

# Transcend Realms

*Examining the Interplay of Stereotomy, Light & Sequence for & Design of Timeless Space*

HUMDA MALIK

MASTER'S THESIS 2017

DEPARTMENT OF ARCHITECTURE AND CIVIL ENGINEERING,

CHALMERS UNIVERSITY OF TECHNOLOGY

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© HUMDA MALIK

H@SALEEM.SE

MASTER'S PROGRAMME IN ARCHITECTURE AND URBAN DESIGN (MPARC)

DEPARTMENT OF ARCHITECTURE AND CIVIL ENGINEERING,

CHALMERS UNIVERSITY OF TECHNOLOGY, GOTHENBURG

EXAMINER: JONAS LUNDBERG

SUPERVISOR: KENGO SKORICK

THESIS COMMITTEE: JONAS LUNDBERG, JONAS LUNDBERG,

DANIEL NORREL, CHRISTINE, KENGO SKORICK & KARIN

JUNE 2017



**CHALMERS**





# Abstract

Through temporary structures, architecture has responded to the ever-changing global climate with responsive, socially inclusive and economically viable solutions around the world. It has put to question the very idea of architecture being synonymous with permanence. While tending to societal and environmental flux may be necessary it is also imperative to bear in mind the user: humans. People, unlike their environment, have little changed physiologically and psychologically since we first came to be. Of both states, humankind has always sought for stability and security, and so it can be said that perennial qualities to space attend to the basic needs of the human just as the ephemeral. Through the study of tangible and quantifiable measures of light, matter and form and the intangible emotive space and atmosphere the thesis aims to define and materialise architecture that is permanent yet adaptable, dynamic and socially relevant throughout time.

Research by design methodology was used to develop concepts of timelessness that are - geometry, composition and light. Studies on psychology (Meyers-Levy, J., Zhu, R Juliet, 2007) and architectural theory (Pallasmaa, J. 1996, Vassella, A. 2013, Kahn. L 1969) complemented this methodology in finding a material link between phenomenology and light. A series of design studies established the relationship of light quality- light distribution in space, the mutuality of light and shadow and its correlation to scale and geometry. The findings were evaluated through theory (Pallasmaa, J. 1996; Rasmussen, S. E. 1964) and resulted in a conical shape with oculi skylight apertures as the core form of the design

prototype.

A study of religious architecture, St Hallvard's Church, Lund + Slaato and Sagrada Familia, Gaudi, substantiated the importance of monumentality and permanence with the design of timeless architecture this consequently led the design exploration to stereotomy.

Inspired by both ancient (Inca ruins) and modern stereotomic architecture (modern construction of Sagrada Familia, Matter design studio) experimentation of tessellated geometry, boolean subtraction and hyperboloid surfaces was conducted using computational design tools.

A proposal for a public building presents the findings of the design research. A largely ignored site set within a highly active Annedal Junction was strategically used to transform the site into a place, a social destination. Informed by architectural theory on levels of intimacy (Alexander, C. 1977) the prototype was organised following a spatial sequence ensuring five graduating levels of intimacy taking the user from a bustling environment to social and private areas.

The thesis illustrates that quantifiable measures - stereotomy, the use of a sequential system of spaces and a calibration of light with matter coupled with a sensitivity to human perception can create emotive and lasting spaces. As such, this research intends to contribute to the greater discussion of designing sustainable architecture that stands the test of time by not only remaining structurally intact but socially relevant.



# Acknowledgments

I would like to give my deepest appreciation and thanks to my supervisor, Kengo Skorick, for offering me excellent guidance and enormous help on every aspect of the thesis. His enthusiasm, rigour, and integrity will forever have an influence on me. I would also like to give my thanks to my examiners Jonas Lundberg and Jonas Lundberg as well as Morten Lund for your inspiring and insightful feedback.

Special thanks to Naeem Saleem and Uzma Mir for the constant and reliable support in more ways than one. To Louiza Papadimitriou Douka for all the help and the best company in the highs the lows and the very late/early hours of the day and finally to Maja Kovac for all the understanding and sound advice that drove me on the path I wanted to lead.



# Background

In an increasingly secularised society that is becoming ever more culturally diverse, it can be argued that religious architecture is losing its relevance and becoming a redundant typology. However, at the risk of demolition or transformation into private buildings, it must be recognised the very purpose of religious architecture. It provided a place for social gathering as well as individual contemplation in a safe and inviting space. Many examples of religious architecture from simple to the highly ornate offer emotive space that stimulates the senses and triggers a psychological and physiological response. There lies the potential for religious buildings to remain socially relevant

to people of any or no faith. Many revered buildings such as Sagrada Familia, St Paul's Cathedral and the Pantheon, are as a consequence to their structure and atmosphere, places where people continually go to and return to throughout time regardless of the original function transforming and changing. This thesis therefore principally, but not only, uses religious buildings as architectural references to understand the systems and elements at play that make certain buildings and atmospheres timeless.

# Design Claim

This thesis has two claims:

- The emotive and psychological experience felt often in religious architecture, and described as a “spiritual” feeling can in fact be, quantified and materialised as a meticulous calibration of light, geometry and structure.

- Digital design and fabrication allows for antiquated architectural methods to resurface into contemporary design practice for architecture that transcends time.



# Structure of Work

## READING INSTRUCTIONS

Part 1: The research thesis is initiated with literature studies of psychology and architectural theories on light. These studies give the reader awareness of the related topics to the thesis question and provide a basis of evaluation to the design studies. A detailed study of a reference project forms the framework of the design studies. Architectural systems that achieve the design resolution of the reference study are identified and the design studies look to establish the rules of the systems. The design studies are a series of computational model studies that examine the relationship of light with form, openings and composition in terms of light distribution, the interplay of light and shadow and light levels with spatial perception. The outcome of these studies is manifested in a design prototype.

Part 2: Research into stereotomy develops the prototype with regards to structure, mass and monumentality. A brief history of stereotomy gives the reader a background to this construction method and its relevancy to the thesis question. Past reference projects provide a basic understanding of the physics and design of stereotomic structures whilst modern design methods of computational design and digital

fabrication used by Mark Burry in Sagrada Familia and Matter Design Studio with their project La Voûte de LeFevre inspire the design development of the prototype. This part looks to tie together the physical aspect of the project with the atmospheric aspect.

Part 3: The prototype is contextualised by selecting a site and adapting the prototype to the surrounding context. A combination of architectural theory and a reference study establish systems to adapt the prototype. This part illustrates how the design prototype can be adapted to any context to achieve the same design concept - a timeless intimate social space within an urban environment.

Part 4: The results of the design studies develop the prototype into a design proposal of a public building at Annedal Junction, Gothenburg. The proposal is illustrated through design drawings that show how the spaces may be used without specifying the function of the building. The timeless nature of the proposal is illustrated through 3D perspectives of different eras and states of the structure. Reflections of the research thesis concludes this part.

## METHODS & MATERIALS

A combination of computational design and physical model making was used in this research to design. Through digital renders and photographs the design was evaluated using the theoretical framework and is to be regraded as empirical research.

Site analysis of the area was conducted through layer mapping, observations from site study visits and computational design programme to model topography and track sun paths.

## DELIMITATIONS

This thesis through research by design methodology looks to establish the link between the phenomenological experience of space with light and stereotomy. It explores innovative computational design to make stereotomy a viable structure in today's economic, societal and environmental climate. The outcome of the design research is to provide the reader with knowledge of how:

- The phenomenological experience of space, particularly emotive space is linked to psychology - how our

minds perceive space and consequently adapt our thinking to our surroundings.

- Computational design can be used in combination with modern stone cutting techniques to produce structures inspired by the past and yet is contemporary. Familiar and yet new.

The research intends to add to the greater discussion of the use of stone in modern construction and therefore will not include the specifics of a particular stone type. The outcome is a design proposal of a structure with a timeless value; defined through its strong impact of grandeur scale and its suitability to adopting various functions as required by the spiritual, physical and psychological needs of the user. The programme/function of the building is purposefully not specific to allow the reader to understand this very concept. The research thesis and resulting design proposal is not intended to be for one site and one programme but rather be an example of how a design system can be altered and adapted according to site whilst maintaining the timeless value of the structure and atmosphere.

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## References



# 1

# Theory

*This chapter forms the foundation of the research topic through the review of literature and architectural theory.*

- I.1 DISCOURSE
- I.2 LITERATURE REVIEW
  - I.2.1 PHENOMENOLOGY
    - I.2.2 LIGHT
  - I.2.3 PSYCHOLOGY
  - I.2.4 INTIMACY

# Research Discourse

PSYCHOLOGY  
+  
SPIRITUALITY

Neuropsychological  
Processes & Spiritual  
Sensation & Experience  
Perception Spatial Stimulation  
Social Behaviour & Cognition

**TIMELESS  
SECULAR  
EMOTIVE/ SPIRITUAL  
SPACE**

COMPUTATIONAL  
DESIGN  
&  
DIGITAL  
FABRICATION

Efficient Design  
&  
Production  
Structural Analysis  
Complex  
Structural  
Design

ANTIQUATED  
ARCHITECTURE

Geometry  
& Nature  
Stereotomy  
Voussoir geometry  
Building  
Techniques &  
Craftsmanship

Hapticity  
Spatial Scale Atmosphere Light  
Materiality Shadow  
Tactility

ARCHITECTURAL  
PHENOMENOLOGY

# Phenomenology

*The Eyes of the Skin: Architecture and the Senses (Pallasmaa, 2005).*

Juhani Pallasmaa addresses the issue of sight as the primary and only sense catered by architecture and the built environment. He not only argues for architecture to cater to all the senses in order for the simple experience of the user but also for deeper concepts relating to people. One such concept is freedom of thought and individuality through the use of light and shadow. The following quote illustrates this argument:

“A society of surveillance is necessarily a society of the voyeuristic and sadistic eye. An efficient method of mental torture is the use of constantly high level of illumination that leaves no space for the mental withdrawal of privacy; even the dark inferiority of self is exposed and violated.”

*Atmospheres (Zumthor, 2006)*

Peter Zumthor describes his personal observations of what creates atmosphere in space in the book *Atmospheres*. The process is divided into nine different themes ranging from the tangible to the intangible elements. His process of subjective observations give a compelling overview of the architectural tectonics that create space of emotion and feeling. He emphasizes on the immediate, visceral and emotional impact the building has on its user upon entry as illustrated in the following words:

“Quality Architecture is when a building manages moves me.”

“I enter a building, see a room, and - in the fraction of a second - have this feeling about it.

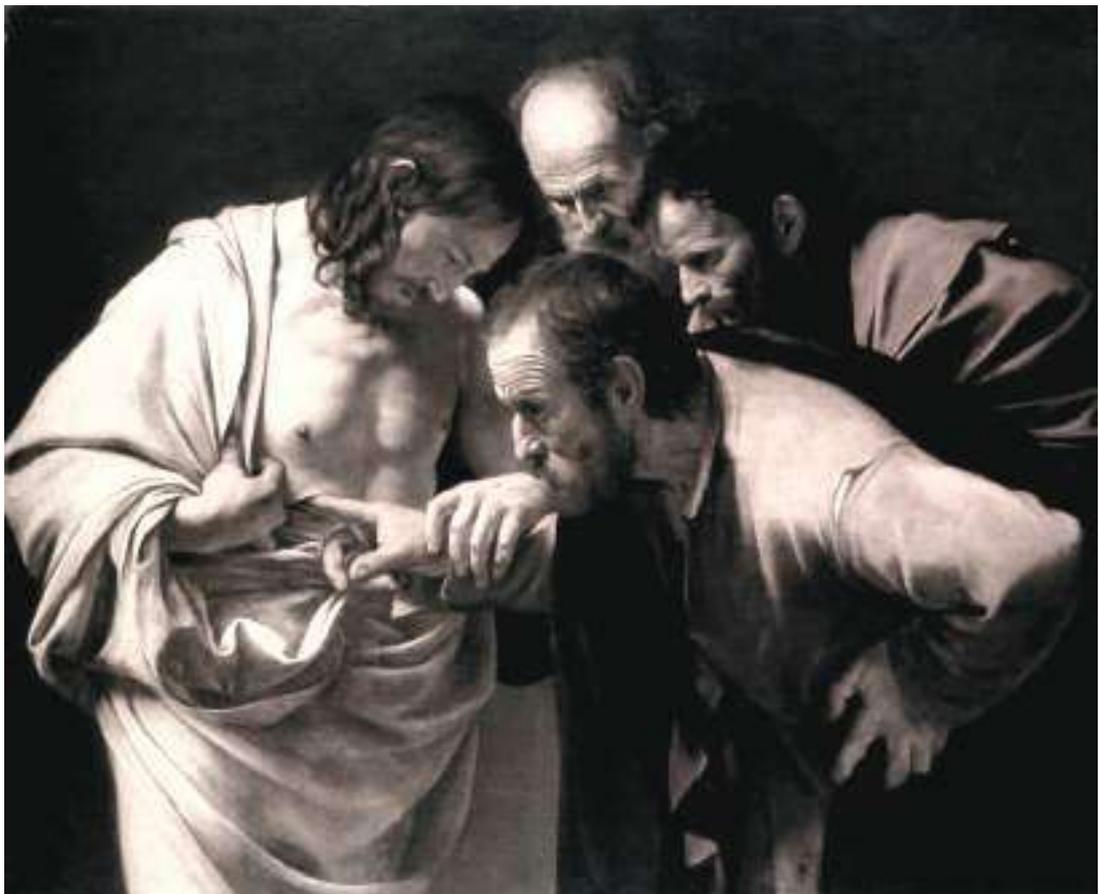
We perceive atmosphere through our emotional sensibility...We are capable of immediate appreciation, of spontaneous emotional response, of rejecting things in a flash.”

*Experiencing Architecture (Rasmussen, Steen Eiler)*

Steen Eiler Rasmussen tries to analyse how the users' experience of space is built upon their previous perceptions of space and their own appreciation of materiality whilst also understanding that the complexity of the experience and how it transpires.

“Architecture is not produced simply by adding plans and sections to elevations. It is something else and something more. It is impossible to explain precisely what it is - its limits are by no means well-defined. On the whole, art should not be explained; it must be experienced.”

Through chapters on daylight, acoustics and rhythm to name but a few he alludes to what has an affect on our experience of architecture through his own observations coupled with an analysis of existing buildings.



# Light

*Louis I. Kahn - silence and light: the lecture at ETH Zürich, February 12, 1969. Zurich: Park (Vassella, A, 2013).*

The book *Silence & Light* is the transcript of a lecture Kahn delivered at the School of Architecture at the Swiss Federal Institute of Technology in Zürich in 1969. The lecture explains his spiritual understanding of architecture and the importance of light in creating space. He emphasizes that architecture exists only with the presence of light whilst also highlighting the coexistence of light and dark. That one cannot be appreciated without the presence of the other.

“To me, natural light is the only light because it has mood. It provides a ground of common agreement for man, it puts us in touch with the eternal. Natural light is the only light that makes architecture ...”

“A plan of a building should be read like a harmony of spaces in light”.

- Louis Kahn

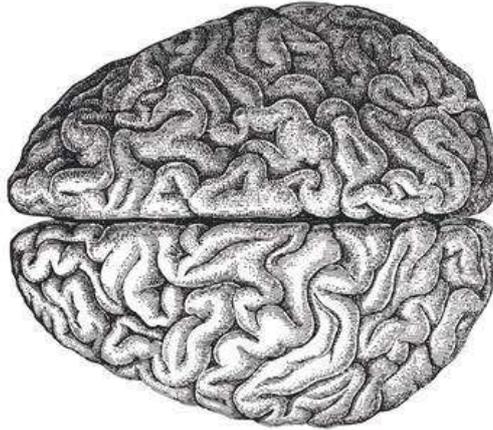
These quotes have inspired the design thinking behind this thesis by acknowledging that light transcends language

and cultural boundaries and is key in creating emotive space that is comprehensible to all. The second quote inspires the design and organisation of a plan that provides spaces with varied atmospheres by differences in light quality.

Steen Eiler Rasmussen also draws to the important of light in his book, *Experiencing Architecture*. He describes through the example of the Pantheon in Rome how the entry point of the daylight (above and through a single doorway) gives the incredible quality of light that exists and has always existed in that space. He shows by this example and through the comparison with the Cathedral in Copenhagen, *Vom Frue Kirke*, that the drama that is created by light is done so only with the contrast of shadow and if there is not a sufficient absence of light the light can fall flat and appear dull.



# Psychology

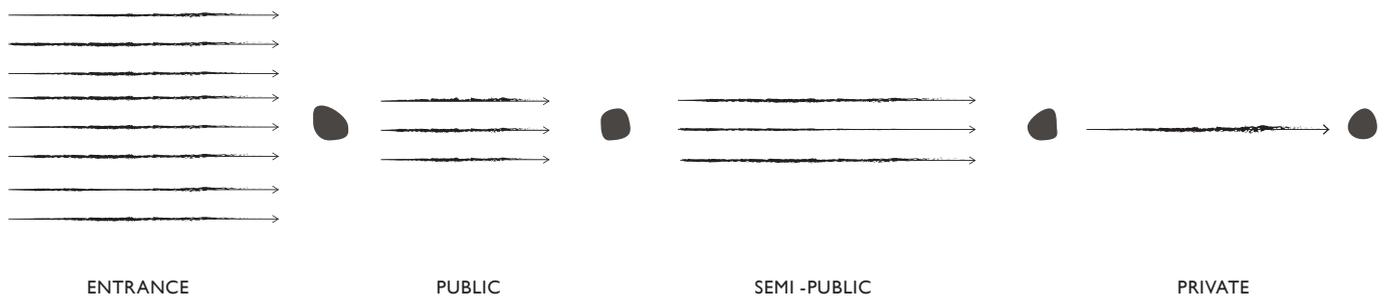


*The Influence of Ceiling Height: The Effect of Priming on the Type of Processing That People Use, (Meyers-Levy, J., Zhu, R Juliet).*

A study conducted by Joan Meyers-Levy in 2007 revealed how ceiling height influences how people think. People in a low height space were found to be quicker at solving anagrams involving confinement, such as “bound,” “restrained” and “restricted.” Whilst people in tall spaces excelled in puzzles that referred to themes of freedom, such as “liberated” and “unlimited.” According to Levy, this is because tall spaces make people feel free. Therefore it can be concluded that tall height spaces encourage abstract thinking, imagination and thinking beyond oneself.

A study published in Science in 2009 examined the influence of colour on imagination. It was found that red encouraged psychological affects of being alert and accurate whilst blue encouraged creativity.

# Intimacy



*A Pattern Language, (Silverstein, Murray, Ishikawa, Sara & Alexander Christopher, 1977).*

Christopher Alexander et al. outlays in pattern #127 the need of having a gradient intimacy to the spaces within a building in order to tackle the issue of homogeneity of space. A lack of variation in the quality, dimension and privacy of space can lead a lack of diversity in social interactions and how space is used generally by its users.

In particular he puts a focus on the sequence of spaces and the users movement through the building arguing that the most public areas are placed at point of entry and the most private is furthest away or more secluded from the point of entry.

“Unless the spaces in a building are arranged in a sequence which corresponds to their degrees of privateness, the visits made by strangers, friends, guests, clients, family, will always be a little awkward.”



# 2

# Design Research (Part 1)

*This chapter introduces the primary precedent study from which design research parameters are deduced.*

## 2.1 PRECEDENT I

### 2.1.1 STUDY

### 2.1.2 PARAMETERS OF ARCHITECTURAL SYSTEM

## 2.2 CONCLUSION

### 2.2.1 DESIGN METHOD I

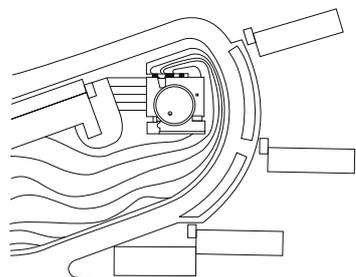
#### (LIGHT STUDIES)

# Study



The church is situated in a residential area. The site is entirely surrounded by housing blocks. The user is not aware of the surrounding context once inside the structure as external sound is muffled, light is diffused and visibility to the outside is highly restricted.

A concave dome hangs low over the nave, it is large in scale and appears heavy and oppressive whilst the circular plan of the nave counters acts this oppression with a geometry that encourages an intimate and secure atmosphere.

