Permacultura

"I belong **here**, at least for a short while."

Earthy 4.0

AR3B011 EARTHY

Earthy 4.0 | November 2021

Faculty of Architecture and the Built Environment
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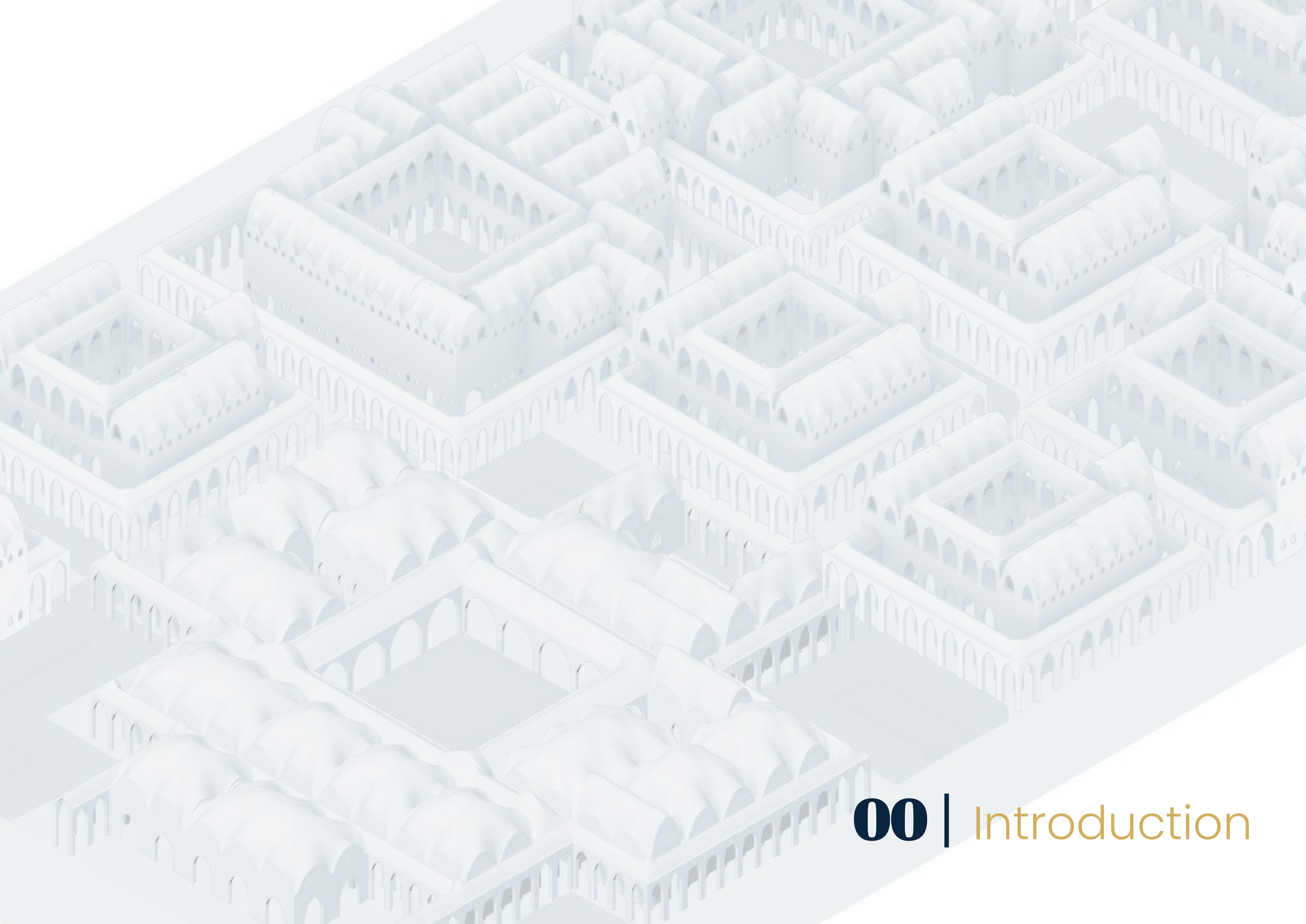


00 | Introduction

00.1 COURSE BRIEF

In the following report, the design methodology and process of our project, **Permaculture**, will be explained and analyzed in depth. Permaculture was developed as a participatory design game, developed from their prospective inhabitants' viewpoint, to enable the dwelling configuration in the Zaatari camp in Jordan for the Syrian refugees, looking at the same time at the opportunities that could be created in order to design new employment positions in the same area.

A neighborhood filled with houses and production hubs that becomes a co-housing system that adds value to manufacture, enhances living conditions and economic development, by taking into account their immediate context and merging it with their culture and needs. The proposal is carried out in various interrelated scales in feedback-loop logic, connecting the design phases from urban configuration to the unit one and the construction details through one manifold system logic.

