really was a great moment for this part of the process. The combination of either cleaved and flat sides really help strengthen the materiality of the piece. This juxtaposition of a smooth surface meeting the hard brittle cleaved texture is quite prevalent while looking at the model. Because the subtractive process cuts the cleaved surface straight, visually the textures merge at one distinct line down the joint.

The fine ridges left on the angled sides of each piece worked really well to help align the joint. It also adds to the surface area strengthening the bond of the glue used. Other small details that where created in the fabrication only add to the final form. Small pieces of wood chipped away when the cleaved texture brought the surface bellow the intended model limit. This helps break up the silhouette of the perfect polygonal shape inputs.



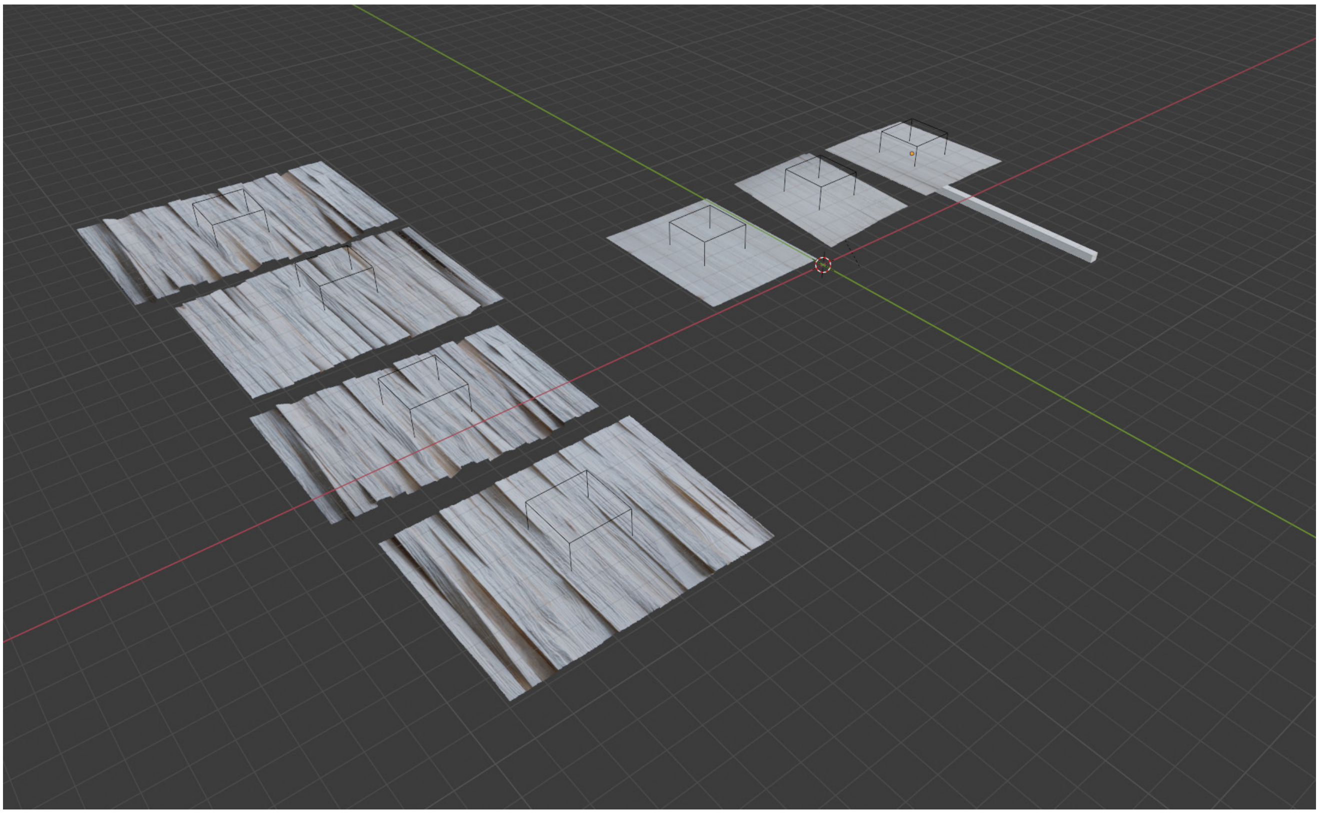


Pseudo-digital/physical model

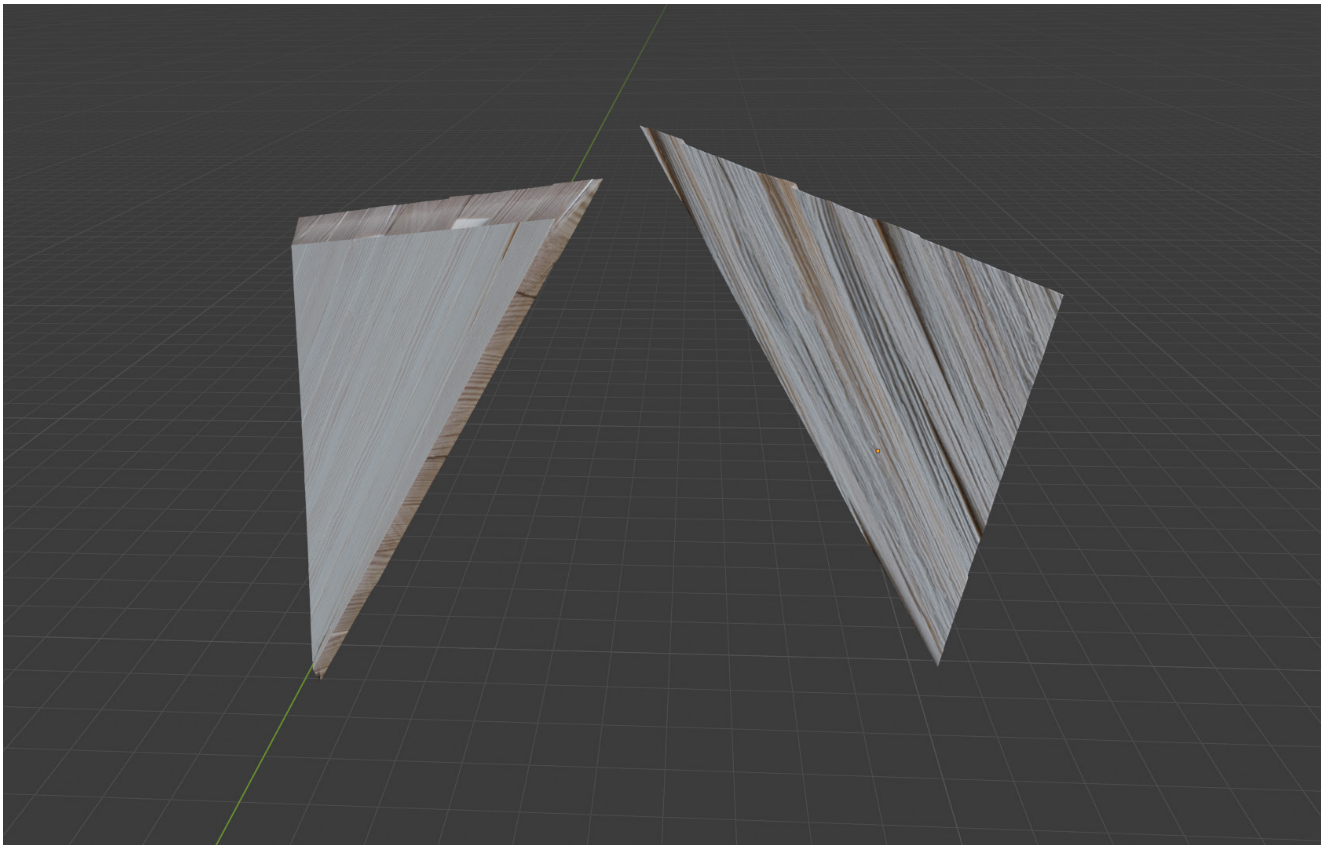
To be able to create a comparison between a physical model and a digital one, the digital needed to be of the same caliber as the prior. Extreme care was taken in this digital model as it was made in a method that tries to retain a materialistic value derived from a physical model. As seen in the screen-grab above, a direct model was created through mesh manipulation based on the earlier tectonic sketch model. Some detail from the meshes is visible but, in this shaded non-rendered view, not much difference can be interpolated between this and the basic digital model.

As earlier in the thesis, many pieces of cleaved wood where assembled to be digitized using photogrammetry. Allowing for the creation of pseudo textures that are really just meshes with their own texture. Their use however, defined the post-digital nature of this thesis. By using a directly created digital representation of a texture, we bypass the traditional 2D texture render. Actually creating meshes that contain the same information as physical models, coupled the model directly back to the physical.

Then what is the difference between this and a physical model? The digitization creates its own information about the texture that would not exist in the physical. That process yields agency to digital model and its materialism.



The four cleaved material meshes and three smooth side meshes used to create each individual piece.