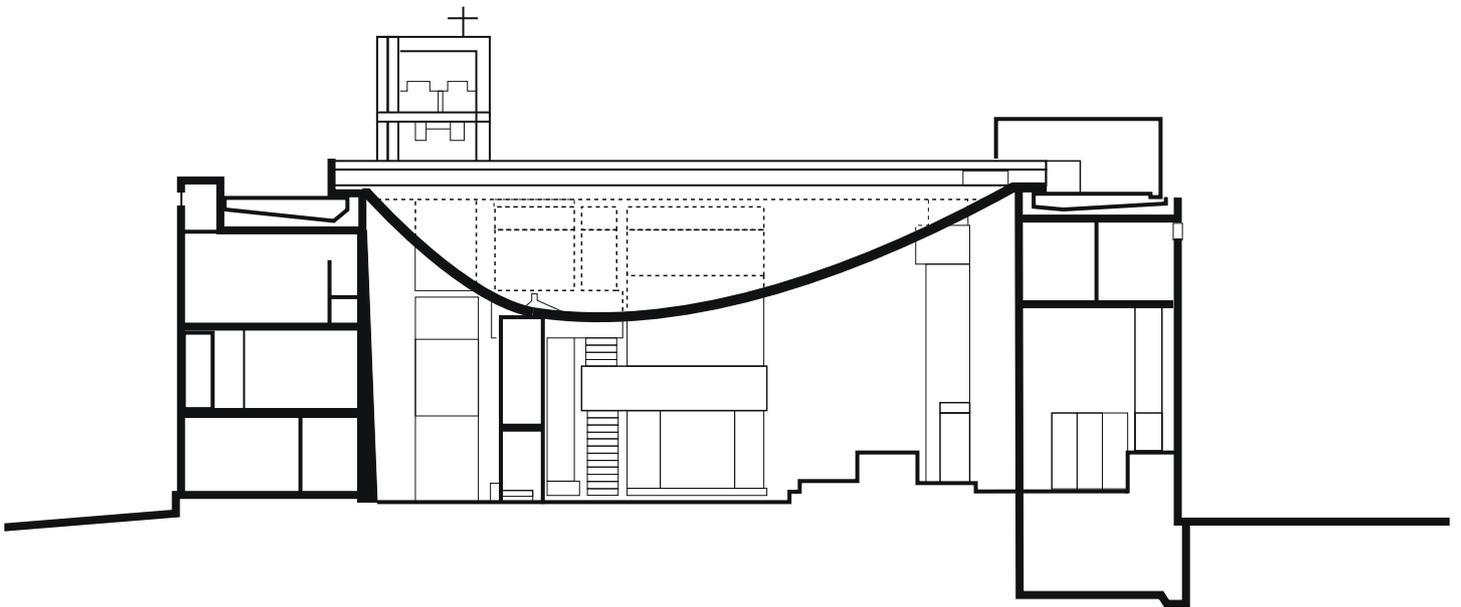
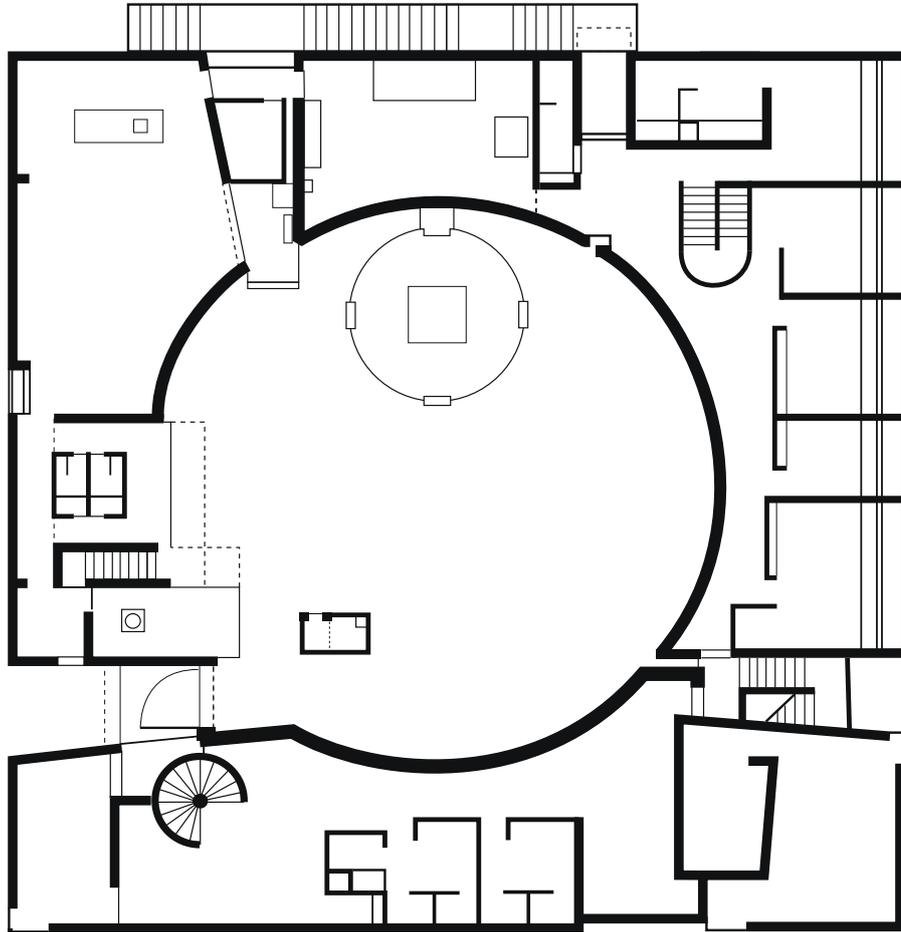


## *Base Architectural systems*

**Geometry:** the geometry (parameter) of enclosed space (element) and its relationship with light (agent) creating an intimate atmosphere (outcome).

**Diffusion of light:** the number and dimension (parameters) of openings (elements) allowing diffused light (agent) to enter into a dark space and retain its privacy (outcome).

**Scale and spatial configuration:** the scale and spatial configurations (parameters) of enclosed spaces (elements) allowing users (agents) to transition through spaces of varied levels of brightness and scale (outcome).



# Parameters of Architectural System

## QUALITATIVE

Privacy

- There is a level of privacy in the space that permits the experience of space without feeling watched or distracted.

Intimacy

- Space that encourages internal focus and/or close interaction with others within the space.

Scale

- Size and proportion of space and elements within the space results in the user feeling small.

## QUANTITATIVE

Light

-Test various light levels to determine how much light or the lack of it contributes to the perception of privacy, intimacy and scale

Spatial Geometry

- Study the relationship of geometry and how light is distributed.

Openings

- Examine the dimensions and position of the openings will determine how the amount of light and the quality of light can be controlled to create varied atmospheres.

Spatial Scale

- Examine the dimensions of the space and the elements that make up the space with relation to light and the human scale.

Composition

- Study the placement of spaces with varied dimensions and the relationship of the juxtaposition of contrasting spaces and the flow of movement and the act of wandering.

# Design Method 1

To transcend from one mental state to another is to describe an experience highly subjective to the individual. However the spatial attributes of the environment in which such an experience may take place may be considered to relate qualitative parameters deduced from the precedent study.

Using digital models design research will be conducted using the identified quantitative parameters with the results evaluated by using the qualitative parameters. The first design study will begin with geometry to determine the basic form of space and following studies will take their point of departure from the results of the previous study and so forth.



# 3

# Design Studies

# 1

*This chapter entails design studies on form with relation to light and spatial quality and sequence.*

3.1 GEOMETRY

3.2 OPENINGS

3.3 GEOMETRY + SCALE

3.4 PROTOTYPE

3.4.1 ELEMENTS

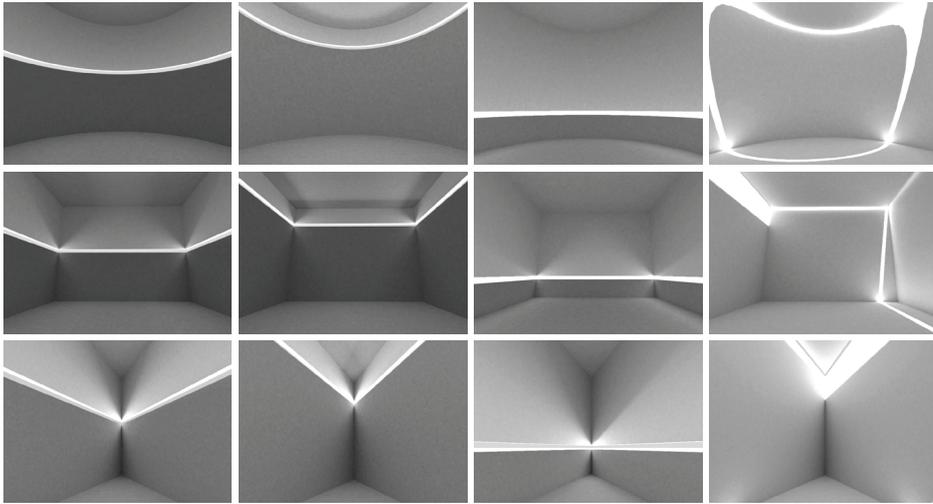
3.4.2 CONFIGURATION OF SPACE 1

3.4.3 CONFIGURATION OF SPACE 2

3.4.4 CONFIGURATION OF SPACE 4

3.5 CONCLUSION

3.5.1 NETWORK OF SPACES



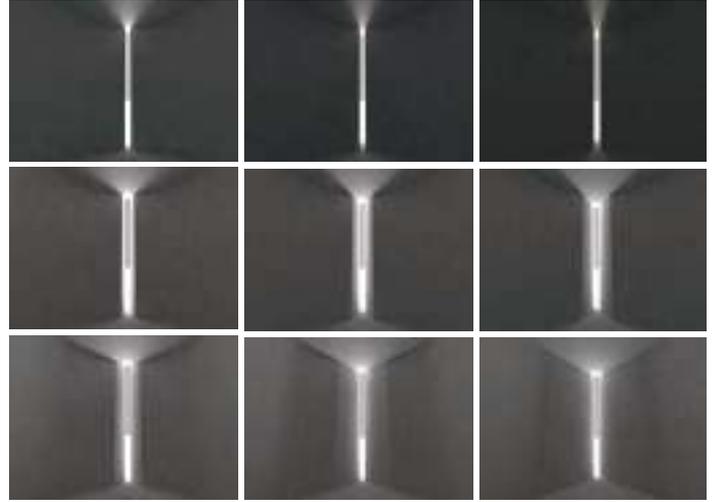
The geometry (parameter) of enclosed space (element) and its relationship with light (agent) creating an intimate atmosphere (outcome).

*Conclusion:*

The cylinder offers the optimal geometry with regards to the qualitative parameters.

As the strip opening affected the outcome of the amount of light entering the space as well as the light distribution and sense of scale, vertical placement of the opening will be further investigated.

Though openings placed above or on the upper half of the space lead the viewer's eyes upwards and gives a greater sense of depth to the space.



1. The number and dimension (parameters) of openings (elements) allowing diffused light (agent) to enter into a dark space and retain its privacy (outcome).
2. This study investigates the depth and angle of the opening which is the full height of the space.
3. This study investigates the depth and angle of the opening placed vertically high in the space.
4. This study investigates the depth and angle of the opening placed vertically low in the space.
5. This study compares the number of elements with the vertical placement of the opening.



*Conclusion:*



1) The scale (parameter) of an enclosed space (element) diffusing and controlling (outcome) the amount of light (agent) entering the space.

2) This study investigates the angle of the opening and the depth of space, treating the geometry as one unified space.

*Conclusion:*

(1) The cone geometry diffuses the light and retains a high level of intimacy, through lack of direct light exposure and visibility.

Outcomes with angled openings of 45 degrees and depth of space of 15000-30000mm were the optimal outcomes of this study. They offered diffused light whilst retaining a level of darkness that achieved a perceived intimate atmosphere.

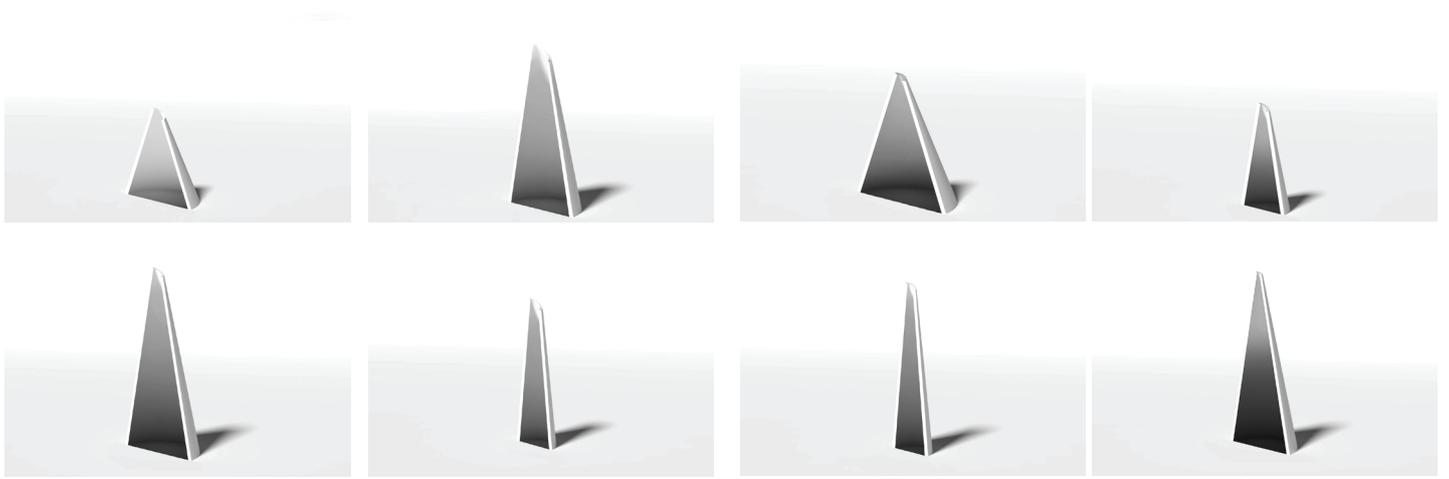
The distance between the opening and user directly

relates to the sense of scale within the space. The further the opening the smaller the user feels.

(2) This study reveals that distance from the opening may not only be achieved on the z axis but also on the y axis. The spherical spaces that were shallower in height but expanded in width shows varied levels of darkness, creating areas of varied intimacy within the same space.

The spherical geometry is without edges and flat surfaces creating a space that has a sense of continuity on every axis. The shallower spherical spaces expand in width and give the illusion of being more expansive than what they are.

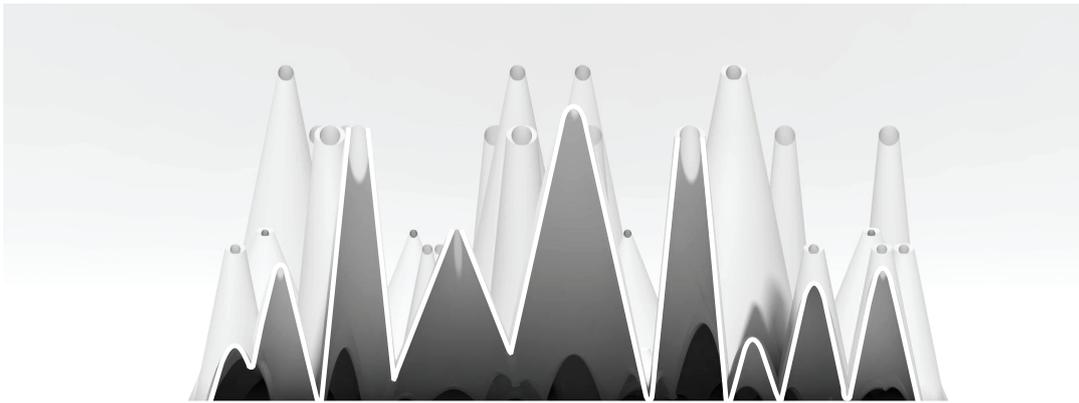
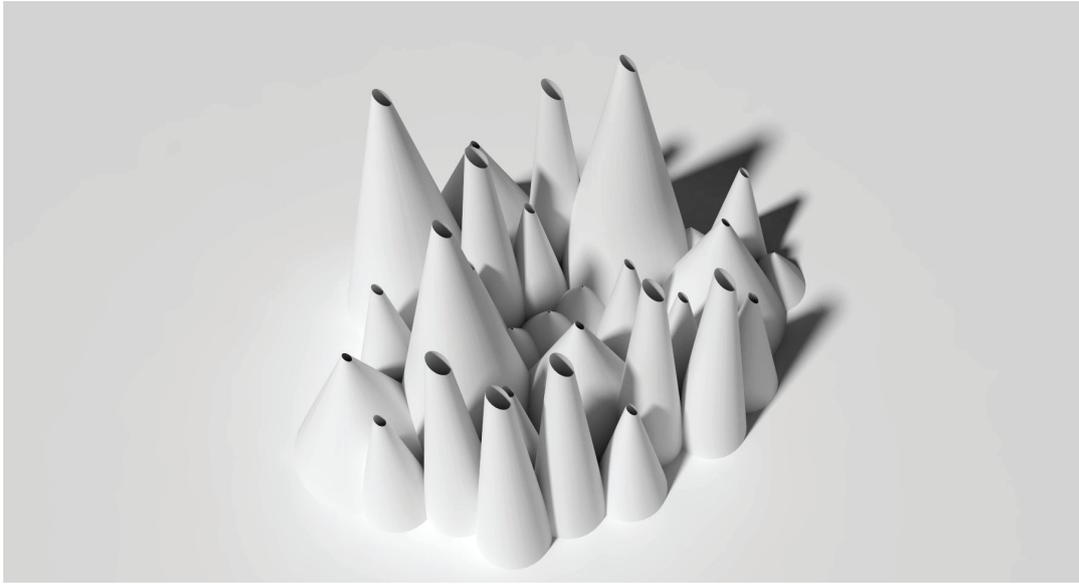
# Elements



The conical shape is taken forward as the prototype element as the entire shape is both the opening as well as occupied space. The cone dimension parameters can also be easily adapted to achieve varying results in terms of light and spatial quality.

Cone elements with two varying heights and two varying diameters were chosen in order to create diversity when developing the prototype.

# Configuration 1



SECTION 1:600

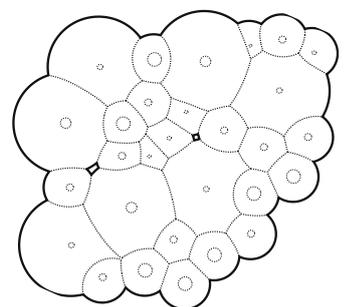
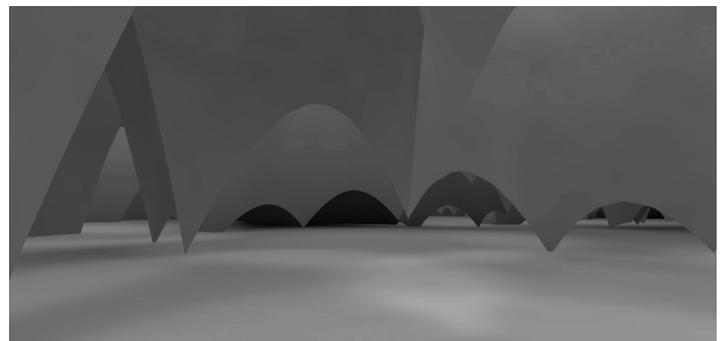
The spatial configurations (parameters) of enclosed spaces (elements) allowing users (agents) to transition through spaces of varied levels of brightness (outcome).

Configuration 1 looks at how various zones of intimacy are created by adding and converging cones together. Where each cone intersects with the other, the mass of both is eliminated to reveal catenary arches that act as gateways to another zone.

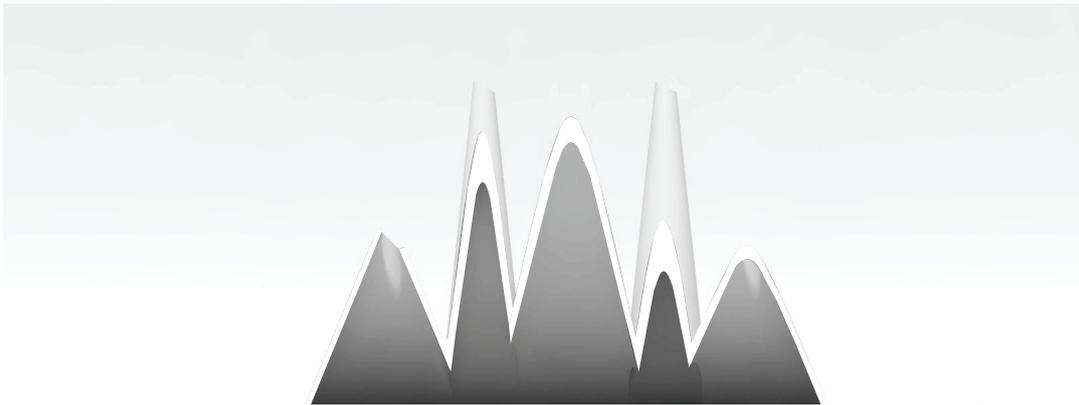
In this configuration the primary investigation was to understand how the prototype behaves when intensely connected in a large network, an extreme situation was created by knitting together the elements in an intense and random arrangement.

## CONCLUSION:

The initial prototype has a complexity to the structure and several spaces are connected to become one space that can be perceived as semi-public.



