The Weave

An Investigation into the Intersection of Craft and 3D-printing

Albin Karlsson
Johanna Jonsson

LUND
UNIVERSITY

Lund University
Faculty of Engineering, LTH
Department of Architecture and Built Environment

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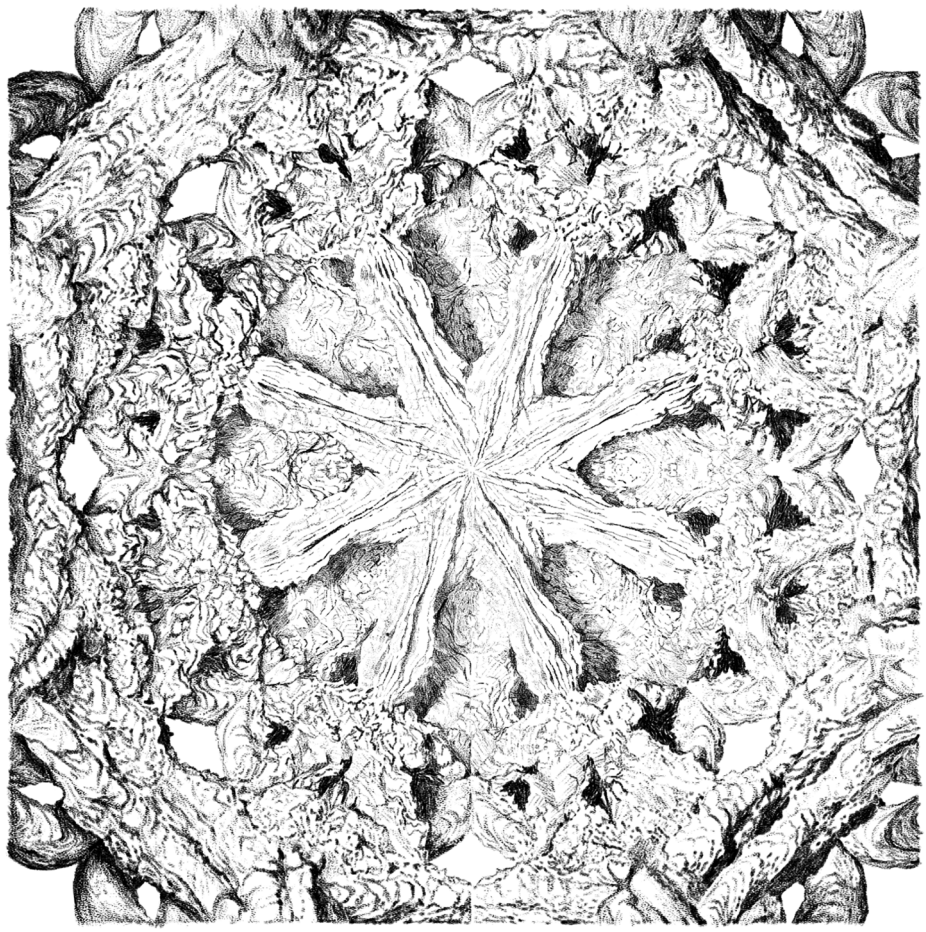
Supervisor:
David Andréen
Examiner:
Per-Johan Dahl



Introduction

This project focuses on the development of a process for the production of a new kind of 3D-printed ceramic brick. The brick has been developed side by side with a metaphysical investigation into the potential to express the living nature of matter through its material and formal attributes. Furthermore, with the use of ”dynamisms” (ways of breaking, copying, scaling, and splitting forms into sub-forms used in Hindu temple architecture as a way to express the continuously unfolding nature of the universe) a process of generating a structure has been developed. Situated in the urban realm, we hope the structure can contribute to the renewed discussion on the liveliness of matter.

The theoretical background to the project is a metaphysical exploration where we are looking into an alternative way of describing the nature of the material world that started with us feeling concerned with the direction the current prevailing view of matter as inert is taking us. This alternative view could imply matter having its own agency, that it is alive in some sense, that mind and matter are deeply intertwined somehow, or that there is a spiritual dimension to it. Perhaps it does not really matter, for the simple reason for this search for an alternative metaphysics is, indifferent of the essential nature of matter, to find a way for humans to reappreciate its liveliness, and through that perhaps change the way we treat our environment.

Going into *The Luminous Ground*, one of the most recent works of the architect and architectural theorist Christopher Alexander, we have looked into how the currently prevailing metaphysical view of matter has come to affect contemporary architecture in several regards, and what is perhaps needed in order to step out of the dogmatic approach to design (and the material world in general) to which it can be argued it has led us. If “living” buildings are to be achieved, Alexander emphasizes the need for the adoption of a new world-view in which the interrelatedness of everything is being recognized and the importance of focusing one’s attention on this at every step of the unfolding process. By merging the digital with the physical, guided by Alexader’s philosophy, we are in this project exploring the potential to convey feelings of relatedness to the world in a structure constructed through the means of ceramic 3D-printing.[1]

1 C. Alexander, *The Luminous Ground*, Berkley, Center for Environmental Structure, 2004 p. 35.

Cosmological Apprehensions

This part of the report will be concerned with the presentation of the theoretical framework relevant to the project. It is divided up into two parts, in the first part we will attempt to frame our concerns regarding the “disenchantment” of the West, and bring up some of its possible inducing factors. In the second part, we will discuss a few alternative metaphysical approaches to the mechanistic world-view, as well as what an alternative view of matter could entail.

The Disenchantment of the West

The human-centered American architect and theorist Christopher Alexander has recognized a problem in contemporary architecture. He argues that our focus on matter as inert has undermined our capacity to create buildings that have "life," and that "Ours is perhaps the period in which architecture has been most barren spiritually, most infected by banality."[1]

Furthermore, being very critical to the mechanistic world-view, he claims that it "[...] has been accompanied by a kind of hopelessness and despair. Who wants to live, who can live, when we believe that we are individually indeed nothing but meaningless machines?"[2] According to Alexander, it is the "[...] ongoing rift between the mechanical-material picture of the world (which we accept as true) and our intuitions about self and spirit (which are intuitively clear but scientifically vague) that has destroyed our architecture."[3]

Architecture is however not always like this. In *The Luminous Ground*, Alexander attempts to describe in what way architecture sometimes touches a difficult to pin-down, inner human essence, giving rise to an experience of the beyond.

> [...] there is a kind of personal thickness - a source, or ground, something almost occult - in which we find that the ultimate questions of architecture and art sometimes touch some connection of incalculable depth between the made work (building, painting, ornament, street) and the inner "I" which each of us experiences. What I call "the I" is that interior element in a work of art, or in a work of nature, which makes one feel related to it. It may occur in a leaf, or in a picture, in a house, in a wave, even in a grain of sand, or in an ornament. It is not ego. It is not me. It is not individual at all, having to do with me, or you. It is humble and enormous: that thing in common which each one of us has in us. It is the spirit which animates each living center.[4]

The "I," Alexander argues, is something vast and impersonal, yet very personal, relating to every person, that we need to look for if we want to make buildings have life. Buildings that have life, according to Alexander, are buildings made by people reaching for the I, and in experiencing these buildings I can thus be felt. Following this line of thought, we may say that a building has life, to the extent that it can connect every one of us to a common ground lying beyond ourselves.[5] It is through the observance of yourself as a part of an infinite universe, existing

1 Ibid. p. 18.
2 Ibid. p. 14.
3 Ibid. p. 18.
4 Ibid. p. 2.
5 Ibid. p. 3-4.

simultaneously inside and outside everyone and everything, that feelings of profound belonging to the world can emerge and the current mechanistic world-view can be challenged. Feelings of "relatedness" to the universe, as he calls them, arises with the connection to an object, or a building expressing I and thus resembles something deep within yourself (your inner I).[6]

Alexander writes that many of the most sublime examples of historical design and architecture has been made within the cultural context of mystical religion, and that at the core of all the works resonating with relatedness there is a common view or assumption: that there exists a ground material of the universe, and that this ground material can somehow be reached. He enhances old religious structures and artifacts as bearers of "relatedness."[7] However, he also claims that a sentimental approach is not the way for creating an architecture that is expressing relatedness today. He instead says that we need to find a new notion of the Divine, a new way of understanding the deep connection between ourselves, each other, and the world, and that somehow our version of the Divine, he writes, must be more in line with the ideas of our contemporary world, and with practices such as physics and biology for us to accept it.[8] This brought us to study different metaphysical views held throughout history, and we will present some of them in this report. But first a quick look into the work of Max Weber, another well-known critic of the mechanistic world-view.

Weber (1864-1920) observed a tendency in his contemporary society which he termed *Entzauberung* - disenchantment. With this word he wanted to point towards an increasing rationalization in society, and a process that he called "intellectualization." In this process, foundational knowledge such as religion, theology, and metaphysics were gradually pushed towards the realm of the superstitious, the mystical, and the irrational. This, according to Weber, leads to a world in which "[...] there are no mysterious incalculable forces that come into play, but rather that one can, in principle master all things by calculation."[9] In his book *The Protestant Ethic and the Spirit of Capitalism*, Weber draws a parable to an "iron cage," where the inescapable unfolding of rationalism has led us to a complete loss of freedom and meaning. What Weber defines as the protestant asceticism has left behind a mechanized petrification of the Western world. In contrast to this, he puts the societies of the various popular religions of Asia where "[...] the world remained a great enchanted garden."[10] As a part of our project, we conducted a study trip to India. This society, quite different from ours in many regards, traditionally has a material notion of the Divine, visible,

6 Ibid. pp. 51-52.

7 Ibid. pp. 31-35.

8 Ibid. pp. 42-44.

9 M. Weber, *The Sociology of Religion*, London, Methuen & Co, 1965, p. 139.

10 M. Weber, *The Protestant Ehic*, London, Routledge, 1922, p. 270.

for example, in Hindu temple architecture, as explained later.

In the book *Det omätbaras renässans* (which translates to "the renaissance of the immeasurable"), the Swedish philosopher Jonna Bornemark discusses the concept of *mätbarhetssamhället* ("the society of measurability"). She criticizes our strong belief in rationalization and measuring as tools for reaching knowledge in most areas of our society. The emphasis of measurement is for us clearly visible in the production of architecture. And we can relate this to what Alexander is writing about buildings lacking life. In order to analyze and find potential alternative approaches for the production of knowledge to the obsessive measuring in our contemporary society, and to find the historical factors that have lead up to it, Bornemark uses three Renaissance philosophers: Nicholas Cusanus, Giordano Bruno, and René Descartes.

Nicholas Cusanus (1401-1464) was one of the first Renaissance philosophers and is generally referred to as the first modern thinker because of his emphasis on the human and her capability of obtaining knowledge. Cusanus was active on the verge between the medieval and the Renaissance era. This put him in the crease between the monastic[11] mystical God, and the scholastic[12], logical framing of the same, in-between logic and mysticism - that he combined in his philosophy. He was also profoundly influenced by the mystical tradition of negative theology, first formulated by Dionysius the Areopagite in the 6th century, and later developed by Meister Eckhart during the 13th and 14th centuries. Negative theology refers to the incapability of language to describe, and for the mind to wholly grasp, an infinite God.[13]

Cusanus theories concerning knowing and the limits thereof are expressed in his work *De Docta Ignorantica* (*On Learned Ignorance*). Central in Bornemark's reading of Cusanus is the notion of the incomprehensible. From this, she draws a line to our present day as she argues that the incomprehensible has been replaced with the not-yet-known. The advocates of the not-yet-known are positivism, reductionism, and scientism, arguing for the idea that everything can be known and measured by meticulous scientific investigations. Cusanus illustrates the incomprehensible as what lies beyond the horizon of the known, in the realm of the Divine. The Divine exists not only in the unlimited but also in the smallest unique aspects of the world. Thus, in Cusanus' concept of God, the largest and the smallest coincide in infinite Divinity-This realms exceeds the conceptual reach of man - as illustrated in the figure to the right In Book I, Chapter III, entitled "Precise Truth is Incomprehensible" in *In Learned Ignorance*, Cusanus writes:

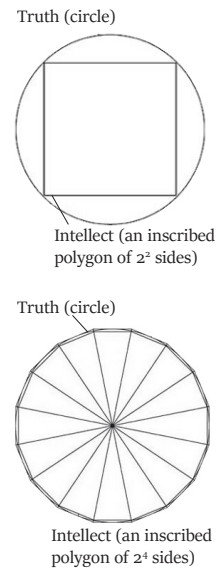
11 Christian monasticism refers to the medieval monkhood, the devotional practice of individuals dedicated to Christian worship, leading ascetic and cloistered lives cultivating mystical traditions. Skeptical towards an over-reliance on reason, Christian monasticists argued for a more affective approach to God.

12 Scholasticism is a method of teaching and learning employed in various disciplines at medieval universities from the 12th to the 17th century. Sholastic thinkers, in very general terms, treasured rigorous argumentation and trusted logic to uncover, through discussion and analysis, philosophical truth.

13 J. Bornemark, *De omätbaras Renässans*, Stockholm, Volante, 2018, pp. 145-157.

"The intellect is to truth as [an inscribed] polygon is to [the inscribing] circle. The more angles the polygon has, the more similar it is to the circle. However, even if the number of its angles are increased to infinitum, the polygon never becomes equal to the circle."[14]

Cusanus developed his theories regarding the human capacities for the production of knowledge around two concepts: "ratio" and "intellectus." Ratio is our capability of thinking using concepts and judgments. It abstracts, generalizes, ties together, separates, and puts in relation. Ratio's attraction to measuring and organizing helps in the development of language and categories. The Divine is however not encompassed by the operations of ratio.[15] Intellectus, on the other hand, is a direct intellectual vision. It is in immediate contact with the sensory impressions. Intellectus is our capacity for reason, imagination, and sensation, and is capable of perceiving the situational in every situation. It is within intellectus the notion central to our project, the metaphysical constitution of the world, can be recognized.[16] Cusanus does not draw a sharp line between the realm of the comprehensible and the incomprehensible. What lies beyond the horizon of the known is the ground of new explorations. Intellectus has, with its sensibility, the possibility to touch upon the realm beyond the horizon. This makes intellectus an essential tool for existential matters and the connection with the Divine.[17]



(Wertz, 2001)

Bornemark criticizes our contemporary society for equalizing ratio with reason. She argues that we have lost intellectus and the notion of the incomprehensible.[18] She looks for the cause of this loss in the Cartesian philosophy. Cartesianism is the development of René Descartes school of thought, and according to Bornemark, a more extreme version of his philosophy. Alexander and Weber also point to the scientific revolution, initiated by the philosophy of Descartes, as one of the leading factors behind the prevalence of the mechanistic world-view.

René Descartes (1596-1650) marks, in some ways, the start of the modern era. His philosophy is mostly known for its inherent dualism and methodological skepticism.[19] Descartes' dualism derives from the separation that he made between "res extensa" (the extended substance) and "res cogitans" (the thinking substance). The external world is that which can be measured and known; it is the mechanic world of machines. Moreover, the inner world, according to Descartes is the world of the soul. The inner world is where the consciousness operates, and also where the correspondence with God occurs.[20]

Later in Descartes life, the strict border between the inner and the outer world

14 N. Cusanus. *De Docta Ignorantica,* Minneapolis, A.J. Benning Press, 1985, p. 8.

15 J. Bornemark, pp. 37-39, 41.

16 Ibid. pp. 42-45.

17 Ibid. pp. 44-45.

18 Ibid. p. 52.

19 Ibid. pp. 23-24.

20 Ibid. pp. 22-23.

softened a bit. In The Passions of the Soul, he elaborated further on the relation between res extensa and res cogitans. In the revised philosophy presented in this book, the passions come to the soul from the exterior, res extensa, and is central to our notion of a self and the pleasures of life. The passions tie together the body and the soul through the senses, but it is still essential for the passions to subordinate to reason - the dualism is still present but somewhat obscured. This part of his philosophy, however, was neglected by the Cartesian heritage that has affected our contemporary society to a large extent.[21] Descartes was a very religious man and did not see his ideas as something that could endanger the Divine order. Criticism contemporary with Descartes, however, pointed towards the atheistic potential of his ideas, a critique that perhaps later showed to be legitimate. In Cartesianism today, only res extensa remains. The soul, res cogitans, has been neglected since it cannot be found as an object in any scientific study of the body.[22]

Reading Bornemark, it is clear that the disenchantment expresses itself in multiple ways across our contemporary Western society, and we believe that the overemphasis on ratio also has a profound impact on the production of architecture. The over-representation of ratio-based affairs such as economy, standardization, and regulations leave no room for the softer, intellectus-leaning goings-on that should be ever-present in a practice as human-centered as architecture.

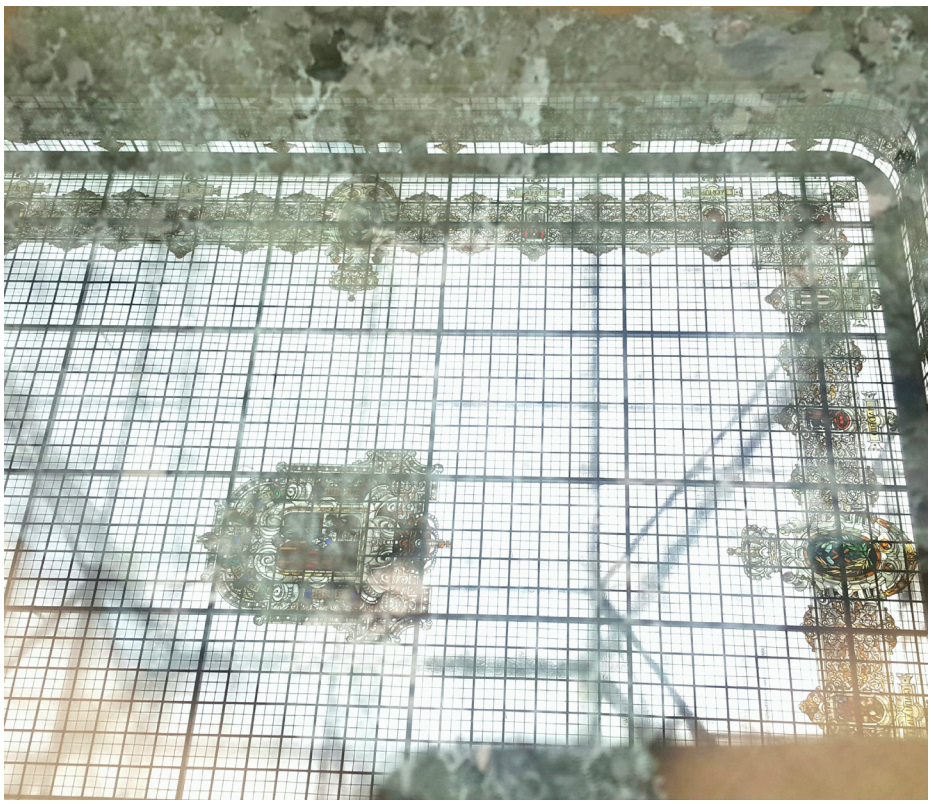
One interesting example of the rationalization within the realm of construction can be found in Manuel DeLandas essay 'Uniformity and Variability'. In this essay, DeLanda explains how, during the last few hundred years, many materials have undergone an intense process of uniformation and homogenization. With the aspiration to make structural behavior of matter simpler and easier to predict, DeLanda points out that we have reached a state where "Many professionals who design load-bearing structures lost their ability to design with materials that are not isotropic, that is, that do not have identical properties in all directions."[23] Contemplating the loss of knowledge, or even ignorance towards the dynamic properties of different types of materials, DeLanda goes on to write that "[...] we may need to nurture again our ability to deal with variation as a creative force, and to think of structures that incorporate heterogeneous elements as a challenge to be met by innovative design."[24] We will now present some alternative metaphysical views that we think could act as a help in the adoption of a renewed approach to architectural production where intellectus practices are revaluated.

