A Park of Process: A Morphogenetic Approach for Sensory Microclimates

by

Luca Di Gregorio

Submitted in partial fulfilment of the requirements
for the degree of Master of Architecture

at

Dalhousie University
Halifax, Nova Scotia
March 2020

Dedicated to my mom, Mary Di Gregorio.

I cannot thank you enough.

Contents

Abstract

This thesis proposes a place for architectural experimentation and public experience; a place to spread ideas through an approach to making: “a park of process.”

The morphogenetic model, which relies on material properties and performance, experimentation, and the processes of ‘making’, will be explored in this thesis. The process and intrinsic material properties preside over historical and symbolic imagery. This will be applied to achieve gradients of sensory microclimates and continuous variations of space and experience through actions of making.

Wax and concrete are investigated for their phase-changing and energy-storing properties to develop sensory microclimates through casting. This process achieves structure by forming concrete with wax, resulting in a range of lighting determined by porosity and thickness of material, and gradients of thermal conditions.

In conclusion this method of design offers an alternate approach to building architecture by reconsidering materials and their properties.

Acknowledgements

This thesis could not have come together if it was not for the guidance, support and influence from countless individuals throughout my academic career at Dalhousie University. I am grateful to have been a part of such a wonderful community and to have had the opportunity to learn and grow alongside so many amazing individuals, it has been a pleasure.

A special thank you to my supervisor James Forren, for your support through this ever changing process and guiding me through some unknown territories. I am very grateful for your guidance and have learned very much working alongside you.

Thank you to my advisor Brian Lilley, who saw this thesis through from the very beginning and for the encouragement and the wealth of knowledge you have shared.

Thank you to the following people for the support and friendship during this thesis and through the years; Julie De Liberato, Courtney Ho, Aziza Asatkhojaeva, George Grant, Jamie Leer, Taylor Um, Stewart Lore, Alejandro Adriazola, and Shaili Chauhan.

Finally, thank you to my parents and family for the unconditional support through it all.

Chapter 1: Introduction

Architectural projects are too often considered teleological, or finite, prioritizing product over process, while disregarding materials and the processes that shape them. Gilles Deleuze and Félix Guattari synthesize these ideas with two contrasting models: the hylomorphic model and the morphogenetic model.

The hylomorphic model of design – from the Greek terms “hyle” (matter) and “morphe” (form) – is a top-down hierarchical approach to design that prioritizes form over process and relies on the conventional use of symbols, images and preconceived ideas that impose form and meaning onto material. In this model, matter is seen as static and homogeneous, which often results in static architecture and material thresholds with a limited range of exploration, which often does not consider the material or its properties. Within the hylomorphic model, there are standards which limit the design process and the overall experience of the architecture. In contrast, the morphogenetic model – where “morphe” means ‘form’ and “genesis” means ‘generation’ – focuses on process, experimentation, and material properties. This thesis looks to explore the morphogenetic model further by experimenting with the materials wax and concrete, in an attempt to take advantage of their phase-changing properties.

The intention of this research is to generate a range of sensory microclimates through thermal, luminous and spatial-variation developed through material properties and processes. The concepts of sensory microclimates will be explored by comparing ‘substantial structures’ and ‘energy controlled space’. The material properties of wax and concrete will be tested through the applications of form, light and temperature to achieve sensory microclimates. The architecture will be organized around the sensory qualities which govern activity, providing a range of experience for users and blurring architecture with its surrounding ecosystem.

In this thesis, wax and concrete are used to discover form-finding prototypes as a model for developing a morphogenetic understanding of the processes that allow form to emerge. These two materials play a role in the search for translating this understanding of the model into an architecture with a heterogeneous interlocking of its parts, which, as a result, produces variation and spatialities indicative of time. Wax and concrete are explored for their viscous and solid nature through phase-changing and energy-storing properties as each harden at different rates. By combining both material properties through molding concrete with wax, wax begins to influence the formation of concrete and, thus, architectural opportunities arise.

The findings from working with wax and concrete are then tested on a site - the Junction Triangle neighbourhood in Toronto. This test aims to develop an architectural translation of the material findings in response to the site's features, history and local culture, to design a park which provides sensory microclimates throughout its program.

Chapter 2: Theoretical Framework

2.1: Hylomorphism vs. Morphogenesis

Architecture can often be an image-based discipline concerned with the final product, designed through a conventional architectural language. Symbols and formal concepts, such as spatial typologies, standardized materials, ways of building, and notions of permanence, have been developed through history and representation and have frequently been the standard in the field of architecture. In the modern and postmodern movements, architecture placed a focus on form and representation. This focus was a product of the hylomorphic model of design – a hierarchical design approach which prioritizes finished form over process. From Gilles Deleuze and Félix Guattari, as a corrective to the hylomorphic approach, recent architects such as Cristina Parreño and Gramazio Kohler Architects have proposed the morphogenetic model for design. This model of design focuses on experimentation and processes, material properties and performance.

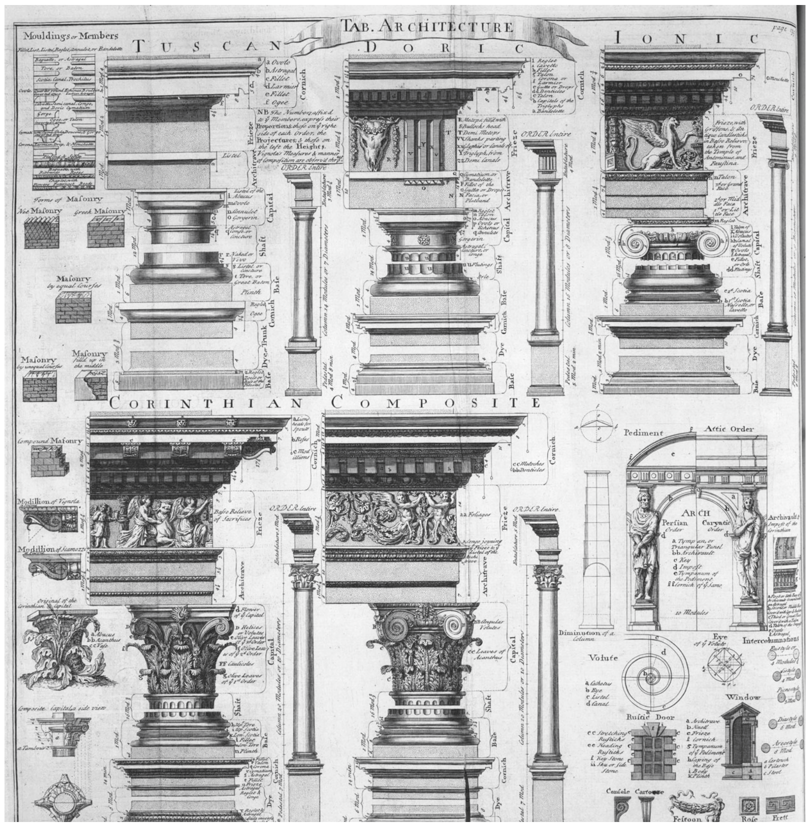
This thesis explores the theories of hylomorphism and morphogenesis. Hylomorphism will be further explained as it relates to material culture and representationalism and the issues it poses on how architects consider materials. Morphogenesis will be outlined as a process oriented design approach that underscores the importance for experimentation to understand materials for their intrinsic properties. This will be followed by a comparison of the hylomorphic result of standardization with the morphogenetic concept of material performance. Finally, theories of permanence and emergence will be introduced as ideas to the design approach.

Hylomorphism: Representation, Image, and Product

Hylomorphism relies on representation, history and images, which has caused a physical disconnect between architects and materials. Through the design process materials are represented but seldom considered past aesthetics or basic technological applications (Menges 2012,106). Artist and philosopher Manuel Delanda reiterates this idea: “the variability and complexity of real materials was replaced with the uniform behaviour of a philosophically simplified matter about which one could only speculate symbolically” (DeLanda 2004, 15). Materials have been stripped of their intrinsic properties, and been replaced with an abstracted simplified idea of what they are and can do. In order to understand the issues with hylomorphism, it is important to understand how materials have come to be understood through material culture. Material culture is defined by the anthropologist Tim Ingold, as culture, history and function imposed on materials which determines what a material is and can do, as opposed to the intrinsic material processes and properties which actually define a materials capabilities (Ingold 2013, 20-21). Instead of understanding a material for its unique physical properties, we often perpetuate a basic formal understanding of materials, developed through historical forms and represented to us over and over again through unchallenged norms. In this manner, materiality is expressed through conceptual ideas, not empirical engagement.

To fully understand how materials have been considered through history as symbols stripped from their intrinsic properties, biologist Jokob von Uexkull explains how history swaps senses for symbols (Uexkull 2009, 148). This results in a need to translate a manufactured meaning to ‘define a reality’ instead of ‘understanding the reality’ through our experience and sensory fields. Theorist Karen Barad defines the latter as a “performative understanding of materials, which shifts the focus from linguistic representations to discursive practices” (Barard 2003, 807). Linguistic representation is an understanding of material through a preconception of what the material or object represents.

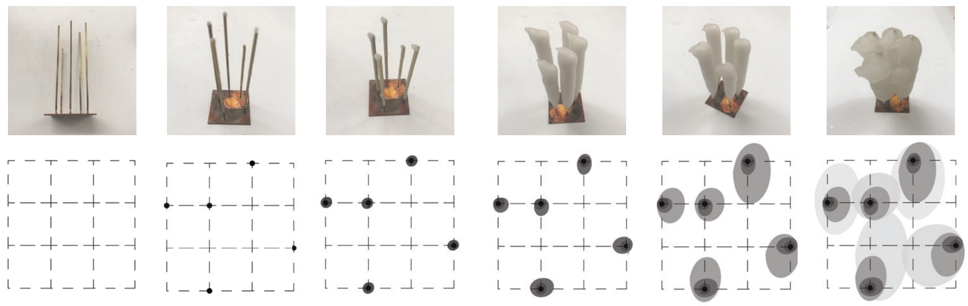
The theory of representationalism, as described by Barard, is “the belief in the ontological distinction between representations and that which they purport to represent; in particular, that which is represented is held to be independent of all practices of representing”(Barad 2003, 804). Barard explains how representationalism is deeply entrenched within western culture and has taken on a common-sense appeal, which corrupts the accuracy of the represented – in this case, materiality. Representation is a translation of what a material is; the empirical scope of material properties, through constant translation from reality to representation,can be lost in translation – and skewed by the constraints of drawing, a simplistic understanding of the material, or a perpetuation of its traditional usage or form. Barard suggests that through representation, we produce a standard and an expectation or rules that become perpetuated, losing sight of reality or empirical aspects of the represented. This is detrimental to architectural design because it limits the possible applications of a material and constantly perpetuates the same use of the material because it is understood as ‘normal’. The representation then becomes fused to the material as its only possible meaning.



“Table of Architecture” from *Cyclopaedia*, Volume 1, (Chambers 1728, 129)
This illustration shows the five orders of architecture which emphasizes the representation of imagery and symbols, rather than the material that contributed to the composition of the orders

Morphogenetic Model: Process and Making

The morphogenetic model of design is focused on understanding and applying materials through a process-oriented method of making. Process is defined by the action of energetic exchange, what Ingold describes as a “correspondence” (Ingold 2013, 7) that spurs change or action of behaviours, which in turn affects the formation of larger entities; this exchange or correspondence is, to some degree, infinite. The process of making is of utmost importance within the morphogenetic model. One example is the experimental engagement with materials which begins to invite us to learn and understand a material’s properties, its quirks and personalities, thus developing a relationship with it.



The morphogenetic model is explored through the process of dipping structural elements into wax. Growth of wax occurs from this dipping process

By working with materials, we develop a deep understanding of their characteristics, which is the necessary stance to take when developing innovative ways of using materials in architecture. Ingold explains how the “experienced practitioners’ knowledge of the properties of materials, like that of the alchemist, is not simply projected onto them but grows out of a lifetime of intimate gestural and sensory engagement in a particular craft or trade” (Ingold 2013, 29). Ingold emphasizes that artists and makers work with materials for a lifetime and develop strong understandings and relationships with them. Furthermore, Ingold highlights two relationships with materials: one based on movement and another based on senses. Through this understanding, a relationship is no longer based on preconceived ideas of form, but is about a reciprocal relationship with materials, movement, and the human sensory field, thus highlighting a subjective and intimate sensory relationship between people and material, and the objects that emerge. It is possible to emphasize that the way materials are produced are more important than the product. Through process it is possible for change and innovation to occur - to break historical molds and take advantage of how materials respond to external stimuli. Ingold suggests we must “switch our perspective from the endless shuttling back and forth from image to object and from object to image… to the material flows and currents of sensory awareness in which images and objects reciprocally take shape” (Ingold 2013, 20). By paying more attention to the material processes of ‘making’, and through a sensory engagement, materials find meaning beyond historical reference. Experimentation will allow for factors which can not be foreseen, such as how a material reacts to different temperatures, or other materials. This thesis will apply a process oriented approach to design, developing an understanding through working with materials wax and concrete to inform an architecture that is developed through a sensory understanding of its materiality instead of one based on symbols and history. This exploratory approach aims to highlight alternative ways to forming concrete and understanding the materials properties to help organize an innovative method of assembly that highlights the materials inherent properties. This approach will aim to add value through ease of construction or through a sensory experience to the user such as through texture, lighting qualities or thermal comfort.

Standardization vs. Performance

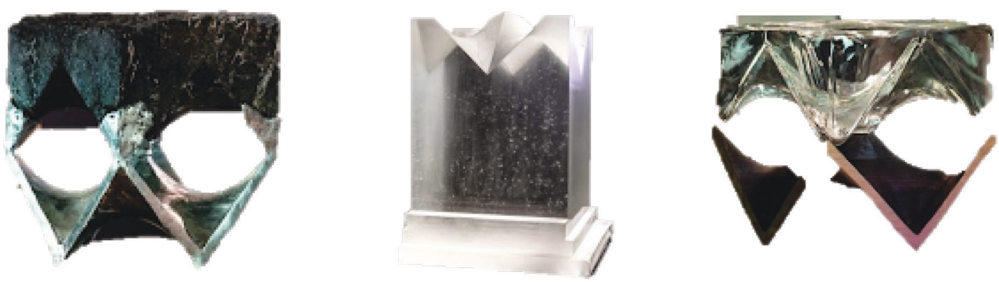
Limitations within the architecture industry and the profession have also hindered the way buildings are imagined, how they are constructed, and what they are constructed of. The hylomorphic model has been strengthened through the development of standardized building materials like dimensional lumber, concrete masonry units and prefabricated glazing. The homogenization of these materials offers reliability, predictability and quality control. Furthermore, the routinized production processes require little skill to work effectively through the steps of production resulting in lost knowledge and a halt in the exploration of materials by craftsmen. Just as building materials were standardized and their processes routinized, so, too, was the design process (De Landa 2004, 20-21).

By contrast the morphogenetic model looks at materials through their intrinsic properties and aims to draw advantages to architecture through their performance. Often these materials are arranged in response to environmental conditions. It is important to consider in the design process, not only what these materials are made of and their inherent properties, but how their properties may be used in a design to yield their greatest potential and how they can begin to work for us, and what more they can provide beyond the standard. This can be considered the labour of materials. De Landa further echoes this idea and urges, “it is precisely the ability to deal with complex, continuously variable behavior that is now needed to design” (De Landa 2004,14-21). De Landa explains that by disregarding a material’s unique properties we cannot take advantage of its innate potential. He goes further to highlight that intrinsic properties are not the only important material factors. The way these factors express themselves or how the materials come to be, are crucial to achieve an architecture that capitalizes on the material properties through construction and assembly. A more holistic and cyclical view of materials and their engagement with the environment, an understanding of what the material empirically is, how it came to be, and how it reacts and responds to its surrounding worlds offers beneficial ways of building. These factors provide passive benefits to structure, energy control through a material's properties and have the potential to outline new forms of social organization through alternate ways of building.

Engagement, experimentation and a reiterative process supports learning and understanding a materials' performance. Architect and theorist Achim Menges has emphasizes the need to understand materials and their intrinsic qualities to provide benefit and a reduction in the large energy expenditure put towards processing standardized materials (Menges 2012, 21). When material properties are considered, materials start to serve more than just a formal arrangement. Materials can be used to regulate energy and the surrounding environments, provide a sensory experience as well as respond to a variation of inputs resulting in a variation of experiences. Architect and researcher Michael Hensel describes how "[m]aterial responds to stimuli and can thus be utilized strategically in the orchestration between material and energetic exchanges" (Hensel 2010, 46).

The use of standardized materials and methods of construction has created a disconnect between the architect and the material. Architects often have not developed the knowledge or experience using materials beyond their standard applications, instead opting for the predefined material palette of the hylomorphic model. Buildings are commonly an assembly of predetermined parts. This architecture is arguably static in its relationship with its environments, where clear boundaries are drawn between the exterior environment and the interior environment. This standardization often results in a homogeneous interior space and a limited architectural experience.

The standardization of the design process has also perpetuated a hierarchical relationship between the architect and the persons building the work within a hylomorphic approach to design. Architects prescribe these standardized practices of building onto crafts persons and trades persons. Through alternate processes of working with materials, non standardized building techniques could offer more design control to the individuals building. Renegotiating the hierarchical relationship between architect and builder through working more collaboratively alongside material this could develop a process of more efficient labour that considers the input of builder, the performance of the material and the response to site context and conditions.



Cristina Parreño, “TRANSTECTONICS”, 2019, glass, stone, wood, and volcanic rock, dimensions vary, (MIT Architecture 2019)

In contrast to the hylomorphic model, architect Cristina Parreño whose work builds on both the negative effects of the standardization of materials and the need to understand material properties while designing and making. In her work “Transtectonics”, she explores materials such as stone, wood, metal, and glass – the most common standardized materials used in construction – and critiques the limited range of systems of assembly considered. Parreño expresses how these materials “in their conventional manufactured states, are often stripped of inherent potentials, embodied cultural histories, and important capacities promised when they are in a raw state. By stepping out of the standard systems of assembly, Transtectonics aims to defamiliarize the processes of construction, transforming it into a process of experimentation” (MIT Architecture 2019).

“Transtectonics” is a prominent example of the morphogenetic approach to design and making. Through the engagement with materials and processes, Parreño develops unique processes of making with materials showcasing novel ways of utilizing material properties as a catalyst to aid and influence design positively and progressively. This process introduces a new approach to materials and invites us to detach our preconceived ideas of how to build with common-place materials in architecture. This morphogenetic process allows material properties and processes to perform in various ways and effectively influence the design process.

Permanence vs. Emergence

The hylomorphic model is based on hierarchies, whereas the morphogenetic model is based on meshworks. Hierarchies are defined as linear systems and, in contrast, meshworks are defined as non-linear systems. De Landa extends Deleuze and Guattari's ideas, outlining that "[hierarchies take] a heterogeneous collection of raw materials… homogenize them by means of a sorting operation, and then consolidate these homogeneous groups into something larger and more permanent"(De Landa 1997, 505). By contrast, meshworks are network-type systems which are unplanned and invite growth and change. Meshworks thus operate more temporally and impermanently and are open to change and shifts within its system and environment. Hierarchies are a top-down approach, which define themselves through order and categorization. Meshworks are a bottom-up approach which thrive on variation. Neil Leach differentiates hierarchies from meshworks: "[where] linear systems (hierarchies) tend to be characterized by a single steady state, non linear systems (meshworks) tend to display multiple steady states. Non-linear systems have the crucial capacity to self-organize" (Leach 2017, 22). Thus through a design-through-making or a morphogenetic approach, this thesis searches to take advantage of self-organizing features of materials to develop alternate forms of construction which considers other systems such as climatic and social implications.

The exploration of materials within a meshwork system invites a process of discovery, where emergent conditions and systems can spawn innovations in building techniques, passive energy solutions to cooling or heating spaces, and new forms which promote new social structures through a performative understanding of materials and the processes that form them. De Landa describes this approach as: "a neomaterialism in which raw matter energy, through a variety of self organizing processes and an intense, immanent power of morphogenesis, generates all the structures that surround us. Such a neomaterialist account renders matter-energy flows, rather than the structures thereby generated, the primary reality" (De Landa 1997, 509). De Landa highlights the importance of the forces that generate change: the energetic processes – movement, making, and material as opposed to the product generated. These energetic processes can provide an understanding of forces, where opportunities may derive from material processes. It is these forces, or flows, where the architect can begin to intervene and harness the potential of a material or material system. This process can also allow for new experiential qualities that are understood not for what they may represent or mean, but for how they are experienced through the human field of sensory awareness and movement.

To counter the conventional hylomorphic ways developed through image and history which standardize systematic ways of building, this thesis pursues a morphogenetic approach. This morphogenetic approach embraces a meshwork system, which allows for a processed-based design method; harnessing a material’s properties and embracing the complexity of materials to perform and invite a variation of space and experience. This process driven approach aims at developing a non-standardized approach to building using material’s intrinsic properties to their greatest potential. In this case, the architecture will be considered as an evolution from material understanding. This morphogenetic approach is increasingly important to harness a material’s innate properties in the pursuit of form and to intervene and innovate to find less wasteful and more productive ways of building. This can allow for low-tech passive solutions to enhance the performance of architecture. This process can also allow for new experiential qualities that are understood not for what they may represent or mean, but for how they are experienced through the human field of sensory awareness.

2.2: Sensory Microclimates

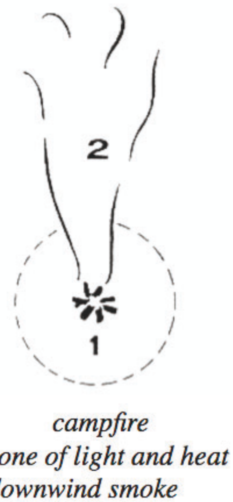
The morphogenetic model is explored in this thesis to achieve an architecture that counters the pitfalls of the hylomorphic model of design. This hylomorphic model has produced architecture that perpetuates homogeneous space. Homogeneous space can be characterized by a consistent quality of experience throughout architecture without consideration for how the material qualities can offer more to the experience of inhabitation and offer passive low-tech solutions to energy conservation. Homogeneous space perpetuates ideas of a static architecture, which is defined by boundaries of the material threshold. The hylomorphic model understands architecture as permanent and fixed.

This thesis will explore materials wax and concrete using a morphogenetic approach, through material experimentation, processes of making, and an understanding of the material properties and their performance aiming to achieve sensory microclimates. Sensory microclimates provide a range of sensory experience and energy modulation in response to their environmental contexts.

This chapter will outline the goals of this morphogenetic design approach. Firstly, architectural historian Reyner Banham's comparison of "substantial structures" and "energy controlled space" will provide a foundation for the concepts of sensory microclimates. Sensory microclimates will be defined and how the material threshold properties can be used to achieve them. Finally, a synthesis of the goals and how they might be achieved through wax and concrete will be discussed.

Throughout history, comfortable environmental conditions for human habitation could not be achieved through structure alone. Banham compares the Western model of 'substantial structures' to 'energy controlled' space. The 'substantial structures' model were erected with an attempt at permanence and environmental control (hard zones) through the implementation of massive structures. Today, the model is erected through mechanical systems. In this model, space is divided by a static material threshold; the boundaries and experiences of space are clear and constant resulting in a homogeneous experience of space. Charles Rice believes it is these boundaries created by 'permanent' structures that "enforce fixed spatial relations and social hierarchies" (Rice 2009, 191). Banham explains how these two approaches have drastically different conceptions of space and how societies organize themselves in response:

> [C]ultures whose members organize their environments by means of massive structures tend to visualize space as they have lived in it, that is bounded and contained, limited by walls, floors and ceilings... Against this, societies who do not built substantial structures tend to group their activities around a central focus - a water hole, a shade tree, a fire, a great teacher - and inhabit a space whose external boundaries are vague, adjustable according to functional need and rarely regular.
>
> The output of heat and light from the campfire is effectively zoned in concentric rings, brightest and hottest close to the fire, coolest and darkest away from it ... but at the same time, the distribution of heat is biased by the wind... so that the concentric ring zoning is interrupted by other considerations of comfort and need. (Banham 1984, 20)



Environmental conditions around a campfire (Banham 1984, 20)

In summary, space defined by energy and activity creates boundaries that are vague. These boundaries are not defined by a hard line, but by a gradient of temperature and a sensory response of social experience, constantly in flux as the space is in relationship with the environment, energy, and social actors (Banham 1984,152). This energy controlled model can provide a variety of experience for a user. Banham's energy controlled model can be interpreted as a means of organizing space to provide variation based on environmental context. In order to ensure variation and a range of experience, it is important to understand microclimates as a design approach – not limited to temperature, humidity, atmospheric pressure, wind, and precipitation – which constitutes the factors that define climate. This definition can extend to encompass structure, light (both natural and artificial), sound (both its limitation and its transmission), movement, textures and smells. Architecture can offer sensory microclimates as a goal, which aims to provide a gradient of these experiences.

To achieve variation relies on a relationship with the material threshold and how these thresholds or boundaries define the qualities experienced in space. To develop sensory microclimates, a change in perspective regarding materials is required because their properties and processes need to be considered to influence space. Michael Hensel explains there is a need to understand space and architecture as an extension of its surrounding ecologies. In order to achieve this, architecture can be approached as system of performative material elements that directly engages with the ecosystem. This engagement forgoes the standard homogenized (interior) environments (Hensel 2010, 42). The strategic orchestration of material processes of making and processes of change within the material adapt and change to both the external environment and the processes of making, help define space and experience.

Working with materials wax and concrete, this thesis aims to develop material thresholds that layer the factors which constitute a sensory microclimate. By studying the material properties and distilling ways in which it can respond to environments and energy to provide a range of experience and support social programing.

It is important to consider architecture to blur and blend, to combine and join, to allow space to constantly redefine experience. Michael Hensel explains how

> the material stratum may then not be primarily understood as the means to provide thresholds, that is divisions between an inside and outside for example, but, instead, serve as an 'active agent' in the orchestration of flows, energetic or otherwise, that generate dynamic gradients of conditions as a way of modulating space in a heterogeneous and motile way. (Hensel 2010, 46)

These are important considerations when trying to achieve spaces of variation through sensory microclimates.

This thesis explores materials with changing states – in particular wax and concrete – to develop sensory microclimates, through material properties, alternate processes of construction and energy modulation. Sensory microclimates will be used to blur the boundary between the 'inside' and 'outside' by creating shelter from natural forces through a nesting of structure, providing a range of lighting conditions throughout and ensuring thermal comfort where needed. The structural capacity of concrete will be used to provide shelter from climatic forces (wind, sun, and precipitation), molding concrete with wax enabling complex forms due to waxes phase change. Gradients of light conditions will be achieved through thickness of wax, determined by an aggregation wax (melted or solid), as well as porosities and light wells created in concrete with wax. The phase change properties of wax and the thermal mass properties of concrete will provide gradients of temperature because both materials store and release heat at different rates. These factors will define sensory microclimates, to support and influence activities that might occur in these spaces such as meditation, art gallery, theatre space and community space. The variety of spatial form and gradients of light and temperature will provide the individual with a diverse range of experiences.

The intention to create sensory microclimates will be explored through material prototypes in the following chapter. An understanding of the material properties of wax and concrete will provide a foundation to achieve spaces that vary in form, light and temperature.

Chapter 3: Materials, Methods and Findings

This chapter tests the morphogenetic model of design through prototyping a series of models which explore the properties of wax and concrete. These models were made without a preconceived idea of what they might look like and instead prioritized the steps and factors that contributed to the process and the material expression. These processes will later be investigated and translated into an architecture. The rational behind choosing wax and concrete for this exploration will be discussed. A closer look at wax's properties will be provided as well as examples of manufacturing with wax. Then the technical approach and investigations will be outlined, followed by a series of diagrammatic studies showing possible translations to methods of construction and possible forms of inhabitation. Finally a synthesis of the findings will be outlined from these prototypes and diagrams.

3.1: Choice of Materials: Wax and Concrete

Wax and concrete were chosen for their liquid and viscous qualities and their fluid aspects of forming. These materials speak to the morphogenetic method through their self organizing characteristics, reacting to external stimuli such as heat and to each other. They are considered quite simply phase changing materials with the ability to change from a liquid to a solid. However, wax is able to undergo many phase changes from liquid to solid and back to liquid continuously. Concrete and wax posses different material properties and performance qualities such as the rate at which they harden. These two materials allow for a morphogenetic relationship where their coupling due to their different rates of hardening allows for each to influence the other. Wax's phase changing properties also allow for efficient energy storing potential.

Wax and concrete are used as form finding prototypes and also as a model for developing a morphogenetic understanding of the processes that allow for form to emerge in the search for translating this understanding into an architecture.

Properties of Wax

Wax is classified as a phase change material. Wax is solid at ambient temperature, thermoplastic in nature, insoluble in water and becomes a liquid with the application of heat. Wax can range in translucency (completely clear to opaque), with a solid appearance (dry, waxy, mottled, shiny). Wax is non-reactive and non-toxic, making it safe to handle and not a danger to the environment. Wax can be categorized as either naturally or synthetically derived. Wax can be categorized in different ways including its needle penetration which is used to measure the hardness of the wax, its viscosity which measures a liquids resistance to flow, congealing point the temperature where the wax begins to harden and melting point which refers to the temperature that the wax melts and becomes liquid. Paraffin waxes have a melting temperature with a wide range from 23 - 67˚C (American Fuel and Petro Manufacturers n.d.).

Paraffin wax is used and tested as a phase change material (PCM) in thermal energy storage systems (TES) due to its low cost, availability, high energy storage density and its latent heat of fusion (charging/ discharging heat at a nearly constant temperature). Also, studies indicate that paraffin wax has very stable thermal properties after 1000-2000 melting/freezing cycles, no degradation of the material was recorded (Akgun, Aydin and Kygusuz 2007, 669).

Paraffin wax stores heat and energy, having a specific heat capacity of 2.14–2.9 J/g−K (joule per gram kelvin) and a heat of fusion of 200–220 J/g. (Cargo Handbook 2018) Compared to water which has a specific heat capacity of 4.1813 J/g-K. Wax stores energy as it is melting and it is recovered as it solidifies. Furthermore, there is a significant volume change during state change, wax expands considerably as it melts.

