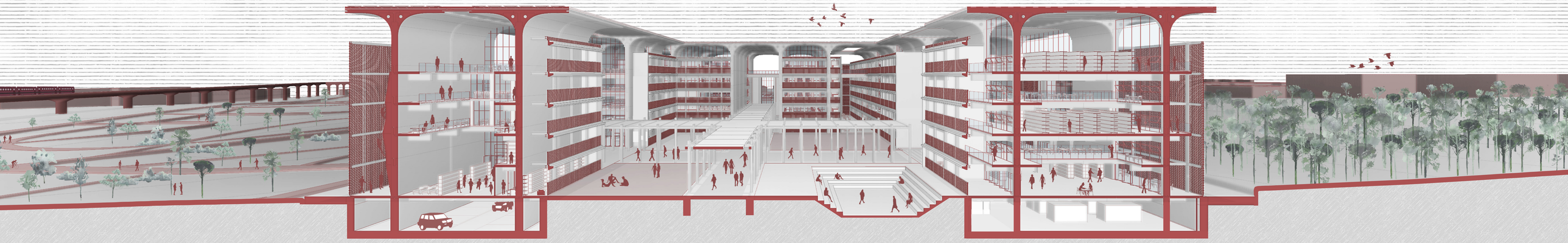
POLITECNICO
MILANO 1863

School of AUIC

Studio of Complex Constructions II

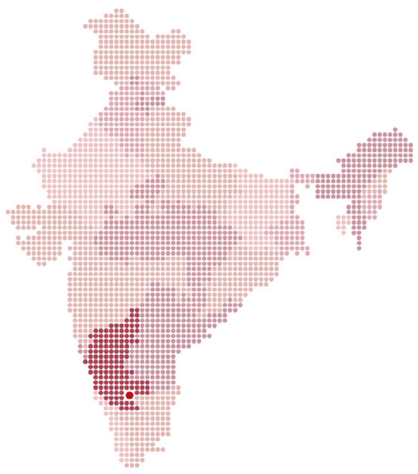


The UniT

Master Thesis : December 2023

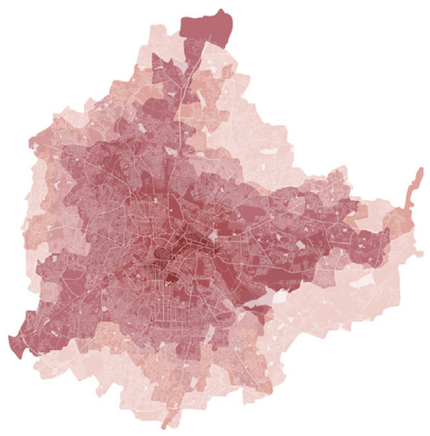
POLITECNICO MILANO 1863 | Architectural Design for Complex Constructions II 2022-2023 Politecnico di Milano School of AUIC | The Unit Library in India | Prof. Maria Grazia Folli Prof.Corrado Pecora Prof. Giovanni Dotelli Prof. Marco Imperadori Prof. Lorenzo Pagliano | Maria Mathai 991184 Ahmad Naderi 992283 Sivan Liteman 995403 | The uniT 1/33

Why India?



Link between the promising future and glorious pastLink between the promising future and glorious pastLink between the promising future and glorious pastLink between the promising future and glorious past

Why Bangalore?



Link between the promising future and glorious pastLink between the promising future and glorious pastLink between the promising future and glorious pastLink between the promising future and glorious past

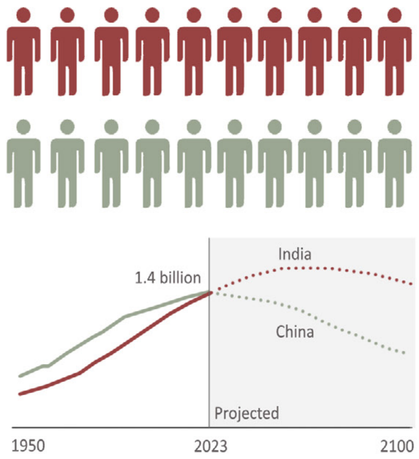
What does a Library mean to India?

Link between the promising future and glorious past

A symbol of modern heritage and new architecture

A platform for the education of the growing population

India Overview

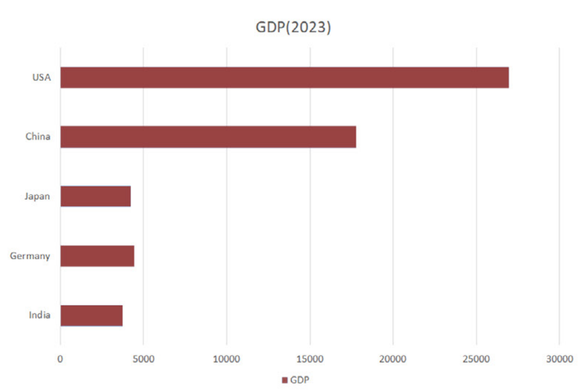


Population

India 2023 population is estimated at 1,428,627,663 people at mid year.India population is equivalent to 17.76% of the total world population.

In 2023, India overtook China to become the most populated country in the world.

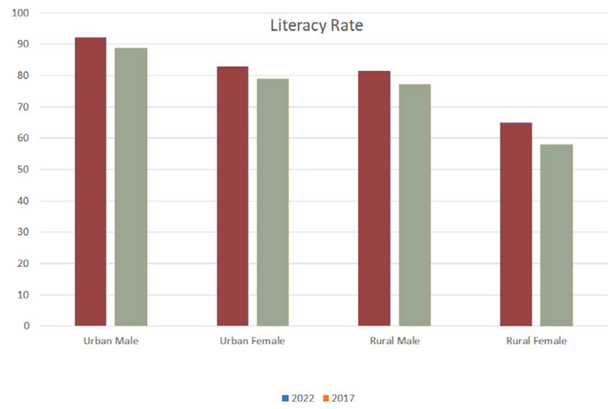
The median age in India is 28.2 years



GDP

It is the world's fifth-largest economy by nominal GDP and the third-largest by purchasing power parity.

The economy of India has transitioned from a mixed planned economy to a mixed middle-income developing social market economy with notable public sector in strategic sectors.

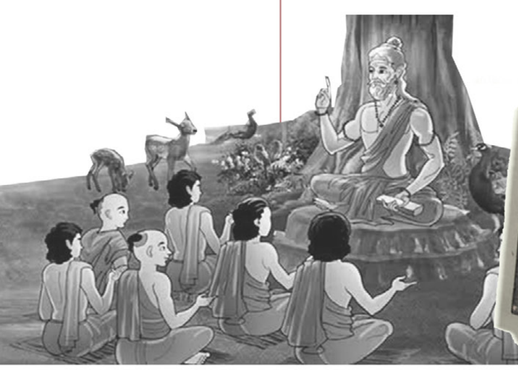


Literacy Rate

The literacy rate among Indian women has witnessed significant progress over the years. In the early days of India's independence, a mere one out of eleven girls, approximately nine per cent, were literate, as reported by the World Bank. Today, the literacy rate among women in India has surged to 77 per cent, whereas the male literacy rate stands at 84.7 per cent.

History of Libraries in India

Oral Tradition



Ancient Period
Harrapa Mohenjedaro

The earliest form of education was through memory (Shruthi-Smriti)

Manuscripts

2nd century AD
Maghada and Mauryan Empire

Manuscripts and palm leaves consisted of the library in the 1st and 2nd century

Nalanda University

4th century AD
Gupta Empire

Nalanda University was built in 4th centure AD and had texts on Vedas , Vedanta philosophy

Vikramshila

8th century AD
Pala Empire

The Vikramshila University had rich texts in Sanskrit, Prakhit and Tibetan languages

Tanjore Saraswati Mahal Library

12th century AD
Maratha Empire

The Saraswati Mahal Library contained thousands of manuscripts and printed books

Nalanda University

15th century AD
Mughal Empire

All the mughal leaders kept palace libraries. Libraries at this time were a private institution

Rampur Raza Library

18th century AD
Nawabs of India

The mughal libraries were destroyed and the collections were carried away by the Nawabs

National Library Calcutta

18th century AD
British Empire

The arrival of the British bought chaos to the Indian way of life and cultural heritage

Asiatic society library of Bombay

1784 AD
British Empire

The first public library was set up in 1784 in Bengal and it was financed by the Europeans living in the town

David Sassoon Library

1835 AD
British Empire

Public libraries were set up in three presidency regions , Bombay ,Calcutta and Madras financed by Europeans

Seshadri Iyer Memorial Hall houses

19th century
British Empire

Subscription libraries were set up in many towns and villages in India where you had to pay a fee

Nehru Memorial Library

1947 AD
Indian Independance

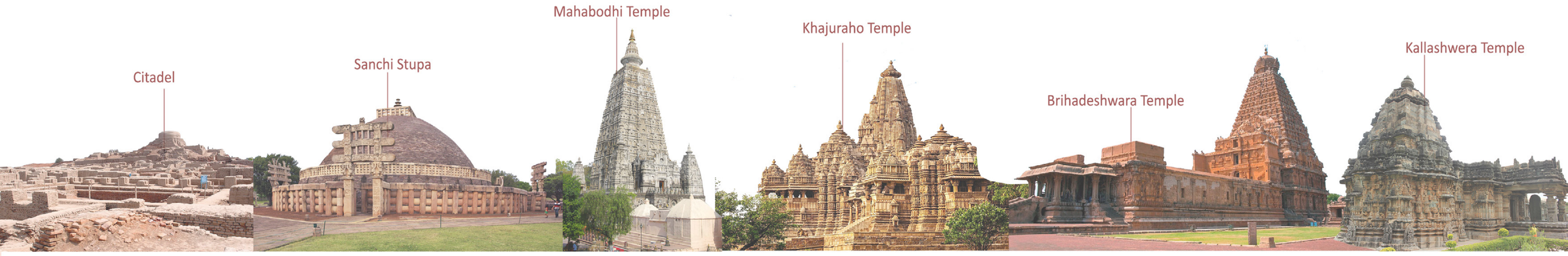
At the time of independence, Those in the rural population, 88 percent of the total, were nearly all illiterate

Lilavati Lalbhai Library

21st century
Democratic India

While the situation has of public libraries has improved, it is still a long way from that of a developed nation

Evolution of Indian Architecture



2600-1000 BC
Harrapa Mohenjedaro

For its time, the Indus Valley civilization's architecture was extremely sophisticated.

321 - 230 BC
Maurya Period

The first examples of Buddhist architecture were caves and rock-cut monasteries.

400 AD - 800 AD
Gupta Empire

The Gupta era saw the construction of Hindu temples from the earlier practise of rock-cut shrines.

900-1100 AD
Chandella Dynasty

Temple architecture in the North was known as Nagara style which has multiple shikaras

1000 AD - 1200 AD
Chola Dynasty

In south India the style of temple architecture was called Dravida Style. There is only one shikara

1000-1200 AD
Chalukya Dynasty

The style which was a mix of both North and South was called Vesara Style

1206-1526 AD
Delhi Sultanate period

This was the introduction of Islamic architecture into India with features like minarets and domes.

1525 - 1761 AD
Mughal Empire

The characteristics of Mughal architecture are large bulbous domes, slender minarets, and delicate ornamentation

1600 - 1823 AD
Maratha Empire

They and the Mughal Empire were at constant war. As a result, their architecture displays multiple fortifications.

1795-1947 AD
British Empire

The revival architectural style known as Indo-Saracenic was used.Its goal was to imitate Indian Imperial architecture.

1947 AD
Post Independance

The state of Indian architecture was in disarray following the British departure in 1947.There was an identity crisis

21st century
Post Independance

A spirit of nationalism took over and the idea was to integrate the past , the present and the future in architecture

Philosophies of Indian Architecture

Pathways

The journey to the space is often as important as the space itself and special emphasis is placed on the treatment of pathways

Openings

The relationship of the openings with the volumes and also its proportions are carefully treated. The quality and quantity of light is an important factor.

Courtyard

The courtyard is a fundamental part of indian architecturewhich evolved from the need to access to sunlight and ventilation indoors

Context

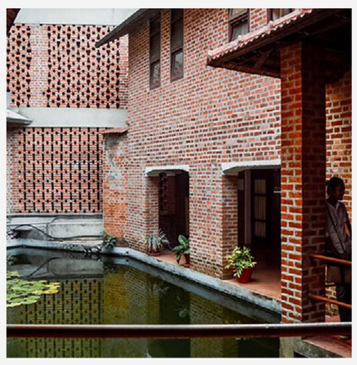
The architecture often evolves as a consequence of the surroundings. Architecture is the part of the identity of each community.

Sun Protection

The interior spaces need protection from the elements of the weather like sun and rain. Different methods like brise soleil, verandahs are used for this.

Patterns

Patterns have been a part of indian architecture from the time of ancient temples. Patterns are prevalent in all forms of art.

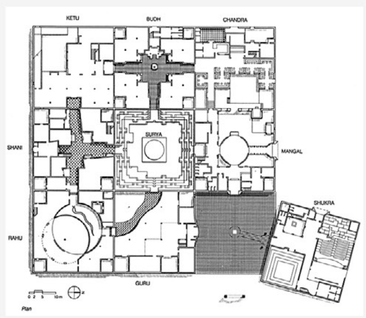


Local Materials

Especially after being a sovereign country,free from british rule, indian architects tried to reclaim India's identity with the use of local materials

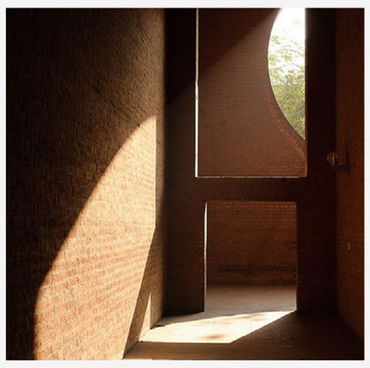
Layers

For protection from the sun and rain, the building is often planned as layers so that the interior spaces are sheltered.



Spatial Organisation

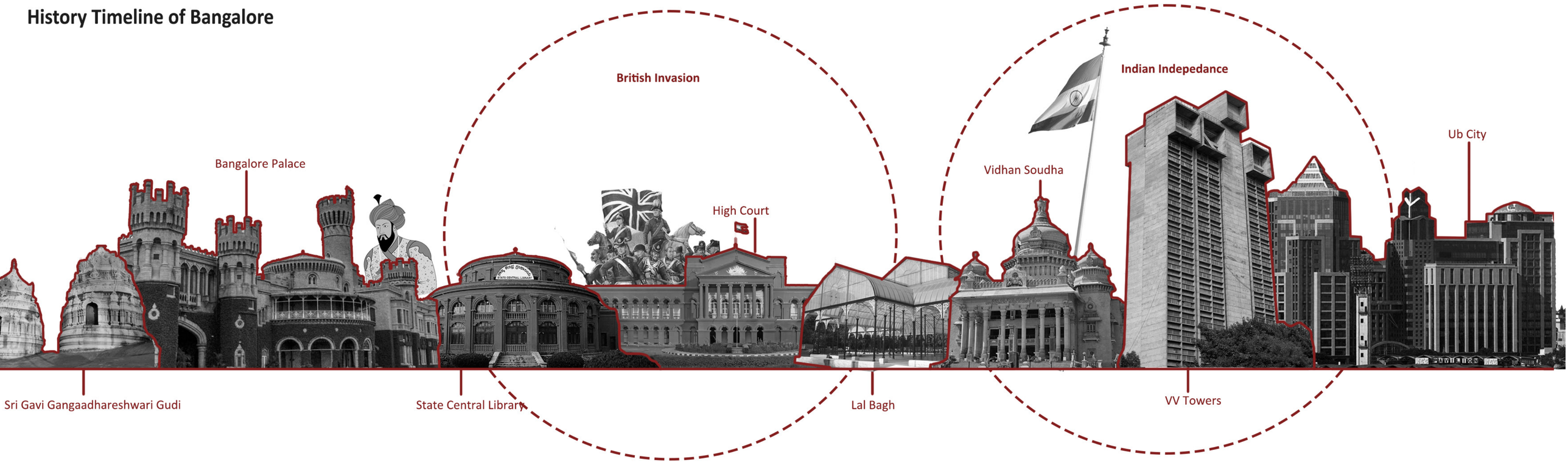
There are often rules or customs for organising spaces. Most of the rules have its roots in climatology and some are tradition.



Light and Shadow

Light and also shadow are used as elements of architecture and is used to define spaces.

History Timeline of Bangalore



1537

Vijayangara Empire
Modern Bangalore was founded by a feudatory of the Vijayanagara Empire, who built a mud fort in the year 1537.

1638

Sultanate of Bijapur
It was captured by the Maratha chief Shahaji Bhosale,working for the Adil Shahi sultans of Bijapur in 1638.

1761

Mughal Influence
After conquering the Sultanate of Bijapur, the Mughals had arrived in Bangalore.By 1761, Hyder Ali had become a de facto Ruler

1791

British Takeover
The Bangalore fort was captured by the East India company armies in1791 during the Third Anglo -Mysore War

1927

Garden City reputation
Construction of parks, public buildings and hospitals were instituted to improve the city for Silver Jubilee celebrations of the rule of Wodeyar IV.

1947

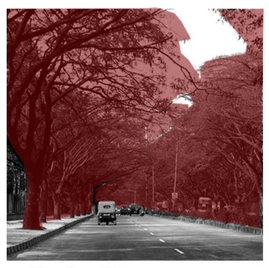
Indian Independance
After Indian independence in August 1947 , Bangalore became the capital of the Kannada-speaking state, Karnataka

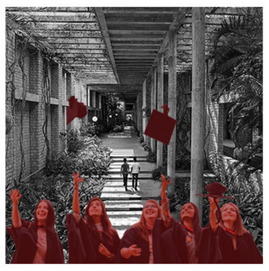
1991

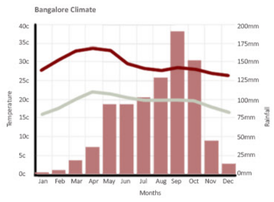
Silicon Valley of India
Bangalore experienced a growth in its real estates market in the 1990s and, by the 20th century, Bangalore had established itself as the Silicon Valley of India.

Pros


Silicon Valley


Garden City


Pleasant Weather



Educational Institutions

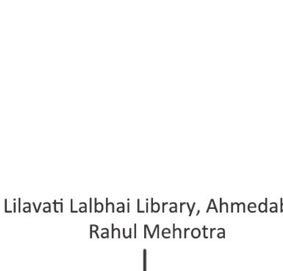
Cognitive Map of Bangalore

Cons


Traffic

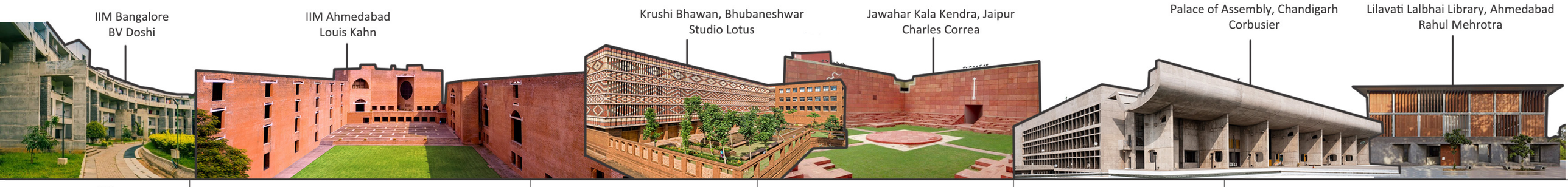

Flooding

Cost of Living


Poor Infrastructure


Pollution

Architecture influences



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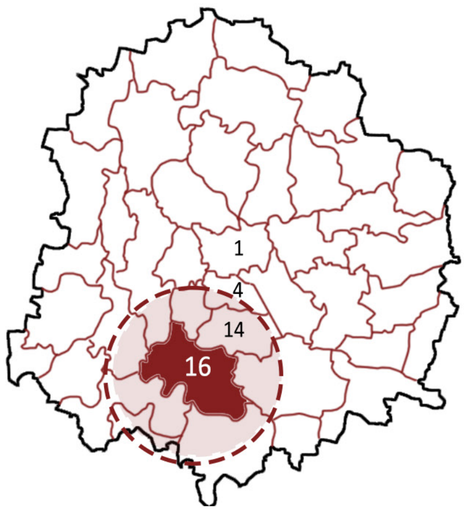
Sivan Liteman	995403

The unit



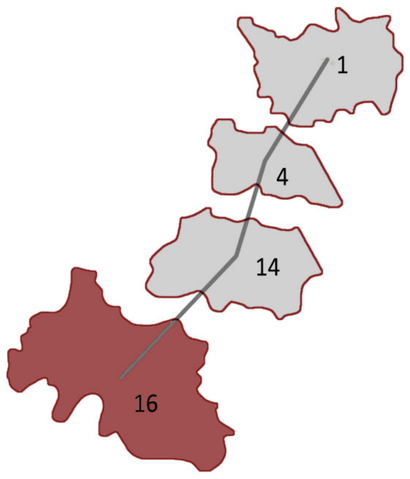
the City

The city is divided into 42 planning districts.

The district 1 is the core with the main commercial, transport and historical centre

The site is located in district 16

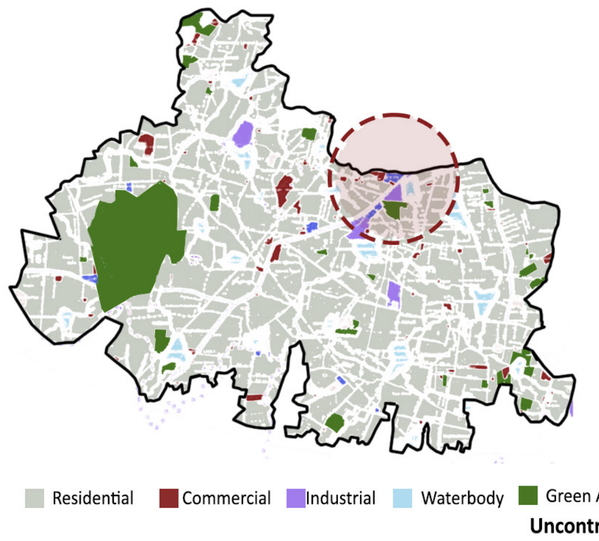
Bangalore grew rapidly and in an uncontrolled manner



the City and the Site

The Planning District 16 is located at southern quadrant of the BMA planning area.

The development plan proposes densification of the residential areas in a planned manner along with increased public transport share and other transit integration and also infrastructure upgradation



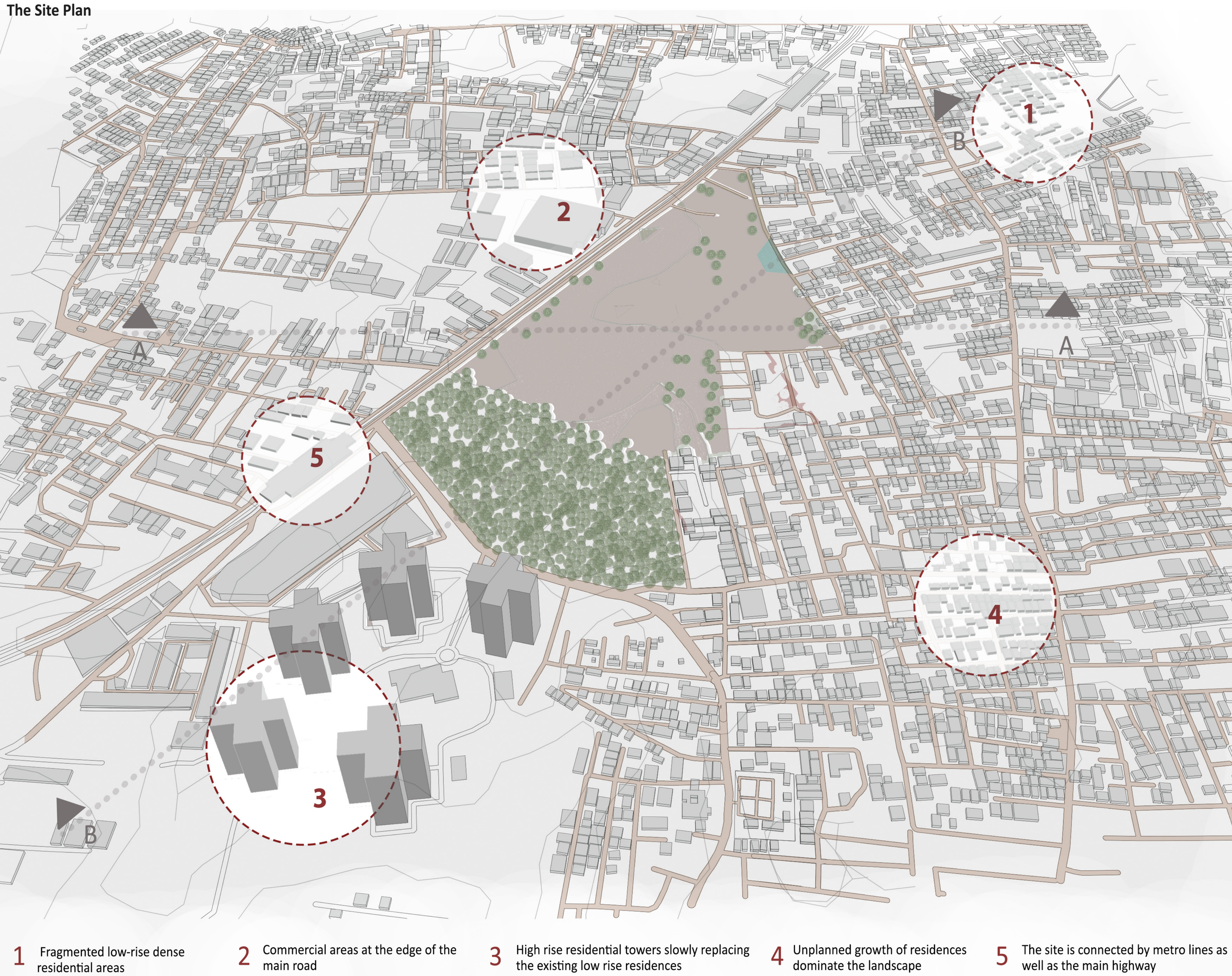
Uncontrolled Growth

the Site

The site was an industrial area now ready to be converted to public infrastructure to upgrade the neighbourhood

It is connected by a major road and also near a metro station. It is located next to a dense residential zone and also has several educational institutions nearby. It is also near a large rubber plantation and a lake in need of rejuvenation

The Site Plan



1 Fragmented low-rise dense residential areas

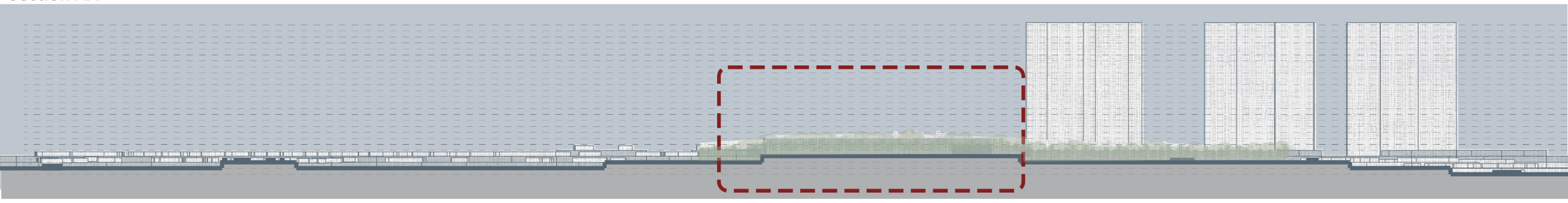
2 Commercial areas at the edge of the main road

3 High rise residential towers slowly replacing the existing low rise residences

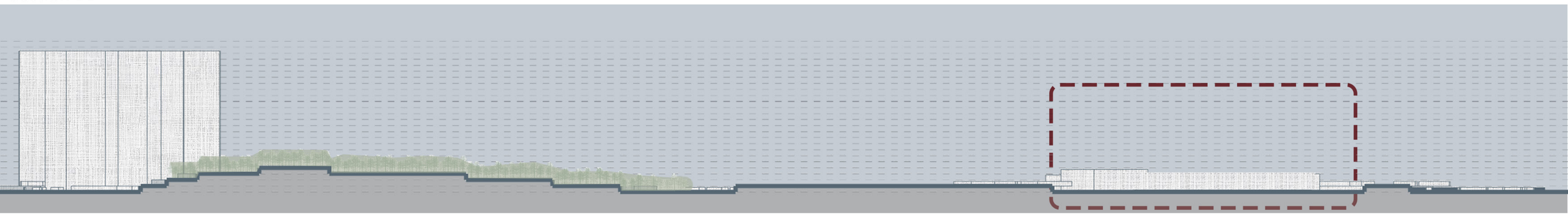
4 Unplanned growth of residences dominate the landscape

5 The site is connected by metro lines as well as the main highway

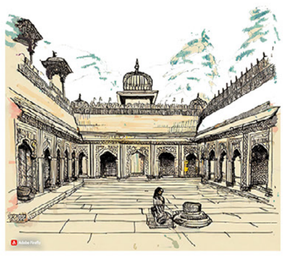
Section AA



Section BB



Notions



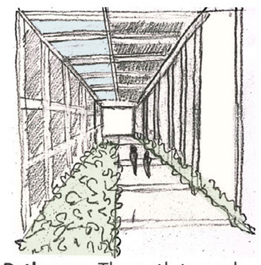
Central Atrium: It is an integral part of many indian buildings to provide light and also climate control

Light/shadow: Indian architecture often utilises elements for a play of light and shadow creating patterns

Spatial Organisation: In traditional Indian architecture, the spaces are organised in such a way that there is no direct access to the main function

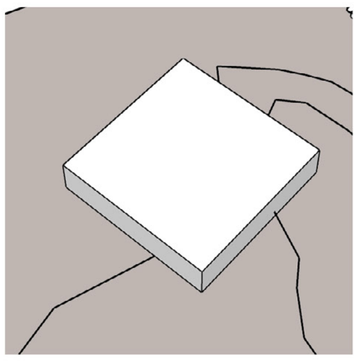
Layers: There are many layers to protect the interiors from heat and light in buildings in India. There are also sunshades for this

Colours and materials: Indian architecture is best characterised by the use of colour and local materials which provide the character

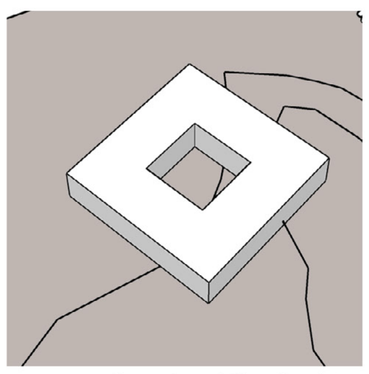


Pathways: The path to each space is often more striking than the space itselft and it is carefully treated.

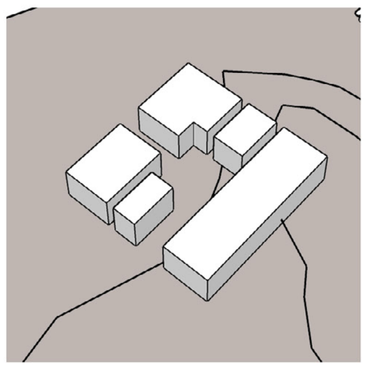
Massing



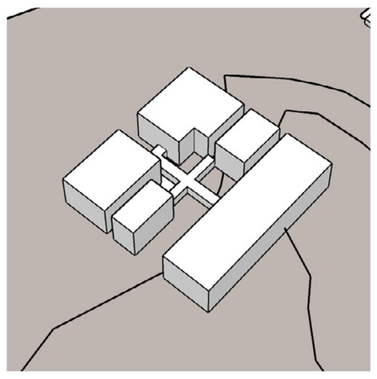
A consolidated building is proposed to provide a semblance of unity in the otherwise fragmented surroundings



A courtyard's use is multifunctional. It aids in climate control, bringing in light and providing a space for gathering



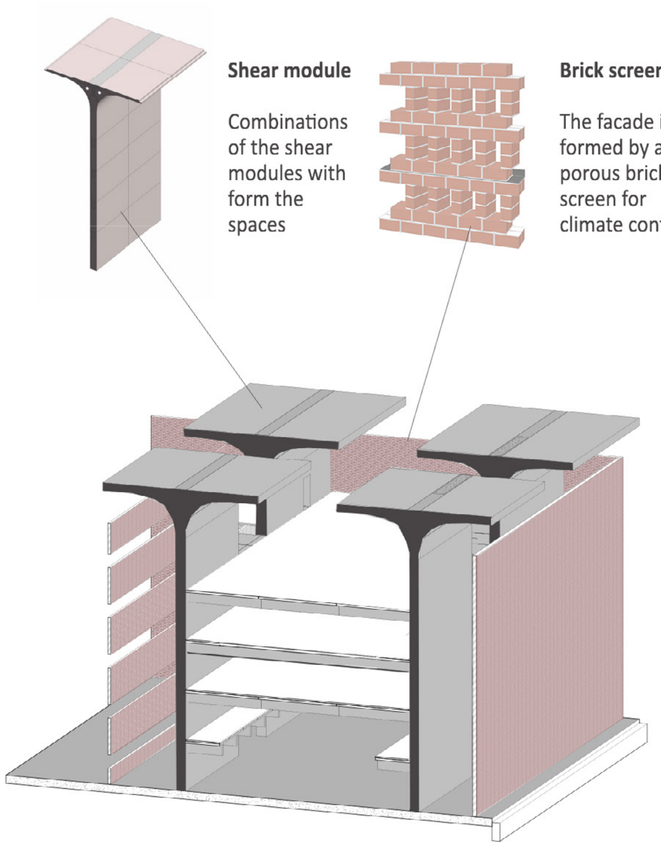
The building is divided into smaller units according to its function so as to provide a sense of heirarchy



The different parts are connected by pathways which also help in dividing the courtyard into different functions

The Library is meant to serve as a new icon for the city, a symbol of modern architecture. It is to function as a link of a promising future with the glorious past. It is envisioned as a unified structure so as to contrast with the very fragmented and unplanned surroundings. It follows the north-south orientation as is the local convention.