21 Ibid. pp. 77-82.

22 'Descartes och den gamla världens död', Människan och maskinen, [podcast], Sveriges Radio P1, 2017

23 M. DeLanda, 'Uniformity and Variability', p. 7.

24 Ibid. p. 7.



An Alternative Cosmology

A problem with the prevailing dualism and the mechanistic view of matter to which it has lead, is, as we have previously explained, that it leaves us with a disunified picture of the world, and the profound difficulty of grasping the relationship between mind and body (known as the mind-body problem), and the existence of consciousness. Furthermore, we believe that the dualism has disconnected us from our environment, making us believe that we are somehow separate from it. And this, we think, is partly what enables us to treat our environment in the irresponsible way we are today.[25]

The philosophical view known as panpsychism, which maintains that mind is fundamental and ubiquitous in the natural world, offers another answer to the question concerning the nature of consciousness and the mind-body problem. In contemporary panpsychism, mentality, most commonly in

25 P. Goff, W. Seager, and S. Allen-Hermanson, 'Panpsychism', https://plato.stanford.edu/entries/panpsychism, 2017, (Accessed 29 April 2019).

26 Ibid.

the form of conscious experience, exists within the fundamental parts of all material objects. Standardly, the panpsychist holds the view that experience is of varying complexity depending on what is experiencing, with humans having incredibly rich and complex experiences, cats, for example, having less so, and the complexity of experience continuing down, in a diminishing fashion, through plants, and through to the basic constituents of reality. Humans, however, do not hold the position of having the most complex consciousness possible. When many humans (and other entities) come together, another, higher consciousness emerges, in the same way that many panpsychist believe consciousness in the human brain to be made up by the consciousness of its smallest parts. Following the hierarchy of complexity in experience upwards, one arrives eventually at consciousness at the level of cosmos.[26]

The roots of panpsychism go far back in history, with two of the pre-socratic philosophers, Thales and Heraclitus, sometimes claimed to be early proponents. Giordano Bruno, one of the Renaissance philosophers Bornemark brings up in her analysis of the society of measurability, is also said to be an advocate of panpsychic views. Bruno developed his theory of matter as a creative, active, and infinite extension of the universe, and argued for a self-forming and living substance that weaves everything together - a substance consisting of both the living and the material. Furthermore, Bruno's self-forming substance can turn towards, and reflect upon itself, and therein lies the birth of intelligence and self-awareness. According to Bruno, all matter thence carry the potential of intelligence, and all intelligence is simultaneously made out of physical matter. Bruno refers to this substance as God, which is characterized by a constant becoming - an eternal, Divine movement.[27]

The second philosopher we have looked into concerning an alternative world-view is the Baroque philosopher and mathematician Gottfried Leibniz. Just as Bruno, he too can be said to be a panpsychist, and his metaphysics has been greatly influential for the evolution of the panpsychic school of thought in the West. Leibniz' panpsychism is centered around his science of "monads," the fundamental, incorporeal building blocks of all of matter. According to him, a monad is a point-like constituent of reality with mainly two attributes: "perception," the capability of perceiving the world around them, and "appetite," a kind of seeking or desiring to reflect the universe. Thus Leibniz, for whom the distinguishing mark of mentality is perception, holds that in all things there are simple, immaterial, mind-like substances that should be thought upon as souls.[28]

27 J. Bornemark, pp. 21-23, 47. 50.

28 J. Jorati, 'Gottfried Leibniz: Philosophy of Mind', https://www.iep.utm.edu/lei-mind/#SH1b, (Accessed 29 april); D. Skrbina, 'Panpsychism', https://www.iep.utm.edu/panpsych/, (Accessed 29 April 2019)

29 G. Leibniz. R. Ariew and D. Garber, eds. *Philosophical Essays*, Indianapolis, Hackett, 1989, p. 139.

30 G. Deuleuze, *The Fold - Leibniz and the Baroque*, London, Continuum, 2006, p. 3.

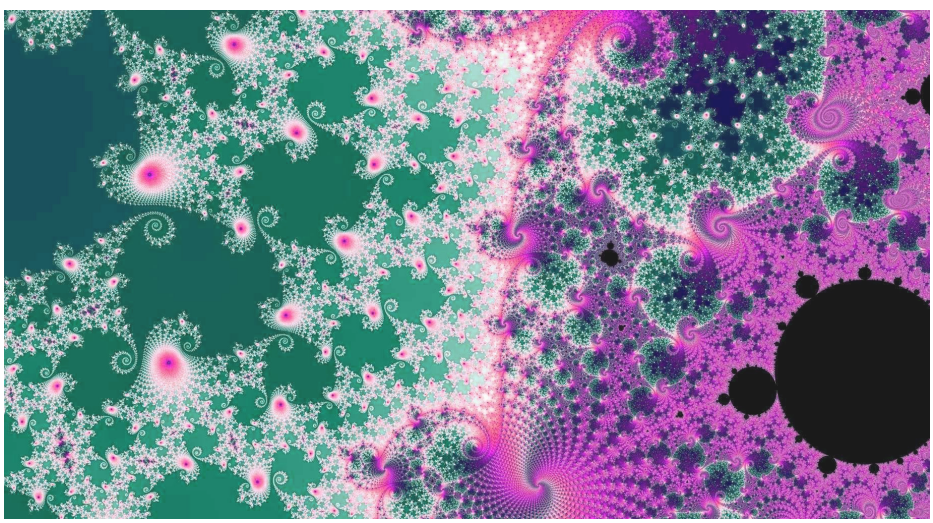
31 Ibid. p. 6.

32 Ibid. p. 3.

> I found that [the monad's] nature consists in force, and that from this there follows something analogous to sensation [that is, perception] and appetite, so that we must conceive of them on the model of the notion we have of souls. [29]

In the book *The Fold: Leibniz and the Baroque*, Gilles Deleuze builds on from the Baroque metaphysics of Leibniz. On the first page of said book, Deleuze writes that "The Baroque refers not to an essence but rather to an operative function, to a trait. It endlessly produces folds."[30] From there he draws a metaphysical picture where different manners of folds that make up different kinds of textures, produced and determined by the forces of their surroundings.[31] The curvatures are differentiated into two parts: the "folds of the soul," and the "pleats of matter." These are intertwined, producing a texture that unfurls to infinity, making matter endlessly folded.[32] In the following quote, Deleuze describes the endlessly unfolding processes inherent to the material world:

> Dividing endlessly, the parts of matter form little vortices in a maelstrom, and in these are found even more vortices, even smaller, and even more are spinning in the concave intervals of the whirls that touch one another. Matter thus offers an infinitely porous, spongy, or cavernous texture without emptiness, caverns endlessly contained in other caverns: no matter how small, each body contains a world pierced with irregular passages, surrounded and penetrated by an increasingly vaporous fluid, the totality of the universe resembling a pond of matter in which there exist different flows and waves.[33]



(Unknown, n.d.)

33 Ibid. p. 5.

34 J. Bennett, *Vibrant Matter - A Political Ecology of Things*, London, Duke University Press, Durham and London , 2010, p. 4-5.

35 Ibid. p. XIII.

36 Ibid. p. 120.

37 Vitalism is a school of thought that attempts to explain the nature of life as resulting from a vital force. To a vitalist, living organisms are fundamentally different from non-living things because they contain some kind of non-physical, life-giving element.

38 Materialism, also known as physicalism, in philosophy holds that all things are fundamentally possible to reduce to, made, or constituted solely by physical processes or matter

39 J. Bennett, p. 93.

As we are reading this, an image of the fractal known as the Mandelbrot set comes to mind. It appears almost as if the Mandelbrot set is a mathematical expression and visual representation of the continuously expanding processes of matter that Deleuze is describing. Deleuze argues for a world fractal in its disposition and underlines with this quote from *The Fold*, the power that fractal geometry has to depict and represent the self-forming, emergent properties of matter.

Not a panpsychist, but nonetheless interesting when it comes to an alternative approach to matter and the implications this alternative approach might have on a societal level, the political theorist and philosopher Jane Bennett tries to, in her book Vibrant Matter, visualize a world where human beings and thinghood overlap. She does this by telling stories about seemingly inert things that, at a closer look, is quite lively, pointing to the agency of nonhumans and emphasizing them as vital players in the course of things.[34] To Bennett, matter has the ability to make things happen; to produce effects. We can relate our previous theoretical investigations concerning panpsychism to the notion of vibrant matter in Bennett's work. However, Bennett is skeptical of the idea of matter being conscious, or able to perceive things, in fact, she would probably criticize panpsychism for it being susceptible to anthropomorphizing tendencies.[35] Nevertheless, towards the end of Vibrant Matter, Bennett indicates that some anthropomorphizing could be worth it to potentially achieve positive political effects concerning our environment.

> If a green materialism requires of us a more refined sensitivity to the outside-that-is-inside-too, then maybe a bit of anthropomorphizing will prove valuable. Maybe it is worth running the risks associated with anthropomorphizing (superstition, the divinization of nature, romanticism) because it, oddly enough, works against anthropocentrism: a chord is struck between person and thing, and I am no longer above or outside a nonhuman environment.[36]

Bennet formulates her own "vital materialism," building on from the work of Bergson and Dreisch, placing herself in-between vitalism[37] and materialism[38].[39] Bennett articulates that vital materialism, compared to other views, holds a greater power for us to connect and understand our own relation to nonhuman actants. She argues that understanding our bodies as complex systems made up of a multitude of different actants, such as gut bacteria, closely intertwined with our "own" bodies, helps us recognize the kinship between humans and

40 Ibid. p. 112.
41 Ibid. p. 8.

nonhumans.[40] Bennett continues, and we agree, that a vital materialist approach could help us reconnect to the actants surrounding and supporting us, and thus aid in the process of reconnecting to the world.

At the beginning of the book, she asks a guiding question: "How would political responses to public problems change were we to take seriously the vitality of (nonhuman) bodies?"[41] This is for us one of the most interesting parts of Bennett's work – the combination of a metaphysical exploration with a political endeavor. We will use some of her questions to analyze and reflect upon our structure and what it means for it to be situated in the urban realm, in the reflection part of this report.

Through establishing and making real the actual inter-relationship between all types of matter, which includes us humans and our surrounding nonhumans, we hope to possibly change the way we look upon that exchange and through that establish a more constructive relationship with nature and the world. To recognize the liveliness of matter and understand the importance of its wellbeing, to us is a crucial part of working towards a possible future. If we were to seriously understand our deep dependency to all surrounding matter we would probably treat it differently. Both Bennet's vital materialism, as well as the metaphysical views ascribed to panpsychism, if those were adopted by a major part of our society, we believe could succeed in that matter.

Hindu Cosmology and Architecture

As a part of our research, we went to India to conduct a field study on the subject of Hindu temple architecture. Hindu temple architecture formally represents certain core concepts of Hindu cosmology. This section is divided up into three parts, the first part will touch upon Hindu cosmology relevant to our investigation concerning an alternative world-view, with the presentation of some concepts relating to the philosophical notions articulated in the previous part of the report. The second part will illustrate the different ways that these cosmological concepts are represented in Hindu temple architecture. And the third part is a case study, presenting a more in-depth description of a few temples in the city of Ahmedabad.

Wholeness Unfolding

Hinduism is sometimes described as the world's oldest religion. But it is, rather than one coherent religion, a synthesis of various cultures and traditions with very diverse roots, and is colored by a radical multiplicity. These traditions were termed Hinduism by British colonials and were later adopted by the Indian society. Its broad range of philosophies, no matter how different in their way of approaching spiritual realization, share some common cosmological concepts. One of them is the Divine presence in the physical world inherent to the notion of Brahman, the undivided whole.[1]

One of the ways the multiplicity in Hinduism is expressed is through its radical polytheism. In India, the rich variety of Hindu deities is visible everywhere. Each God is elaborately praised in their own individual hymns, and as the creator and sustainer of all. The ostensibly kaleidoscopic picture drawn by this pluralism, should, however, not be seen as a representation of a fragmentized cosmology. The German indologist Betty Heiman uses the image of a crystal to describe the multiplex whole common to Hindu cosmology, through which diversity is acting as a uniting factor, rather than a dividing one.[2]

> Whatever Man sees, has seen or will see, is just one facet only of a crystal. Each of these facets from its due angle provides a correct viewpoint, but none of them alone gives an accurate all-comprehensive picture. Each serves in its proper place to grasp the Whole, and all of them combined come nearer to its full grasp. However, even the sum of them all does not exhaust all hidden possibilities of approach.[3]

The notion of "Wholeness" is in Hinduism is represented by Brahman, the unified and unbroken whole, or the world soul. According to Hindu philosophy, Brahman is expressed in various ways through every manifestation of life - in nature, people, birth, growth, and death. Thus every fragment of the universe is believed to, in itself, carry Wholeness and contain all of the information of the whole.[4] In the well-known mantra from *Isha Upanishad* this notion is expressed as follows:

> Om
> That is whole
> This is whole

1 D. Eck, *Darsan: Seeing the Divine Image in India,* New York, Columbia University Pres s, 1995, p. 24.

2 Ibid. p. 25.

3 B. Heiman, *Facets of Indian Thought*, London, George Allen & Unwin, 1964, cited in D. Eck, *Darsan: Seeing the Divine Image in India,* New York, Columbia University Press, 1995, p. 25.

4 D. Eck, p. 10.

From Wholeness emerges Wholeness
Wholeness subtracted from Wholeness
Wholeness still remains[5]

Everything that exists in the world is exuberant transformations of the One Brahman. As everything is indeed believed to exist in everything, a quite fractal notion, the idea of the Divine as something invisible or intangible would be a foreign notion for a lot of Hindus.[6]

The connection between the inner, true nature of everything, and the world soul, is bound up with the notion of an all-containing unity (known as the cosmic egg) as the source of creation.[7] The coming into being is understood as taking place through the sequential emergence, or successive bursting forth, from one form to another, everything inseparable from everything else.

5 Isha Upanishad, invocation

6 D. Eck, p. 10.

7 A. Hardy, *The Temple Architecture of India*, Hoboken, Wiley, 2017, p. 46.

8 Ibid. p. 17.

Cosmological Representations

In India, there are mainly two types of traditional Hindu temples: the northern *Nagara*, and the southern *Dravidra* modes which started to distinguish themselves in the sixth and the seventh century. During our study trip to India, we investigated temples of varying sizes belonging to the *Nagara* (literally meaning "of the city") language. Certain procedures of production called dynamisms rule both temple traditions (except some *Dravidra* temples in the district Tamil Nadu, and some Nagara ones in Orissa), explained later in this section, that we found interesting in relation to our field of study.[7]

The ever-unfolding nature of the universe in Hindu cosmology and the notion of Brahman described in the previous section is reflected in various ways in Hindu temple architecture. According to ancient architectural traditions, Hindu temples are models of the cosmos, and their structure represents fundamental concepts of the nature of the universe. Brahman is represented symbolically in Hindu temple architecture through self-similarity, discretization, and fractalization. Through these processes, the idea that everything exists within everything, and that the whole cosmic principle repeats itself again and again in ever smaller scales, can emerge formally.[8]

In the ancient *Vastu Shastra* (which translates to "science of architecture") one finds texts describing principles regarding the design, layout, dimensions, ground preparation, and space arrangement of Hindu temples. By following the instructions given in the *Vastu Shastra*, the traditional Hindu temple can be created through rules determining its proportion and growth. All of the temple's elements are dependent on the whole as the *Vastu Shastra* does not rely on absolute dimensions, but defines all dimensions as a set of relationships of components with respect to the whole. The existence of such a general system of proportional relationships enables the same procedures to be repeated at various scales and is a potential of bringing forth self-similar properties in the architecture.[9]

The self-similar and fractal geometry of the temples is found through the application of certain processes called "dynamisms" by the architect and architecture historian Adam Hardy in his book *The Temple Architecture of India*. These dynamisms are methods of breaking, copying, scaling and splitting forms into subforms, and together they determine their characteristic visual features. The dynamisms common to the *Nagara* temples that we studied are

7 Ibid. p. 14.

8 K. Trivedi, 'Hindu Temple: Models of a Fractal Universe', Visual Computer, vol. 5, no. 4, 1989, p. 243.

9 Ibid. p. 247.

called: projection, staggering, splitting, bursting of boundaries, progressive multiplication, and expanding repetition.[10]

Projection arises simply with the emanation of a form sideways, diagonally, or backward relative to the observer inside or outside the temple or shrine. **Staggering** is recognized as a progressive stepping out or expansion in space as the form is recursively multiplied and moved in a particular direction. **Splitting** is when two aligned halves of something familiar as a whole is split and separated apart from each other. Sometimes an uncut version of the split piece emanates between the divided parts in a manner of projection, as if emerging from the void. **Bursting of boundaries** is at play where a projected form overlaps the confines of its frame, and a greater sense of expansion thus accompanies its emergence. **Progressive multiplication** is a proliferation of the whole and is present where elements are found arranged in a sequence of rows, starting with one and progressively increase in number. In **expanding repetition**, growth is expressed as elements similar to one another get progressively bigger next to each other. Compared to the staggering dynamism, however, expanding repetition grows in an upward outward manner, compared to along an imagined horizontal line.[11]

The dynamisms not only enable aspects of self-similarity to emerge in the architecture to symbolically represent the notion common to Hindu cosmology: that everything exists within everything. They are also, because of their dynamic character, ways of expressing the related notion of an ever unfolding universe. Concerning this aspect of Hindu temples, Hardy writes the following in his book:

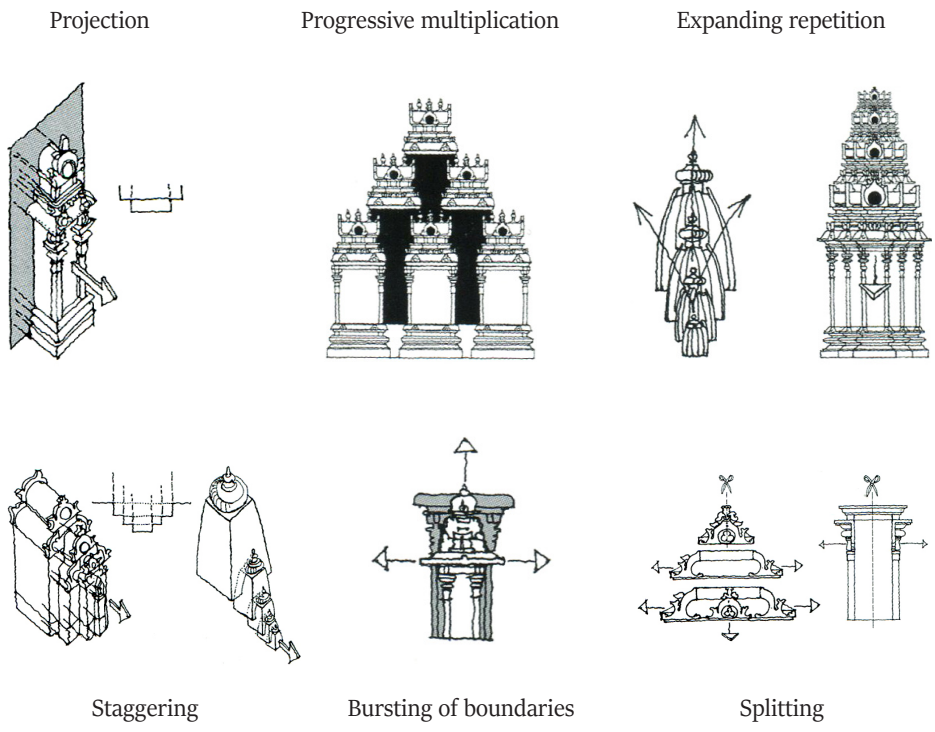
> Most inspiring and mysterious about [the temple] geometry was the way it starts from a point and unfolds towards infinity, one figure giving birth to another. Relationships between geometry and the emergent forms of Indian temples must be considered not merely in terms of static shapes, but as processes. In the act of orienting and then setting out a temple, geometry unfolded before people's eyes, showing them that a universe of emanation is how things really are.[12]

Through the various dynamisms, different forms emerge and particular architectural elements arise. One example is the many aedicular elements found at very precise locations, most often on the exterior of each temple. "Aedicule" is a term which applies to both miniature shrines and the representation of a shrine in architectural ornament. However, these small models of larger buildings are not just ornaments; they are the very unit of which Hindu temples are composed, and they are of great importance as more often than not, each

10 A. Hardy, p. 37.
11 Ibid. pp. 37-43.
12 Ibid. pp. 136-137.

aedicule is devoted to a particular God belonging to the entourage (or one of the different manifestations) of the main deity for which the specific temple is dedicated.[13]

Just as the exterior of each temple is made of images of buildings, the ceilings of the various bays found in the *mandapas* (the audience hall of the inner sanctum) and their adjoining porches, are made of images of ceilings. They unfurl through expanding repetition and/or progressive multiplication. Proliferating ceiling patterns are termed *nabhi-chchanda*, *nabhi* meaning navel from the Sanskrit root "nabh," to expand. The ceilings, often simple in principle, creates a profound sense of complexity as they evolve and grow through the dynamisms, sprouting "new" forms while manipulating "previous" ones.[14]



(Hardy, 2007)

13 Ibid. p. 10.
14 Ibid. p. 156.

Hindu Temples in the Urban Fabric

In the book *Space - Body - Ritual: Performativity in the City*, Reena Tiwari writes about bodily experiences in relation to the spirit and space, and about the importance of the ritual in spiritual practice. Using Henri Lefebvre's theory describing how physical space and imagined space come together to create lived space, explained in his work *The Production of Space*, she analyses various ritual acts and ceremonies and their relation to space and body in the city of Varanasi, India[15]. A lived experience, she argues, is constructed when the body connects to the mind in the physical environment and lived experience is necessary in order to transcend through liminality to a spiritual state. The liminal state is the phase of ambiguity or disorientation that occurs in the intermediate stages of a rite when the initial state no longer remains, and the approaching post ritual mood has not yet been reached. She emphasizes the importance of material space as an actor in the spiritual experience[16]. The physical space carries memories and connotations that triggers the events of the imagined space, and together they create the lived experience. The lived space could furthermore be of a spiritual nature if the experienced signifiers associate with actors of that kind.

The body is an essential tool in Hindu rituals with chanting, gesticulating, the clapping of hands, and the circling of artifacts all being some of the everyday ritual activities. Tiwari emphasizes the importance that the emotions and sensations are properly channelized in the rituals for the body to move from one state to another, and to become one with Brahman[17]. During our study trip to India, we witnessed several rituals, and while observing them, we noticed their incredible sensuousness. The burning of incense, the decoration with flowers, the application of *bindis*, the tasting of food offerings, the touching of deities and temples, the pouring of water, and so on, are all triggering the senses in various ways. The materiality of the world is highly relevant in this context and ways of using matter for worshiping unfolds in an incredible number of ways.

We conducted our studies in the Old Town of Ahmedabad, where we wanted to investigate the role of Hindu temples in the urban fabric - how they are used and how they affect their closest surroundings. Temples of various sizes are included in the study, and we formulated four categories depending on their size: tiny (maximum $1m^2$), small (maximum $10m^2$), medium (maximum $50m^2$), and large (minimum $50m^2$). We found the size of the temples to determine quite a lot concerning their usage. Factors that seemed to be affected by this was, for

15 R. Tiwari, *Space - Body - Ritual: Performativity in the City*, Lanham, Lexington Books, 2010, pp. 3- 5.

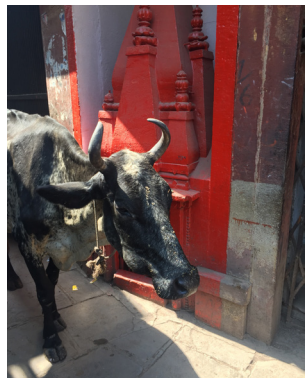
16 Ibid. p. 17.

17 Ibid. p. 95.

example, the notion of privacy, the time spent at the temple, and the number of participants in each ritual. On the coming few pages, we shall describe the six temples a bit closer.





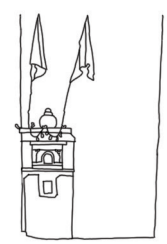







The Tiny Green Temple

This tiny temple is situated on Swaminarayan Road, a quite busy street connecting Relief Road, which is the most prominent road in Old Town, to the sizeable Swaminarayan temple. Rather than withdrawing in a pocket, the tiny temple pops out straight into the approximately seven-meter wide road. The protrusion is painted green, and the small shrine is situated on its left corner. The tiny shrine is about 50 centimeters tall and 50 centimeters wide and is elevated about a meter from the ground. On each of the protrusion's sides pockets are created. The left pocket is primarily used for feeding the dogs that hang around the shrine all day, and sometimes a begging woman is also sitting there. The right pocket is often used as a parking space for the visitors' vehicles. The central placing of the shrine makes it very accessible, people stop their bikes and scooters on their way to somewhere, and some even perform a prayer on their bike as they are going by, putting their hands together and nodding towards the shrine. The ones who stop, however, take their shoes off, steps in front, bows with their hands in *anjali mudra* (prayer hands), touches various places of the shrine and sometimes leaves an offering. The time spent by this temple is generally quite short, rarely more than a minute, and mostly around 30 seconds. Sometimes, however, it is just a two-seconds glimpse in the passing by. A caretaker is hanging around, cleaning the shrine, performing the waking ritual, decorating the temple with flowers, and lighting incense.



The Small Temple with the Tree

In a little pocket on the busy Jayanti Dalal Road sits this small temple. The Jayanti Dalal Road connects Gandhi Road with Relief Road. From the afternoon till night the road is a bustling market street where sarees and fabric are being sold. At that time the temple is barely noticeable behind all of the items on display. Different though is it in the morning time, when the only ones on the street are the dogs looking for leftovers from the night before, and the group of elderly women performing the waking ritual, with bells, incense, and song for the Gods in the temple. The small temple sits in a pocket on the road about eight meters deep and four meters wide. On the north side of the temple, there is a stone step running as a bench along the edge of the buildings. During the mornings, this step acts as the seating for the women spectating and participating in the ritual, and in the evenings this is part of the shop's extension out on the street. On the shrine's south side there is a path leading to a pol[18]. The path is narrow and articulated through a small step down from the pocket, distinguishing the mini *chowk* (square) in front of the temple. The temple is about one and a half meters wide and deep, and about two meters tall. The holiest sanctum is marked with a *shekhari* roof structure, with one cupola on each side of it. The temple's backside is built along a tree trunk, merging the two.

The focus of the temple shifts tremendously during the day. During the morning it is the street's main attraction, as the group of women performs the morning ritual. People passing by often stop to pray and ring the bell hanging by the side of it, sometimes taking their shoes off as they do so. During the afternoon a radical transformation of the space is happening. As the shops open, the street becomes narrower, the intensity of the traffic is increasing, and the temple is not the main focus anymore. The group of women is replaced by the male shop owners and their potential customers. This excited state continues until late evening when the shops close down one by one. The street is now dirty and the city rest till early morning, when the cleaning of the road and the waking ritual starts again.

18 A Pol is a, sometimes enclosed, residential housing cluster common to the city of Ahmedabad, where different families belonging to a particular group is living.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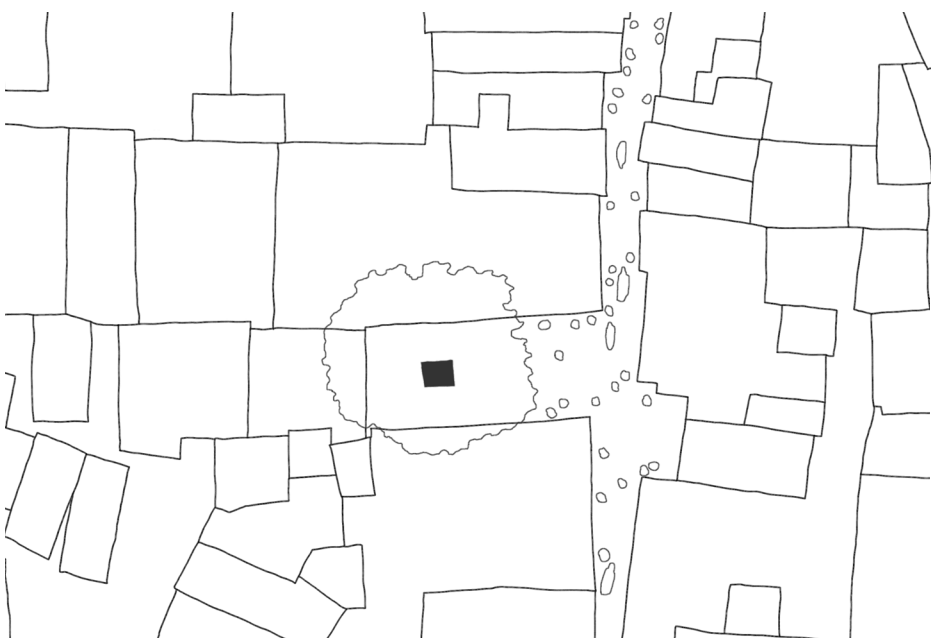
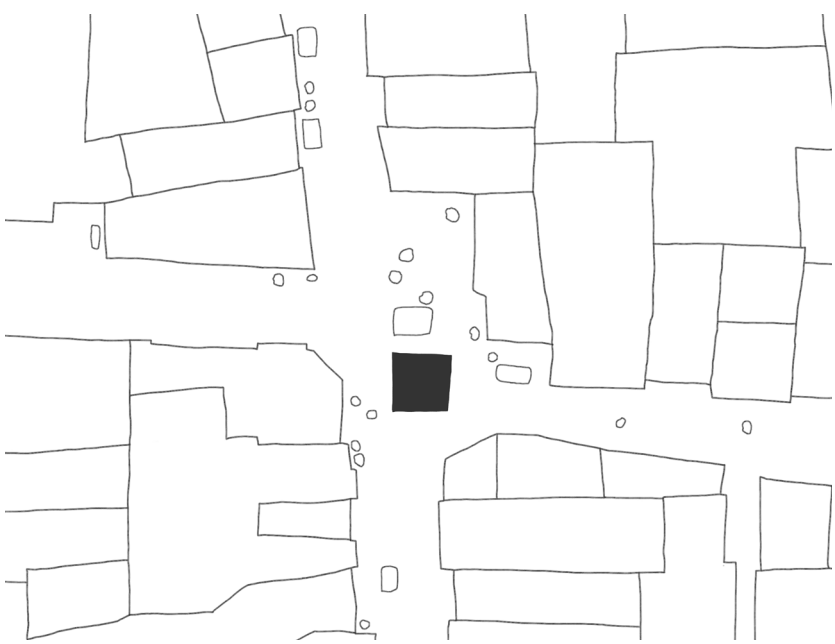
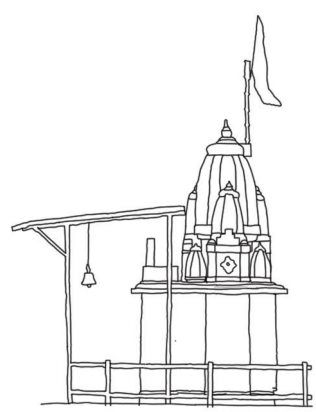


The Small Temple in the Crossing

In the middle of an intersection on Swaminarayan Road sits this small temple, about two times two meters big in plan with one big *shekhari* spire covering the deity. The traditional structure has two additional parts. The first is the canopy in front of the shrine, giving protection from sun and the rain, and the second is the bird feeder behind it, providing food for potential hungry animals. The bird feeder is a small but ornate structure upon a column, where seeds and grains are placed every day. The temple in the small crossing is visible from afar, which enables fast praying on the move. Most visitors stop, however, and takes their shoes off, rings the bell hanging from the canopy and steps in front of the main deity. Offerings, bowing and touching of different parts of the temple occur in the individual *puja* (ritual). On the idol's right side, just outside the sanctum, sits the caretaker: a man dressed in orange, the sacred color of Hinduism. He is the one who performs the waking ritual, keeps the space clean, and decorates the interior with flowers every morning. It is a very public and popular temple, and its peculiar placing in the middle of a crossing creates a calm area around it where one can sit for a while and perhaps drink some chai.





The Small Temple with the Benches

On the street next to a pol entrance, in a pocket on the road which hosts space for several religious activities, sits this particular temple. Sharing the space with the temple is a big tree that also is being worshiped, and religious activities such as the water pouring ritual in honor of the sun God is being performed in the morning light.

The temple is about four times three meters large in plan, and one big *shekhari* with a cupola in front constitutes the roof structure. This temple is also extended with a canopy, just as the previous small shrine, and under it, three stone benches are facing each other and the temple. This temple has both a *mandapa* and a *garba-griha* making it larger than the other small temples we have looked at. The mandapa is about half the size of the *garba-griha* and hosts different deities. The size of the temple allows one to enter the temple, but the shoes are removed before entering beneath the canopy outside of the built structure. The benches allow people to stay for a longer time, to sit for a while, and to perhaps watch as others perform their acts of worship. Some sit inside the temple, on the side of the sanctum, maybe a caretaker or two. Two bells hang from the ceiling of the temple, and loudspeakers play various mantras. Two holy men dressed in orange visited the temple while we were observing it, and were greeted with respect by the other visitors. The religious activities are present here for a substantial time of the day, it is the main activity of this pocket, and it manages to sustain through the spatial transformation of the city throughout the day.

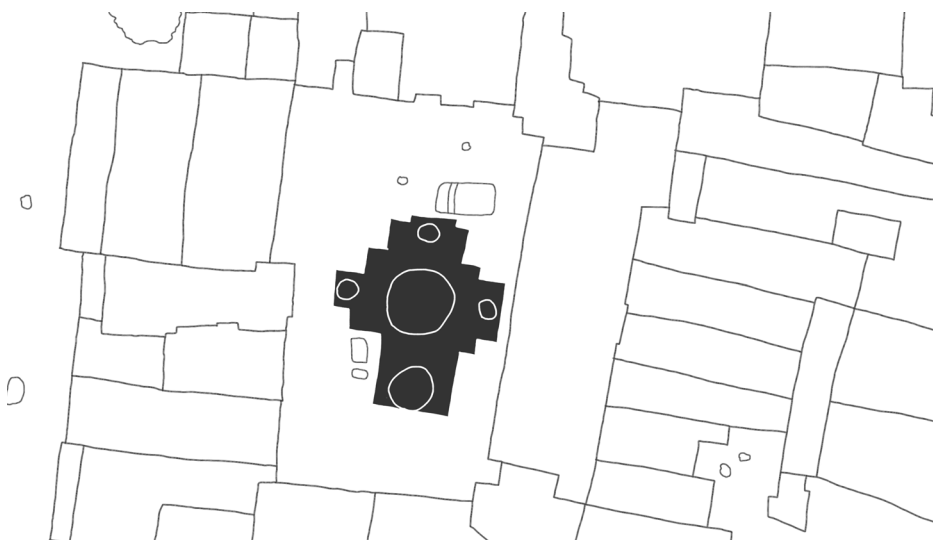
The Medium Pol Temple

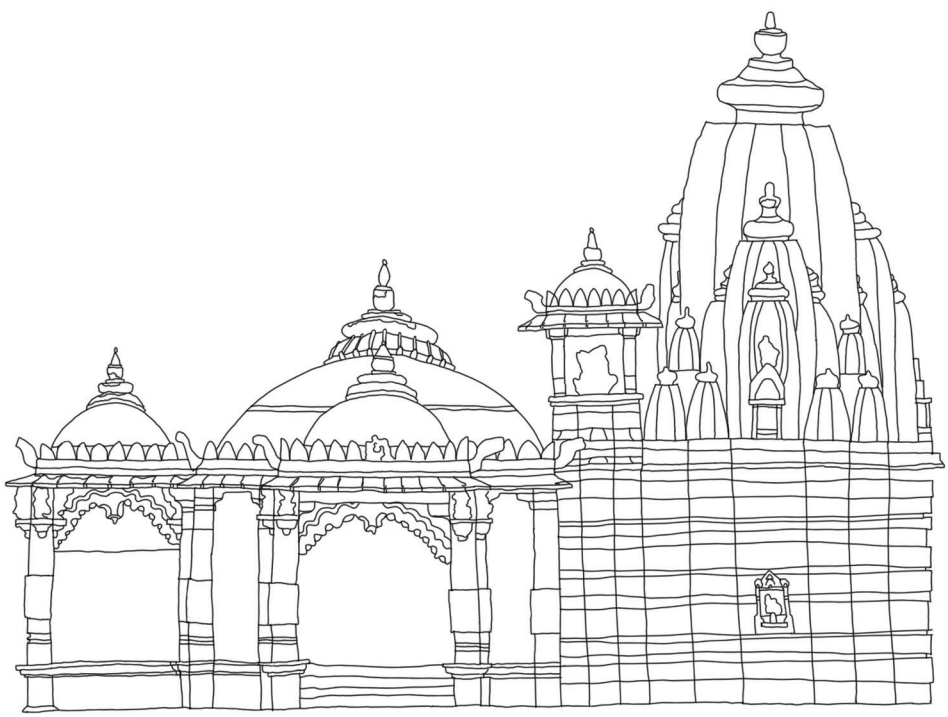
Inside a pol, we find this five-hundred-year-old temple. It is on private ground, so we carefully ask the men sitting at the pol's entrance if we can take a closer look at the temple.