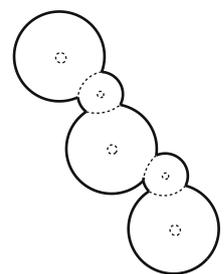
# Configuration 2



To redefine the space in terms of light and physical space, this study looked to limit the number of intersections of each conical element.

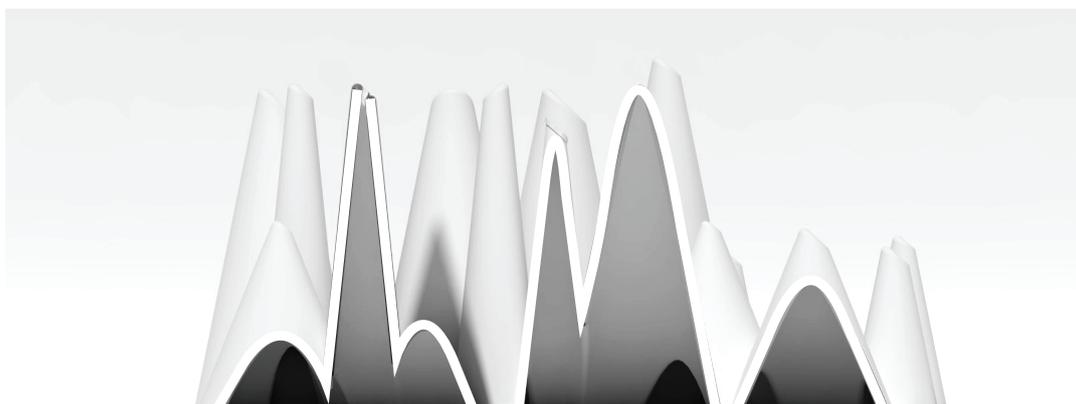
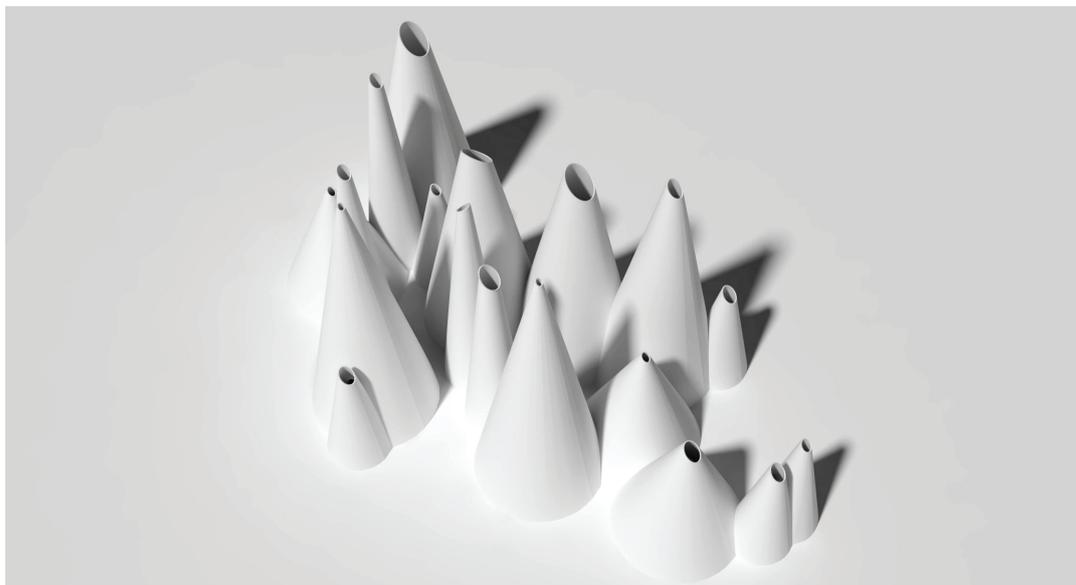
CONCLUSION:

Limiting the intersections to 1-4 and placing cones of contrasting light and spatial qualities found the optimal results in retaining defined spaces.

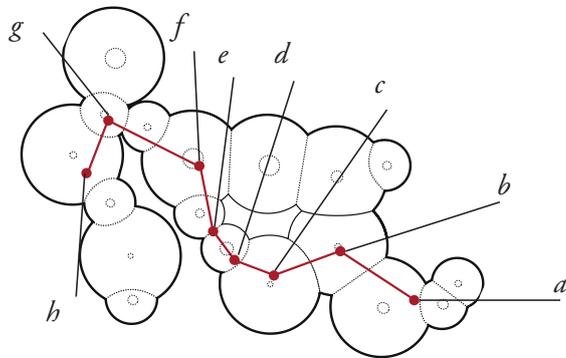
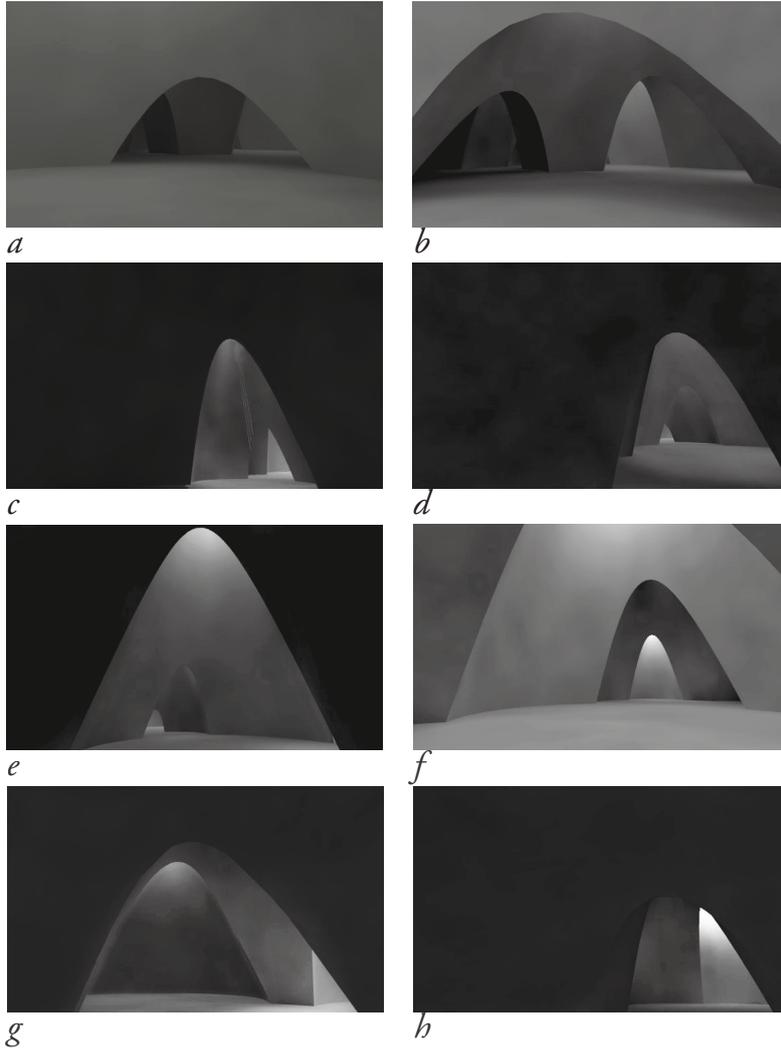


1:1000

# Configuration 3



This study expands from the previous study to create a more diverse network of interlocking spaces.



# Network of Spaces

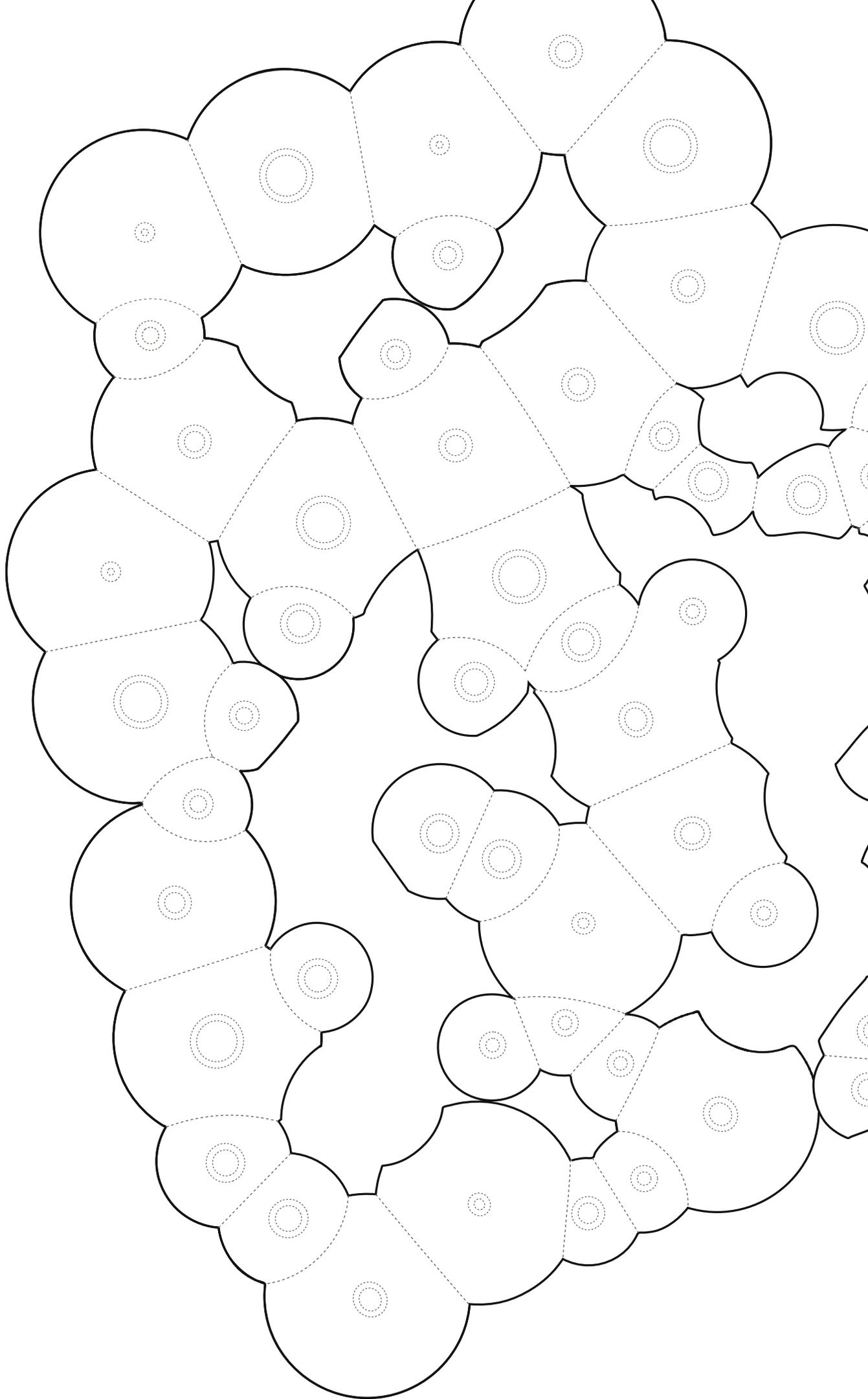
The prototype has expanded into a network of spaces that offers varying degrees of intimacy, scale and spatial geometry. Through the process of design iterations the opportunity to explore rhythm of light and shadow presents itself as well as creating an open plan of interconnected spaces. The light in the space, how enclosed the space is and the angle at which it is juxtaposed to an adjoining defines and differentiates the spaces.

“The Architectural Promenade” concept inspires the logic of how the prototypical elements interconnect with one and other. With this concept the individual spaces are then experienced sequentially with glimpses of varied and “unexpected” aspects in a fluid plan.

The calculated composition of spaces create a varied landscape of alternating light and spatial qualities whilst also establishing a hierarchy of spaces of architectural events.

“Architecture is experienced as one roams about in it and walks through it...So true is this that architectural works can be divided into dead and living ones depending on whether the law of ‘roaming through’ has not been observed or whether on the contrary it has been brilliantly obeyed.”

(Le Corbusier, 1942)





# 4

# Contextualising Prototype

*In this chapter the process of contextualising the prototype is elaborated on through precedent study and a design iteration.*

## 4.1 SITE

### 4.1.1 SITE INTRODUCTION

#### 4.1.2 ANALYSIS

#### 4.1.3 SUN PATH DIAGRAM

#### 4.1.4 STRATEGY

## 4.2 PRECEDENT 2

### 4.2.1 PRECEDENT STUDY 2

### 4.2.2 PARAMETERS OF CONTEXTUALISING SYSTEM

## 4.3 CONCLUSION

### 4.3.1 DESIGN RESEARCH METHOD 3

## 4.4 DESIGN ITERATION

### 4.4.1 ORGANISED FORMATION

### 4.4.2 CROSS SECTION & WORM'S EYE PLAN



# Site Introduction

The site lies at the junction of Annedalskyrkan. It is surrounded by busy vehicular movement as well as pedestrian traffic. It is at the bridging point between the south and the city centre and has a close connection to various institutional establishments. Annedalskyrkan overlooks the site and is situated to the north of the site.

The site challenges the prototype by two principle factors: physical context and symbolic context.

## *Physical*

There is constant movement around the site and there is a lot of diversity in terms of the surrounding urban fabric. This conflicts with what the prototype aims to provide which is, a blank canvas space in which users have the freedom to contemplate, momentarily transcend to another realm or engage with others in an intimate place.

## *Symbolic*

Annedalskyrkan is a dominant structure in the context both with its physical position overlooking the surrounding area as well as its massive scale. It is a religious building that looks to offer transcendental space in a heavily articulated religious context. The prototype on the other hand represents a public structure that offers transcendental space free from symbolic ornamentation and oppression. It also aims to embed itself within the context rather than dominate it.