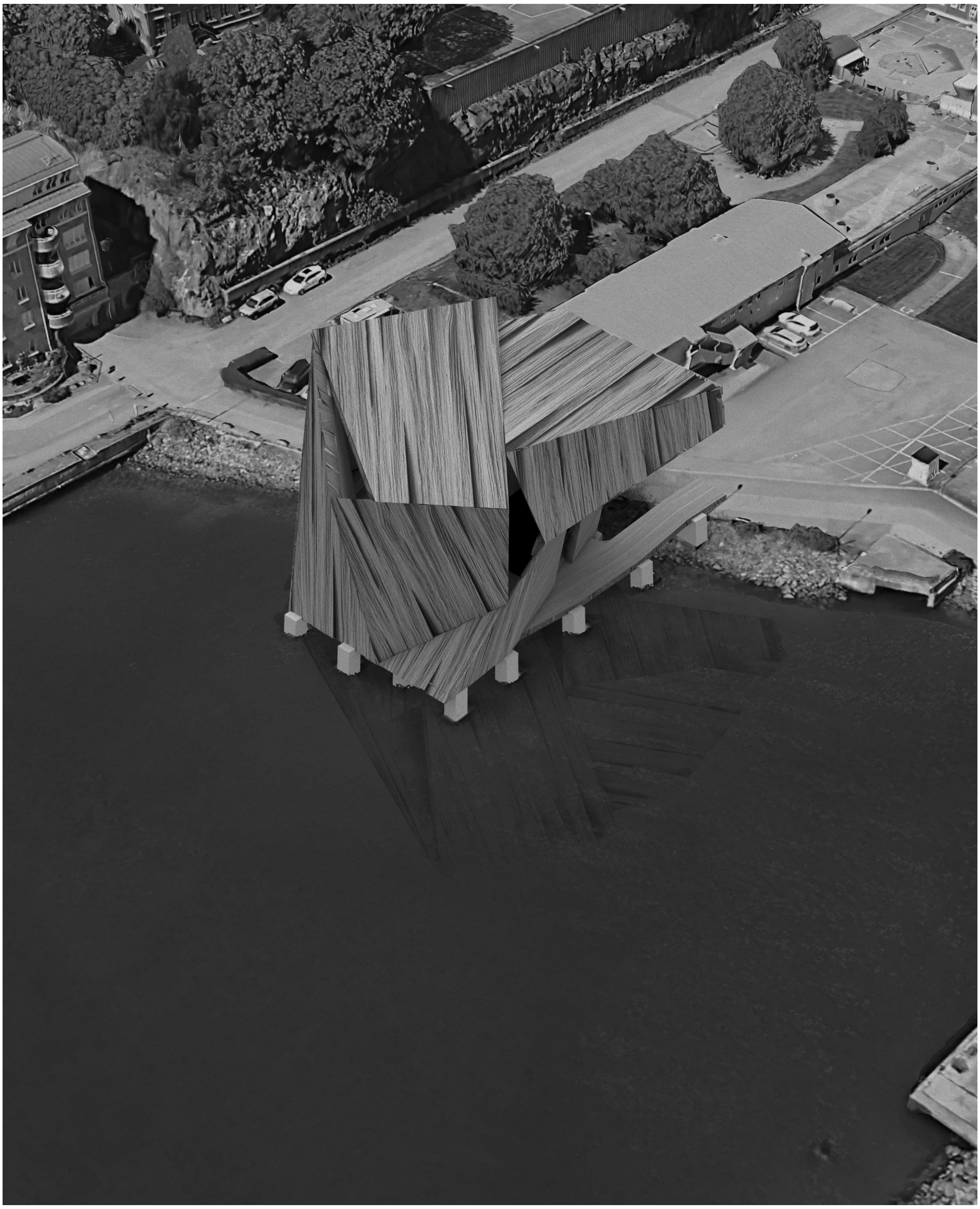


A single mirrored piece showing the lofted “endgrain” in between the two distinct digital textures.

Final design

The chapel lies directly over the water in Gothenburg harbor. Reusing foundations from a emergency ship evacuation testing structure, the design stands firmly over water. The location puts the wooden structure as close as possible to moisture that introduces a form of danger to the building. The large plate structures have two sides, one cleaved and one flat. These flip inside out according to the position in relation to an idea of how much water each would be subject to.