Components



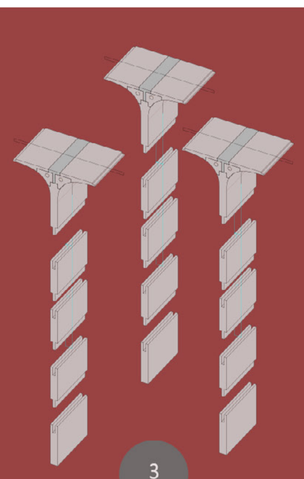
Structure

1

The modules are first prepared off-site in the required dimesions

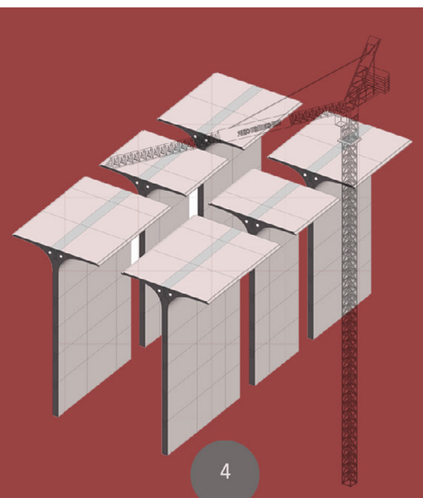
2

The modules are sized in such a way(maximum dimension:6m) that they can be transported



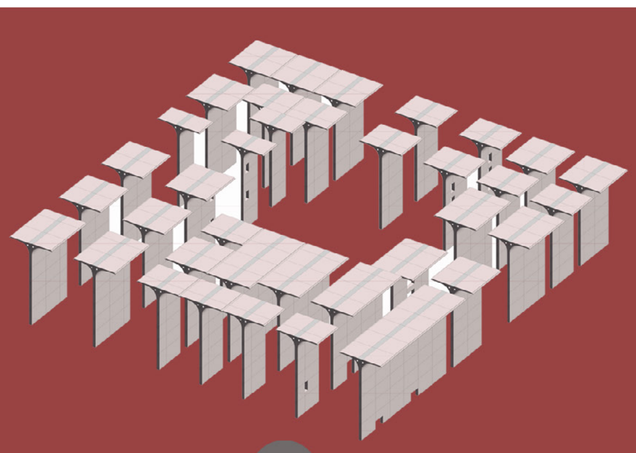
3

Each space is formed by large shear structures which are in turn formed by pre- cast modules



4

The shear structures are then assembled on site with the use of a crane. They are assembled in the east-west direction for utilising the wind direction

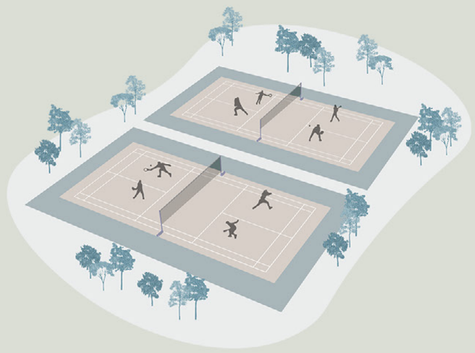


5

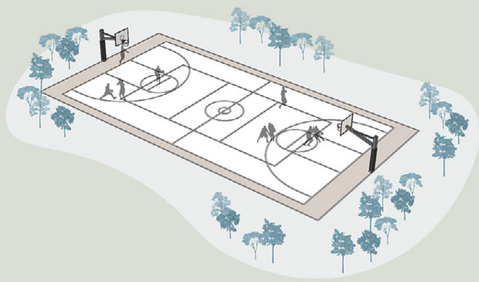
Thus the whole structure is formed in a way which is cost effective and fast , with less scope for mistakes.

Lake

Installation park



Badminton court



Basketball court

Community garden

Site Plan
Scale 1:2000

1. Lawn
2. Community farming
3. Community Park
4. Dog Park
5. Seating Area
6. Children's Play Area
7. Seasonal Lake
8. Basketball Court
9. Badminton Court
10. Skate Park
11. Installation Area
12. Mini Installation
13.Seating Around lake
14. Main Entry Road
15. Vehicular Entry Road

The Library is to also function as a park for the neighbouring areas. This sector in particular has a lack of green spaces for interaction.

The site also contains a lake which is essential for the drainage of the area. It is in a bad condition and rejeuvenation is required.

Actvities like community garden and skate park is also planned

Bangalore : Garden City

To up with Bangalore's reputation of garden city,a variety of trees and plants are chosen to be planted in the park planned

The plants chosen are going to be bug repellent to combat the growing mosquito problem in the city

The site is also adjacent a large plantation of rubber trees which provide a backdrop to the library

Tabebuia Rosea

Jacaranda

Tabebuia

Gulmohar

Trees to be planted on site

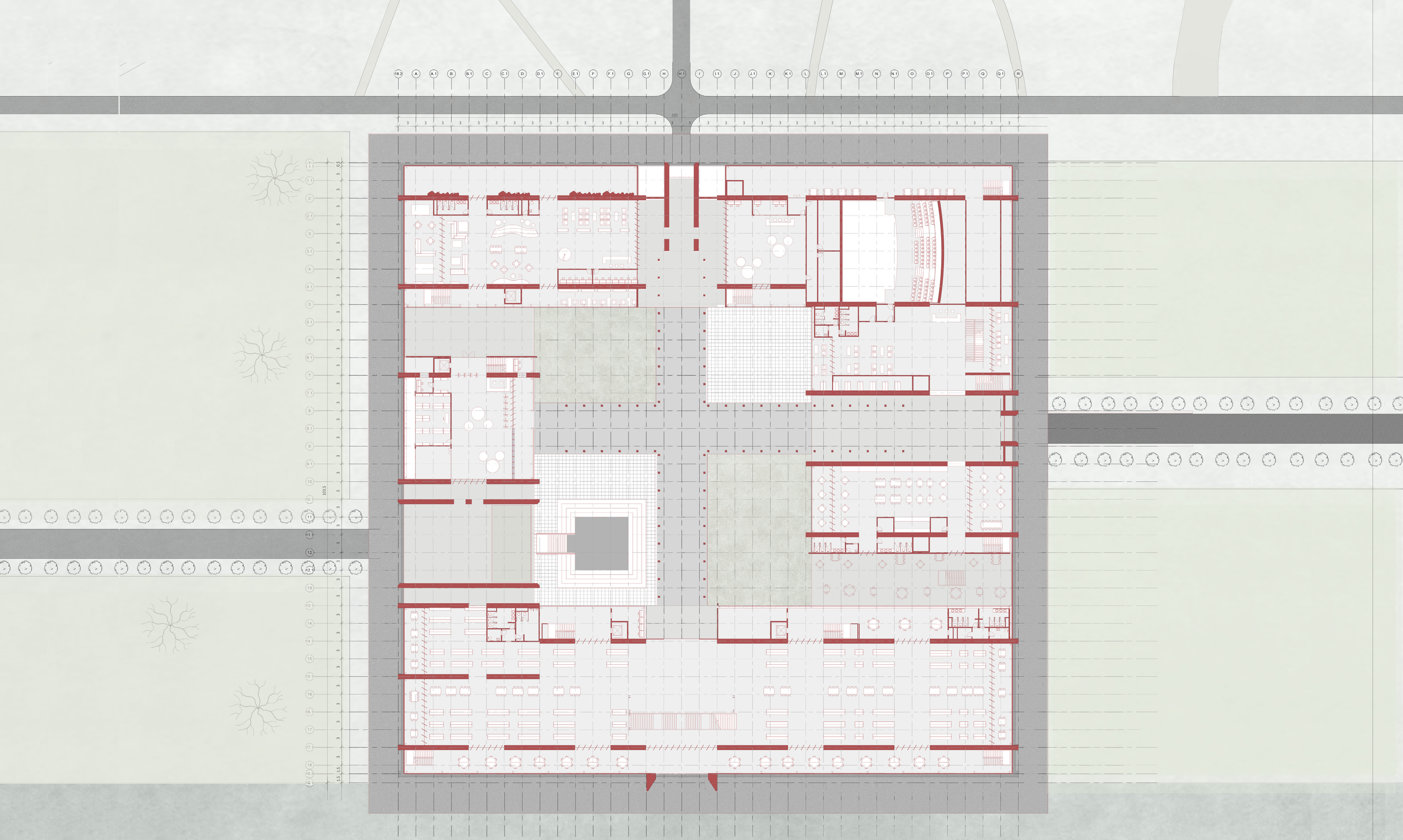
Citronella Grass and Lemongrass

Nasturtiums

Scented

Phenomenal

Bug-Repellent Plants



Ground Floor Plan
Scale 1 :200

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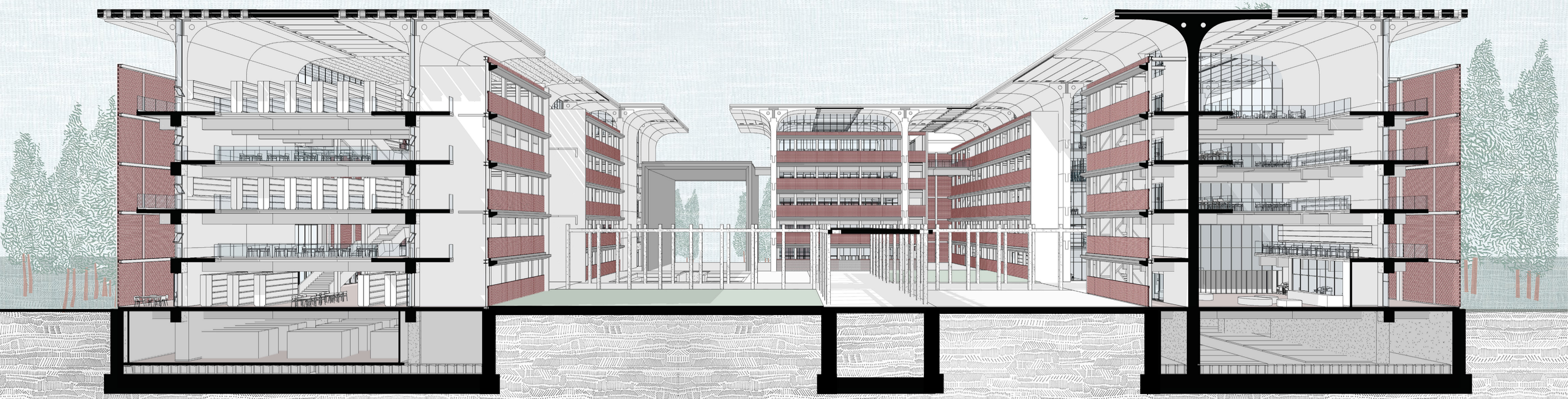

Perspective Section 1

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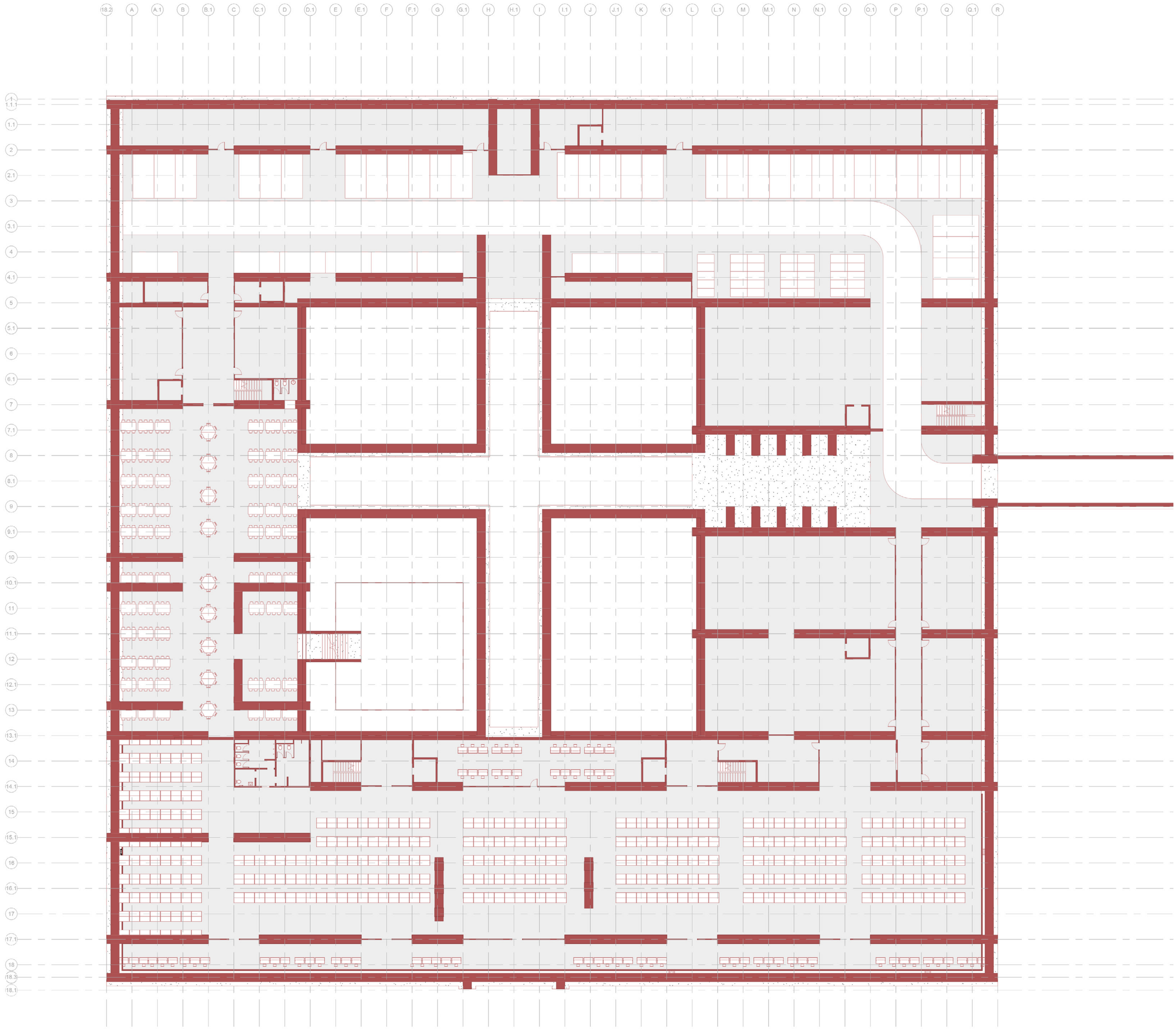
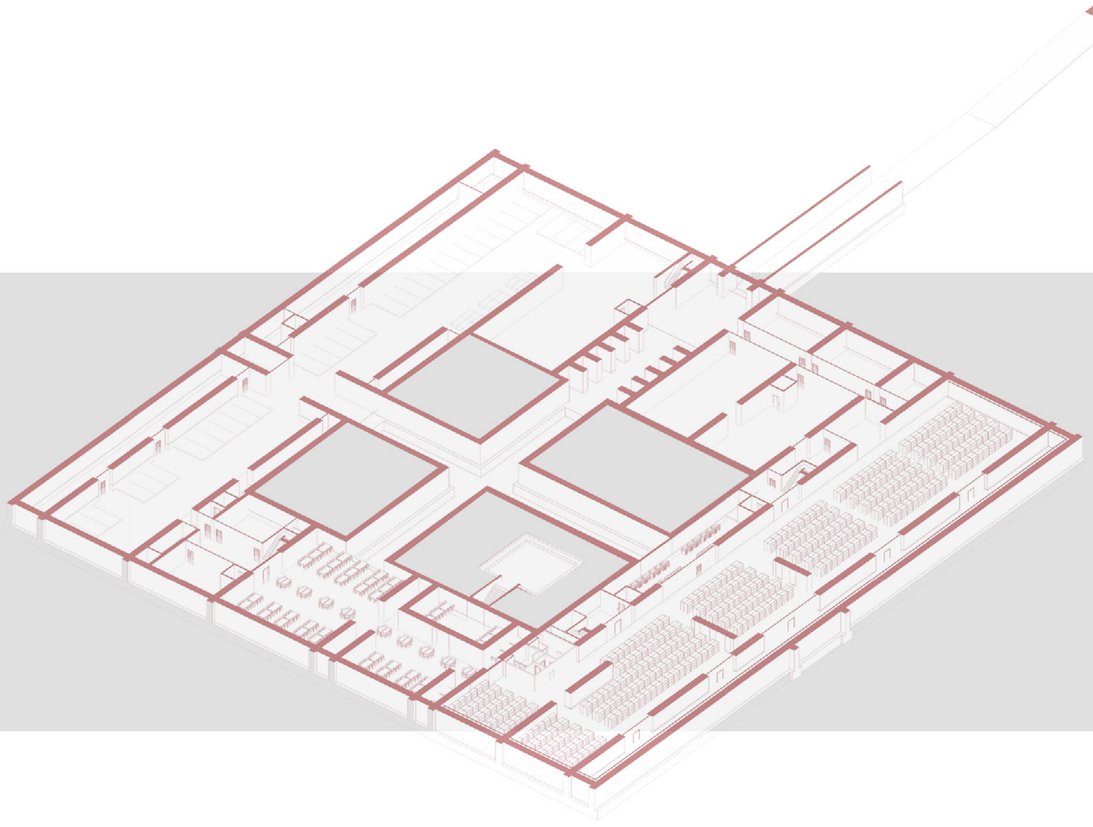
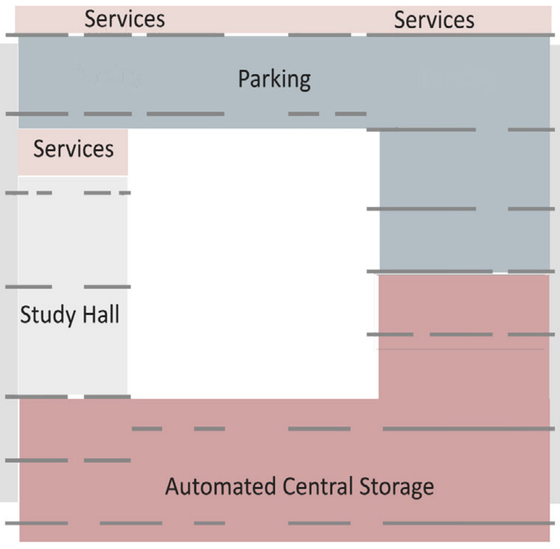