# Analysis

TRAFFIC



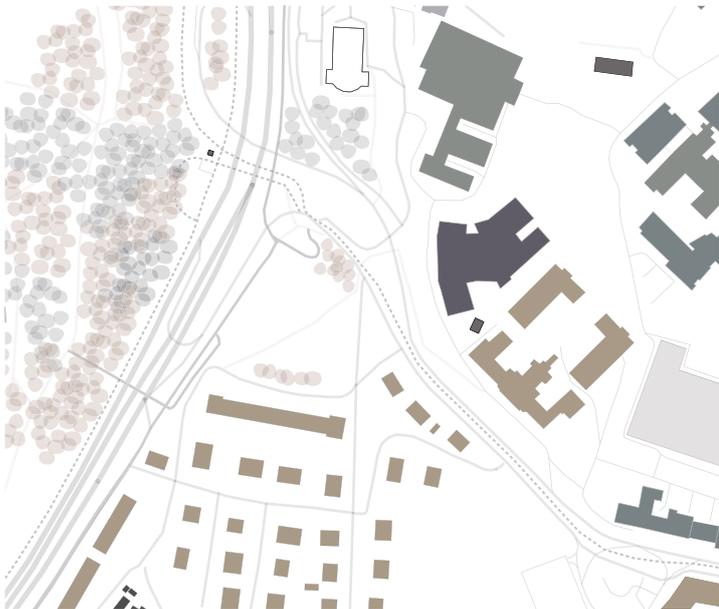
SOUND



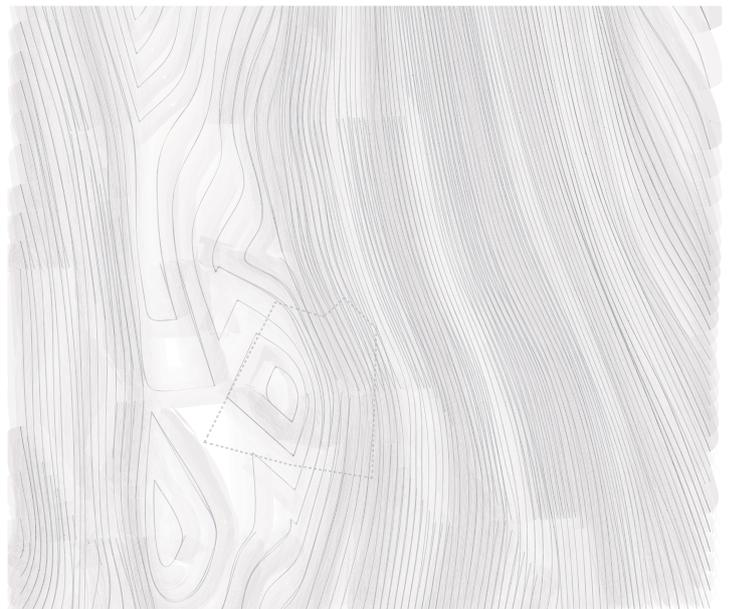
- MAJOR ROAD
- MINOR ROAD
- FOOTPATH
- CYCLEWAY
- TRAM LINES

- DBA LEVELS
- 50 - 55
  - 55 - 60
  - 60 - 65
  - > 65

THEMATIC INVENTORY

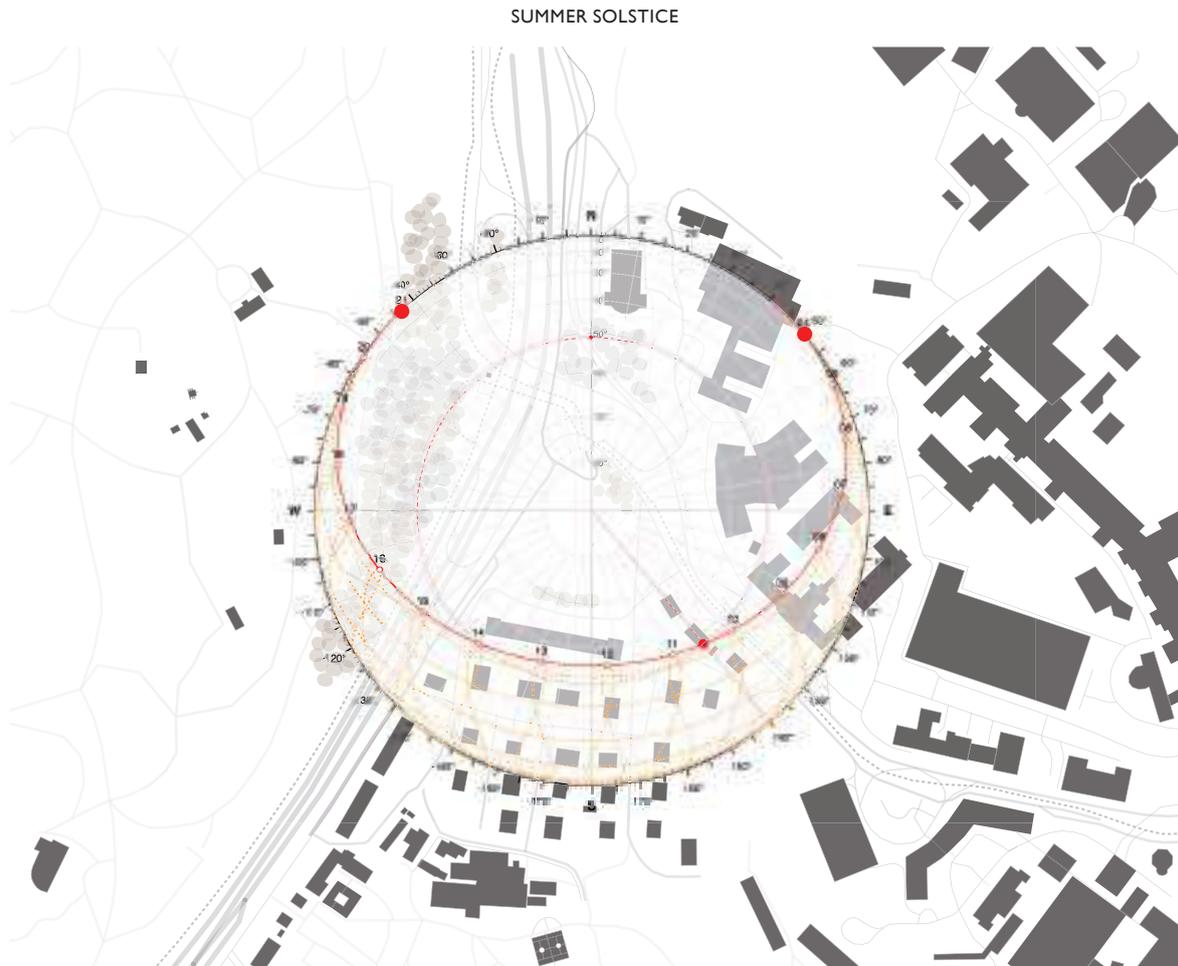


TOPOGRAPHY

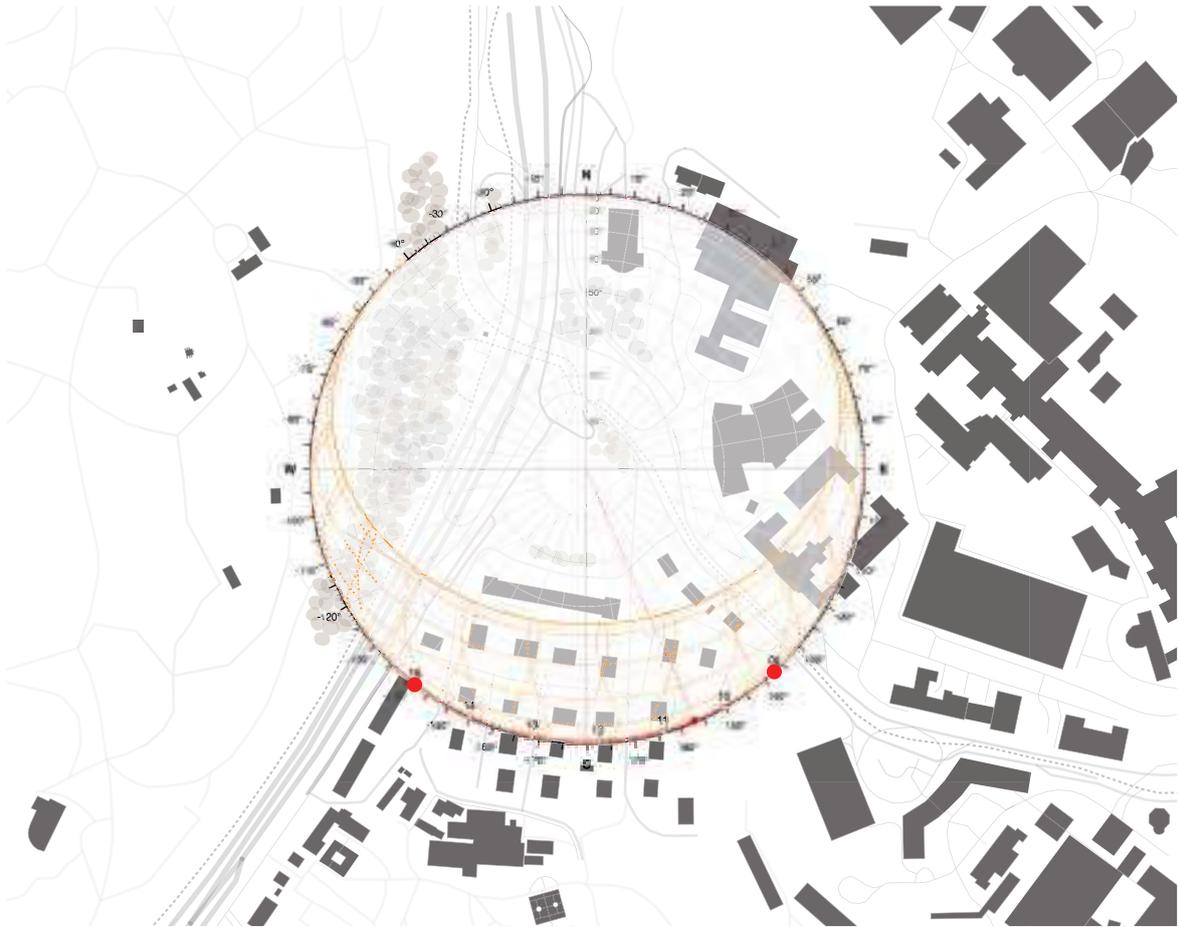


-  RESIDENTIAL
-  SITE
-  PARK
-  MIXED USE
-  RELIGIOUS BUILDING

# Sun Path Diagrams



WINTER SOLSTICE



# Strategy

ENTRY POINTS



Entry points to site exist in each corner of the site

1:5000

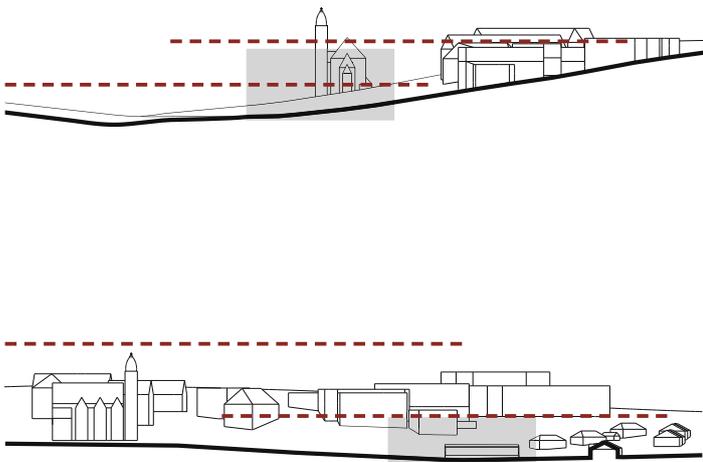
BARRIERS & APPROACH



— Greater depth and height of barrier/ structure  
— Internal structure  
... Dissolved barrier/ structure and of lower height

1:5000

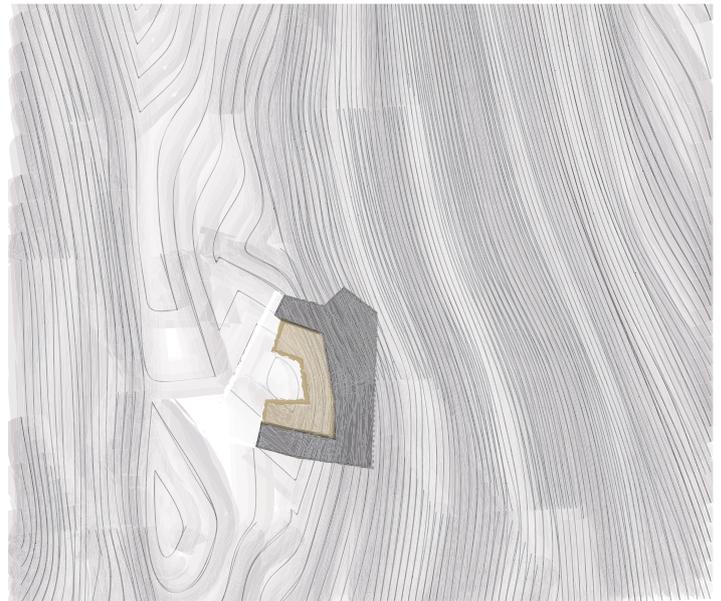
### LEVELS & HIERARCHY



--- Levels in topography and building scales show a distinct hierarchy of urban areas. Site relates to low residential area to the south whilst also facing dominant structures to the north.

1:5000

### ZONES & ORIENTATION



- Intimate
- Semi-intimate
- Public

The topography of the site offers varying degrees of perceived intimacy.

1:2000

# Precedent Study 2

CCP PAVILION, REPÚBLICA PORTÁTIL, PLAZA DE LA INDEPENDENCIA CHILE

The site is frequented by hundreds of people daily and is in the middle of the productive and creative sectors of the city. This pavilion aims to provide a place to gather people of both sectors in an intimate environment in the middle of a busy junction that connects both sectors.

“Unless the spaces in a building are arranged in a sequence which corresponds to their degrees of privateness, the visits made by strangers, friends, guests, clients, family, will always be a little awkward.”

A Pattern Language,  
Alexander Christopher et. al

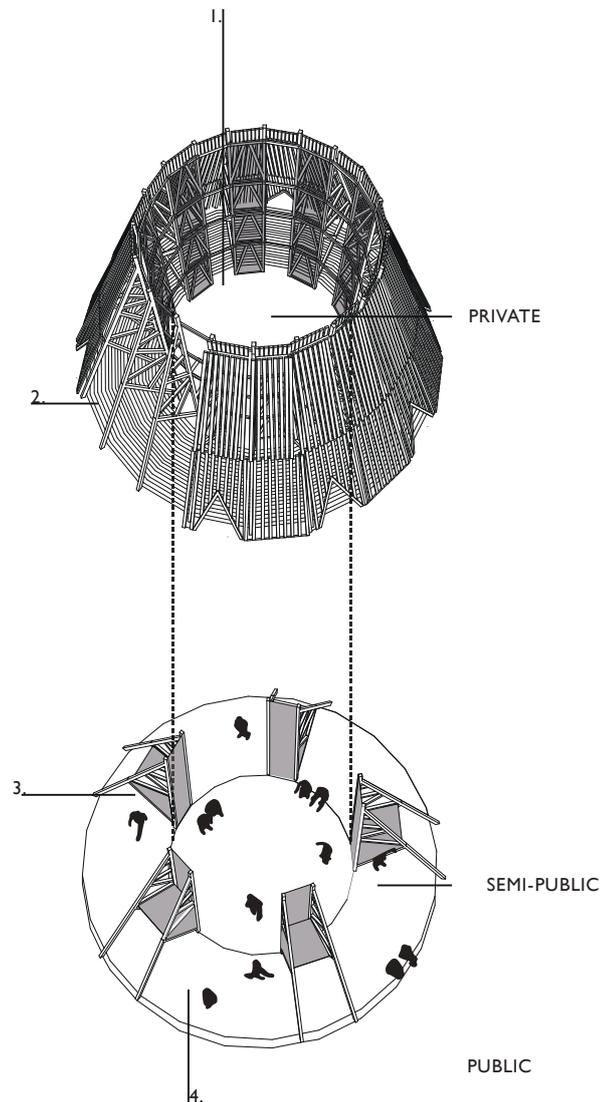


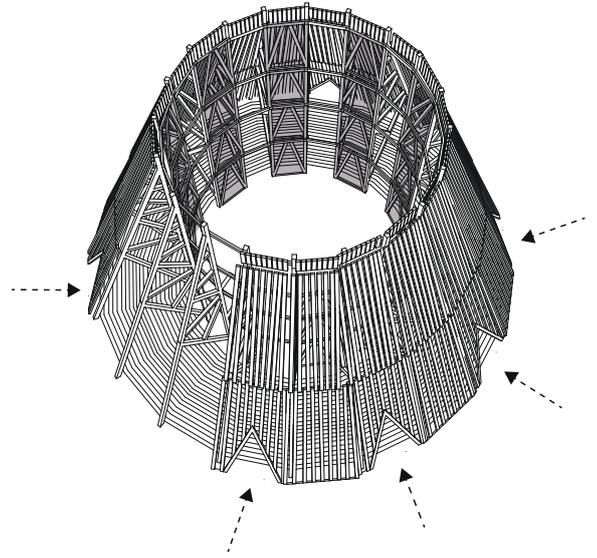
# Organisational System

## BASE ORGANISATIONAL SYSTEM:

The composition of spaces (parameters) created by the “arcade” and inner courtyard (elements) allowing people (agent) to experience a gradient of intimate zones (outcome).

1. Inner courtyard, a semi public introverted space. Cylindrical in form further enhancing intimacy.
2. “Arcade” of vertical structural elements creating a series of arches around the perimeter of the pavilion.
3. Lower height levels achieved by solid elements inserted within the structure to create more intimate zones.
4. Entry points leading straight to the inner courtyard.



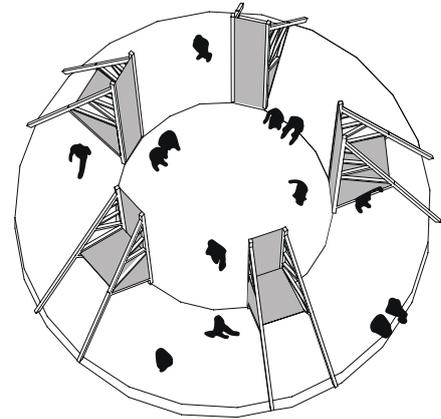


#### ENTRY POINTS

Access to the inner core is permitted from around the entire pavilion perimeter- thereby no formal entrance or spatial hierarchy.

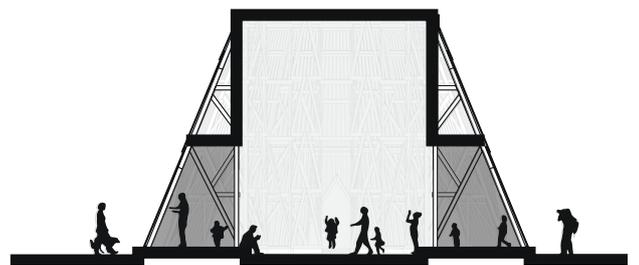
#### ZONES

Layers of intimacy is created through the “arcade”. The “arcade” creates an intermediate zone between the public and private areas.



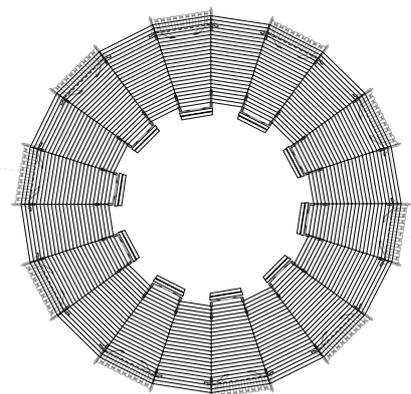
#### LEVELS

A change in floor level as well as height levels correspond to semi public space and enclosed space corresponds to semi private space.



#### CORE

Whilst the core is the courtyard space within the pavilion, it is an introverted space that creates intimacy in an urban environment.



# Design Research Method 3

## MERGING CONTEXTUAL ANALYSIS WITH ORGANISATIONAL SYSTEM

The second precedent study provides an Organisational system to create an intimate introverted space within a busy urban environment. This system will be superimposed with the contextual analysis to adapt the system according to the chosen site for the design proposal. This system when combined with the context analysis allows for this prototype to be adapted to make it site specific. The parameters of the contextual analysis and precedent study will be used to inform the placement of the prototype elements in the digital design process. The parameters are as follows:

### HEIGHT

Cones of varying heights and diameter to create spaces with diverse spatial quality.

### INTERCONNECTIONS

Limit intersections to 1-2 for private and semi-private zones.  
Increase intersections for public and semi public areas.

## ZONES

The composition of (parameters)structure/ form (elements) to create a gradient of intimacy zones (outcome) corresponding to existing traffic (agent).

### ENTRY POINTS & BARRIERS

The placement (parameters) of entry points (elements) allowing people (agent) to enter the structure from the most calm areas (outcome).

The composition (parameters) of barriers (elements) blocking noise (agent) from surrounding major roads to create intimate and peaceful zones where there currently is none (outcome).

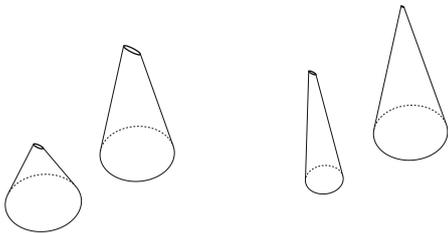
## LEVELS

The organisation of (parameters) structure/ form (elements) that corresponds to surrounding building scale and hierarchy (agent) to contextualize the prototype accordingly (outcome).

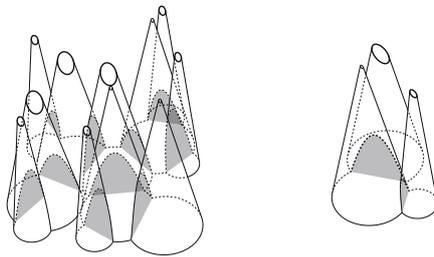
## ORIENTATION

The individual elements are orientation towards south east, south and south west in order to maximise daylight throughout the prototype throughout the day.

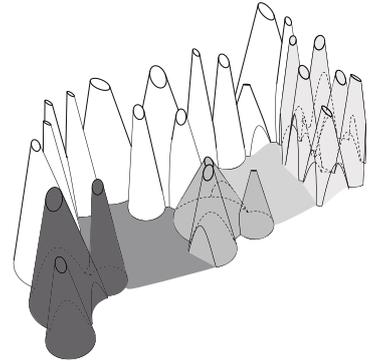
HEIGHTS



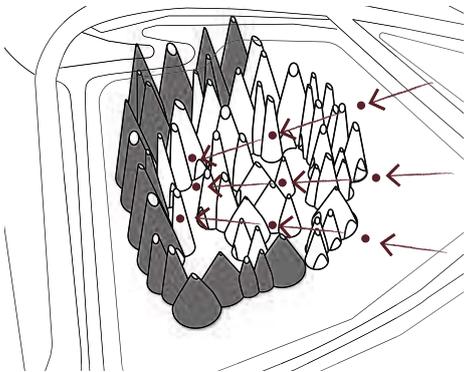
INTERCONNECTIONS



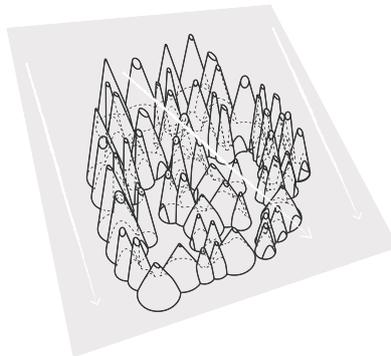
ZONES



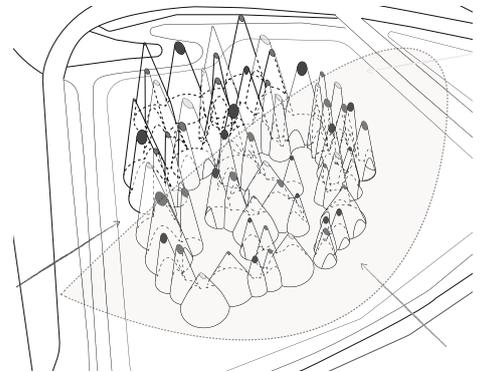
ENTRY POINTS & BARRIERS



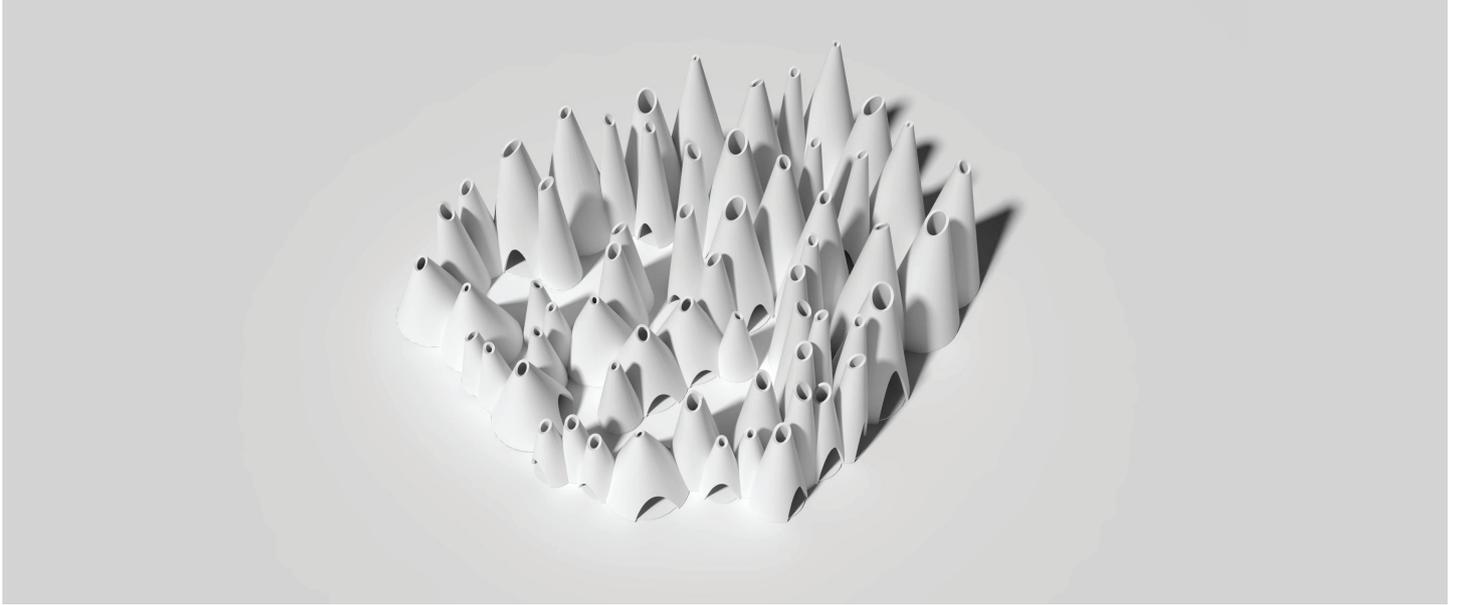
LEVELS



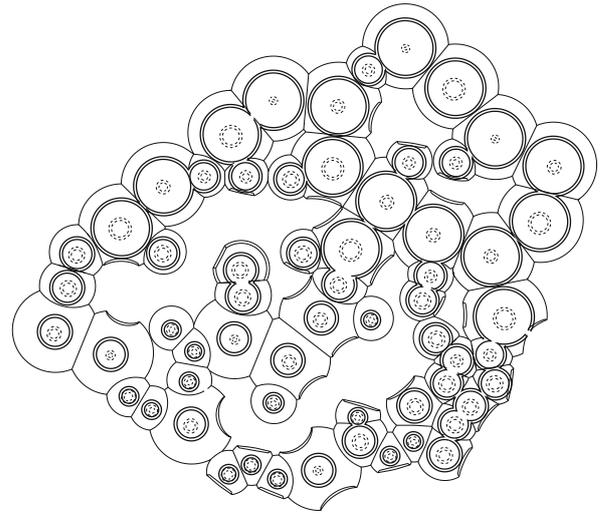
ORIENTATION



# Organised Formation



Following the Organisational system coupled with contextual analysis of the site the prototype has developed its formation to be site specific with an internal organisation of creating a space a gradient of intimacy zones.