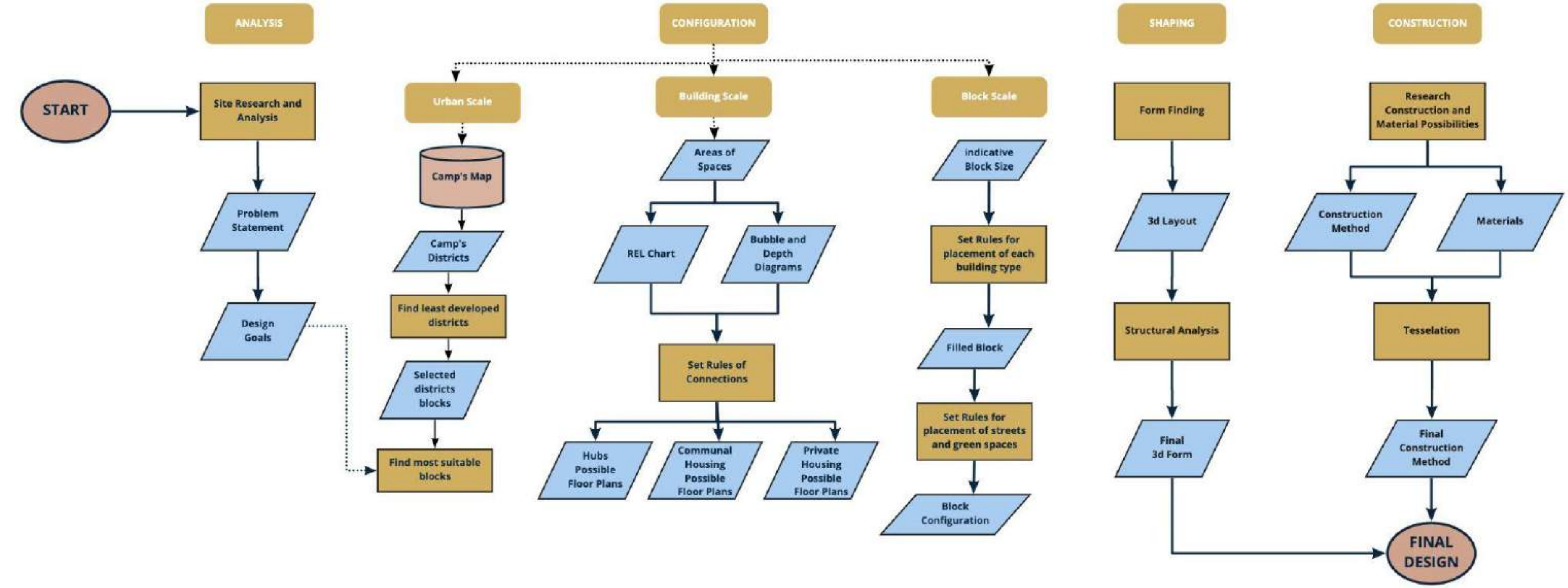
As for the general picture, the course of EARTHY AR3B011 in the Building Technology Master track at TU Delft has as objective to create a range of projects that could assist to improve the living conditions of the Syrian refugees in the Zaatari camp of Jordan, due to the prolonged necessity of the camp, the regional and local properties, a more permanent urban structure is sought. Within this course multidisciplinary topics were addressed, ranging from methodology and programming to the construction and structural design approaches. Main challenge was the development of such a project that combines elements of earth architecture with computational methods, strategies and tools, and finally come up with a structurally sound design, that add value to the configuration logic, form-finding, structural and construction processes, using only earth and local-based materials that are available at the site.

Simultaneously, this report is following the same logic, starting by elaborating on the existing situation in Zaatari camp, the general idea behind the Permaculture Project and its game logic and finally diving into each aspect of design. The configuration methodology will be explained, followed by the shaping process, the structural analysis and verification, and lastly the construction part, defining each element that takes a role in this procedure and highlighting their relation and connection every time until the final result.

In all, Permaculture became a participatory design game, which defines a set of rules and guidelines to the refugees to build their own house, by explaining the steps and options available and providing them with a kit of parts and a construction manual. This offers a combined computational and manual approach, providing an open-ended and flexible system, which can lead to various possible housing solutions and configurations. In the end, it has a universal logic, which can be applicable in different scenarios and situations that exceed the ones covered in this theme, extending its possibilities. These will lead to an urban configuration that grows with the camp and finally becomes a city, worthy of their culture.

Production Hubs + Housing = Neighbourhood

00.2 METHODOLOGY | Overall Flowchart



The methodology followed in the course of this project is defined by a systematic approach and is divided in four main parts. The initial step consists of the Research and Analysis phase where the existing conditions related to the quality of life, infrastructure are studied in order to have an evaluation of potential problems that we could address with our design proposal. Moreover, the social and economic aspects of the current situation are taken into account and finally, the cultural background of the Syrian people is studied in terms of their art and architecture.

After the problems we want to target have been identified the Configuration part begins. This part is divided into three scales, the urban scale, the block scale and the building scale. In the urban scale the procedure aims at setting a set of parameters and a procedure through which the most suitable blocks the whole camp can be identified as such so that our design vision can be applied. The building scale configuration consists of the procedure that identifies the needs for each building type and furthermore sets the rules for the connection of the individual elements comprising the buildings. There are three different types of buildings studied, the makers hubs, the communal houses and the private houses. Finally, the configuration taking place in the block scale addresses the issue of the relationship and connectivity of each building type.