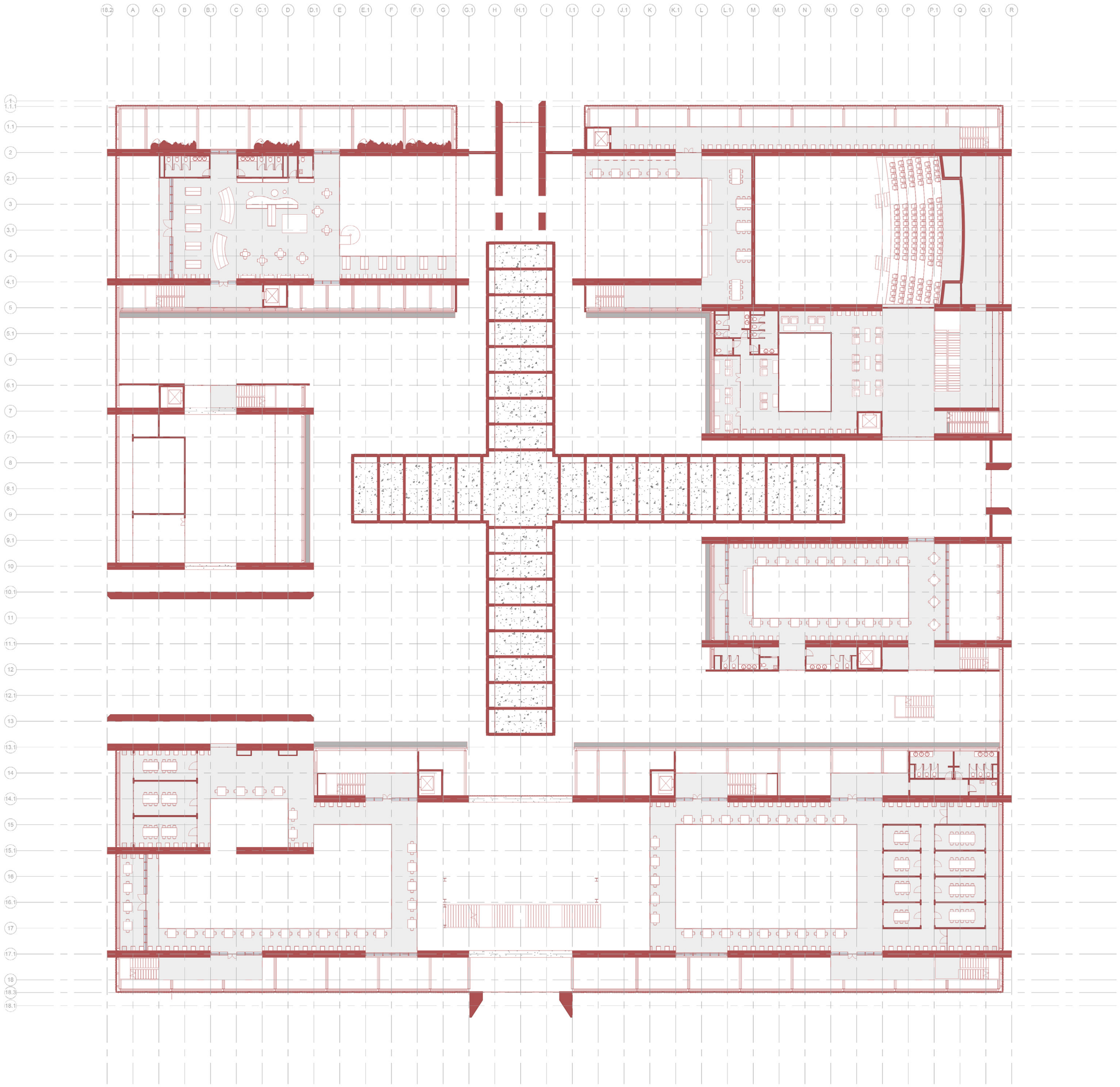
Underground Plan
Scale 1 :250



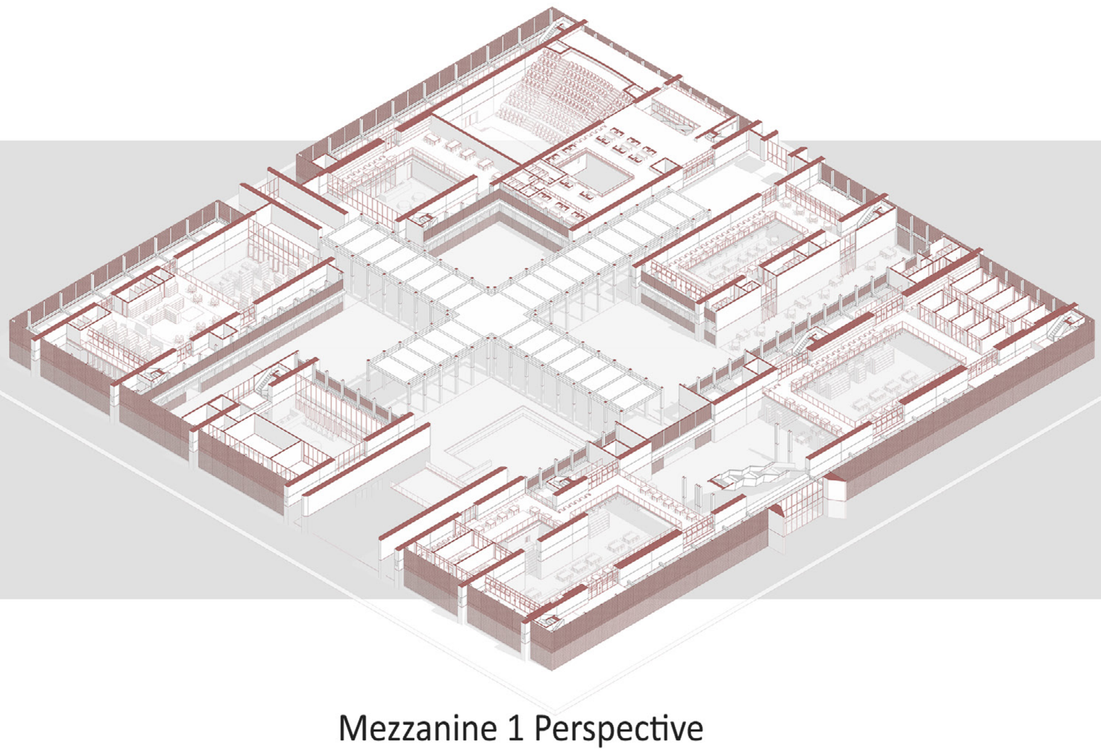
Underground Perspective



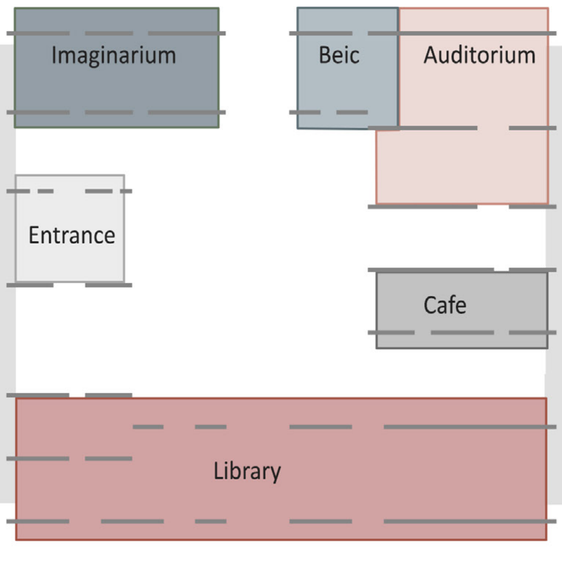
Underground Function Distribution



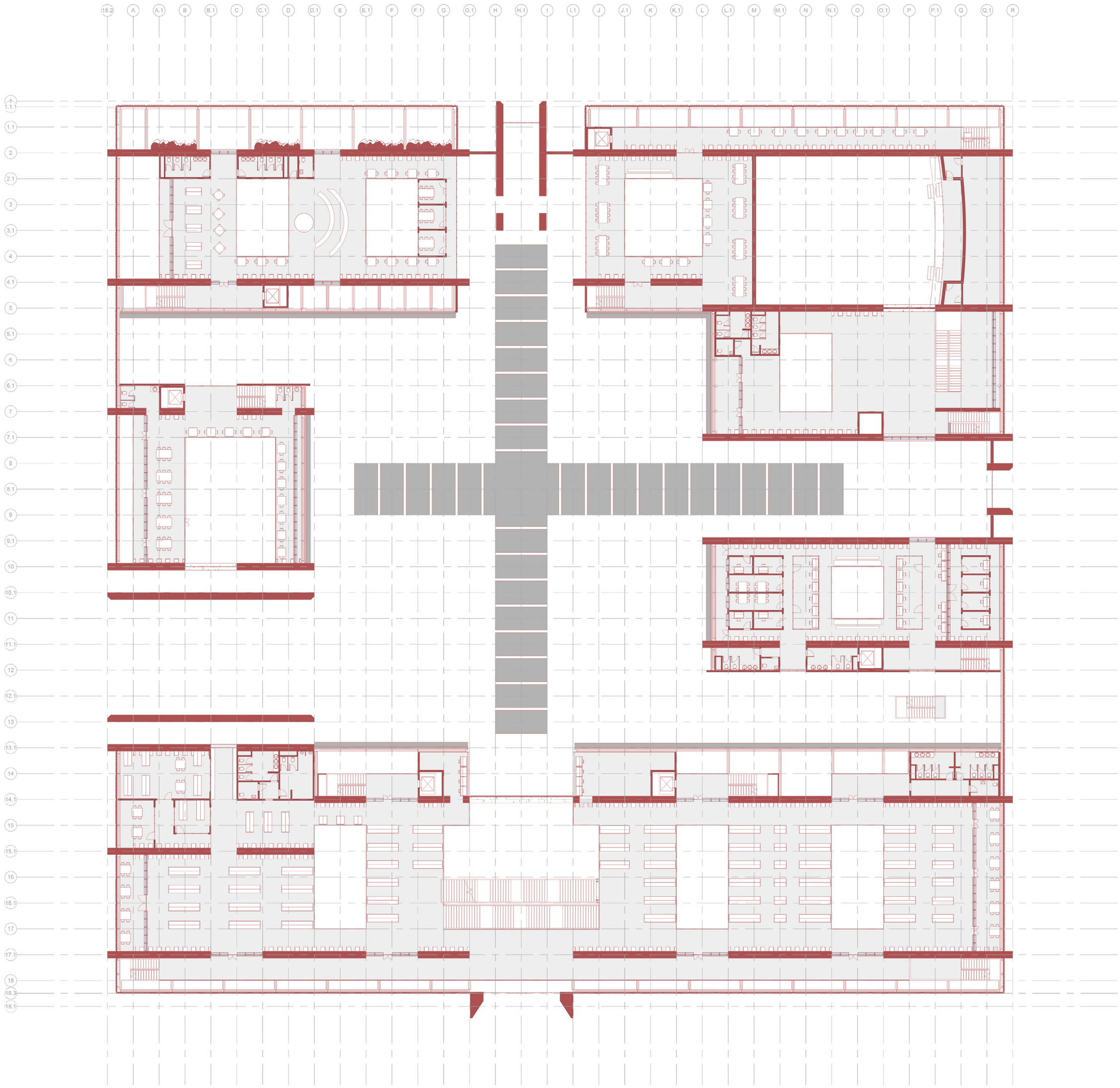
Mezzanine 1 Plan
Scale 1 :250



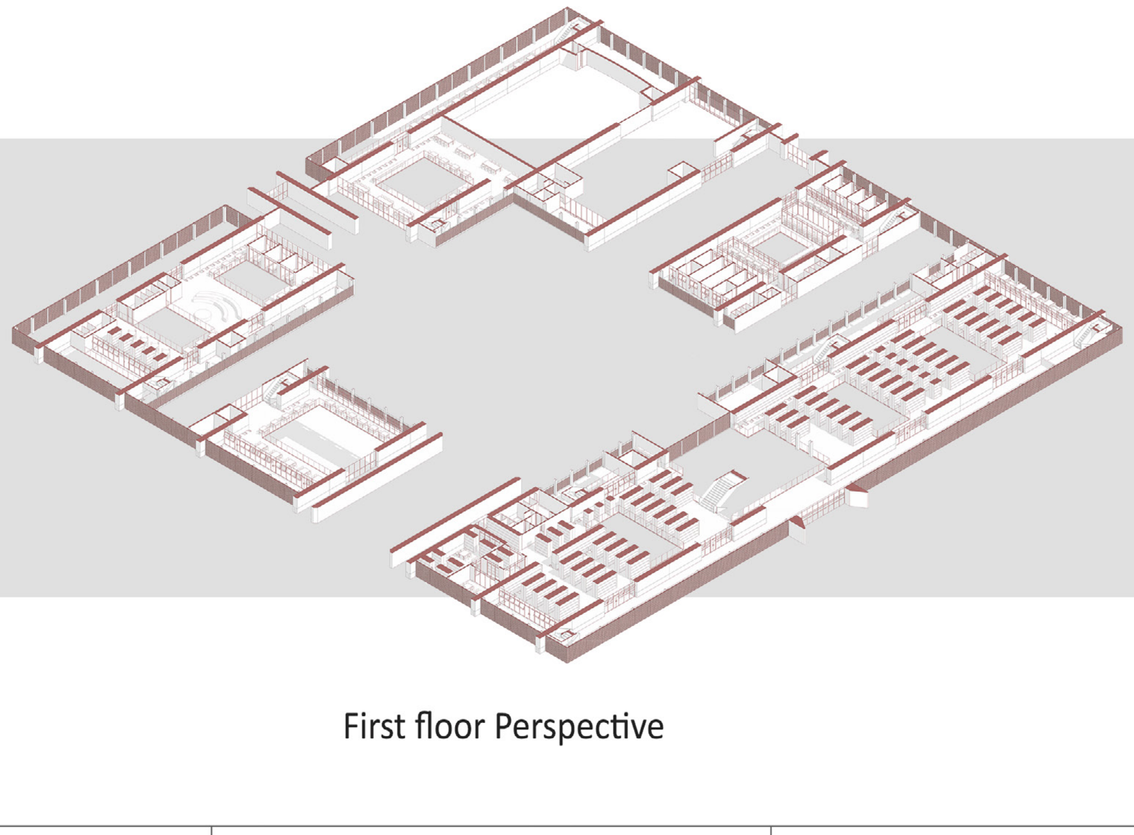
Mezzanine 1 Perspective



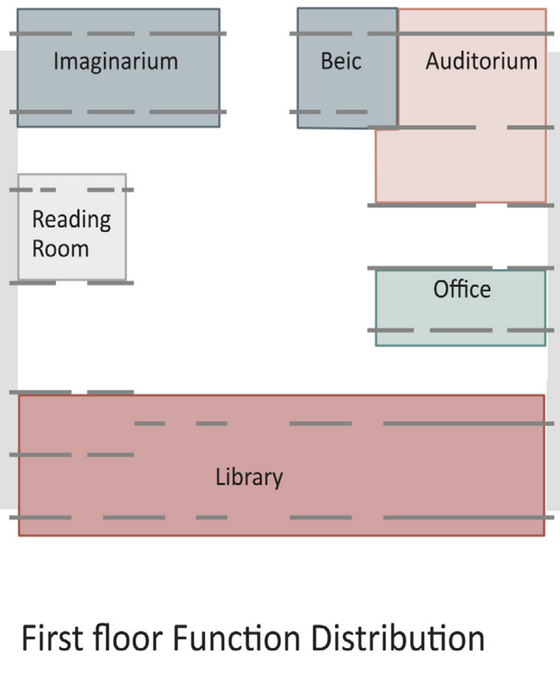
Mezzanine 1 Function Distribution



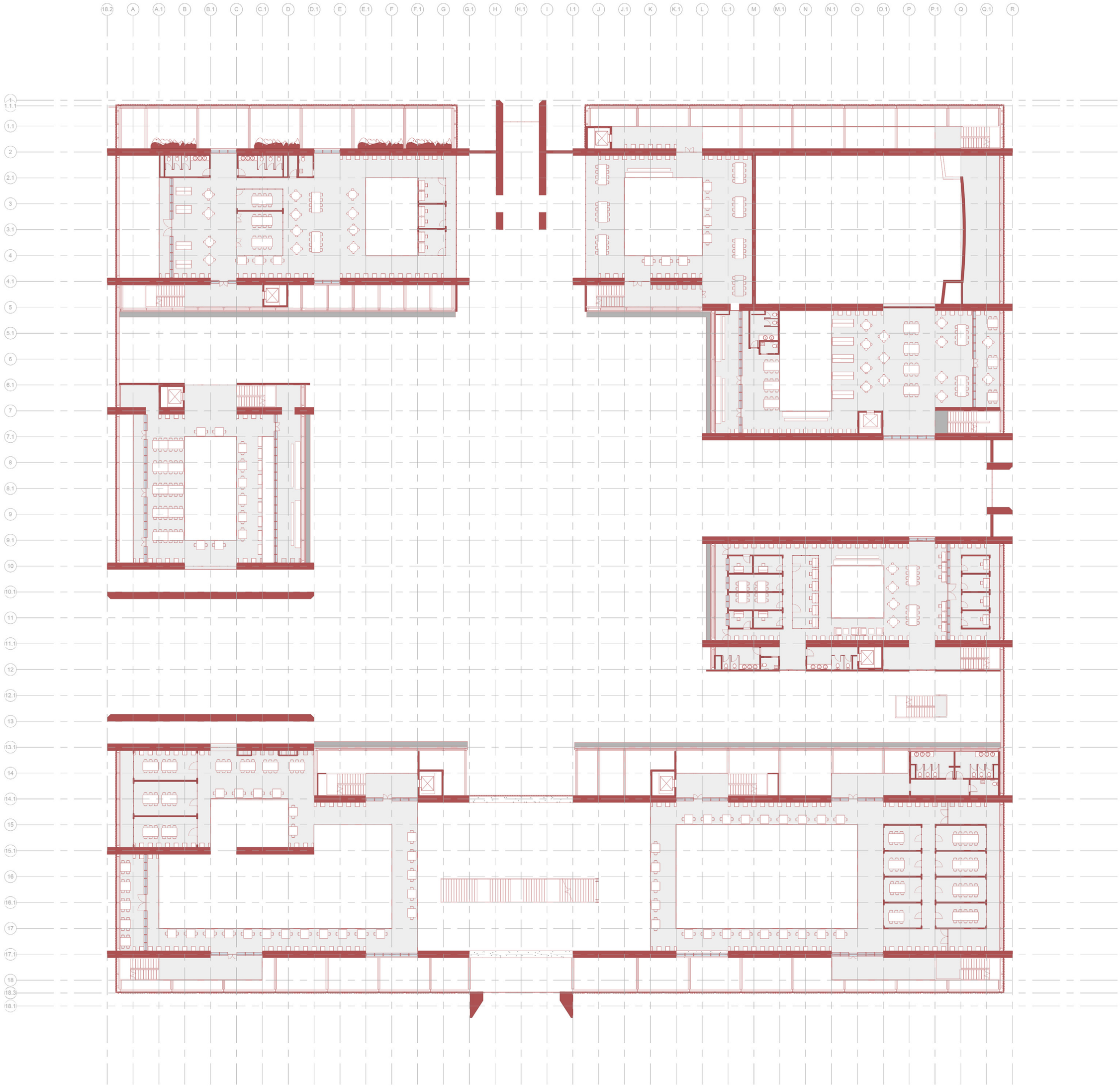
First Floor Plan
Scale 1 :250



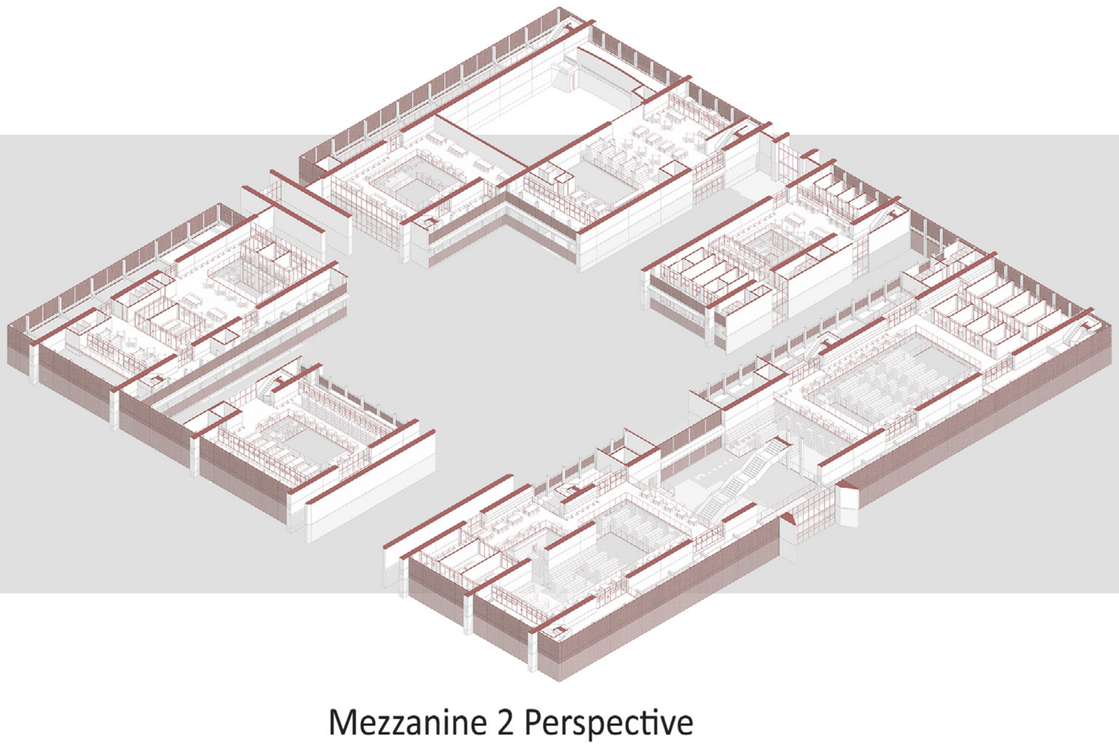
First floor Perspective



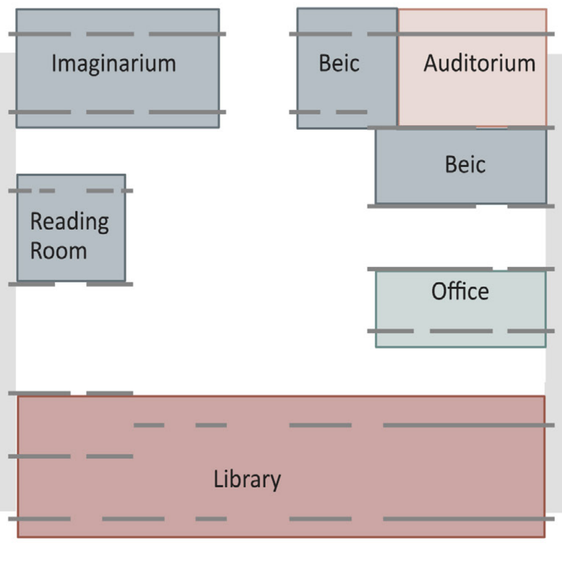
First floor Function Distribution



Mezzanine 2 Plan
Scale 1 :250

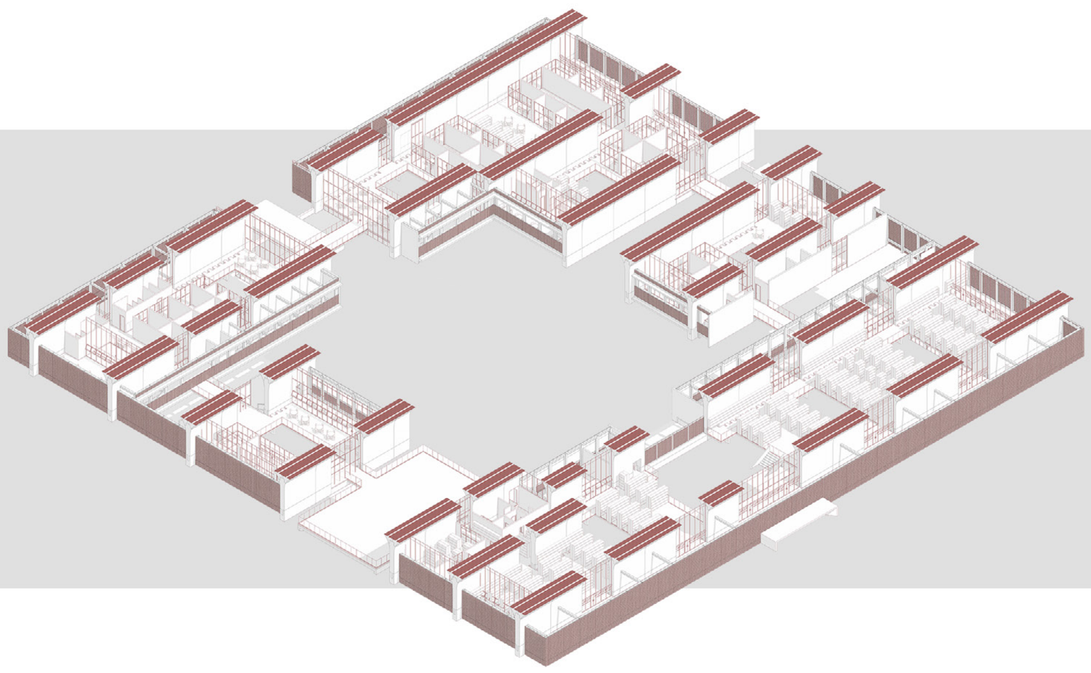


Mezzanine 2 Perspective

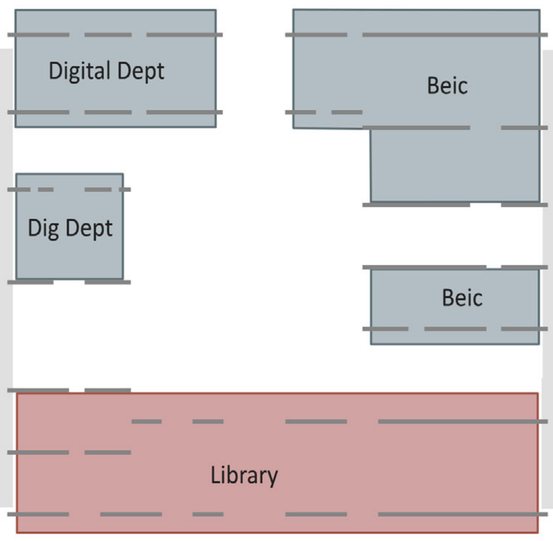


Mezzanine 2 Function Distribution

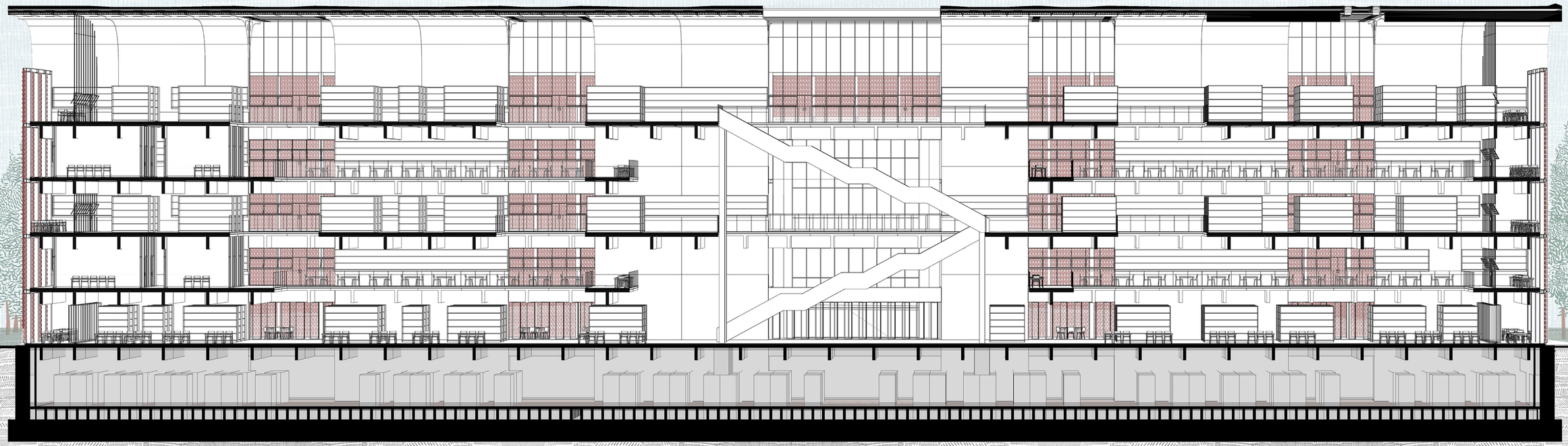
Second Floor Plan
Scale 1 :250



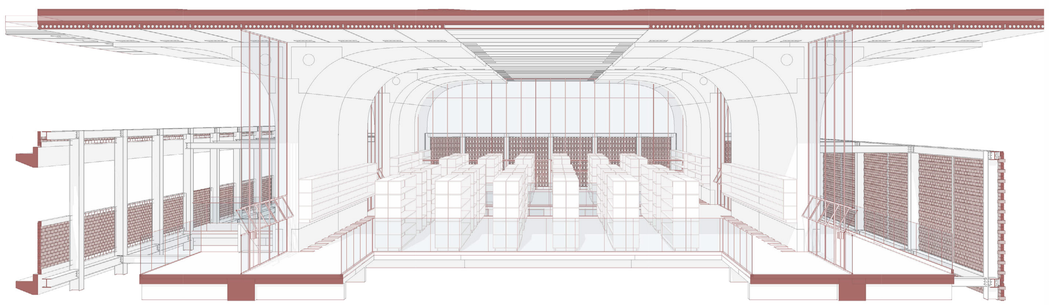
Second Floor Perspective



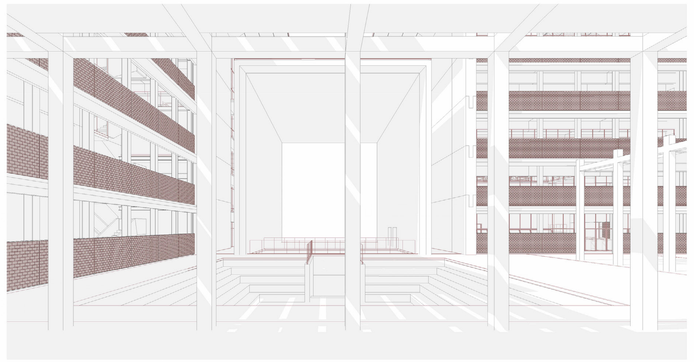
Second Floor Function Distribution



Perspective Section 2



Perspective Section 2



Courtyard View

Pathways view

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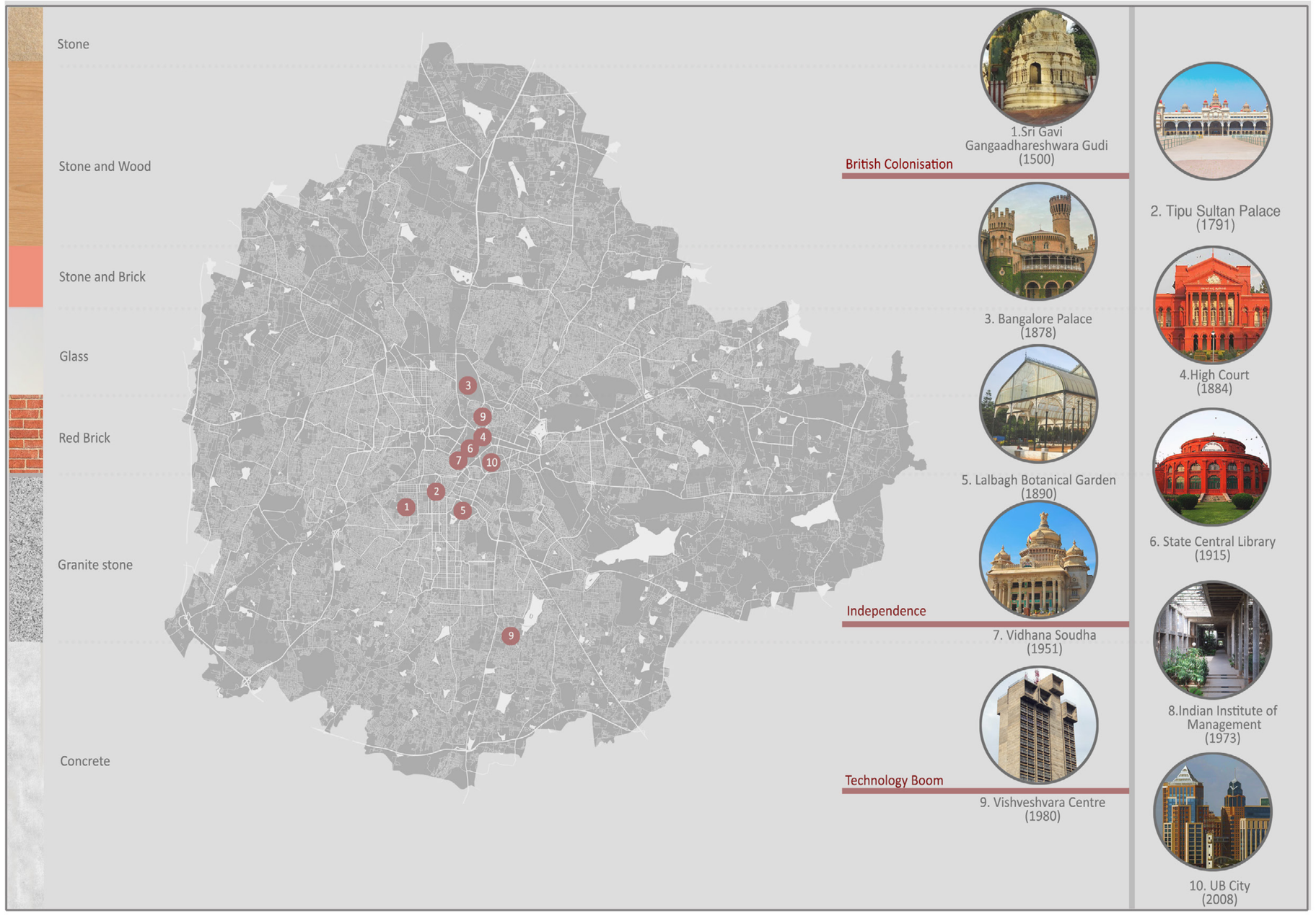


1 Pre-cast concrete : ARTO Pre-cast concrete

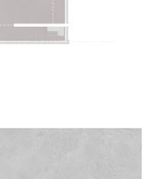
Pre cast concrete is more sustainable than cast-in-place. Precast uses little water during production and hardly any at the construction site.Quick erection minimizes noise and pollution impact on the neighbourhood

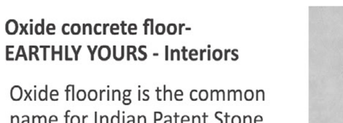
2 Compressed stabilized earth bricks (CSEB)- Earth Blocks India Pvt. Ltd.

TYPE : CROWN RED ORANGE

These are earth blocks stabilised with 6-8 percent cement. It has 10 to 12 times less carbon emmision and embodied energy than fired brick. It can be recylced after its lifetime

3 Toughened Glass: Saint Gobain





Toughened glass is strong and durable and is 100 percent recyclable. It causes less injury when broken as it breaks into large pieces. It consumes less energy than traditional glass to manufacture

4 Flooring

Oxide concrete floor- EARTHLY YOURS - Interiors

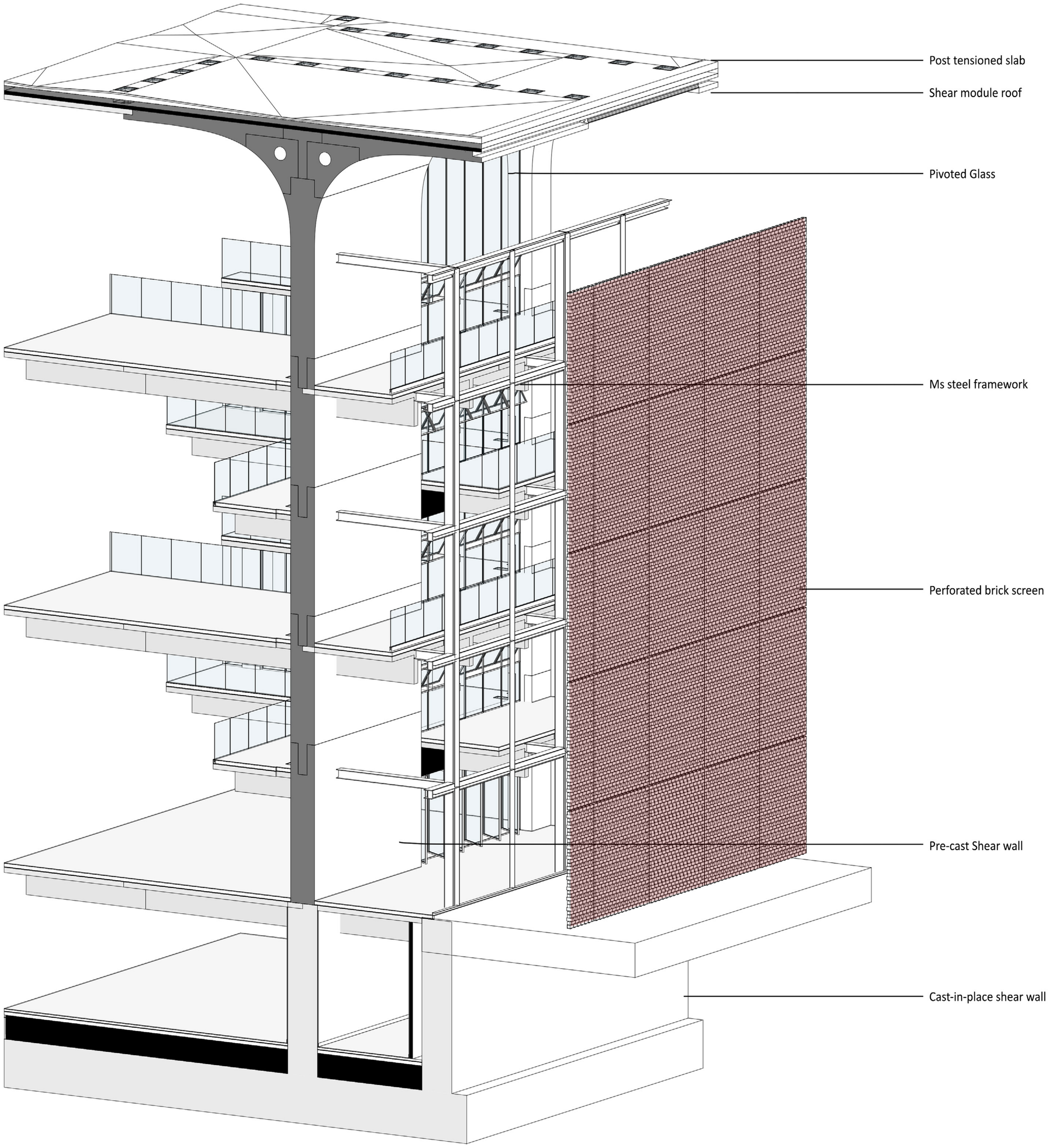
Oxide flooring is the common name for Indian Patent Stone or IPS.It is a cement based artisanal flooring technique found across India.Ubiquitous in most rural houses in India.

Thunder white Granite- REGATTA granites India

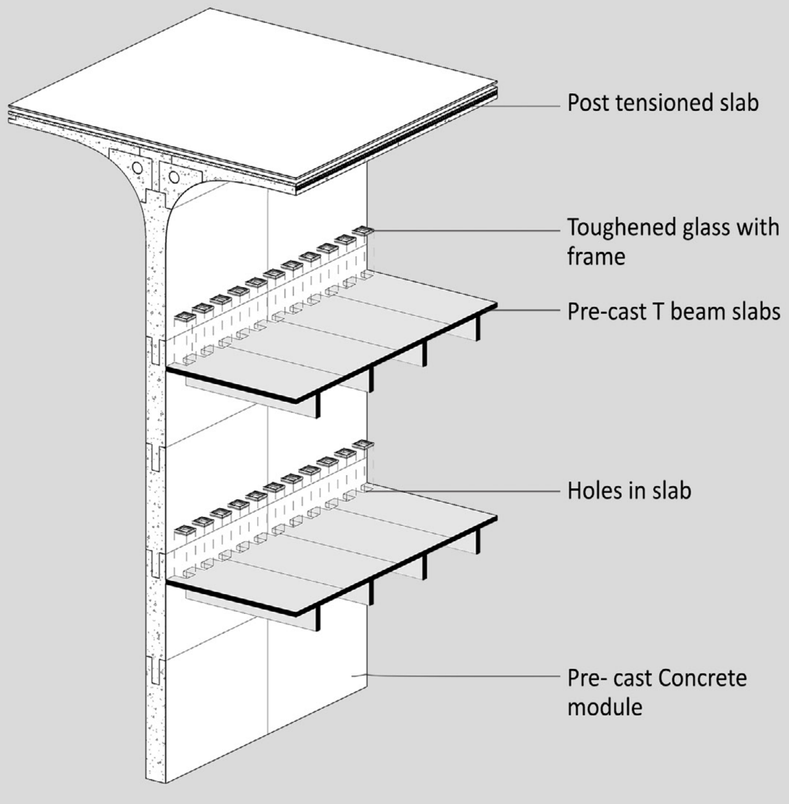
White Granite is quarried in South India . It has a white base with light grey bands. Different finishes like polished, honed etc are available

Kuppam green granites- REGATTA granites India

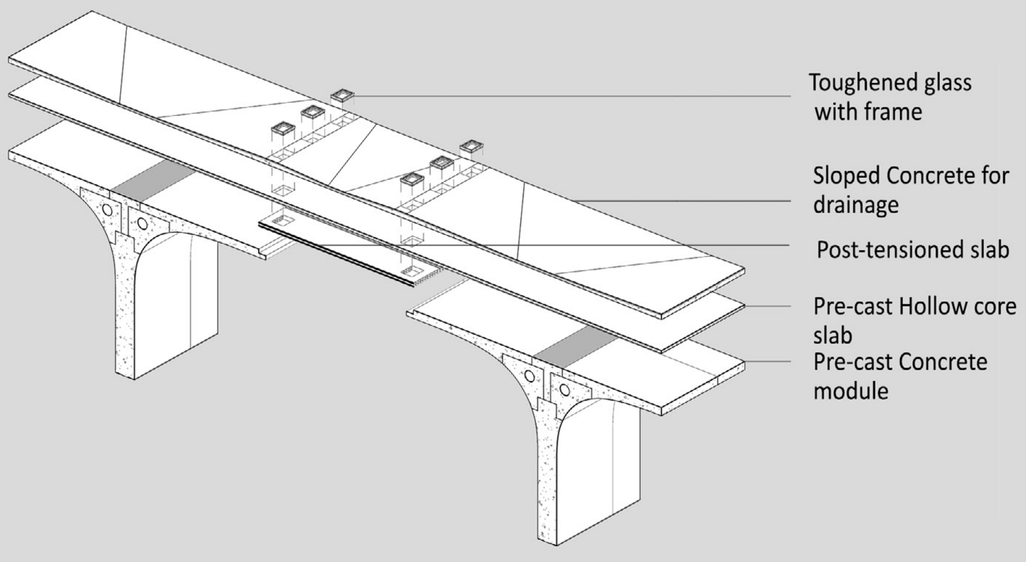
Kuppam Green granite is also quarried in South India and is available in different finishes. It is slip resistant.