Paraffin wax has a low thermal conductivity between 0.167- 0.346 W/m˚C. (the rate at which heat is transferred by conduction through a cross section of a material) making it an sufficient insulator. However heat transfer within the material can be enhanced with the integration of metal such as a metal matrix structure or aluminum shavings (Farid et al. 2004, 1599-1604). Paraffin wax is also an adequate electrical insulator, with an electrical resistivity of between 1013 and 1017 ohm metre (Cargo Handbook 2018).

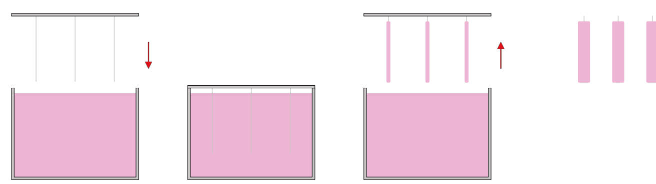
Wax and Manufacturing

Processes of manufacturing that use wax will be analyzed to understand how wax can generate form.

Wax is able to be machined to create parts with extreme precision which allows wax to be used with standard machining tools typically used for metal as well as rapid prototyping machines such as the CNC and 3d printers that print in wax.

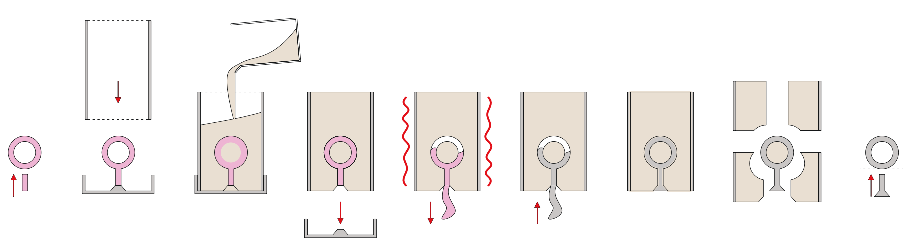
Wax is used often during mass production or for mold making in general because of its ability to pick up detail and precision within the mold producing higher quality casts and reproductions. Specific waxes are used for their specific properties which allow the wax to be injected as well as pick up the most amount of detail.

In candle making**,** String is dipped into a vat of liquid wax repeatedly, slowly building up a tapered wax form. This process relies on a precise timing and temperature of wax to ensure the most efficient wax growth along the string.



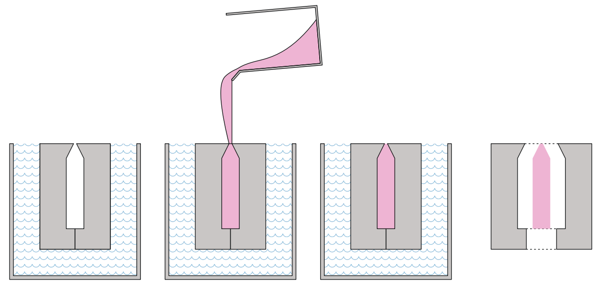
Candle making

Lost wax casting methods are used extensively in manufacturing as well as for jewelry and sculpture to generate molds for production. The wax is either carved or molded is used as a sacrificial form to produce molds to produce exact replicas in metal and other materials. Wax can hold form as a solid to create a ceramic mold and then flow out of the mold as a liquid with the application of heat. This process is possible because of wax's phase change abilities. The wax in this process can be used over and over.



Lost wax casting

In injection casting, metal molds are used to form wax and the molds are submerged in cold water cooling the metal causing the wax to harden quickly and release easily from the molds.



Injection casting

In March 2012, Tailorcrete developed by Garmazio Kohler Research won the Global Holcim Innovation Prize for a new wax based formwork technology. The reusable wax formwork was developed to provide new ways of working with concrete.

TailorCrete: Wax Formwork Technology, 2009-2013. (Gramazio 2016)

Through further understanding of the properties of wax and analyzing manufacturing processes, it provided an understanding for undertaking the following investigations using wax and concrete. The lost wax casting process provided a starting point for the investigations.

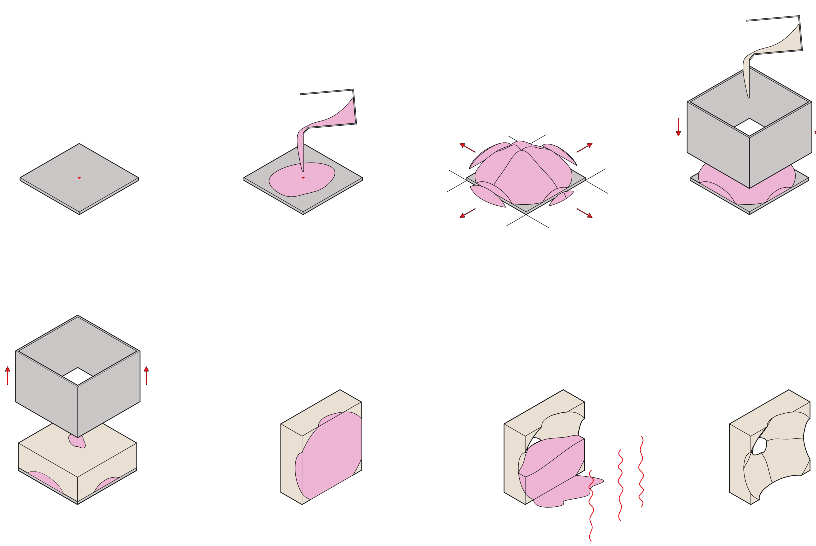
3.2: Methods and Technical Approach

Investigation 1.1

Investigation 1.1 concrete model

Description - Wax was slowly built up on the formwork by pouring liquid wax in the same spot over a 3-hour period. A mound of wax developed. This wax form was then encased in formwork and concrete was poured over top, leaving the tip of the wax form exposed. The formwork was dismantled, and the wax melted out with a heat gun.

Materials **-** Paraffin Wax, Concrete, ½" Douglas-fir Plywood



Investigation 1.1 - Diagram of process

Method

1. Prepare 10” by 10” module platform of douglas fir plywood.

2. Cut side panels using table saw & chop saw for mold box to slip over module.

3. Drill pilot holes in side panels and counter sink hole so screw lies flush. This step is important so the mold does not break when screwed together. It also ensures that the mold can be used multiple times.

4. Prepare double boiler. Place pot on hot plate and fill with water. Place large metal container filled with paraffin wax into pot of water. Turn heat to medium/high to begin boiling the water.

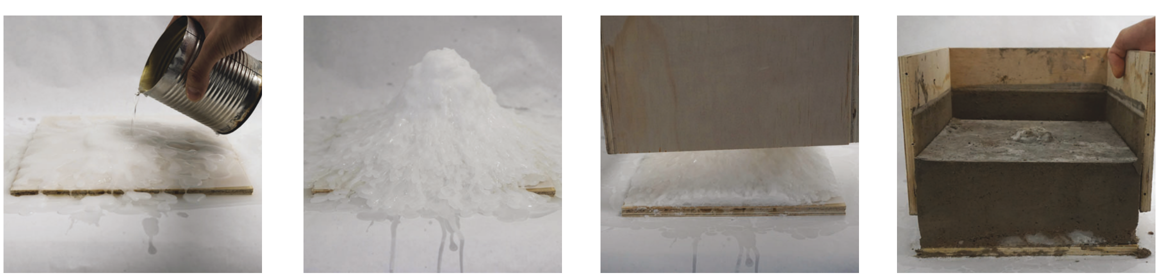
5. Once wax is melted transfer into smaller container and begin pouring onto 10” module in small intervals. Continue this until wax builds up to desired result.

6. Wait for each layer to cool a bit before pouring the next layer.

7. Once desired form is reached and wax has cooled, place wooden box mold around module.

8. Mix concrete. Pour into mold to desired height. Place metal rod or wire to provide structure and tap and shake mold to release air and ensure the concrete fills cracks to pick up texture. Finally, cover top of mold in order to ensure even drying and prevent cracking. Wait 24 hours for concrete to cure.

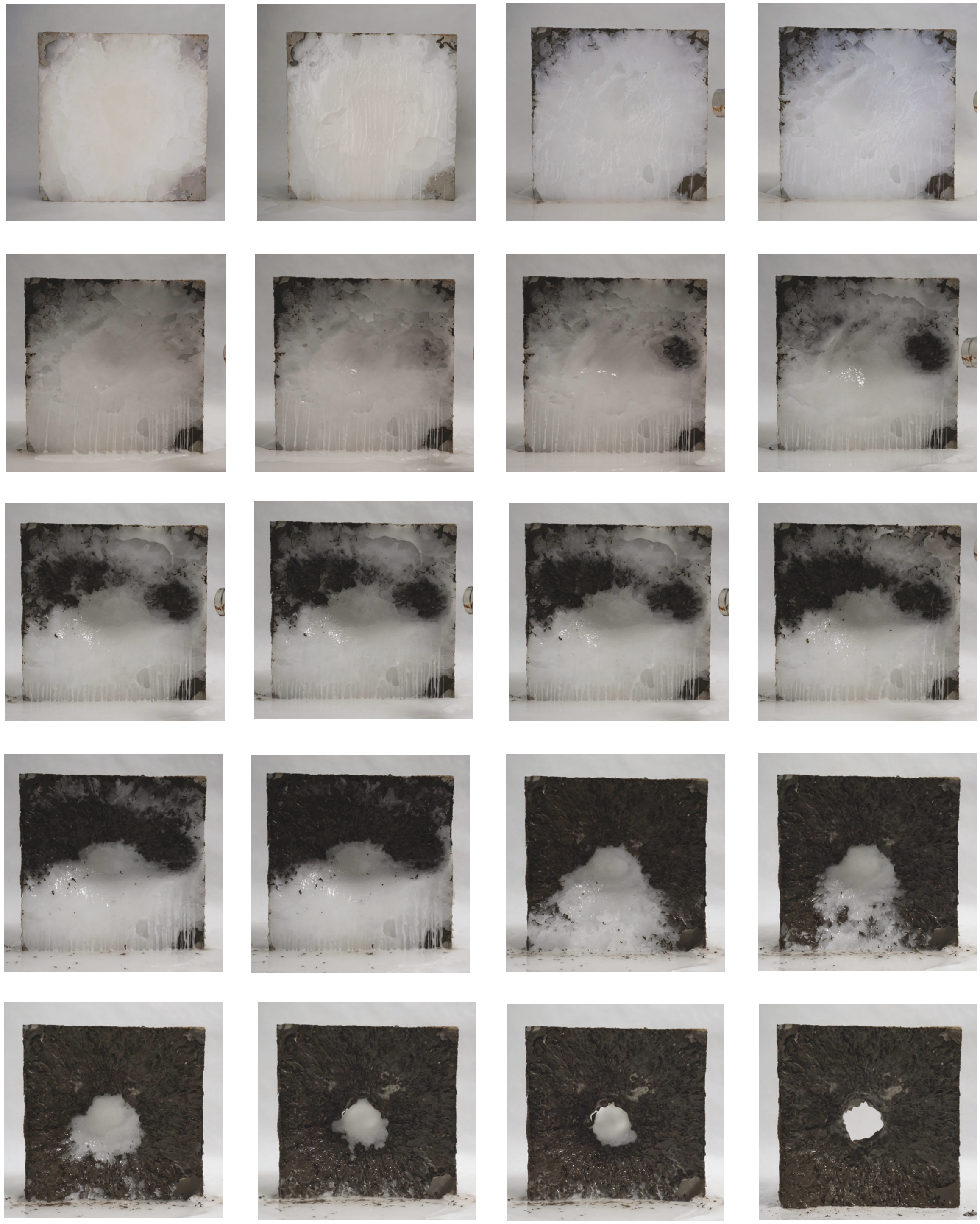
9. Remove mold and begin melting out wax with heat gun. Melt on top of large paper in order to avoid mess and to capture and reuse wax.



Investigation 1.1 - Construction process

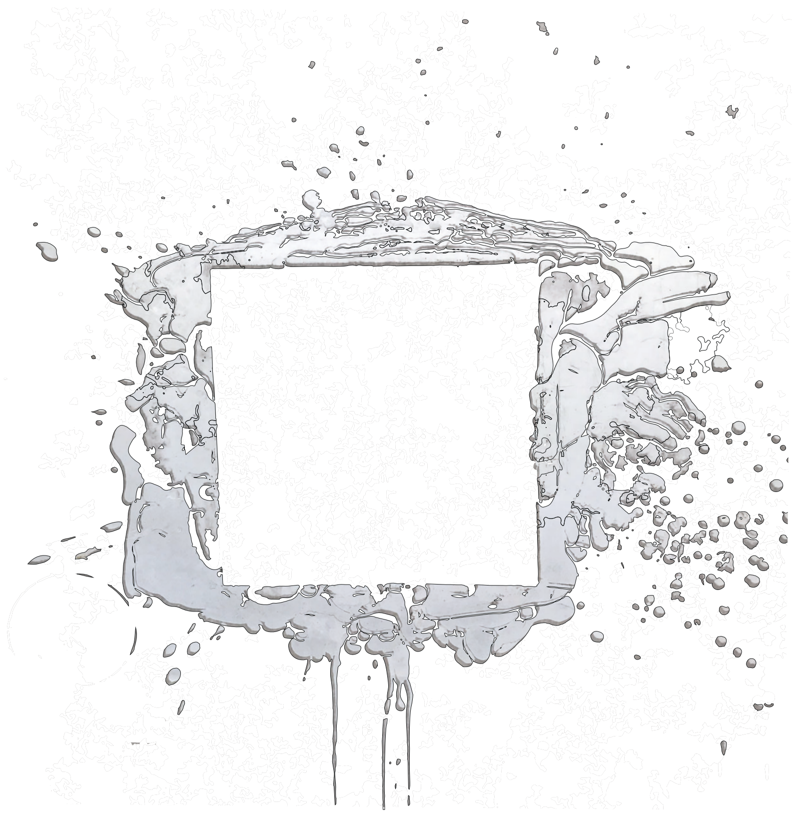
Documentation

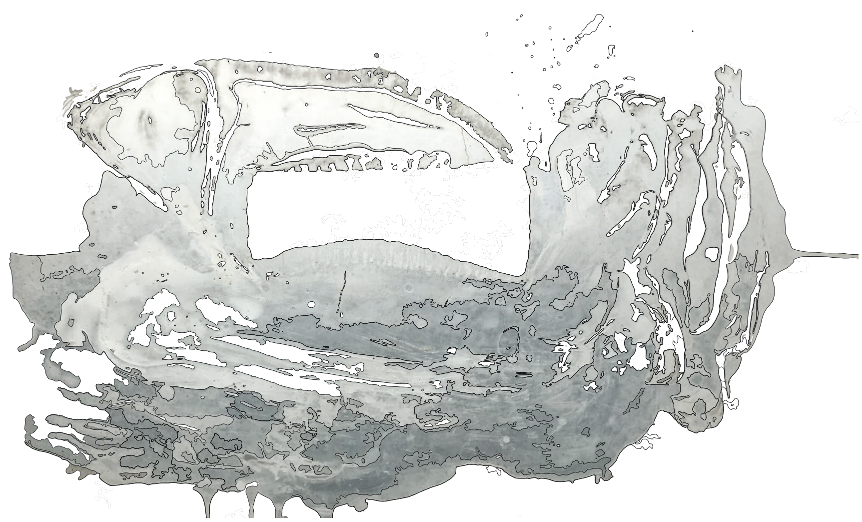
Investigation 1.1 - Before wax melt out



Investigation 1.1 - Sequence of melting wax out of form

Investigation 1.1 - After wax melt out





Wax drawings captured on paper as a result of melting wax out of concrete form

Findings

Temperature of wax-controlled form. The hotter the wax the more viscous it was which caused it to run and spread farther resulting in thinner layers and over time a more vein like texture. The cooler the wax the less it spread, and the layers ran far thicker building up form much faster and resulting in a rounder smoother texture as a result.

It became necessary to allow the wax after each pour to cool a bit in order for the layers to build up, otherwise the wax would just melt the layer beneath it and run.

The wax mass stayed warm for a surprisingly long time (hours) after pouring was complete. Moving forward documenting the thermal loss of the wax could be a worthwhile investigation, especially comparing different formal compositions.

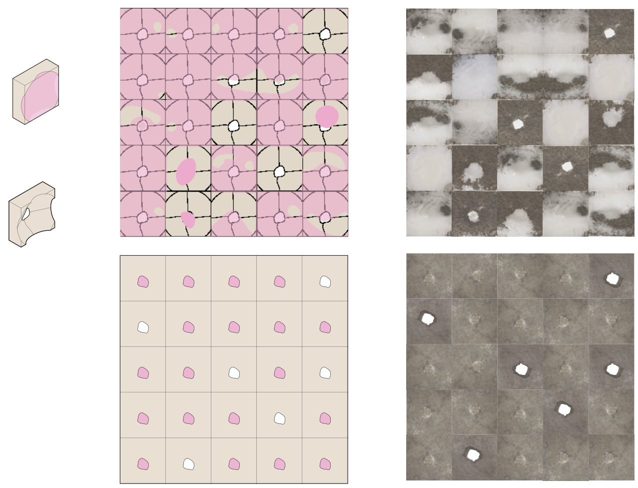
Moving forward it is important to control the quantity of wax being poured and the temperature the wax is being poured at as this investigation had little control over that factor.

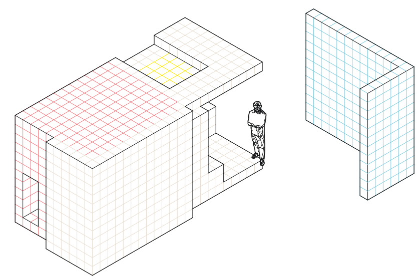
The wax, which was melted out during the investigation, impregnated the paper used to capture the wax creating very interesting patterns. The paper when held to light was translucent in the areas the wax had formed. Photos were taken of the paper in front of a light filled window in order to capture the tones of light transmission caused by the wax. The photo was then manipulated in Adobe illustrator cleaning up the background and applying line work to highlight the forms and patterns created.

These drawings of the melted wax forms if interpreted as plan and section drawings begin to offer interesting spatial organization, a meandering labyrinth like composition with different layers of transparency, a blending of space through form and a variety of ways of moving through the space.

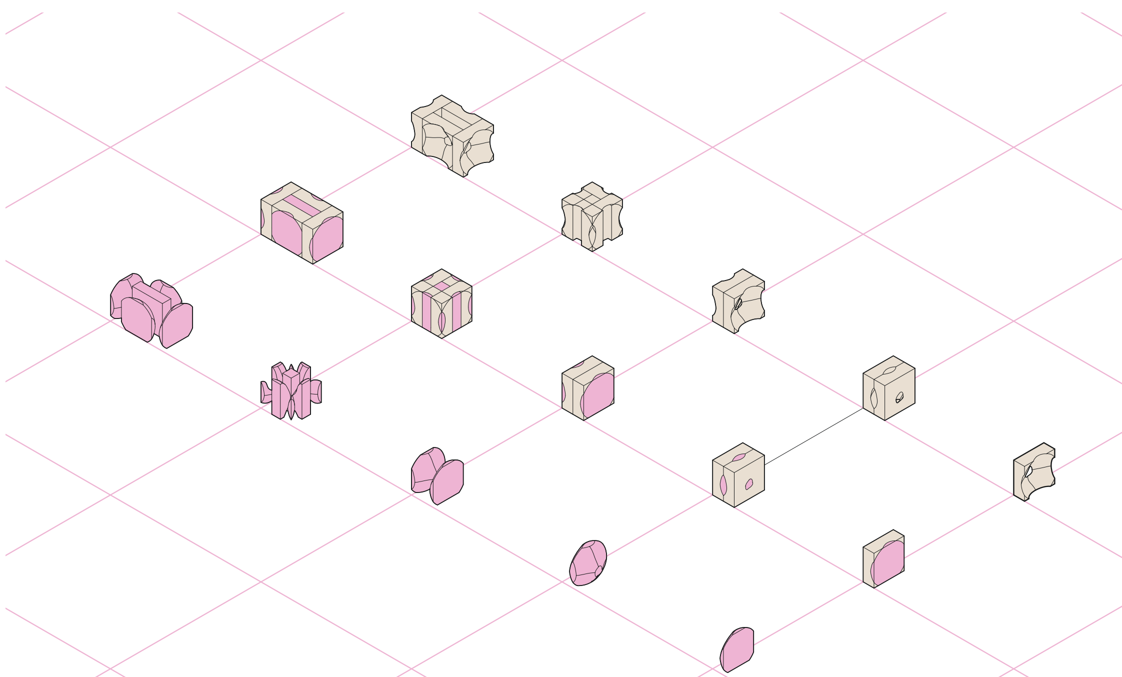
The final piece has potential as a building block. A concrete block coupled with wax may create a very promising thermal mass system. Also, the wax and its spatial relationship with concrete has the potential to create a wide range of lighting conditions, through porosity and wax's ability to diffuse light. This could be at a larger building scale or at a smaller scale that explores its potential as a screen wall operating at various thicknesses or perhaps even smaller and functioning as sheet material, something applied to a window, or as a layer in the buildings envelope.

The texture produced due to the wax dripping method explored in this investigation may also be a great draining system. The pattern naturally repels or holds water. Also due to the convex shape it would move water well.

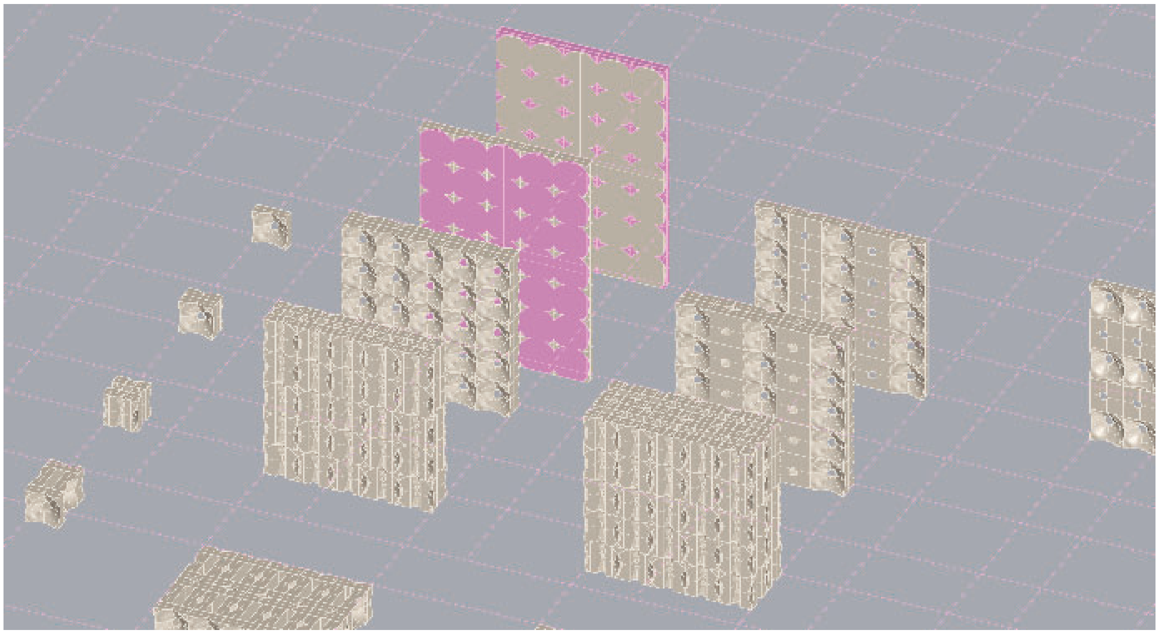




Block arrangement in response to environment: structure, wind, light, and thermal



Diagrams of potential block configurations - relationship between wax and concrete



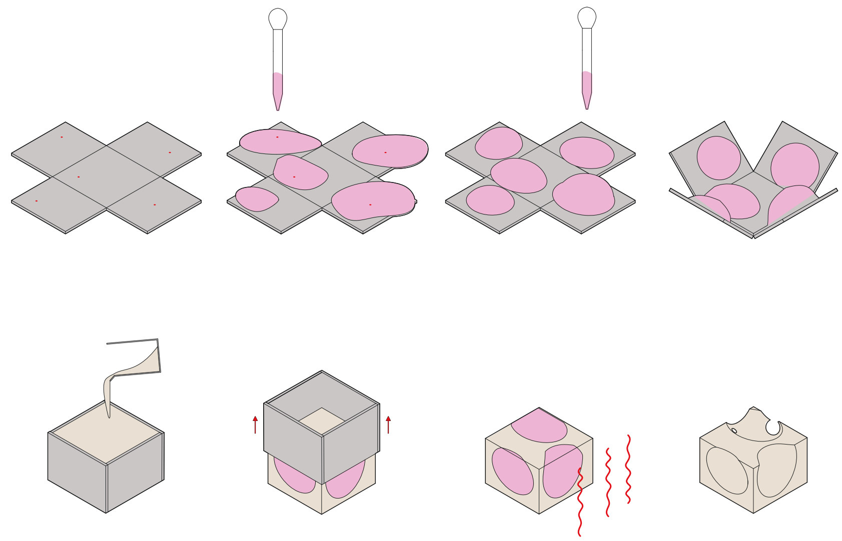
Modeling of how the block may aggregate

Investigation 1.2

Investigation 1.2 - Concrete model

Description - This investigation is an evolution from 1.1. Using the same process for building up a wax form; however the form is built up on all sides of the block formwork in order to affect all the faces.

Materials: Paraffin Wax & Concrete, Wood (douglas fir 1/2” plywood)



Investigation 1.2 - Process diagram

Method

Repeat steps 1 - 4 from Investigation 1.1

5. Layout Panels flat so they may be tilted up in place and screwed together.

6. Once wax is melted use basting tool to transfer controlled levels of wax onto mold panels. Continue this until wax builds up to desired result. Wait for each layer to cool a bit before pouring the next layer.

7. Once desired form is reached and wax has cooled, trim wax that has extended past the panel.

8. Tilt up formwork and screw together.

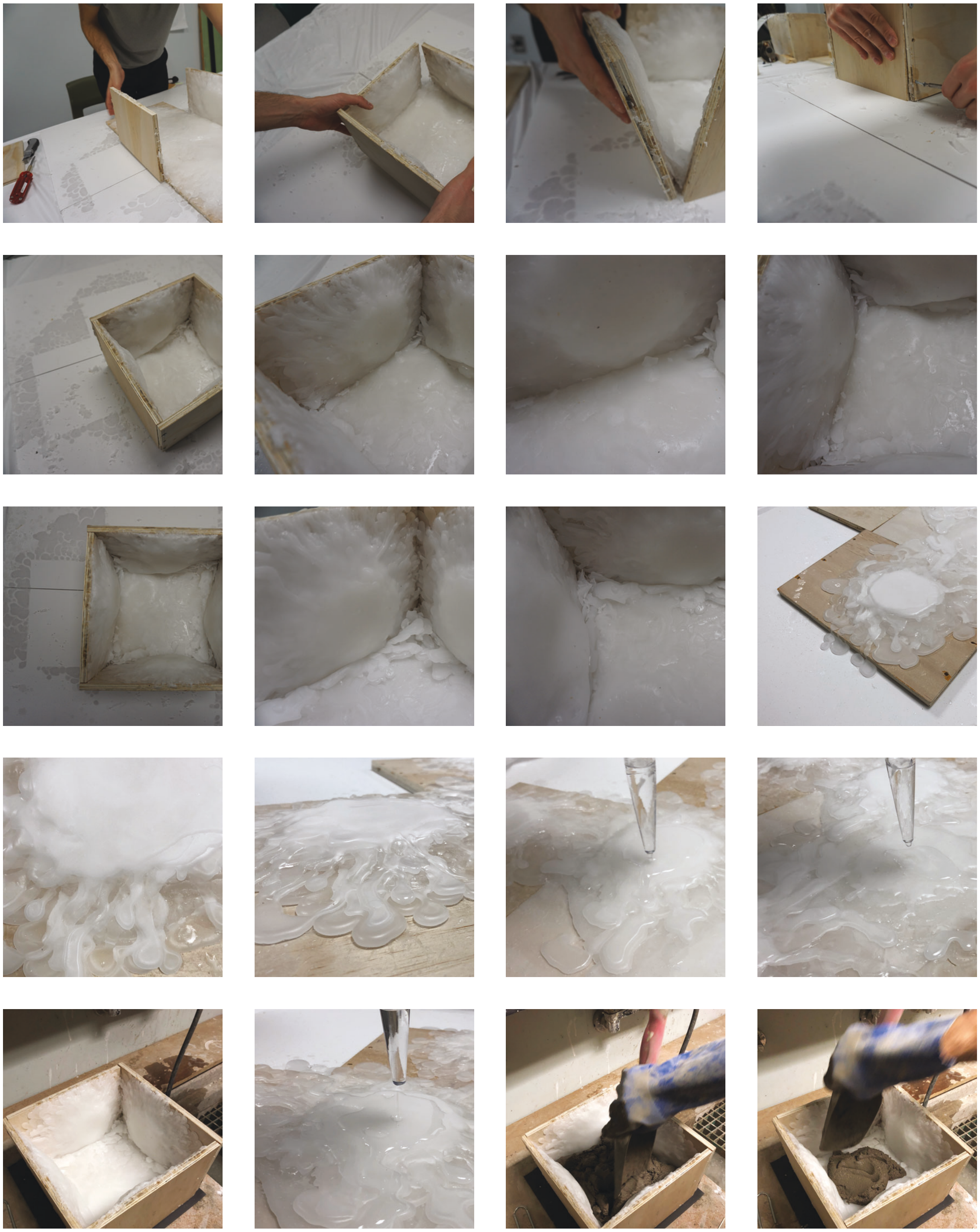
9. Mix concrete. Pour into formwork. Place metal rod or wire to provide structure and tap and shake mold to release air and ensure the concrete fills cracks to pick up texture. Finally, cover top of mold in order to ensure even drying and prevent cracking. Wait 24 hours for concrete to cure.