The next step in this systematic approach is the Shaping phase. This is where the form finding occurs together with the structural analysis defines the final shape of each 3d form.

Finally, once the final shape has been configured, a research on materials and building techniques associated with earth is conducted, and once the section of the most suitable materials and techniques is complete the selection of the construction parts can happen.

Diagram 00.1: Overall Methodology Diagram

01 | Analysis

01.1 SOCIAL CONTEXT

"Refugees are people who have fled war, violence, conflict or persecution and have crossed an international border to find safety in another country", "someone who is unable or unwilling to return to their country of origin owing to well-founded fear of being persecuted for reasons of race, religion, nationality, membership of a particular social group, or political opinion". This was stated by The UN refugee Agency (UNHCR) in their key legal document of 1951 Refugee Convention.

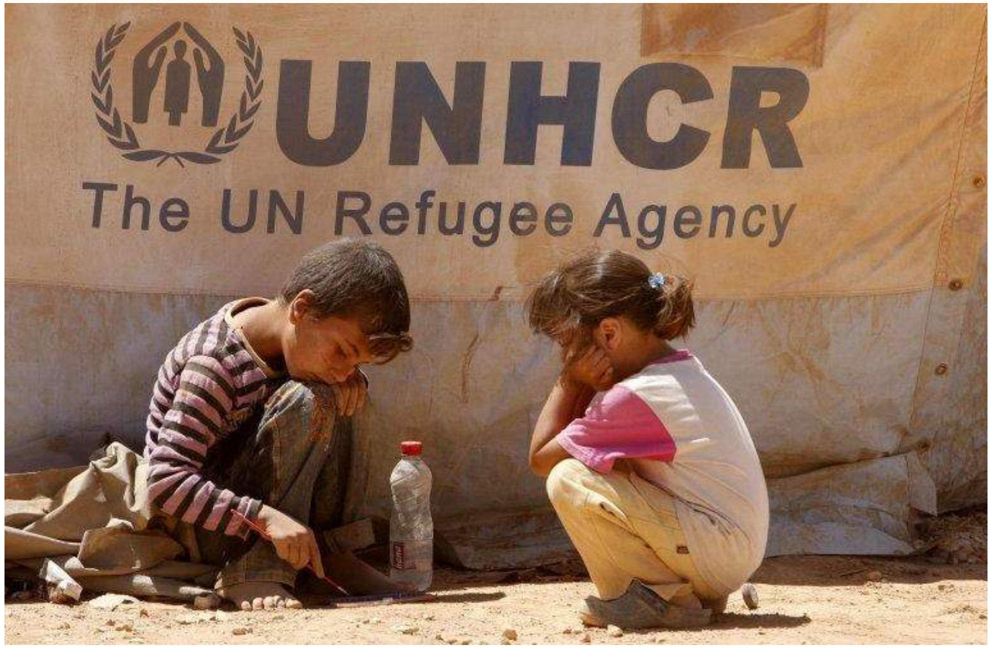
The protection of refugees has many aspects. These contain firstly safety from being returned to danger, access to fair and efficient asylum procedures, and measures to ensure that their basic human rights and needs are respected while they secure a longer-term solution.

For the aforementioned reasons, camps are constructed to protect and save lives and become actually a core for humanitarian work in the hosting country and the new home. The UNHCR has settled and provides an emergency handbook for the construction of such establishments, like tents, containers, etc., though, there are still some limitations to these measures. However, this handbook is made from a practical and reactive perspective of architecture, and it does not consider the needs of a society that thrives from their sense of belonging, community and family.

By the end of 2017, there were 25.4 million refugee men, women and children registered across the world. After 10 years of crisis, life is harder than ever for displaced Syrians. Millions of them have been forced to flee their homes since 2011, seeking safety as refugees in Lebanon, Turkey, Jordan and beyond, or displaced inside Syria. As the crisis continues, hope is fading. With the devastating impact of the pandemic and increasing poverty, every day is an emergency for Syrians forced to flee.

"This is one of the largest refugee exoduses in recent history, with no end in sight" (Kruijt, 2014). The longer the battle continues, the harder it becomes for the families at the camp. Many have arrived with limited means to cover even basic needs, and those who could at first rely on savings or support from host families are now increasingly in need of help.

Picture 01.1 : Zaatari Camp: Temporary Home for Syrian Refugees
Christian Jepsen/NRC (source)



Picture 01.2 : Children Refugees playing with the sand.
UNHCR (source)

01.2 REFUGEE SITUATION

The World's largest Syrian Refugee Camp, The Zaatari Refugee Camp, developed since July 2012 and within one year, the population grew up to 200,000 people (Krujit, 2014). Reaching more than five times its maximum capacity, the UN Handbook states that the development of this camp is extremely difficult, while the living conditions are deficient.