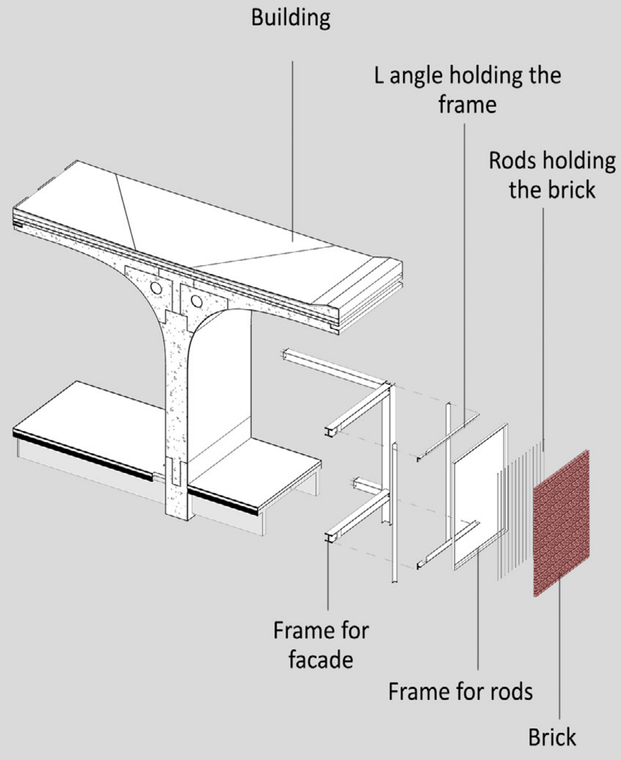
Edge Detail



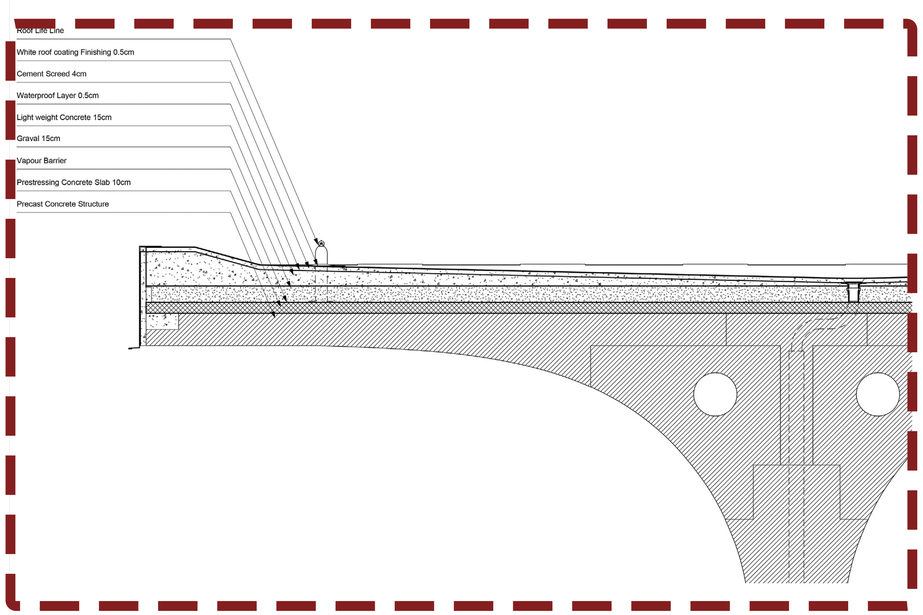
Slab Detail



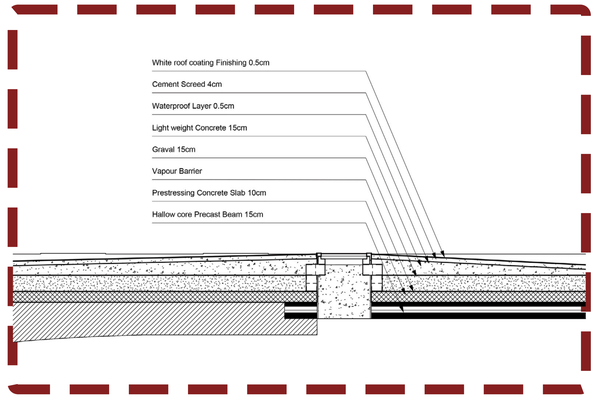
Roof Detail



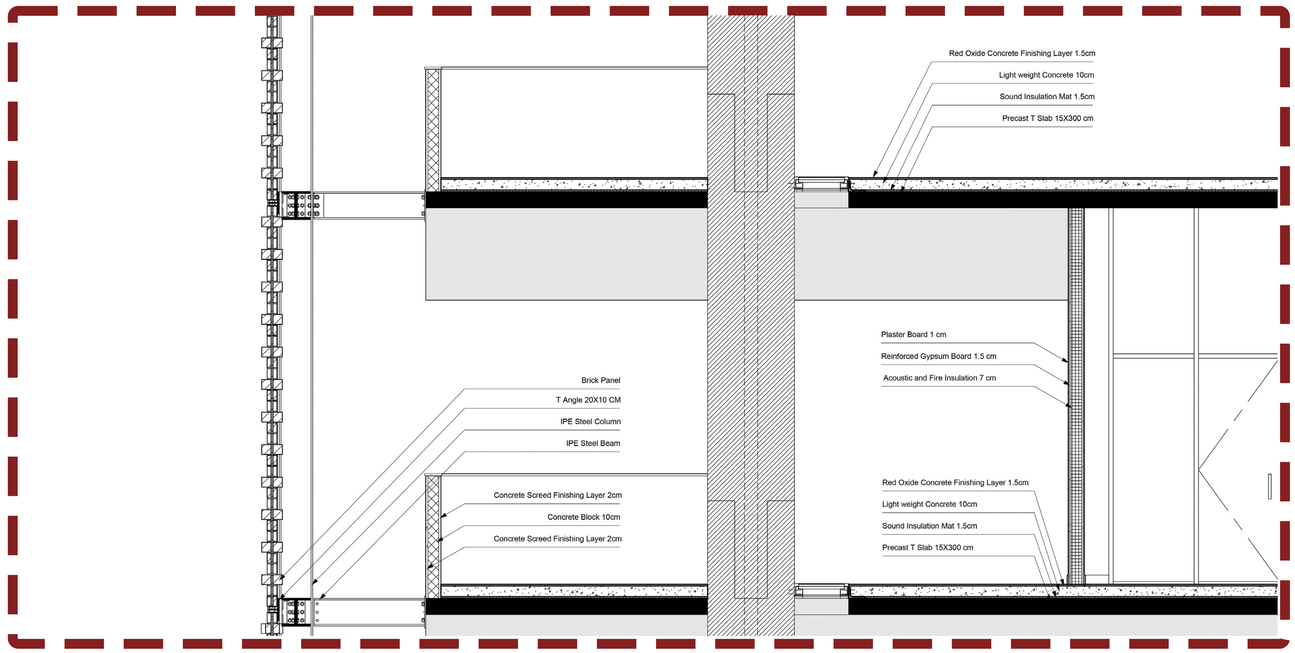
Facade Detail



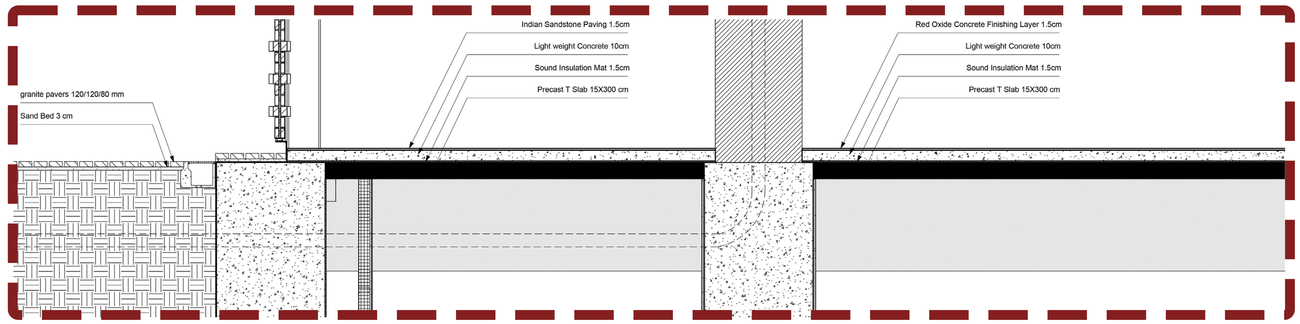
Detail A
Scale 1 :20



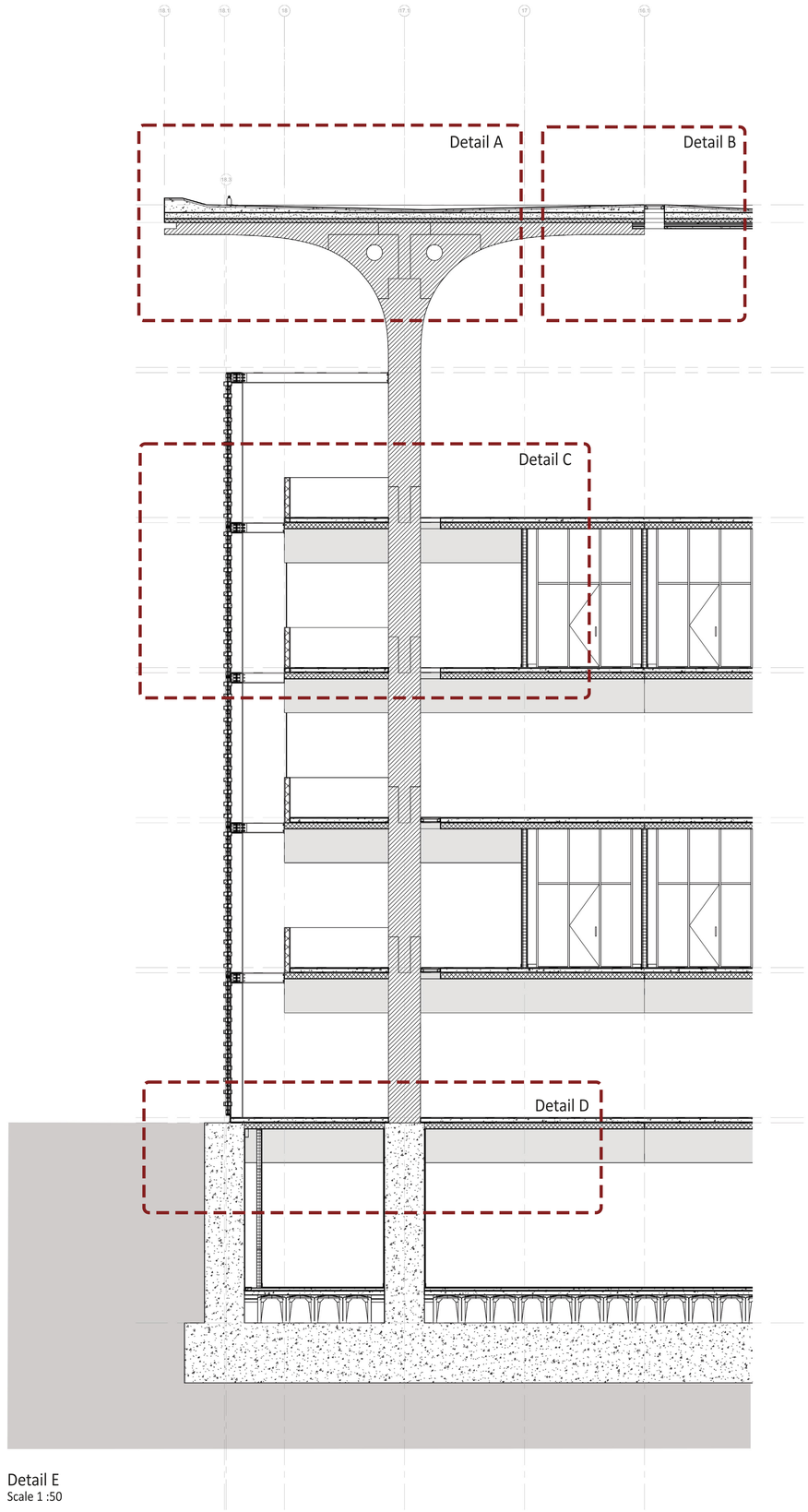
Detail B
Scale 1 :20



Detail C
Scale 1 :20



Detail D
Scale 1 :20



Detail E
Scale 1 :50

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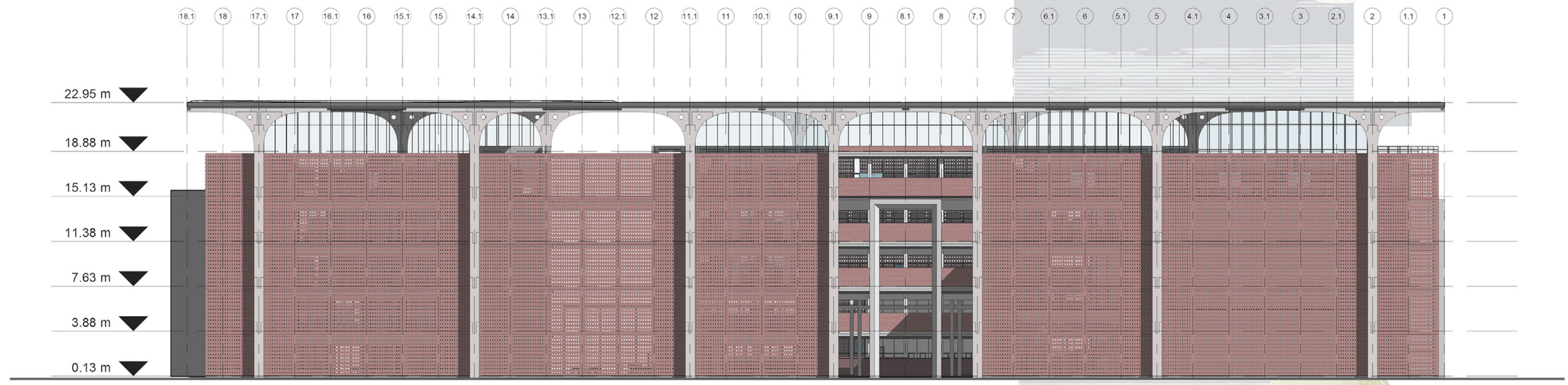
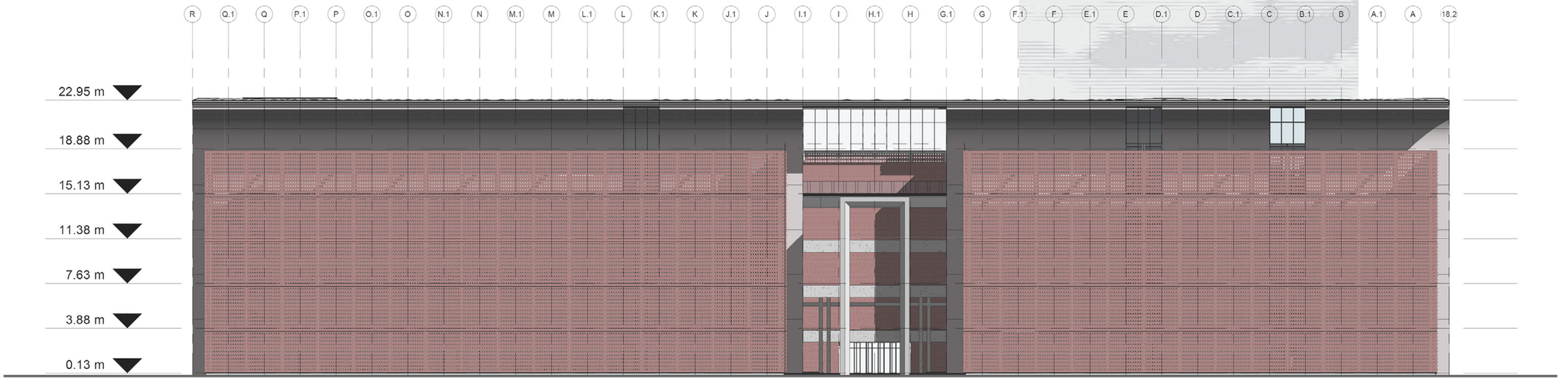
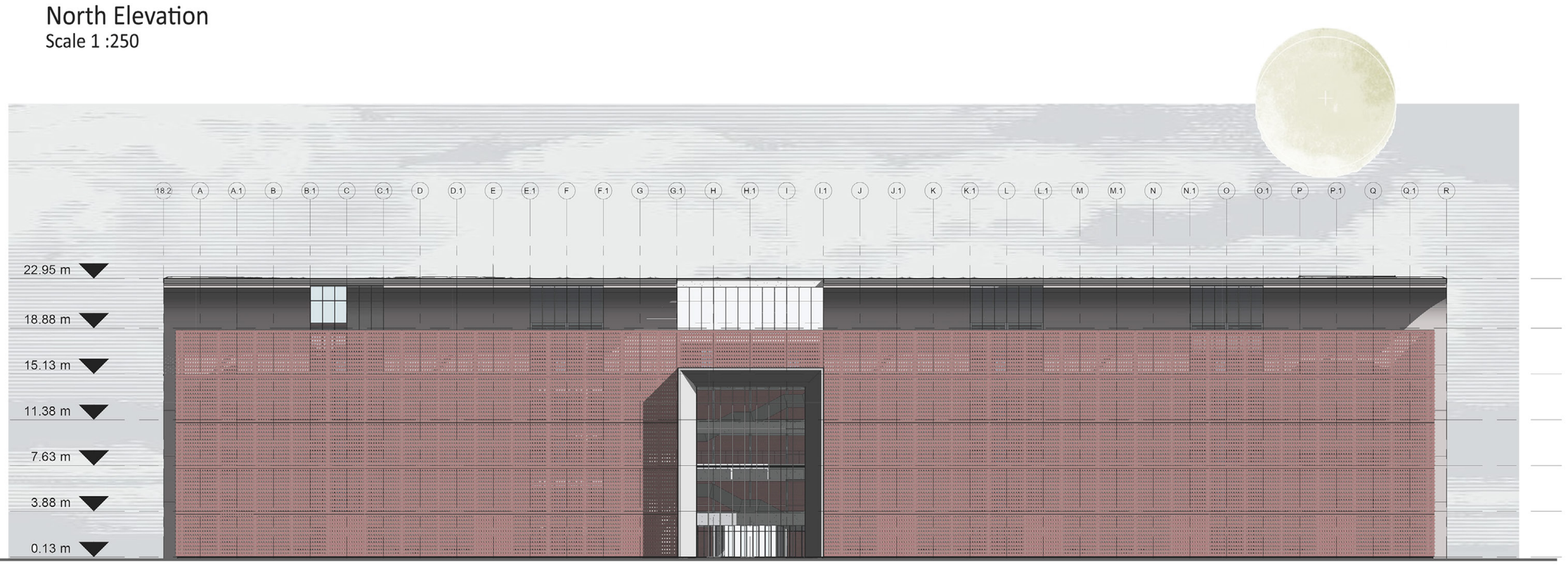


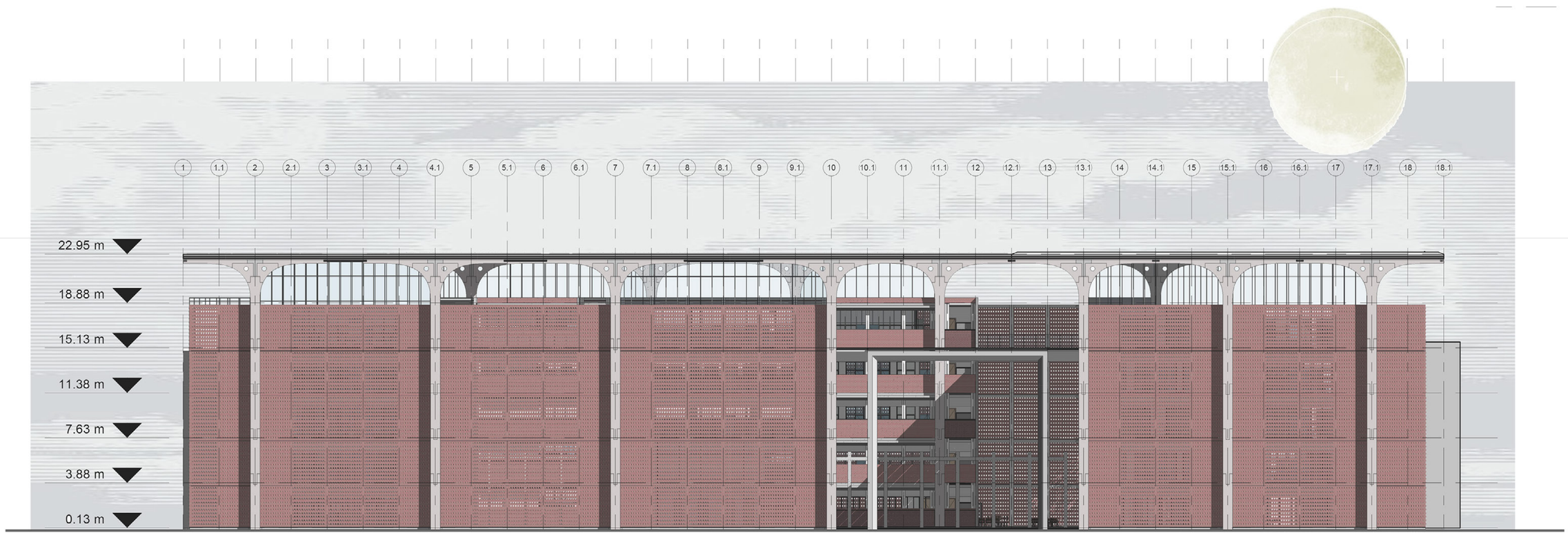
West Elevation
Scale 1 :250



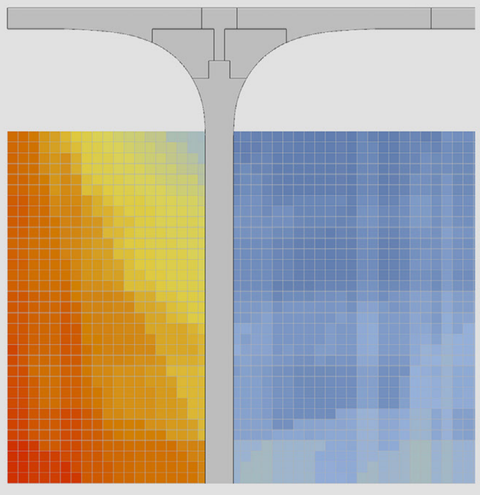
North Elevation
Scale 1 :250



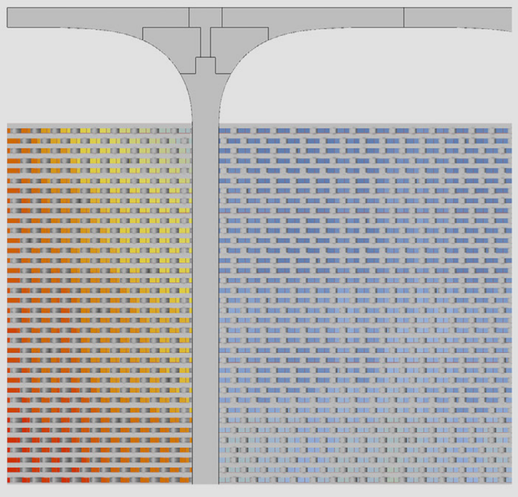
South Elevation
Scale 1 :250



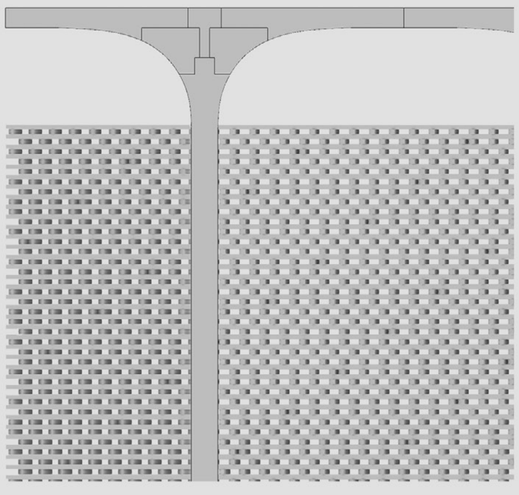
East Elevation
Scale 1 :250



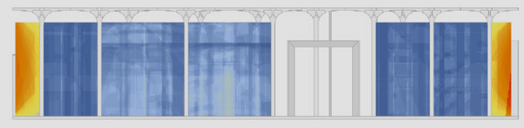
The rotation of each of the bricks in the facade is determined parametrically by first analysing the solar radiation with falls on it. Red means higher radiation and blue means lower.



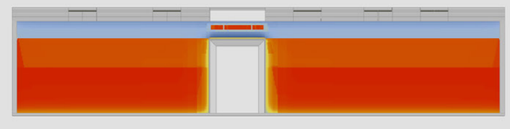
Higher the radiation , the rotation of the brick is less. That means less sunlight will come in. This rotation is done by the use of the software grasshopper



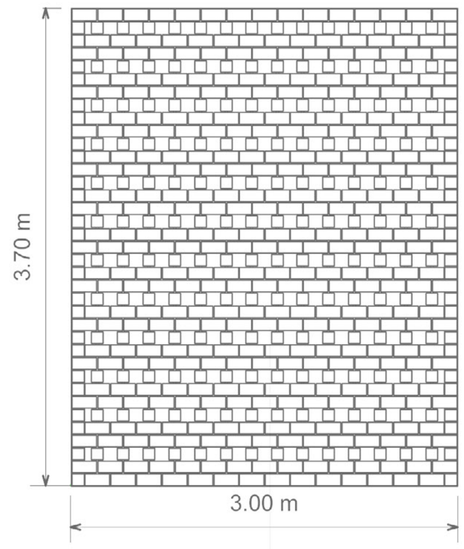
This means there will be a pattern accross the brick panels which will depend on the amount of sunlight falling on it.These panels will be assembled off-site.

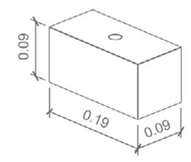


Solar radiation analysis of east elevation

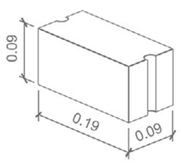


Solar radiation analysis of south elevation



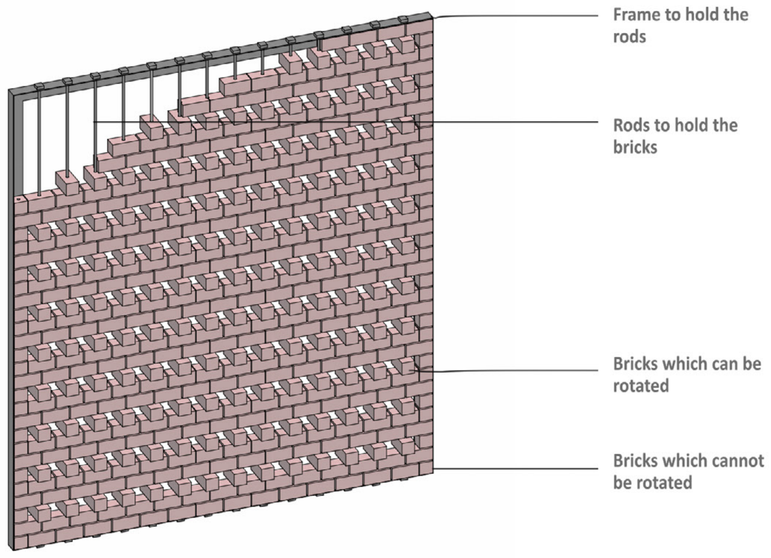


The bricks are the size of a standard indian brick with a hole for the rods to go through

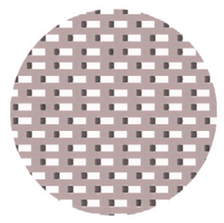


There are two kinds of bricks . One with a hole in the centre and the other with a hole on the side depending on which course the brick is on

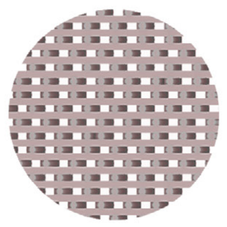
Brick Panel Elevation



Brick Panel View

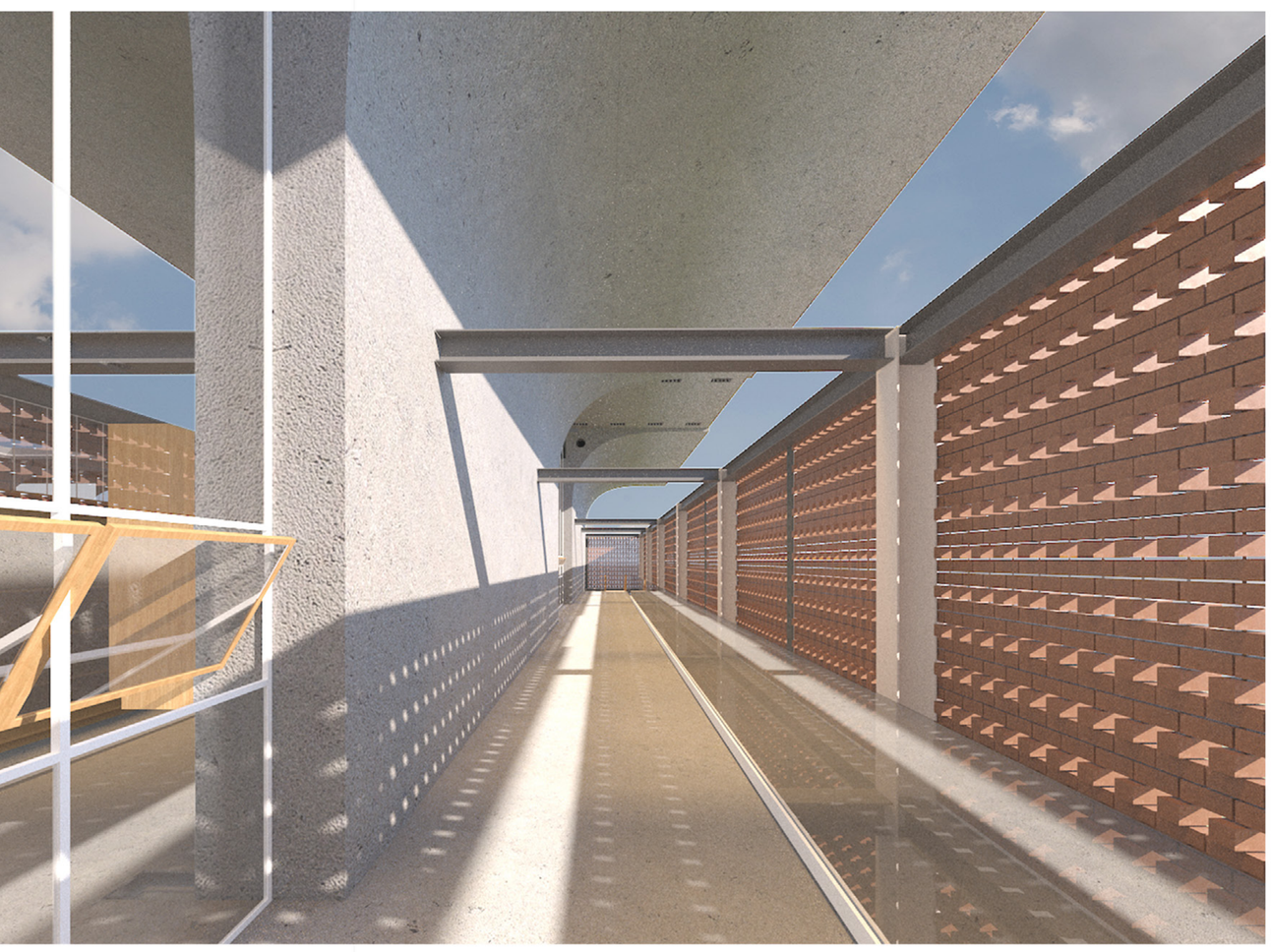


The pattern of brick are less dense in zones where the sun light radiation is less.



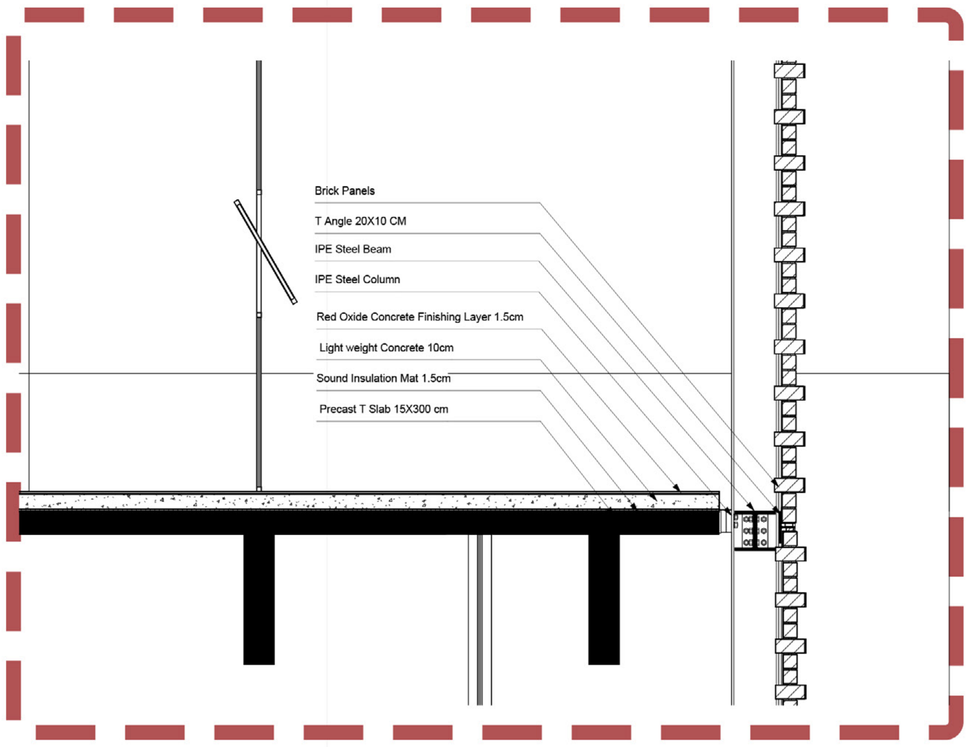
The pattern of brick are more dense in zones where the sun light radiation is less.

Brick Panel Pattern



View of balcony on second floor

View of balcony on first floor



Facade Detail
Scale 1 :10

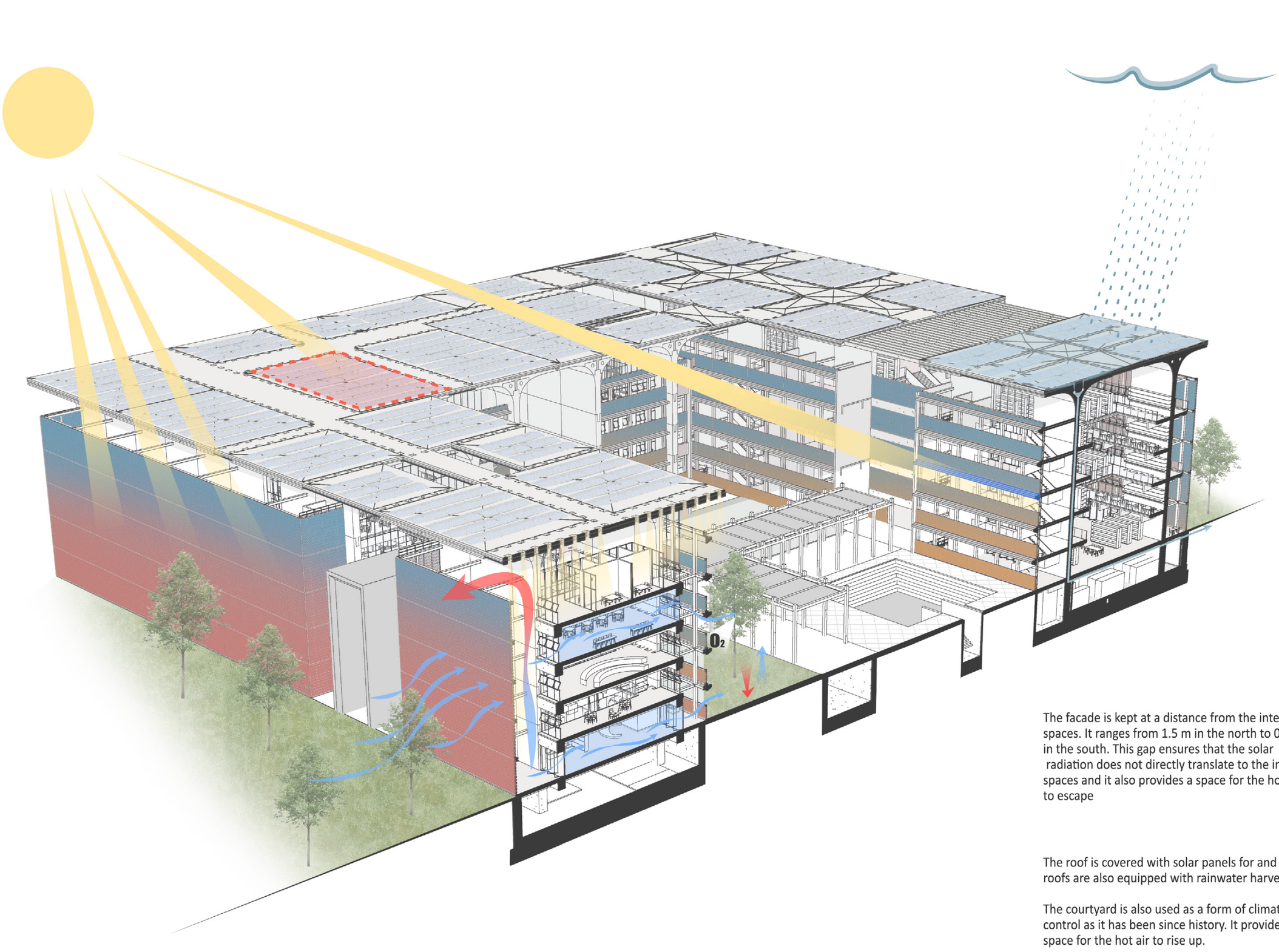
Facade Detail
Scale 1 :10

The space in the library is formed by the juxtaposition the modules and it is lit by the skylight from above

The spaces are punctured with courtyards so that the curves of the ceiling are visible to all

The courtyard in the centre is a space for gathering and relaxation for all.It also acts as a form of climate control

The pathways connect the different spaces to each other and have the same concrete treatment.