10. Remove formwork and begin melting out wax with heat gun. Melt on top of large paper

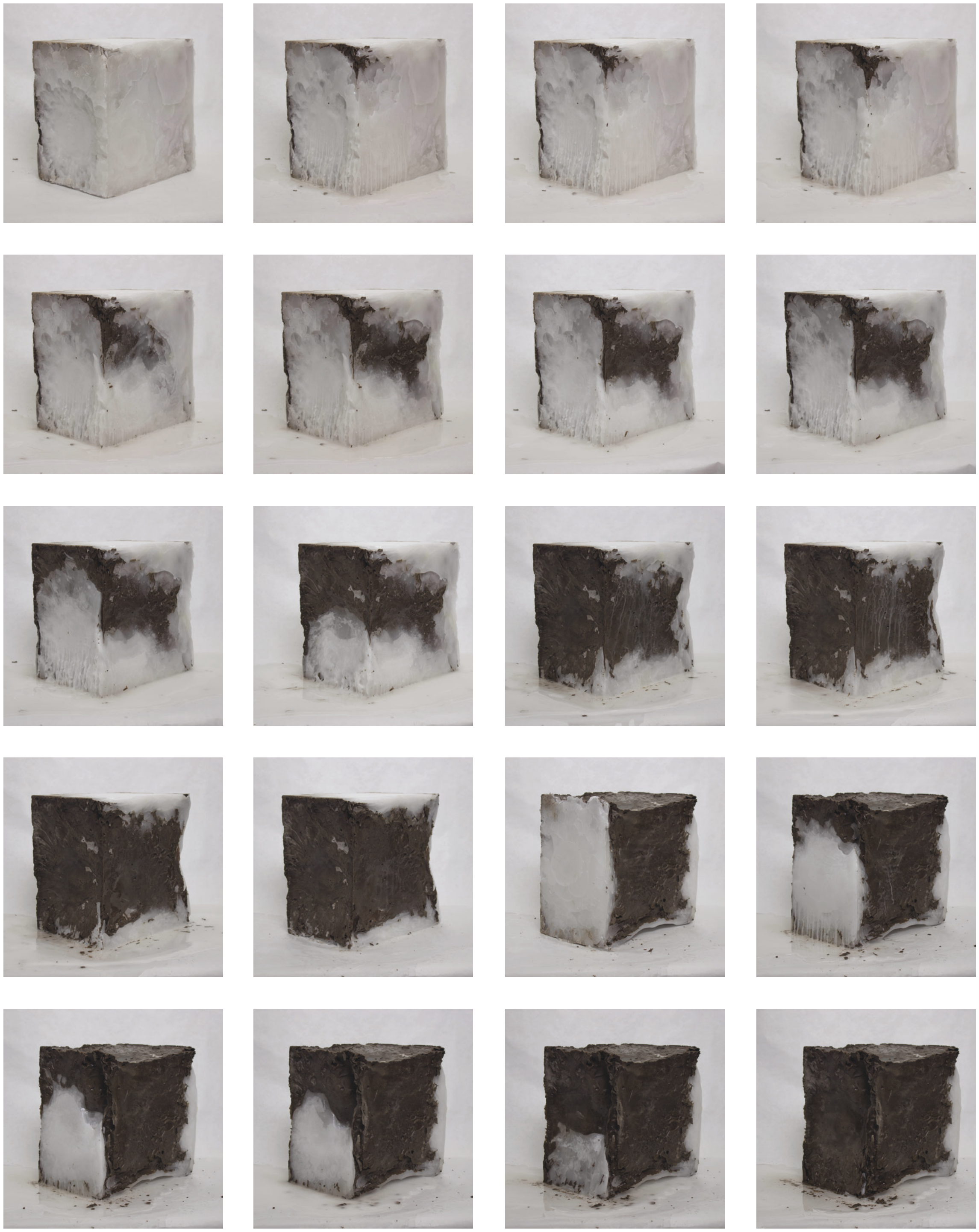
in order to avoid mess and to capture and reuse wax.

Documentation

Investigation 1.2 - Process of making

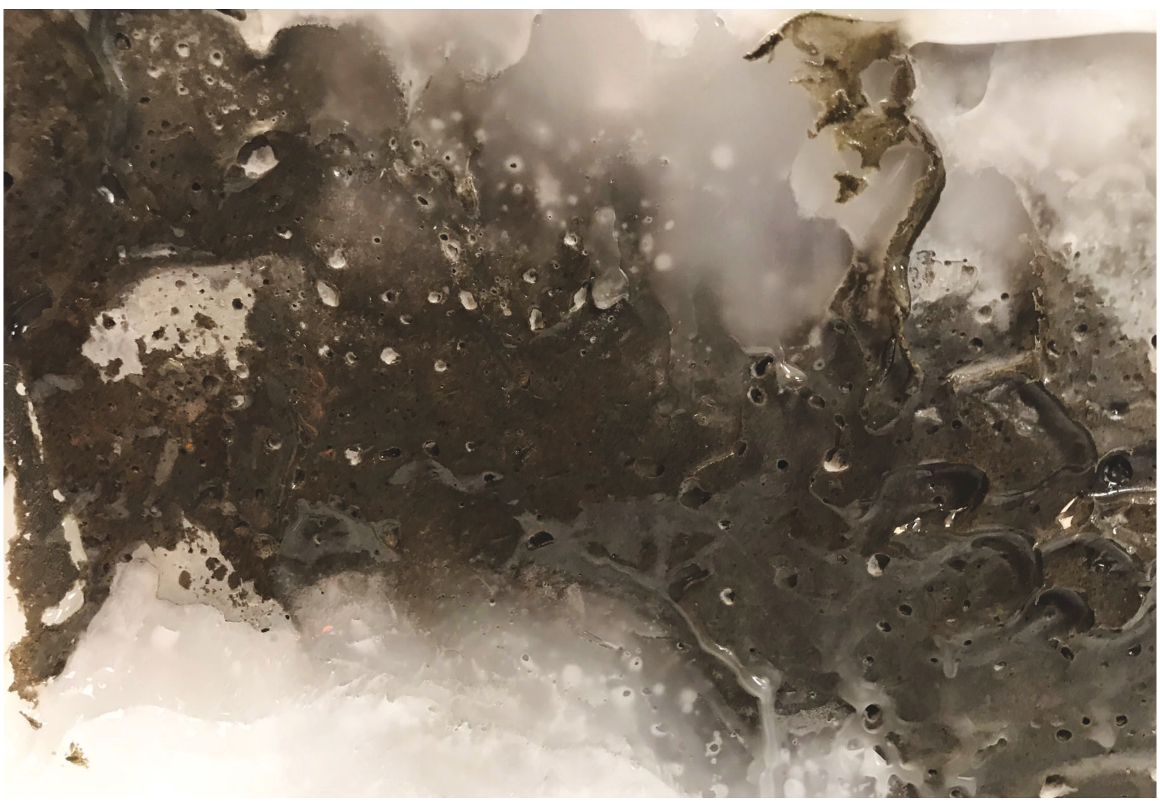


Investigation 1.2 - Process of making



Investigation 1.2 - Sequence of melting wax out

Investigation 1.2 - Model before and after melt out



Investigation 1.2 - Model after melt out

Investigation 1.2 - Connection test - wax could allow for complex joints

Findings

Using a turkey baster allowed for measured and more controlled dripping on the wood formwork. This caused the wax to build up in a smaller radius faster.

Building up the wax on four sides allowed for an erasure of rectilinear form from the object.

The overall texture produced is quite tactile, smooth and almost rubbery with the fresh wax coat from the wax melt out.

Wax as a finish, the concrete seems to absorb the wax as it is melted off, creating a sealant and offering finishing qualities as these areas stand out from the areas without wax. This is a nice result of the process and remains with the finished object. A visual description of the process.

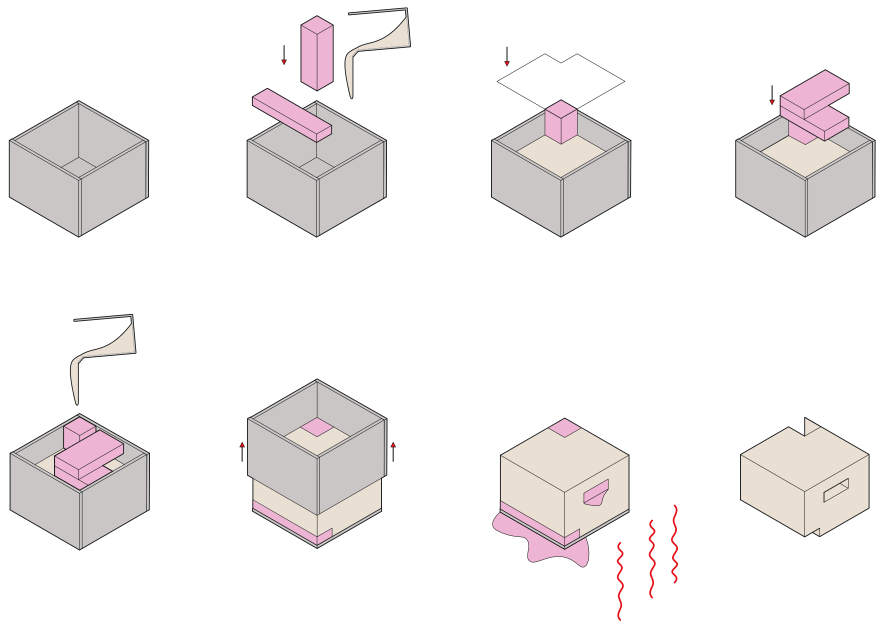
A test for a simple joint was successful as a way of creating complex joints or to allow connection points to other materials such as wood.

Investigation 2

Investigation 2 - Concrete model

Description **-** Wooden formwork is constructed, wax blocks are carved, molded or joined and then placed into the formwork. Concrete is then poured over top of the blocks and metal sheet structure is embedded into the concrete for strength. The wax is being used to carve out space within the block.

Materials: Paraffin Wax, Concrete, ½” Douglas-fir Plywood, Metal Container, Water, Hot Plate, Metal Mesh/Rod, Heat Gun



Investigation 2 - Process diagram

Method

Repeat steps 1-3 from Investigation 1.1

4. Using wax block cut/ carve and join wax to desired shape. Keeping in mind desired spatial goals or ideas.

5. Mix concrete.

6. Place wax blocks in desired location and pour concrete over top repeat as you ascend the formwork.

7. Place metal rod or mesh sheet to provide structure and tap and shake mold to release air and ensure the concrete fills cracks to pick up texture. Finally, cover top of mold in order to ensure even drying and prevent cracking. Wait 24 hours for concrete to cure.

8. Remove formwork and begin melting out wax with heat gun. Melt on top of large paper in order to avoid mess and to capture and reuse wax.

Documentation

Investigation 2 - Sequence of melting wax from concrete form

Investigation 2 - After melt out - view of interior

Investigation 2 - Model after wax melt out. Wax sealed the surface of the concrete, creating a finish.

Findings

Wax floats inside the concrete, making it difficult to control where the blocks exist in place. Keeping the concrete mixture on the drier side helps, also using large aggregates to hold wax down. Something can be embedded in the wax and attached to the formwork to keep wax in position, perhaps the wax forms are all connected to allow for more structure and control as well as an easy way to drain the wax from the form. This piece needed to be repositioned in order to allow the wax to flow from certain areas, the wax staining shows what position the block was formerly in due to wax draining with gravity.

Concrete finds its way around the wax blocks, requiring parts of the concrete block to be smashed into in order to access the wax for melting.

The voids within the blocks offers great potential as creating inhabited space and intricate formal qualities. Additionally, the voids can work as a means of providing a range of lighting conditions, as light wells drawing light into the interior spaces. Also, these openings can be a way of providing circulation, inspiring a meandering circulation through out the structure, almost like walking through the veins of a building a tunnel like composition. Finally, these voids can be used to allow airflow through the structure (cross breeze, stack effect), redirecting or breaking winds. The texture and formal composition of these openings can be further studied to offer more in terms of how it interacts with light, wind and movement. Potentially the addition of another material into these voids may be a promising investigation, within the entirety of the void or perhaps at different scales, a portion of the void, or perhaps at a smaller scale within the textured concrete produced by the wax.

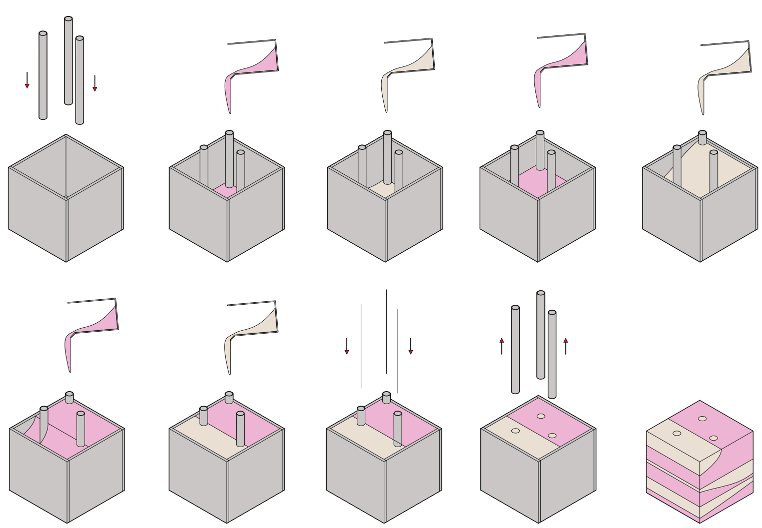
These voids and opening can also provide a method for connecting multiple blocks together, by stringing them together with an alternate material. Perhaps steel cable. This can provide a necklace like construction.

Investigation 3

Investigation 3 - Concrete and wax model

Description - wax and Concrete are layered in sequence into wooden form work. Cardboard tubes are placed in order to ensure an uninterrupted concrete structure extends throughout the block. The paper tubed would be filled with concrete once the formwork is full and then the paper tube removed slowly leaving behind the concrete and allowing the concrete to merge and bind within the formwork. The wax should melt out but the concrete levels should be suspended due to the concrete structure.

Materials Paraffin Wax, Concrete, Mixing Pale, Water, ½” Douglas-fir Plywood, Metal Rod, Paper tube, Small Shovel



Investigation 3 - Process diagram

Methods

Repeat steps 1-5 from investigation 1.1

6. Place cardboard tubes into mold.

7. Begin pouring concrete and wax consecutively waiting for the wax to harden enough between each pour.

8. Fill cardboard tubes with concrete and embed metal rod for structure. Pack down concrete and pull tube out to ensure concrete layers connect to each other. This is to ensure when the wax is melted out the concrete layers are supported and do not fall apart.

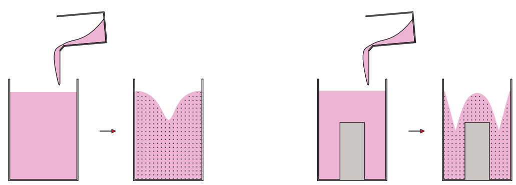
Investigation 3 - Process of construction

Investigation 3 - layers of wax and concrete

Findings

Cardboard tubes did not work as intended because they absorbed water and fell apart too quickly. This resulted in some issues while trying to ensure the concrete layers were supported. Using plastic or even metal tubes would be better as it would not absorb water and can be better managed.

When wax hardens it shrinks, causing the areas that stay warmest the longest to become sunken zones. This is interesting because it is something that can be measured and controlled. A self organizing feature of wax that truly takes advantage of waxes natural processes, this processes can be altered by controlling the various thickness levels of the wax within a model which will determine where and how intense the sunken zones become. To do this objects can be embedded, this also causes the area around objects to cool faster which becomes another element into ways of controlling waxes natural drying structure. This observation spurred Investigation 4.

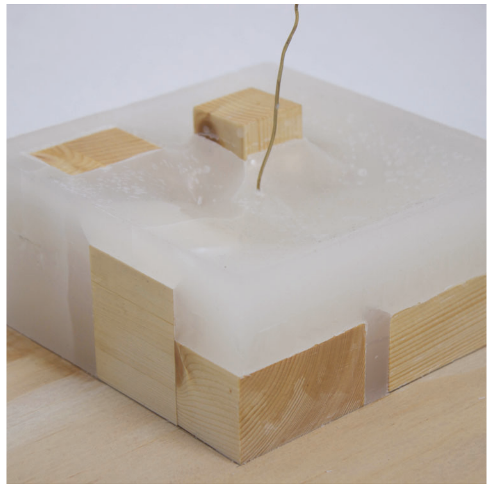


Wax’s self organizing features - shrinkage during hardening

The 10” X 10” cube requires too much material and is also very heavy and requires a lot of space. In order to cut costs, work faster and save space the size of the cube will be 5”x5” cube moving forward.

Also, the wooden molds that have been used thus far have become very damaged from absorbing water, the wood is very hard to clean as the concrete sticks to it. To solve this problem the molds will be made of plexiglass so it is easy to clean and can be laser cut easily with the smaller size allowing for more consistent forming.

Investigation 4



Investigation 4 - Wax and wood model

Description - Wax's hardening behaviours are tested. Wooden blocks of various sizes are glued to a wooden base, foam formwork is placed around the blocks, sealed with tuck tape finally liquid wax is poured into the formwork over the blocks. Once it has dried the form-work is removed. Areas with the largest thickness of wax will become sunken from wax's shrinkage. Hopefully the wax form will be able to be removed from the wooden form work.

Materials Paraffin Wax, Wooden Blocks (various sizes), ½" Douglas-fir Plywood, Metal Pot, Metal Container, Hot Plate, Water, ½"Foam Core, Tuck tape

Method

1. Start with 10" x 10" panel.

2. Cut blocks using table saw.

3. Glue blocks down to panel in a 5" x 5" boundary.

4. Cut foam core to create temporary form work around the blocks, use tuck tape to seal and secure foam core.

5. Prepare double boiler. Place pot on hot plate and fill with water. Place large metal container filled with paraffin wax into pot of water. Turn heat to medium/high to begin

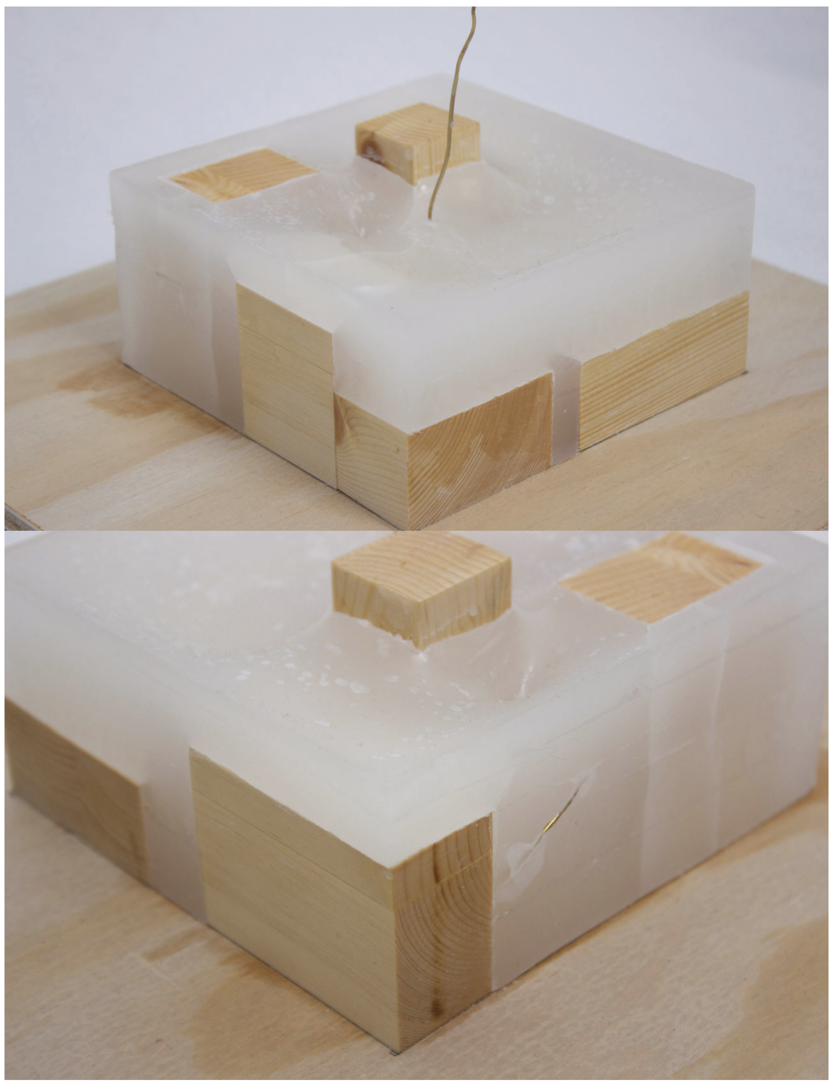
boiling the water.

6. Once wax is melted poor over blocks into formwork.

7. Place a wire into the wax in order to help with extraction.

8. Once wax is cool, remove formwork and pry wax from wooden mold.

Documentation



Investigation 4 - Image of wax shrinkage influenced by wooden blocks

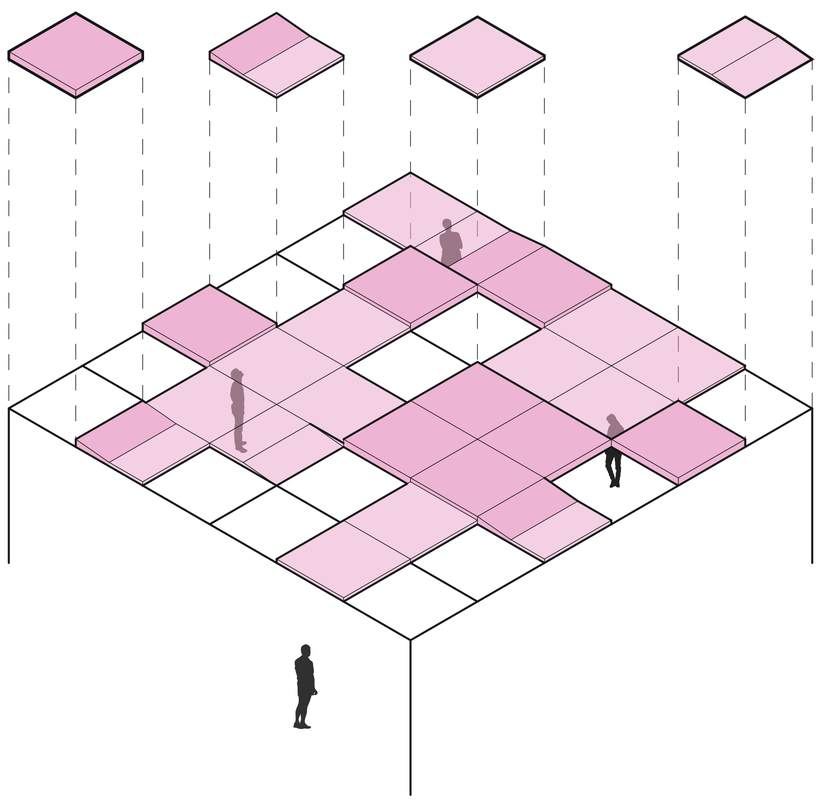
Findings

Wax did not release form wood.

Wax responded how it was intended. The thickest deepest portions between the blocks of wood shrunk and became sunken. However, wax around the wooden blocks hardened faster.

This feature of wax can be used to organize water collection areas within a roof structure naturally pulling water away from buildings into concentrated areas. The wax does the calculations.

This model also revealed the various light transmission qualities of wax, working with different thicknesses of wax to produce a range of different lighting conditions.



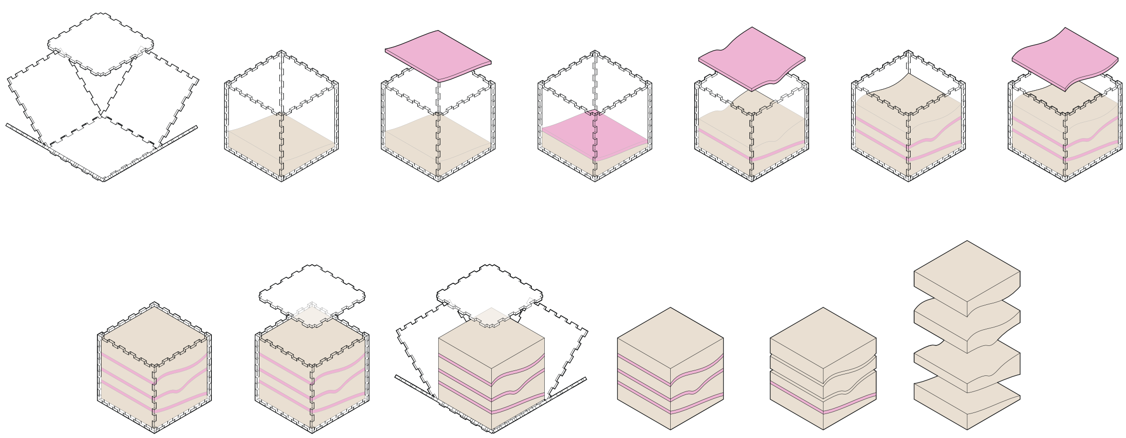
Wax roof concept - thickness of material would determined porosity - could also be reimagined with a material with similar light diffusion qualities

Investigation 5.1

Investigation 5.1 - Construction model

Description - Wax sheets will be formed and layered with concrete in a plexiglass form-work to create joints.

Material Paraffin wax , concrete and plexiglass



Investigation 5.1 - Process diagram

Method

1. Plexiglass form work with finger joint construction is laser cut to make 5”x5” cubes.

2. The formwork is snapped together, and tuck taped.

3. Wax sheets of about a ½” thickness are formed using the method from investigation.

4. Concrete is poured into the mold.

5. Wax sheet cut to 5”by 5” is placed into the mold.

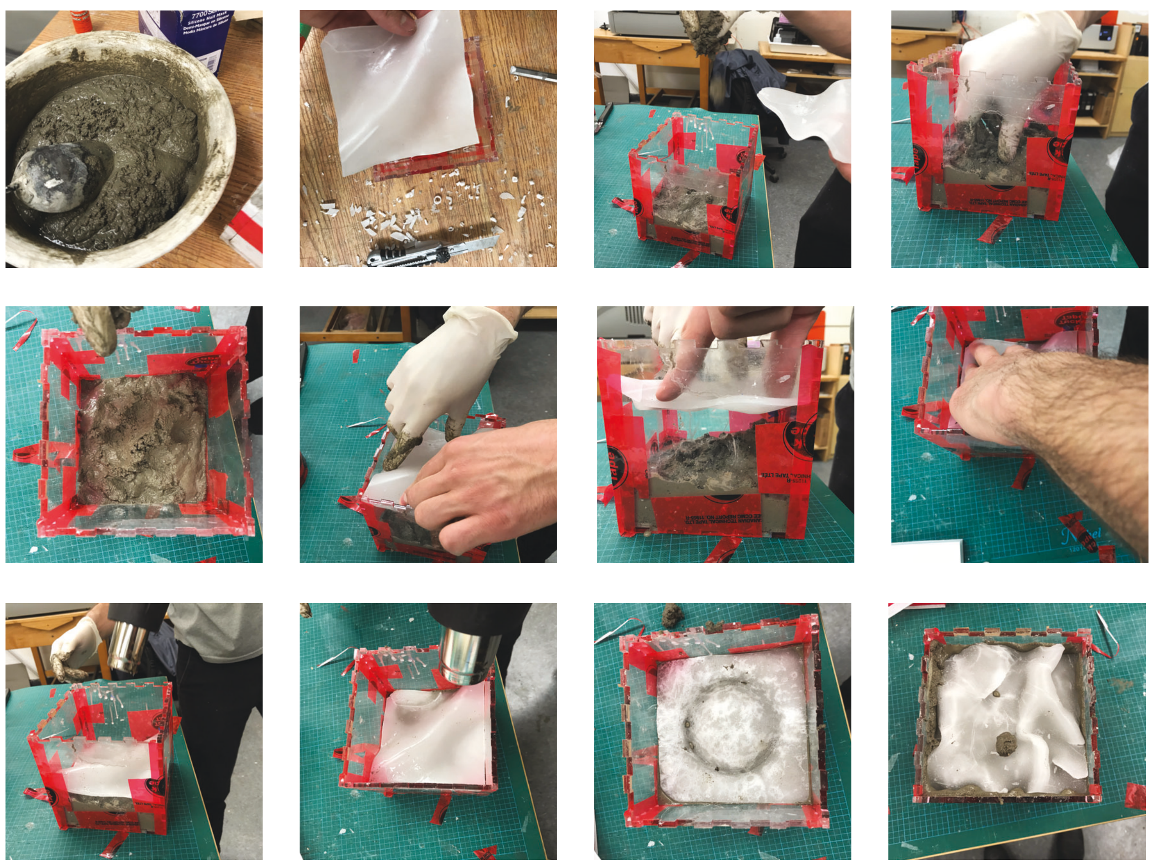
6. Repeat until mold is full.

7. Snap plexiglass lid on mold.

8. Tap mold to release air.

9. Once the concrete cures remove mold and melt wax with heat gun to pry pieces apart.

Documentation



Investigation 5.1 - Process of construction

Investigation 5.1 - Sequence of melting and disassembly

Investigation 5.1 relationship of pieces

Investigation 5.1 - Reciprocating forms

Findings

The plexiglass creates a very nice polished finish on the concrete.

Concrete poured over the edges of the wax sheets making it difficult to separate the pieces. Instead of using wax sheets if the liquid wax was poured directly into the mold and poured out it would create a seam against the plexiglass which would prevent the concrete layers from joining around the wax. See Investigation 5.2.

This method produces a very effective way of creating very fluid joints within concrete elements. In one case with the circular wax form created grooves which allow the concrete pieces to spin. Although, since the sheets of wax were thick the joints are not very tight.

Investigation 5.2

Investigation 5.2 - Concrete and wax model

Description - Concrete and Liquid Wax will be layered in a plexiglass formwork to create joints.

Method

1. Plexiglass form work with finger joint construction is laser cut to make 5”x5” cubes.

2. The formwork is snapped together, and tuck taped.

3. Prepare double boiler. Place pot on hot plate and fill with water. Place large metal container filled with paraffin wax into pot of water. Turn heat to medium/high to begin

boiling the water.