The data available about the zaatari camp are as follows :

- **Nearly 20%** of the population are children.
- **19,243** children are enrolled in 32 schools
- **58** community center offer activities
- **30%** of the households are female headed
- **4,105** refugees are engaged in Incentive-Based Volunteering
- **4,361** weekly health consultations are done on average
- **13,773** refugees have work permits, with **23%** female

SHELTER

Upon their arrival to the Zaatari camp, each family or individual is given a tent, after that, the families also receive a caravan to counter the difficult climate. In most cases the refugees improve their own household by buying more caravans from an informal market or by moving existing caravans from other family members or friends to improve their living conditions. The plan is to 'caravanise' the whole camp, so that every family has the security of living in a solid building that they can turn into their home; and this shelter solution is best suited to the people and the environment.

From observing the pictures and some extensive research it was found that ideally, a household in Zaatari is made from four caravans and tents, Sanitation is present in between the two caravans, and the tent is used for cooking (Stromme, L., 2013).

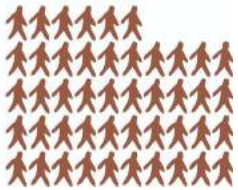
Due to the lack of interior spaces and hot environment, they cook outside in shaded areas, which allows for a better air quality (Edstram, M. Zaatari 360 2 UNHCR, Refugee Response).

Certain facilities are provided at the central location (offices, healthcare, warehouses, market, community centers), while others are decentralized throughout the camp (water, latrines, bathing, garbage,education). (Corsellis, 2005) Some other facilities can be seen at the outskirts of the camp.

7,822 tents in camp

24,000 caravans in camp

4.6 – average family size



461,000 – refugees have passed through the camp

Diagram 01.1 : Shelter and People Zaatari Camp
UNHCR (source)

01.3 THE ECONOMY: PROFILE OF SKILLS

In february 2016, Jordan took the unprecedented step to provide formal employment opportunities to the Syrian Refugees. Following the developments, In February 2017 the Ministry of Labour announced that the Syrian Refugees living in the camp can obtain work permits to work anywhere in the country. In this context, the available skills of among the refugees were analysed and their willingness to take over formal employment outside the camp was assessed.

In Zataari, during the assessment, the number of refugees between 18 and 59 were **30,709** individuals. **14,847** of them were males and **15,857** of them females. A total of **372** males and **342** females were interviewed , this sample size had a confidence level of 95% and 5%margin of error.
30% of the men and women interviewed worked inside Zataari camp through cash for work schemes as Incentive Based Volunteers. The majority of the interviewees were willing to work in agriculture; however, men were more interested in **construction work**, transport or wholesale/retail trade. Women were interested in cooking/catering, education and **Tailoring.**

The survey also found that although women were generally more educated than men in the camp, they were not willing to work outside the camp.The test also showed that the refugees showed interest to work in sectors they didn't have experience in and are happy to do job-training. There was a strong need for training and defining the typology of training.

This data was further used to decide the area programming for the hubs of our project. The relative % of the interests and skills provided an overview of the space requirements depending on the population and could be customised where ever needed based on the demographics.

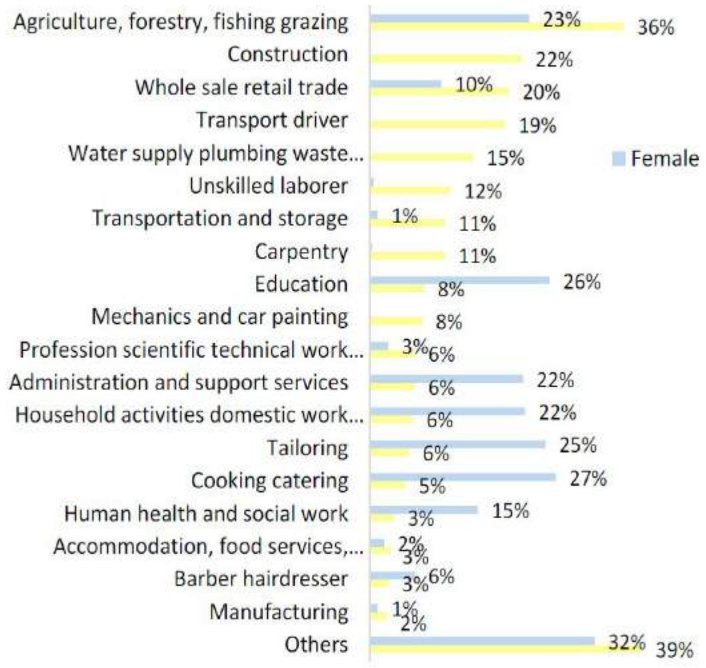


Table 01.1 : Skills, work experience and interests
A *UNHCR* (source)

01.4 SITE ANALYSIS

LOCATION

The zaatari camp is located in the semi-arid-desert landscape in Northern Mafraq. The province of Mafraq covers the second largest area in Jordan. The region where Zataari Camp is located is classified as steppe vegetation. This Vegetation is confined to the Irano-Turanian region. Low shrubs and dense bush cover dominate the vegetation.