1:1000

# Sequence of Spaces

1. PRIVATE ZONE



1. PRIVATE ZONE



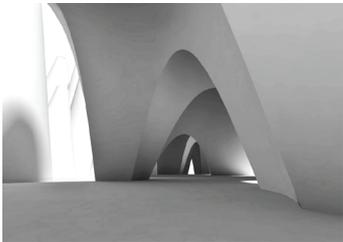
2. PRIVATE COURTYARD



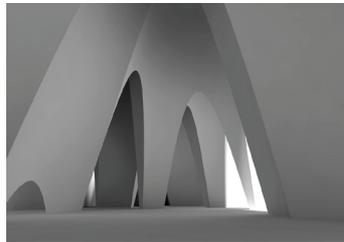
2. PRIVATE COURTYARD



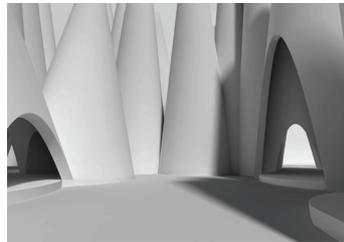
3. SEMI-PUBLIC ZONE



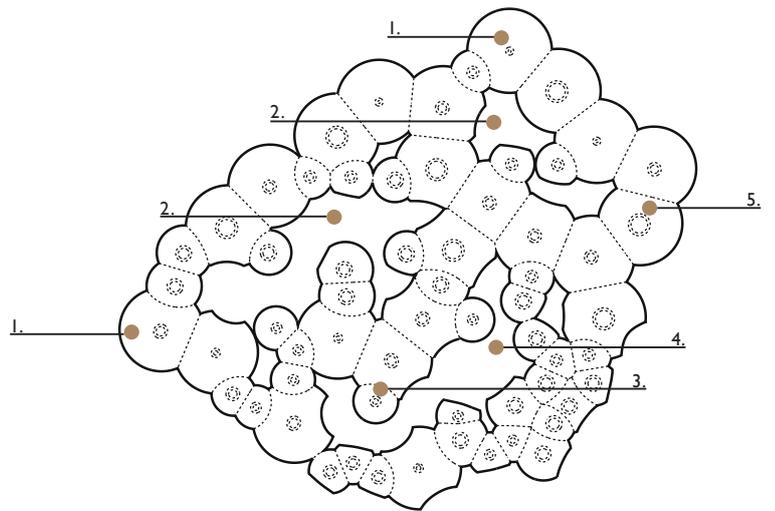
SEMI-PUBLIC ZONE



4. PUBLIC COURTYARD



5. SEMI-PRIVATE ZONE



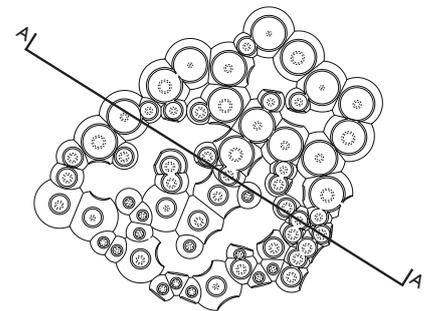
# Cross Section & Worm's Eye Plan

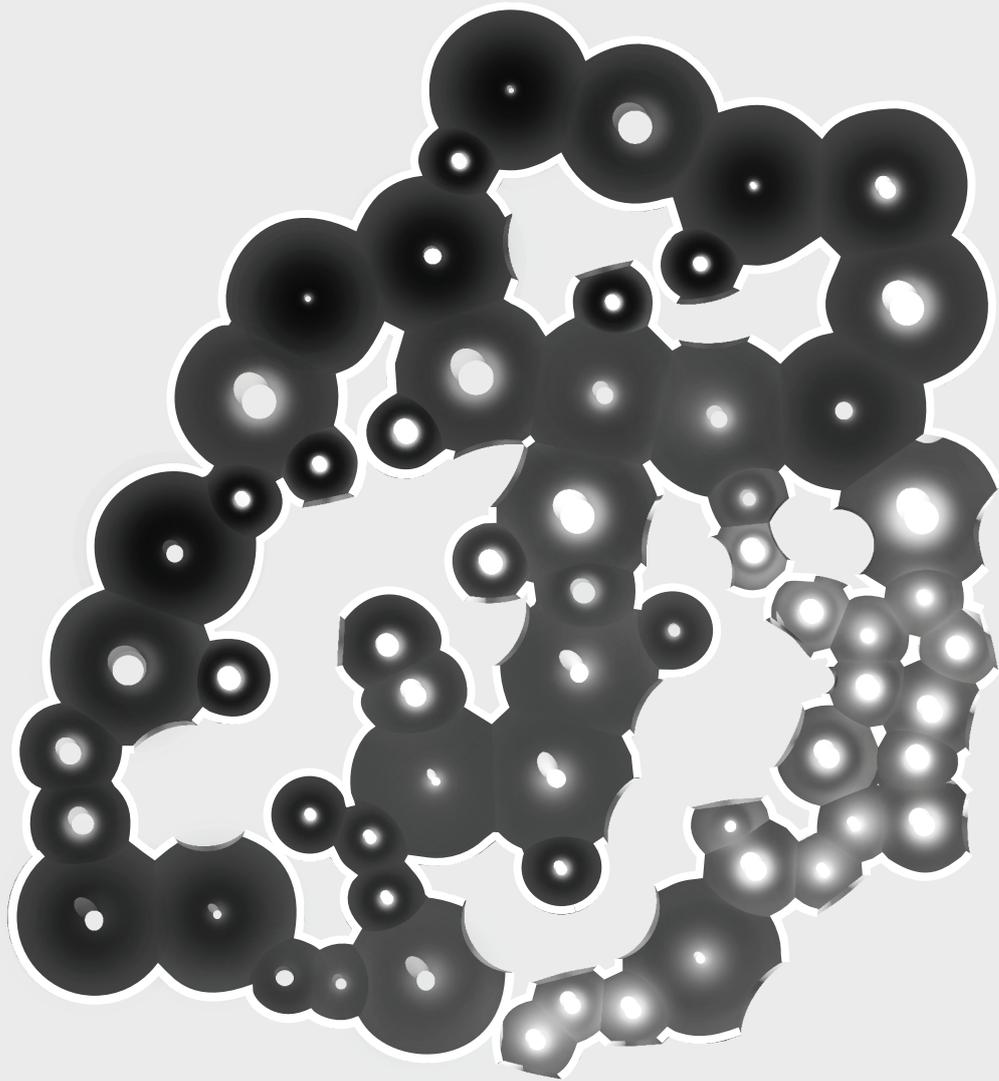


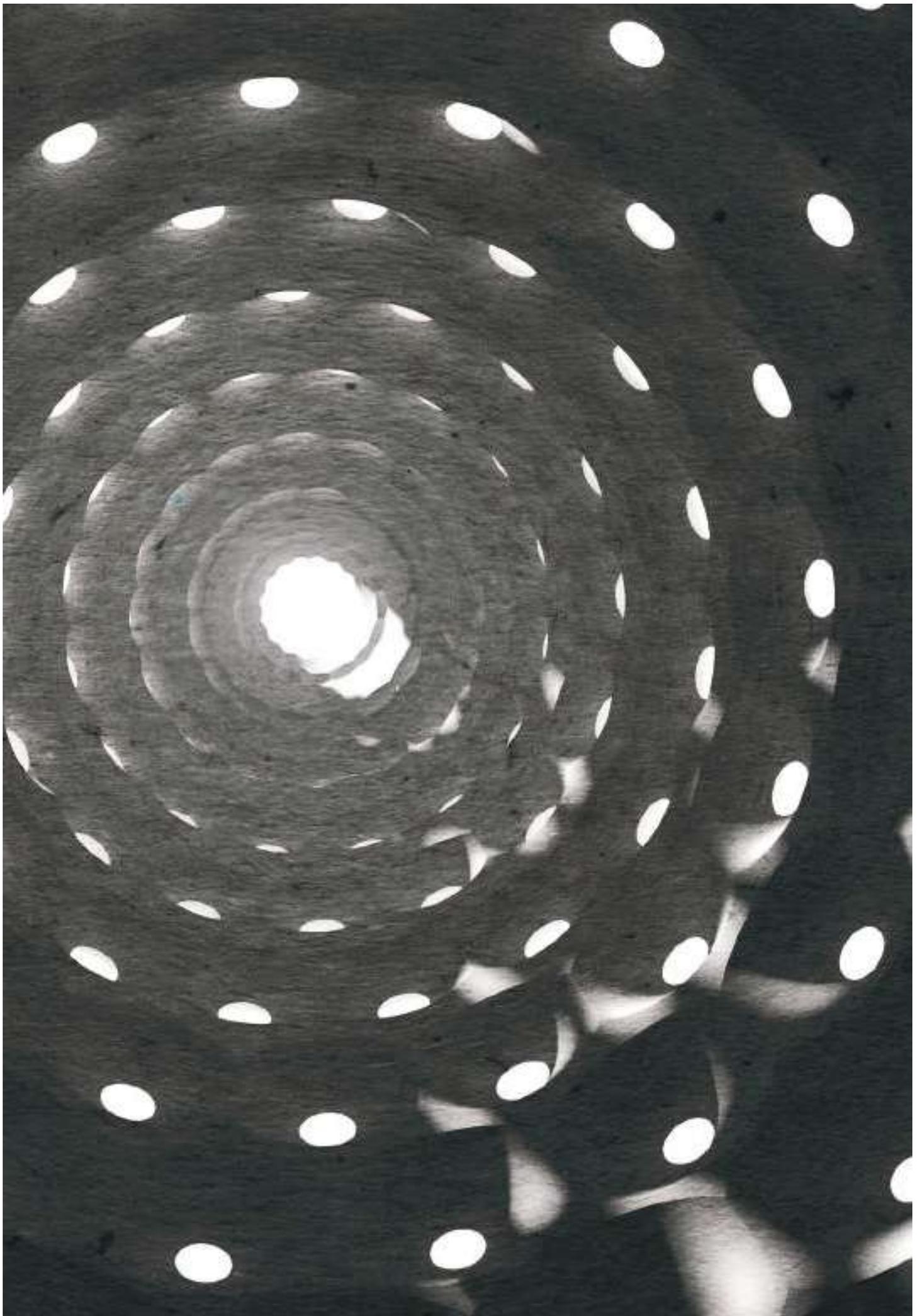
SECTION A-A 1:500

## CONCLUSION:

The formation has revealed a natural tendency of the prototype to create “courtyard” spaces. This was exploited whilst designing the formation as it created the “core” space, a design strategy from the organisation system.







# 5

# Form to Mass

*Chapter 5 investigates stereotomy as the structure of the prototype.*

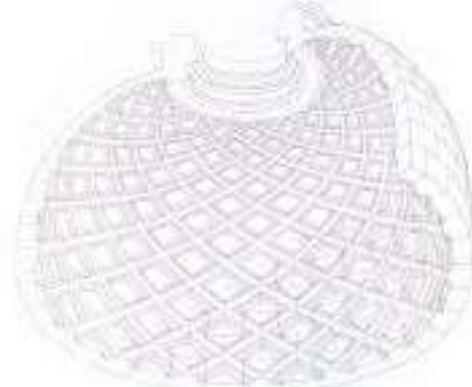
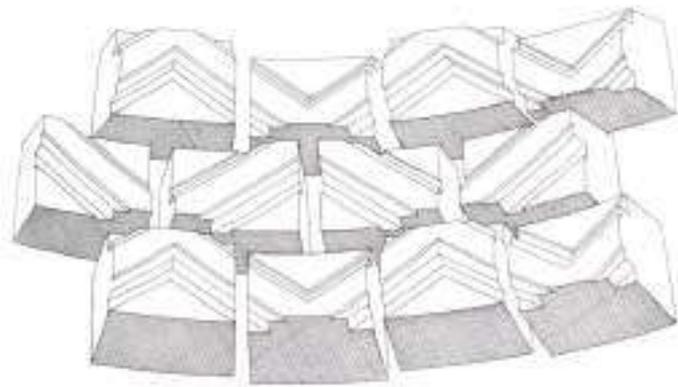
- 5.1 STEREOTOMY
  - 5.1.1 ANTIQUATED & CONTEMPORARY EXAMPLES
  - 5.1.2 PARAMETERS OF STRUCTURAL SYSTEM
- 5.3 CONCLUSION
  - 5.3.1 DESIGN RESEARCH METHOD 2
- 5.4 BLOCK CONFIGURATION
  - 5.4.1 PHYLLOTAXIS & RADIOLARIAN
  - 5.4.2 LOGARITHMIC SPIRAL PATTERNS
- 5.5 DIGITAL MODEL STUDIES
  - 5.5.1 TESSELLATION
  - 5.5.2 ALIGNMENT OF ARCH BLOCKS
  - 5.5.3 HYPERBOLOID BOOLEAN SUBTRACTION
- 5.6 PHYSICAL MODEL STUDIES
  - 5.6.1 CNC MILLED HYPERBOLOID SURFACE
  - 5.6.2 PROTOTYPE PRINTED IN 3D
  - 5.6.3 1:1 SINGLE BLOCK MODEL
  - 5.6.4 CONCLUSION

# Antiquated & Contemporary Examples

1.



2.



Stereotomy describes practice of cutting stone to fit and interlock with one another three dimensionally. It fulfills the function of static structure and decorative form - combining structure and aesthetic in one. This art of construction dates back to ancient times with the Inca architecture as one of the first and oldest examples existing today. Baroque architecture serves many examples of stereotomic architecture, Philippe L'Orme provided some of the finest examples of highly decorative and impressive stereotomic architecture. The blocks of stone are massive stone mathematically and geometrically calculated to hold each other up without the need of bonding or a secondary structural system. The tessellated pattern of the blocks gives rhythm and a haptic quality to the structure making it highly expressive and sensual and ideal in qualitative

terms for the development of this prototype,

## 1. INCA WEDGE SYSTEM

A section of the wall of Sacsayhuamán, a citadel on the northern outskirts of Cusco, Peru.

## 2. BAROQUE ARCHITECTURE

Chapel, dome, stones assembly diagram From Philibert de L'Orme, Philippe Potié, Éditions Parenthèses, Paris 1996



Recent examples of stereotomy that inspire this thesis are Sagrada Familia, Gaudi; La Voûte de LeFevre, Matter Design Studio and Armadillo Vault, ETH, Block Research Group. These projects use the principles of ancient stereotomic structures in combination with modern computational design and fabrication techniques. By doing so, they allow antiquated systems to resurface into contemporary construction by means of efficiency in design, fabrication, transportation, construction and thus making stereotomic architecture more economically viable.

“reengage a problem that may be unfamiliar in contemporary culture. This terrain produces something new, an architecture that is somehow ancient yet contemporary, heavy yet light, familiar yet alien.”

- Matter Design Studio.

# Parameters of Structural System

## QUALITATIVE

Monumental

- Readily identifiable as being a construction achieved by something greater than oneself.

Atmosphere

- Architectural space that engages the senses and has an emotional sensibility

Timeless

- A structure that appears lasting physically and functionally in all stages of existence (newly built and ruin)

## QUANTITATIVE

Component Geometry

- Study the size and complexity of the geometry with regards to monumentality and fabrication.

Aperture

- Design research apertures/porosity within the fabric of structure for diffused and dappled light in interior spaces.

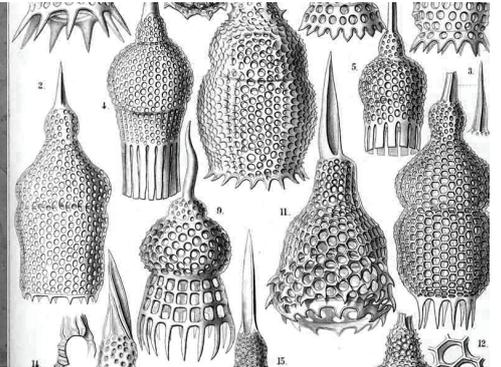
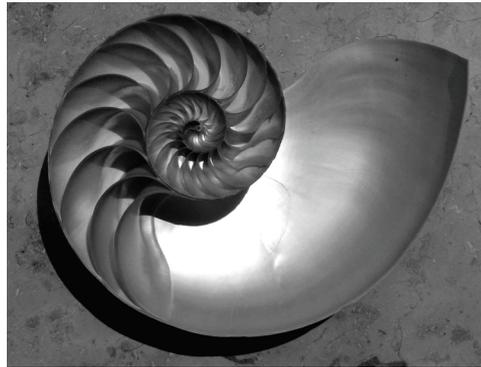
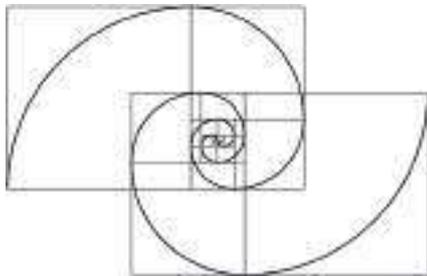
Surface Treatment

- Design research how design of blocks and apertures can add tactility to surface of structure and articulate light and shadow.

# Design Research Method 2

Design research into stereotomy will further lead the development of the prototype. A study of Sagrada Familia, Barcelona, Gaudi, substantiated the importance of monumentality with the design of emotive atmosphere and consequently led the design development through research of stereotomic architecture. A brief look into nature and naturally occurring mathematical pattern arrangement will initiate the design research of how the blocks of each cone will be arranged. Digital modeling will initiate the research and physical models will be used to test and evaluate the design.

# Phyllotaxis & Radiolarian

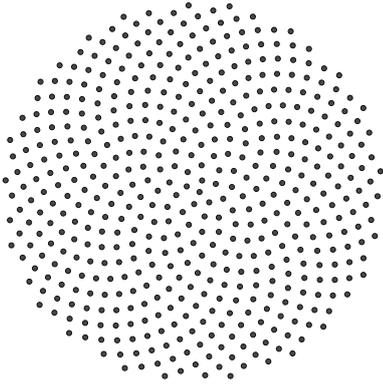


By looking at logarithmic spirals such as the Fermat's spiral also known as a parabolic spiral an understanding of how blocks can be configured in a stereotomic manner- meaning blocks that fit together and will hold each other in place. The sunflower is an example where the mesh of spirals follow the Fibonacci numbers. When the disc in the sunflower has matured the spirals are Fermat's spirals, turning equally around the annuli.

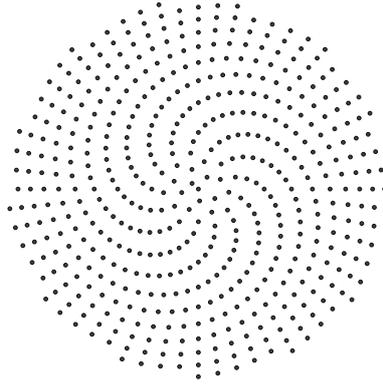
The diatom and radiolarian have a perforated hexagonal structure that have considerable compressive strength whilst allowing the structure to remain light. The curvature of the structure and its apertures provides inspiration in the design of the apertures.

# Logarithmic Spiral Patterns

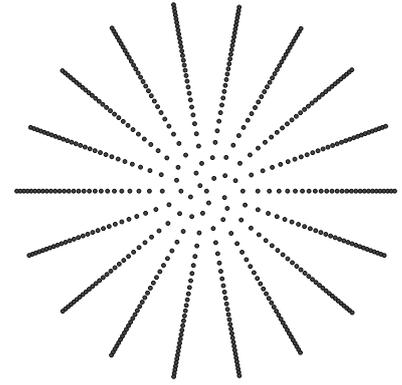
GOLDEN RATIO ANGLE  
FERMAT'S SPIRAL MESH 137.508°



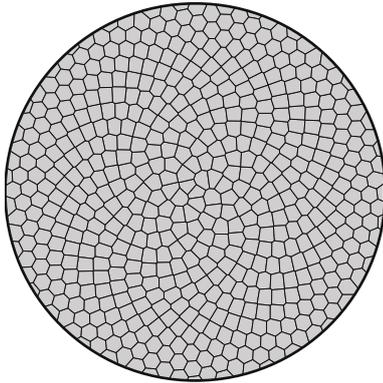
SPIRAL 138°



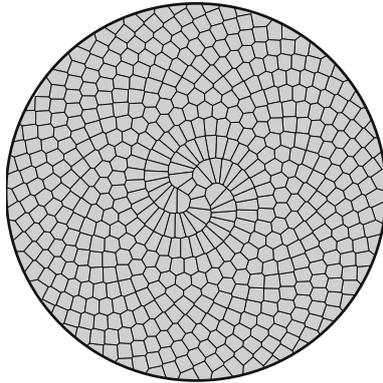
SPIRAL 140°



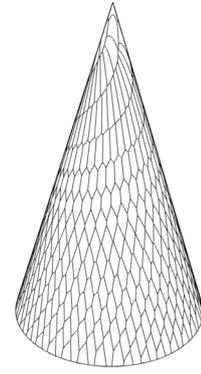
SPIRAL 139.508°



SPIRAL 142°



PROJECTED PATTERN 142°

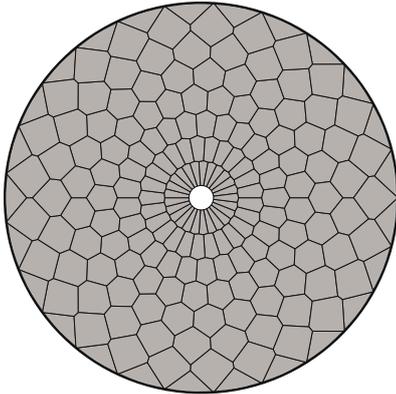


The above graphics illustrate the experimental patterns created using digital modeling (grasshopper + rhino). By slightly adjusting the angle of divergence the spiral mesh changes to reveal considerable different meshes.