They happily invite us and takes us to the inner sanctum. In the *garba-griha*, there is a Shiva *linga*, a smooth, dark stone with a water collector beneath it. Water is poured on the stone, and the seven-headed snake looms over it. We are the only visitors except for a man and woman who lives in the pol and takes care of the temple.

The temple is about twelve times ten meters in plan and consists of several parts: a *garba-griha* with a *shekhari* roof structure, a *mandapa* with a cupola, and three porches leading up to it. The temple is very old, something that is noticeable from all the vegetation growing on the different roof structures. It has been painted before, but the color has now fallen off. Its time-stained state is not lessening the proud communal feeling it gives to the pol, however.

Placed in the pol's central courtyard, it is always in view from the dwellings of the residents. We were invited to the woman's home one floor up, and her kitchen window was framing the view of the great *shekhari* roof structure just outside the window. In this temple, both privacy and intimacy are emphasized and the time spent here is generally longer compared to the smaller temples. Few visitors from the outside come here, this is somebody's home.



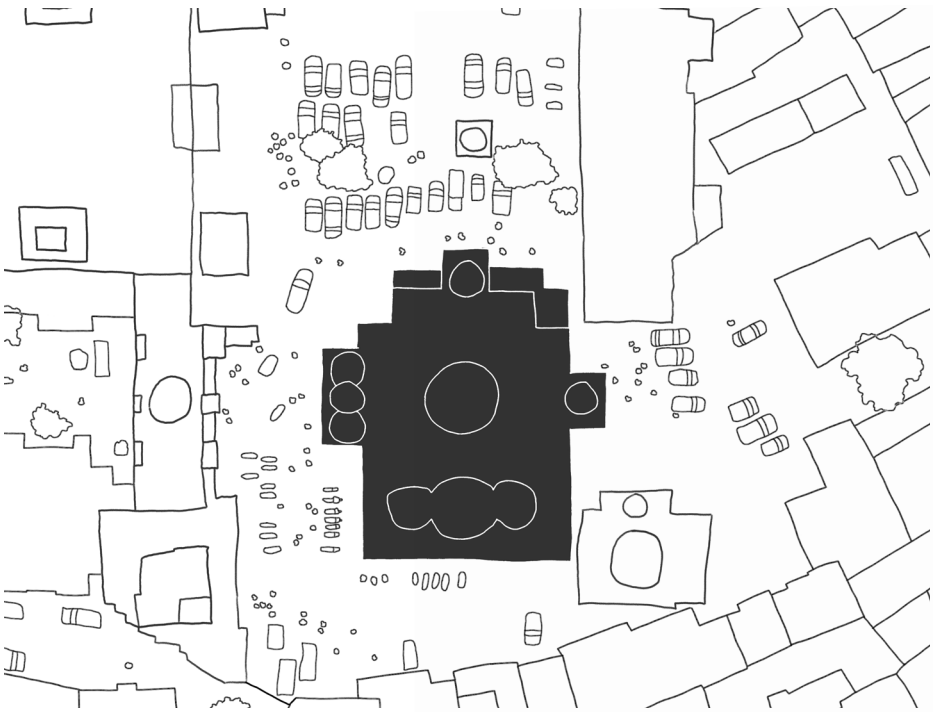


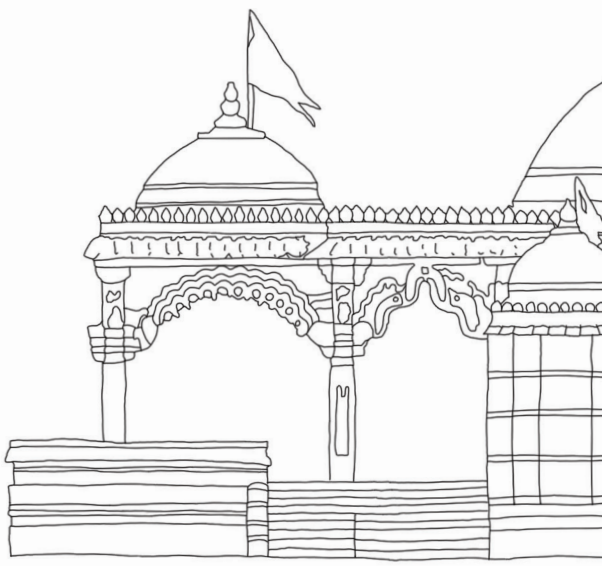
The Large Swaminarayan Temple

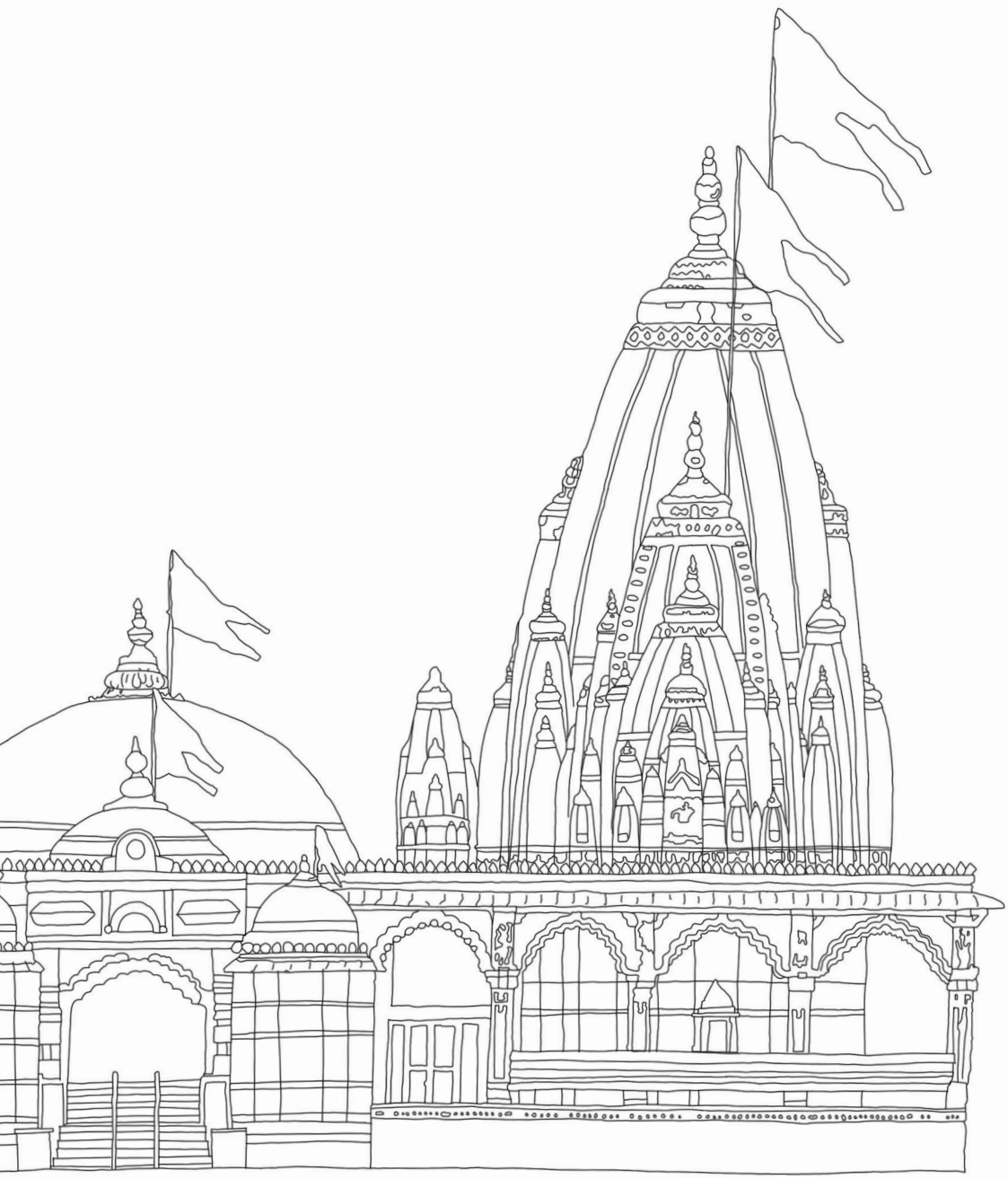
The Swaminarayan temple is embedded in the dense urban fabric of Old Town. It is one of the largest religious structures that exist in this part of the city. The road mentioned before, Swaminarayan Road, connects the temple to Relief Road. A big colorful gate manned with guards protect the temple area. This place is more than just a temple: it is an institution with several buildings. Here are monasteries for both monks and nuns, and also the Ahmedabad heritage office lays here as Ahmedabad is a UNESCO world heritage city. Many people come from afar to visit this temple, and the courtyard is nowadays a parking lot filled with big white cars, an otherwise kind of rare vehicle in Old Town.

The morning waking ceremony at eight o'clock is well-attended. A drum machine is playing a rhythm, and the participants are standing, clapping their hands and singing the waking mantra as one person is circling a brass tray with small candles upon it in front of the deity. The ceremony goes on for about ten minutes until it reaches a crescendo, and then the participants start to walk three laps around the *garba-griha* of the temple. If you are in a hurry, however, it is okay to turn three laps around yourself.

The temple is big and has arcades around its center that are being used as walking paths during the rituals. Along the arcades, there are stone benches to sit on. Men and women are separated in the temple by a brass fence. Visitors sit in groups along the pathway, men at their place and women at theirs. The architectural layout is similar to the design of the medium temple, but just scaled up and thus has more iterations of the dynamisms. The plan measures about twenty times thirty meters. Several *garba-grihas* sits under three big *shekhari* structures, the *mandapa* and the porticos have cupolas with beautiful ceilings. It is a big space with many auxiliary buildings connected to the temple. Found on the courtyard are several caring facilities, a small temple structure stands in front of the main temple, and the ground around it is filled with various grains and seeds. A woman sits crouched down with her palms open feeding the birds and squirrels. There are also toilets on the edges of the courtyard, and lodging is provided in one of the buildings. This big temple area affects the whole city, visitors come from afar, and it is also a famous tourist attraction.







Experimentation

In this section of the report, we will describe some of the things we discovered during our quite extensive physical experimentation with the ceramic 3D-printer for the production of elements in an architectural scale, as well as recount all of the steps necessary in the production of a composite brick. Over the course of the project four different structures were produced: two columns, an arch, and a 1:2 prototype of a section of the final architectural proposal - the Weave.

Expressing the Liveliness of Matter

The panpsychic and pantheistic cosmologies we have presented in this report portray a fractal disposition of matter. This fractal constitution of the world is represented, with the help of various dynamisms, in Hindu temple architecture. For us to do a material translation from theory to structure, we have thus looked into ways of working with fractal geometry and the various processes giving rise to self-similarity in Hindu temples. Some of these processes and investigations we shall present in this part of the report.

Since the notion of relatedness, that Alexander writes about in *The Luminous Ground*, is very important to us, we have also tried to understand what is necessary to make our own temple have life – what kind of properties, be they textual, or geometrical, or something else, are necessary to make feelings of relatedness emerge? Alexander articulates, that the new notion of the Divine necessary to adopt in order for the production of a new architecture that has life to be possible, must imply an understanding of yourself as a part of a larger system of interrelated things. The new world-view he proposes is one that understands and recognizes the inherent connection between all things.[1]

> The core of what I intend to prove is this: Each of us, as we are, is connected to the world. We are connected to it in a concrete way. The character of this relatedness is not invented or concocted in our minds, but actual. I seek to demonstrate that the tree which stands is entangled with myself, and I am entangled with it. This entanglement exists in a fashion which – when I understand it thoroughly – will forever change my conception of my place in the world. Once we understand it, it will change our conception of the universe and our conception of the matter of which we are made.[2]

Alexander points out, that scientific attempts have been made, with the development of chaos theory, the theory of complex systems, and fractals, to name a few, to approach a cosmology contemplating the interdependency of all things.[3] This is quite in line with the ability to express the liveliness of matter we've previously attributed fractal geometry of having, and made it even more interesting for us to investigate the possible application of fractal geometry in architecture and its potential effects.

Considering the many examples of architecture and design in *The Luminous*

1 C. Alexander p. 15.

Ground, Alexander also emphasizes handicraft in the production of objects as having the potential of triggering a deep sense of relatedness with the viewer. We will touch upon this aspect of Alexander's theory in the Reflection.

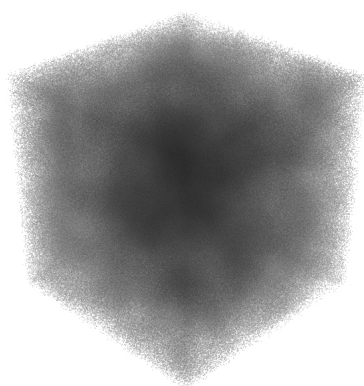
2 Ibid. p. 52.
3 Ibid. p. 16.

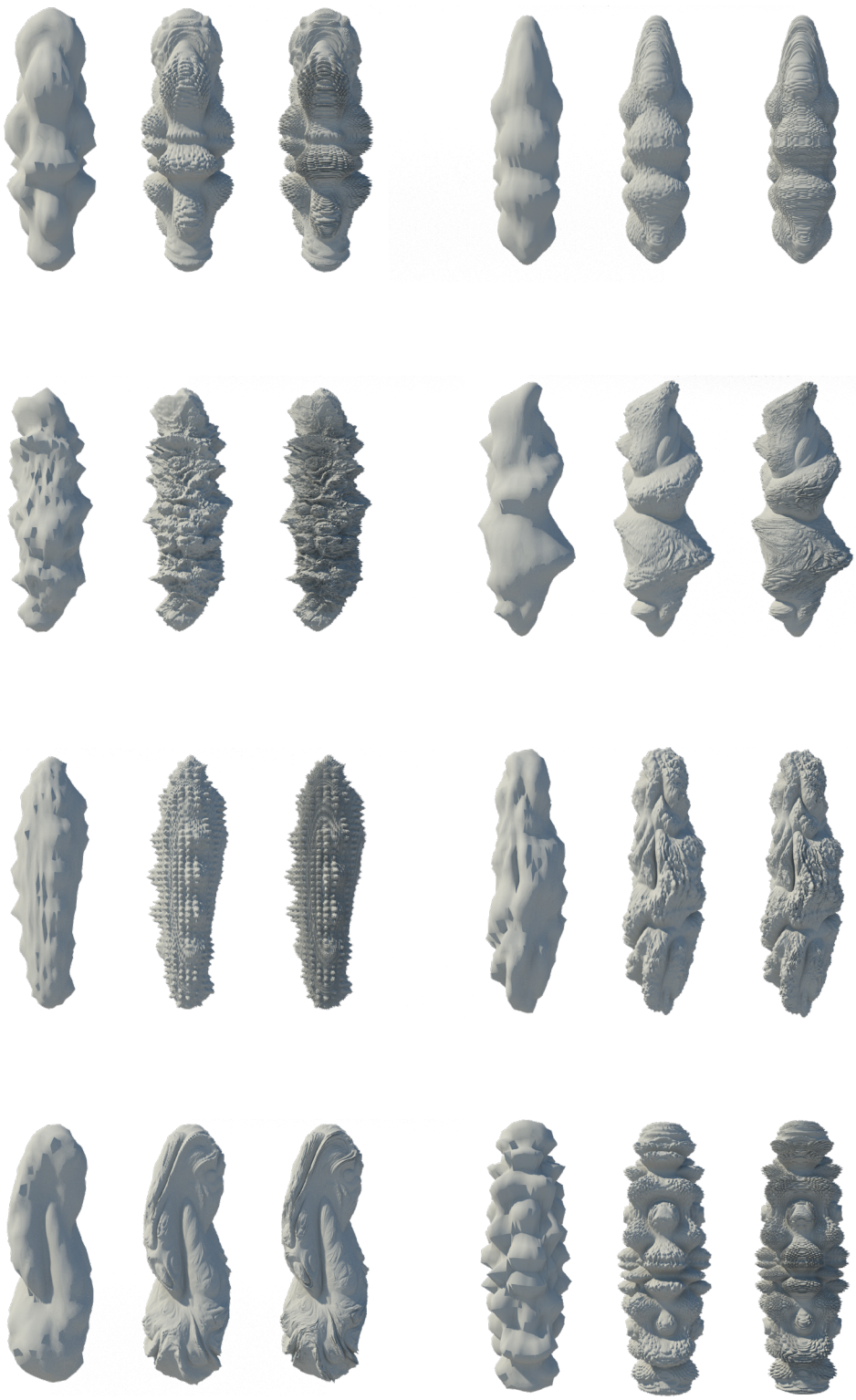
The Fractal Noise Soup

In our investigation into fractal geometry, we ended up experimenting quite extensively with fractal noise. Noise has a multitude of different uses in the digital fields, and is commonly used to increase realism in computer graphics and motion effects, utilized for example in video games to create terrains such as mountains and oceans, but also to distribute things across a digital map that should not be completely randomly placed, such as the trees in a forest for example. Compared to complete randomness, noise is more organic because it produces a naturally ordered ("smooth") sequence of pseudo-random numbers compared to the harshly ordered sequence of random numbers - and it's possible to control.

In 3D noise, which is what we used in the production of our structures, the noise can be thought of as a sort of soup of evenly spaced points in a 3D space, each with a force and a direction assigned to it. Furthermore, all of the points recieve their unique attributes (where they are pointing and how greatly) from looking at the closest neighboring points. If one "dips" a geometrical shape into a noise soup, the points will transform the geometrical shape by tugging and pulling it in different directions. At the bottom of this page, a visual representation of a 3D noise known as Perlin noise can be seen.