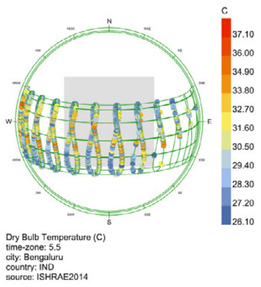


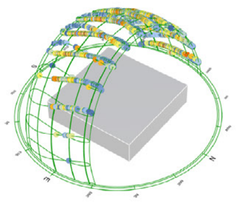
The facade is kept at a distance from the interior spaces. It ranges from 1.5 m in the north to 0.5 m in the south. This gap ensures that the solar radiation does not directly translate to the interior spaces and it also provides a space for the hot air to escape

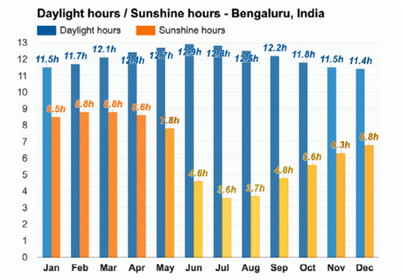
The roof is covered with solar panels for and the roofs are also equipped with rainwater harvesting.

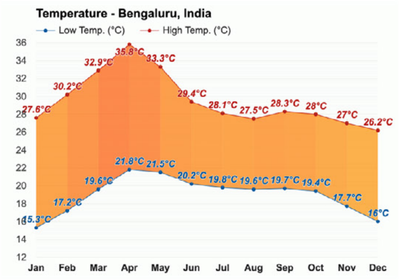
The courtyard is also used as a form of climate control as it has been since history. It provides a space for the hot air to rise up.

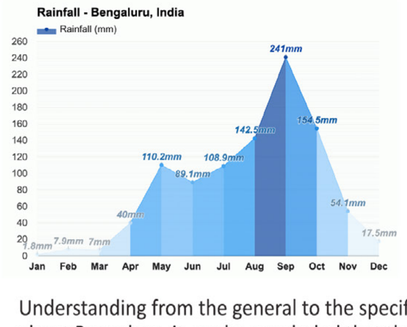
General Analysis

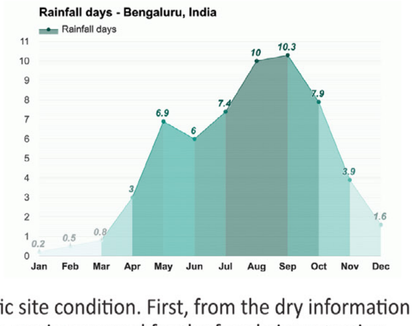








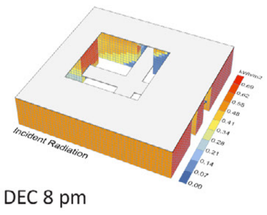




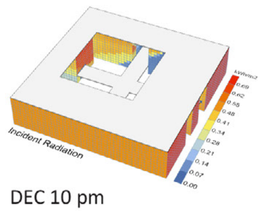
Understanding from the general to the specific site condition. First, from the dry information about Bangalore, it can be concluded that the maximum need for the facade is protection from the intense sun and high temperatures, creating an optimal natural ventilation system, and roofing against rain.

Solar Analysis (without shading)

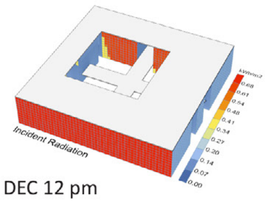
ANALYSIS OVER THE DAY:
without shading



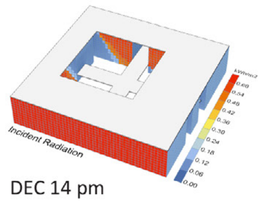
DEC 8 pm



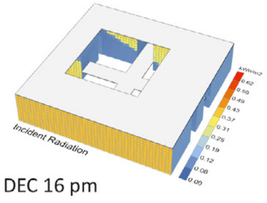
DEC 10 pm



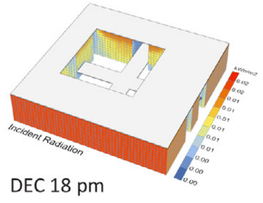
DEC 12 pm



DEC 14 pm



DEC 16 pm

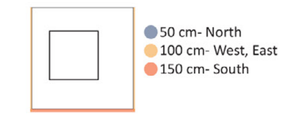


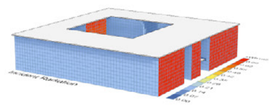
DEC 18 pm

The solar analysis on the facades is done in stages in order to create an ideal fit for the site. First, the volumes were tested without any shading to see the level of radiation and the necessary size of shading.

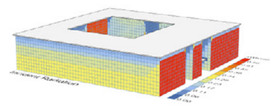
Solar Analysis (with shading)

ANALYSIS OVER THE DAY:
with shading

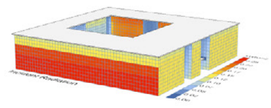




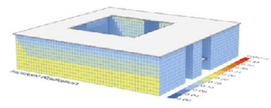
DEC 8 pm



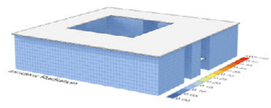
DEC 10 pm



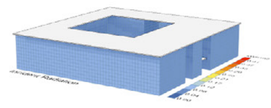
DEC 12 pm



DEC 14 pm



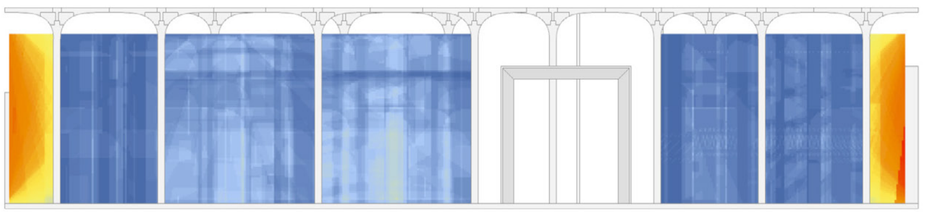
DEC 16 pm

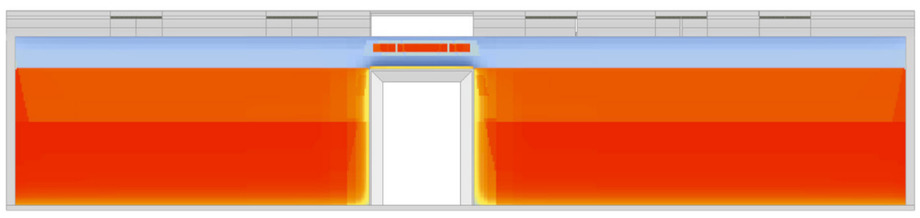


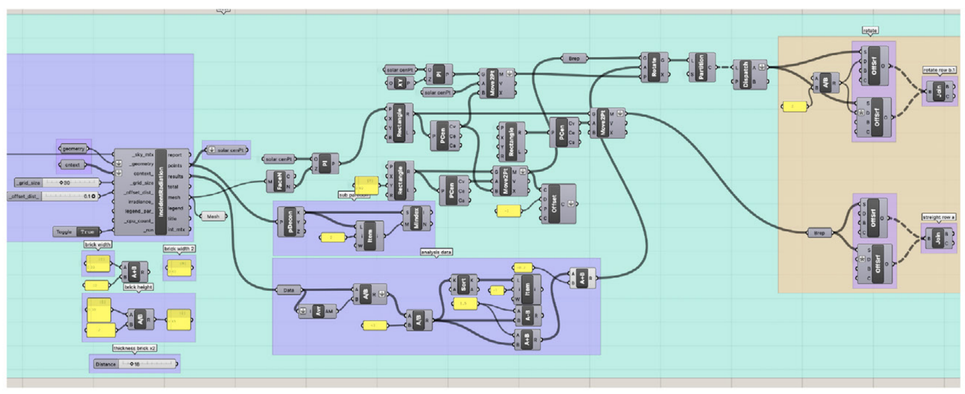
DEC 18 pm

After creating a deep shading system, it was evident that no efficient change was seen, and we decided to make a double wall system.The outer layer will be made of perforated bricks to allow indirect light to enter and to have natural ventilation to cool the semi-open spaces. The inner glass layer will allow controlling the ventilation and control of the humidity level.

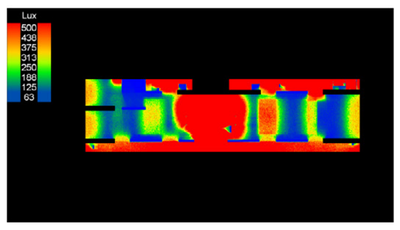
Solar radiation(facade)

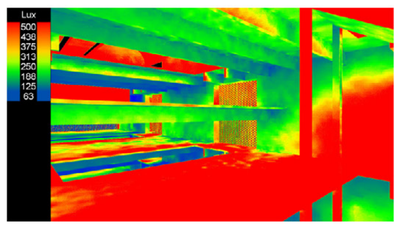


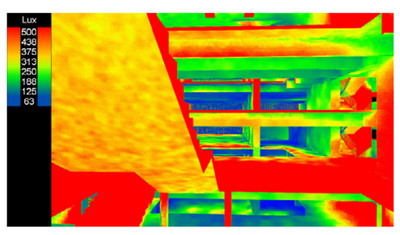


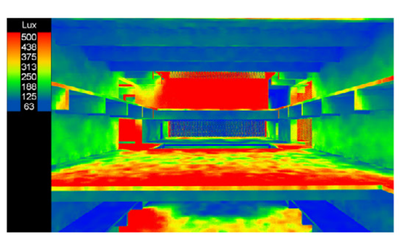


Velux (Daylight Analysis)

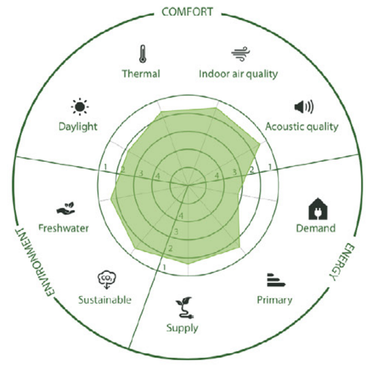






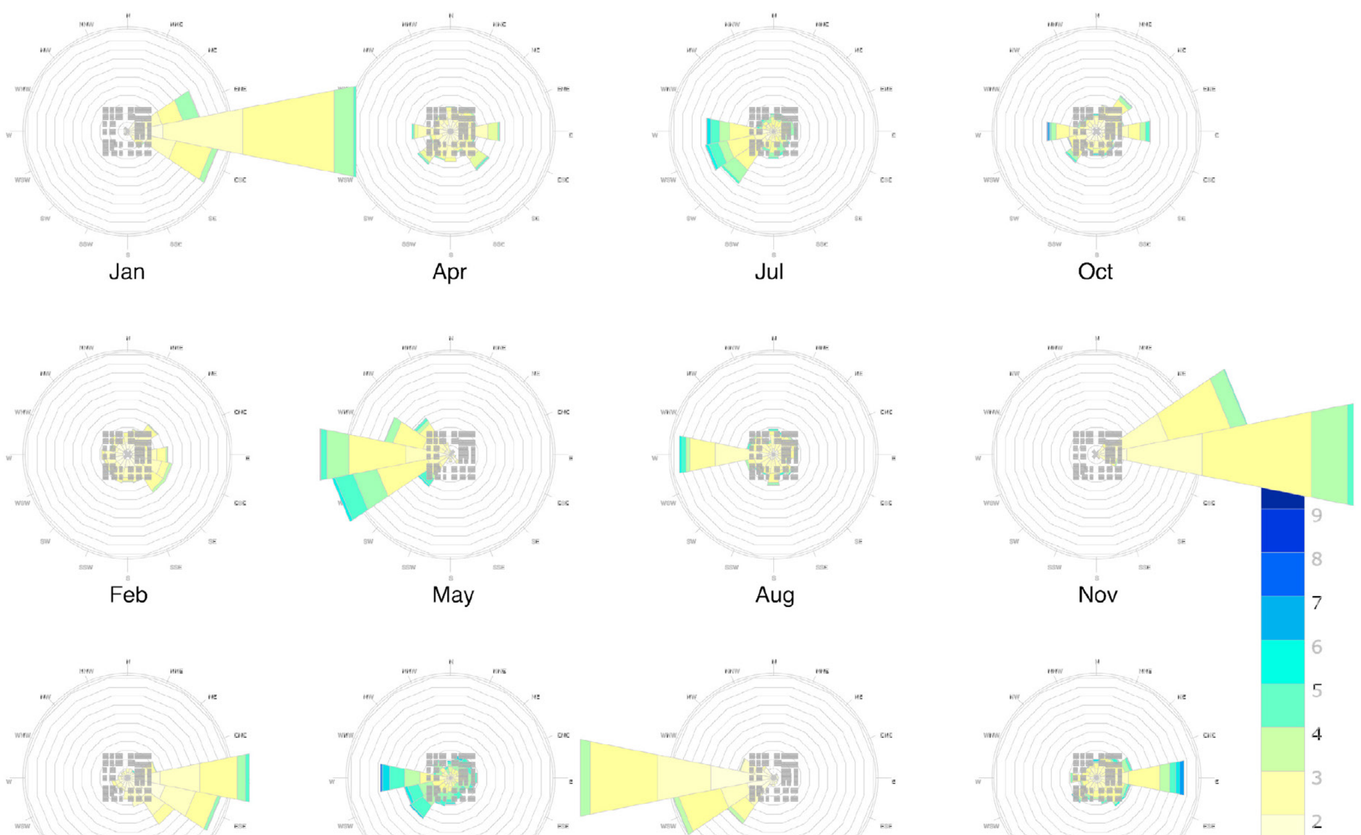


Activehouse Sustainibilty Certification



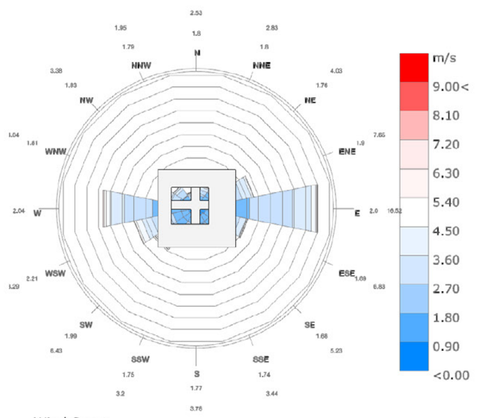
Mean active score	1.8
Daylight score	2.2
Thermal environment score	1.7
Indoor air quality score	1.4
Acoustic quality score	1.4
Energy demand score	3.2
Primary energy score	1.6
Energy supply score	1.7
Sustainable construction score	1.5
Freshwater score	1.7

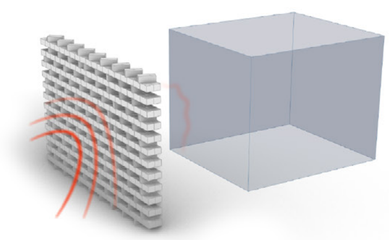
Wind Analysis

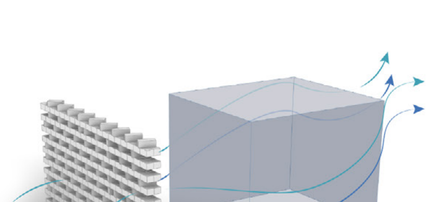


The wind directions and an understanding of optimal circulation that can cool the inner glass shell allow for the correct use of artifi-

Facade Strategy

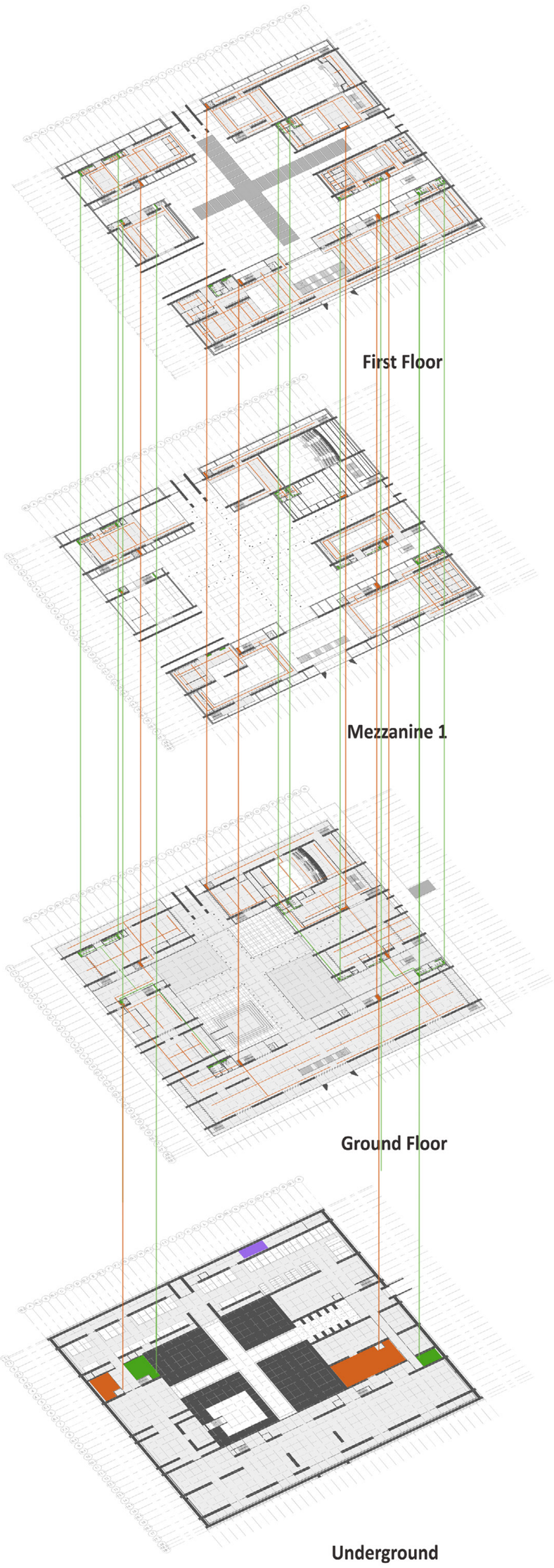






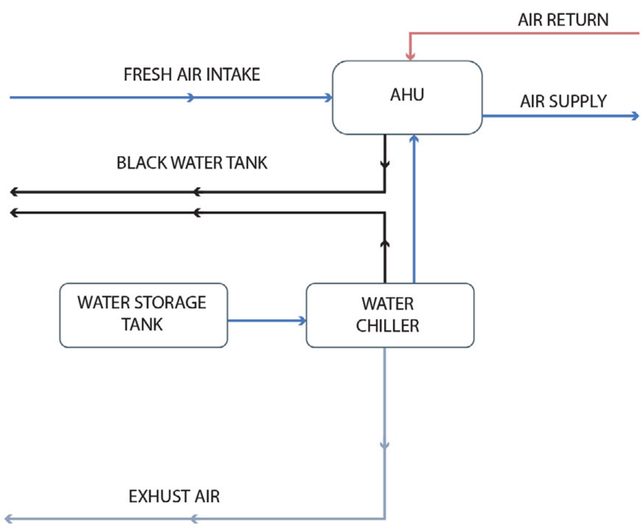
The wind directions and an understanding of optimal circulation that can cool the inner glass shell allow for the correct use of artifi-

Service Diagrams

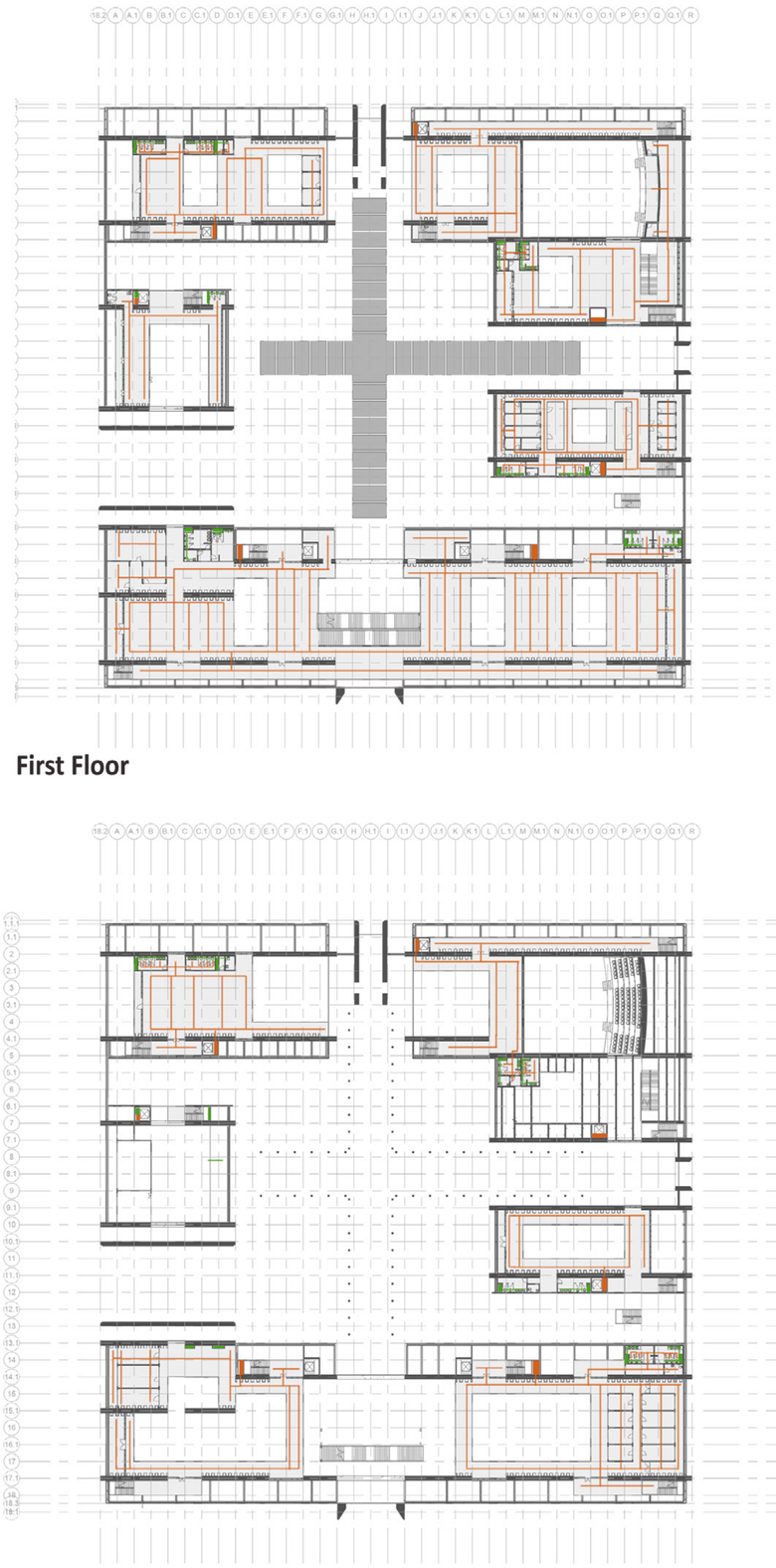


The services are planned in such a way that the machine rooms and electrical rooms are located underground.

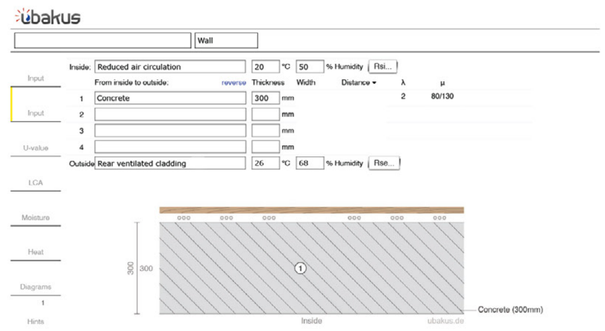
The building is naturally ventilated except for the auditorium

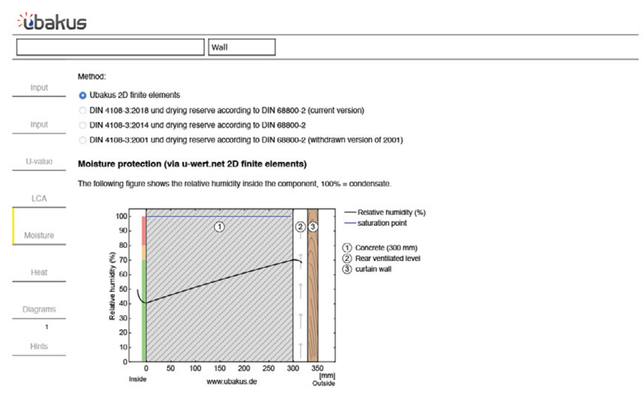


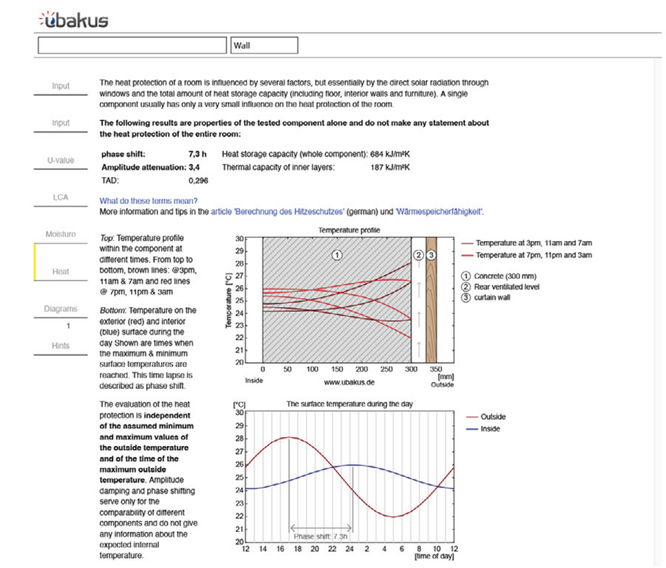
Service Plans

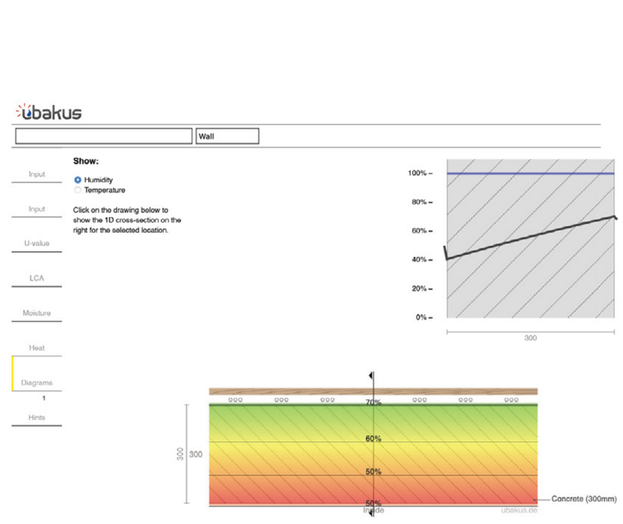


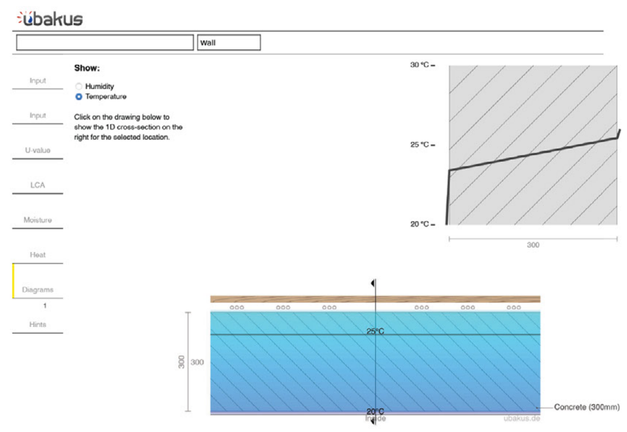
Ubakus Calculation

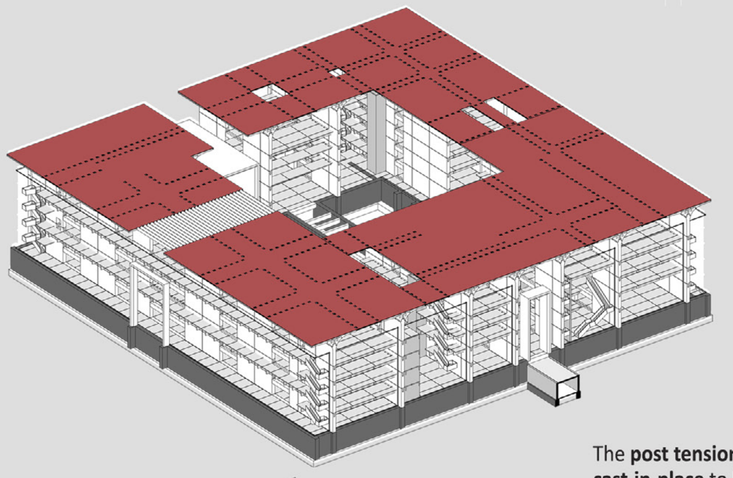




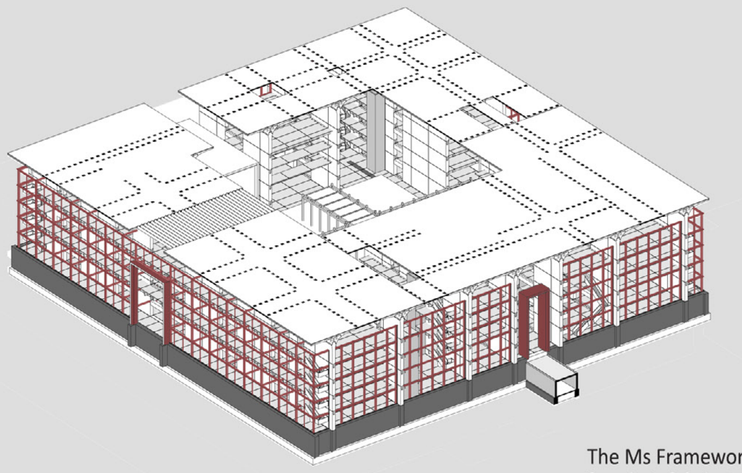




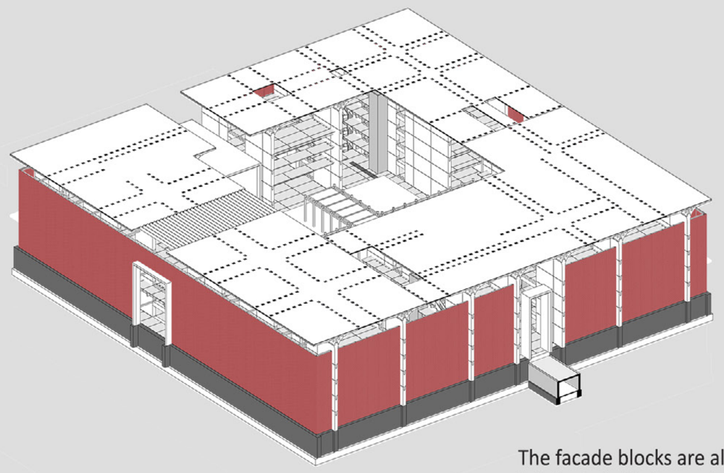




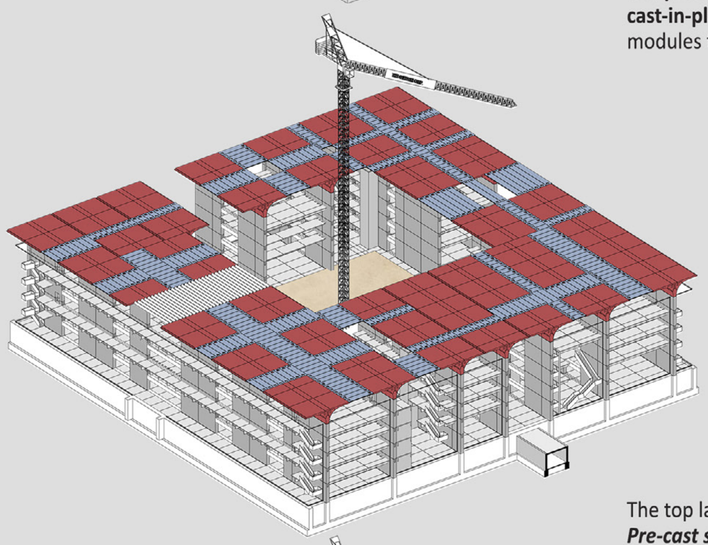
The **post tensioned** slab is **cast-in-place** to hold the modules together



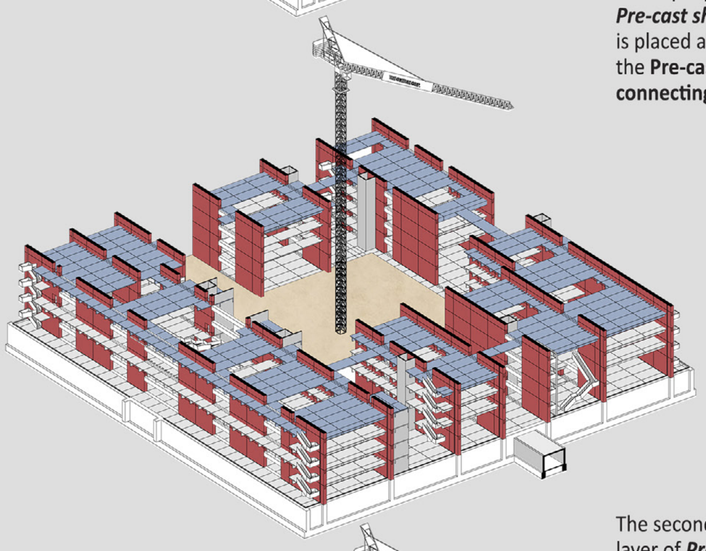
The Ms Framework of the facade is **fabricated off-site** and **assembled on-site**