The Zataari Camp was chosen to be located as close as possible to the Syrian border to facilitate easy transportation of refugees. The access to the ground water is necessary for a refugee camp, in this location the aquifer is relatively shallow compared to the water level in the region. For safety the UNHCR uses an existing military pase for protection.

Around the camp some landscape structures are visible. The creek [dia. 01.2] runs along the camp, and olive orchards are visible in the vicinity. The main occupation around Zataari is housing and agriculture.

THE CAMP DEVELOPMENT

Zataari is overpopulated and completely full. It had to accommodate a fairly large number of refugee in a fairly short time, and this resulted in a gridded system of the camp divided into 12 districts [Dia. 01.3]. Initially the tents and caravans had spaces around them for vehicular movement and hygiene. But as the density increased, the new refugees settled around the existing tents/caravans. Due to this there is limited open space for activities and hygiene. Asphalt Roads are present around the districts to facilitate movement of cars and trucks. The black blocks [Dia. 01.3] represent the commercial and public facilities distributed around camp. The Older districts have more facilities density than the newer ones.

Diagram 01.2 : Land Use around Zaatari Camp

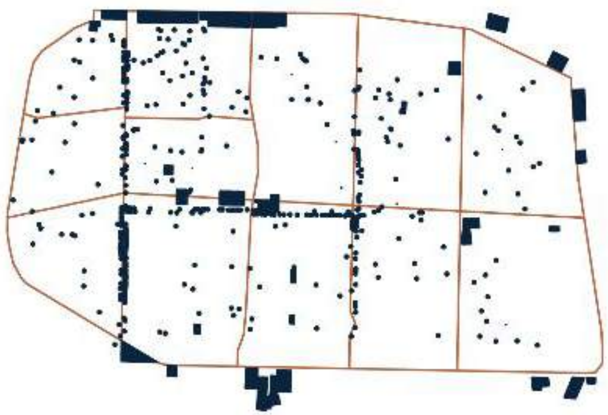


Diagram 01.3 : Current layout of the Camp Divided into 12 Districts

01.4 SITE ANALYSIS

ECONOMIC ACTIVITIES AROUND THE CAMP

As the Camp grew the economic activities and services grew along with it. To cater to the refugees, within the camp there are 3000 little shops which have a monthly economic value of 10 million dollars (Rettman, 2014). The oldest street in the camp was renamed "Champ-Elysees". The street hosted a wide variety of shops [Dia. 01.4] ranging from bridal shops, internet shops and everything in between. Another source of income for the refugees were the goods provided by the aid agencies. There are other employment opportunities available such as cash for work schemes as Incentive Based Volunteers.

HUMANITARIAN ORGANISATIONS

There are around 70 active organisations inside the camp the provide all kinds of aid. (Ledwith 2014). During the first year, the number of refugees grew enormously. Therefore the physical space expanded in proportion. The surface area of the camp covers 5 sq. km. To reduce travelling distance, the NGO's were decentralised and spread out [fig 01.5]. The current typology of schools, hospitals, and distribution centers are temporary structures such as tents. Some of the kitchens, sanitation buildings have permanent characteristics.