As previously stated, the noise that we worked with is known as a fractal noise, meaning the same noise soup is applied over and over again at diminishing scales. This gives rise the same transformation of the input geometry across several scales, and simultaneously the emergence of fractal geometry.



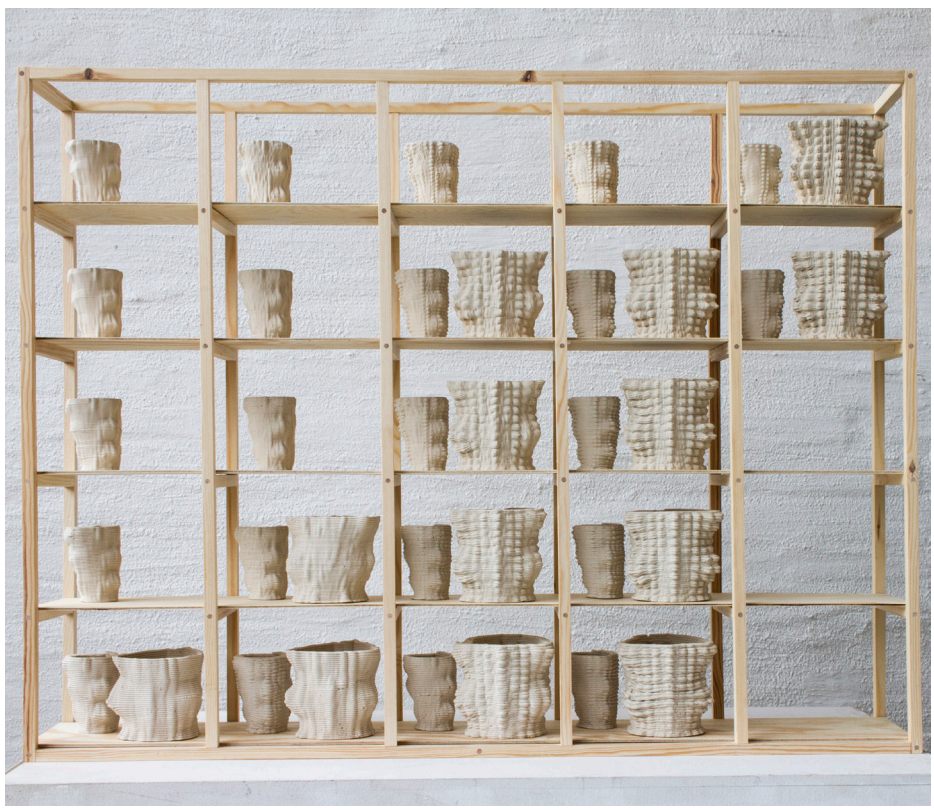


Initial Experiments

Some of our initial tests with the ceramic 3D-printer was aimed at achieving a better understanding of the correlation between the level of subdivision of the computer model, and the size of the nozzle when 3D-printing. In the image to the right, depicting a shelf with various objects standing on it, the result of some of these experiments can be seen. Objects closer to the right on the shelf have an increasingly higher level of subdivision, and objects closer to the ground were printed with an increasingly bigger nozzle.

Evidently more iterations of the fractal noise were able to emerge when 3D-printing an object with a higher level of subdivision, compared to one with a lower level - something that was visible in the review of the computer model, even prior to 3D-printing it. However, one of the most interesting discoveries of this experiment was that when 3D-printing using a big nozzle and simultaneously having a high level of subdivision of the computer model, more iterations of the fractal noise failed to emerge formally. It became apparent that the minute movements of the extruder, derived from the high resolution of the computer model, simply did not succeed in being accurately represented by the relatively thick diameter of the string of clay being extruded.

We also conducted a series of investigations into how different noise soups can be used to alter the shape of geometrical forms. At the bottom of this page, the result of the four different noises that we experimented with the most, can be seen applied to a cylindrical form. These are, from left to right, known as **Sinusoid**, **Periodic Perlin**, **Perlin**, and **Worley**. The difference between Perlin and Periodic Perlin is that the latter is repetitive in its manner and thus patterns are able to reappear in a geometry manipulated by a noise of this sort. Sinusoid is, by nature, also periodic.



The First Column

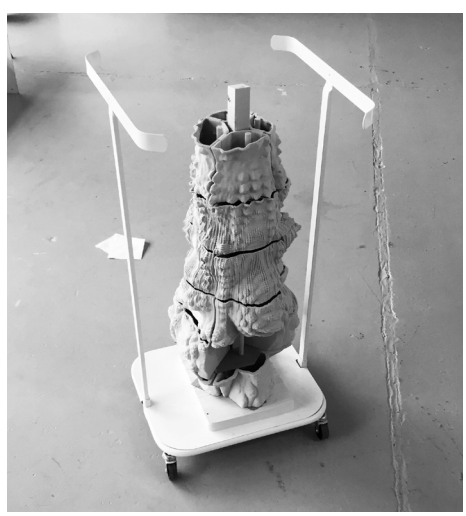
Over the course of this project, we produced two columns. During the production of the first column, we put what we learned in the initial phase described above into the crafting of a structure composed of elements in an architectural scale for the first time. To achieve different levels of subdivision across the same 3D model, we started with having the same, high level of subdivision across the whole piece and then polyreduce certain areas (the top and the bottom of the column in this case) according to a gradient in the upward and downward direction, finally ending up with a 3D model with varying levels of subdivision ready to be sliced into bricks and 3D-printed using nozzles of different sizes.

In the crafting of the column, we discovered numerous things that helped us improve the fabrication process of the subsequent structures. Each layer of the first column was made up of four bricks. The bricks were fashioned in such a way so as to put them together would imply the column having a hollow core. However, because each of the inner sides of the bricks was flat, they did not really sit perfectly next to each other and gaps of varying distances were visible in the structure. Reviewing the column, we also discovered that some of this aforementioned unexactness of the bricks could possibly have to do with the clay and the fact that the proportion of clay to water was different when printing different bricks. Thus some bricks would, as a result, shrink more during the drying process compared to others.

When 3D-printing the bricks for the first column, we did so on pieces of cardboard. This, we noticed, was not optimal for the bricks to retain their shape during the drying, and thus, for the consecutive structures, we replaced the cardboard with acrylic glass.



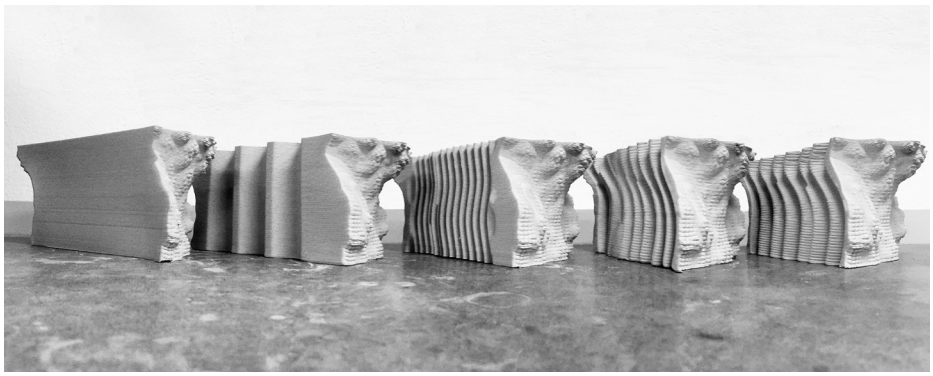


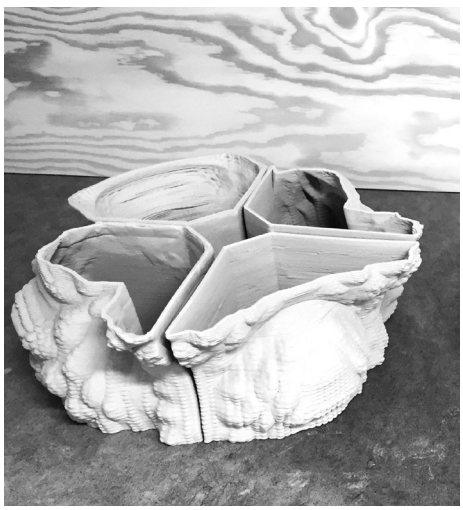


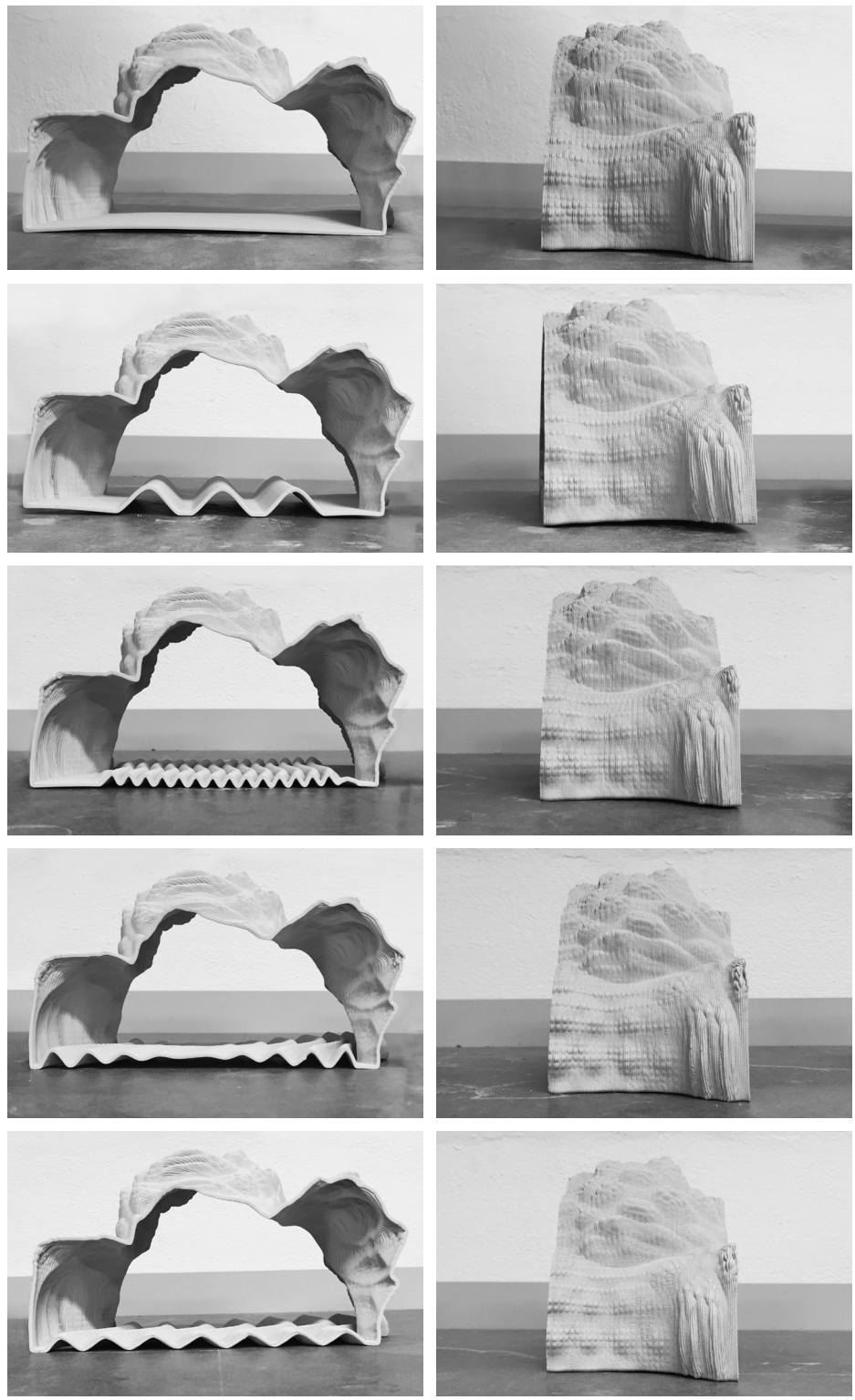

Improving the Process

To get rid of the flat surfaces causing us problems, several different versions of creased surfaces were tried out and evaluated. We finally settled for a variant involving wavy transformations of the straight surfaces in three different directions. By using an undulating plane, shaped to fit the surface in need of being treated, to cut away from the flat surface, all of the flat inner sides of the bricks could be replaced with wavy ones, and thus increasingly exact bricks could be made for the second column.

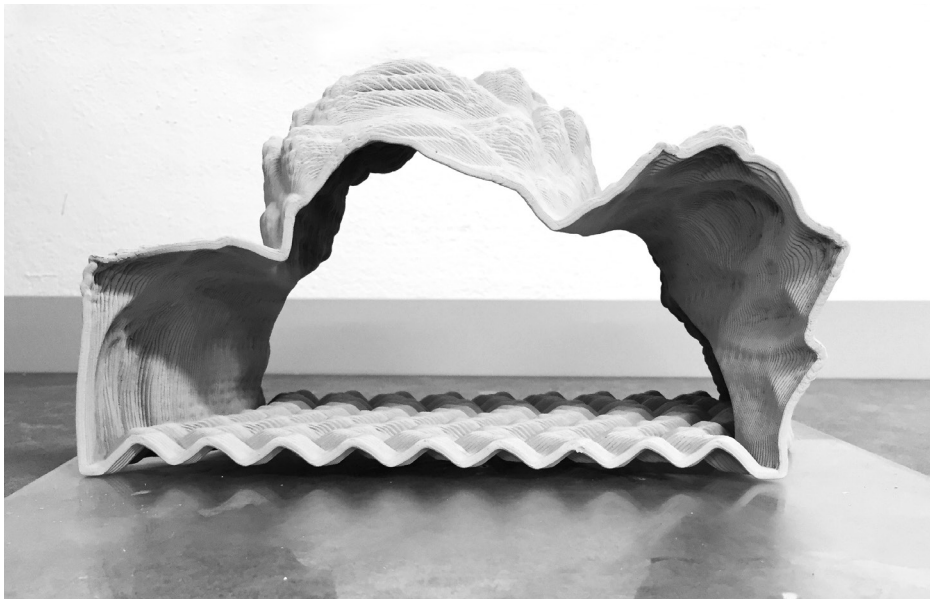
Furthermore, in the production of the second column, we decided to have each layer of the structure to be comprised of only two bricks, and thus make the bricks twice as large. To have fewer but bigger bricks increase efficiency when 3D-printing as one does not have to start anew quite as often.

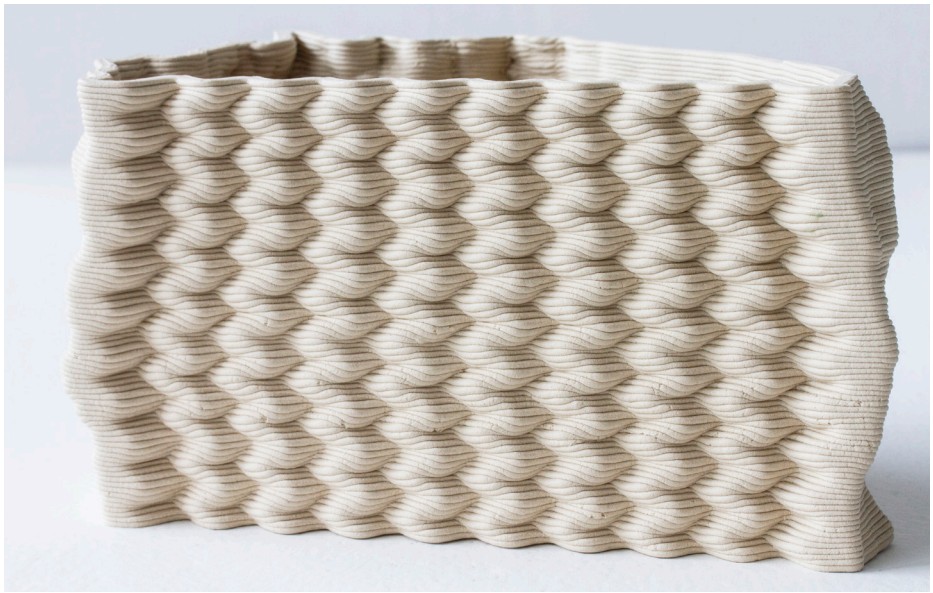






To the left the process of the development of the folded backside is represented though photographs, and below the final version of the backside of the brick can be seen. This texture is used in all three prototypes following the first column. We still had some problems with defomation in the second column, but that was probably due to the bold overhangs created by the noise. In the arch and weave however, we had very little problems with deformation.





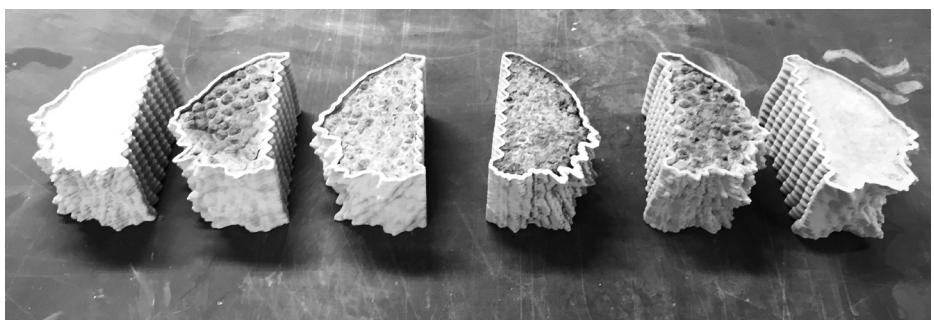
Filling the Bricks

Even though it was never really under serious consideration for the production of an actual architectural structure, the beginning experiments into filling the bricks with something to make them more study was made with gypsum. We quickly moved on, however, to try out filling them with a mix of cement and different granulates such as vermiculite, perlite, and leca balls to make the bricks weigh less. Depending on the position of the specific brick being filled different amounts of granulates was put into the cement. More granulates were added to the mixture when filling bricks further up in the structure, rendering them lighter in comparison to bricks closer to the ground - a common structural strategy.

Out of the three different granulates used, the vermiculite and the perlite being easy to mix with the cement and able to get into every nook and cranny of even the most intricate bricks, worked best. The downside, however, of these two, is the price. They are substantially more expensive than leca balls.

With the leca balls added to the cement, we encountered the problem of the mixture not filling the bricks up entirely, as the size of the leca balls (even though we crushed them thoroughly) restricted them somewhat in that matter. Also, the weight of the bricks was considerably heavier using leca balls as the granulate, something that was further emphasized the more crushed the leca balls were.

To actually fill the bricks, we embedded them partially in sand. We noticed that having a flat surface, such as foam board or a piece of wood underneath each brick, helped to make the cement and granulates mixture flat at the bottom, flush with the lower end of each brick. This was something that we did not do when filling the bricks for the fourth prototype - the Weave. By not using foam board, or a sheet of wood in this case, we were able to leave a bit of room for the mortar to bond to the bricks instead and simultaneously increase efficiency.