4. Concrete is poured into the mold, an impression is made in concrete with fingers.

5. Liquid wax is poured over the concrete and then quickly poured out leaving behind a super thin layer of wax over the concrete.

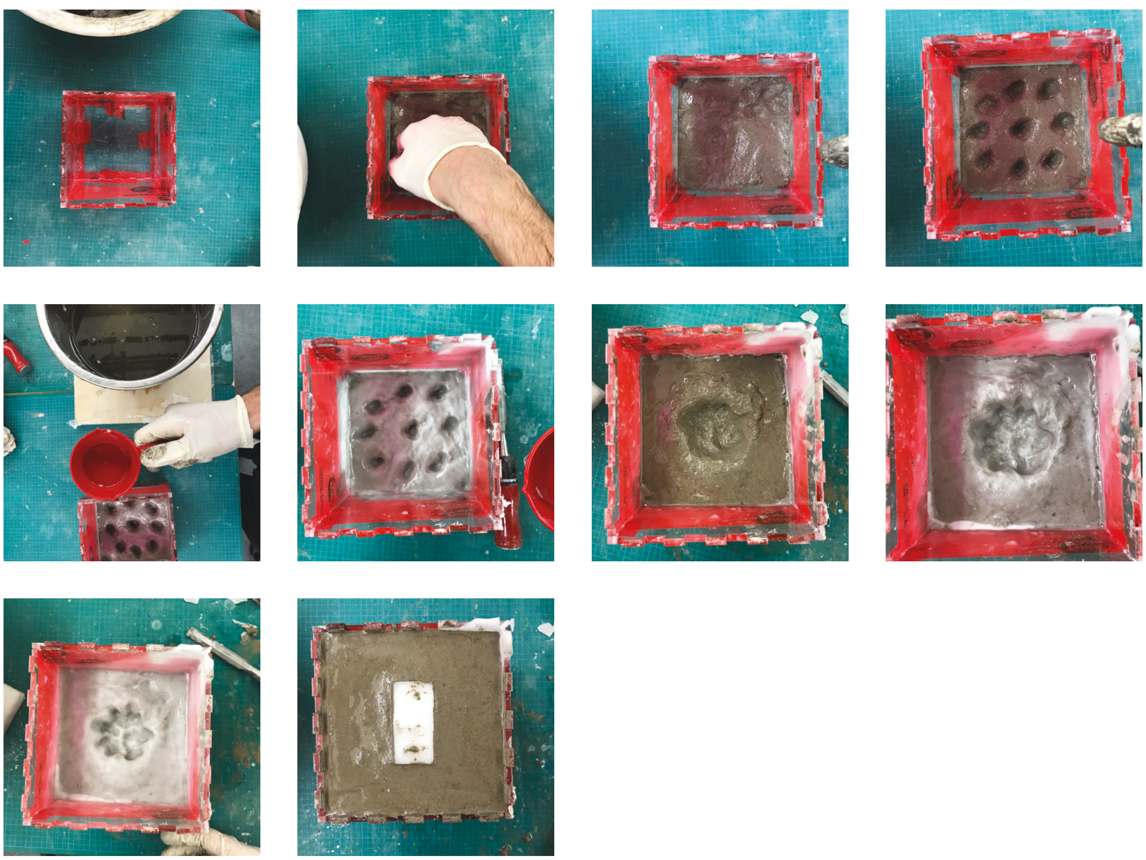
6. Repeat until mold is full.

7. Snap plexiglass lid on mold.

8. Tap mold to release air.

9. Once the concrete cures remove mold and melt wax with heat gun to pry pieces apart.

Documentation



Investigation 5.2 - Process of construction

Investigation 5.2 - Sequence of melting and disassembly

Investigation 5.2 - Disassembled joints

Investigation 5.2 - Reciprocal faces

Findings

This method prevented the concrete layers from joining because the liquid wax created a seal against the plexiglass.

The layer of wax was so thin that the joins are very tight and accurate.

Because there is very little wax the melting process was extremely fast.

Investigation 5.3

Investigation 5.3 - Concrete and wax model

Description - Concrete and liquid wax will be layered in a plexiglass formwork to create joints.

Materials:

Paraffin Wax, Plexiglass, Tuck tape, Mixing Pale, Concrete, Water, Hot plate, Metal Pot, Metal Container, Small Shovel

Method

1. Plexiglass form work with finger joint construction is laser cut to make 5”x5” cubes.

2. The formwork is snapped together, and tuck taped.

3. Prepare double boiler. Place pot on hot plate and fill with water. Place large metal

container filled with paraffin wax into pot of water. Turn heat to medium/high to begin boiling the water.

4. Concrete is poured into the mold.

5. Liquid wax is poured over the concrete and then quickly poured out leaving behind a super thin layer of wax over the concrete.

6. Repeat until mold is full.

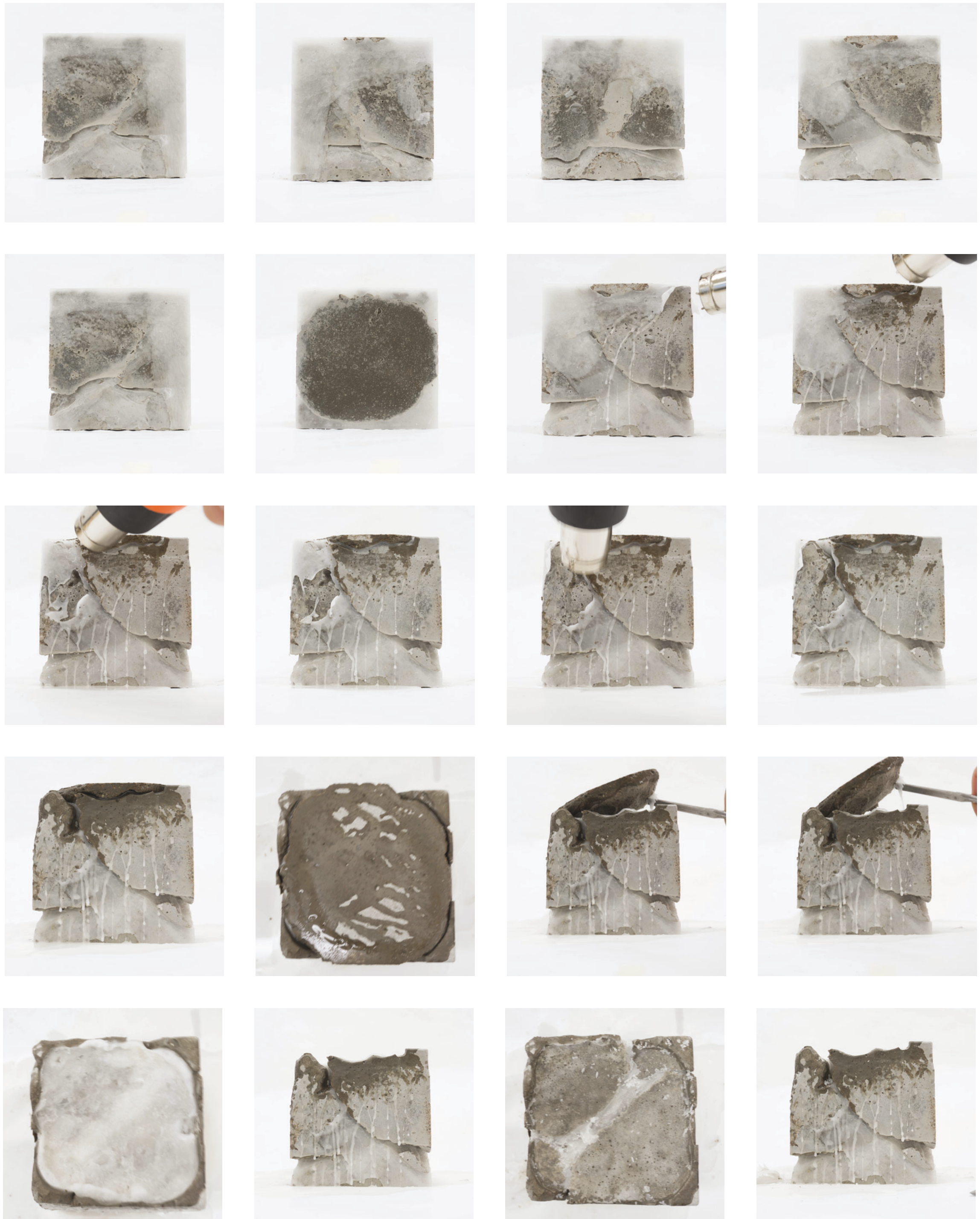
7. Snap plexiglass lid on mold.

8. Tap mold to release air.

9. Once the concrete cures remove mold and melt wax with heat gun to pry pieces apart.

Documentation

Investigation 5.3 - Process of construction



Investigation 5.3 - Melting sequence

Investigation 5.3 - Melting sequence and reassembly

Investigation 5.3 - Disassembled

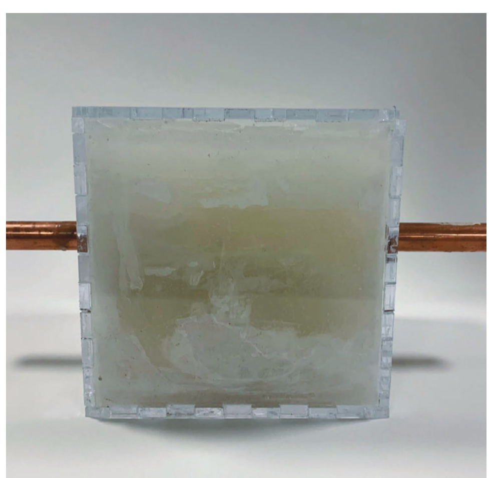
Investigation 5.3 - Assembly

Finding

This iteration of the investigation produced very organic shapes, that fit together like puzzle pieces. The very clear rectilinear form of the cube breaks apart into various organic pieces. This might be a way of developing a wall that can be dismantled or that through time dissolves and reconfigures the landscape.

Diagram of a wall made to fall apart through time, becoming a part of the landscape.

Investigation 6



Investigation 6 - Wax and plexiglass model

Description - Liquid wax will be contained in plexiglass to explore light diffusion properties through running steam through model.

Materials: Paraffin Wax, Plexiglass, Tuck tape, Mixing Pale, Copper pipes

Method

1. Plexiglass form work with finger joint construction is laser cut to make 5”x5” cubes.

2. The formwork is snapped together, and tuck taped.

3. Prepare double boiler. Place pot on hot plate and fill with water. Place large metal container filled with paraffin wax into pot of water. Turn heat to medium/high to begin boiling the water.

4. Fit copper pipe through mold.

5. Wax is poured into the mold

6. Snap plexiglass lid on mold

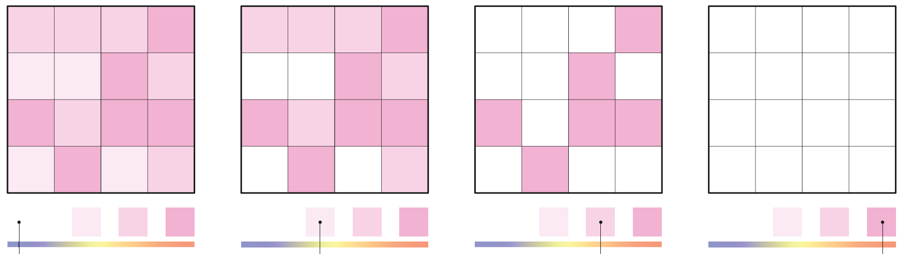
7. Tap mold to release air

8. Let harden

Findings

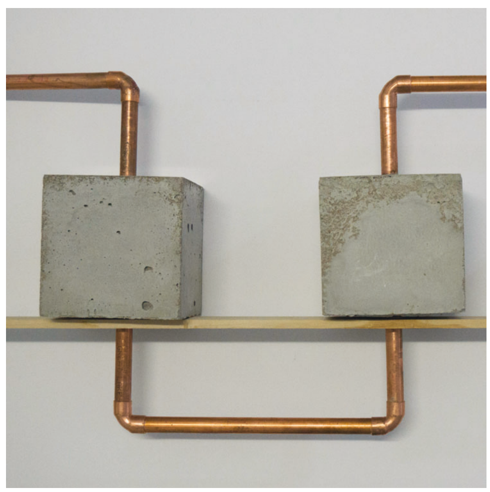
This concept could not be fully tested as the plastic would melt if steam was run through it. However, it is clear that it is to thick, the wax does not diffuse much light through it. Ideally this could be testing with a thinner class encasing.

This system could be used to create a window like system that uses wax’s phase change to control opacity of light that is diffused. This could provide a passive energy storing and heating system.



Wax's phase change properties can determine opacity. When it is hard it is opaque, when it is liquid it is clear

Investigation 7.1, 7.2 and 7.3



Investigation 7.1, 7.2, 7.3 - Concrete and copper model

Description - Different wax forms are embedded in concrete blocks, copper pipes are used to heat the blocks with steam. Using a infrared camera in order to see if the wax forms are thermally expressed through concrete.

Materials - Concrete, wax, copper pipe, plexiglass mold

Method

1. Plexiglass form work with finger joint construction is laser cut to make 5"x5" cubes.

2. The formwork is snapped together, and tuck taped.

3. Prepare double boiler. Place pot on hot plate and fill with water. Place large metal container filled with paraffin wax into pot of water. Turn heat to medium/high to begin boiling the water.

4. Concrete is poured into the mold.

5. Build up wax form onto copper pipe and place into mold. Or place wax form directly into concrete.

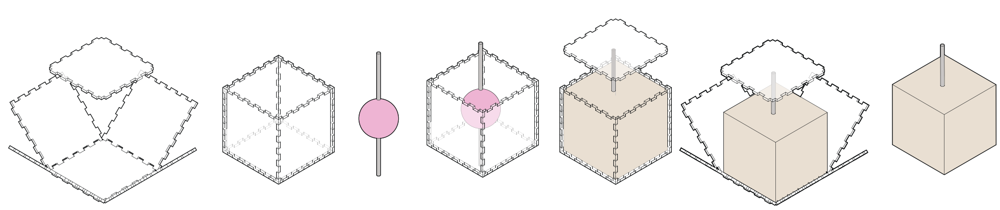
6. Fill mold with concrete.

7. Snap plexiglass lid on mold.

8. Tap mold to release air.

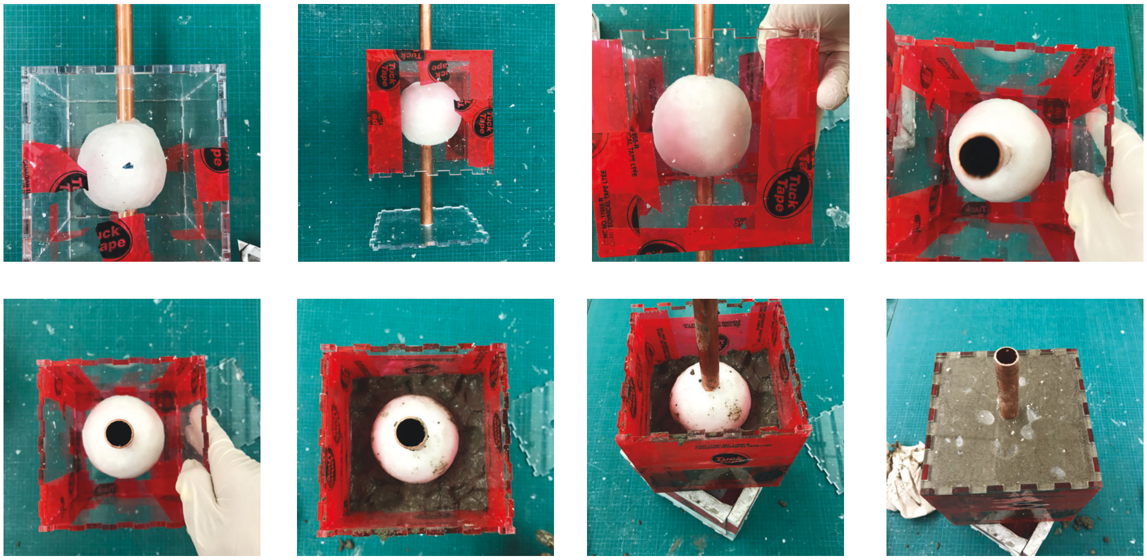
9. Once the concrete cures remove mold and connect copper pipe to steamer.

10. Let concrete charge with heat while photographing every 10 minutes with infrared camera.

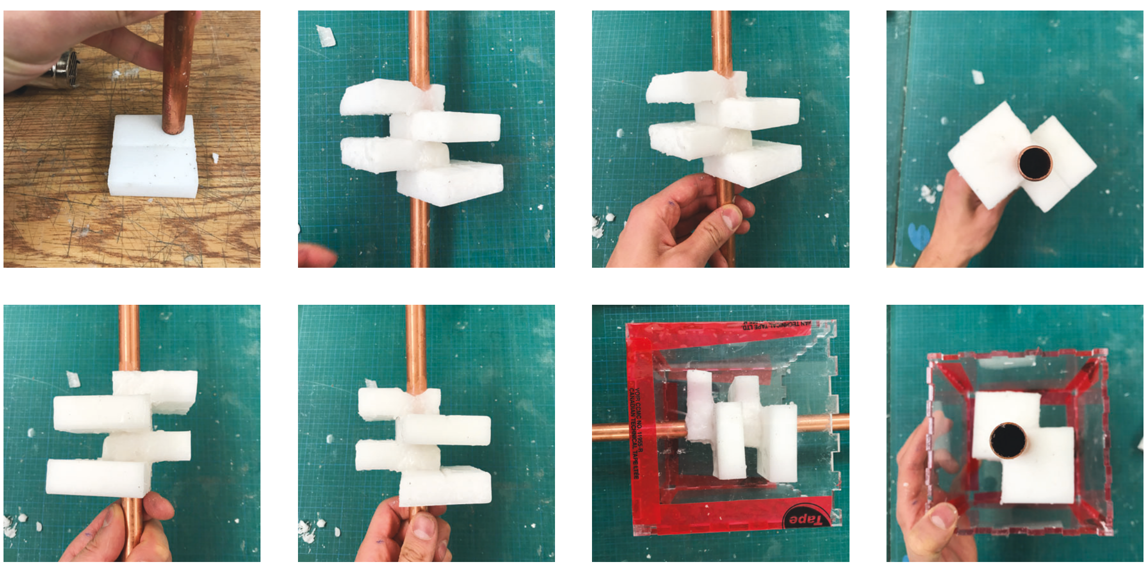


Investigation 7.1- Process diagrams

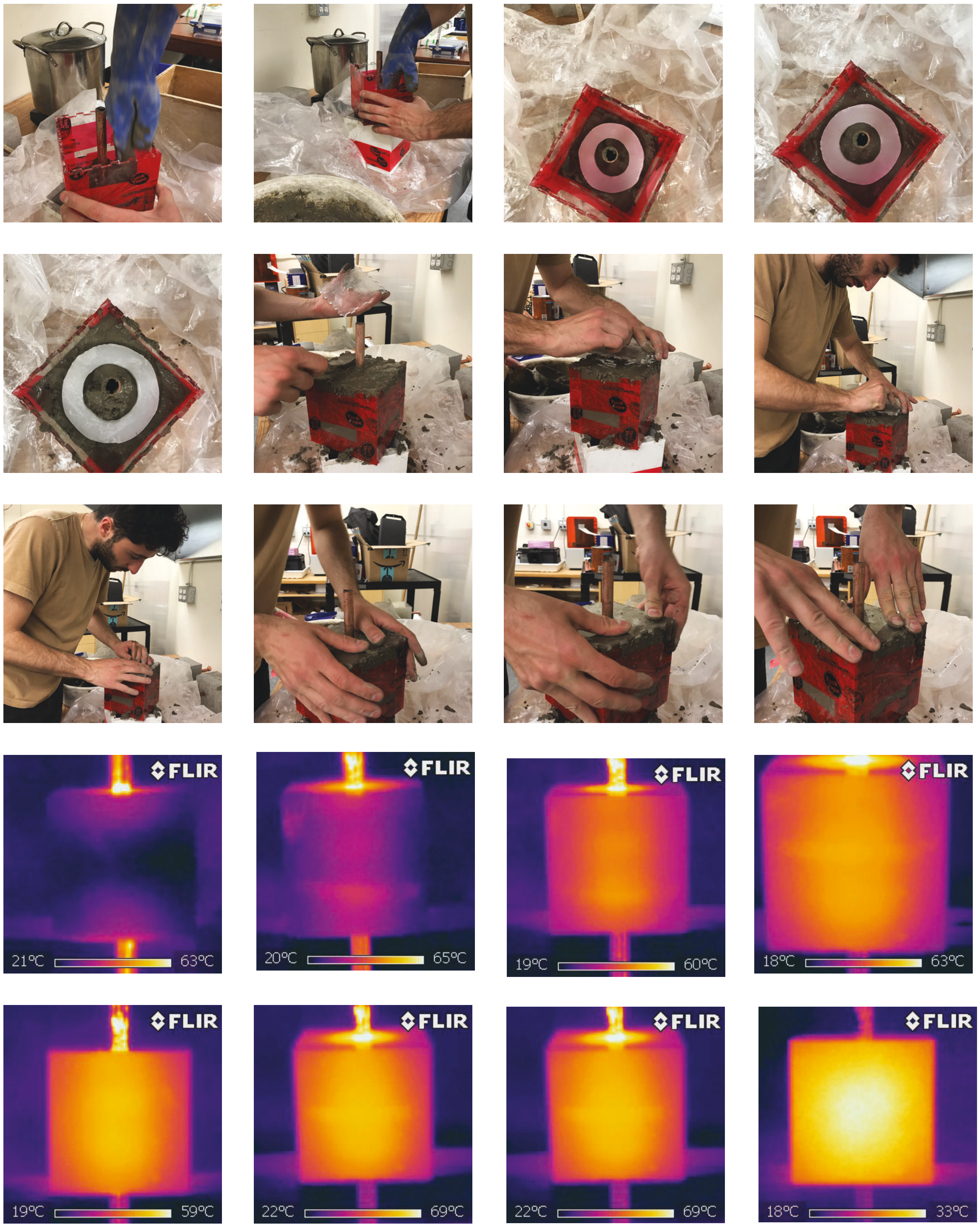
Documentation



Investigation 7.1
Process of constructing wax sphere on copper pipe



Investigation 7.2
Process of constructing wax blocks on copper pipe



Investigation 7.3 - Process of constructing

Using a wax ring embedded in concrete instead of building up wax directly onto copper pipe like in Investigations 7.1 - 7.2. This was done to create a concrete buffer between the copper and the wax to prevent the wax from cooling quickly from the thermal lose due to the copper pipe being a point of heat loss. Also experiments 7.1-7.2 are susceptible to leaking wax through the pipe as well as the pipe coming loose due to the smaller concrete to pipe contact.

The concrete pieces are then connected to a stream of steam in order to study how they charge and discharge heat. Using a thermal camera to monitor the changes. In this case the forms of the wax rings can be read thermally.

Findings

Thermal images did in fact show the wax forms being expressed.

Building wax directly onto copper pipes was not the best idea because the copper pipes were a site of heat loss, pulling heat from wax forms. 7.3 was affective because it had a concrete buffer between the copper pipe and the wax.

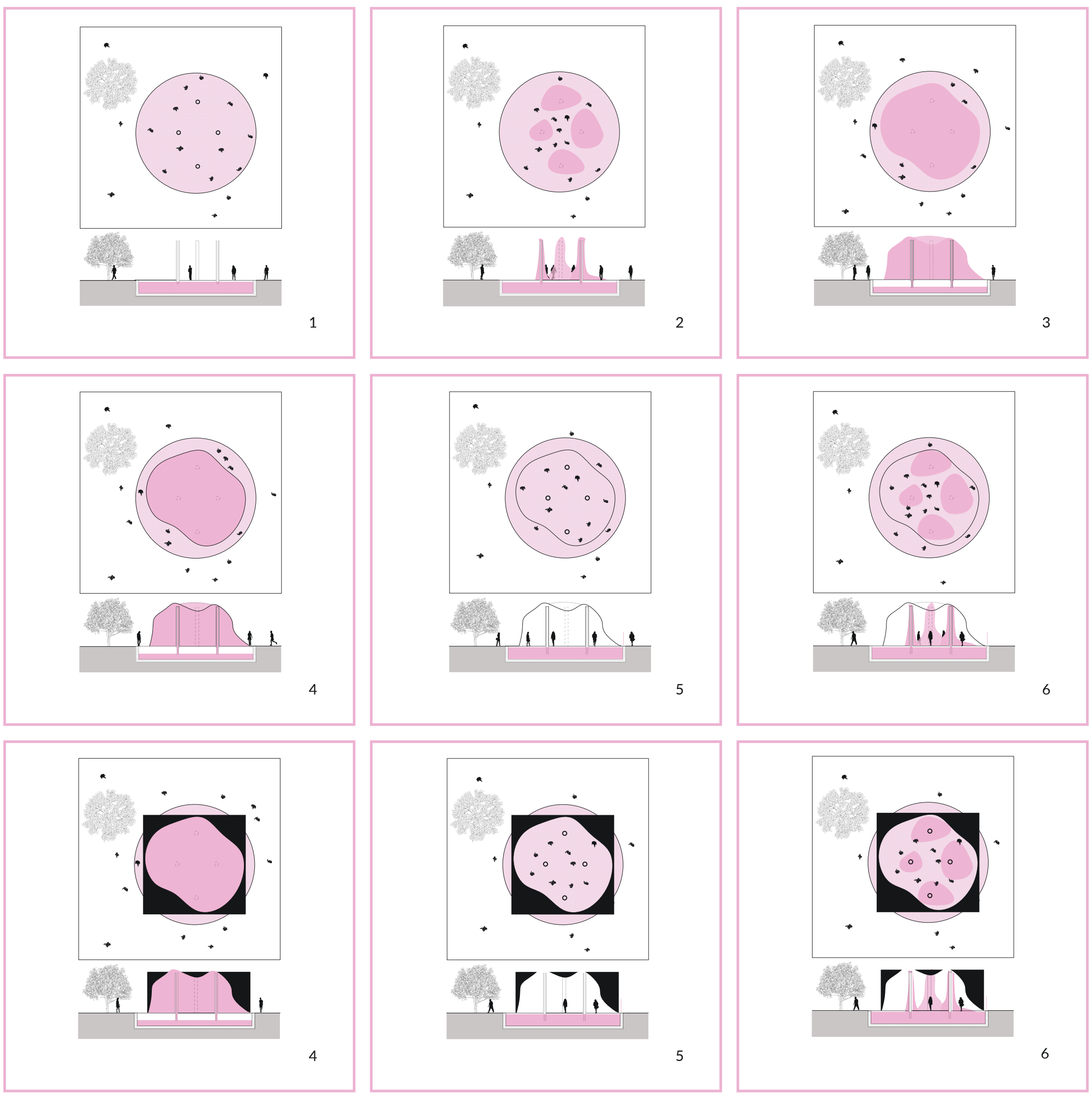
Concrete and wax store and release heat at different rates, coupled together can provide a larger range of thermal storage capacity.

Concrete and wax's heat storage cycle diagram

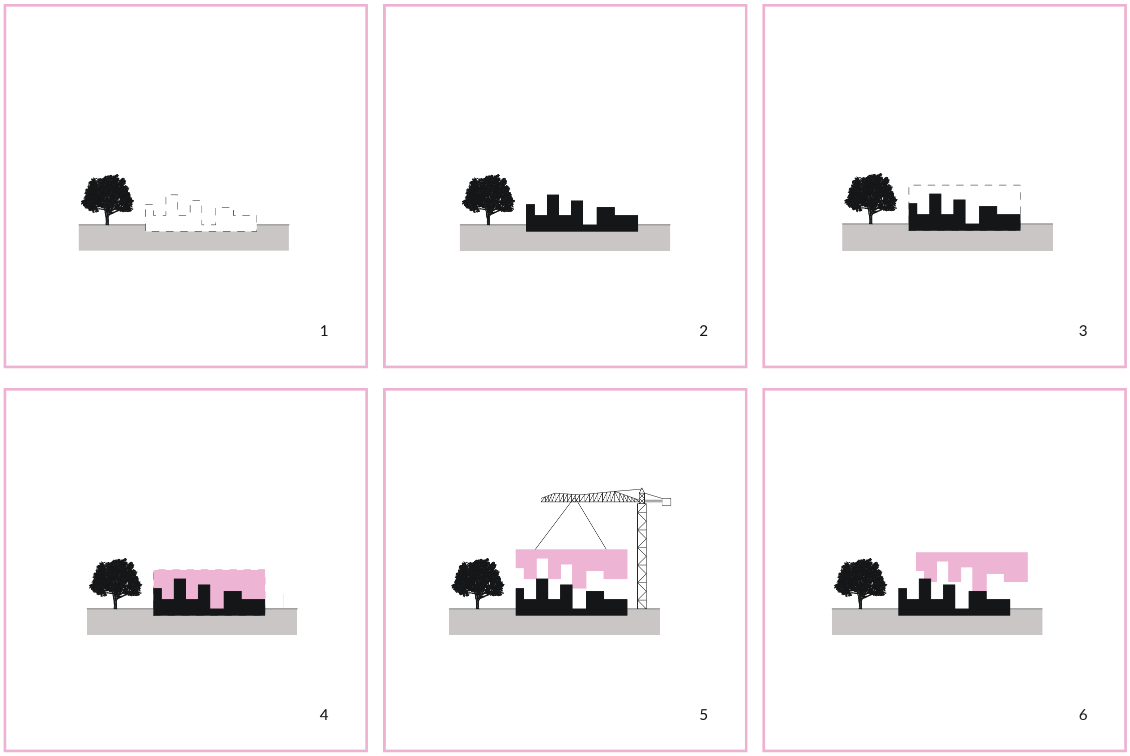
Diagram representing concrete and wax's thermal storage properties - charging and releasing heats at different rates. Wax charges and releases faster which maybe works within hours while concretes cycle runs over the span of a day.