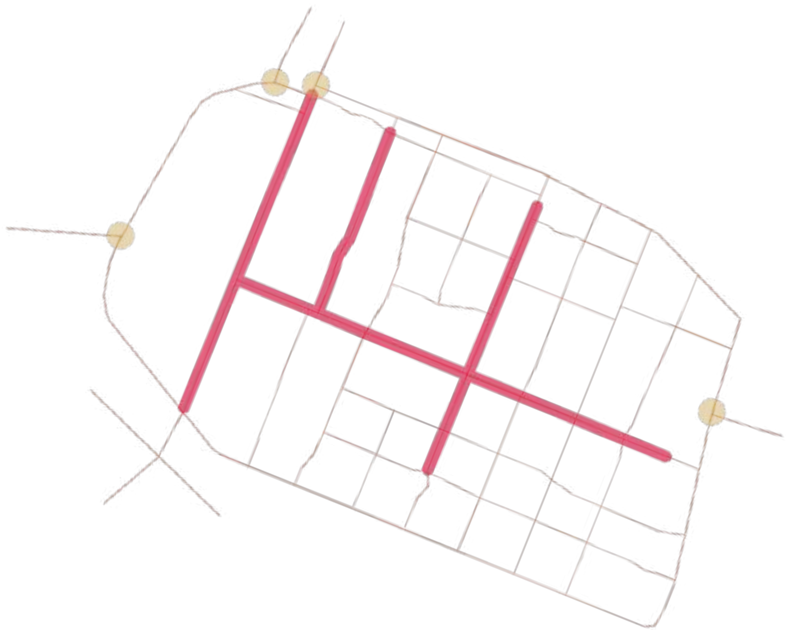


Diagram 01.4 : Market Streets

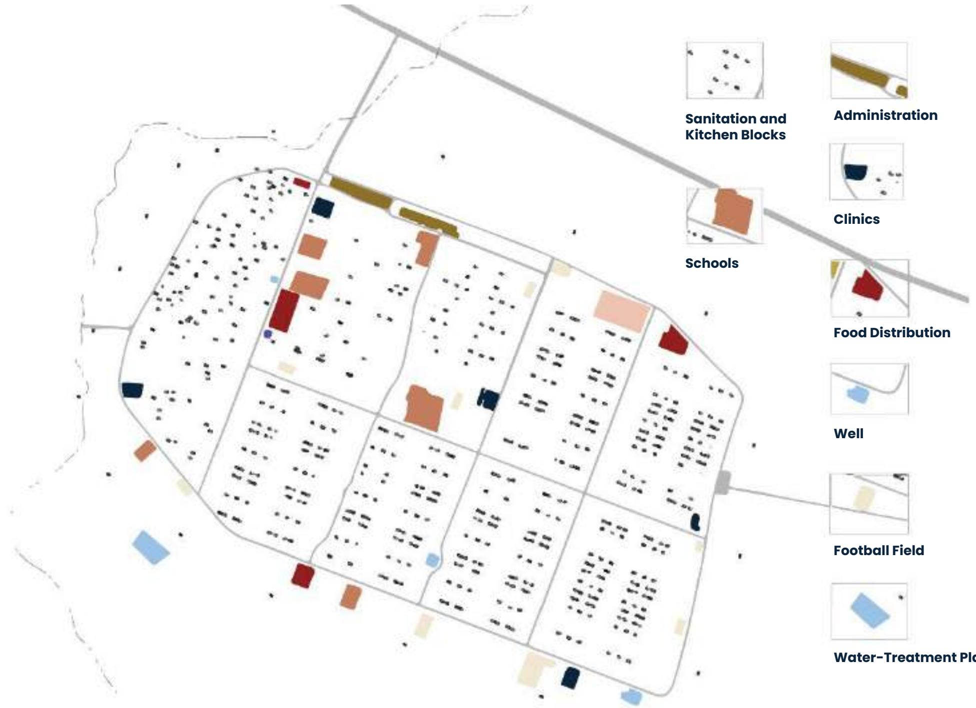


Diagram 01.5 : Humanitarian Infrastructure

01.5 CLIMATE

Jordan's climate varies from Mediterranean in the West to desert in the East and South, but the land is generally arid. Its land is consisted of four main physiographics regions: highland, valley, steppe and desert. The majority of the land is covered by desert while a really small percentage is occupied by valley and highland, which are located in the North of the country.

Zaatari camp is located 10 kilometres (6.2 mi) east of Mafraq, North Jordan, in a desert territory. Average temperature conditions changes notably during summer period, range from 15ºC to 33ºC and from 5ºC to 16ºC in winter. However, these numbers also bring out that there is a big temperature difference between day and night time.

The average annual precipitation amount reaches roughly 160mm which mostly occurs between November to March. The wind rose shows how many hours per year the wind blows from the indicated direction, blowing mainly from West to East, while the highest wind speed can reach 38 km/h.

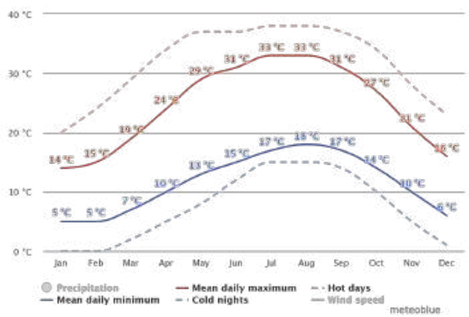


Diagram 01.6: Temperature Chart
Meteoblue (source)

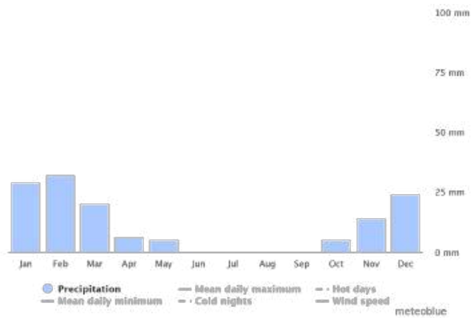


Diagram 01.7 : Annual Precipitation Chart
Meteoblue (source)

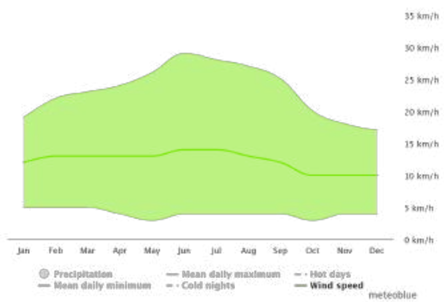


Diagram 01.8 : Wind Speed per km/h Chart
Meteoblue (source)