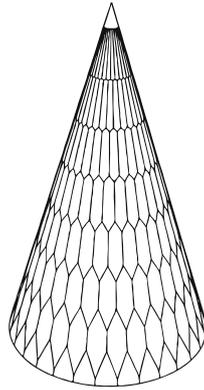
Two adjusted mesh were used to create a voronoi pattern that was then project to the cone geometry to explore the geometry and flow of the block components.

# Tessellation

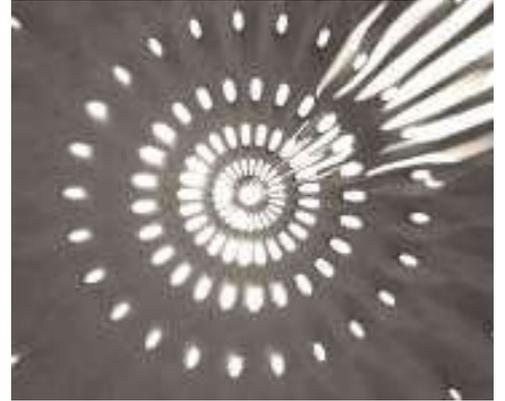
HEXAGONAL



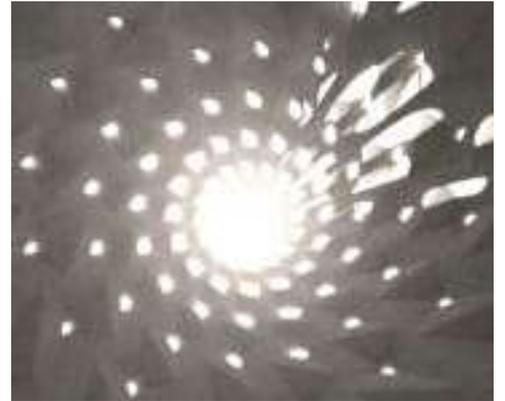
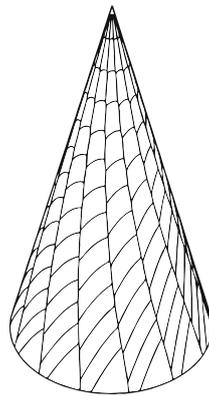
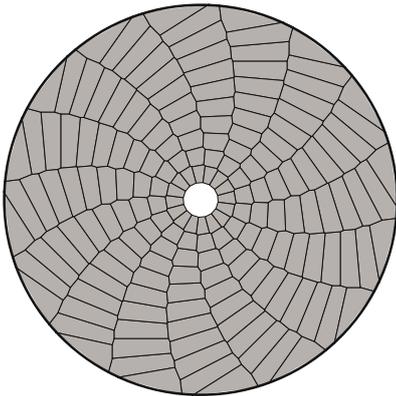
PROJECTED PATTERN ON SURFACE



INTERIOR VIEW OF OCULI



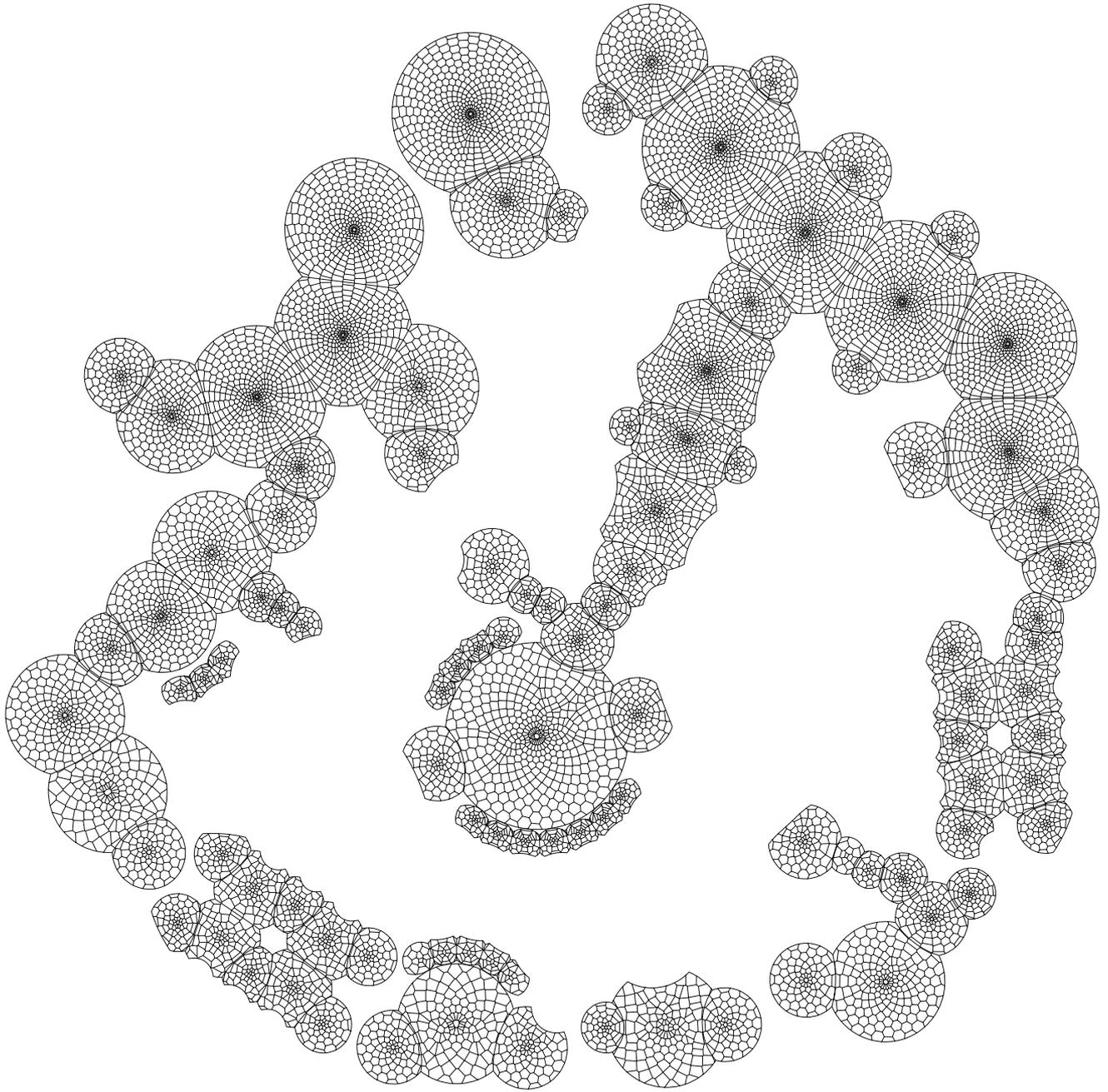
SPIRAL



Using computational design tools, a tessellated pattern was generated. This pattern, informed by the basic conical shape of the prototype surface, was used to generate the block geometry corresponding to the tessellated pattern. Once the pattern is generated on to the circular plan it is then projected on to the cone.

Experimentation of boolean subtraction and hyperboloid surfaces, inspired by the masonry sculpting techniques of Mark Burry and Danial Davis for the modern construction of Sagrada Familia, led to the boolean logic of creating the apertures and the articulation of the surface (further illustrated on pages 76-79).

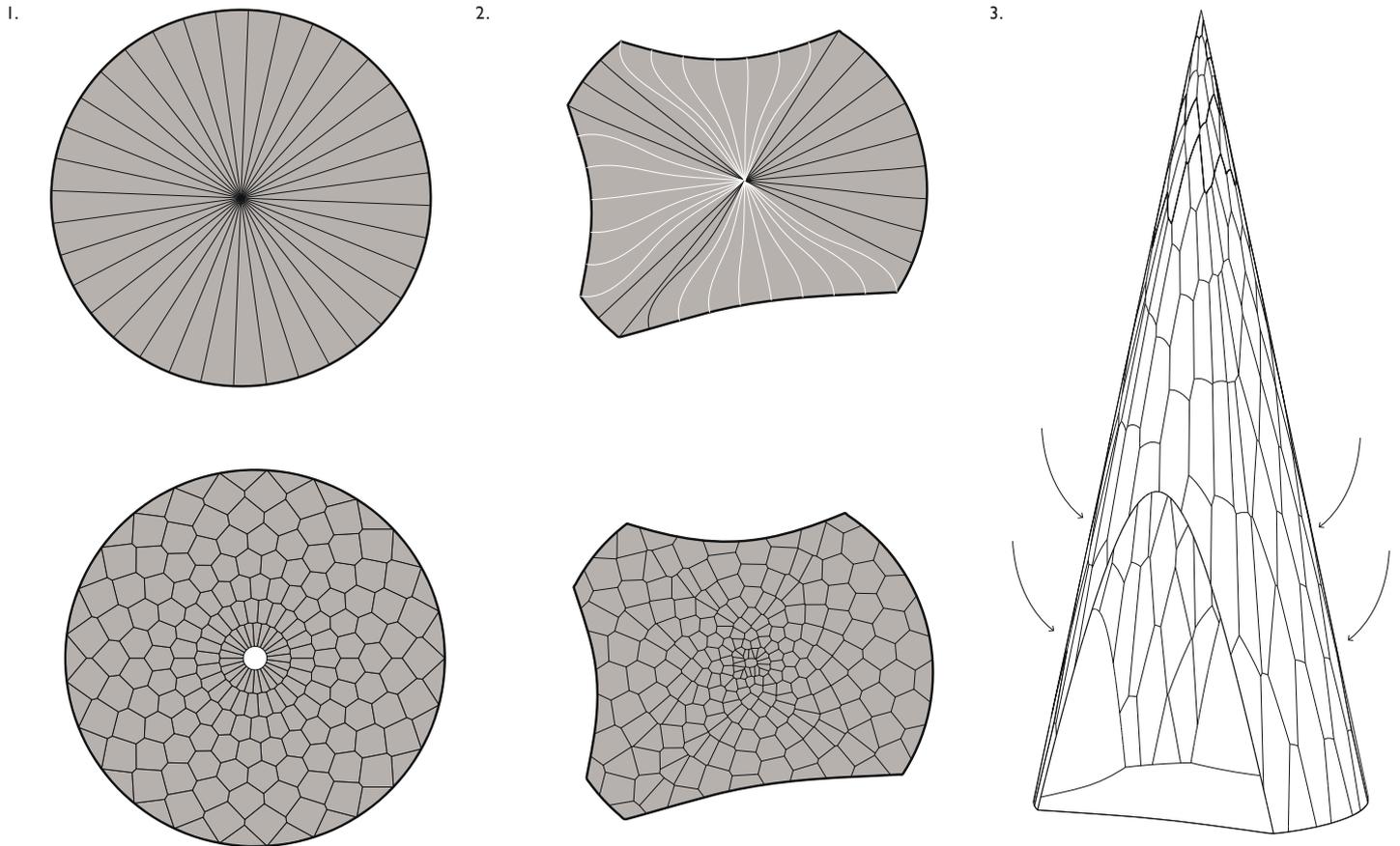
As each conical space intersects with the other in a continuous plan the geometry of one space informs the geometry of other. This meant that to generate the tessellated patterns of the conical spaces required to be done at the same time or in clusters of cones that connected with one another.



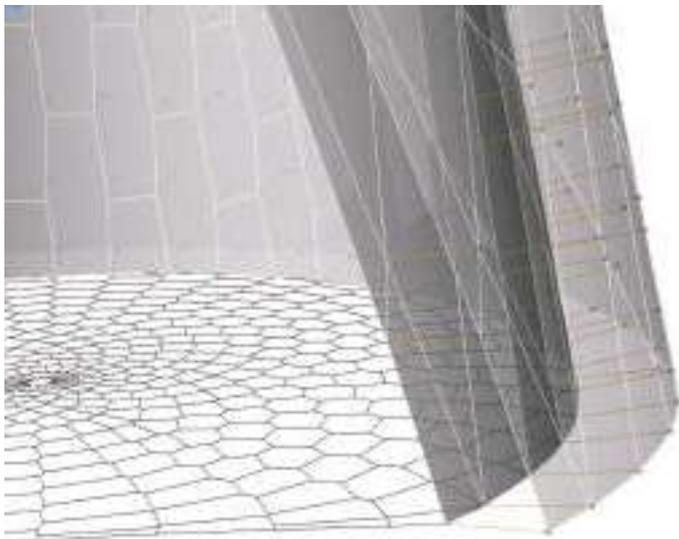
1:300 TESSELLATION OF ENTIRE BUILDING FORMATION

# Alignment of Arch Blocks

VORONOI PATTERN TO PROVIDE LAYOUT OF INTERLOCKING BLOCKS



4. COMPUTATIONAL DESIGN TOOLS TO GENERATE BLOCKS GEOMETRIES



1. The circular base of the cone with curves dividing the circle at intervals that correspond to the width of the pattern and the directional flow of the blocks. These segments are then divided horizontally using rings at equal intervals. The centroids of each divided segment inform the voronoi pattern.

2. The truncated base of a conical space with arches. The white curves indicate the directional flow of the blocks that align with the arch to meet the arch line perpendicularly in order for the blocks to hold each other in place.

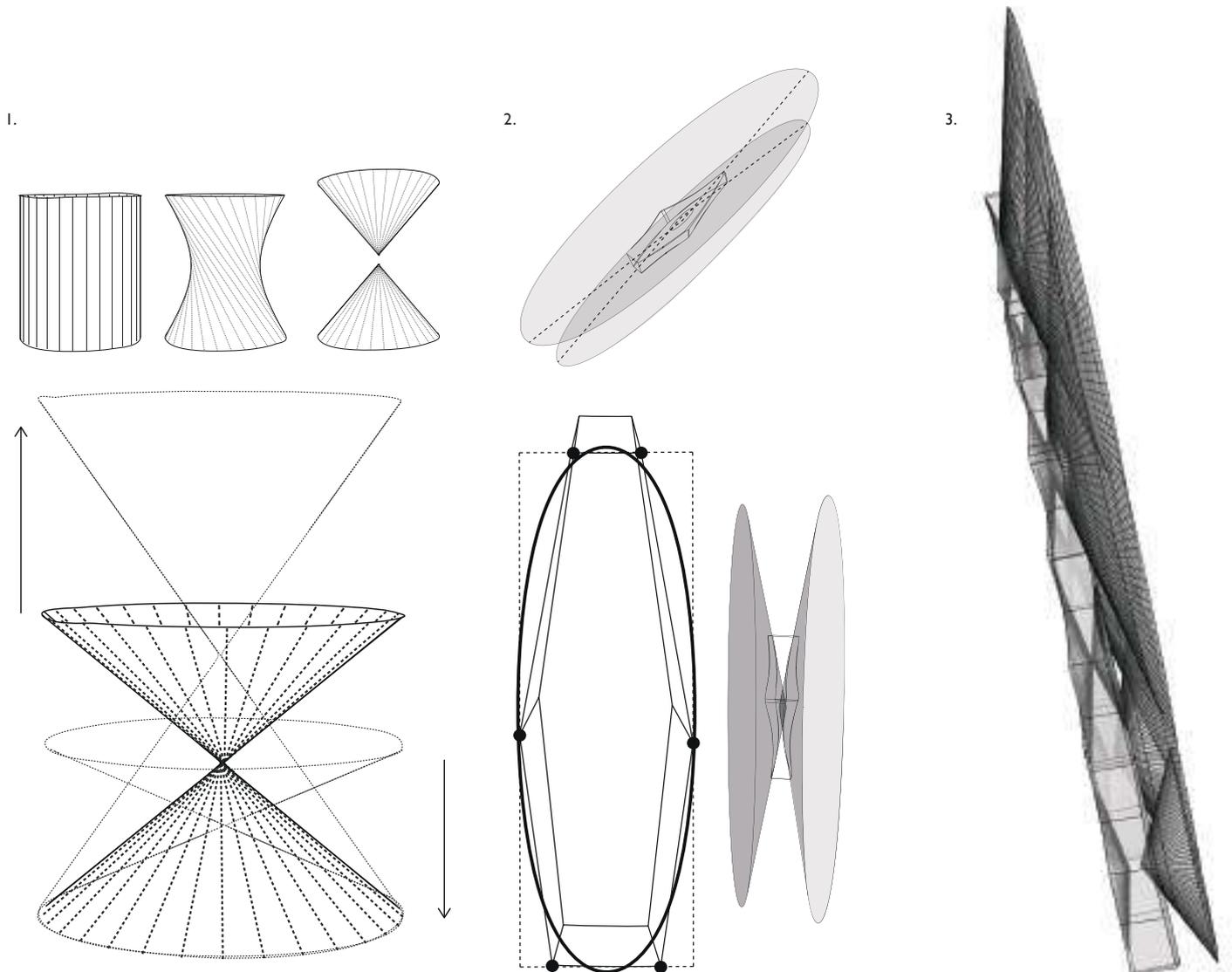
3. Tessellated pattern is projected on to the truncated cone. The arrows indicate the directional flow of the blocks.

4. An inner truncated surface and outer truncated surface determine the depth of the block. Connections are made from the inner surface perpendicularly to the outer surface to generate the block geometry.



I:300 ALIGNMENT CURVES

# Hyperboloid Boolean Subtraction

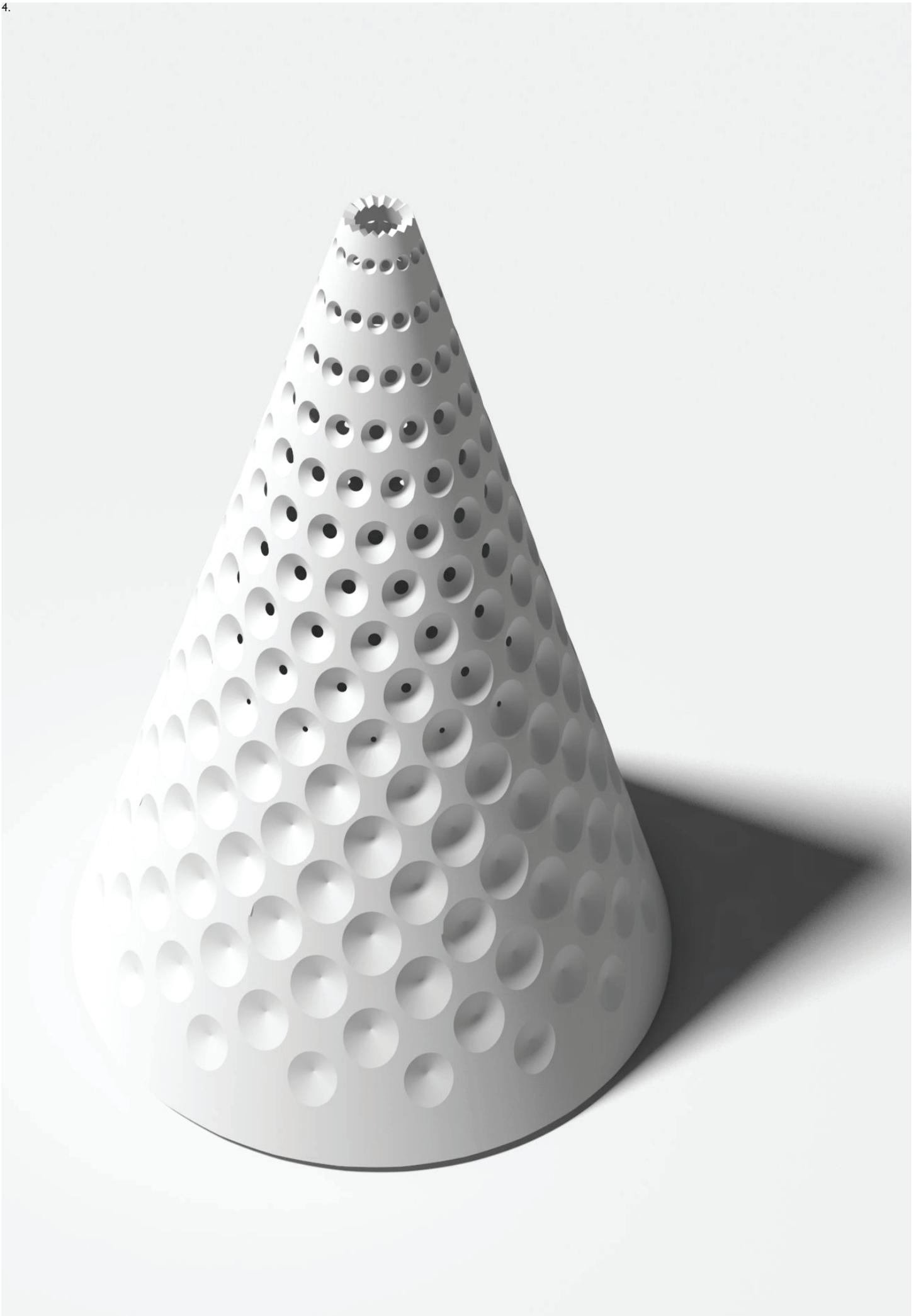


Sagrada Familia provided inspiration for the method of sculpting the stone to create apertures. Hyperboloid surfaces exist all over the church and provided a method for stonemasons to sculpt stone with minimal instruction and tools. As construction of the church continues to this day, construction techniques have adapted and modernised to provide faster and more efficient methods of producing the same outcome. Research into Mark Burry and Danial Davis digital modeling methods inspired the exploration how hyperboloids may be used to boolean subtract the stone blocks.