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Crafting the Column

Here follows an image based description of the production of the second column. This was the first 1:1 prototype we finished. The printing and drying processes were improved from the first column, and we did some smaller tests of filling and bricklaying in advance, but most of the later process was new grounds for us. We did not glaze the bricks for this structure. That enabled us to do only one firing, moving straight up to the maximum temperature of 1240°C. The non-glazed surfaces of the bricks keep more of the resolution and intricacy.







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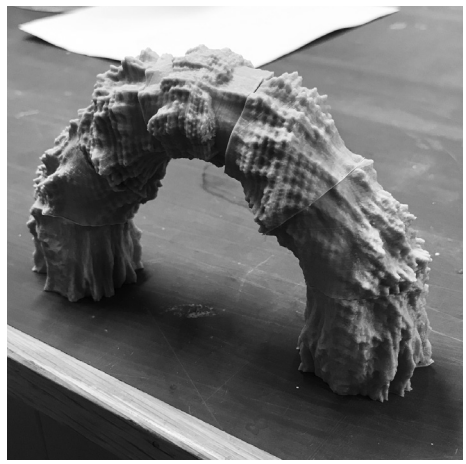
Glazing

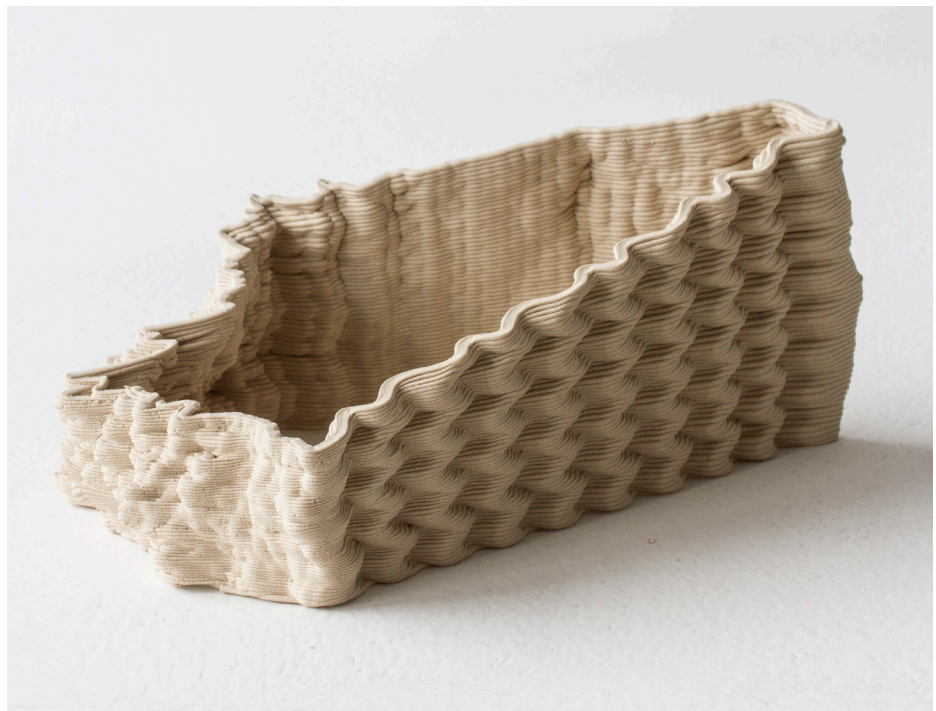
In order to assure ourselves of the structure coping with rainfall and general humidity, we looked into the potential of glazing the bricks. The first glaze that we tried was a green, glossy one. From that we moved on to trying a series of less colorful glazes, finally settling for a beige glaze with a tint not too cold to avoid the structure becoming too bright in the sharp natural light common to the northern countries. Moving forward, we glazed all of the bricks for the consecutive structures with this glaze.

To apply the glaze onto the bricks, we simply dipped them into a large bucket of well-blended glaze. This technique, we noticed, worked well for the application of an even coating of glaze to our bricks. We also, however, experimented with sprayng the glaze, but using this technique it was harder to assure a full coverage.

The Arch

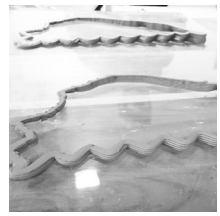
After having constructed the two columns, we found it only fitting to try to make an arch. The bricks constituting an arch, however, are not parallel as the bricks that make up a pillar, but oblique. Thus, for the purpose of printing an arch, we had to explore the potential of non-planar 3D-printing.





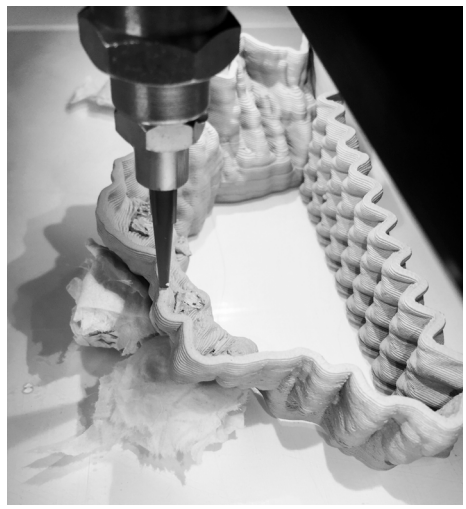
Non-Planar 3D-Printing

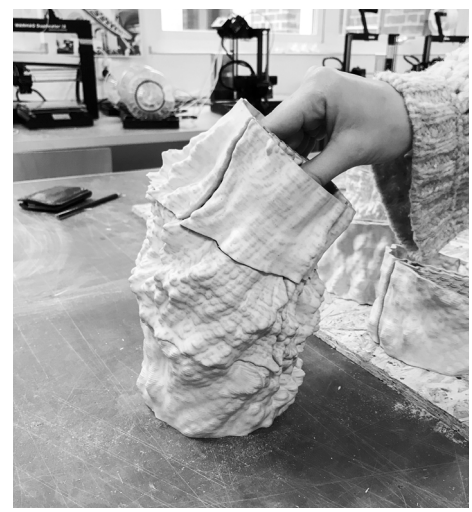
Following the digital process of dipping a geometrical shape into a noise soup and thereby transforming it, as the last step, before the production of a physical brick can begin, the G-code (a kind of instruction for the 3D-printer) must be generated for each individual brick. Since the bricks that make an arch are all angled differently we have to adopt non-planar printing techniques in the generation of the G-code for each brick for the arch. Using several, increasingly angled planes with different distances between them, depending on the size of the nozzle meant to be used for printing the brick, and intersecting them with each brick, the tool-path for the 3D-printer can be generated. Since the angle of the bricks causes the distance in height between each lap to be higher in one part of the brick in comparison to another, in order to achieve even bricks, the flow value has to change during the 3D-printing process. The solution to this was to diminish and increase the flow value depending on where the extrusion is occurring in relation to the x-axis. A lower position in the x-direction corresponds to more distance between the laps and thus there is more clay being extruded in those areas.



Crafting the Arch

Here follows an image based description of the production of the arch. The process builds on from the knowledge gained from the crafting of the two columns. The parts of the process that differs in the production of the arch are the non-planar 3D-printing, the glazing of the bricks, and the assembling implying a lot more challenge as it is a spanning structure. The manufacturing of the arch was, like all other experiments in this project, heavily influenced by us trying different things and failing. We had to redo some of the steps several times in order to get them right.









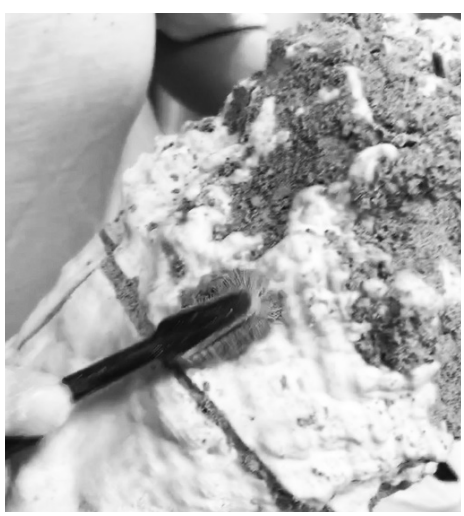








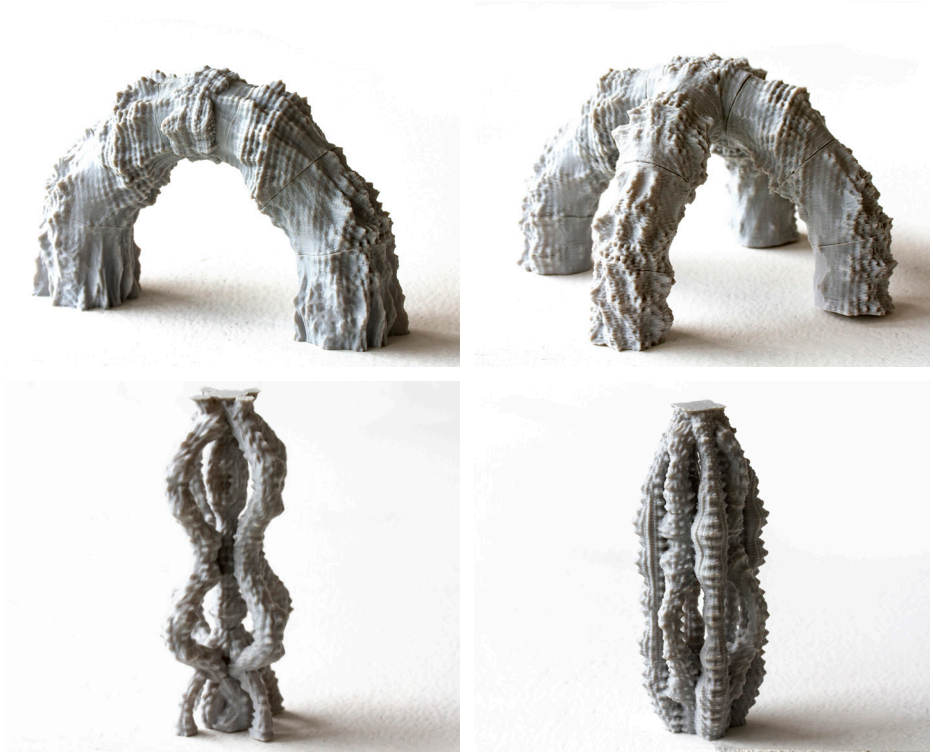





Developing Weaves

In our architectural proposal, much like Hindu temples, we have made use of different dynamisms to express the notion of a living world. When letting various processes determine the design of a structure the question of what particular shape or form to apply these processes onto is very important. In Hinduism the dynamisms are often applied to rather well-defined architectural elements, the most striking one perhaps being the *latina* shape which when subjected to a dynamism evolves into the fractal *shekhari* superstructure. In the generation of the structures presented here, however, the dynamisms that we use (which we shall describe soon) are applied to something that we call "threads." And through the various dynamisms the threads are in turn combined to create "weaves."

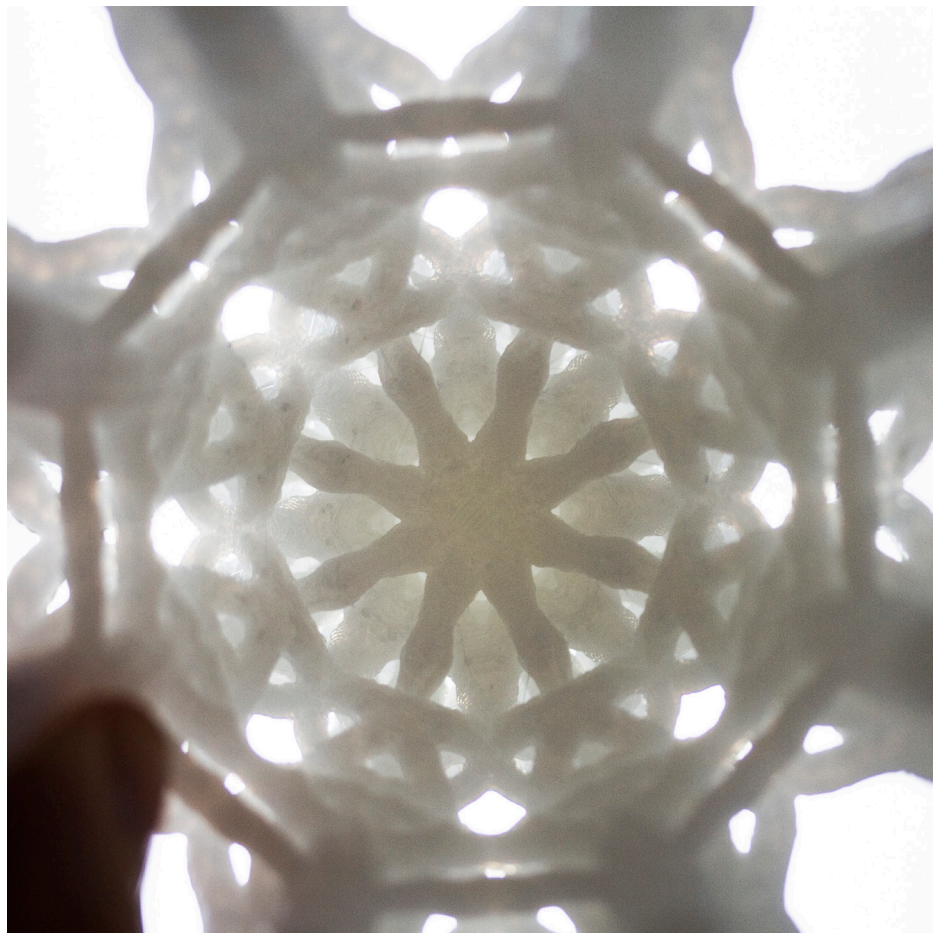
On the images depicting 3D-printed PLA models of various structures, some of the results of our investigation into various dynamisms can be seen. Out of the dynamisms that we used the most frequently, one of them, "staggering," comes from Hindu temple architecture, and two of them, "radial array," and "mirroring," we came up with ourselves.

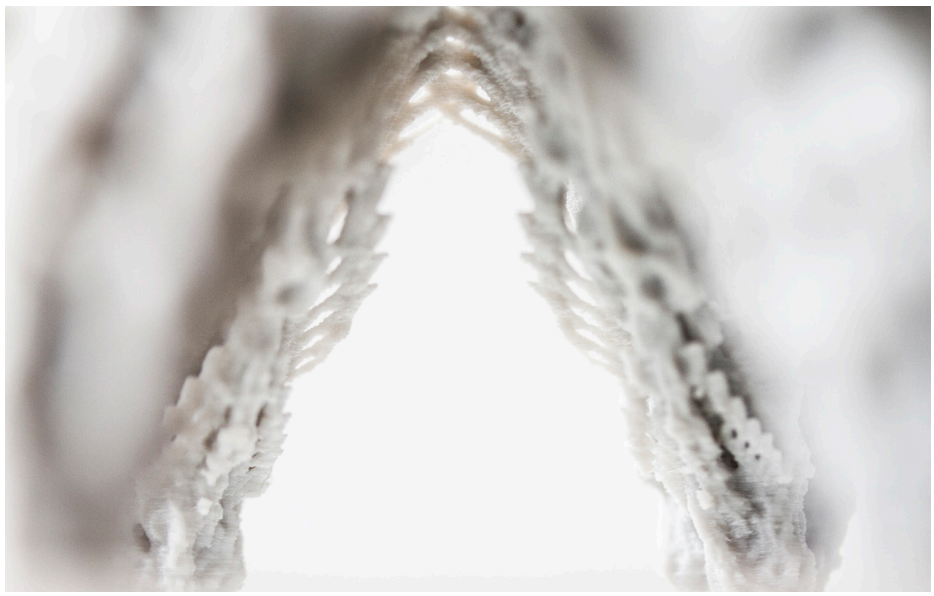


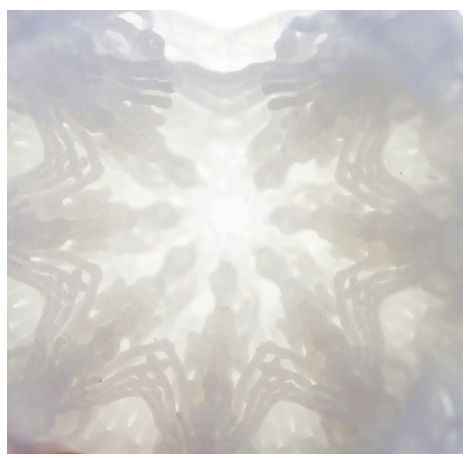










The Making of the Weave

The threads and the weaves have certain properties inherent to them. The thread's pertaining property is texture, and the property of the weaves, which arise when threads are combined and woven together, is porosity - not completely unlike a tree, having branches with texture, and a crown with varying density.

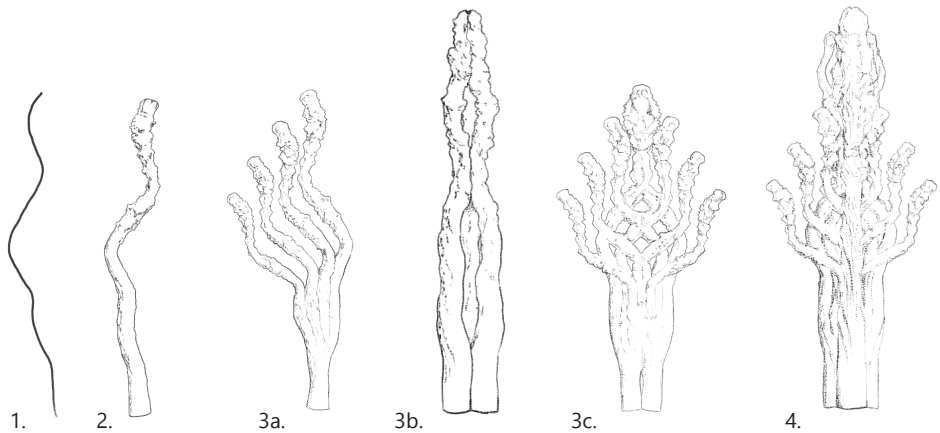
Thus the creation of a thread, being what we apply the dynamisms onto, is different from the generation of a weave. The threads are created from a vertical line (1) which has had its shape transformed by a noise algorithm. This is the first generation of a fractal process since the line is then thickened and turned into a mesh, and the same noise algorithm is applied over and over again in increasingly diminishing scales to transform the mesh surface and apply texture (2).

The noise is a sort of three-dimensional soup consisting of points each with a particular direction and force attributed to it. Each point receives its direction and force from looking at the properties of its neighboring points. We feel that the fact that the noise soup literally transforms and shapes geometry that is being put in it contribute to the experience of the living, continuously unfolding nature of matter for geometry that has been altered by it.