3.3: Diagrammatic Construction Sequence and Inhabitation

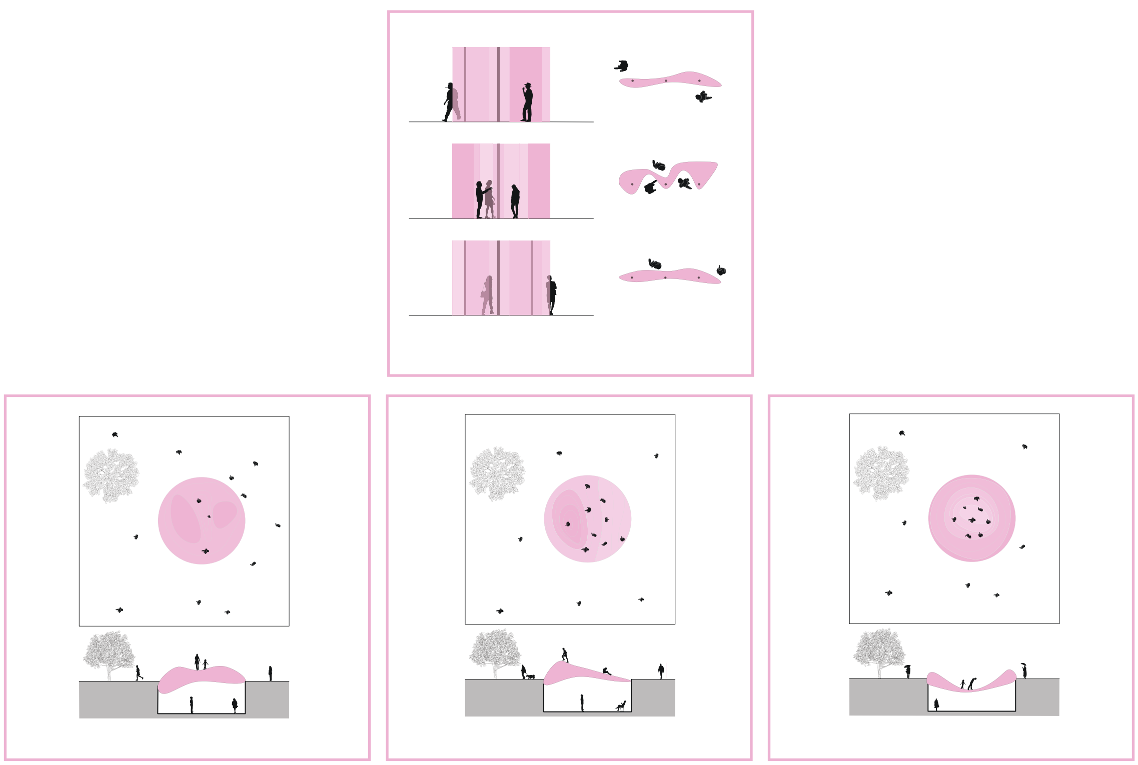
The next step in this morphogenetic process of design was to diagram methods of construction that drew conclusions form the material investigations in section 3.2. This is a way of aiming to translate discoveries into a way of building, and to study potential inhabitation in response to the material performance and the process of making. These diagrams are drawn as sequences of construction. These diagrams look at a variety of ways of casting concrete with wax.



Using aggregations of wax to cast concrete form



Reciprocal molds
Wax is used to take form from existing architecture. This wax form is then used to cast new form



Form - Interaction - Transparency
Wax is embedded within a plastic bag, movement and activity define form and transparency

Layering and Subtraction
Landscape is flooded with wax. The wax is carved and cast in concrete. This process can continue to grow.

3.4: Findings

Through these material investigations wax and concrete have proved to provide a range of possibilities to achieve architectural translation. Distilled from these methods were processes to achieve form, light and temperature. These attributes will be used to achieve sensory microclimates.

Form

The first discovery, utilizes wax's ability to influence concretes formation through the rate at which each harden. Wax becomes a container for the concrete because it hardens very fast where as the concrete takes time to cure. This difference in curing times creates an opportunity to use liquid wax as a means of creating formwork for concrete, when the concrete is finally cured it cannot be reversed, unlike wax which can undergo a secondary phase change and return to it's liquid state releasing the concrete forms as it melts back into a liquid. This phase change advantage is an opportunity to explore the ability to develop complex forms due to the gentle form release of wax as well as its ability to articulate very fine detail and textures this is evident in 1.1 and 2. A very small amount of wax can be used to form concrete, seen in investigations 6 - 6.3 where very fine amounts of liquid wax produced very tight joints between the concrete.

The structural factors are developed through the process of molding concrete, taking its shape from various wax formwork. The formwork is developed through an aggregation of wax through pouring, using wax blocks as formwork or void production, using thin layers of liquid wax to create thin joints or connections within the concrete. In some instances, the concrete can be reinforced with rebar of fiberglass to ensure structural integrity.

Light

Wax transmits light very well, diffusing it through the mass. Different light conditions can be achieved by controlling the thickness of the material and by what phase wax is in. Solid wax is more opaque providing a diffused light and in its liquid form wax is completely transparent. This spectrum opacity allows for a gradient of lighting conditions, as seen in investigation 8. These features may also be translated to other materials such as glass, and plastics, using thickness to determine transparency and diffusion qualities and seen in investigation 3 and 8. Wax can be used to form perforations and light wells within concrete to achieve different lighting conditions, as seen in investigations 1 and 2.

Temperature

Wax and concrete coupled together can create an energy system that stores heat and energy while it is available and releases it when it is needed. Wax stores heat in liquid form and releases it as it hardens and concrete absorbs and stores heat in its mass when there is an abundance and releases it when the temperature drops. The advantage in this system when applied to architecture is wax and concrete store and release heat at very different rates. The temperature storage differential takes advantage of the energy providing a larger gradient of temperature conditions throughout the day. This was explored by embedding wax forms into concrete blocks and running steam through the forms as seen in investigation 7.1 - 7.3.

Wax can be used to insulate as it provides a thermal buffer, maintaining temperatures through absorption of heat and releasing heat once it is charged.

Wax embedded in glass can also work as a passive energy system, charging by solar gain and releasing in the night, similar to concrete. This provides the lighting gradient as discussed.

These factors of structure, light and temperature help modulate sensory microclimates. Sensory microclimates help define the types of activities that might occur in these spaces, based on comfort and sensory experience. These factors will be tested to determine the implications of specific site conditions.

Chapter 4: Site and Program

4.1: Basis for Choosing a Site

The material investigations detailed in Chapter 3 have led to a number of possibilities as to how they may translate into a possible architecture. These studies brought to attention the capabilities of variation of space and experience, varieties of lighting conditions and potential microclimates. However, these studies have been explored and tested in a vacuum without a deeper consideration of how this approach to design may affect the user in a specific context. The selection of a context is critical to analyze its affect on factors such as the climate conditions, social dynamics and programmatic needs. The nature of this process is dependant upon its context as it responds to and influences the outcome of the architecture. A number of conditions were considered to determine the sites capacity to respond to this design method. This included finding sites with high volumes of human activity, sites in development with potential change, sites within an urban context, sites with complimentary program adjacencies to influence program, sites that provide waste energy sources, sites with pedestrian, vehicular and transit connections, and sites with relevant history and strong community engagement.

The City of Toronto was chosen as it has a large spectrum of these factors. This includes having a temperate climate and predicted growth. Initially three sites were selected for consideration:

Yonge-Dundas Square in downtown Toronto is a public square in the city’s downtown core, a prominent landmark and tourist attraction. The Square is used as an event space lending itself well to a changing architecture. The Square is very dense with commercial spaces and is privately owned. There are many program adjacencies with potential to harnessing power such as the kinetic energy from the commuter trains that run below the site. It is also a prominent transit hub in the city making it very connected to all aspects of the city. Is located at the corner of a major intersection (Yonge St. and Dundas St.) making it very active, filled with human activity. However, due to its commercial nature it is quite a transient site lacking a strong community presence.

The Gardiner Expressway at Spadina Ave. and Lakeshore Ave. was also considered as a potential site. The Gardiner expressway is one of Toronto's municipal highways, running close to the shore of Lake Ontario. The highway creates a divide between the city and the waterfront and is currently unused. The highway has the potential to be repurposed and is in need of activation. The existing infrastructure would provide a framework to utilize, as would the kinetic energy of the cars overhead. However, there is a lack of community in this area as it is a newer residential area of high rise condo towers.

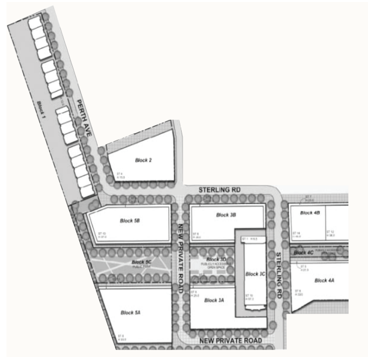
The Junction Triangle neighbourhood on Sterling Rd. in West Toronto, adjacent to the Tower Automotive Building was the third site under consideration.

The Junction Triangle is a community under major growth and transformation and is gentrifying quickly changing from an industrial area to a more commercial and residential one. This change provides an opportunity to work to preserve aspects of the industrial history of the site and to preserve and celebrate the artist culture of the area. This site was chosen in the end for its history, the site conditions, adjacent programs and community values.

4.2: History, Site and Program

The morphogenetic design methodology is tested in Toronto in the Junction Neighbourhood. Adjacent to the Museum of Contemporary Art (MOCA) and transit arteries and is a prior manufacturing-industrial neighborhood which had a strong focus on material production. This neighbourhood has disappeared and is being quickly replaced by static, standard architecture designed and developed through the hylomorphic model that is not capitalizing on material properties but, instead, develops form through image and styles. Private residential and commercial properties is the current proposed programming for this site, which contributes to the problem of gentrification in the area and site, deviating it from its industrial past.

This proposed intervention homogenizes the area with the rest of Toronto by reducing free public space. In contrast to the proposed intervention, this thesis proposes a place for experimentation and material exploration, an architectural intervention with a continuous development to showcase a morphogenetic approach of 'making' in public spaces and a place to develop and spread ideas: "park of process".



Site Plan Approval and Project Renderings Submitted to the City of Toronto by
Castle Numa and Greybrook Capital (Chen 2017)

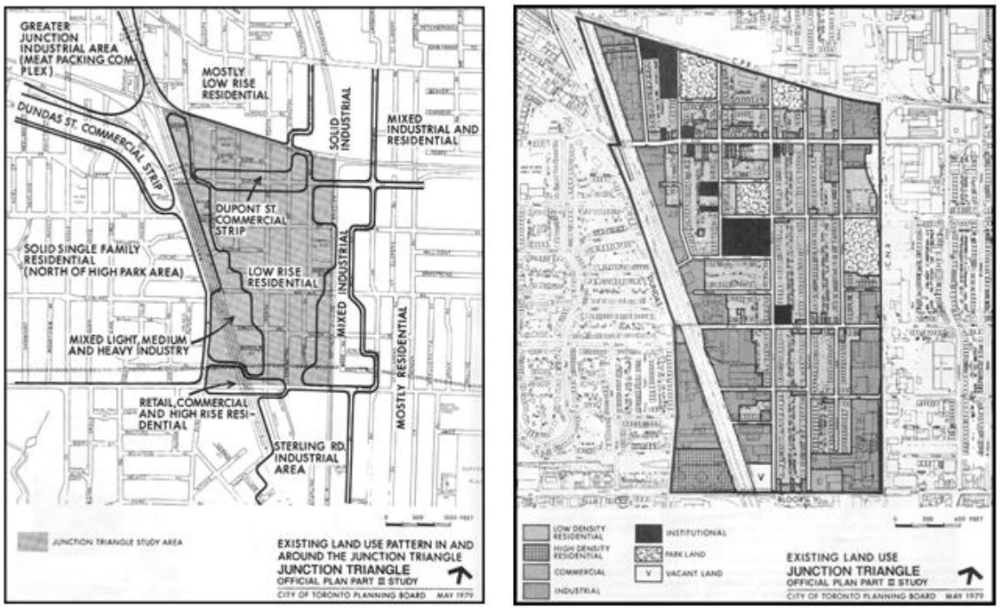
History

The site for this proposal is located in Toronto, Ontario in the Junction Triangle neighbourhood. The Junction Triangle is bounded by railway lines which were once lined with manufacturing industries. The Junction Triangle and the surrounding neighbourhoods were historically the centre for manufacturing in Toronto since the industrial growth of the 1890s. Factories produced and developed materials, such as metals, ceramics, and paints. This was a period of new materials, manufacturing, and makers.

By the 1950s, the Junction Triangle became home to factory workers and became a multicultural hub for mainly Italian, Polish, and Macedonian immigrants. In 1979, the neighbourhood still had a thriving industrial component. There were 11,500 job opportunities with a large percentage living in or near the area: “60% of the male labour force and 28% of the female labour force were employed in blue collar jobs such as processing, fabrication and construction.” (Options for Davenport Community Group 2016)

At the time, some of the key problems encountered by industries in the area were insufficient room for expansion, traffic congestion, inadequate access to highways, insufficient parking space, inadequate buildings, and unfavourable community attitudes. (City of Toronto 2013)

A report on the neighbourhood concluded that a mix of residential and industrial use has the potential to create conflicts in the form of trucking and pollution. Vacant sites that have potential to be redeveloped as residential developments, presumably due to a higher rate of return, could further destabilize the industrial community. The report recommended that residential development should not be permitted to occur in employment areas, as this creates disturbances to employment uses, causing more industries to relocate out of Toronto. (City of Toronto 2013)



Historical existing land use patterns in and around the Junction Triangle Toronto. Planning board neighbourhood plan proposals: Junction Triangle. City of Toronto Planning Board, 1979 (City of Toronto 2013)

Issues of public health due to proximity to industry lead to many industries and manufacturing jobs leaving the neighbourhood. Between 1987 and 1996, fifteen factories employing approximately one thousand people left. This period marked one of economic downturn for the neighbourhood. These vacant factories became the site for underground parties and squatters and the neighbourhood was defined by street crime, drugs and prostitution.

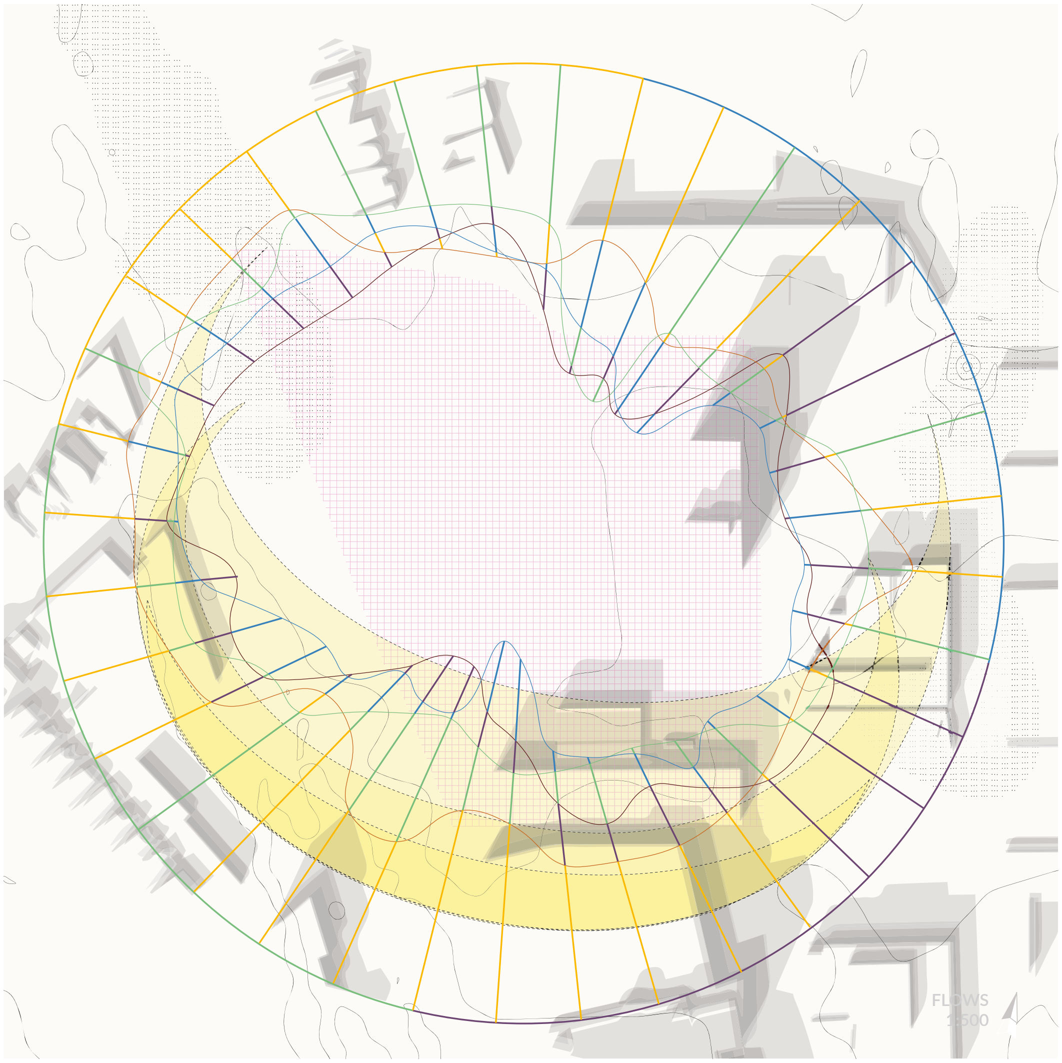
By the early 2000's, the neighbourhood had significantly shifted from industrial to residential with many of the former factories being converted for residential and small/medium size businesses. Housing prices increased immensely and according to the Municipal Property Assessment Corporation, the neighbourhood has the highest increase in property value in Toronto. (City of Toronto 2013) Several galleries moved into the neighbourhood, the most recent being the Museum of Contemporary Art (MOCA) which now occupies the old Tower Automotive building.

As the neighbourhood continues to develop, it is necessary to ensure it develops in accordance with its local culture which has been shaped by the industrial landscapes.

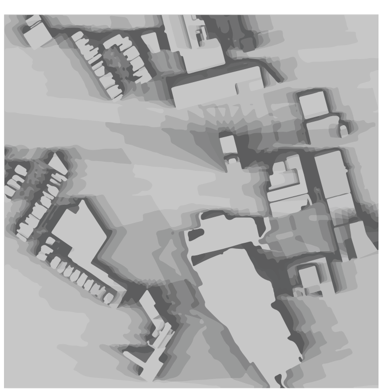
Site

The site for this thesis is a large empty lot adjacent to the historical Tower Automotive Building which was recently renovated in 2017 to house the Museum of Contemporary Art. This lot was once a collection of aluminum manufacturing factories adjacent to the Tower Automotive Building.

City of Toronto map
Various transit connections to site



Site flow map - Sun, wind, shadow, sound



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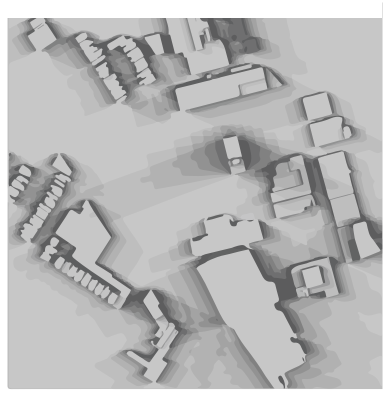

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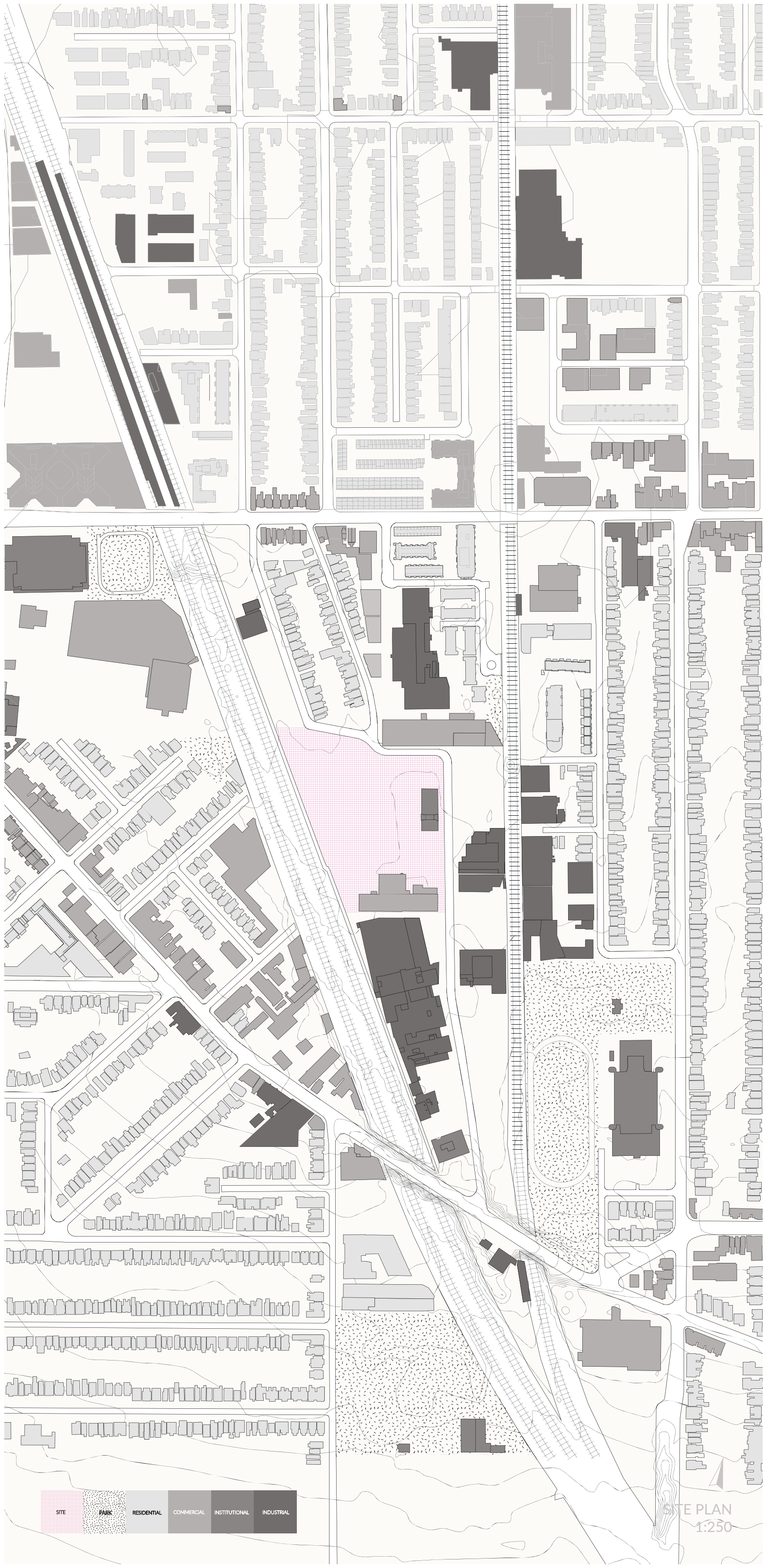
Shadow studies



Site Plan 1:2000 The Junction Triangle

The Junction Triangle is considered a transportation hub. The site is in close proximity to Toronto Transit Commission (TTC) stations including Landsdowne and Dundas West subway stations, and Dundas Street and College Street streetcars. There are also connections to the Greater Toronto Area through the Bloor Go Station. The Bloor Go Station provides access to the UP Express Train to Union Station, Billy Bishop City Airport and Toronto Pearson International Airport.

The West Toronto Rail path also runs jus behind the site. Completed in 2009, is a multi-use asphalt trails that runs along the rail corridor from Cariboo Avenue (north of Dupont Street) to the Dundas Street West overpass and has a planned extension to the Toronto Waterfront. This path promotes a pedestrian/ cycling infrastructure which has begun to knit the surrounding neighbourhoods together through the path as well as through art programs. Art programs run along the path with community groups such as Friends of West Toronto Rail path comprises of a volunteer group who work with and advise stakeholders such as the City of Toronto, Metrolinx and various community organizations. The group is made up of cyclists, artists, planners, urban ecologists, landscape architects and community members. The group helps organize various art installations throughout the rail path such as “We Burrowers” by Linda Duvall and Rui Pemental, which expresses themes of connection to place, grief and loss, and the many meanings of exclusion and absence.

The DeRail Platform for Art + Architecture, is another community group with a strong presence in the neighbourhood. DeRail Platform for Art + Architecture is a registered non profit providing a platform for dialogue and collaboration across disciplinary, geographical, and ideological boundaries. They work to reinterpret public space in the neighbourhood, to challenge understandings of public space and to create an opportunity to experience these spaces in a novel way. The DeRail Platform for Art + Architecture project “We Pause at Twilight” for Toronto’s Nuit Blanche provided platforms to pause and contemplate and imagine new possibilities for public space in the neighbourhood.

These community groups as well as the Museum of Contemporary Art provide a community base and values which can be carried forward and integrated. These values can be integrated into the design of a place, the development of program, and can influence how the space can be made as a community, building together - defining a program based on the values of community.

We Burrowers by Linda Duvall and Rui Pemental 2015
(Artspin 2015)

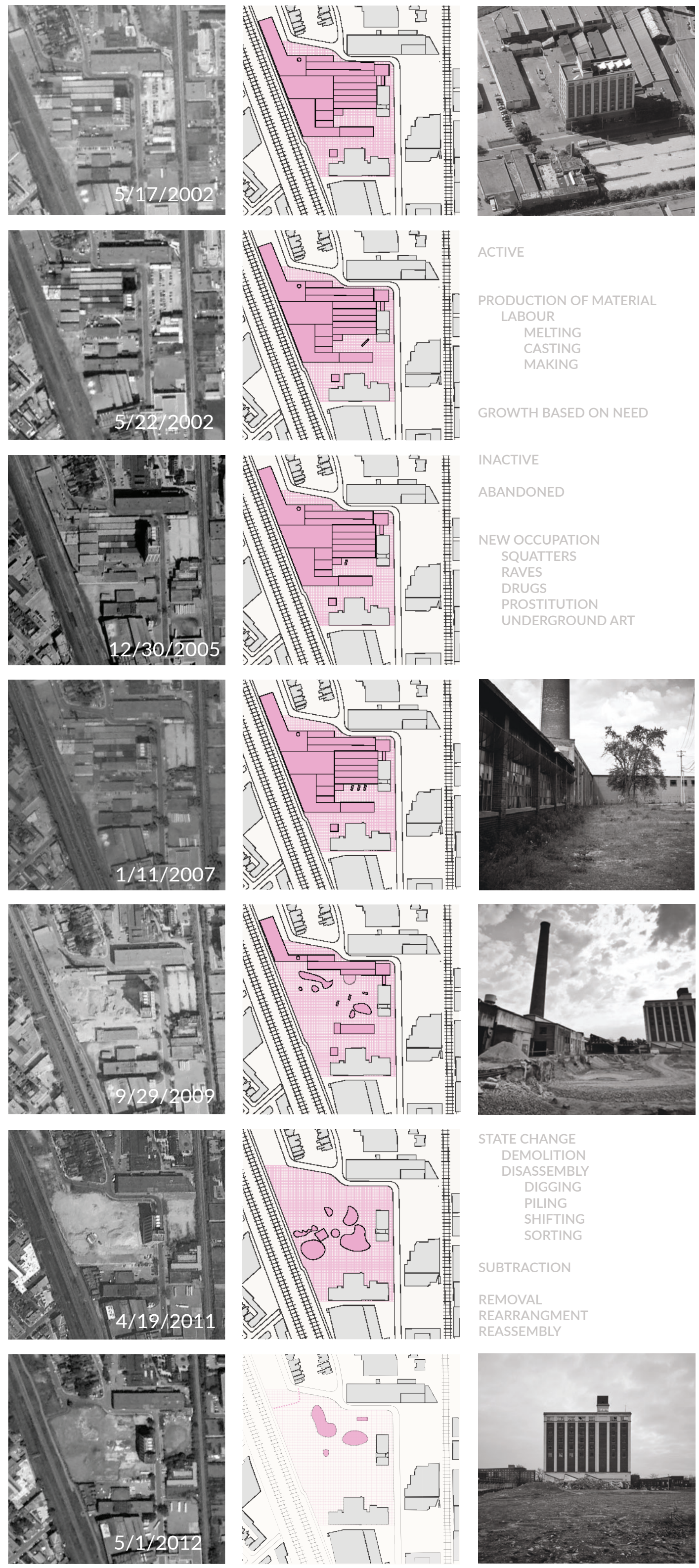
The forensic drawing is morphogenetic reading of the site, considers everything on site as material and maps their flows and changes over roughly two decades. The reading documents changes which occurred as viewed from Google Maps. First just small architectural changes to the factory and eventually its demolition, then changes in the landscape due to construction; mounds of earth, holes, piles of debris (constantly being shifted or reorganized on the sight) the holes filling with rain water creating small ponds, political lines being drawn by construction crews putting up fences marking territory, storing trucks, desire paths and short cuts forming from trespassing pedestrians. This simple study shows how active and in flux the site actually is, the different elements (social environmental and physical) being renegotiated, redefining the space and experience of the site quite dramatically, yet very quietly. This all occurred while the automotive building lay empty and deserted.

This reading of the material flows of the site is a starting point for the intervention on the site. site. The reading provides an understanding of the changing relationships of the different aspects and materials of the site. It also shows how the materials have developed overtime, which is crucial as to not impose on the sites predetermined design. By respecting these flows, processes and relationships which emerged on, A Park of Process, will integrate new processes which shall respond to the existing conditions and evolve slowly, defining relationships and processes which will slowly start to integrate programmatic elements. This approach does not have an end and will continue redefining itself to needs, flows and relationships.

Program

A Park of Process is a place for architectural experimentation, a platform for exploring the morphogenetic design approach. The park has a range of programming including theatre, playground, sculpture garden, art galleries, market spaces and sport courts. The site takes advantage of the cultural flows of community groups and the support from the Museum of Contemporary Art to help implement programming and logistics. The site is an ideal location and connects locally, to the rest of the city and internationally. The Park will become a main neighbourhood attraction along side the Museum of Contemporary Art and be a space that can be accessed upon arrival to the city from the airport. The Park will integrate the public fostering connection between the public, materials and the process of making.