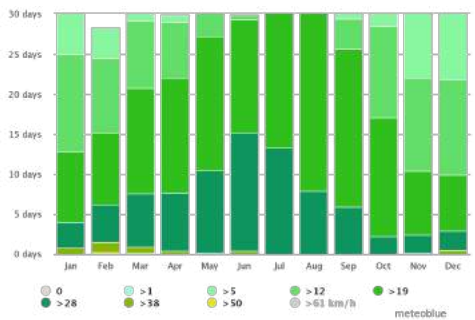


Diagram 01.9: Wind Volume Chart
Meteoblue (source)

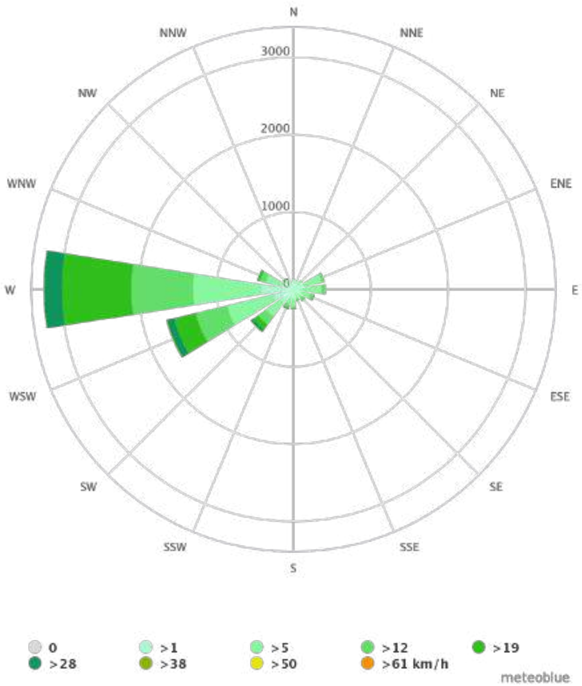


Diagram 01.10: Wind Rose Chart
Meteoblue (source)

01.6 CULTURAL HERITAGE | Syrian Architecture

Part of the research process was the identification of architectural elements that derive from the traditional syrian architecture and can be used in this project as a way to create a bond between the refugee's current situation and their familiar spatial qualities.

One of the main architectural elements identified during this process are the existence of an inner courtyard in the houses. The courtyard influences the spatial configuration of the houses as it acts as a core around which the rest of the functions are placed. Moreover, it is an element that plays an important role in the quality of the people's daily life as it acts as a space of gathering and communication.

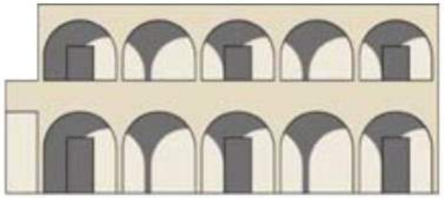
Some further elements that were found interesting as far as their architectural and spatial qualities are concerned are the Iwan which acts as a semi-open space and the Riwaq which plays the role of a transitional space between the closed spaces and the courtyard.

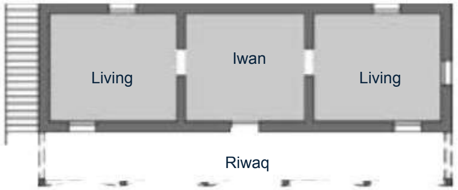
The identification of these elements is very important as they will act as inspiration during the next phase.