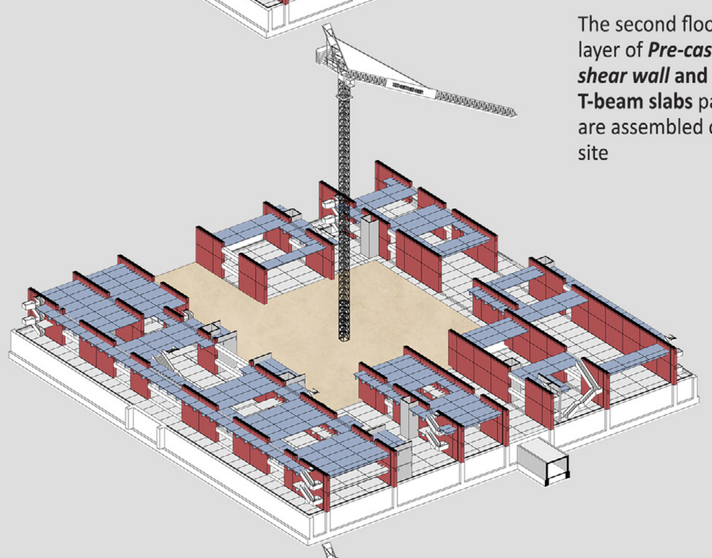
The facade blocks are also **fabricated off-site** and then **assembled on-site**



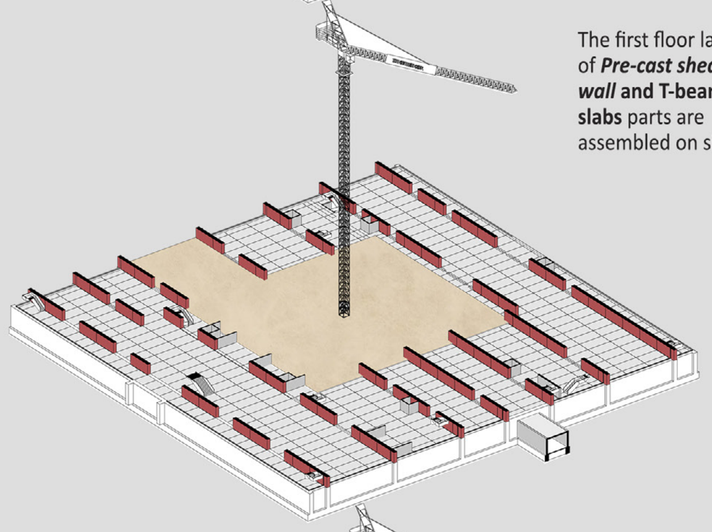
The top layer of ***Pre-cast shear wall*** is placed along with the **Pre-cast connecting slabs**



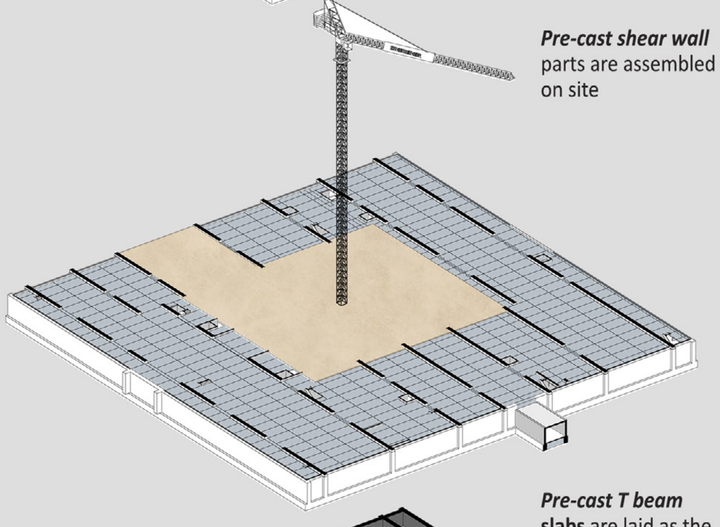
The second floor layer of ***Pre-cast shear wall*** **and T-beam slabs** parts are assembled on site



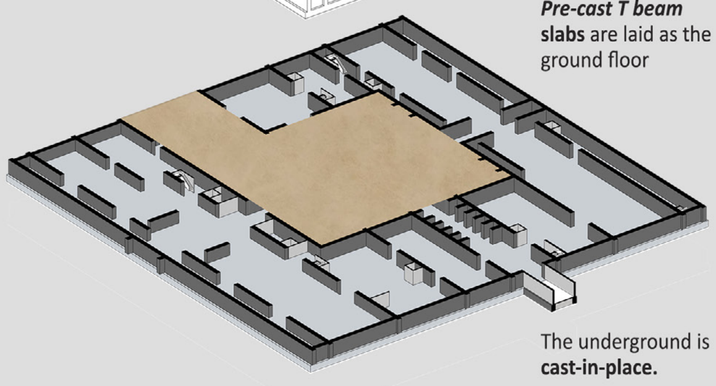
The first floor layer of ***Pre-cast shear wall*** **and T-beam slabs** parts are assembled on site



Pre-cast shear wall parts are assembled on site

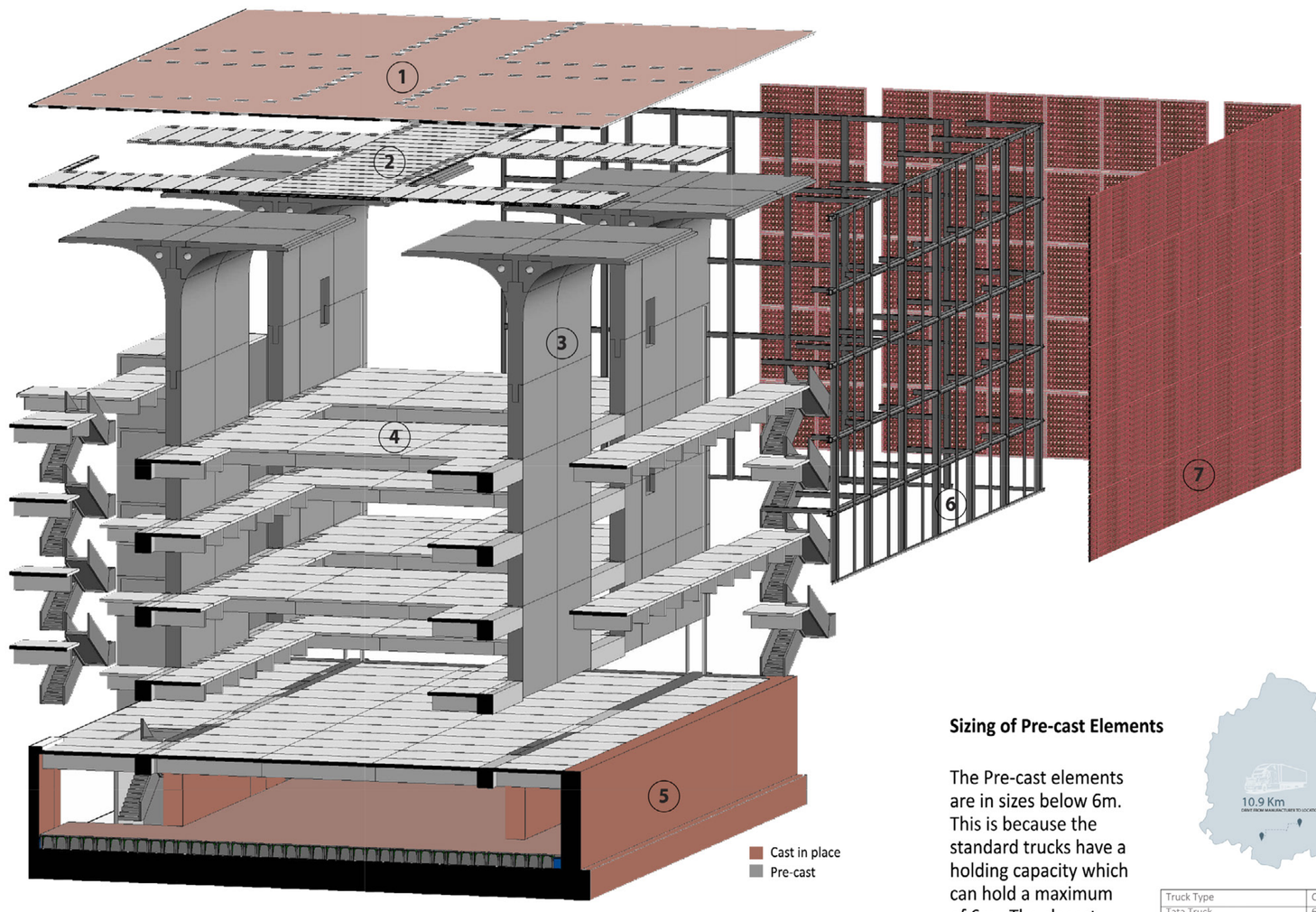


Pre-cast T beam **slabs** are laid as the ground floor



The underground is **cast-in-place.**

Exploded Diagram



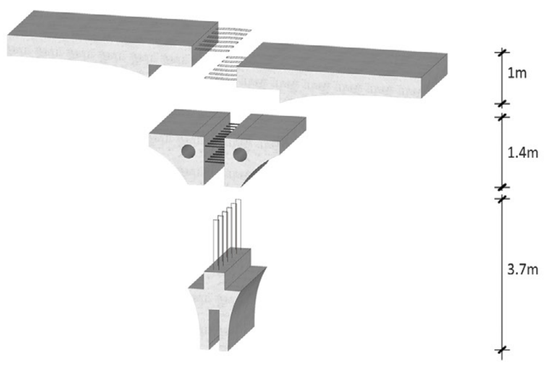
1. Post tensioned slab 2.Pre-cast roof slab 3. Pre-cast Shear module 4. Pre-cast T-beam slabs
5.Cast-in-place underground 6.MS framework 7.Facade Blocks

Sizing of Pre-cast Elements

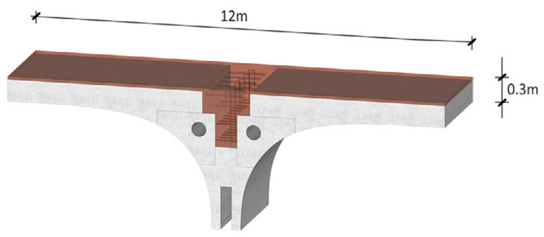
The Pre-cast elements are in sizes below 6m. This is because the standard trucks have a holding capacity which can hold a maximum of 6m . The closest manufacturing factory is also just 10km away

Truck Type	Capacity
Tata Truck	6 x 2.2 x 2.1
Taurus 16T	6.4 x 2.2 x 2.1
Taurus 21T	7.3 x 2.2 x 2.1
Container 20ft	6 x 2.4 x 2.4
Tata 22 ft	6.7 x 2.2 x 2.1

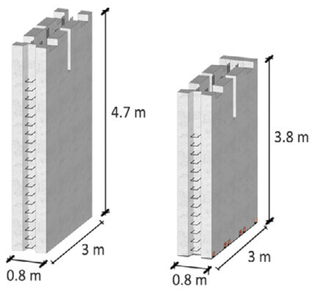
Pre cast Elements



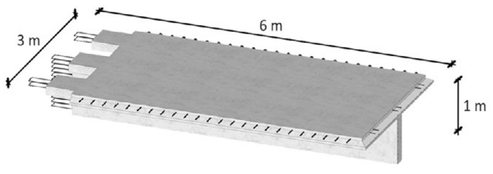
The top part of the shear module is divided into **pre- cast** parts held together by rebars



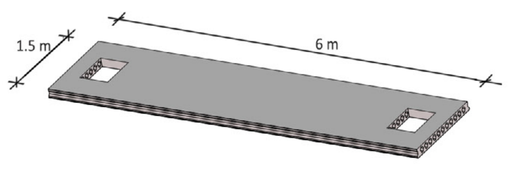
The pre-cast parts are then held together by concrete which is **cast on site**



The walls are also divided into **pre-cast** parts are of different sizes depending on floor height

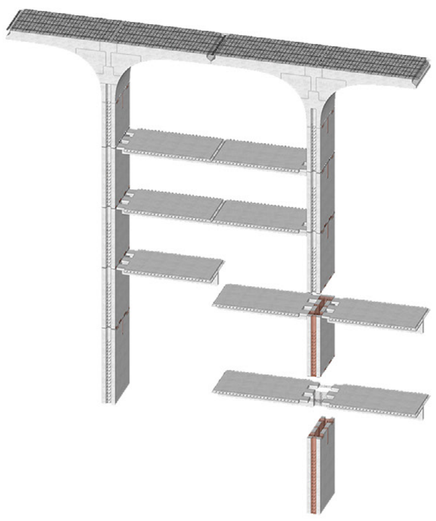


The slabs are formed by **pre-cast** T beam slabs of 3m width and a beam of depth 1m

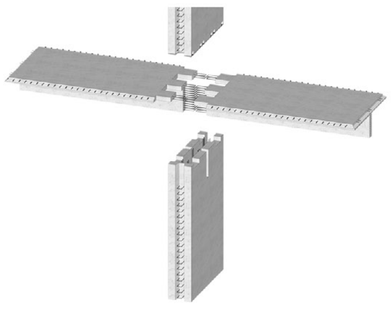


The roof slabs are made of hollow core slab and are **pre-cast**

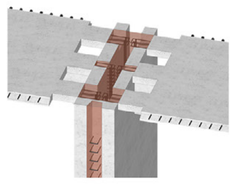
Joinery



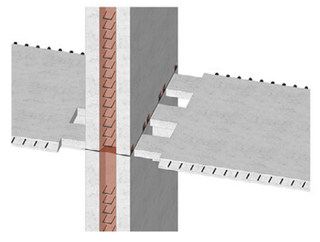
The parts of the wall and parts of the slab are joined together to form the structure



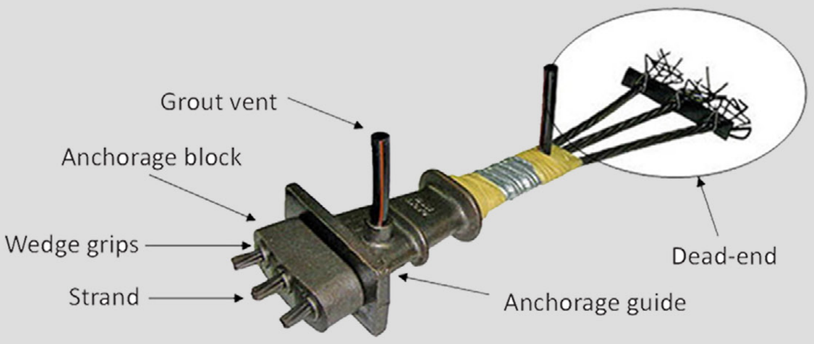
The slabs are attached to the walls like a jigsaw puzzle with rebars of the slab going into holes in the wall



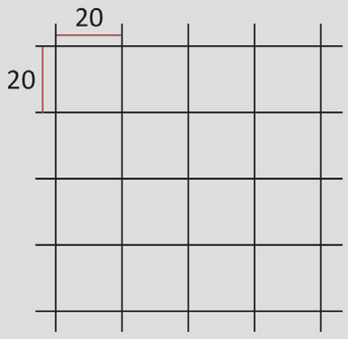
The rebars of the slab are then attached by use of concrete on site



The walls are also attached to each other with the help of rebars and concrete on site



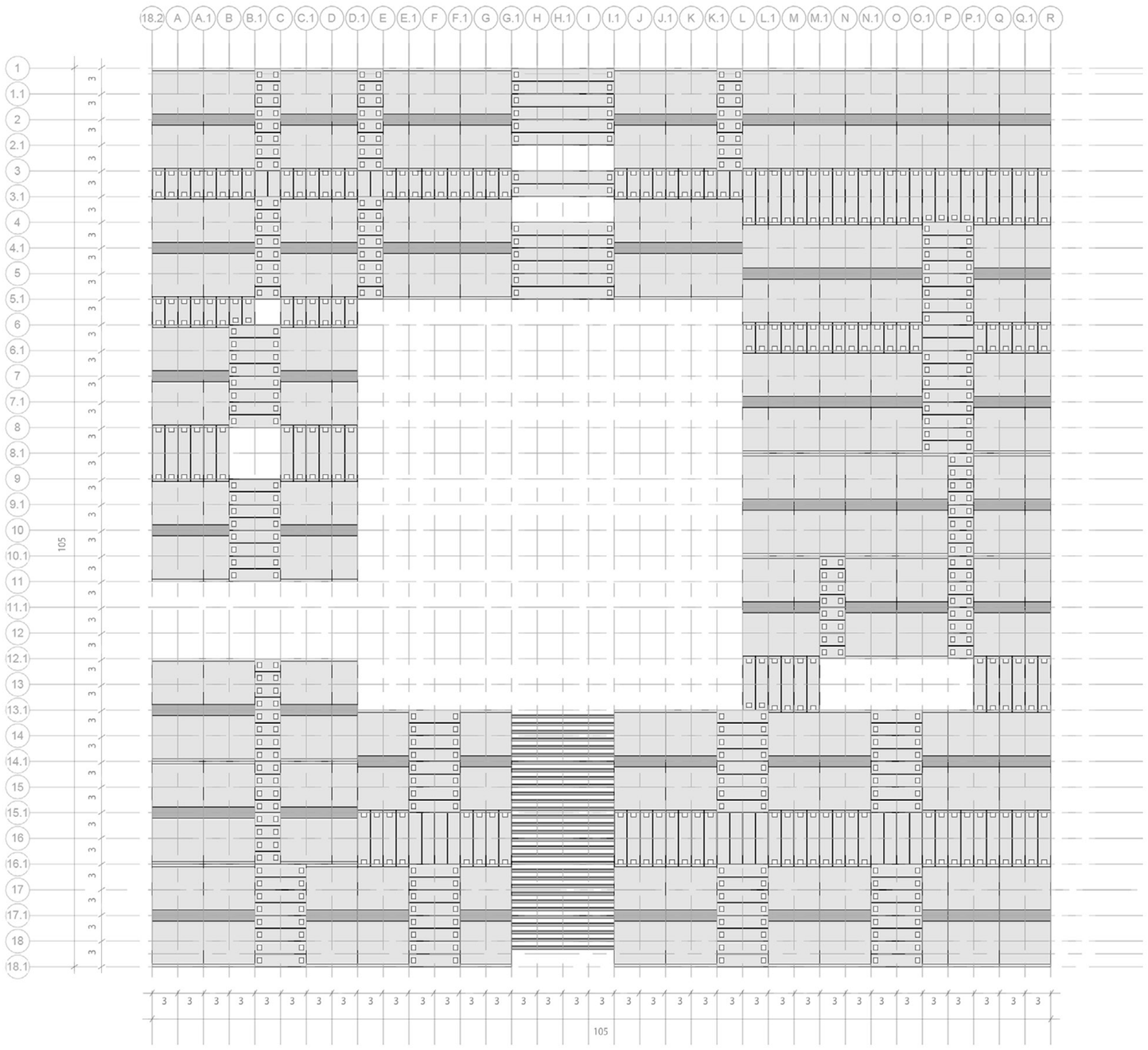
Cable : The cable has 3 strands and are placed as 2 every 1 metre



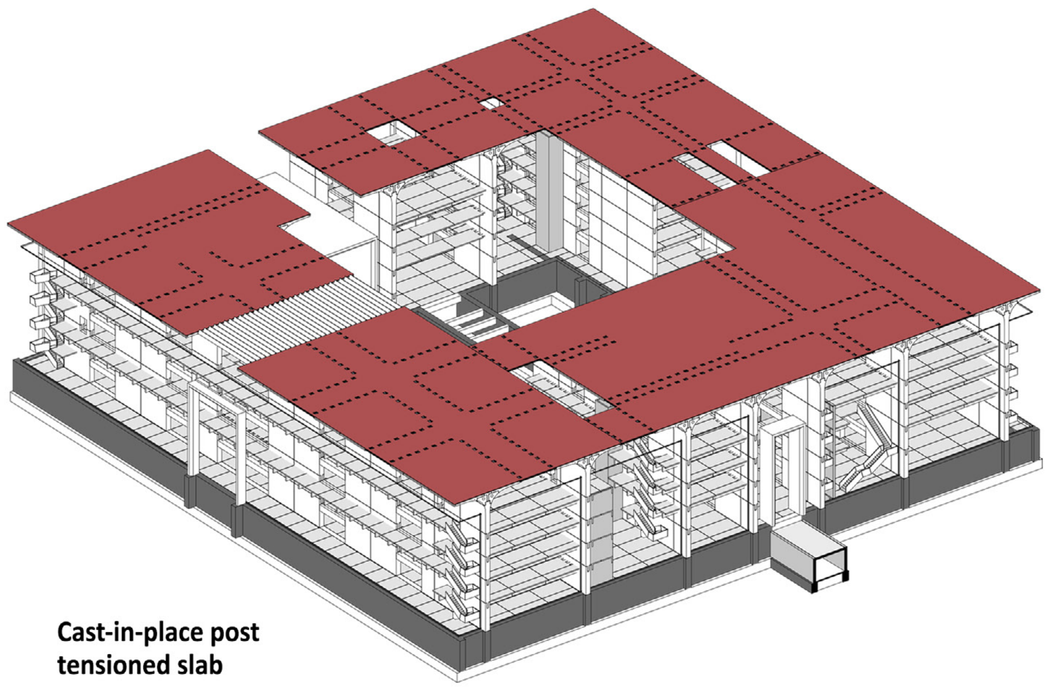
Grid of Rebars : The rebars are spaced at 20 x 20 cm

Site photos : These photos represent post tensioning of a slab

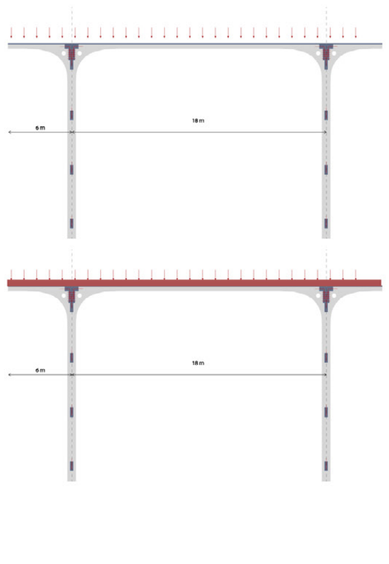
Cast in place elements



Roof Structural Plan
1:400



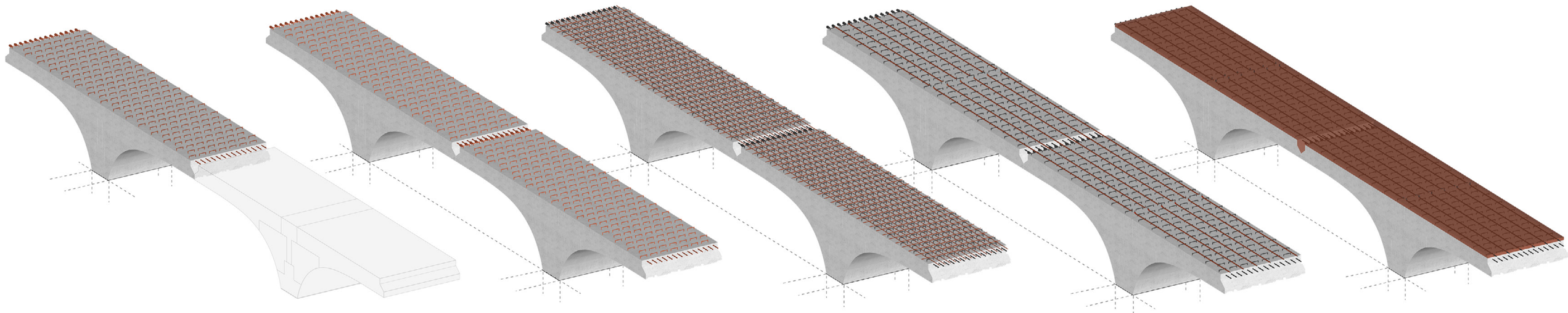
Cast-in-place post tensioned slab

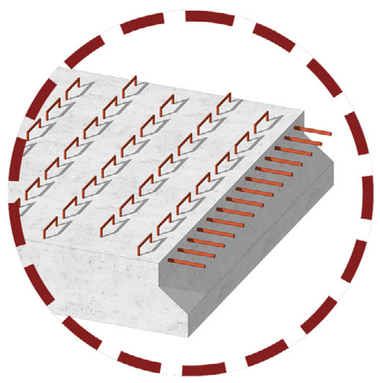


The various shear modules have high stresses and to be held in place , it needs a layer of cast-in-place concrete. This slab is then post tensioned with the use of cables

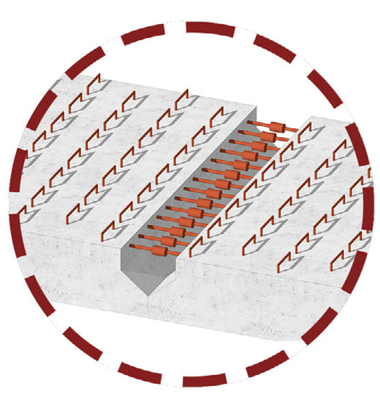
The cables are calculated and a cable with 3 strands is chosen. This is also further analysed with the help of midas

Post tensioned slab

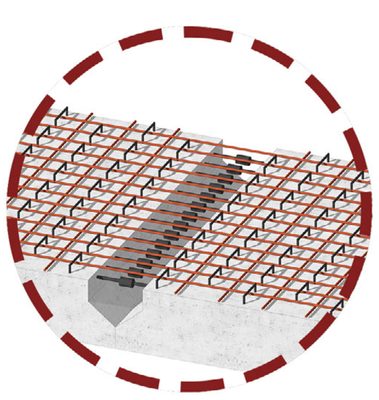




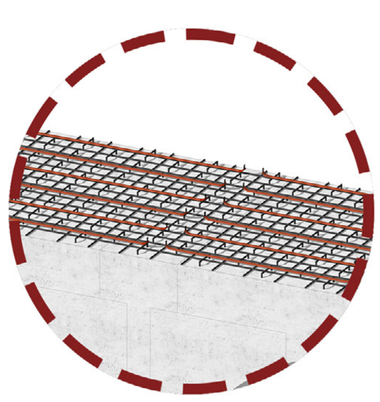
This is the top of the shear modules with its rebars and connection region



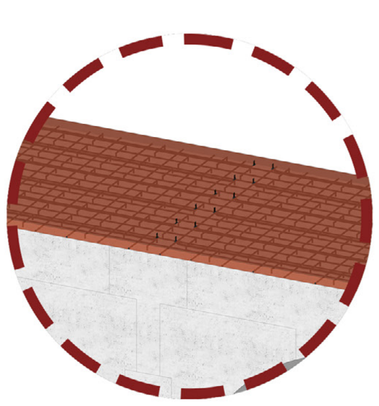
The modules are connected to each other with the help of grid couplers



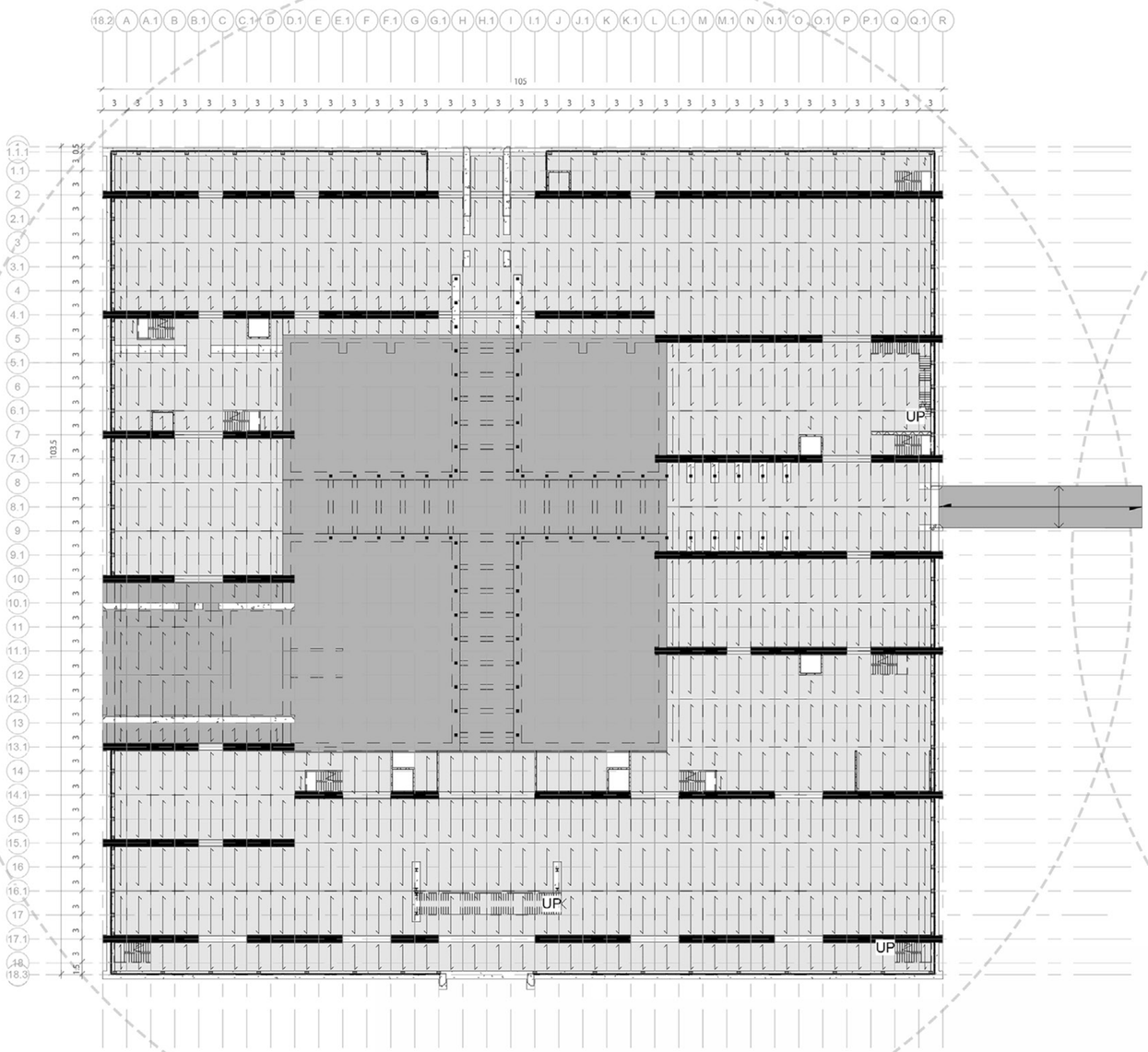
The rebars are then assembled on top of the shear module



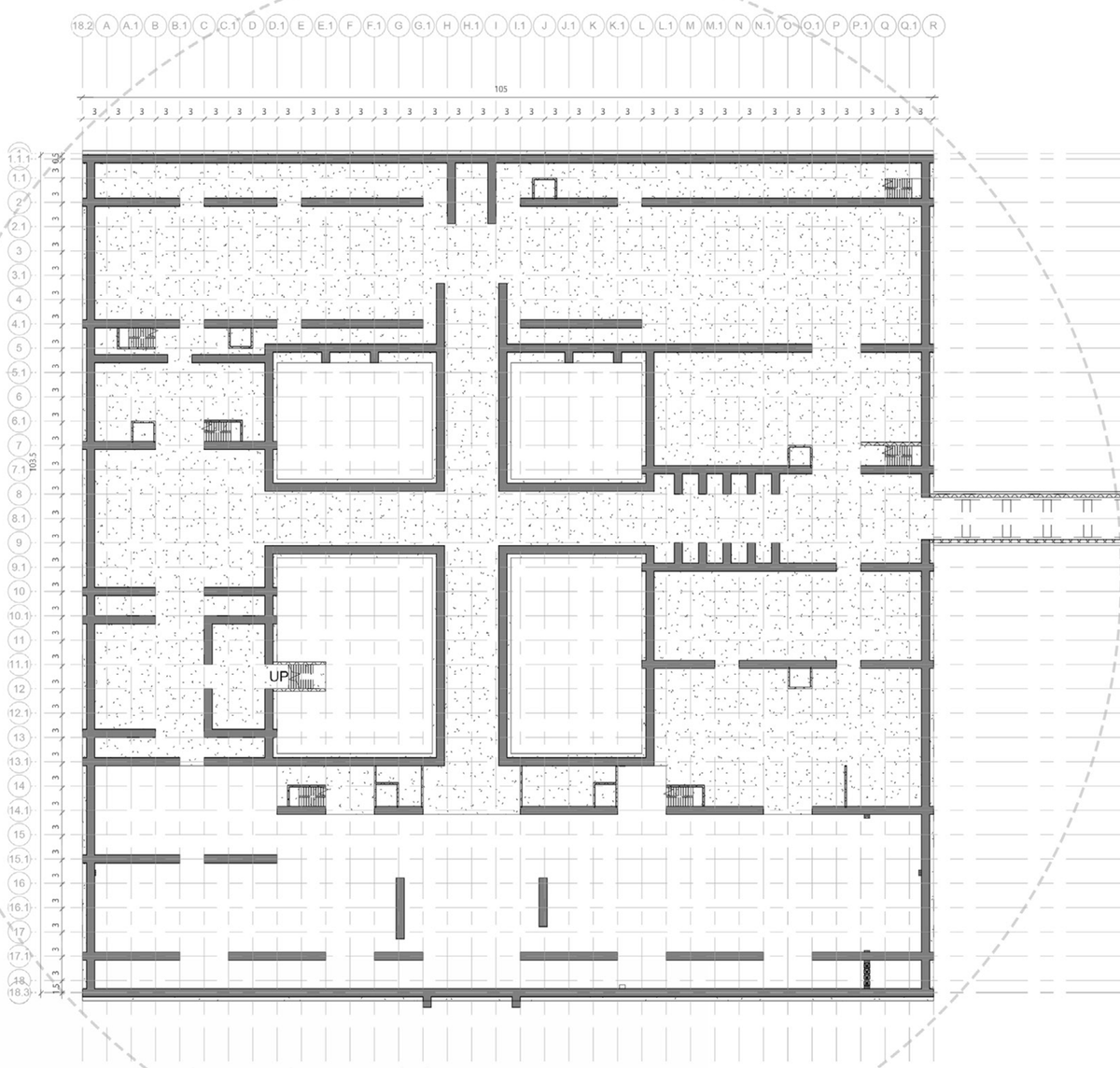
The cables(each tendon:3 strands) are then laid . There is 2 every metre