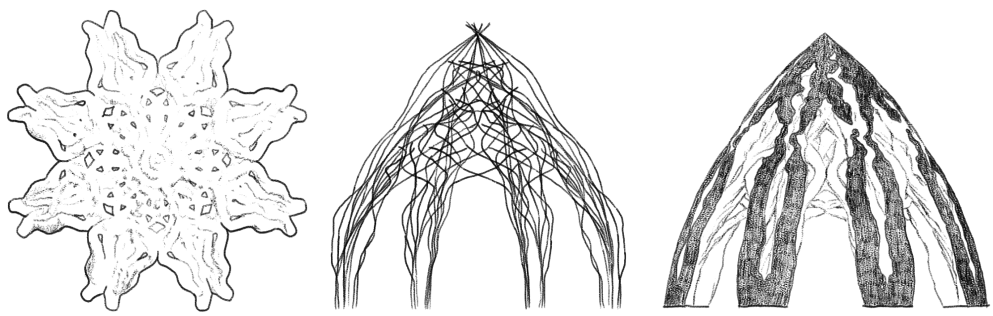
In our project, we have explored several different dynamisms inspired by Hindu temple architecture. Out of these, three are used in the generation of our project proposal, one of which is taken straight from Hindu temple architecture: the staggering-dynamism (3a), and two of which, at least to our knowledge, are not. These two we call "radial array," (3b) and "mirroring" (3c). Radial array is the copying of a form in a circular manner, and mirroring is, quite simply the doubling of a form by mirroring it in any direction.

After the threads have been generated, we combine them using the dynamisms to form what we call a "sub-weave." (4) Then we proceed with bending the sub-weave for it to achieve the desired shape and apply the radial array dynamism once more (5) to create a weave in the form of a dome-like structure.

Since we in our project are exploring possible ways of realizing a structure through the means of ceramic 3D-printing, in order to extract elements from the overall structure possible of being 3D-printed, following the procedural transformations of the dynamisms, several slicing operations need to be done. The various dynamisms weave the threads together, causing several self-



1. 2. 3a. 3b. 3c. 4.



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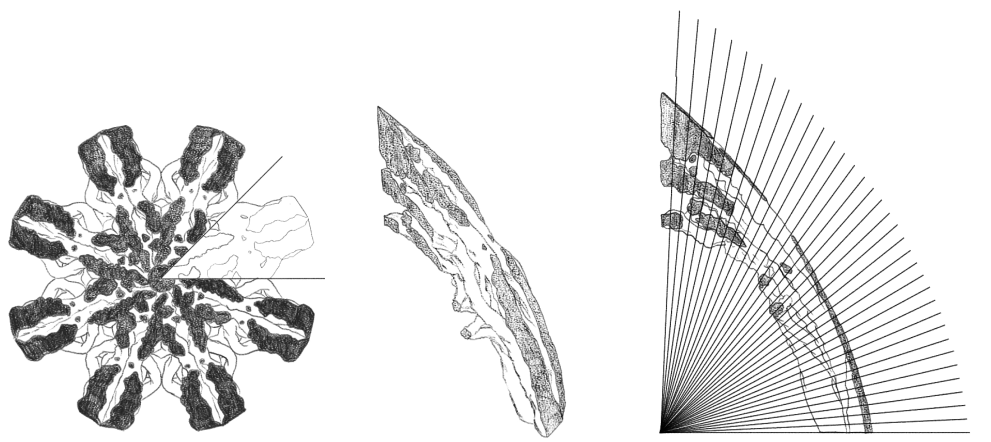

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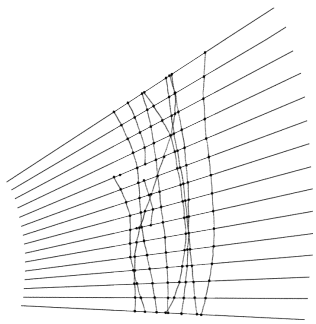

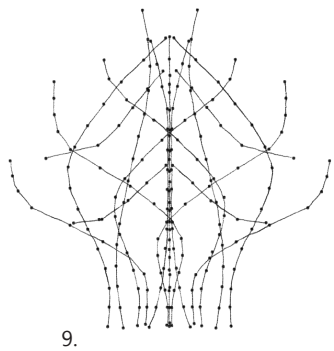

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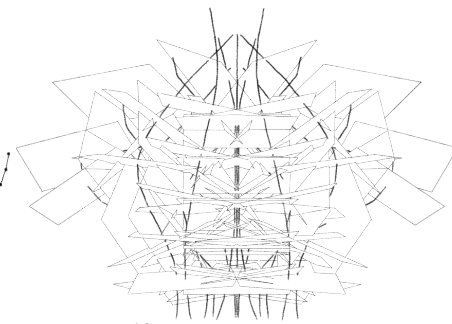

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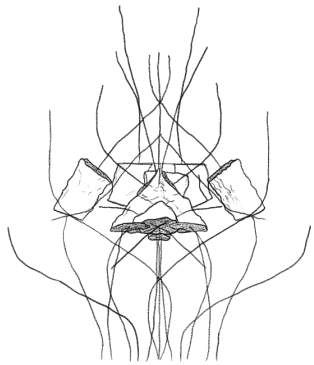

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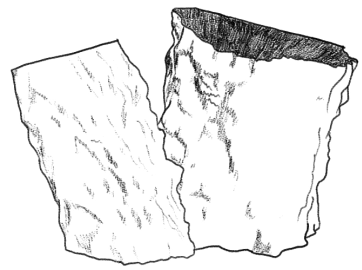

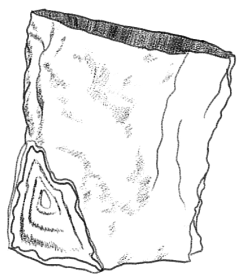

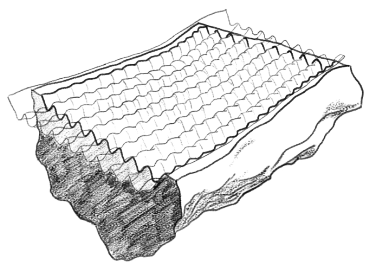

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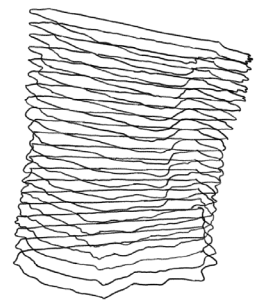


13.

intersections in the overall structure. These are generally a problem since the boolean operations used to cut the structure into bricks require a geometry with one continuous, unbroken surface. The solution was to keep the information of each thread after the structure had been generated, and use “for each”-loops for each individual thread in the weave when performing the necessary boolean operations.

One of the first slicing operations implies “skinning” the whole structure (6). Then we separate each of the pillars from the rest of the structure (7). This process is then followed by, using the lines that make the threads and not the threads themselves, a process involving the creation of intersection points where the lines intersect with a given number of planes arranged as a folding fan (8). These intersection points are then grouped together in groups depending on the specific plane that intersected with the lines (9). In turn, these points are then used to create planes facing the direction of the line (10), used to cut the threads into bricks (11).

The process of making a weave can be seen as an entangling and untangling process. Using for-each loops on each individual thread, we enabled ourselves to place the cuts in areas where they make sense, and using planes derived from the lines that make the threads, rather than turning the entire, woven structure into a single non-self-intersecting mesh by converting it into a volume and then back to a mesh (which would have been very strenuous, if at all possible, for our computers to do) we avoid having to arbitrarily slice it. By using planes that correspond with the direction of the lines, we also minimize the occurrence of too steep angles for the 3D-printer to manage.

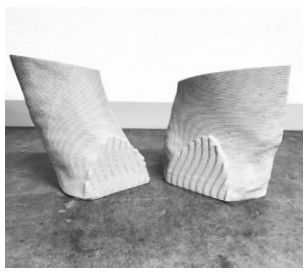
There are also some processes necessary to apply to specific bricks, such as making the back surface of each brick, or the surface of an intersection between two bricks wavy (12) - explained why and how in the coming section.

As the last step, before the production of a physical brick can begin, the G-code must be generated for each individual brick extracted from the structure (13).

Intersecting Threads

As previously stated, the process of weaving threads gives rise to numerous intersections in the computer model, and by using for each-loops we are able to cut the structure into 3D-printable bricks regardless. However, where two bricks meet, to avoid flat surfaces, the intersecting area between them has to be treated somehow, similar to the back side of the bricks constituting the second column or the arch.

We experimented with a few different surfaces before finally settling, in the production of bricks for the prototype of the Weave, for one involving copying whilst continuously making smaller the intersection curve towards the center of the intersection. Every other contour is then moved slightly, and a surface is finally generated by the lines. As just mentioned, the result is something similar to the wavy surface made by the plane used to treat the back side of each brick, but since the intersecting areas of two threads might be confined to an area rather small, another technique had to be used to avoid cutting away pieces of the brick meant to be left untouched.



Crafting a Brick

Preparing the clay

Prior to 3D-printing, the clay needs to be prepared. To achieve an even clay, without any dry pieces, we process the clay with a meat grinder.

3D-printing

Once the cartridge has been loaded with the processed clay and the G-code has been generated, the 3D-printing can begin. The printing time for each brick is greatly dependant on the nozzle size and varies from 15 minutes to a couple of hours.

Drying

The drying of a brick takes no more than 24 hours. This is a critical phase in the process. To make sure each brick dries evenly, we cover potential protruding elements with cling film.

First firing

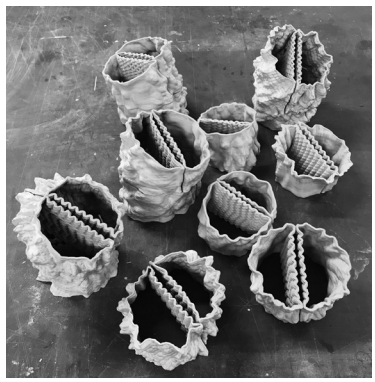
In the first firing (known as a bisque firing) the temperature of the kiln reaches 800°C. The goal of bisque firing is to convert greenware to a durable, semi-vitrified porous stage where it can be safely handled during the glazing process.

Glazing

The glaze is applied to each brick by dipping them into a large bucket. This technique, we noticed, worked well for the application of an even coating of glaze to our bricks.

Second firing

In the second firing (known as a glaze firing), the temperature of the kiln reaches 1240°C. The glaze firing melts the glaze and makes the bricks very durable.

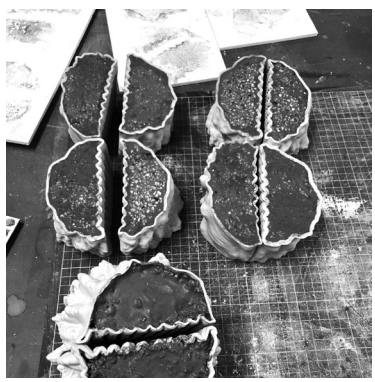


Filling

In order to be filled, the bricks are placed in sand, keeping them in place and enabling us to evenly fill bricks that have an angle. The bricks are filled with a mixture of cement and a granulate of vermiculite, perlite or crushed leca balls, making the bricks less heavy.

Assembling

After the filling has hardened, the bricks can be assembled together with mortar.



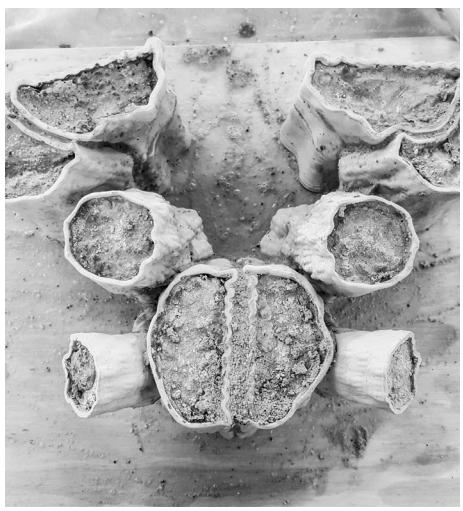
Crafting the Weave

In this section follows an image based description of the crafting process of the 1:2 prototype of the Weave. Like in the production of precedent structures, the methodology is building on from the knowledge gained from the manufacturing of the previous prototypes. The biggest challenge here was the assembly process. The structure's vertical elements posed no problem, but some of the threads are almost at a horizontal angle and thus needed support of some kind. We discovered that working with tension suited well due to the symmetrical form of the prototype. So by tieing strings around the critical parts and then tightening them by twinning the string around a stick, we developed a support system.











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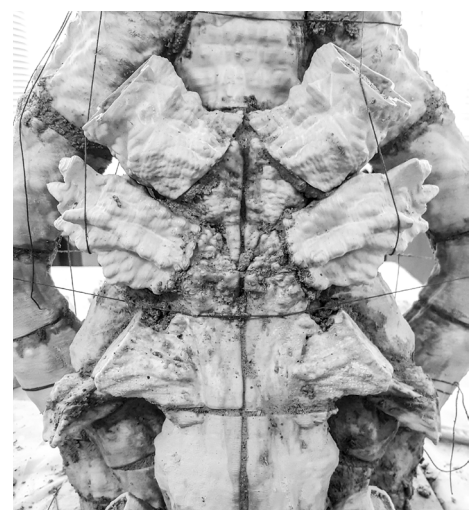
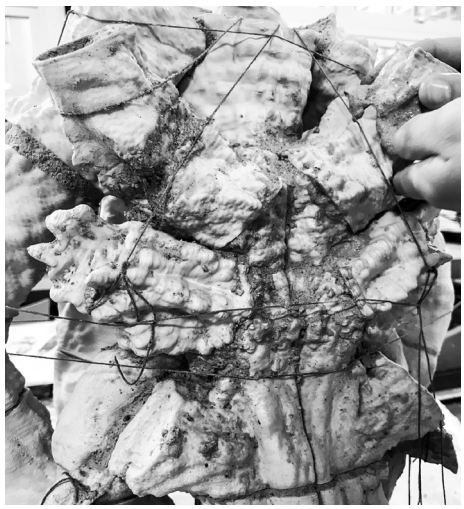
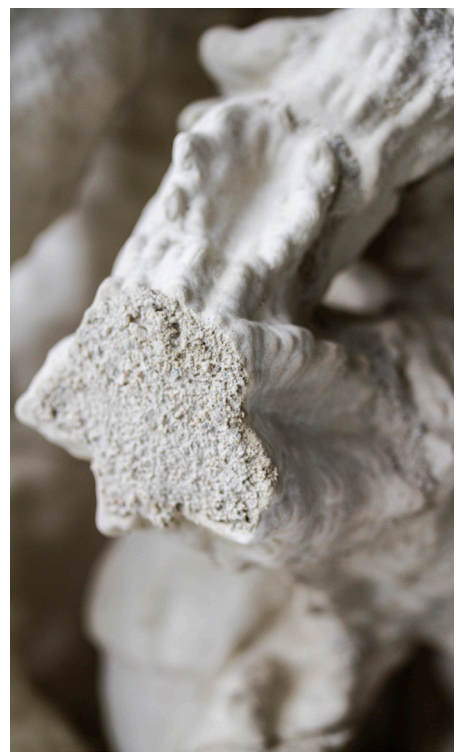