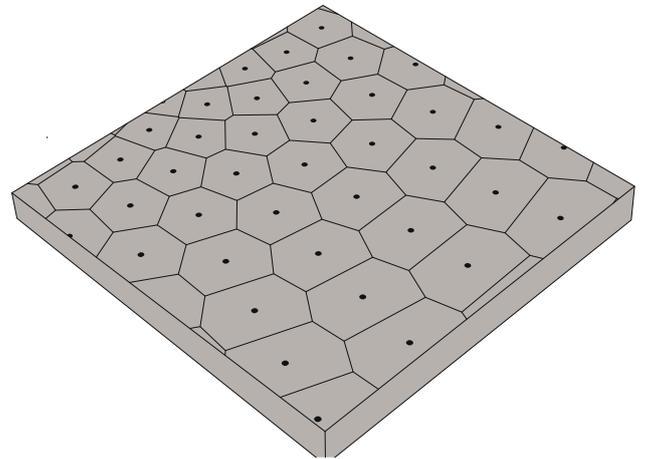
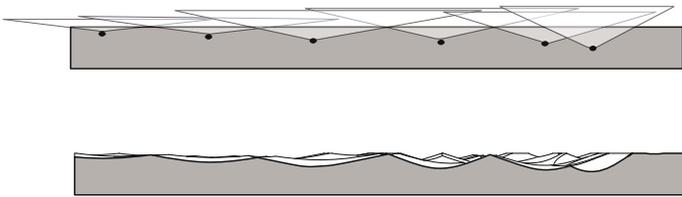
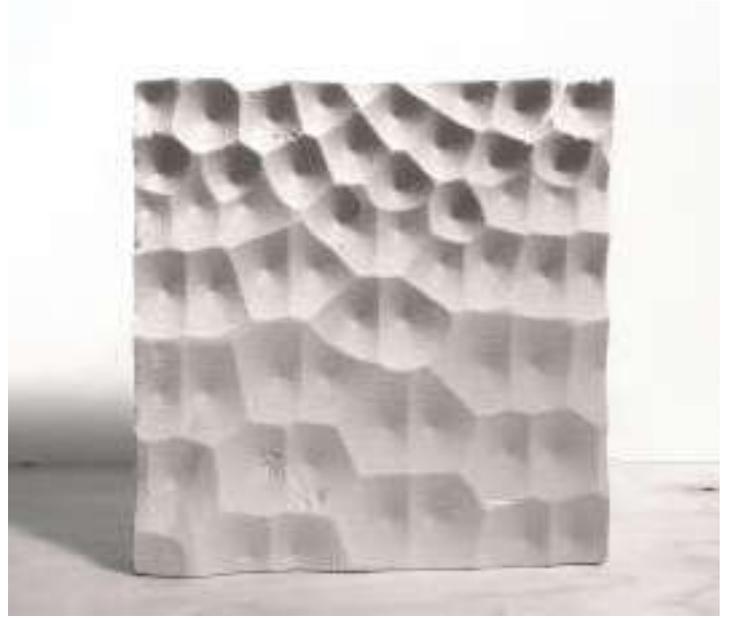
The hyperboloid is split into two sheet hyperboloid-essentially two corresponding cones. These cones are parametrically scaled to in vary depth and used to subtract

mass from stone. The parametric system is designed to reveal shallow surface sculpting at the base of the conical form to deeper sculpting at the top of the form to reveal apertures in the structure.

1. Scaling the hyperboloid to create a two sheet hyperboloid
2. Using the corner points of the block to inform the shape of the cone in order for the cone to sculpt entire block. This transforms the two sheet cones to elliptical cones that sculpt the blocks.
3. Image shows a section of the blocks from base to peak and the generated cones uses to boolean mass from the block.
4. Render of a sculpted cone using two sheet hyperboloid cones. This image informed the research process to find a method of sculpting the entire stone block.



# CNC Milled Hyperboloid Surface



In order to test the boolean subtraction the logic was tested on a 300x300x50mm piece of foam. Parametric cones were generated with a gradient of depths to reveal shallow to deep sculpting. The CNC machine used restricted the ability to cut through the material on the deeper side however this physical study primarily tested the sculpting technique of elliptical cones being used to boolean subtract material. This test model proved the technique to be successful in the effect that was desired- irregular pattern with all edges of each hexagonal shape sculpted.

# Prototype Printed in Gypsum



3D printing was chosen as an appropriate method of fabricating two conical spaces for reasons of time, quality of materiality and scale. This model at 1:100 scale was used to evaluate the spatial quality of the interior space as well as the sculpting of the blocks. The lack of articulation of each individual block was due to incorrect settings when of the 3D model when exporting the file to the printer.

1:100 MODEL

# 1:1 Single Block

The investigation into contemporary masonry fabrication was explored and simulated through CNC wire cutting of a 1:1 scale foam model. Above illustrates the process of cutting a single block of the conical structure.

Due to the restrictions of the CNC wire cutting machine, the block was made in 4 parts. This eliminates this investigation as one to simulate the technique for cutting a 1:1 scale block model, however, this investigation was fruitful in understanding the techniques of this fabrication and in particular the sculpting of the aperture.

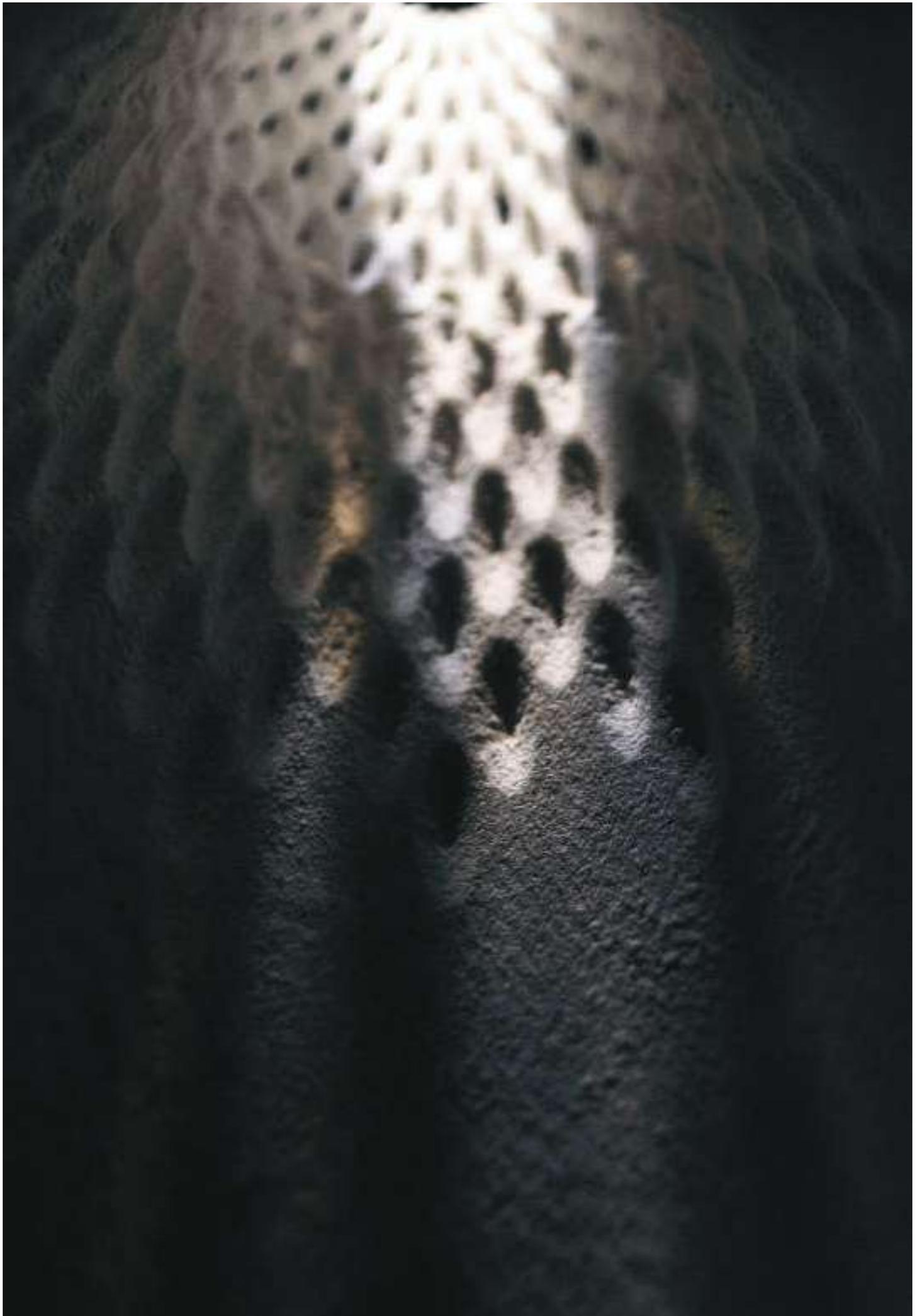


# Conclusion

The renders revealed interestingly, that the diminution in size of the pattern towards the oculi alters the perspective and gives the impression the cone height as much higher than it is. This altered perspective works in favour towards the psychology of tall height spaces encouraging abstract and imaginative cognitive behaviour.

The process of wire cutting the block was initiated as a means to emulate the hydraulic saw method of cutting however due to restrictions with the wire cutting machinery available the experiment quickly diverted from this purpose with the entire block being cut in 4 parts. However, the process of preparing the block to be cut - understanding the sequence of cuts and how to inform the rudimentary machine to make a cut was very informative. The final product also gave a sense of scale to the digitally generated blocks.





# 6

# Design Proposal

*The design research culminates in this chapter through the proposal of a secular spiritual space that is adaptable and lasting, timeless.*

## 6.1 FORMATION

### 6.1.1 PLAN

## 6.2 DEFINING THE SPATIAL CLUSTERS

### 6.2.1 QUANTIFIABLE MEASURES

#### 6.2.2 SPATIAL CLUSTERS

#### 6.2.3 SEQUENCE OF SPACE

## 6.3 PROPOSAL VISUALS

### 6.3.1 COURTYARD

#### 6.3.3 HALL

#### 6.3.4 ARCADE

#### 6.3.5 SOLEMN PASSAGE

#### 6.3.6 HALL

#### 6.3.7 SECTION

## 6.4 PHYSICAL MODEL

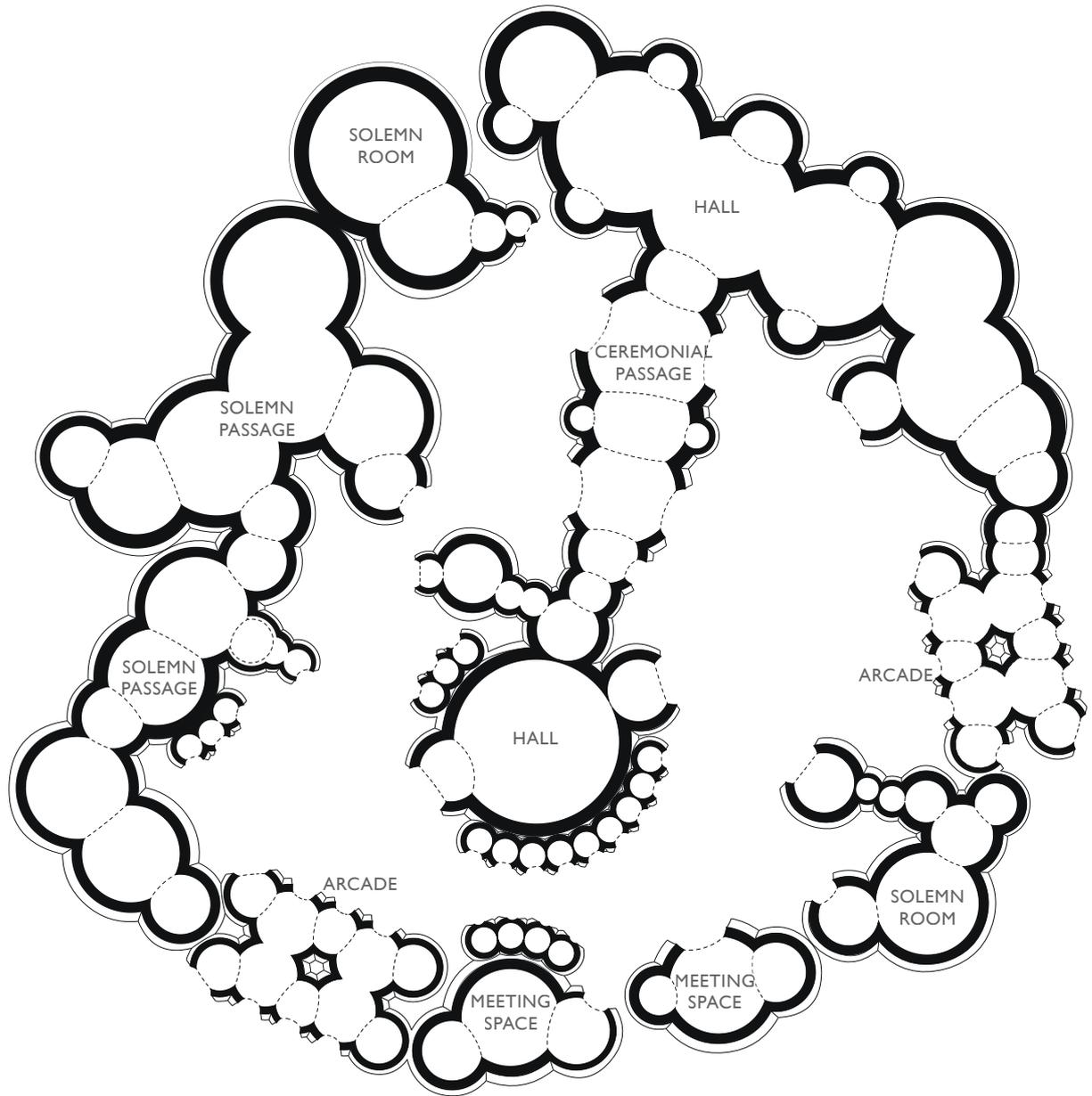
### 6.4.1 ENTIRE FORMATION

#### 6.4.2 COURTYARDS

## 6.5 DISCUSSION

### 6.5.1 CONCLUSION

# Plan

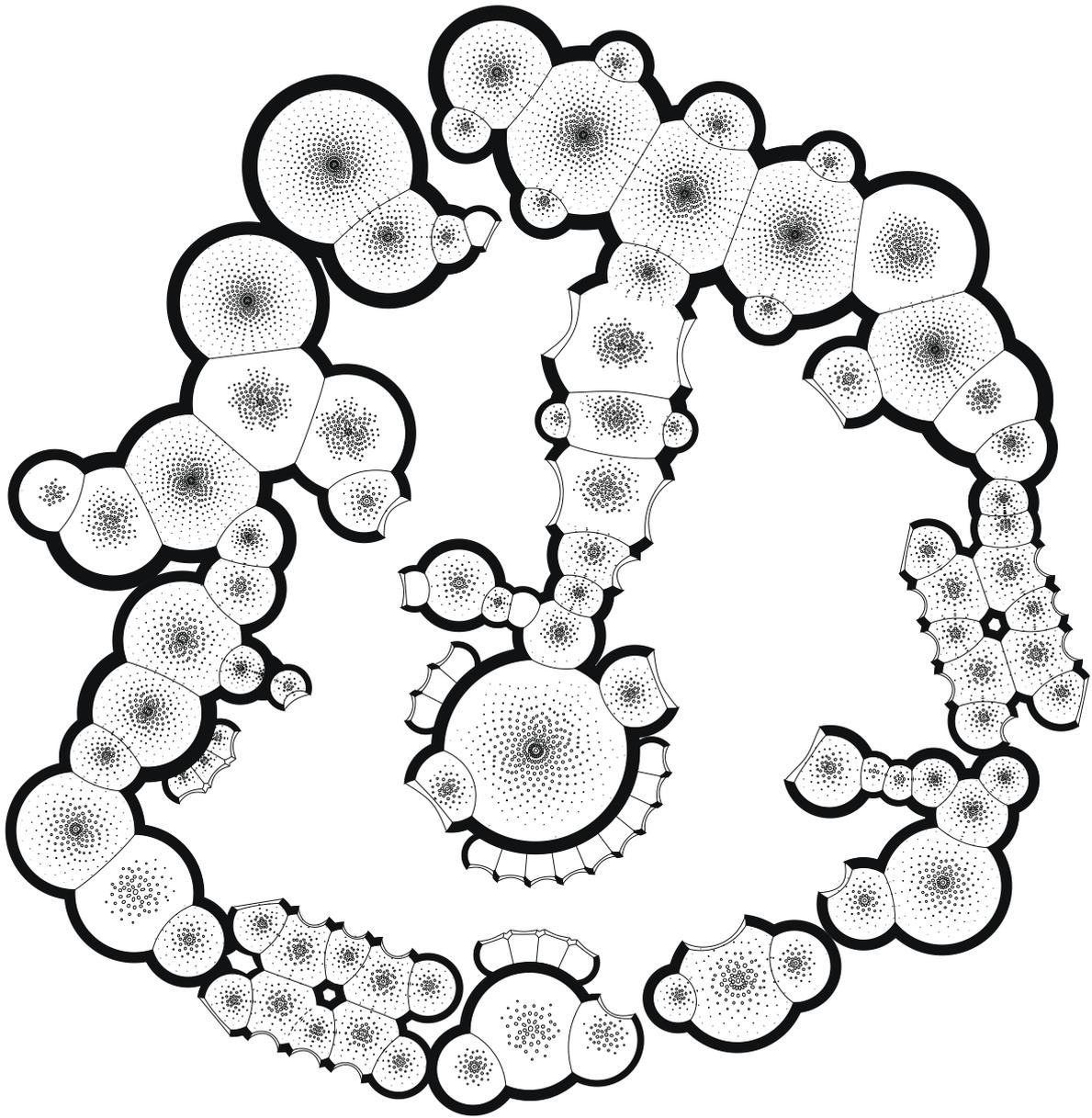


1:300 FLOOR PLAN

The open fluid plan is both formal and informal. Inspired by the concept of the architectural promenade and the English garden the different spaces are experienced sequentially with glimpses of varied and “unexpected” prospects creating an informality to how the spaces are experienced. The method of organisation - the calculated composition of spaces through offsetting one conical space to another with a specific angle gives order and formality to the seemingly informal plan, much like the English garden. The formality insures the varied landscape of alternating light and spatial qualities

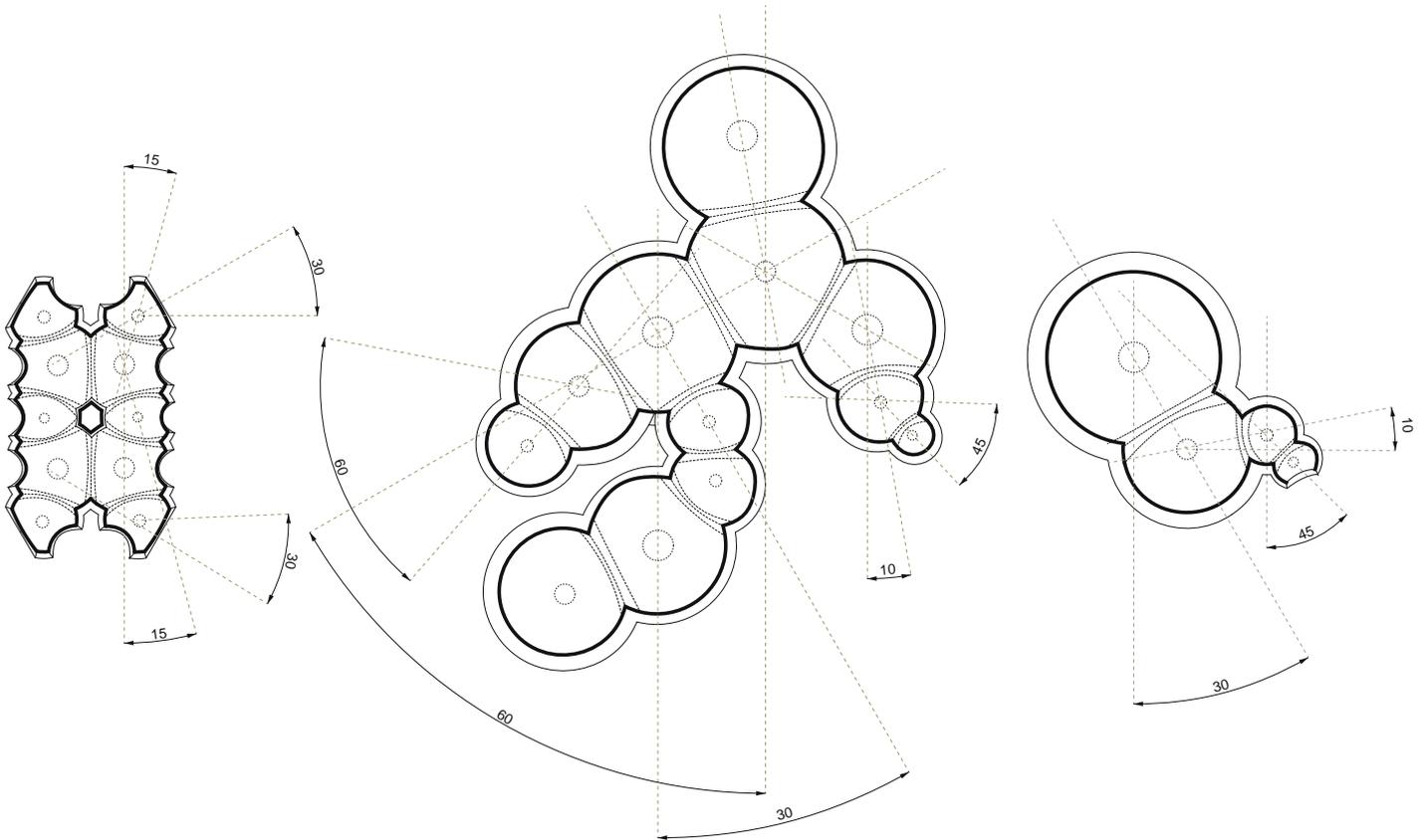
whilst also establishing a hierarchy of spaces of architectural events. By having this dichotomy informality and formality a plan is created that encourages a kind of wandering movement through the spaces and as such a plan that will remain alive.