The process of construction will seek to evolve through time and change naturally through engagement. The Park will develop slowly and continuously with no projected completion date, allowing it to constantly re-establish relationships between the various components in response to the process of making, environmental conditions and social actors. These aspects will be used to develop various microclimates to provide a gradient of experiences for the different programmatic elements which can emerge in response. The Park will draw from the sites industrial past, including the labour, material and population, which shaped the city, the rich neighbourhood and culture.



Forensic drawing 1/2

Forensic drawing 2/2

Chapter 5: Design

This thesis follows the morphogenetic model to achieve sensory microclimates. This process includes a series of steps, the first being physical modeling and experiments to explore the material properties of both wax and concrete in order to conceive a potential for architectural translation. Following these experiments, was a process of diagramming these potential translations into a sequence of construction and possible inhabitation. In order to test this project fully a site was selected based on its complex site conditions including climate, activity, connection, community culture, history, and program adjacencies all within an urban context.

This chapter will outline how the research, material studies and site context come together in the design of a park that adheres to the morphogenetic model with the intention of creating sensory microclimates.

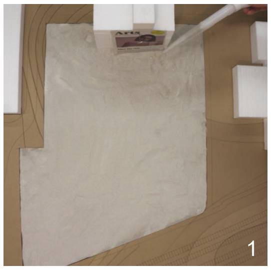
The design process continued with a modeling exercise on a scale site model to develop a site strategy. From this site strategy a schematic design was developed, as well as a program brief. These schematic plans provide the foundation to develop working plans. A process of drawing, scale modeling and photogrammetry develop a sequential drawing method. The program for which these spaces are designed came out of an understanding of the site and its history, community culture and adjacent programing. The spaces developed include a meditation space, a design research and community space, a theatre and artist residency and a garden space. These spaces all exist within a park context. Through this morphogenetic lens, these spaces are imagined as generative, the process for which they develop is one that unfolds through time and is influenced by the process of their construction, the environment and the material properties and those involved in its construction.

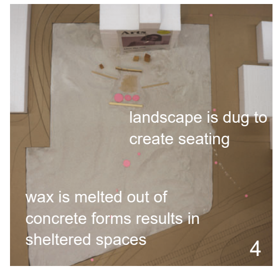
5.1: Process

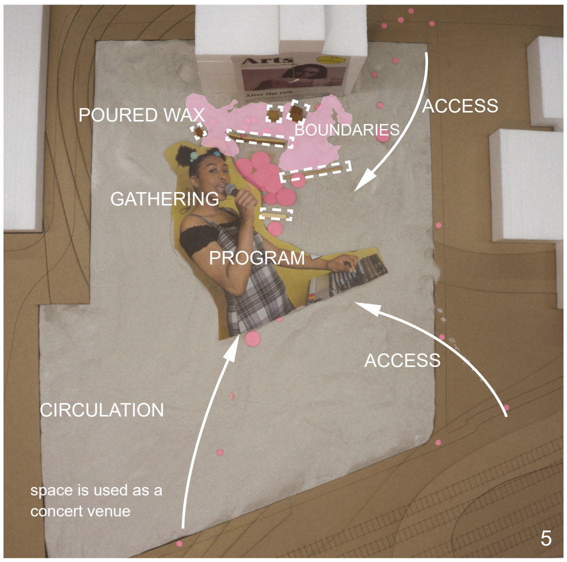
Sand Model Study

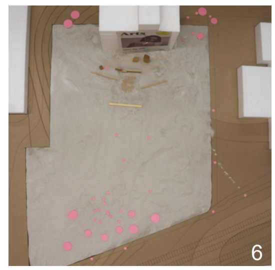
This Sand Model Study was made to help determine a site strategy for organizing the architecture and aid in the translation of the concrete and wax material studies to the site and to an architecture through a morphogenetic process. The Sand Model Study was made at 1:250 scale and the site boundary was made into a sand box to easily shift the landscape and provide an impermanent relationship with the earth. It was important to use wax in this process to stay consistent with the material expression. The process began by establishing an event or program and then responding to its needs by mapping form, circulation and boundaries with liquid wax. Using a liquid/ fluid and changing process of construction in this exercise was an attempt to translate the material process into a design organization on this particular site. Wax would harden upon contact with the sand to define space and structure. Other materials such as wooden blocks were used to create boundaries to control the flow of wax, similar to formwork. The wax forms that were poured could also be removed, altered and shifted as this process continued to establish relationships between the pieces in response to the needs of program. While the forms and pieces shifted so did the paths and circulation that formed to access these spaces, resulting in changing paths developing throughout the site as well the architectures relationship to landscape. Furthermore, pink pieces representing quantities of people were used to study how people might interact with these spaces, and how they may access the site from the various points of entry and the potential relationships of surrounding program. This process became a balance between the materials response, program and the choreography of their relationships. There was a level of abstraction as to how this model was interpreted, wax forms were seen as either a wall or mass (positive space) or as being a void or corridor (negative space), this interpretation was reminiscent of the casting process. The need to have an active construction site for the architecture to continually change, evolve and express the morphogenetic idea of the material performance became evident. This included access routes for vehicles such as cranes, concrete trucks, bob cats etc. and boundaries for construction areas to occur on site.

This is not a master plan exactly, there is no end nor was there a preconceived vision but instead it is a performance of the morphogenetic design strategy. Initially, this model was used as an exercise to develop a way of working on site with phase changing materials and casting. Also integrated were ideas of programing and events which determined the forms relationships as well as the circulation throughout the site. This site resulted in ideas of changing circulation paths, and evolving structures developed providing more clear idea of how the design could proceed into schematic design.





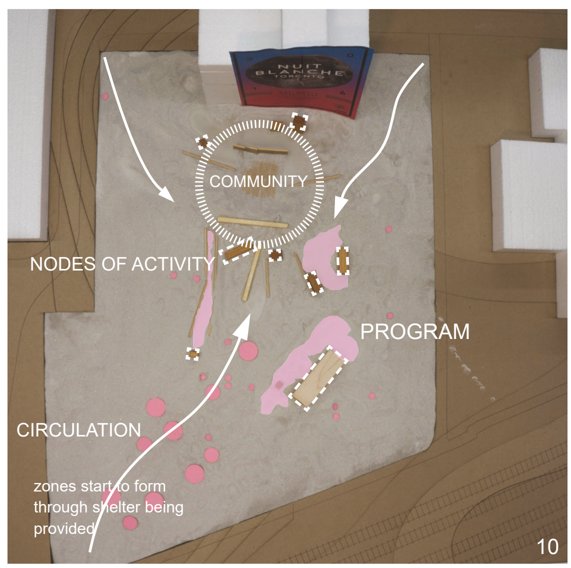




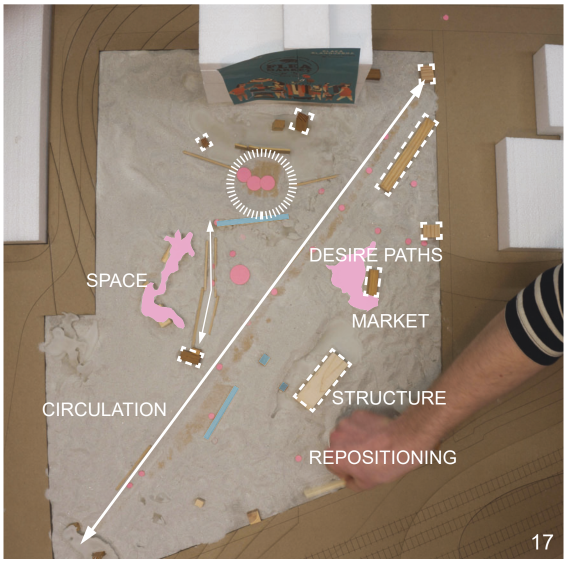
Flows of people occupying the programmed spaces are represented as pink circles

Clusters of small spaces surround program and create sheltered areas.

People arrive through various access points on site

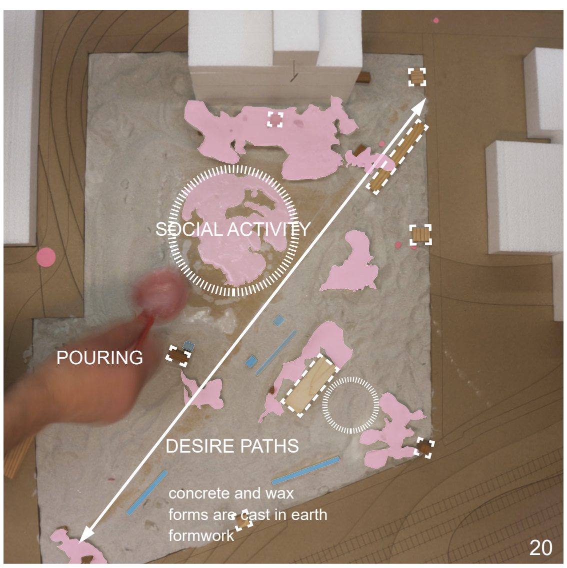


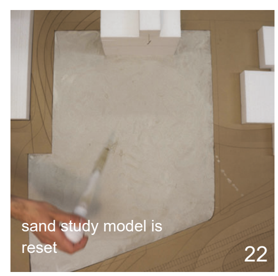
Sand study model 1:250
This series of photographs document the process of the studies made on the 1:250 scale model of the site. Wax and small blocks of wood aim to model a site strategy in relation to events and program



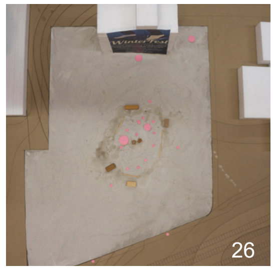
Direct circulation through site based on access develop into desire paths

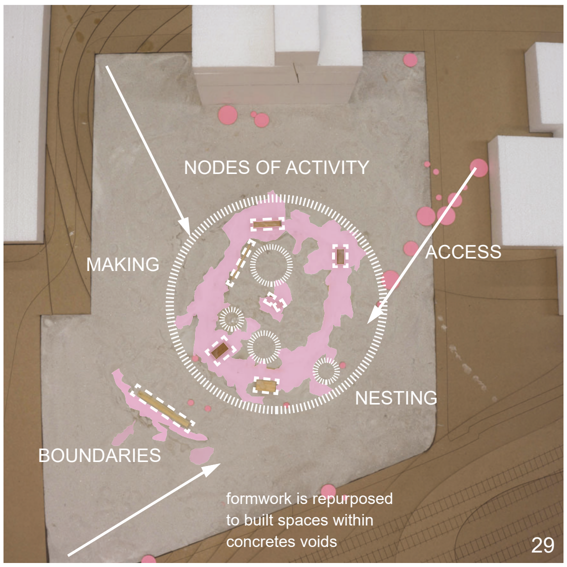
Additional structures and programming devlop out of site usage and community involvment





Sand study model
1:250
The site strategy emerged from the material expression of the wax as it flowed over the site model

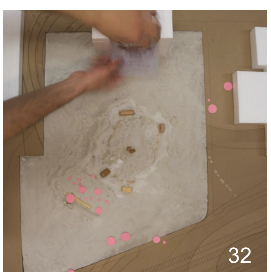


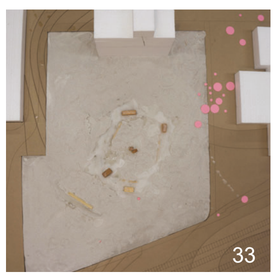


Growth of forms start to develop a layering and labyrinth like circulation

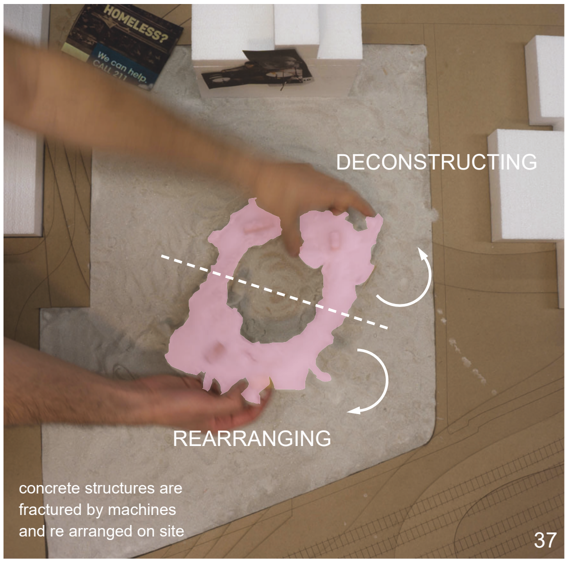
Zones begin to form and dynamic program relationships are developing

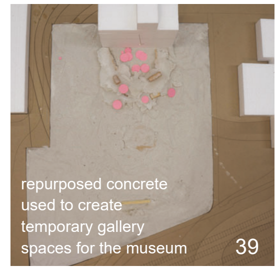
Fluid circulation paths evolve between the emerging forms





Sand study model
1:250

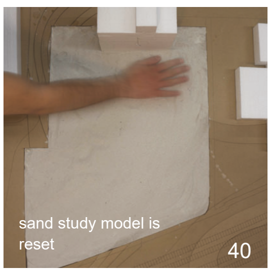


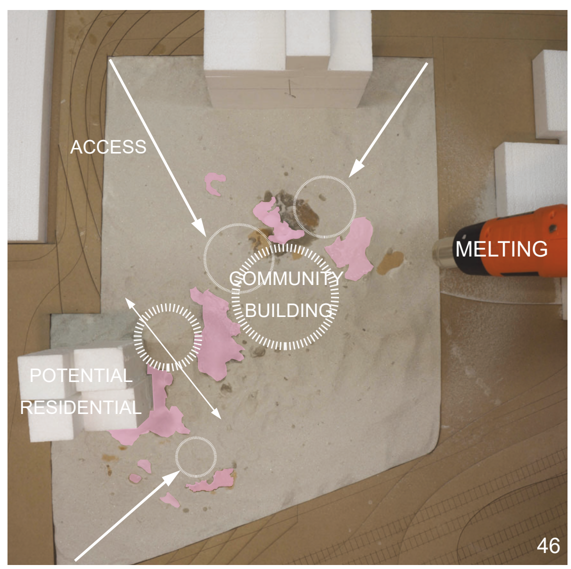


Cast pieces are rearranged and altered on the site model

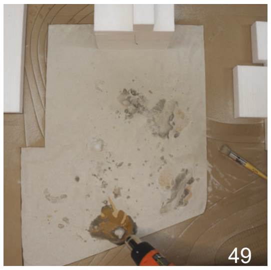
Architectural relationships are constantly being renegotiated

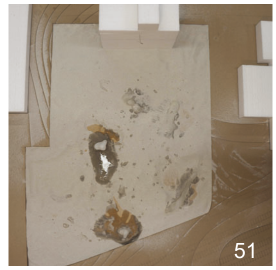
Community building and construction zones





Sand study model
1:250

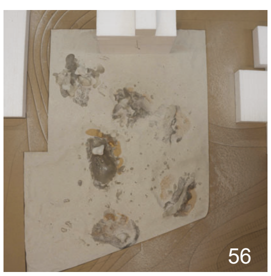




Forms block wind and create microclimates

Spaces blur the inside and the outside, the edge of the architecture and the landscape is vague

Circulation develops around and through forms



Sand study model
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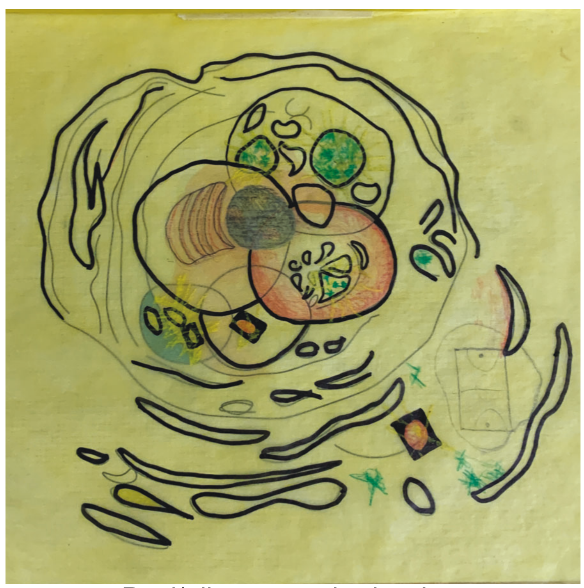
Schematic Design

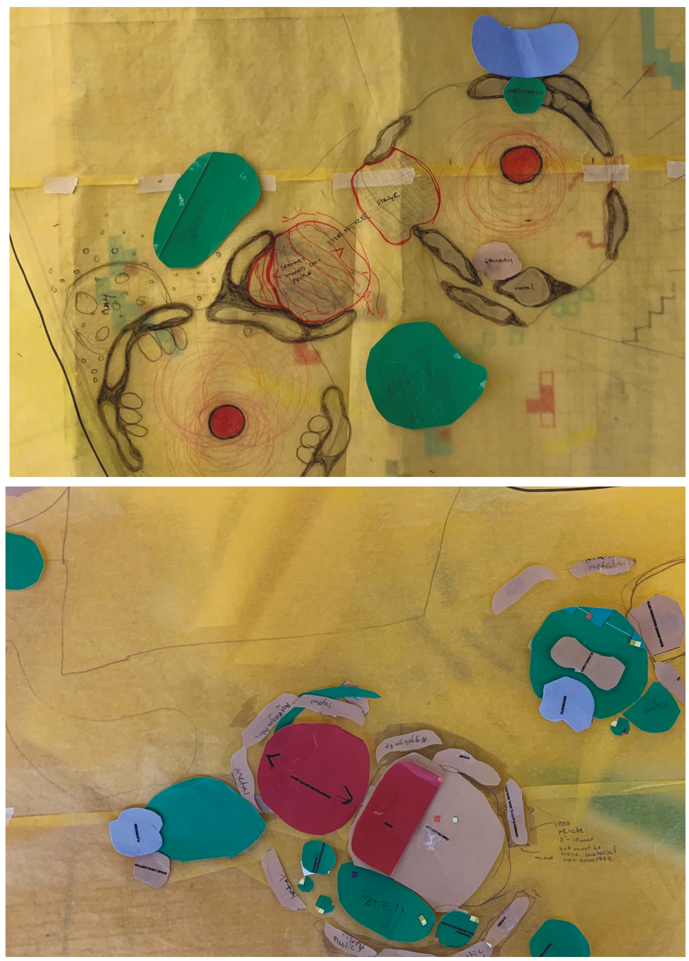
Emerging from the site Sand Model Study diagram parti sketches were developed that illustrated how spaces can be layered and overlap to develop complex relationships. A blending of program and a range of material qualities. Through layering of sketches, it assisted in imagining the spaces developing through time. An energy system became the focus in which programmatic elements would grow around nodes to provide a heat source to the spaces. Material compositions varied in regards to program adjacency to provide sensory microclimates - forming through casting processes, passive systems to heating and cooling and a range of light transmission. Aiming to blur the boundaries between indoor and outdoor spaces through a labyrinth like circulation, and a layering of the material threshold. These design goals were imagined to be achieved through a process of aggregation through time, a building process which grows slowly and changes as a result of process and program. This way the architectural forms communicates the process from which it emerged. Moving forward, these concepts of growth, blurring and blending were explored with program.



Parti/ diagrammatic sketches
Program organization informed by the processes of layering on sketch paper

Program

The next action was to develop programming for the architecture. This began with imagining the types of programming that might exist in a park context and then attributing a required square footage to that program. Programming developed included: gardens and green house spaces, artist residences, design and research areas, construction zones, basketball courts, meditation areas, outdoor workout areas, theatre spaces and playgrounds. Each program was then assigned a level of control to each space in relation to temperature and light: spaces that require a high level of temperature control vs. spaces that require less and spaces that require high levels of light vs. spaces where lighting is less important. This defined how these spaces are arranged in relationship to each other, sun, energy systems and form. This exercise was beneficial to understand different program relationships and overall organizing concepts.



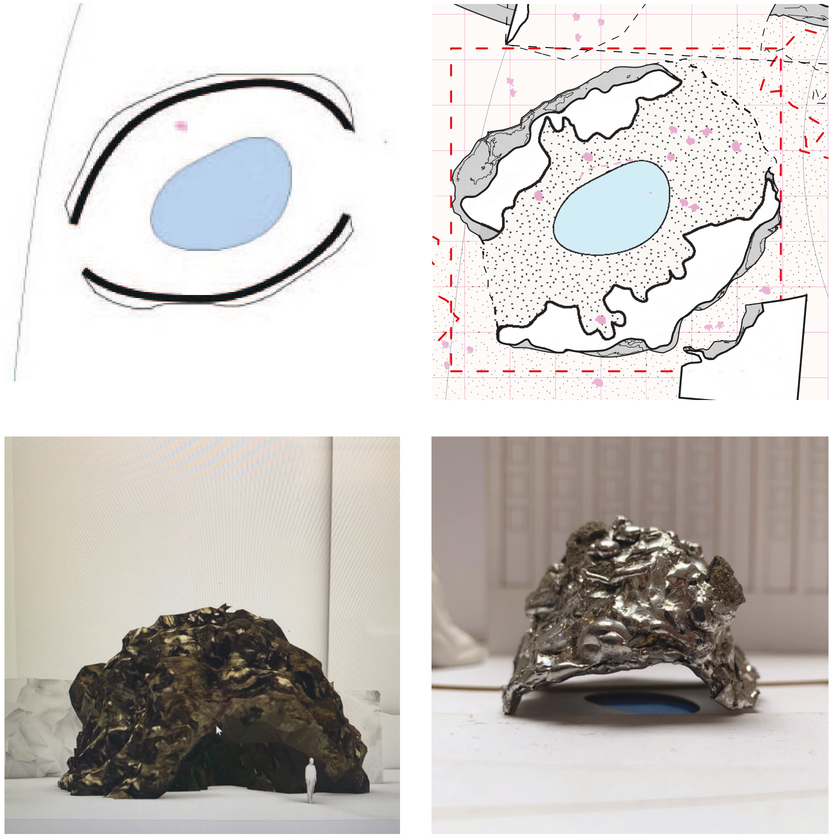
Program arrangement studies

Developing a Process of Drawing and Production

The organization diagrams and program outline informed 2D plan drawings. This approach quickly proved to be unproductive as what was being drawn came out of preconceived idea to how it might look instead of developing out of a process, a series of steps which build off of one another. This prompted a switch to 3D modeling in Rhino to play out construction processes on the virtual site, each step unfolding in sequence.

This was an attempt to develop a way of drawing that was in line with the concepts of the morphogenetic model and was driven by process as oppose to image. This required drawing in sequence, anticipating and hypothesizing how the materials might react, what tools and machines might be necessary and how it might actually evolve through time. Various challenges were faced, the many steps to each process and it is hard to recreate these steps in a 3D modeling software like rhino. Limitations to this approach included modeling skill level which hindered the production of complex shapes and to replicate some of the steps of the construction process. This resulted in simplified forms, that were not representative of the process or qualities the final outcome might posses. Also, because these steps were unfolding virtually there was not the material response factor which has a strong influence on how these forms would manifest.

In response to these issues and to develop a process of representation that was in line with ideas of the morphogenetic model, modeling physically alongside the virtual became important. A variety of forms and outcomes were explored with plaster and concrete, wax and various materials. Applying a photogrammetry application to scan these models offered the opportunity to work with the physical models digitally. This process of drawing was more in line with the outcomes of the physical modeling which allowed for a connection to the material expression. Furthermore, by importing these models into Rhino allowed for a reinterpretation and the opportunity to manipulate the forms through scaling and digital modifications. This hybrid process of working both digitally and physically became a productive way to begin imagining and developing spaces as well as drawings of how these forms might be interpreted.



Photogrammetry
Top left image shows form developed in rhino, top right image shows drawing made form scanned model, bottom left shows photogrammetry model, bottom right shows physical model

Sand model study
Model developed alongside drawing and digital modelling, cast forms produced were then scanned through photogrammetry and worked with digitally

5.2: Design

The Sand Model Study influenced the site strategy and the organization of program was a result of the schematic design and methods of drawing through photogrammetry and physical modeling, and thus the Park of Process took shape. The design is illustrated in a series of three plans, showing the park under three instances of its successive growth. Followed by this is a section through the site showing the relationship between the architectural pieces and the site context.

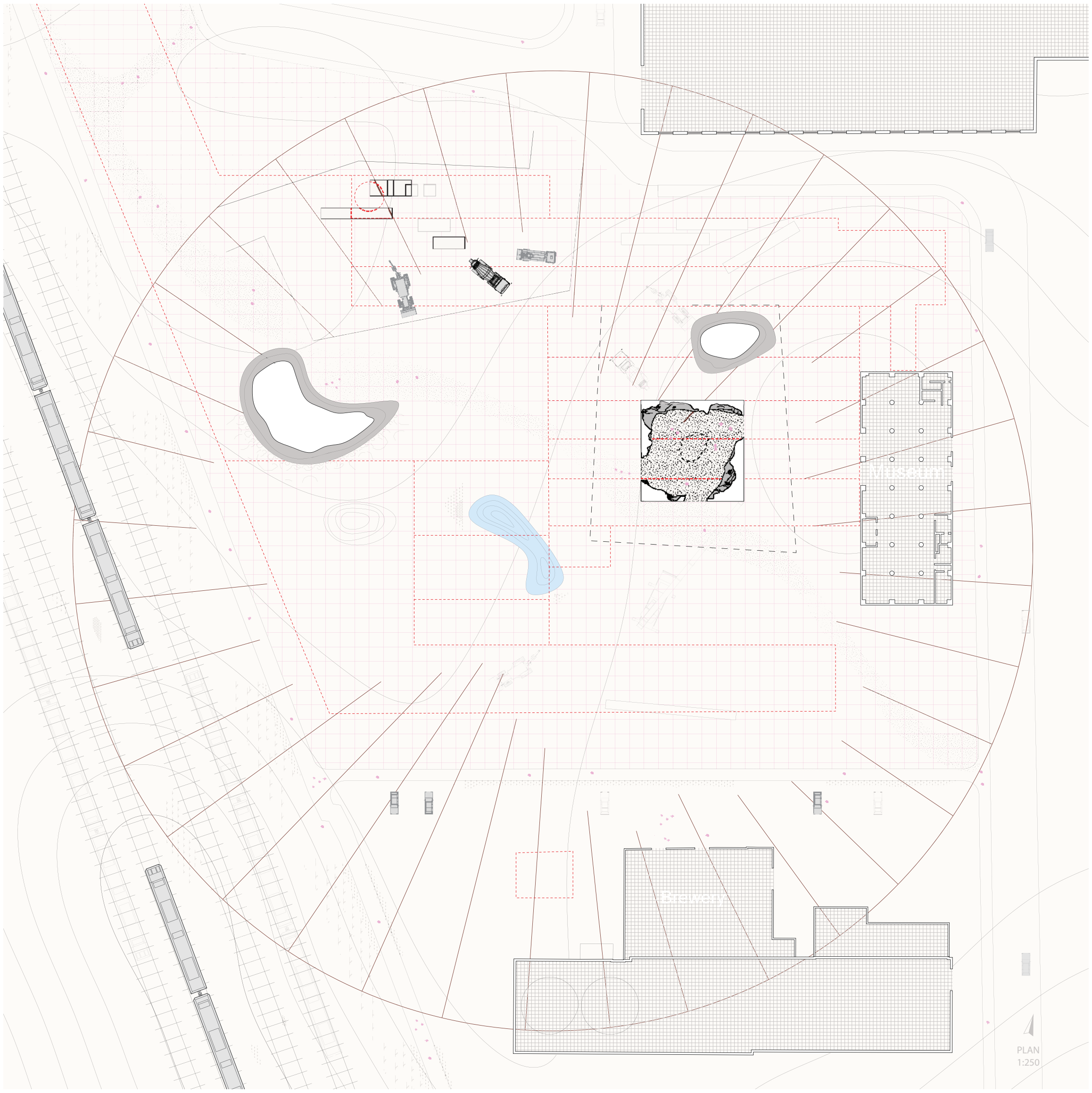
A heating system was introduced into the design using wax and concrete to passively heat spaces through waste heat from the nearby brewery. Finally, four program spaces were developed including a meditation space, a research and community space, a theatre and artist residency, and a garden. The design of this park and the spaces within it have been arranged on site in successive phases, each phase shaped by the processes, conditions and activity on the site. The accumulation of these phases have been considered to build upon the previous phase, encouraging a morphogenetic unfolding of construction on the site. These separate spaces were intended to blur the interior and exterior environment, with a variety of spatial form, a range of lighting and thermal conditions understood as sensory microclimates.

This design was represented through a series of three plans to show their successive growth. Plan 1 shows the first development, a meditation space which is cast on an existing mound of concrete rubble and earth that existed on site. The rubble was removed from the concrete form and the interior became a place of meditation and rest. Pathways and desire paths developed on site to access the space. Construction zones claim territory in order to store materials, build and keep pedestrians safe. The former factory is dotted in and the evolution of the construction sequence is ghosted in to communicate the process.

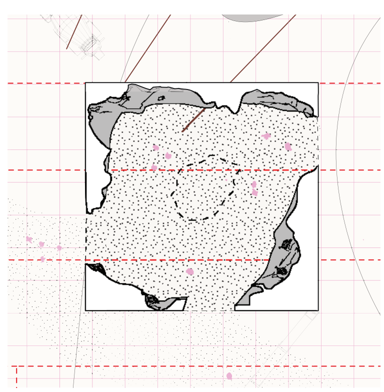
Plan 2 shows the evolution of the meditation space. The previous concrete form was used as a formwork, filled with earth by the community to cast the meditation space in aluminium to pay homage to the former aluminum factory on the site. The concrete formwork was then removed leaving behind bits of concrete embedded in the aluminum form, becoming a record of its morphogenetic process. The concrete formwork was then repositioned on the site to break wind and create circulation paths around the meditation space.

The research and design space was also cast on a mound on site, and an interior pit for community gathering was placed in its center. This pit is heated from an energy system of wax and concrete that works as a heat sink to collect waste heat from an adjacent brewery. The paths have developed to access these new spaces. The theatre space is also under construction at this time.