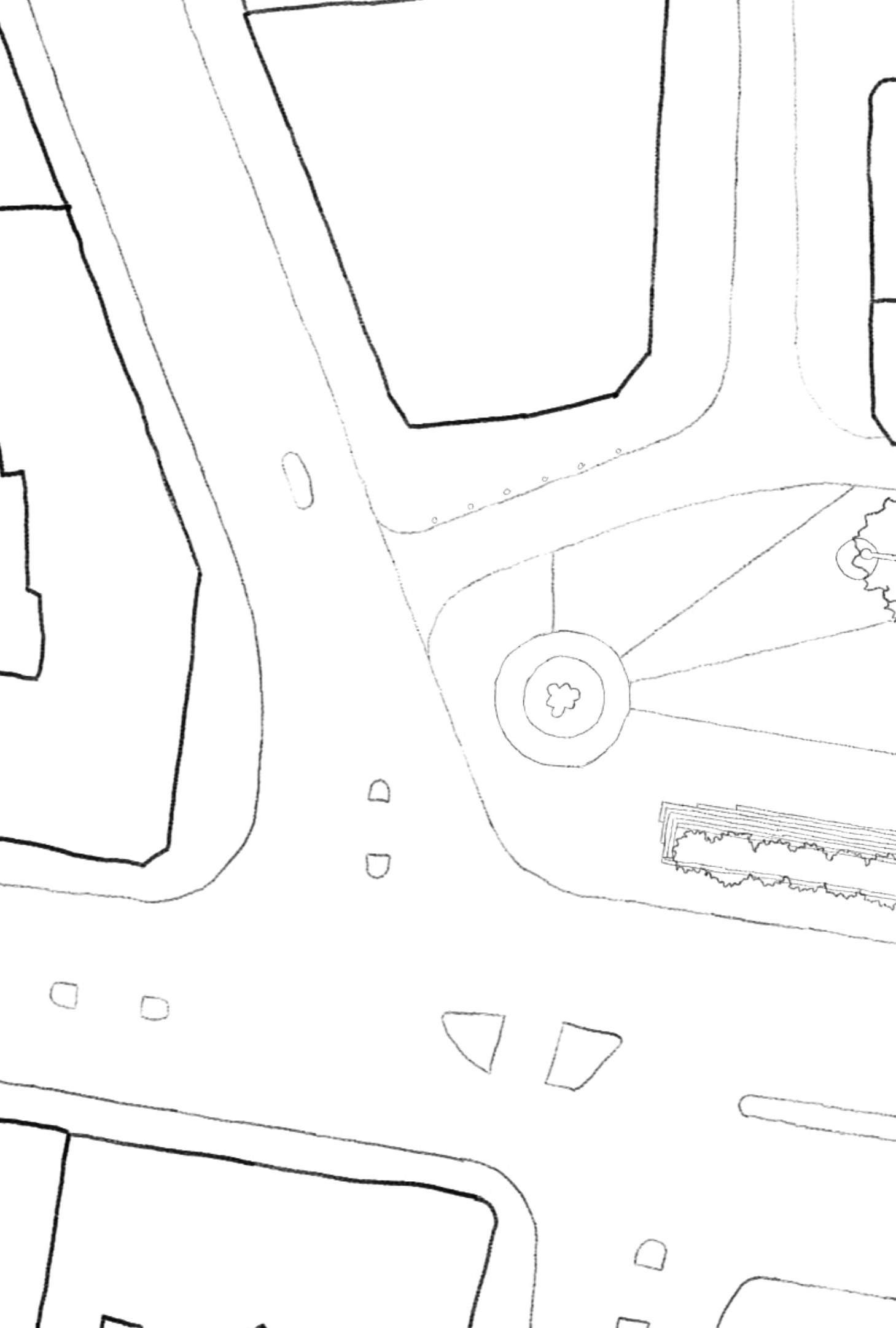
A Proposal

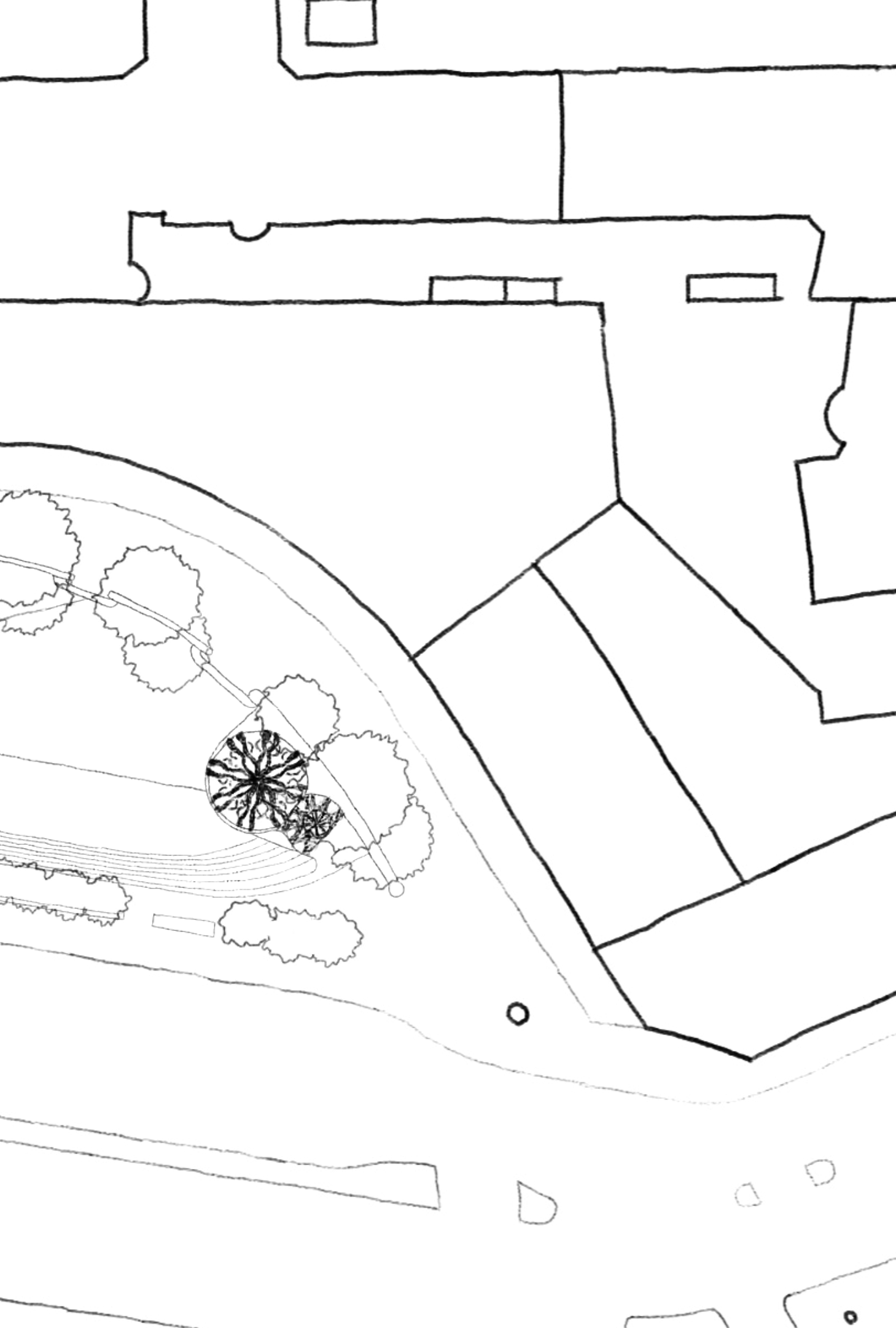
In this part of the report, we give a closer description of the site for our architectural proposal: the Weave - an urban shrine that, instead of being devoted to a God, is devoted to the liveliness of matter, and how this structure relates to its urban context.

Triangeltorget

We have chosen a location in central Malmö, Triangeltorget (which translates to “the triangle square”), an iconic place named after a triangular platform that stood here when Malmö had a running tram network, as the site for the Weave. The square was renewed in the ‘90s but is now quite neglected in some regards. Still, a considerable amount of people pass Triangeltorget either to or on their way from the more central parts of Malmö every day. Just next to Triangeltorget lies the shopping mall Triangeln, named after the square, extending the most central shopping street in Malmö, Södra Förstadsgatan. There is also a train stop not far from the square, with trains leaving for Copenhagen and other towns and places in Sweden. Triangeltorget could be seen as a node at the end of the busy shopping street of Södra Förstadsgatan, connecting the central parts of Malmö with its southern districts.

When people pass Triangeltorget, either by bike or by foot, most people move along the curved facade of the buildings facing the square, not crossing the actual space per se, perhaps due to the rather large octagonal kiosk standing in the middle of Triangeltorget blocking the visual connection to where most people are heading. As a part of our proposal, we got rid of the kiosk, imagining what Triangeltorget would be without it, and allowing for the free flow of people across the square

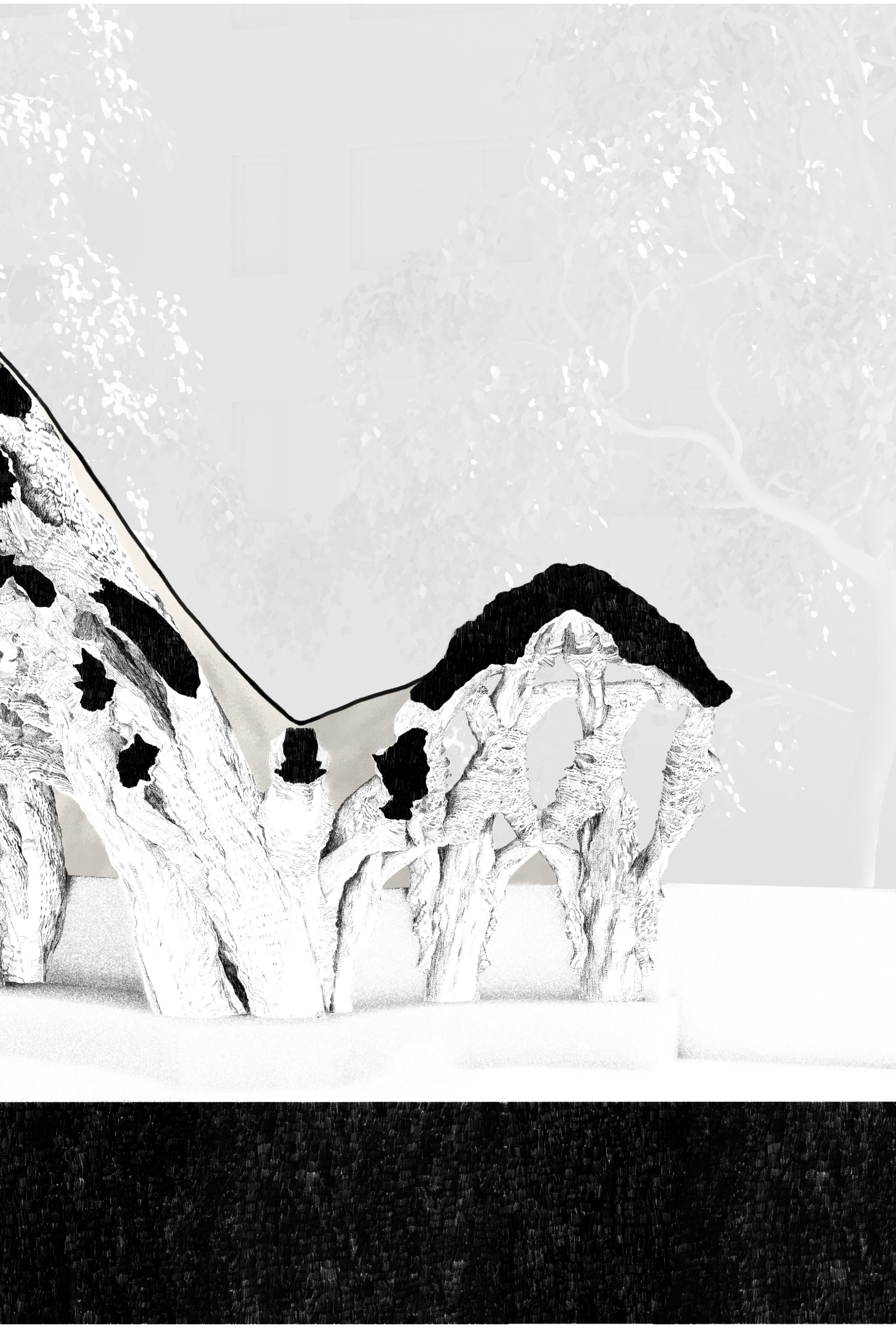


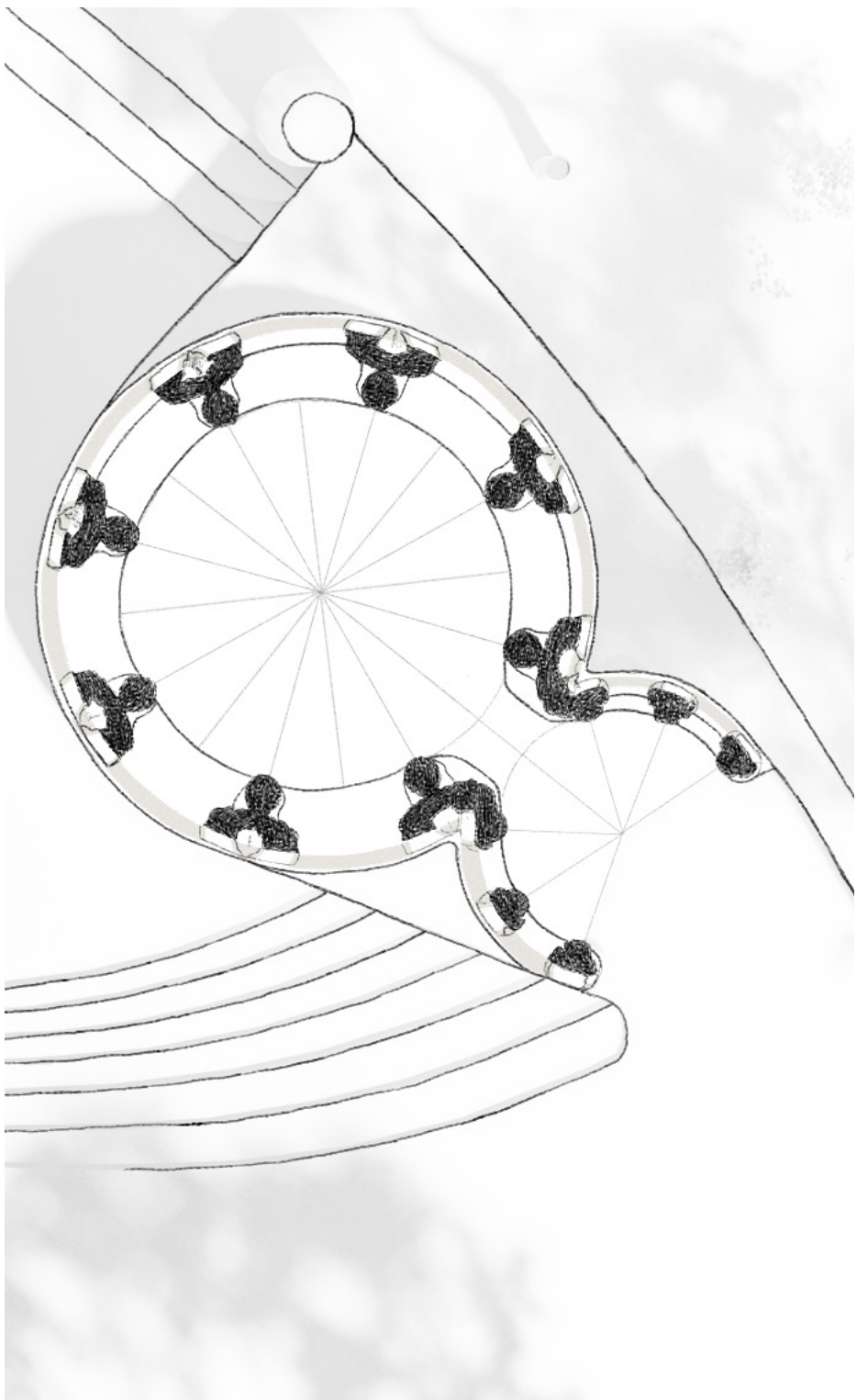


The Weave in the Urban Fabric

When placing the structure in the urban context, we have been looking to our mapping of Hindu temples in the city of Ahmedabad, and more specifically at the small ones, generally placed openly and accessible close to a natural flow of people, infusing the urban context with a spiritual notion. As seen in the plan on the previous spread, we have placed the structure facing south to catch the sun, and to open up towards the people passing by on Södra Förstadsgatan, walking and biking towards the center of Malmö. It sits under some trees, close to a wall, from which a base emerges, providing seating possibilities inside the structure, and grounding it to the site. The structure consists of two parts, which we call weaves: an inner, and an outer weave. The inner weave is protected from the weather by a skin of canvas. The outer, entrance weave, being only partly covered by the canvas is, however, covered by the canopy of the trees visible through the structure.

As one pass by the structure, intrigued by the odd shapes perhaps one stops to take a look, to pause for a minute or two. Perhaps walking inside to sit down for a bit, to appreciate the light shining through the canopy of trees above, the leaves casting shadows on the canvas partly covering the structure. Surrounded by the uncustomary surfaces and masses it is easier to forget the outside world. To allow oneself to think about something else for some time. Or to think of nothing. The intricacy of the geometry in the forest of interwoven forms beckons one to experience it, not only in a visual way but to reach out and touch it, to get to know it. To understand what it is. It is relatable, it is real, yet the strangeness of it all alludes to something deep within. The elaborateness of the structure resonates with the complex, intricate nature that is you. Simultaneously it seems to almost represent something, through the expanding, ever-unfolding forms as they tangle into each other growing and diminishing in size, something deeply human, infinitely more than the huge, flat, colossuses of steel and concrete on the outside, too shiny and bright for someone to be able to look at them with eyes wide open. Soaring too high for anyone to try and reach out for them. Showing it all, and exposing nothing. After some time has passed, perhaps one stands up again and begins to walk outside. Flinching slightly as the eyes had acclimatized to another condition, to finally walk away to wherever one was heading. To go on with the business of one's life.





Reflection

In this concluding part of the report, we will briefly discuss the core subjects of the project as well as bring forth a few interesting things that we discovered over the course of it that perhaps can function as a starting-point for further discussion.

Reflection

The process of producing 3D-printed ceramic bricks in an architectural scale for the assemblage into a structure requires a lot of human interaction from the initial preparation of the clay, to glazing, and final assembly. The actual 3D-printing is, in fact, a rather small part of a quite extensive process, yet it is clear that the aesthetic expression of the structures that we have produced would have been extremely hard to achieve, at least for us, using more traditional means of working with the clay.

This project focuses on an investigation into the intersection between craft and ceramic 3D-printing, and over the course of the project, their profound interdependence became evident to us over and over again. This was further emphasized by everything that comes with the fact that the outcome of the project was supposed to be elements in an architectural scale for use in the urban realm, bringing on a multitude of things that has to be taken into account, such as consistency of form, and the ability to withstand structural dampness.

During our physical experimentation using a 3D-printer to produce ceramic bricks, we experienced several difficulties (we hesitate to call them "problems" as they are, above all, expressions of the inherent characteristics of the material) primarily having to do with achieving consistent shapes, but also things that can cause more general issues in the printing process. All of the different techniques and undertakings that we developed in the production of the structures are necessary in order to produce bricks that work. The many different factors that come into the process of manufacturing a brick are dependant on the vast inherent characteristics and expressions of the clay, and different ways of working with it. The sheer amount of interrelated factors inherent to a material, clay, in this case, is nothing that, at least we, are possible of simulating or calculating with the use of a computer. Practical knowledge of the clay, it's intricate modes and manners when subjected to various ways of treating it, is necessary. To us, at least, it is clear that the role of handiwork is significant in the process of manufacturing 3D-printed ceramic bricks.

Beside handicraft, for the purpose of producing architecture that has life Alexander emphasizes the need of focusing one's attention at the ground of all things, the inner I that each of us experiences and relates to the world. Fractal geometry, as the representation of an emergent system, he writes, is one way of

expressing the composition of the new world-view that we need to adopt and the new notion of the Divine that we need to focus our attention at in the process of designing architecture. By making use of fractal geometry, and emphasizing the prominence of handicraft in the process of manufacturing 3D-printed ceramic bricks, we hope that our structure, the Weave, can be a bearer of relatedness through its textural, material, and formal aspects.

During our experiments with fractal geometry and the various dynamisms, sometimes alien, almost scary shapes emerged from the digital processes. The form-finding of a structure was thus sometimes colored by us trying to hold back the intricacy and intriguing formal expressions to avoid creating something too alien that might be hard to relate to. However, to create something too ordinary could also potentially be a problem. Hence the digital processes can be compared to a balancing act between the ordinary and the alien.

Moreover, what we noticed was that the 3D-printed PLA versions of the structures had a tendency of feeling more alien than the fully assembled structures made of 3D-printed ceramic bricks. Somehow, when the structures were brought into a much larger architectural scale and needed to be assembled with mortar and handicraft as a result became more pronounced, ties were tied to our physical reality, and as a consequence the structures felt less alien and managed to relate more to us as humans, which was the main goal of the structures all along - to somehow formalize and help to bring forth the much-needed reconnection between humans and matter and the material world.

The potential power of a structure like the Weave in the contemporary urban context is certainly something worth reflecting upon. It could be argued that there are already structures out there contemplating the ever-unfolding nature of the material world that we see each day - trees and clouds, for example, demonstrate fractal geometry in a wonderful way, but most of us normally do not give them much thought. However, the fact that the Weave is a built structure, designed and constructed, emphasize the notion of the lively dimension of matter and makes this idea concrete and serious in a sense.

In a similar way that Hindu temples are representations of certain aspects of Hindu cosmology, the Weave can reflect the notion of matter as living, and by standing in the urban realm constantly act as a reminder for the inhabitants of the city for the nature of matter. Hypothetically, if the city would be sprawling with little structures like this, not unlike the urban fabric in India, they could act as a possible way of re-enchanting our world.

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All other photographs and drawings were made by the authors.