The building has no fixed programme or function other than to be space that is emotive, inspiring and timeless and as such has been left in its diagrammatic representation. The plan simply has a suggestion of what each cluster of spaces may hold function to.

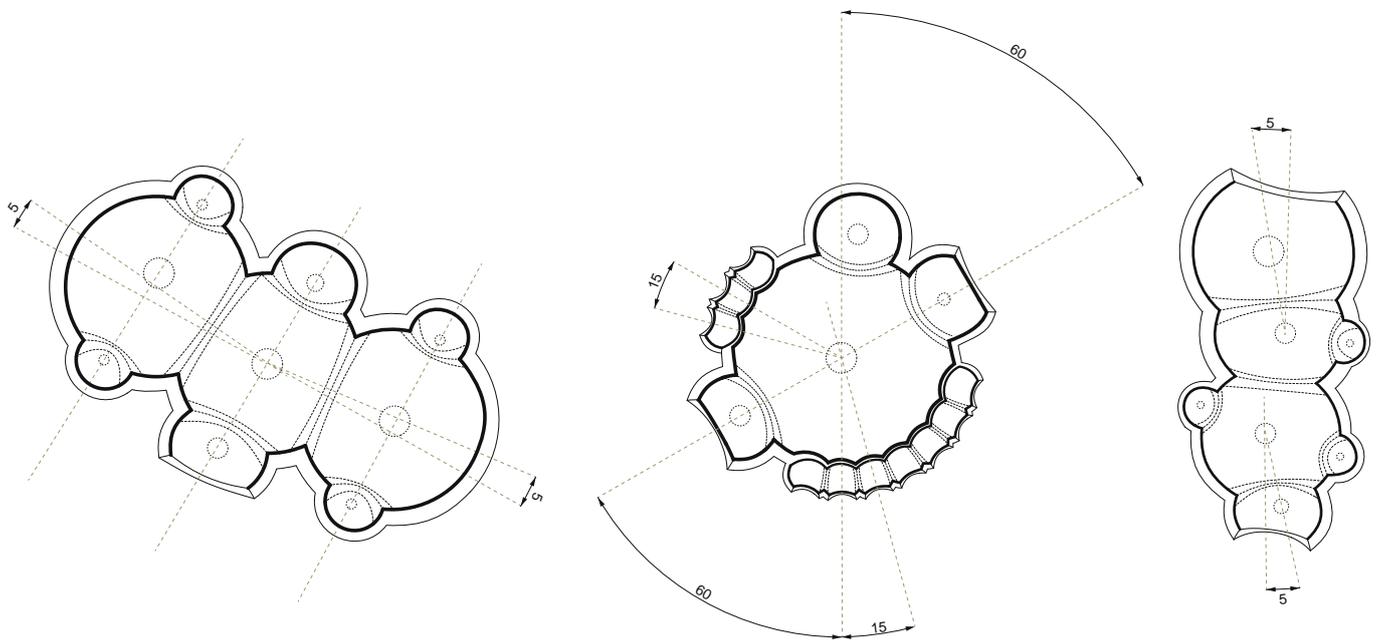


1:300

# Quantifiable Measures



Each space is offset to the adjoining space in order to create the ordered informality of space. Taking inspiration from the English garden and the architectural promenade, the spaces are arranged in such a way as to encourage wandering through moments of “discovery” with every turn the user makes.



1:300 DIAGRAMMATIC PLANS OF INDIVIDUAL CLUSTERS

# Spatial Clusters

## ARCADE

Intimacy layer 1.

The arcade cluster acts as the entrance to the complex/ building and provides a level of intimacy whilst remaining an open structure.

## COURTYARD

Intimacy layer 2.

The courtyard is an intimate exterior space, the level of its privacy depends on how many layers/ at what distance the courtyard is located in relation to the entrance.

## CEREMONIAL PASSAGE

Intimacy layer 3.

The ceremonial passage has a linear formation with a focal point that is the entrance to the hall. The structure is partially open to courtyards on both side of the formation. The open and enclosed structures are organised in a rhythmic sequence.

## HALL

Intimacy layer 4.

The hall is a large open space, the scale is dwarfs the user and provides a calming space. The regularity of its formation, including architectural elements such as alcoves and arches creates a space that can be read as a single entity.

## SOLEMN PASSAGE

Intimacy layer 5.

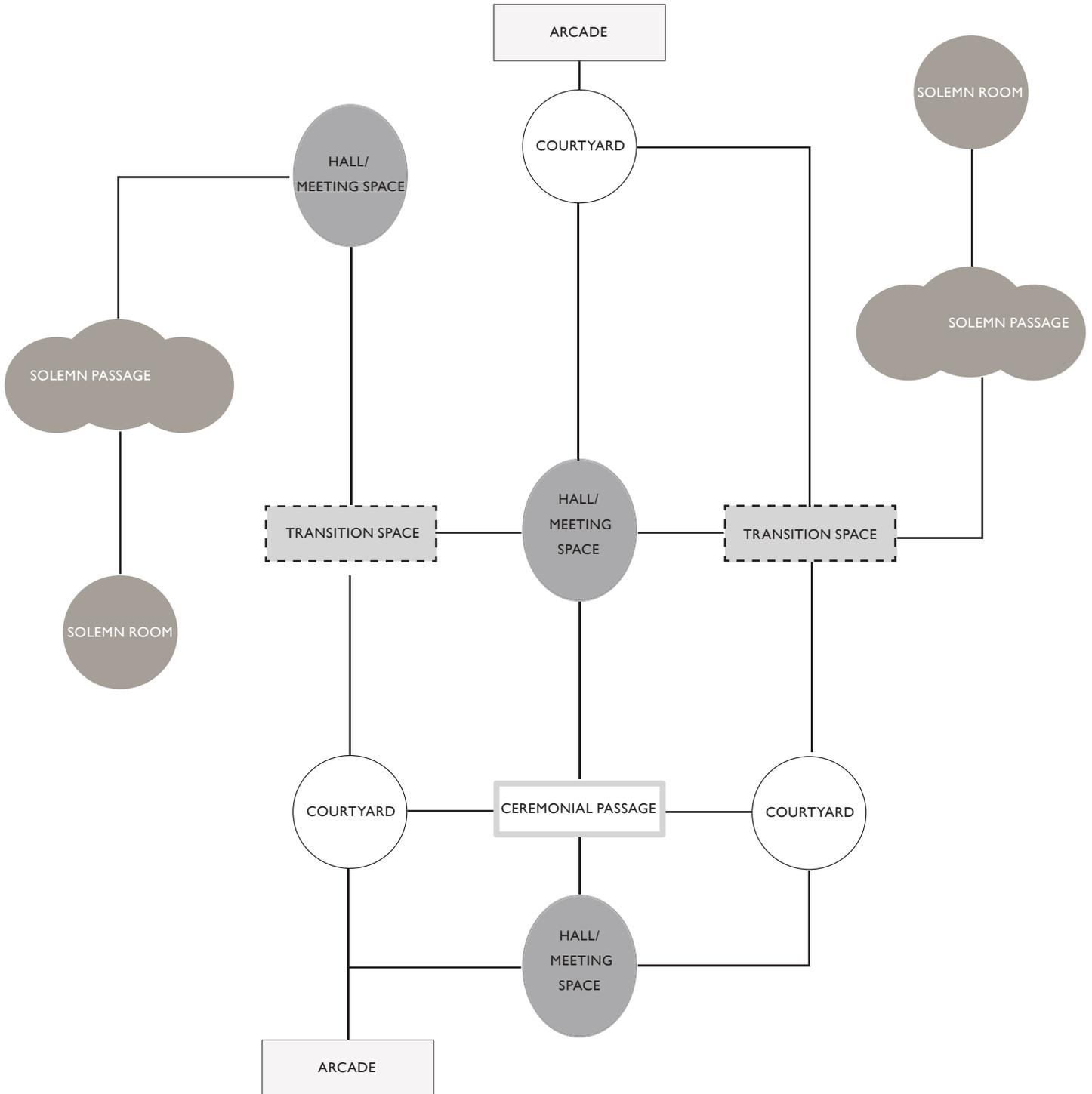
The solemn passage is formed by limiting the number of entrances to the passage. This limits the light that enters the space and retains its darkness as well as its privacy.

## SOLEMN ROOM

Intimacy layer 6.

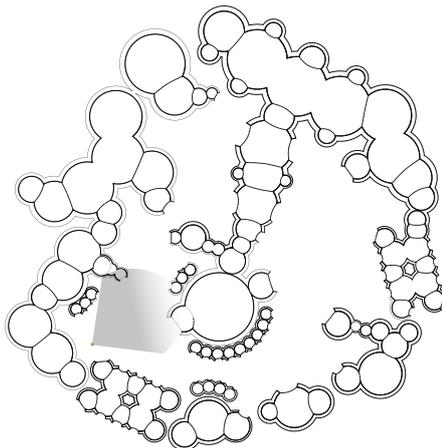
The solemn room is formed by adjoining a space with another with a single entry point. It can only be accessed through the solemn passage and the spatial quality is very private.

# Sequence of Space



# Courtyard

This project has been designed as a public space. The courtyard is the introverted public open space designed to create intimacy within a busy urban environment. Though the courtyard is integral to the concept of creating intimacy, as understood through the precedent and literature studies, the courtyard in this design project was created as a by-product of the interconnecting conical spaces. As such, the courtyard form undulates in plan and thus provides outdoor space that varies atmosphere and size. There are more open areas as well as “hidden corners”.

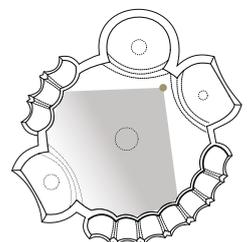




# Hall

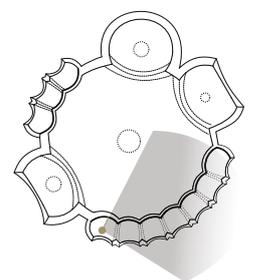


This is the smaller and more informal of the two designed halls. It places itself directly above the existing footpath on the site and with two entrances, one to the south and the other to the north, it acts as a node where one can pass through or walk around through the arcade (illustration to the right). Its geometry also lends its self as an appropriate space to hold artistic performance as illustrated above, or a place to hold local gatherings such as meetings and discussions.



VIEWPOINT

# Arcade



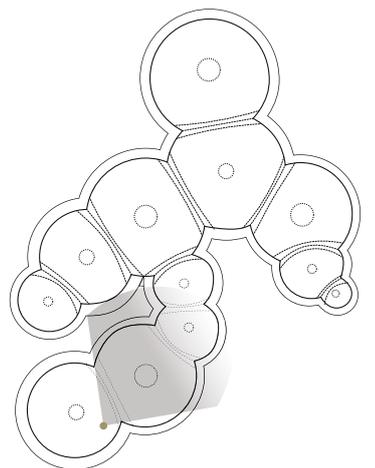
VIEWPOINT

# Solemn Passage



The solemn passage and room is darker than the other areas of the formation. The dark and tall spaces are designed to inspire self reflection, quiet contemplation and imaginative thinking. In terms of activities this can include meditation, prayer, art installation, the display of art or personal individualistic ceremony. The lack of light and sound heightens the other senses in the body making the experience within these spaces highly sensual and emotive.

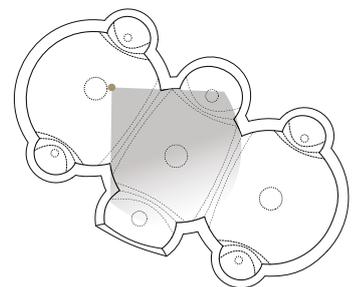




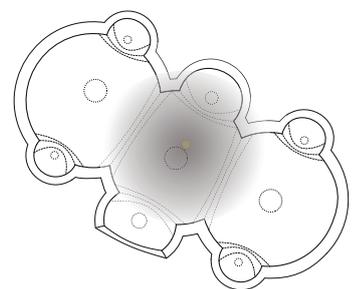
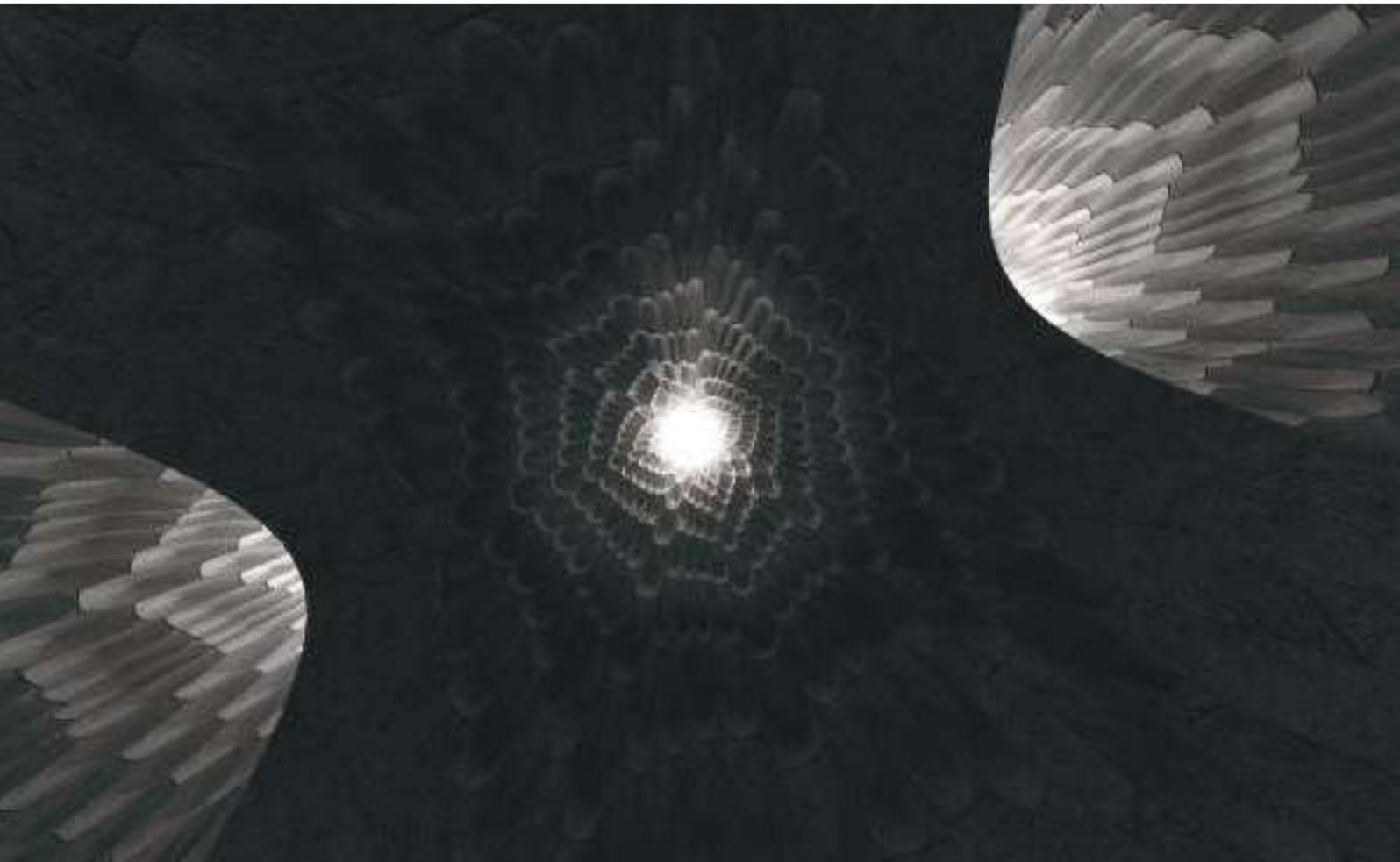
# Hall



This is the more formal hall; the scale, symmetry and entrance make for a grand and monumental structure. The light is evenly distributed in this space and the alcoves that frame the hall give space an interesting play of light and shadow as well as focal points. This space is appropriate for large gatherings and ceremonies. The stereotomy provides the ornamentation keeping the designed space neutral, free of symbolism and secular.



VIEWPOINT



VIEWPOINT

# Section





1:150 LONG SECTION

# Entire Formation



1:400 3D PRINTED MODEL



AERIAL VIEW OF FORMATION

# Courtyards



1:400 3D PRINTED MODEL



VIEW FROM EAST COURTYARD



# Conclusion

Religious building typology has some of the world's greatest examples of spaces that are timeless. They are monumental and appeal to people of various cultures, ages and, beliefs. They offer an experience that appeals to the user's emotional sensibility. This realisation led to the question- if religious programme and symbolism are not vital for the experience, then what is? And what makes certain spaces timeless? Timelessness in that these spaces remain attractive to people regardless of time and culture and their structures remain standing and impressive throughout various stages of age. These questions were the point of departure for this thesis.

The research by design methodology provided a highly creative process and led the project to touch various connecting subjects such as psychology, philosophy and stereotomy. The chosen methodology meant computational design methods - digital modelling and printing - were given priority in terms of time and development. Literature studies as a consequence were only lightly touched upon, however, these studies led to further questions. With regards to psychology and philosophy, the question of creating a new building typology arises to fulfil the need of the ever-growing secular society. The level of research conducted into

stereotomy for this thesis asks for further research into testing the structural capacity of the design as well as fabrication and procurement of the material.

The intention of this thesis is to contribute to the greater discussion of designing structures that are timeless, adaptable and always relevant to the user. The research methodology developed in this thesis illustrates that qualitative intent can be quantified. As such, the design proposal is an example of how a prototype, informed by contextual analysis, develops a formation that is site specific whilst retaining the qualitative intent whatever the context. This design project however also shows that intuition and subjectivity is inherent in creativity. The prototype was quantifiably developed whilst the formation was developed informed by contextual analysis and not entirely through a mathematical logic. Upon reflection, one can see the thesis research topic and design as dichotomous on every level. There is a tension between formality and informality, mathematics and intuition, science and mysticism and secularism and religiosity - which leads to the conclusion that perhaps architecture that intends to embody timelessness must in its very nature encompass all perspectives.



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