Plan 3 shows the growth of the park at its most developed. Multiple heating towers are being used to heat program spaces. The construction of the theatre, artist spaces and garden have evolved. Pathways have developed further around the program spaces, carving out spaces of shelter next to structures. Space for construction vehicles is maintained to allow access for the construction process to occur. A temporary road cutting through the site is imagined as a space for events such as parades as well as access to importing materials onto the site.

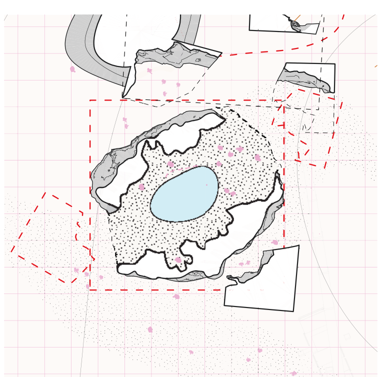


Plan 1/3

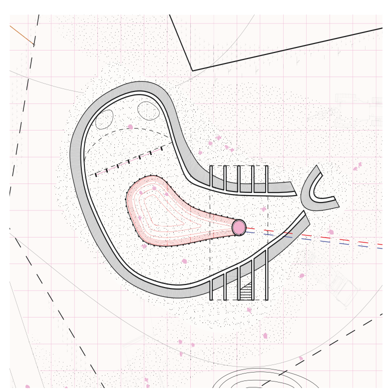


Meditation space

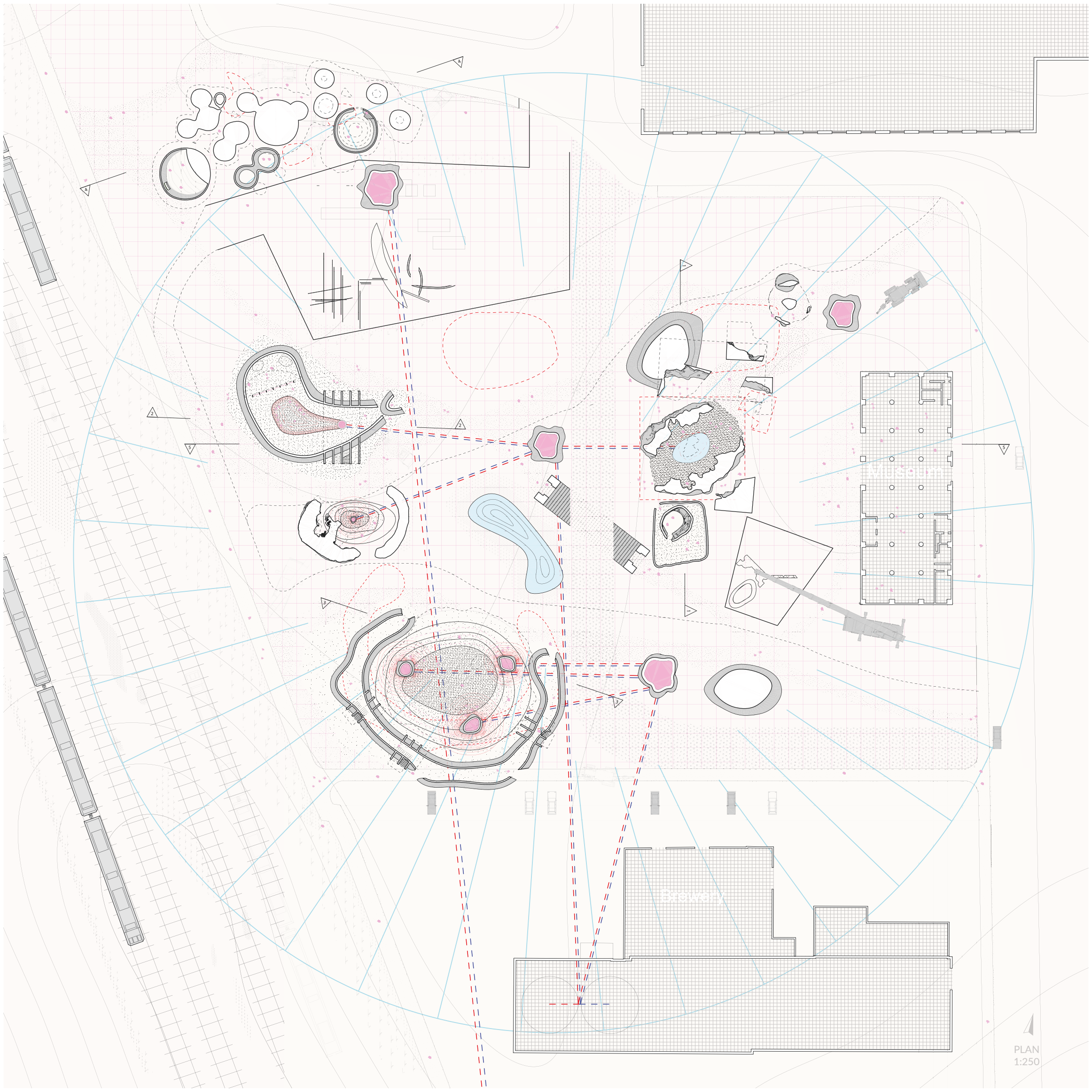
Plan 2/3



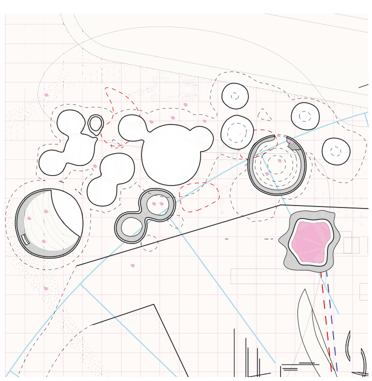
Meditation space



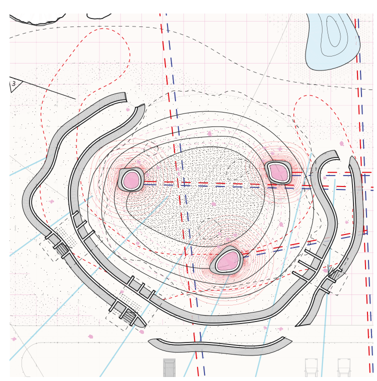
Design, Research and Community space



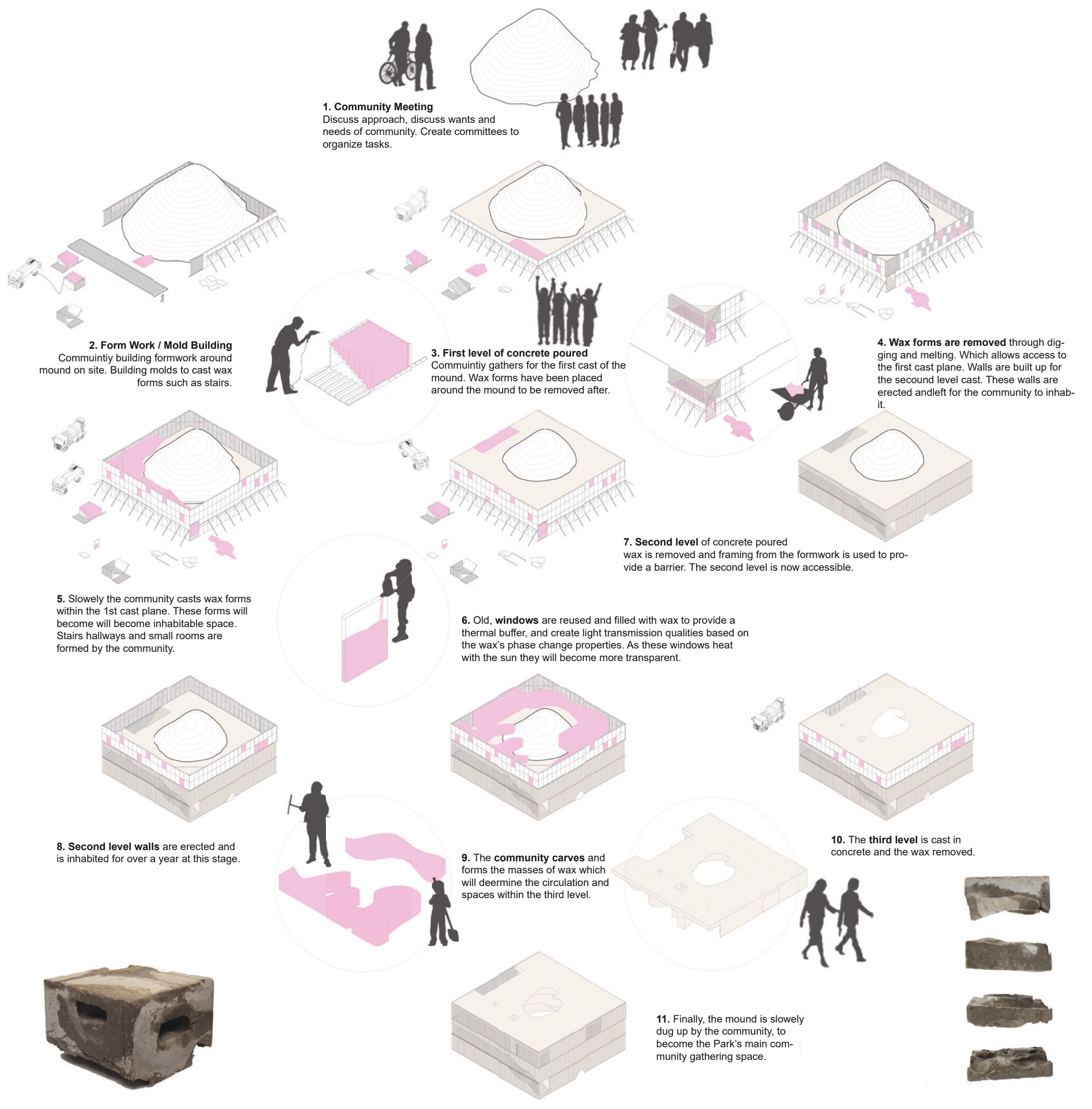
Plan 3/3



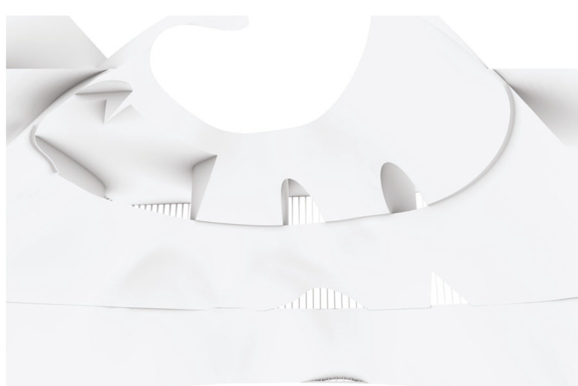
Garden



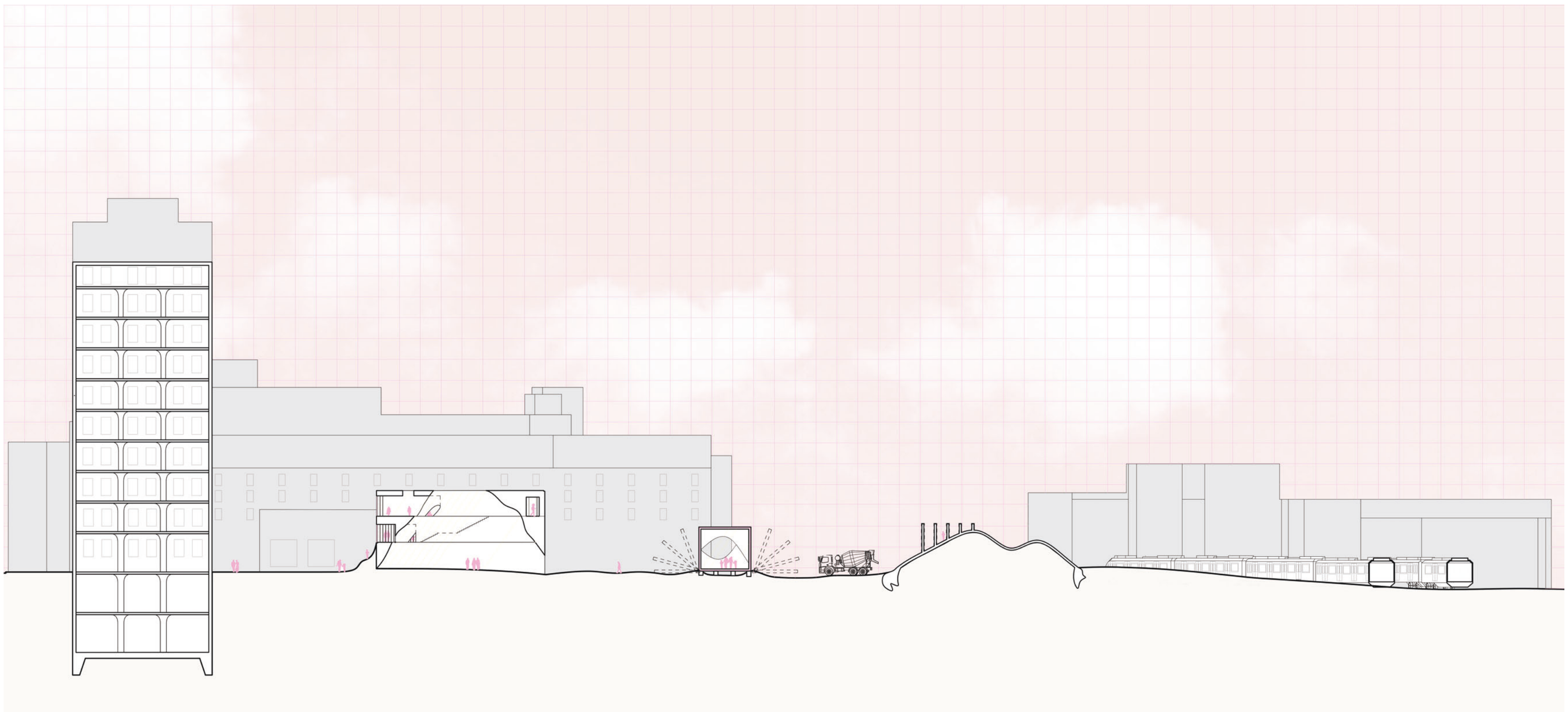
Theatre



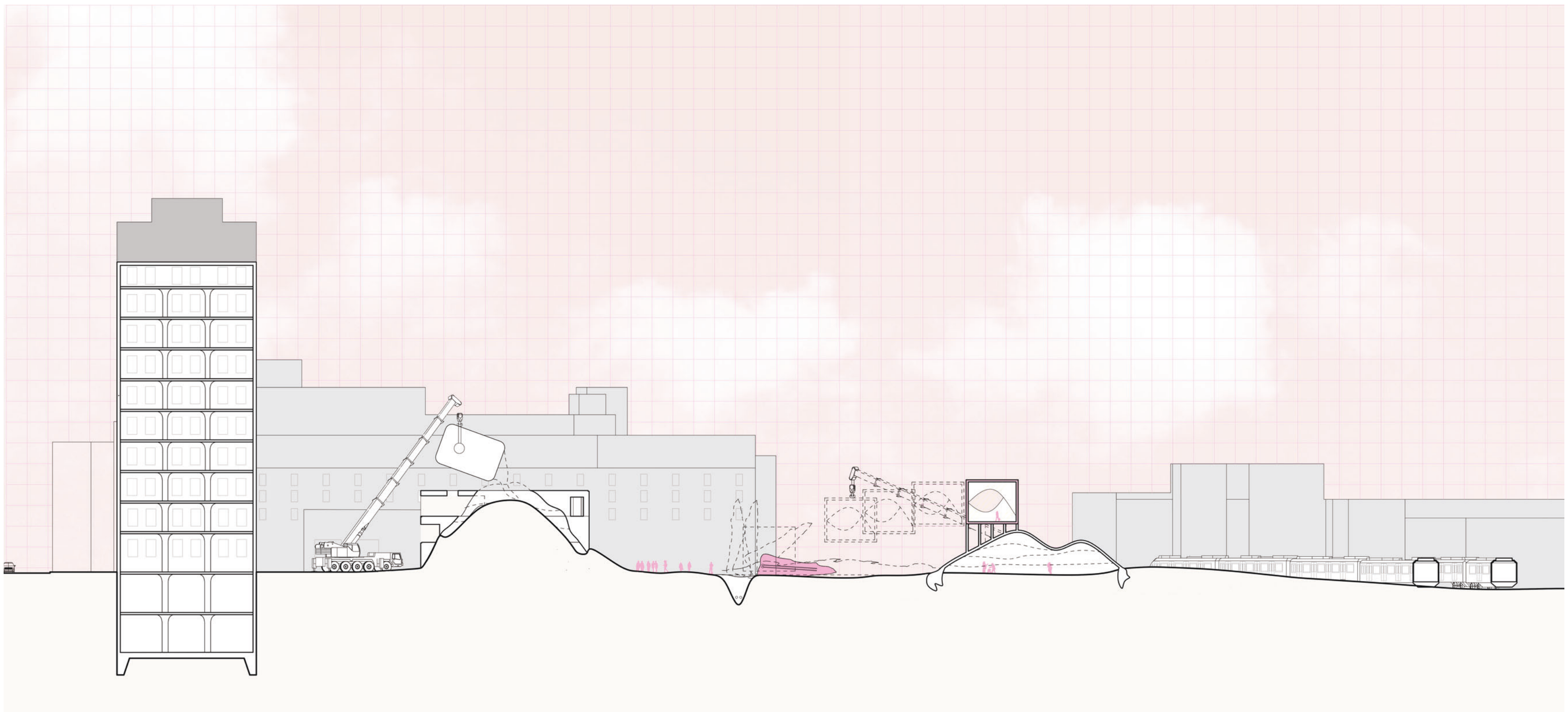
Series of construction and community involvement over time



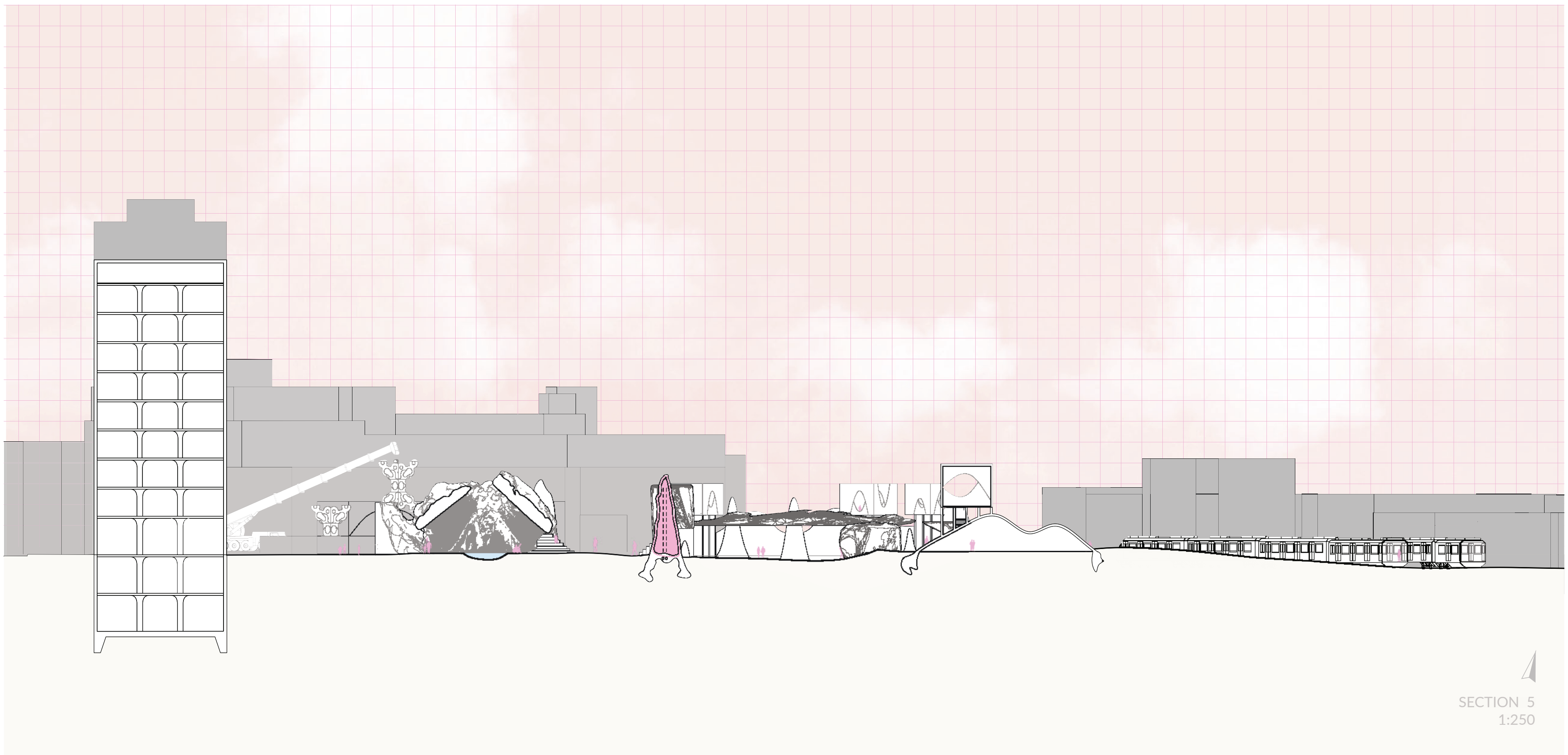
Interior view of above construction



Long section 1/3



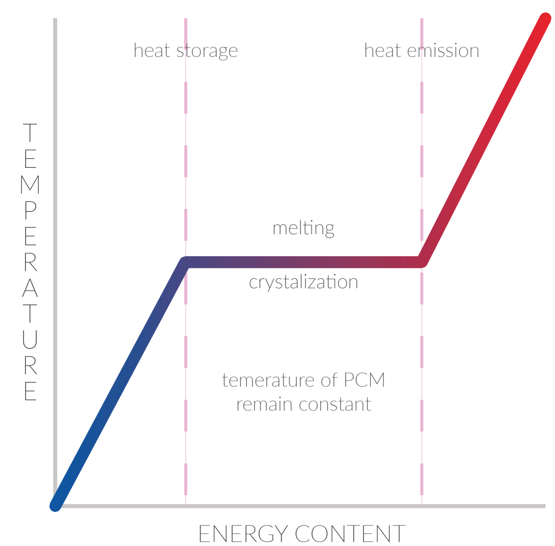
Long section 2/3



Long section 3/3

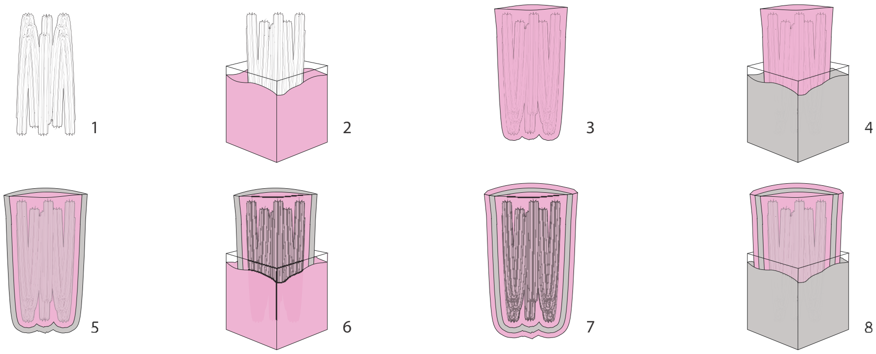
Heating System

To achieve thermal comfort throughout the park, a heating system was developed using wax and concrete's phase changing properties to allow for thermal storage. This heating system was designed as structures cast on site. By embedding the piping system within a wax form and dipping these forms into concrete to build thickness and then again in wax to build up an insulating layer and once more in concrete to produce an outer shell. This way of building is reminiscent of the candle making process. These structures work as heat exchangers absorbing waste heat from steam produced by the nearby brewery. Wax or a phase changing material (phase change material) absorbs the heat from the waste steam and stores it, transferring it into a separate closed loop system of wax or PCM which transfers that heat to a local region where it is used to heat the concrete and in tern the users of the space.

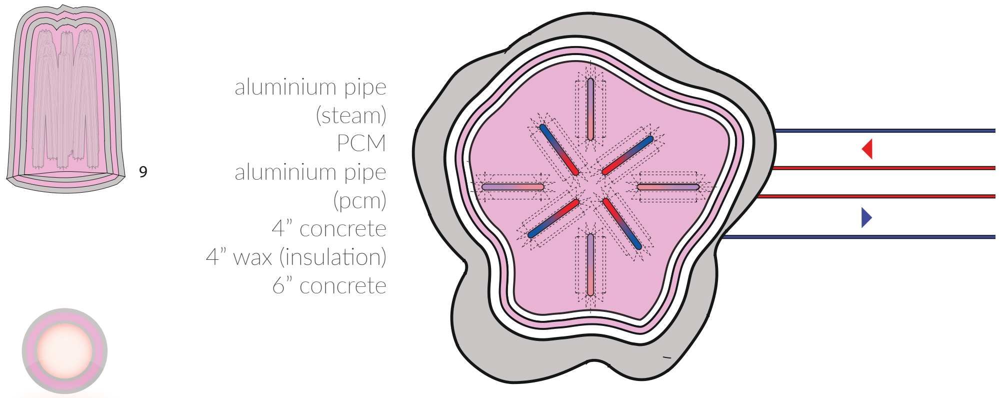


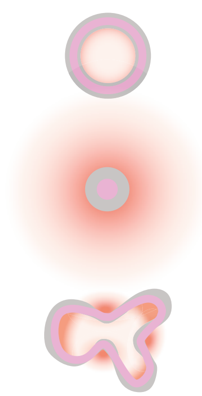
Variation of temperature with energy provided to a PCM. (Recreated from Mishra, Shukla and Sharma 2015)

Phase change material (PCM) is a substance having a high heat of fusion which, on melting and solidifying at a certain temperature is capable of storing and releasing large amounts of energy. PCM store energy at a constant temperature. A lot of energy can be stored in a small volume with a thermal storage of 200kj/kg or 150 mj/m3. (Mishra 2015, 534-540)

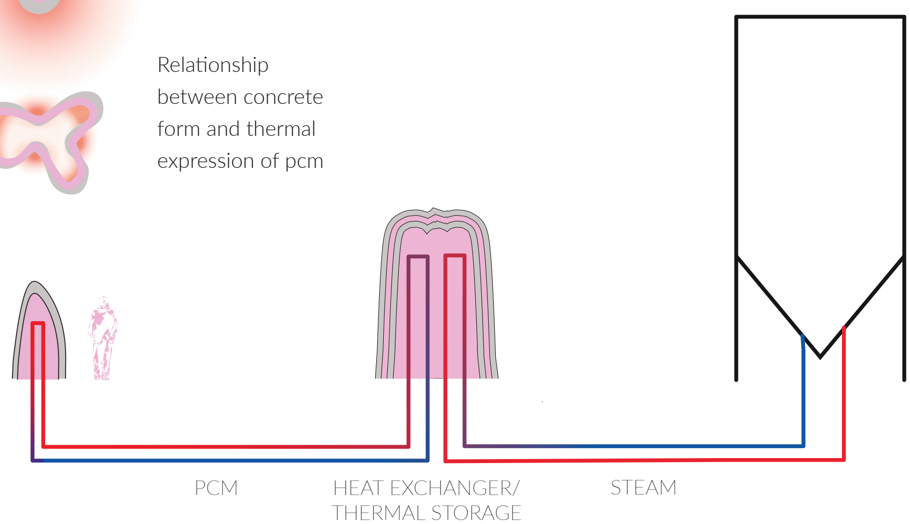


Sequence of construction





Relationship between concrete form and thermal expression of pcm

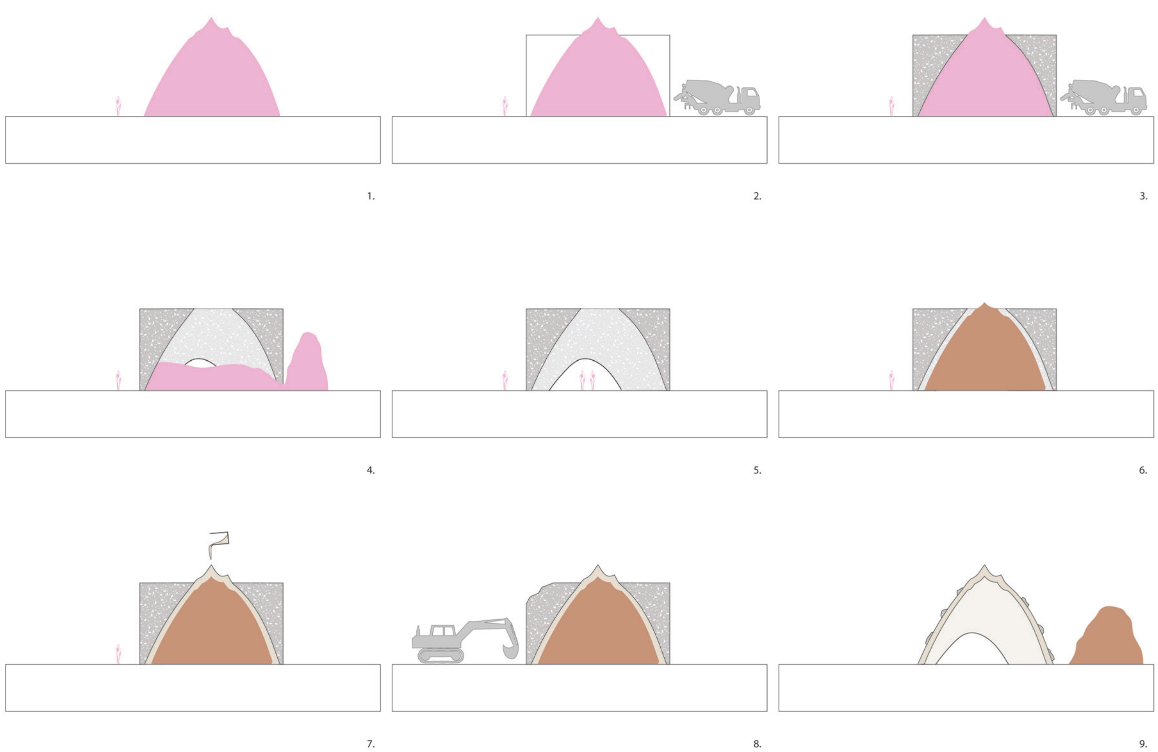


Heating System
Utilizing waste steam from a nearby brewery through wax's energy storing properties to provide heat locally through the park

This heating system utilizes the material properties to store and transfer heat. The relationship between the concrete and wax also has an influence on how the heating is experienced based on its form. The thickness of the concrete in relation to the wax determines how much heat will be transferred, allowing the form to determine the distribution of heat. This heat is then localized to areas that need heat to support programming, such as the stands within the theatre space and the community pit. This heating system produces a range of temperatures and zones of thermal comfort throughout the park, to aid in the goal to achieve sensory microclimates.