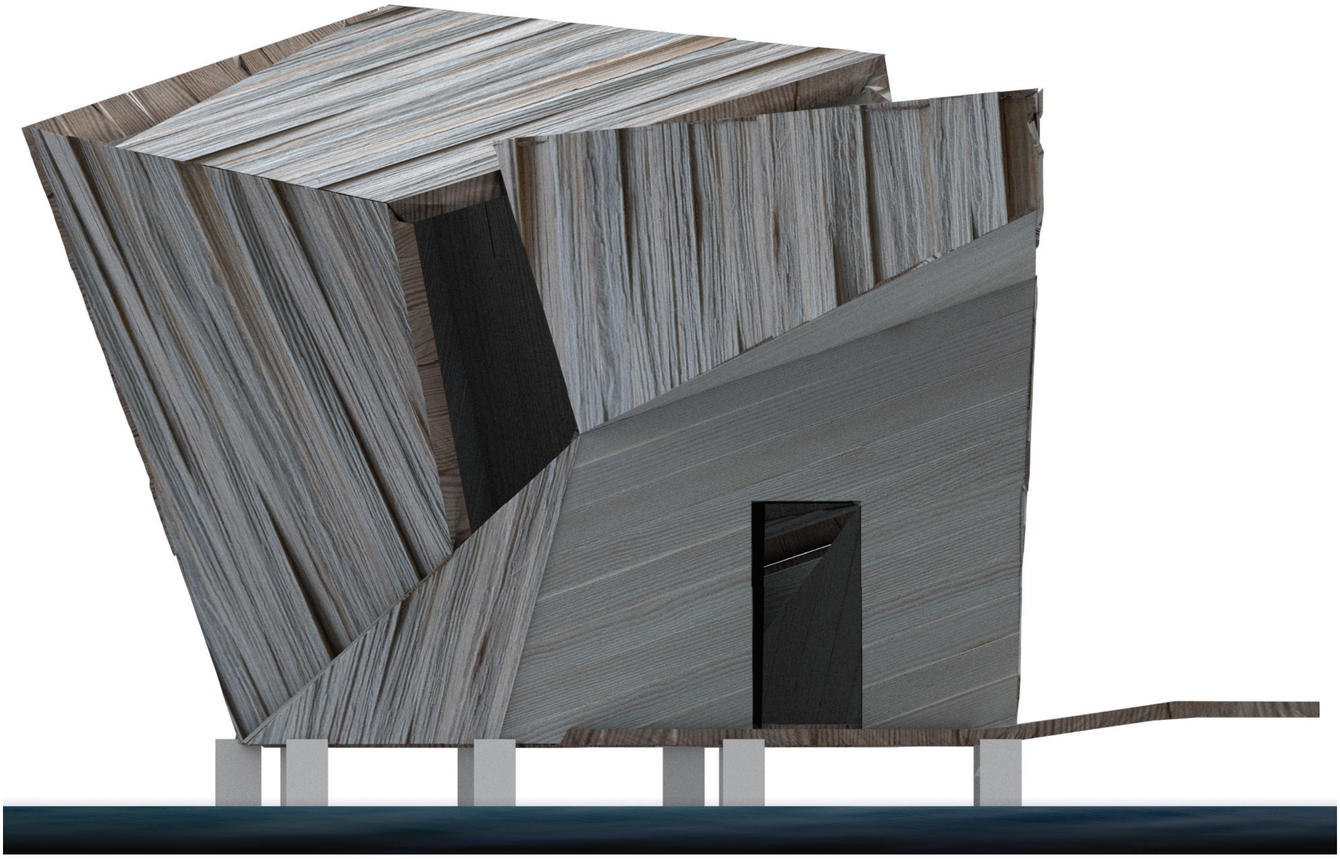
Situation plan



View from birds perspective

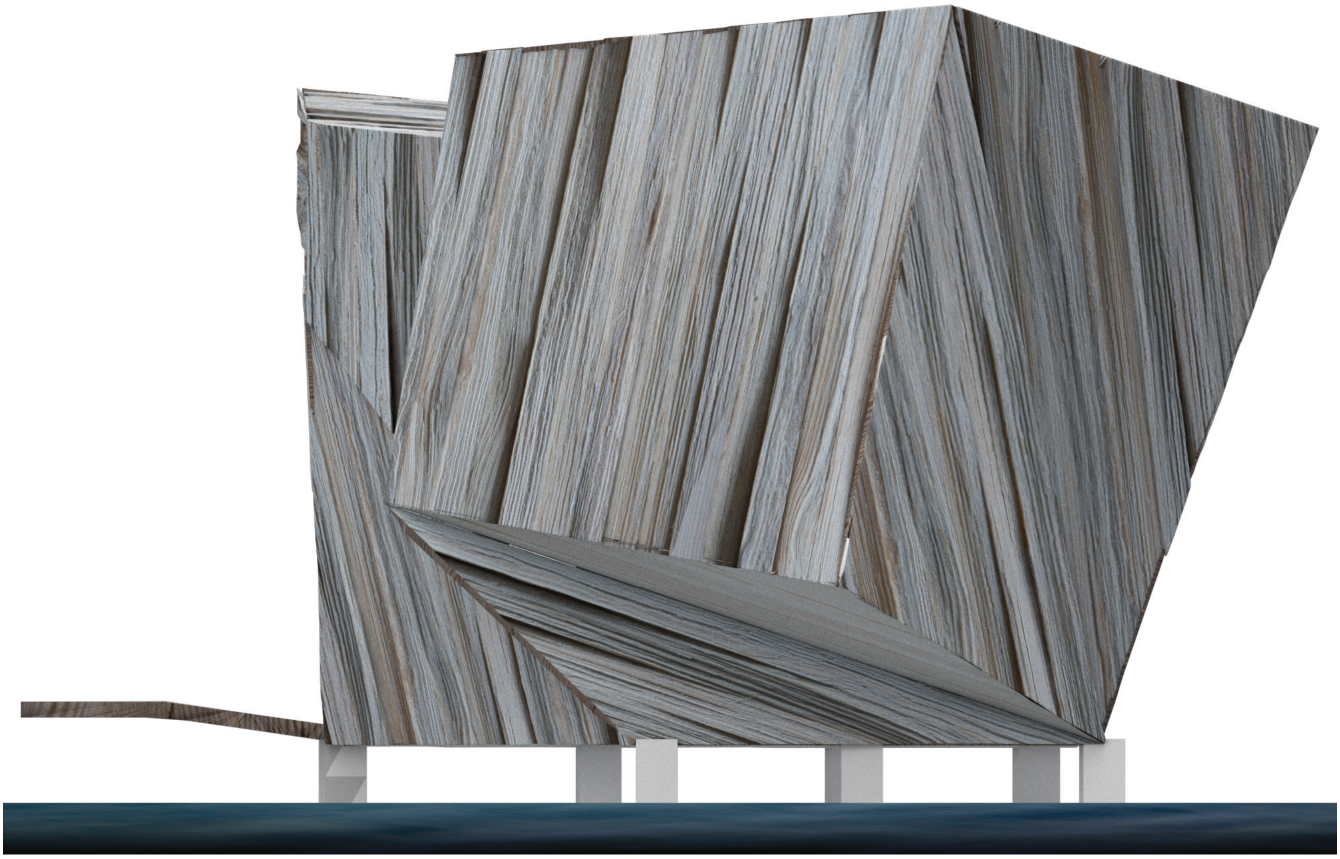
Design application

Plan View



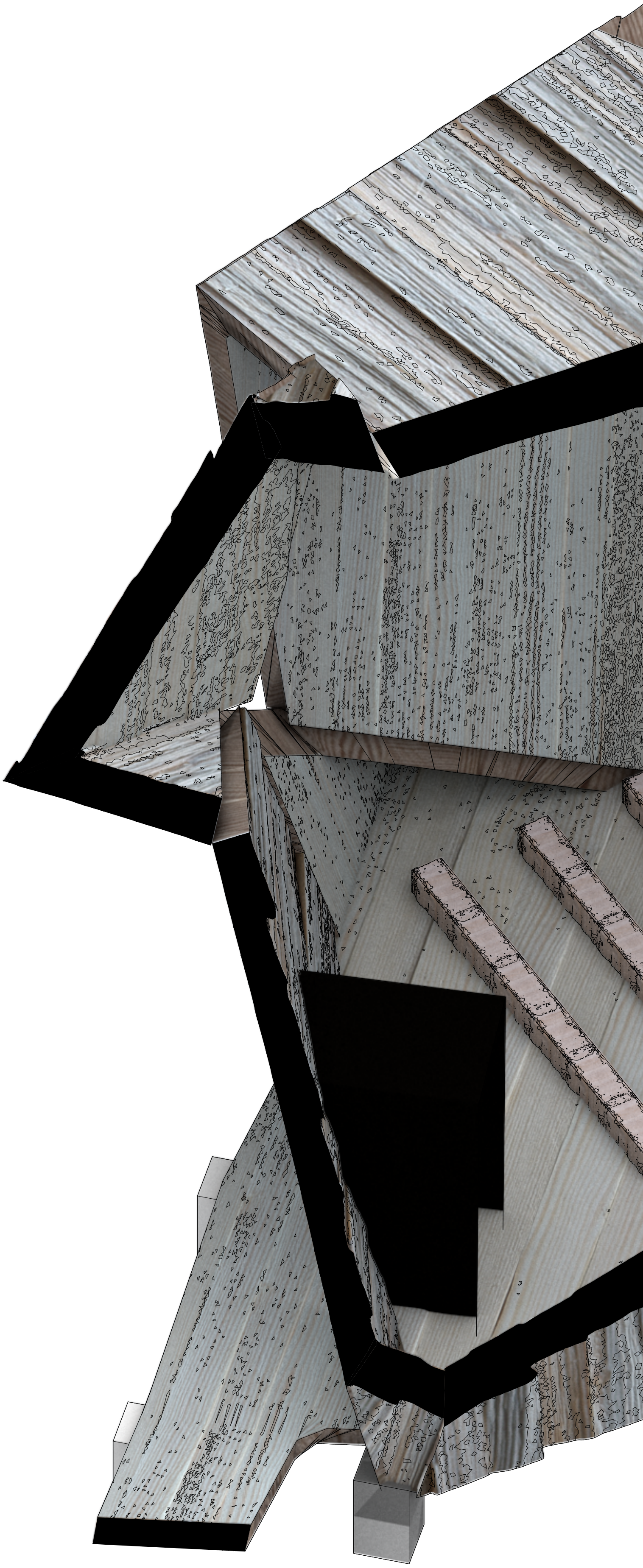
View from front

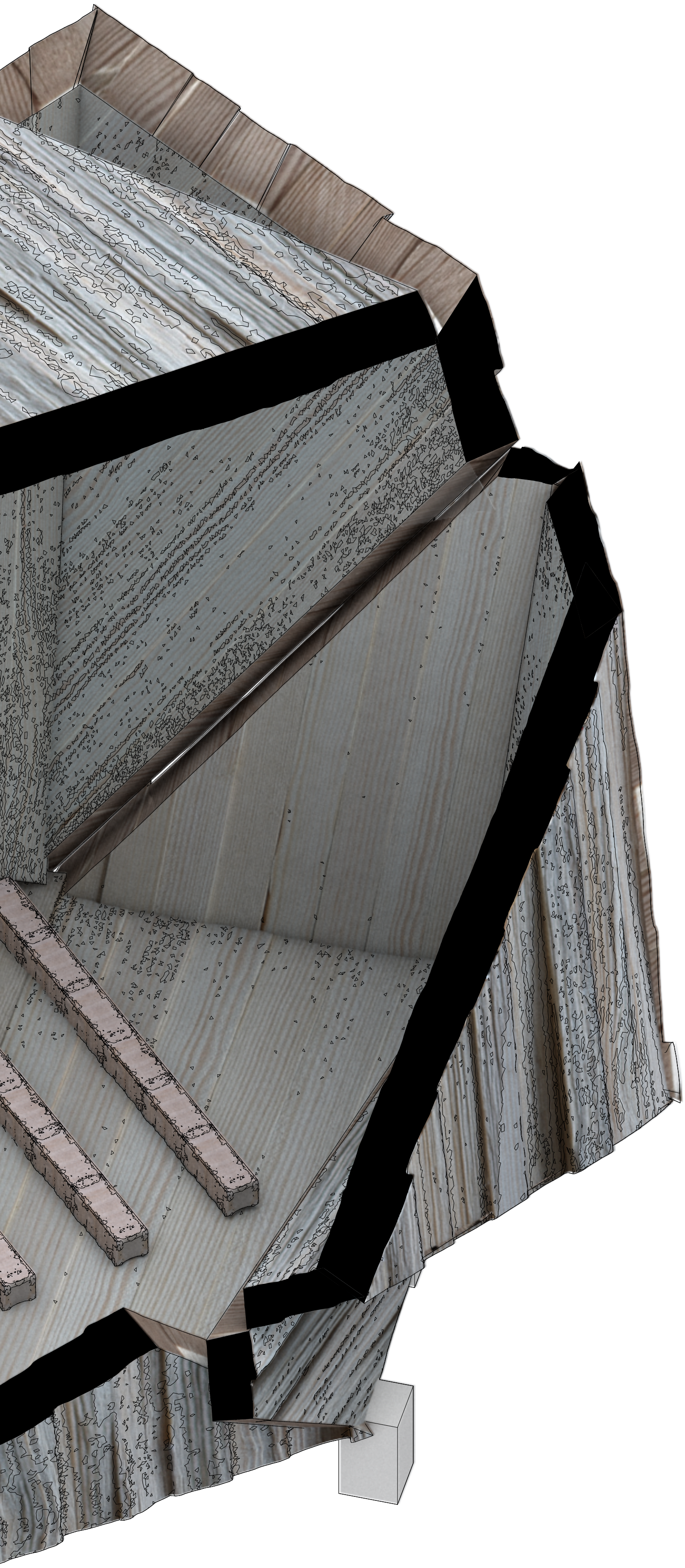
View from right



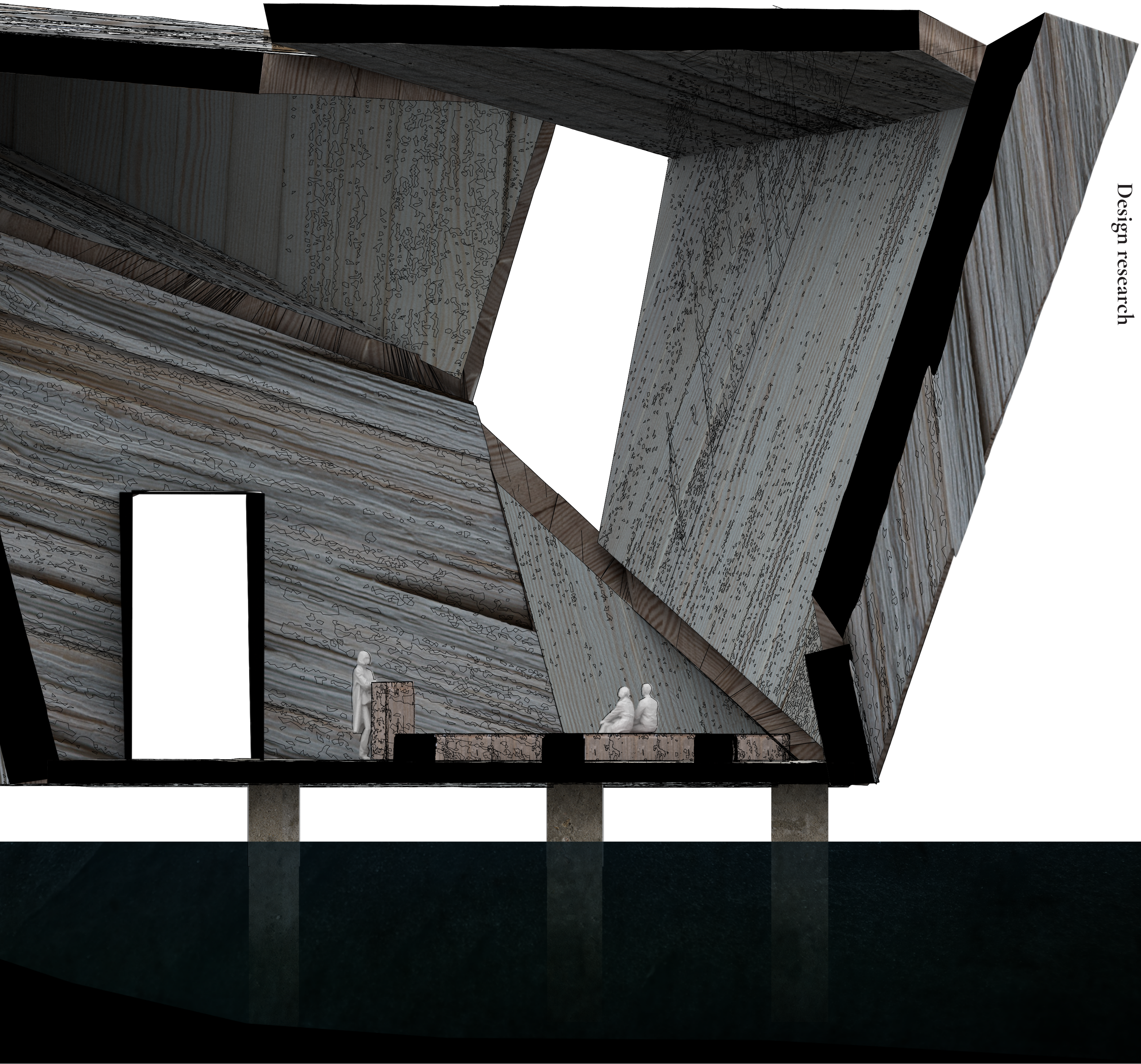
View from back

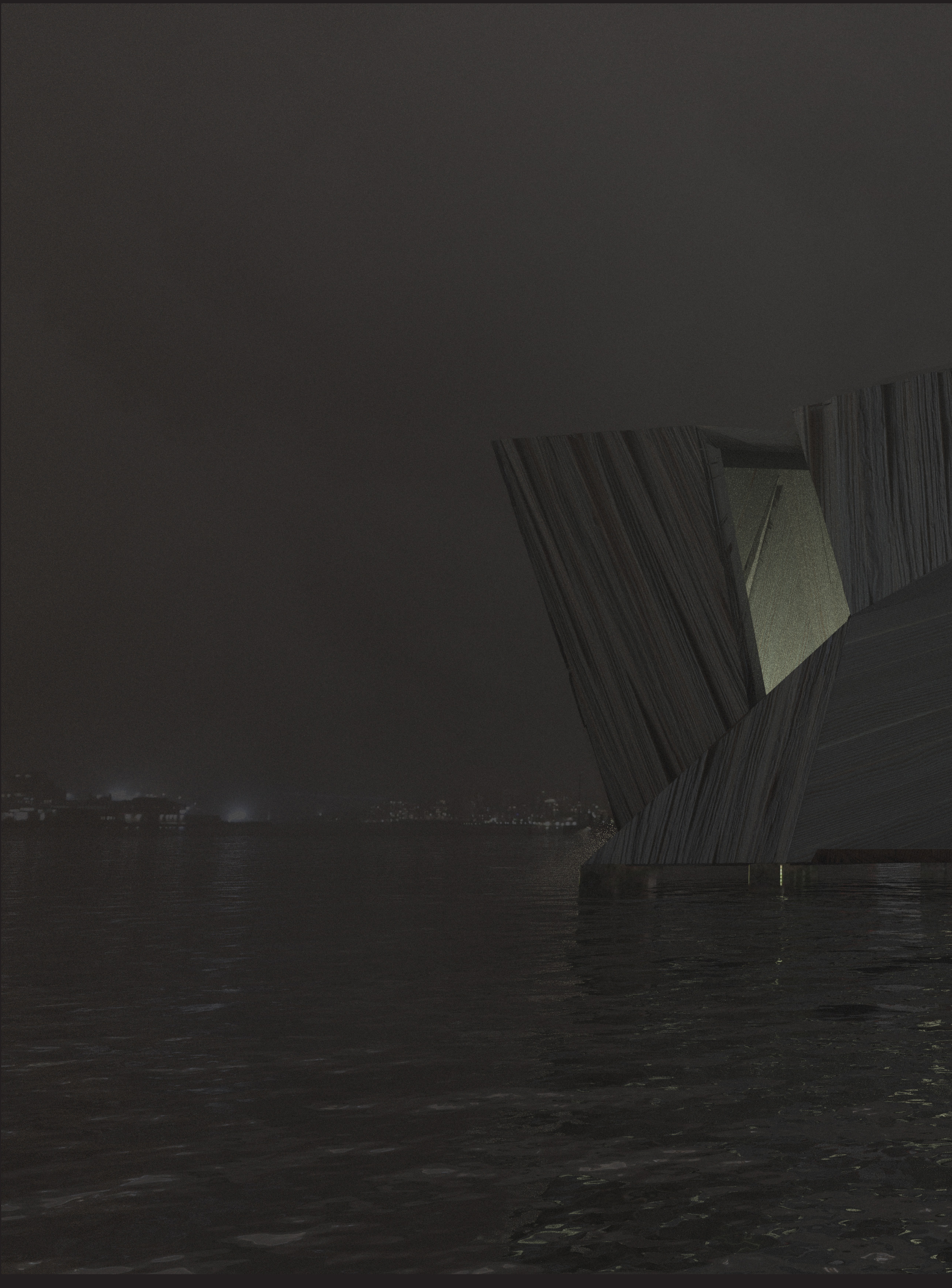
View from left





Military perspective section drawing of interior





Reflection

This thesis expanded from its initial scope very quickly, but the original aim and explorative methods remained applicable entirely. By testing many different methods and creating workarounds to the studies, a coherent structure emerged. These methods included many steps of moving between the physical and digital realms, processes