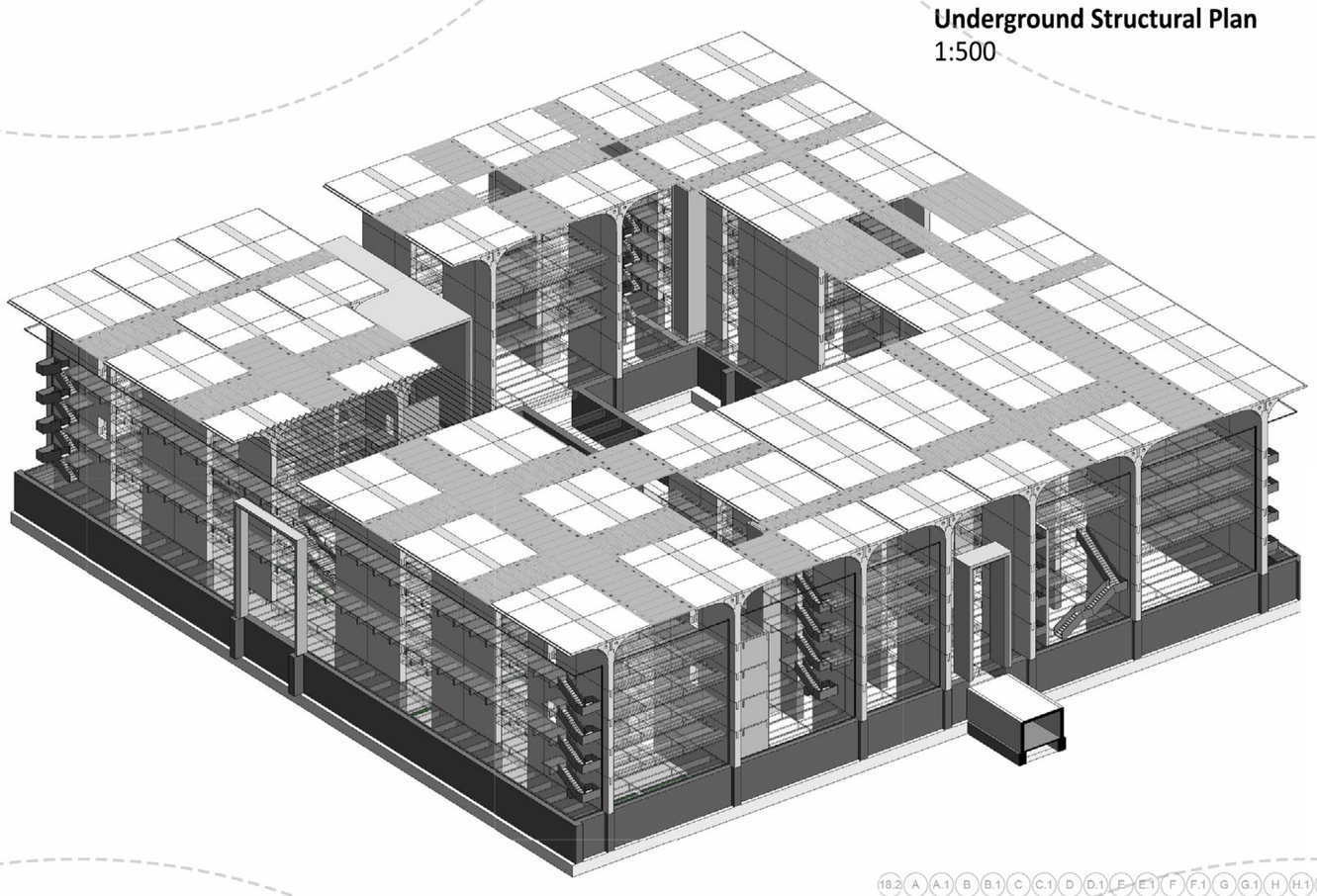
The concrete is finally poured on top and the cables are post tensioned

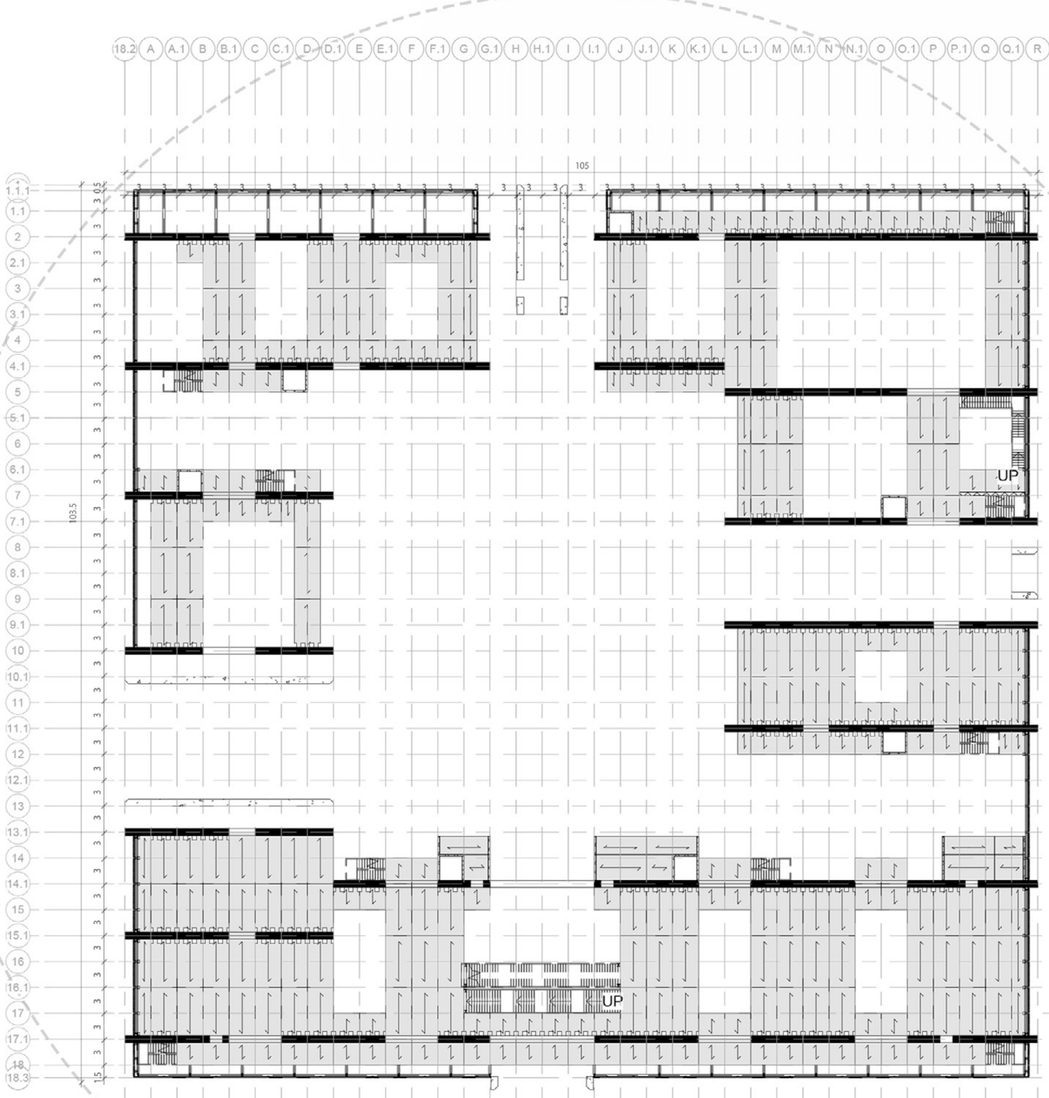


Ground Floor Structural Plan
1:500

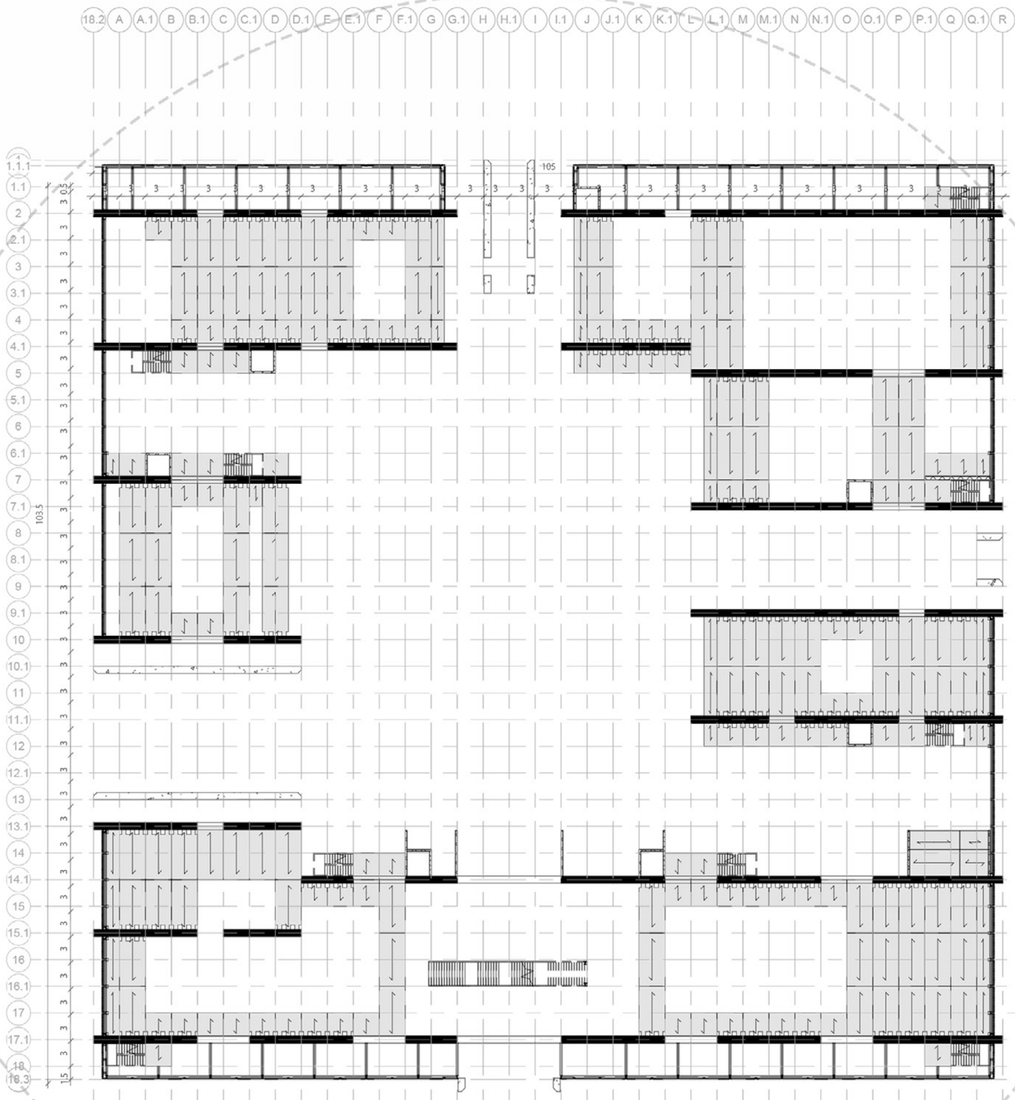


Underground Structural Plan
1:500



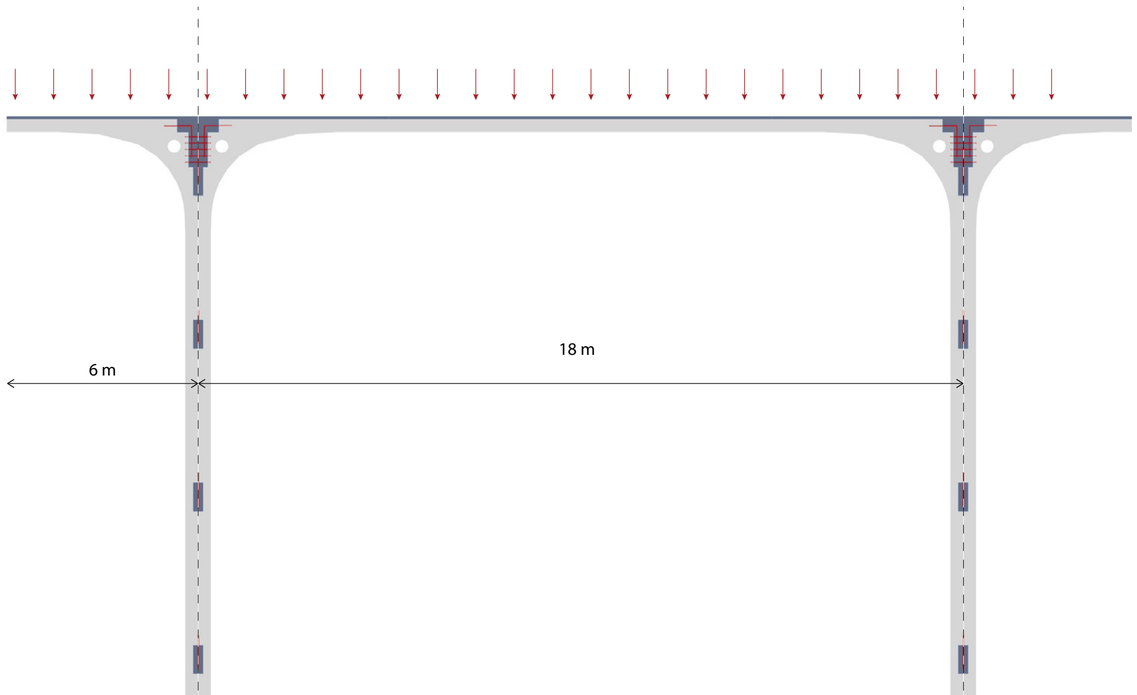


First Floor Structural Plan
1:500



Mezzanine 2 Structural Plan
1:500

CALCULATIONS FOR ROOF



1. ULS Calculations

a. Floor Total Load Calculations

ROOF MODULE			
Influence area width I	1.0	m	
Area load g1"	7.5	kN/m2	Area load: floor structural
Linear load G1'	0.0	kN/m	Dead load: Beam self weight
Linear load G1	7.5	kN/m	Dead load: permanent structural
Area load g2	5.8	kN/m2	
Linear load G2	5.8	kN/m	Dead load: Permanent non structural
Area load Q1	1.5	kN/m2	
Linear load Q1	1.5	kN/m	Live load: Roof

Linear load G1	7.5	kN/m	Dead load: Beam self weight
Linear load G2	5.8	kN/m	Dead load: Floor Self weight
Linear load Q1	1.5	kN/m	Live load: C3
Coefficient for G1	1.3	-	
Coefficient for G2	1.50	-	
Coefficient for Q1	1.50	-	
$Quls = 1.3\,G1 + 1.5\,G2 + 1.5\,Q$			
TOTAL floor LOAD Quls	20.7	kN/m	

ROOF SLAB			
Influence area width I	1.0	m	
Area load g1"	2.5	kN/m2	Area load: floor structural
Linear load G1'	0.0	kN/m	Dead load: Beam self weight
Linear load G1	2.5	kN/m	Dead load: permanent structural
Area load g2	5.8	kN/m2	
Linear load G2	5.8	kN/m	Dead load: Permanent non structural
Area load Q1	1.5	kN/m2	
Linear load Q1	1.5	kN/m	Live load: Residential

Linear load G1	2.5	kN/m	Dead load: Beam self weight
Linear load G2	5.8	kN/m	Dead load: Floor Self weight
Linear load Q1	1.5	kN/m	Live load: C3
Coefficient for G1	1.3	-	
Coefficient for G2	1.50	-	
Coefficient for Q1	1.50	-	
$Quls = 1.3\,G1 + 1.5\,G2 + 1.5\,Q$			
TOTAL floor LOAD Quls	14.2	kN/m	

b. Bending Moment And Shear Force Calculation

The Bending Moment and Shear Force are calculated using the wXcBA software

length	6m	6m	6m	6m	6m
g	18.45	18.45	11.95	18.45	18.45
q	2.25	2.25	2.25	2.25	2.25

Figure 6 Table of Loads and spans

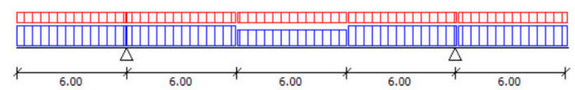
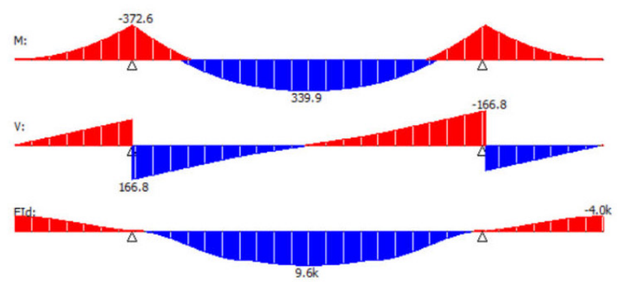


Figure 7 Load diagram of span



continuous beam 5 spans:

l:	6.00	6.00	6.00	6.00	6.00	m
defR:	0	-1	0	0	-1	0
rotR:	0	0	0	0	0	0

permanent loads:

p:	18.45	18.45	11.95	18.45	18.45	kN/m

live loads:

p:	2.25	2.25	2.25	2.25	2.25	kN/m

results - characteristic loads (1.0 1.0):

Mmax:	0.00	282.60	339.92	282.60	0.00	kNm
Mmin:	-372.60	-372.60	0.00	-372.60	-372.60	kNm
Vmax:	0.00	166.80	44.85	0.00	124.20	kN
Vmin:	-124.20	0.00	-44.85	-166.80	-0.00	kN
Eldmax:	0.00	8221.95		9589.30	8221.95	0.00 m
Eldmin:	-4027.93		-49.77	0.00	-49.77	-4027.93 m
Rmax:	0.00	291.00	0.00	0.00	291.00	0.00 kN
Rmin:	-0.00	257.25	-0.00	0.00	257.25	-0.00 kN

1. Single load calculation

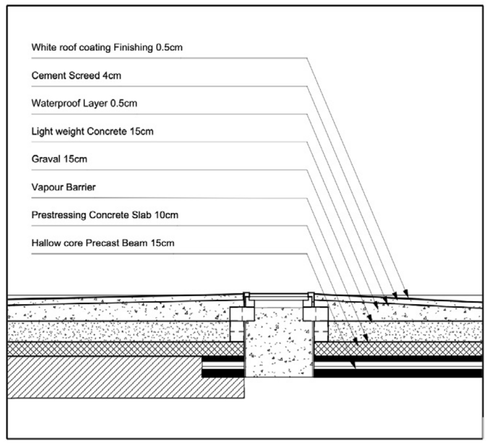


Figure 2 Section of Roof of Pre-cast Module

a. Roof of module

MODULE ROOF

Dead load: Floor self-weight (structural)

Layer	Length		Width		Height		Volumetric weight		Weight		source
Concrete layer	1.0	m	1.0	m	0.3	m	25	kN/m3	7.5	kN/m2	Eurocode
Area load g1"									7.5	kN/m2	

Roof(Non structural)

Layer	Length		Width		Height		Volumetric weight		Weight		source
Solar Panel	1.0	m	1.000	m	0	m	0	kN/m3	0.110	kN/m2	LG
Sun reflecting	1.0	m	1.000	m	0.05	m	0	kN/m3	0.000	kN/m2	negligible
Finishing Concrete	1.0	m	1.000		0.04	m	12	kN/m3	0.480	kN/m2	negligible
Water Proofing Layer	1.0	m	1.000	m	0.050	m	0	kN/m3	0.000	kN/m2	Eurocode
Light Weight Concrete	1.0	m	1.000	m	0.15	m	12	kN/m3	1.800	kN/m2	Eurocode
Gravel	1.0	m	1.000	m	0.06	m	15	kN/m3	0.900	kN/m2	negligible
Vapor Barrier	1.0	m	1.000	m	0.02	m	0	kN/m3	0.000	kN/m2	Eurocode
Pre Stressed Concrete	1.0	m	1.000	m	0.1	m	25	kN/m3	2.500	kN/m2	Eurocode
Area load g2									5.8	kN/m2	

Variable load:C3

standard live load		
Area load q	1.5	kN/m2

b. Connecting Slab

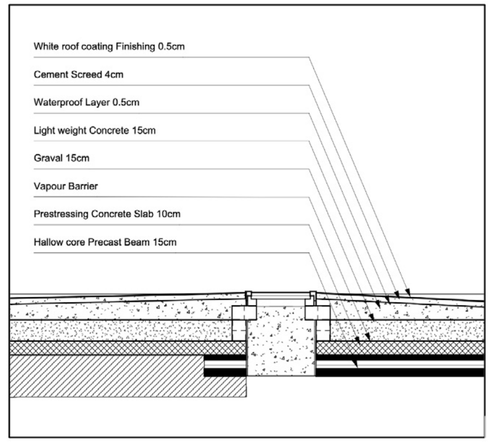


Figure 2 Section of Roof of Pre-cast Module

CONNECTING ROOF SLAB

Dead load: Floor self-weight (structural) - take 2/3 of height

Layer	Length		Width		Height		Volumetric weight		Weight		source
Concrete layer	1.0	m	1.0	m	0.1	m	25	kN/m3	2.5	kN/m2	Eurocode
Area load g1"									2.5	kN/m2	

Roof(Non structural)

Layer	Length		Width		Height		Volumetric weight		Weight		source
Solar Panel	1.0	m	1.000	m	0	m	0	kN/m3	0.110	kN/m2	LG
Sun reflecting	1.0	m	1.000	m	0.05	m	0	kN/m3	0.000	kN/m2	negligible
Finishing Concrete	1.0	m	1.000		0.04	m	12	kN/m3	0.480	kN/m2	negligible
Water Proofing Layer	1.0	m	1.000	m	0.050	m	0	kN/m3	0.000	kN/m2	Eurocode
Light Weight Concrete	1.0	m	1.000	m	0.15	m	12	kN/m3	1.800	kN/m2	Eurocode
Gravel	1.0	m	1.000	m	0.06	m	15	kN/m3	0.900	kN/m2	negligible
Vapor Barrier	1.0	m	1.000	m	0.02	m	0	kN/m3	0.000	kN/m2	Eurocode
Pre Stressed Concrete	1.0	m	1.000	m	0.1	m	25	kN/m3	2.500	kN/m2	Eurocode
Area load g2									5.8	kN/m2	

Variable load:C3

standard live load		
Area load q	1.5	kN/m2

c. Internal Floor Slab

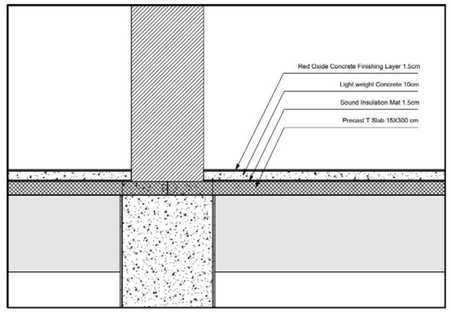


Figure 4 Section of Internal Slab

INTERNAL FLOOR

Dead load: Floor self-weight (structural)

Layer	Length		Width		Height		Volumetric weight		Weight		source
Concrete layer	1.0	m	1.0	m	0.15	m	25	kN/m3	3.8	kN/m2	Eurocode
Area load g1"									3.8	kN/m2	

Internal Floor (non-structural)

Layer	Length		Width		Height		Volumetric weight		Weight		source
Red oxide Floor	1.0	m	1.0	m	0.015	m	12	kN/m3	0.180	kN/m2	Eurocode
Screed	1.0	m	1.0	m	0.1	m	12	kN/m3	1.200	kN/m2	Eurocode
Mat sound Insulation	1.0	m	1.0	m	0.015	m	3	kN/m3	0.045	kN/m2	Eurocode
Divisor walls									0.400	kN/m2	Eurocode
Area load g2									1.4	kN/m2	

Dead load: Beam self-weight

Concrete rectangular beam

B	20	cm	0.2	m
H	100	cm	1	m
Material density	2500	kg/m3	25	kN/m3
Linear load G1'			5.0	kN/m

Variable load:C1

Internal Floors live load

Area load q	3.0	kN/m2

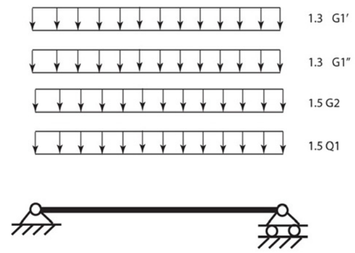
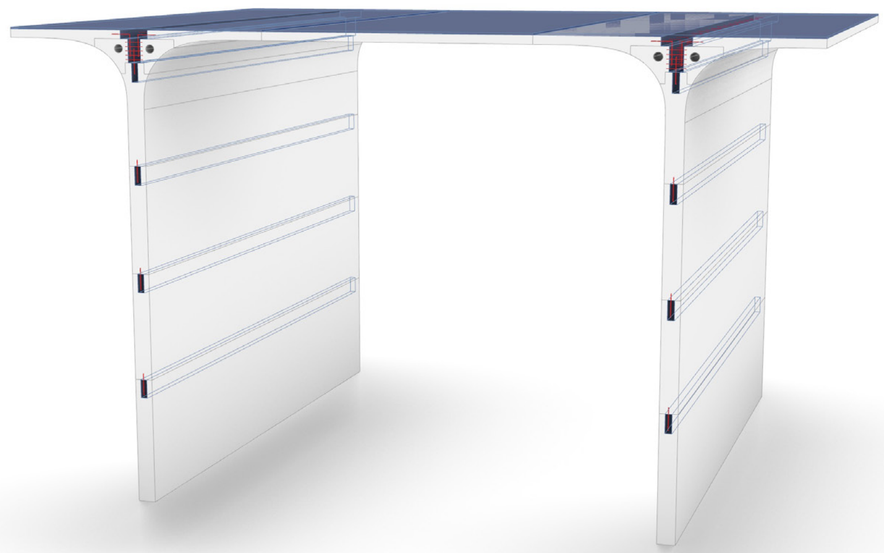


Figure 1 Schematic drawing of Floor Load

CALCULATIONS FOR ROOF



2. SLS Calculations

a. Floor Total Load Calculations

ROOF MODULE			
Influence area width I	1.0	m	
Area load g1"	7.5	kN/m2	Area load: floor structural
Linear load G1'	0.0	kN/m	Dead load: Beam self weight
Linear load G1	7.5	kN/m	Dead load: permanent structural
Area load g2	5.8	kN/m2	
Linear load G2	5.8	kN/m	Dead load: Permanent non structural
Area load Q1	1.5	kN/m2	
Linear load Q1	1.5	kN/m	Live load: Roof

Linear load G1	7.5	kN/m	Dead load: Beam self weight
Linear load G2	5.8	kN/m	Dead load: Floor Self weight
Linear load Q1	1.5	kN/m	Live load: C3
Coefficient for G1	1	-	
Coefficient for G2	1.00	-	
Coefficient for Q1	1.00	-	
$Qsls = 1.0\ G1 + 1.0\ G2 + 1.0\ Q$			
TOTAL floor LOAD Qsls	14.8	kN/m	

ROOF SLAB			
Influence area width I	1.0	m	
Area load g1"	2.5	kN/m2	Area load: floor structural
Linear load G1'	0.0	kN/m	Dead load: Beam self weight
Linear load G1	2.5	kN/m	Dead load: permanent structural
Area load g2	5.8	kN/m2	
Linear load G2	5.8	kN/m	Dead load: Permanent non structural
Area load Q1	1.5	kN/m2	
Linear load Q1	1.5	kN/m	Live load: Residential

Linear load G1	2.5	kN/m	Dead load: Beam self weight
Linear load G2	5.8	kN/m	Dead load: Floor Self weight
Linear load Q1	1.5	kN/m	Live load: C3
Coefficient for G1	1	-	
Coefficient for G2	1.00	-	
Coefficient for Q1	1.00		
$Qsls = 1.0\ G1 + 1.0\ G2 + 1.0\ Q$			
TOTAL floor LOAD Qsls	9.8	kN/m	

b. Bending Moment And Shear Force Calculation

The Bending Moment and Shear Force are calculated using the wXcBA software

length	6m	6m	6m	6m	6m
g	13.3	13.3	8.3	13.3	13.3
q	1.5	1.5	1.5	1.5	1.5

Figure 9 Table of Loads and spans

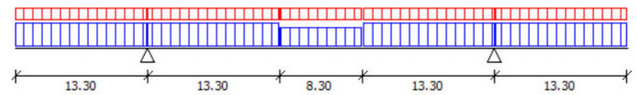


Figure 10 Load Diagram of Span

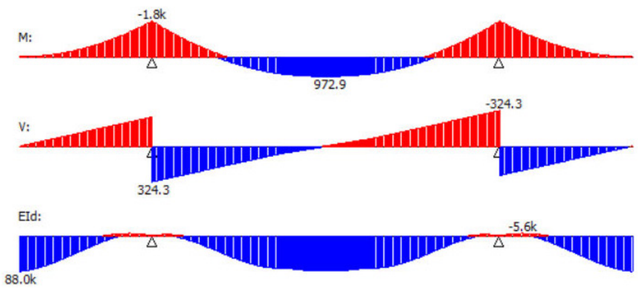


Figure 11 Bending Moment and Shear Force Diagrams

continuous beam 5 spans:

l:	13.30	13.30	8.30	13.30	13.30	m
defR:	0	-1	0	0	-1	0
rotR:	0	0	0	0	0	0

permanent loads:

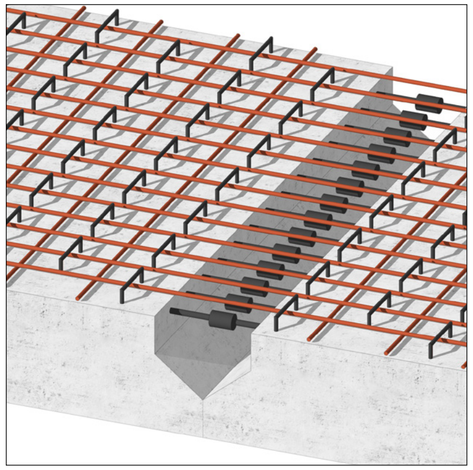
p:	18.45	18.45	11.95	18.45	18.45	kN/m

live loads:

p:	1.50	1.50	2.25	1.50	1.50	kN/m

results - characteristic loads (1.0 1.0):

Mmax:	0.00	865.88	972.89	865.88	0.00	kNm
Mmin:	-1764.48	-1764.48	0.00	-1764.48	-1764.48	kNm
Vmax:	0.00	324.26	62.73	0.00	265.33	kN
Vmin:	-265.33	0.00	-62.73	-324.27	-0.00	kN
Eldmax:	87956.66	79678.70	86687.07	79678.70	87956.66	m
Eldmin:	-5639.59	-3242.93	0.00	-3242.93	-5639.59	m
Rmax:	0.00	589.60	0.00	0.00	589.60	0.00 kN



3. Rebar Calculation for the Roof of Pre- cast Module

M_ED_ULS	339.92	kNm	339920000	Nmm
(ql^2/2 or software value)				

2. Choose steel class

Steel class S...	450	
fyk	450	MPa
γs	1.15	
fyd	391	MPa

3. Choose concrete class

Concrete class C...	25	
fck	25	MPa
γc	1.5	
fcd	17	MPa

4. Slab parameters

b	1000	mm	usually 1/2 - 2/3 h
h	400	mm	usually 1/8 - 1/12 span
c	40	mm	
bar diameter	20	mm	
d	350	mm	effective depth

5. Section calculations

$$K = \frac{M}{bd^2 f_{ck}} = 0.111 < 0.167$$

$$z = d\left(0.5 + \sqrt{0.25 - \frac{K}{1.134}}\right) = 312 \text{ mm}$$

$$A_s = \frac{M}{0.87\, f_{yk}\, z} = 2789 \text{ mm2}$$

Check minimum and maximum reinforcement

$\rho_{min} \le \rho \le \rho_{max}$,

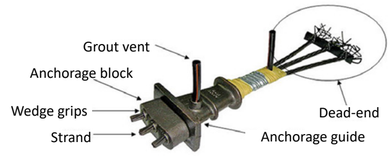
0.13%		4%	
455	mm2	14000	mm2

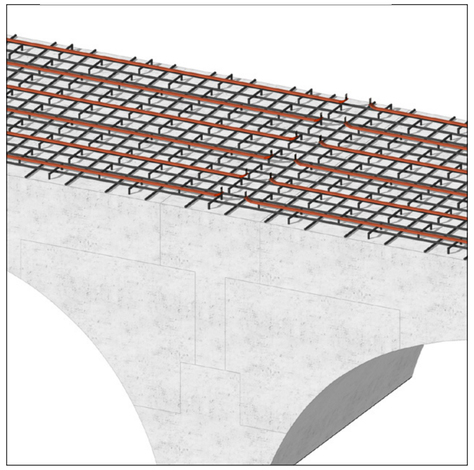
6. Convert reinf. area into bars

Bar diameter		25	mm	suggestions: slab - fi 8 - fi12 mm concrete beam fi 14mm or more
Bar area		490.6	mm2	
Provide bars		6	per meter	
Provided area		2944	mm2	OK
	bars @	167	mm	
ro = A_s/bd		0.84%		OK

7. Summary

One way slab thickness	400	mm			
Tension Steel	f	25	bars @	166.7	mm
			with As=	2944	mm2/m
Distribution Steel (min ratio)	f	8	bars @	200	mm
			with As=	251	mm2/m