Meditation Space

The design of the meditation space emerged through the morphogenetic model by way of its processes of formation and material properties to create sensory microclimates. These sensory microclimates were created by providing shelter and light for the program within. The space is in response to the site's history and the program is derived to support the community.



Process of construction - Meditation space

The formation of this space began initially as a mound of earth on the site. Formwork is built around the mound, and then cast in concrete. Once the concrete is cured, the earth inside is removed leaving behind a concrete structure. This structure can be inhabited by the community. Eventually, earth is piled within the concrete structure leaving space between the earth and the concrete, creating a formwork. Aluminum is then cast into the void between the concrete and the earth. The concrete exterior is broken away and the earth inside is removed revealing an aluminium cast structure.

This space provides shelter from wind and an ocu

lus to allow for light to penetrate the space. The aluminum texture informed by the earth, reflects light and water into the space creating a serene and tranquil environment. This variation of light, texture and shelter demonstrate the possibilities of sensory microclimate that can be achieved through the morphogenetic design process.

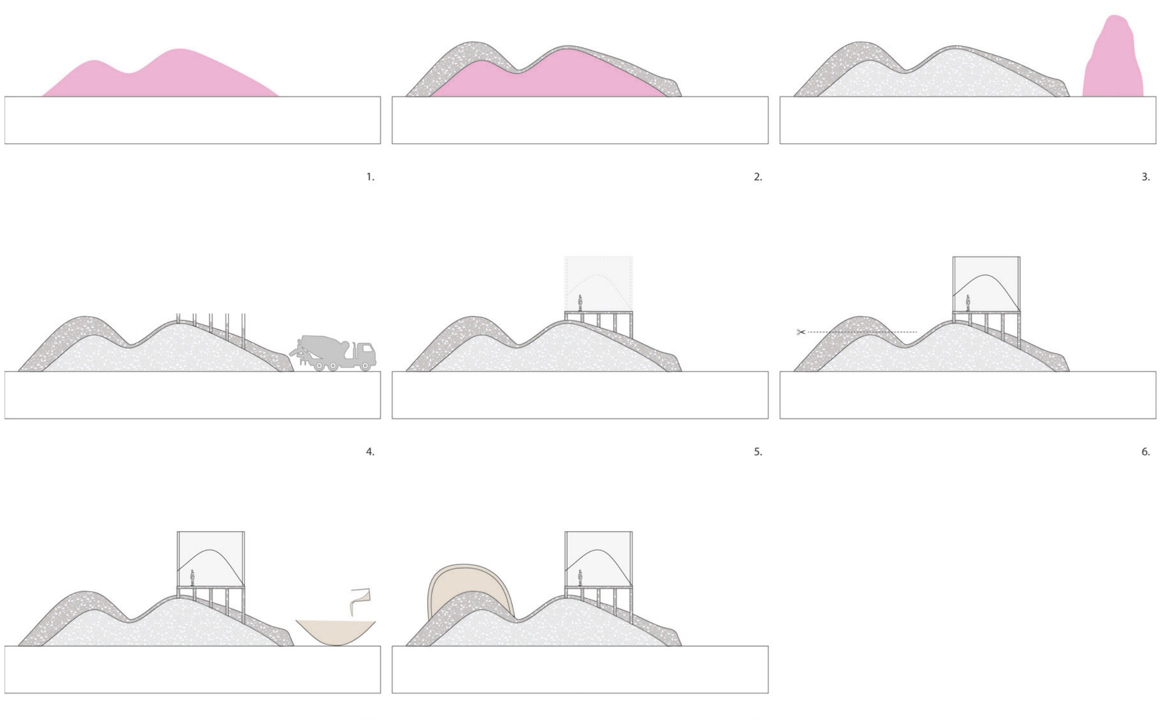
Meditation space

The program of the meditation space may develop out of the communities desire for a place of reflection and inward contemplation, a place to slow down and focus in ones journey to understanding self and the site which they inhabit.

In the future after reflection, its possible the community can pay homage to the site's industrial history and the former makers who toiled in the factories. They adopt processes that once existed on site which informs the aluminum casting. The final form develops a texture which expresses a record of its process of making.

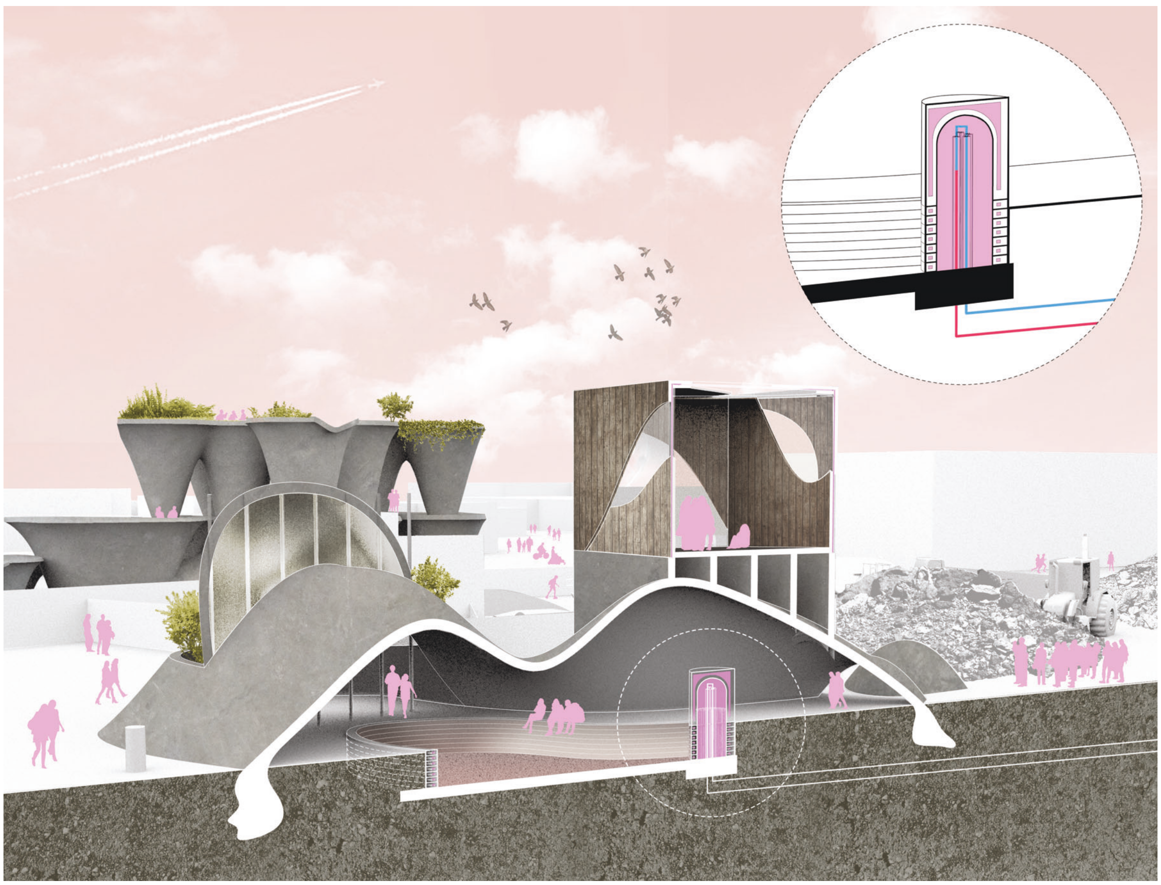
Design/ Research/ Community Space

The development of a design and research facility and community gathering space is necessary for this park to function, due to the complexities of perpetual construction within a public space. This space provides a place for research and community gathering. This implements the morphogenetic model through its use of material properties to not only achieve form but also utilize materials to achieve shelter, lighting conditions and thermal comfort.



Process of construction - Design/ Research and Community space

The main structure is cast from an existing mound on site, the form is cut to allow for light penetration, this offcut is cast in aluminum and positioned towards the south to scoop light into the space. Formwork is built to cast structural fins along the main form. This same formwork is used to build a structure on top of the fins for a private office space. Again, this aims to express the process of its making. Wax embedded in glass is used between the wooden formwork to produce a passive heating application which also diffuses light into the space.

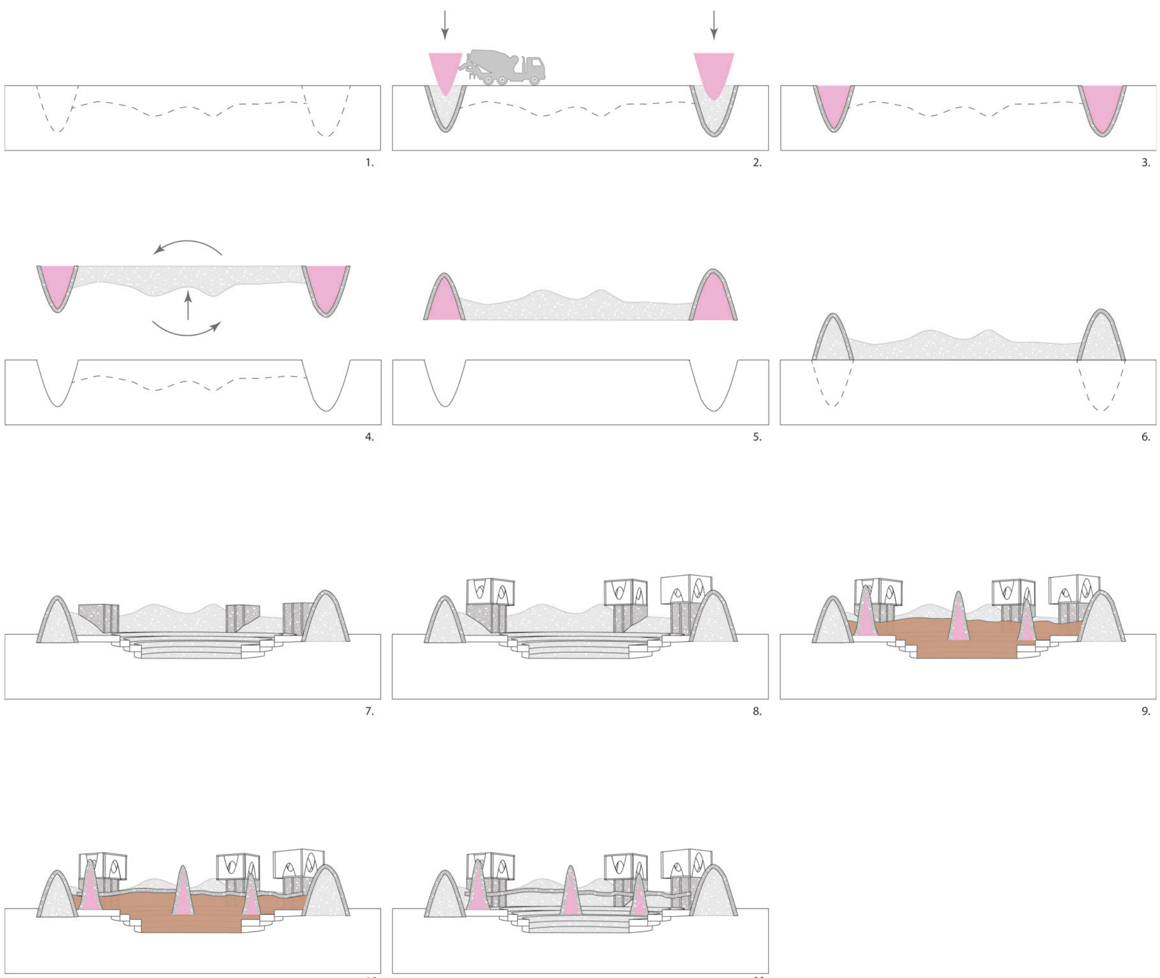


Design, Research and Community space

The space creates sensory microclimates by providing a range of shelter from wind and sun through its curved form and strategic apertures. It also provides a range of spatial experiences based on its amorphous form and undulating roof heights. Lighting is implemented in this design, through the courtyard space which brings the majority of lighting into the hall, this lighting will allow for vegetation to grow providing sheltered green spaces. Additionally, the aluminium scooped light well uses its reflective qualities to direct light into the darkest areas of the space. The community gathering pit is heated by a phase change energy system which takes advantage of waste steam and the wax's innate properties of thermal storage, this heats the walls of the pit in order to provide thermal comfort where it is needed.

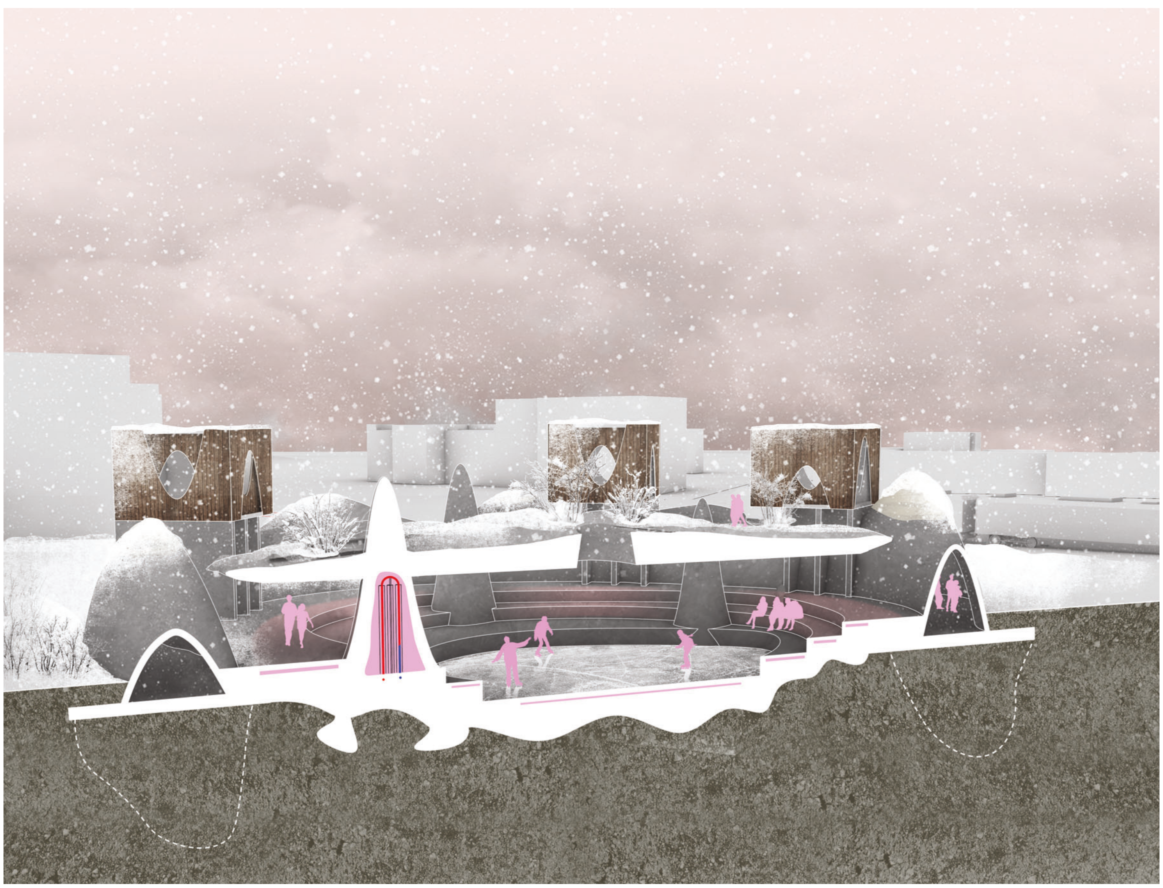
Theatre

The design of the theatre space can be conceived through the relationship between the park, the Museum of Contemporary Art as well as artist community groups. The intention is to support the artist culture of the neighbourhood with an opportunity for artist residences and theatre for the public. The morphogenetic model is played out through its process of formation. The theatre achieves sensory microclimates through its range of spatial experience, various lighting conditions and a gradient of thermal comfort.



Process of Construction - Theatre and Artist space

The forms are cast within the ground from a dugout formwork and a wax form is used to influence what would become the interior space. This form is then flipped over to provide circulation space that can be used as a gallery and market space protected from the wind. The tips of the structure are cut and covered in a plastic to allow for light to be diffused into the space. Within this sheltered area theatre steps are cast with formwork. Heating elements are placed throughout the seating to diffuse heat through the stands for localized comfort, also as structural columns to bear the weight of the roof. Earth is then piled within the stands to cast a roof overhead to provide shelter, this roof is perforated to allow for light penetration. Concrete fins are cast along the circulation space and the formwork is later used to create the rectilinear artist spaces above, repurposing the records of the process of making underscoring the morphogenetic process of design. The material expression of the wooden formwork lends itself to a more linear form versus the phase changing fluid expression of the wax and concrete that results in a more amorphous form.



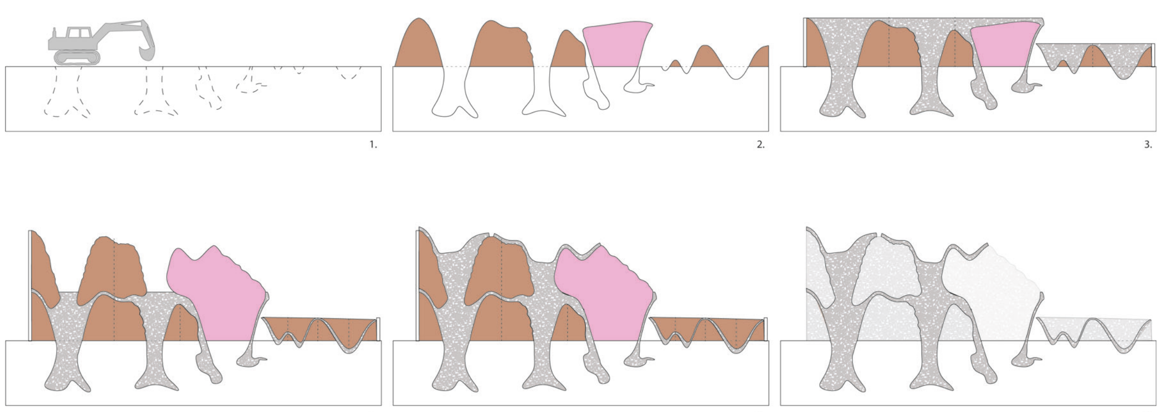
Theatre and Artist Residence

The theatre aims to achieve sensory microclimates by providing spatial variation through the undulating circulation space, the experience of the ceiling heights changing through out the space opening up to pockets of light. The theatre space is embedded in the earth creating an interesting relationship between body, ground level and the roof above. Various lighting conditions are achieved through the use of perforations within the concrete and the light wells within the circulation space.

Within the artist spaces, wax is embedded in glass and used between the formworks to diffuse light into the space. Depending on the temperature of the environment, the opacity of the wax changes allowing for a variety of lighting conditions which contribute to sensory microclimates that are connected to the material expression. Finally, a gradient of thermal comfort is achieved through the use of a wax's energy storing properties to heat local zones within the seating areas.

Garden

The design of the garden was developed to buffer the flows of the park from the residential area to the north and provide the community with a space for communal gardening as well as green space. The garden space uses the morphogenetic design through its methods of construction. Sensory microclimates are achieved through the spatial variety, the different lighting considerations and finally a range of thermal experiences.



Process of Construction - Garden space

The process of making the garden occurs over a long duration and provides a different landscape experience to users at each stage. The forms are cast by digging holes and building up earth to create formwork. Wax is used to be more precise in certain area such as areas of perforation. Each level is built upon the next slowly moving vertically. Wax embedded panels are used to shelter select areas and the hollow forms are filled with earth to create both garden space and as a means of providing circulation.

Garden

Sensory microclimates are achieved through the variation of spatial qualities throughout, being formed by earth, a loss of control in terms of the casting, allowing the formation of these spaces to the mercy of the materials. Undulating floors and roof scapes are merged with earth to provide a variation in flooring conditions from concrete surfaces to earth and vegetation, blurring the inside and the outside providing exciting ares to discover. A range of lighting conditions are achieved through light wells positioned over vertical access that include stairways and also bring light to the lower ground level that will become the darkest areas. These light wells contain openings and perforations throughout to provide views and light to different levels of the garden. Finally, thermal variation is achieved through shelter provided by the concrete forms, vegetation as shading as well as wax embedded within glass to provide shelter in the main spaces to passively store and release heat in response to environmental conditions.

Chapter 6: Conclusion

6.1: Summary

This thesis is an exploration of the morphogenetic model of design, and is tested at multiple scales through experiments, culminating in a design of a park in the Junction Neighbourhood in Toronto. Stemming from the theoretical framework of Deleuze and Guattari, the morphogenetic model of design prioritizes material experimentation, processes of making, material properties and material performance.

Material experimentation is at the core of this project, exploring wax and concrete through prototyping models. These investigations and explorations grow a wider range of possibilities to making architecture. These models search for forms through material properties and fluid phase changing methods of construction and varied spatial organization through material qualities with a focus on process over product. The investigations were used to develop a process of making, using wax and concretes viscous phase changing properties to influence concrete's form through casting. Wax's ability to undergo multiple phase changes compared to concrete allowed for the gentle removal of wax from the concrete forms.

The investigation models of concrete and wax discover form finding prototypes but also are models for developing a morphogenetic understanding of the processes that allow for form to emerge. Without a preconceived idea of what the architecture should look like, the investigation allowed the process and the material properties to define form.

There was initially no scale attributed to these models to leave a wider range of interpretations of these material relationships. They are at once a 1:1 scale component that may be assembled and aggregated to create structure or they are representations of spaces to be inhabited. This approach prioritized the process of making over the product. This was an application of the morphogenetic model of design, prioritizing the process; however, introducing a greater number of fixed variables such as attributing a definitive scale or function to the experiments sooner may have allowed for a clearer lens to interpret these models and develop them further within the prototyping phase. During the design phase, the process shifted to a scale of 1:250 to address the site conditions, however it resulted in developing forms at a building scale, and influenced the larger scale application of the process in the final design. The models were successful in outlining a range of ways wax and concrete could produce architectural form.

The next step in my explorations of the morphogenetic process of design was diagramming methods of construction to draw conclusions from the material explorations found in the investigation models. The aim to translate these discoveries into ways of building, and to study potential inhabitation. They are drawn as a construction sequence, studying also how people may interact during each step. These diagrams look at ways of casting concrete around aggregations of wax, developing reciprocal molds, using wax as a means of heating spaces based on wax's phase change, light transmission based on temperature and melting points to control transparency.

To understand the implications of the morphogenetic model as it applies to the social and local climatic conditions it was necessary to test this design approach on a site. A former industrial site in the Junction Triangle in Toronto was chosen for its historical origins of manufacturing materials and for its current state of becoming a cultural anchor in the city. It is a very active urban site and is connected via multiple train systems, bike routes and pedestrian paths. The site was formerly an aluminum factory which underwent casting processes similar to what was being proposed providing an opportunity to celebrate that history. Also, complimentary program adjacencies such as the Museum of Contemporary Art and a brewery helped supplement and inspire programmatic needs. Finally, because the Junction Triangle is an area under transition and currently being gentrified, using this project as a way of engaging the strong community ties celebrate the values and culture which have been manufactured in this unique industrial area. These dynamics helped form and influence an architecture that is impermanent, emerging and changing perpetually.

Moving from the material studies onto the proposed site posed a challenge that was addressed through two exercises. First, through a mapping exercise that studied the site over a period of two decades using satellite photographs to map changes which occurred on the site, everything on the site was considered material and all the changes that occurred were documented. This process of documentation showed the site's layered history of which the dynamics were expanded upon and guided into the initial design moves. The reading of the site through this morphogenetic lens allowed for a translation of the processes occurring on site to merge with the processes developed through the material investigations. The initial design moves were informed by and literally cast into the landscape of this former industrial site.

A modeling exercise was used to fully understand the approach to the initial design moves and develop a site strategy whilst still abiding by the morphogenetic approach. This modeling exercise used a sand model and wax that employed the material expression of wax to determine how this architecture may occupy the site. The site strategy that emerged from this exercise brought program, process and social activity together. Nodes of activity and program were the focus in which the architecture grew around. These nodes evolved and changed through time and renegotiated their relationships based on the access routes and the desire paths created from users. The forms were cast, rearranged, cast again, deconstructed, moved around the site, piled and stacked. This layered site strategy demonstrated how the process may lead to a development of potential microclimates.

The spaces which emerged from this process were programmed not only in relationship to the sites history, but also towards the adjacent programing of the site such as the Museum of Contemporary Art and the programing that surrounds the needs for this continually changing site. A meditation space was cast in aluminum as a homage to the sites former aluminum production history. A research space and community gathering space was cast from an existing mound on site and its formwork repurposed to create inhabitable areas. The theatre space was cast from forms dug by the community. The garden space was cast within mounds of earth. The sequences of construction express a record of the architecture's making. These forms were not premeditated or designed beforehand, their composition was defined by the materials and the processes used to create them, a layering of material, process and engagement, one building off the next in a perpetual cycle. These forms that emerge offer a variety of spatial qualities and varying lighting conditions which could not have been conceived through the use of standardized materials that follow the tropes of the hylomorphic model. This Park of Process offers a departure from the hierarchical confines of image based design.

The design of this thesis was able to adhere to its intentions of developing an architecture out of process and material properties as oppose to image-based design. Using this morphogenetic model, experimental process driven approaches were applied at every stage of the design generating architectural form without preconceived ideas of what it should look like. For example, the meditation space was cast from an existing mound on site, its form was derived directly from site conditions and the material's expression. The form that resulted from the successive steps in its construction were generated from the process of its making as opposed to referencing historical symbols. The intentions to counter the hylomorphic model of image-based design were extended to the use of non standardized materials.

Wax, an unconventional building material, was explored for its material properties - specifically its ability to change phases, diffuse light and store and emit heat. These phase changing properties were used to develop methods of casting concrete in complex forms, by using wax as formwork to gently release as it changes into its liquid phase. The interior circulation space of the theatre is revealed after melting a wax positive formwork that was cast in concrete. The light diffusing properties of wax were implemented through embedding wax between glass to provide light transmission due to the material's varying opacities determined by its temperature. The thermal properties of wax were coupled with the thermal mass of concrete to create a heating system that provided localized zones of thermal comfort throughout the site. The applications of wax's material properties offer a variety of architectural experiences resulting in sensory microclimates.

The spatial arrangements that have emerged and the use of phase changing materials as a means to thermally regulate the environments in the Park of Process, proposes a potential for an alternate approach to conceiving architecture. This morphogenetic model of design is not concerned with the final product, rather searches and encourages a continual exploration of process to achieve a wider range of architectural experience.

6.2: Moving Forward

In the pursuit of a morphogenetic design to achieve sensory microclimates through non standardized building methods, the focus of this became primarily about material and process expressed in the design. Because this focus was the primary goal, certain factors needed further attention and in turn are areas in which the research and development of this thesis may continue.

Upon reflection of the consequences of the design which derived from the morphogenetic model, it came into question how might this design process further consider the social implications linked to the material properties and construction methods being explored? How can this process of design incorporate public opinion and culture? More specifically, how does an architect communicate the specific knowledge of craft and material understanding to the public?

The Park of Process aims to incorporate and develop a relationship with community groups and tap into local histories through engagement; however, it is unclear how this engagement will be organized. It was imagined to include group meetings which would involve meditations and conversations on the history of the site, the wants and needs of the community, and how these goals might be achieved. Although these approaches can provide promising goals and conclusions, it will inevitably be the job of the architect to synthesize this information and apply it through experimentation and process. It is the role of the architect to determine how public and process come together in a physical engagement to develop a response in line with a community, and how the morphogenetic model of design can be extended into the arena of public consultation. The morphogenetic model promotes process and physical engagement with materials. Researching how to engage the public or community through interactive modeling exercises may better incorporate communities needs within the morphogenetic approach. The Sand Study Model used in this thesis incorporated site, program, process, and physical engagement through making, this model was used to generate urban scale moves on the site. Perhaps similar exercises can be tested through public consultation. It is the design of these public consultations that may be fruitful area of research as well as studying ways the public can engage with the materials.

To go beyond the design stage, a Park of Process is imagined to incorporate community in the construction of the project. However, the scale of construction that emerged through the design is a very large scale, requiring heavy machinery, large amounts of material and expertise of skilled labour. Developing the process into components that allow more accessible assembly may contribute to community participation in its construction. An accessible assembly would need to be developed to allow the potential for broader groups of people to take part in the architecture's construction. This notion of an accessible assembly proposes the question of how might an architect communicate design intention, as typical architectural drawings may not be easily translated to the general public. Accessible assembly may provide agency to the persons building, in the case of a community the architecture produced would be a physical representation of the values, backgrounds and programmatic needs of the users involved in the emergence of the forms. Labour of people involved in the building is a part of the morphogenetic approach, as their actions and movements influence the process which in turns affects the expression of the architecture.

A Park of Process is envisioned as a park of architectural experimentation, a place to work with materials to develop alternate approaches to building. Using the morphogenetic model through experimentation and process, this project aims to create a variation of space through sensory experience of material properties as a counterpoint to image based architectural design. This approach hopes to provide innovation and benefit to the public by using architecture as a means to blur and blend, combine and join and allow space to constantly be redefining experience. To achieve this, architecture must consider materials and their intrinsic properties in the face of a homogenizing world.

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