that where created to further push how a material study could conducted. Treating the physical and digital as equals further helps the notion that our understanding, and thus our eventual use, of the scope of a new materialism is inevitable.

A fundamental method was approached in the final design application. The shifting physical/digital realm notion could become the driving factor of a complete design process, a post-digital manifesto towards manipulation new materialism. The explorations conducted do not push this concept to this eventual conclusion. By moving between the realms, the information that is created/destroyed must be brought through each time, adding to the agency of the material. The trails of approximation created in subtractive manufacturing must be digitized and held to the same scrutiny as the digitized cleaved surface. The eventual mesh and mesh manipulation needs to be analyzed and created physically, because it becomes an approximation of a material. This looping action could be used to drive a design process that challenges the concept of new materialism.

Overall the explorations taken in this thesis give a general overview of a method of working with new materialism with the use of its analysis of a cleaved texture. The results of which are many in both architectural representation material and data to aid in its creation, but also the groundwork that is laid for a way of conducting a design process. This fundamental view of material, its use, the design capabilities, and explorative nature of this process is becoming more of a personal manifesto on how I want to conduct my work. A holistic conclusion to a diverse and difficult thesis.

Giulio Brugnaro - Adaptive Robotic Training for Subtractive Manufacturing

Giulio works with integrating force feedback sensors into subtractive wooden manufacturing. Developed simulations and tools to chisel wood with a robot. This process looks at how many of inherently human aspects of fabrication can be conducted

Historical - Vikingeskibsmuseet

Vikings boat builders cleaved wooden logs directly into planks. These boards were more resistant to water but required much large trees then the more efficient sawn wood. Gave a very detailed overview into the historic way of cleaving large oak timber. Progress photos show the extreme effort required to cleave it in half.

Philippe Block - BRG (Block Research Group), ETH

Researched Gothic techniques and construction and design methods within masonry. Developed new ideas using modern techniques and fabrication methods. Active in working with digital solutions to design problems.

Siteless: 1001 Building forms

932
corner extensions

933
panel geyser

934
excavated cantilever

935
slab trail

936
grid bulge

937
fillet tower

938
panel locks

939
whirling pillars

940
continuous façade

941
bridge tower

942
marble block

943
street settling

108

This book attempts to classify the current architectural field, through the use of simple shapes. These shapes show the state of the current architectural field around the world and their limitations.

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