4. Cable Calculation for the Pre-stressed Concrete Slab

M_ED_ULS	372.60	kNm	372600000	Nmm
(ql^2/2 or software value)				

2. Choose steel class

Steel class S...	1800	
fyk	1800	MPa
γs	1.15	
fyd	1565	MPa

3. Choose concrete class

Concrete class C...	25	
fck	25	MPa
γc	1.5	
fcd	17	MPa

4. Slab parameters

b	1000	mm	usually 1/2 - 2/3 h
			usually 1/8 - 1/12
h	400	mm	span
c	40	mm	
bar diameter	20	mm	
d	350	mm	effective depth

5. Section calculations

$$K = \frac{M}{bd^2 f_{ck}} = 0.122 < 0.167$$

$$z = d\left(0.5 + \sqrt{0.25 - \frac{K}{1.134}}\right) = 307 \text{ mm}$$

$$A_s = \frac{M}{0.87\, f_{yk}\, z} = 775 \text{ mm2}$$

Check minimum and maximum reinforcement

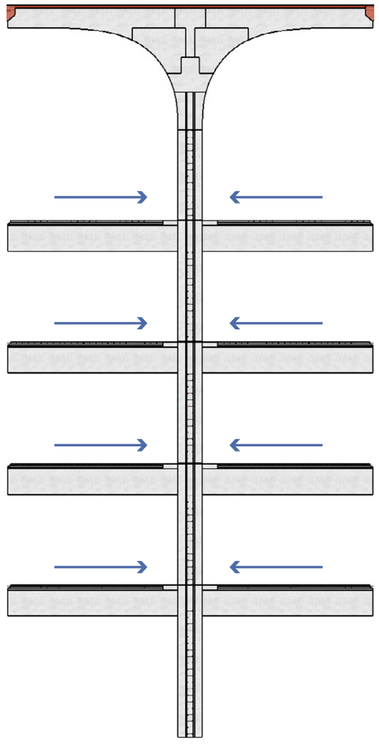
$\rho_{min} \le \rho \le \rho_{max}$,

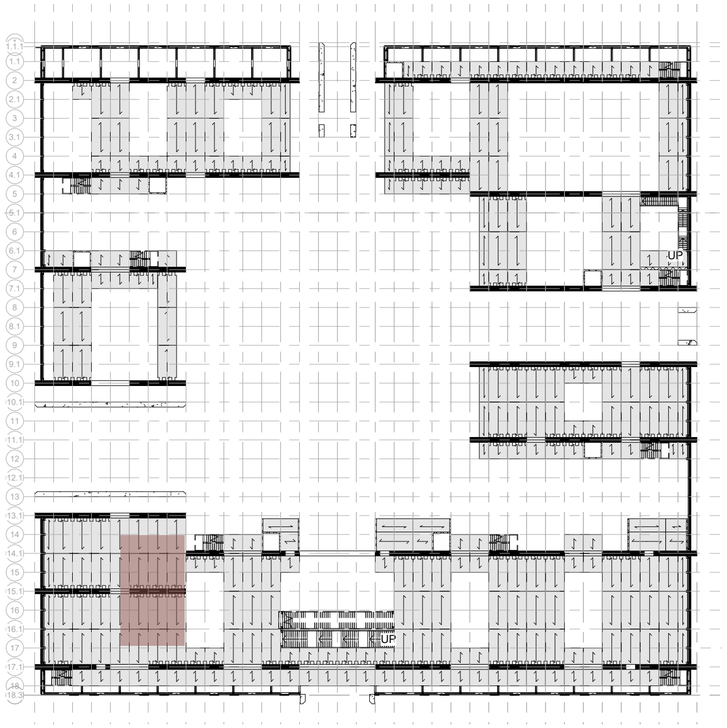
0.13%		4%	
455	mm2	14000	mm2

6. Convert reinf. area into bars

strand diameter		15.2	mm	
Tendon area		150.0	mm2	
Provide strands		6	per meter	
Provided area		900	mm2	OK
	bars @	167	mm	
ro = A_s/bd		0.26%		OK

(mm)	No of Strands	Strand Diam (mm)	Anchorage Block			Trumplate		
UNIT			A	B	C	D	E	F
3S13	3	12.7	50	135	45	80	150	137
2S15	2	15.2						
4S13	4	12.7	50	214	45	83	233	215
5S13	5	12.7						
3S15	3	15.2						
4S15	4	15.2						
5S15	5	15.2	5 x monostrand anchor			77	260	269





4. Shear Wall Calculation

1. Floor Total Load Calculation

INTERNAL SLAB

Influence area width I	9.0	m	
Area load g1"	3.8	kN/m2	Area load: floor structural
Linear load G1'	5.0	kN/m	Dead load: Beam self weight
Linear load G1	39.2	kN/m	Dead load: permanent structural
Area load g2	0.9	kN/m2	
Linear load G2	8.1	kN/m	Dead load: Permanent non structural
Area load Q1	3.0	kN/m2	
Linear load Q1	27.0	kN/m	Live load: Residential

Linear load G1	39.2	kN/m	Dead load: Beam self weight
Linear load G2	8.1	kN/m	Dead load: Floor Self weight
Linear load Q1	27.0	kN/m	Live load: C3
Coefficient for G1	1.3	-	
Coefficient for G2	1.50	-	
Coefficient for Q1	1.50	-	
TOTAL floor LOAD Quls	103.6	kN/m	

2. Beam Total Load Calculation

BEAM

Influence area width I	6.0	m	
Area load g1"	3.8	kN/m2	Area load: floor structural
Linear load G1'	5.0	kN/m	Dead load: Beam self weight
Linear load G1	27.8	kN/m	Dead load: permanent structural
Area load g2	0.9	kN/m2	
Linear load G2	5.4	kN/m	Dead load: Permanent non structural
Area load Q1	3.0	kN/m2	
Linear load Q1	18.0	kN/m	Live load: Residential

Linear load G1	27.8	kN/m	Dead load: Beam self weight
Linear load G2	5.4	kN/m	Dead load: Floor Self weight
Linear load Q1	18.0	kN/m	Live load: C3
Coefficient for G1	1.3	-	
Coefficient for G2	1.50	-	
Coefficient for Q1	1.50	-	
$Quls = 1.3\,G1 + 1.5\,G2 + 1.5\,Q$			
TOTAL BEAM LOAD Quls	71.2	kN/m	

3. Loads on Shear Wall Calculation

Length of shear wall	9	m
Length of slab 1	6	m
Load on slab 1	103.6	KN
Length of slab 2	6	m
Load on slab 1	103.6	KN
Length of beam 1	1.5	m
Load on beam 1	71.2	KN

Length of shear wall	9	m
Length of slab 1	6	m
Load on slab 1	17.3	KN
Length of slab 2	6	m
Load on slab 1	17.3	KN
Length of beam 1	1.5	m
Load on beam 1	71.2	KN
Total of loads on shear wall	105.8	KN

4. Self-weight of shear wall

Density

Shear wall Base dimension a	9.0	m
Shear wall dimension b	0.8	m
Shear wall Height H	3.8	m
shear wall SELF-WEIGHT Puls,self(1.35 x a x b x h x 25)	911.3	kN
Number of shear walls	6	
Total load self weigth shear wall	5468	kN

5. Total Load

Load on shear wall 1	0	KN
Load on shear wall 2	105.8	KN
Load on shear wall 3	105.8	KN
Load on shear wall 4	105.8	KN
Load on shear wall 5	105.8	KN
Load on shear wall 6	105.8	KN
TOTAL AXIAL LOAD	5996.5	KN

6. To check

Nu = fcd x 80 x 900

Fcd = 0.85 x 0.83 x Rck/ 1.5

Rck = 40 Mpa

Nu = 108365> 5996.5 K

Hence the load is fine

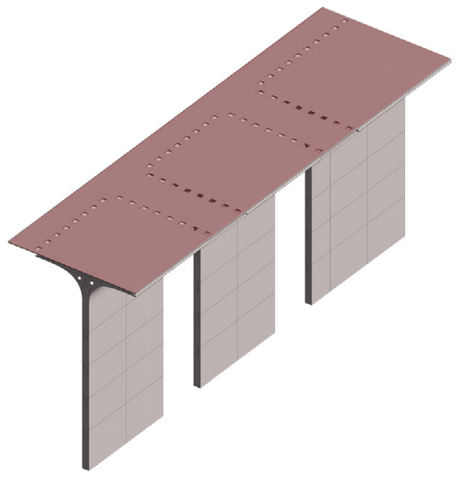
Midas Gen Analysis

1 Modelling

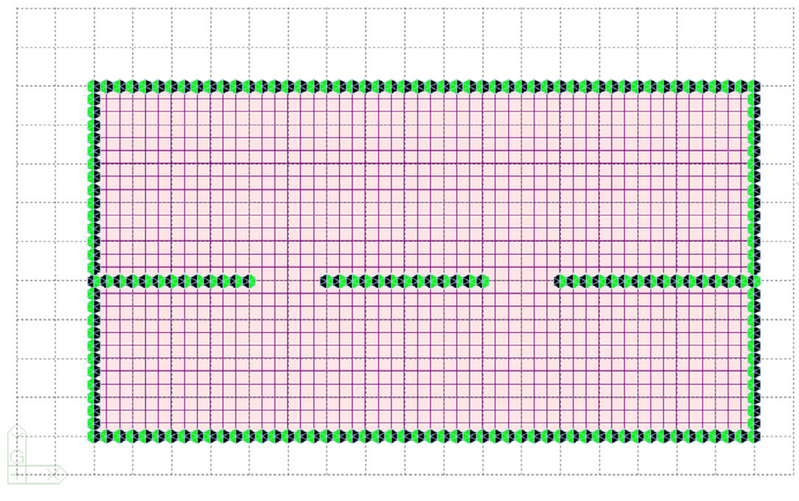
The aim of this analysis is to conduct checks on the pre-stressing of the roof.

First a zone of the roof which covers 3 supports is modelled.

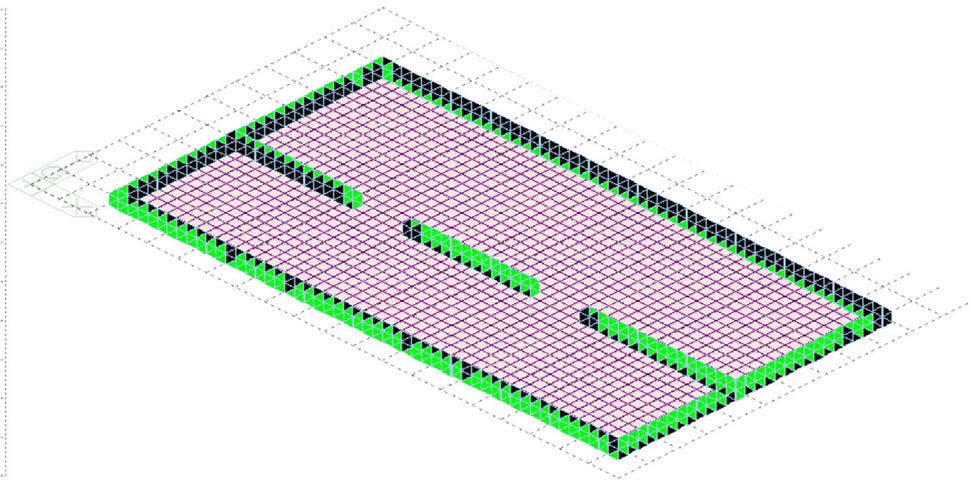
Next the supports are added in the centre and around the edges



Part to be modelled



Midas Model Plan



Midas Model View

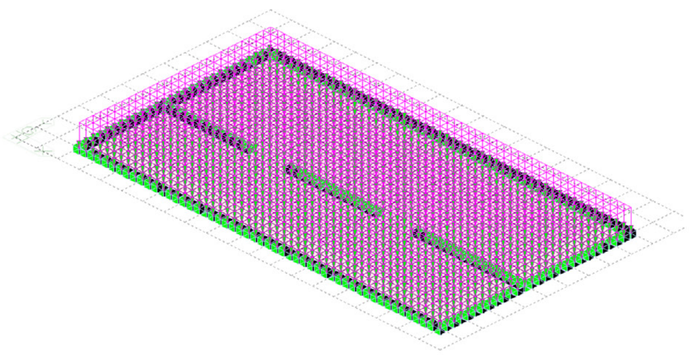
2 Loading

The dead loads and live loads as well as the load combinations (ULS and SLS) are defined.

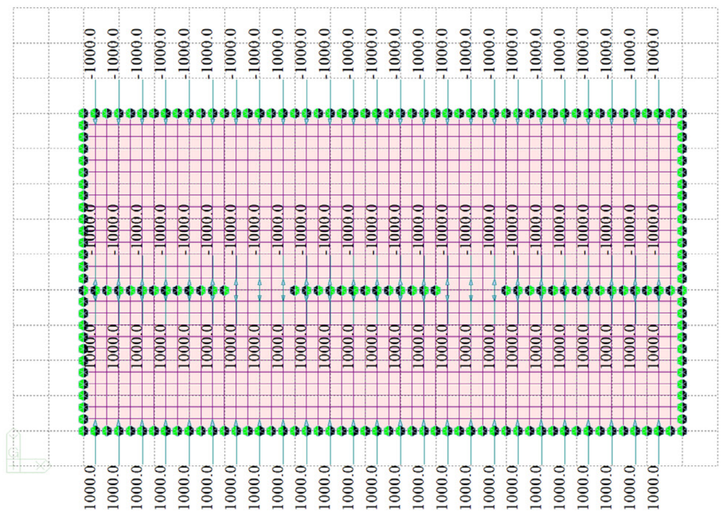
For the prestressing, two cases are considered

a. 1000KN every 2m
b.3000KN every 6m

The idea is to have the same load in different distributions



Vertical Loads



Prestressed load of 1000 kn every 2m

Prestressed load of 3000 kn every 6m

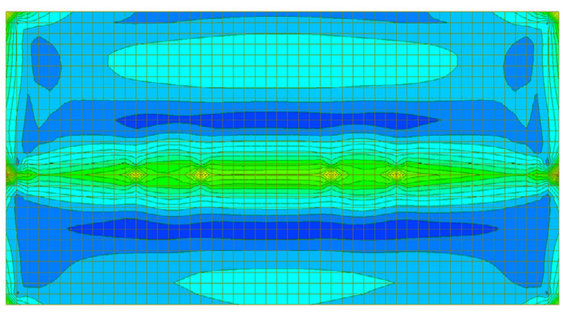
3 SLS Analysis

The stress is analysed with the SLS load combination.

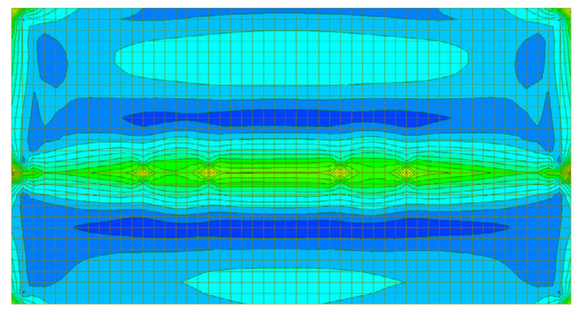
The stress is analysed with the prestressing loads and without and the differences are noted.The sig eff at top and bottom is analysed

The middle of the section is analysed as we have only horizontal nodal loads

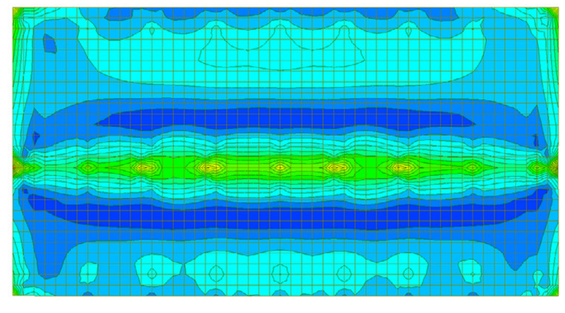
From this analysis



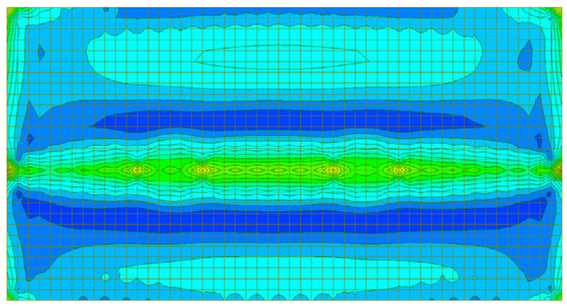
SLS1(no prestress) - Sig eff top



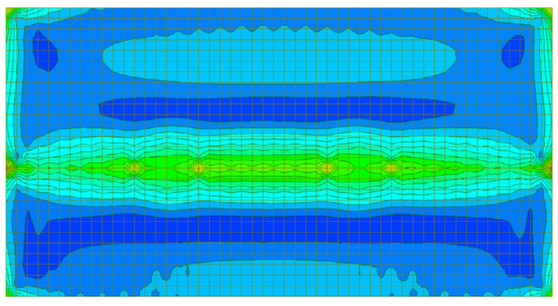
SLS1(no prestress) - Sig eff bottom



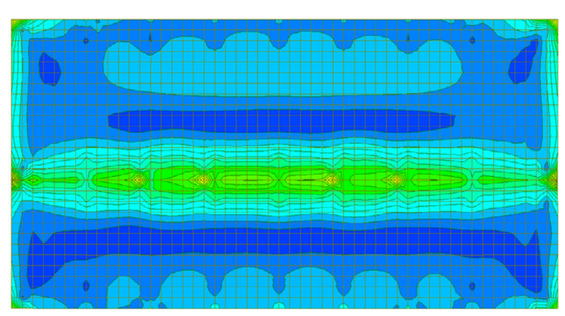
SLS1(3000kN) - Sig eff top



SLS1(1000kN) - Sig eff top



SLS1(1000kN) - Sig eff bottom



SLS1(3000kN) - Sig eff bottom

4 ULS Analysis

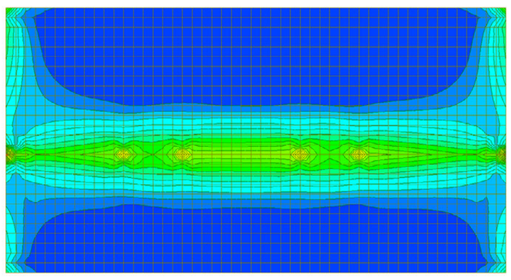
The ULS analysis is done on three different models

1. Without hole
2. With a 3x3 hole
3. With a 3x6 hole

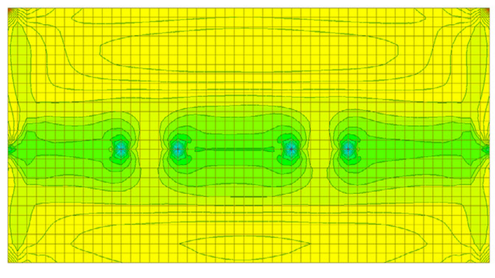
These models are subjected to 3 different load conditions

a. No prestress
b.1000 kn prestress every 2m
c.3000 kn prestress every 6m

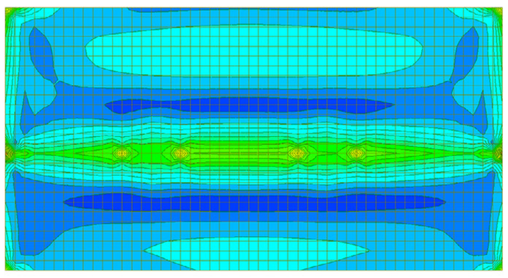
The analyses are performed and the differences about stress at ULS with and without prestressing loads on sigmax, sigmin and max shear at top and bottom is noted



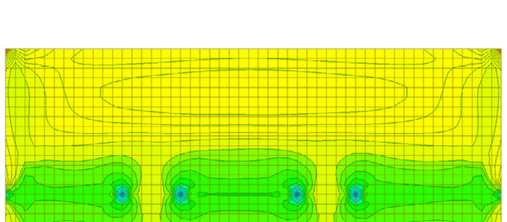
ULS1(no prestress) - Sig max top



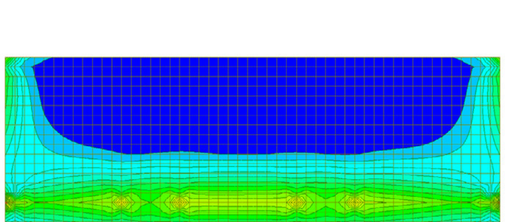
ULS1(no prestress) - Sig min top



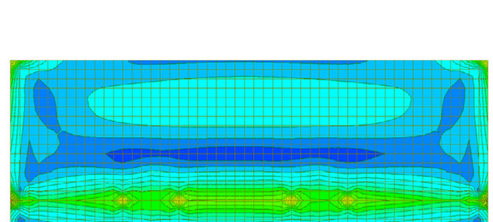
ULS1(no prestress) - Max shear top



ULS1(no prestress) - Sig max bottom



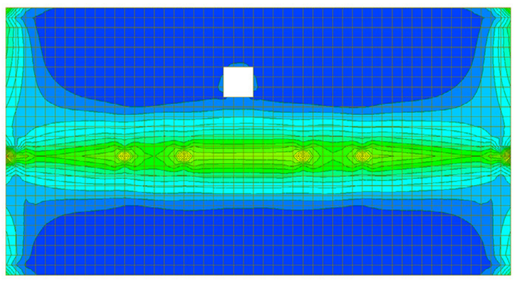
ULS1(no prestress) - Sig min bottom



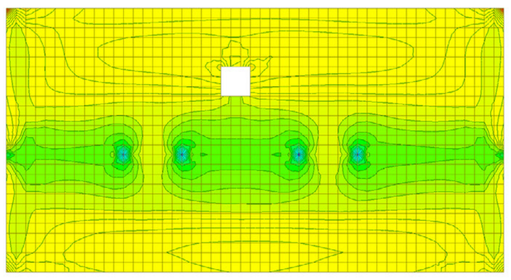
ULS1(no prestress) - Max shear bottom

4 ULS Analysis

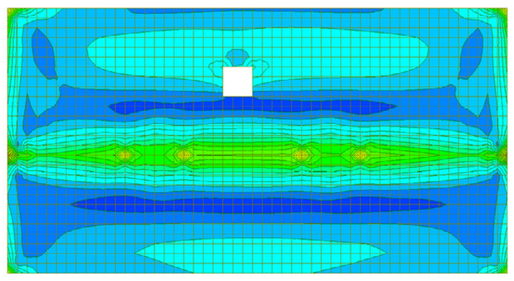
The aim of doing these analysis is to compare the effects of soft distribution (more cables with low level of force) and poor distribution(less cables with high level of force)



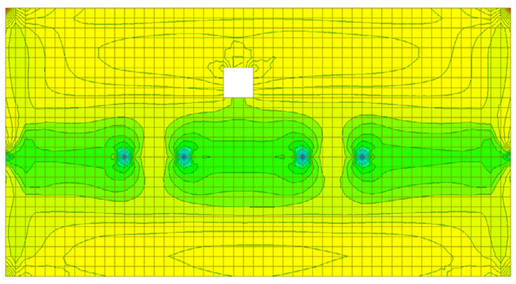
ULS1(no prestress) with 3x3 hole - Sig Max top



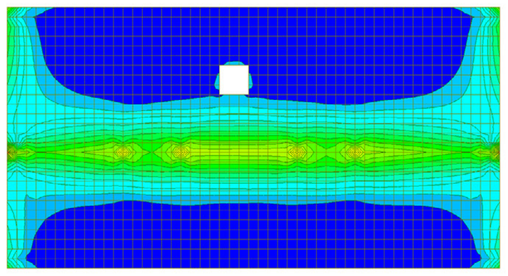
ULS1(no prestress) with 3x3 hole - Sig Min top



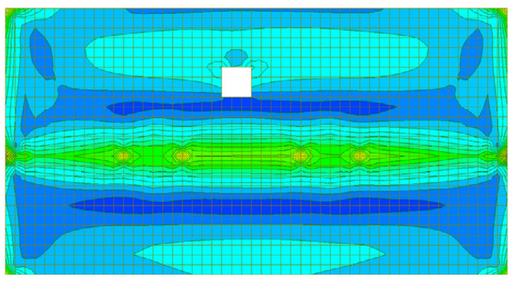
ULS1(no prestress) with 3x3 hole - Max shear top



ULS1(no prestress) with 3x3 hole - Sig Max bottom

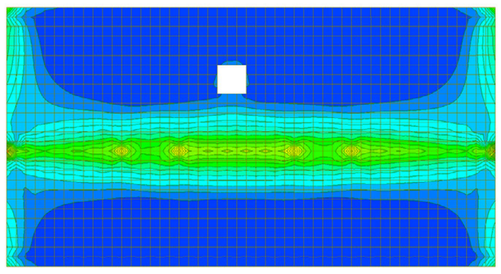


ULS1(no prestress) with 3x3 hole - Sig Min bottom

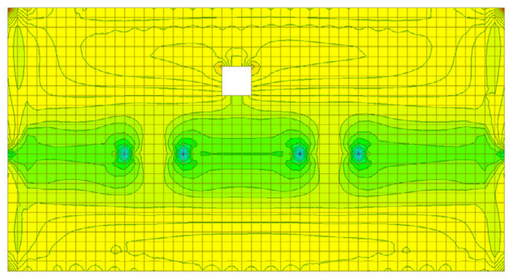


ULS1(no prestress) with 3x3 hole - Max shear bottom

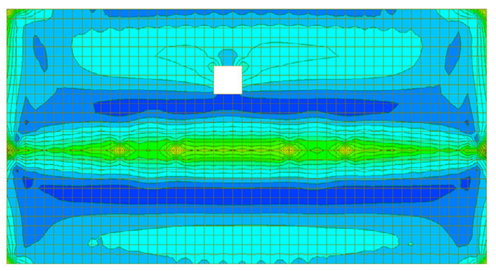
One an understand from this analysis that poor distribution is more effective than soft distribution when there is a presence of holes in the slab



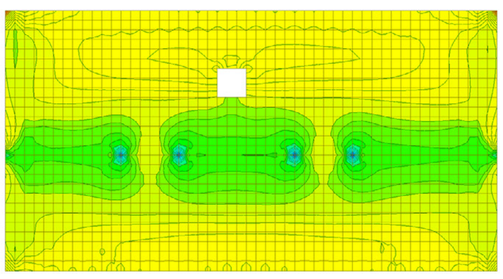
ULS(1000 Kn) with 3x3 hole - Sig Max top



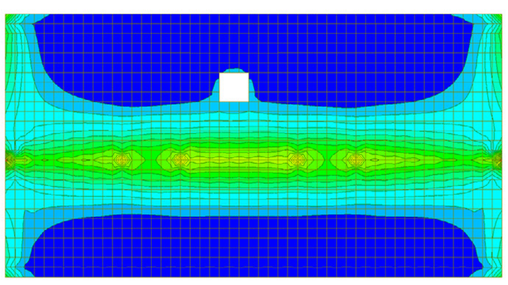
ULS(1000 Kn) with 3x3 hole - Sig Min top



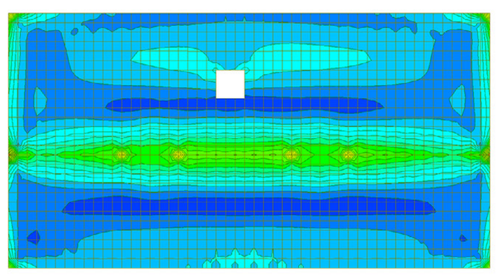
ULS(1000 Kn) with 3x3 hole - Max shear top



ULS(1000 Kn) with 3x3 hole - Sig Max bottom

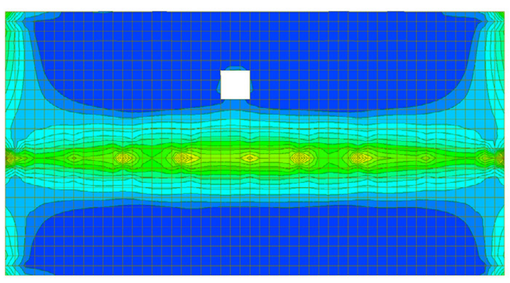


ULS(1000 Kn) with 3x3 hole - Sig Min bottom

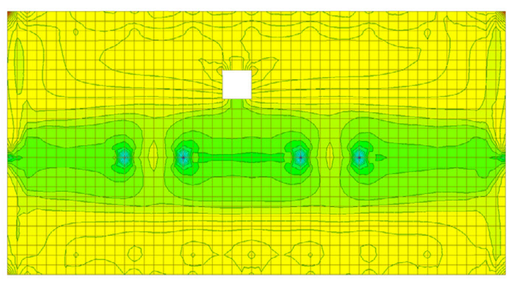


ULS(1000 Kn) with 3x3 hole - Max shear bottom

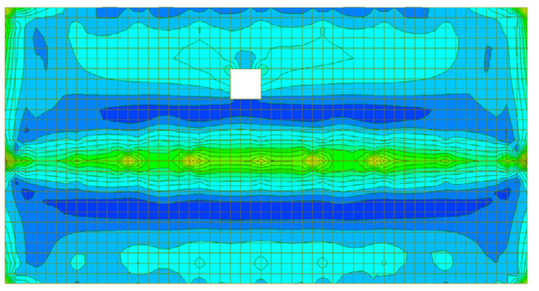
it is a first order of evaluation of the behavior of a prestressed slab, because the study of the curvature of the cable is not available



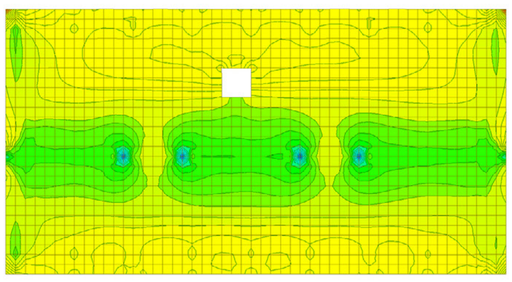
ULS(3000 Kn) with 3x3 hole - Sig Max top



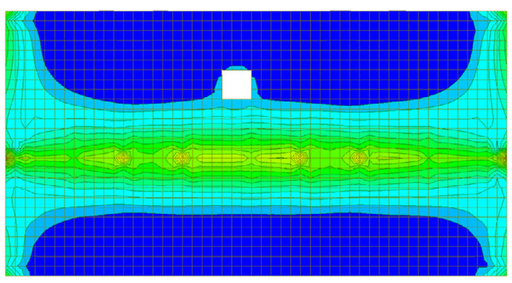
ULS(3000 Kn) with 3x3 hole - Sig Min top



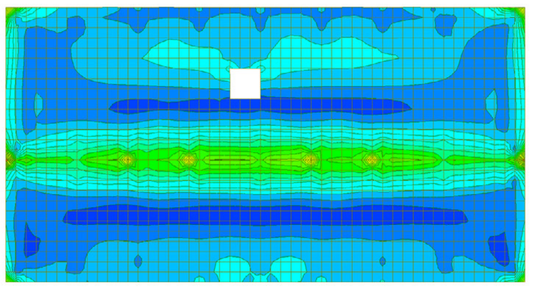
ULS(3000 Kn) with 3x3 hole - Max shear top



ULS(3000 Kn) with 3x3 hole - Sig Max bottom



ULS(3000 Kn) with 3x3 hole - Sig Min bottom

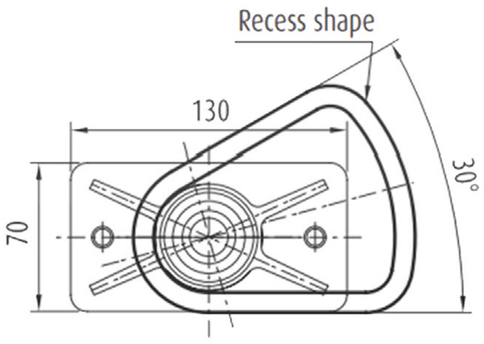


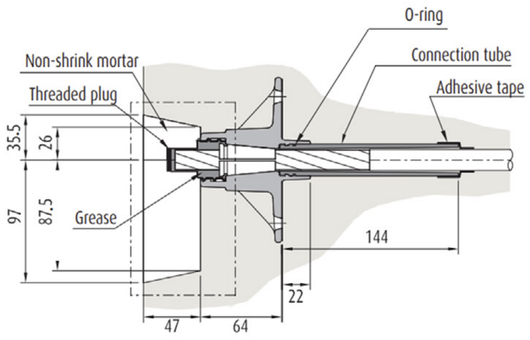
ULS(3000 Kn) with 3x3 hole - Max shear bottom

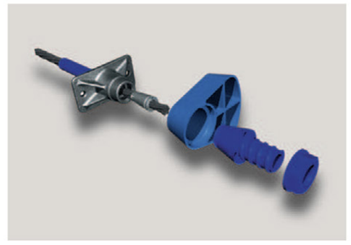
5 Details

Option 1

An option corresponding to the 1000kn example would be to use a single strand unit every 2m . A single cable contains 13 strands of nominal diameter 15mm which corresponds to a failure load of 3445 KN



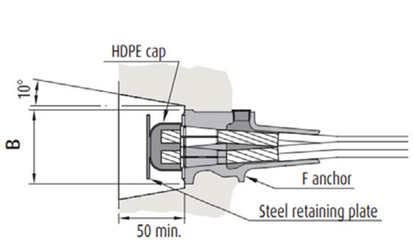


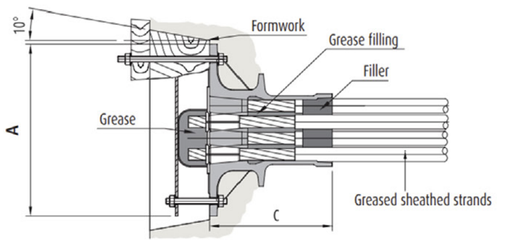


Single Strand Unit

Option 2

Another option corresponding to the 3000kn example would be to use A 3F 13/15 every 6m





Multi Strand Unit