House with Liwan

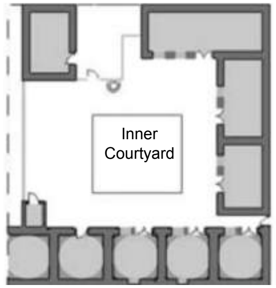
Multipurpose Rural House

- living
- warehouse
- workshop
- shelter for domestic animals





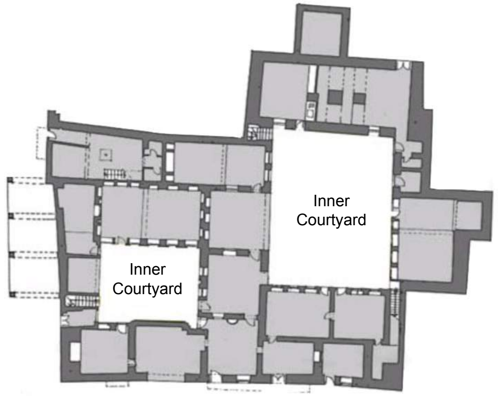
Rural House with Inner Courtyard



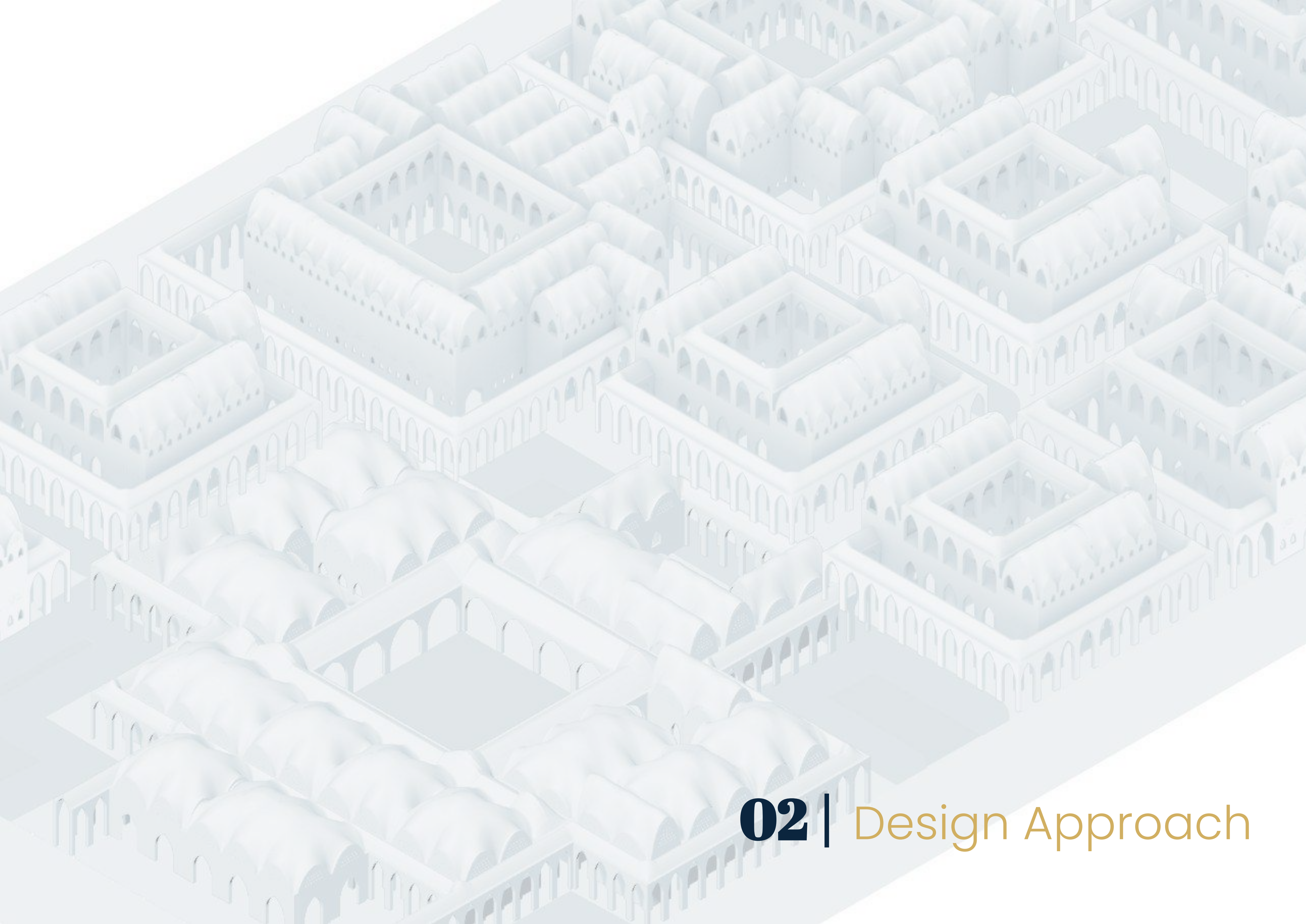
Urban House with Inner Courtyard

found in most Syrian cities

- Height= 10m for two storeys
- Ground Floor: Living, Service Rooms
- Upper Floor: Bedrooms
- Few and Small openings on external facade
- More and Larger openings onto inner courtyard
- Inner Courtyard
    a. gives feeling of privacy
    b. space for family relationships
    c. strong attachment to house
    d. garden



Pictures 01.03 : Pictures and diagrams of typologies of traditional syrian houses
SYRIAN ARCHITECTURE (source)



02 | Design Approach

02.1 DESIGN APPROACH | Design Problems

In order to reach a design a design proposal that can make a difference to the lives of people living in Zaatari camp the problems related to their lives their first needed to be identified. The problems that we found during the research phase can be divided into three main categories. The first category is associated with the infrastructure of the camp itself and its growth over the years. Regarding this aspect, it was noticed that the infrastructure if the camo does not cover the basic need of the people since the living conditions are poor due to the informal growth of the camp over the years and the fact that there are districts that are extremely densely populated.

A second aspect that causes problems to refugee's life is the lack of elements to make people feel a sense of belonging. The sense of community that is very strong in the syrian culture is not being enhanced under these living conditions since there are no communal spaces or activities. Moreover, there is a severe lack of architecture that can provide them with familiar images and space qualities that are associated with their culture.

Finally, another very important aspect to consider as a problem concerns the financial aspect. The unemployment rate inside the camp is very big. Moreover, the camp is completely dependent on external resources and completely lacks self sufficiency. The skills that people already have from their lives before the war are not being used. All the aforementioned issues result firstly in a poor economy of the camp as well as a lack of activity and purpose in people's life from the lack of financial or other activity.

- **Informal growth of the camp over the years**
- **Unevenly developed districts**
- **Poor living conditions that don't cover basic needs**
- **Overcrowding households without privacy**

- **Lack of communal spaces**
- **No feel of a community**
- **Inexistent architectural identity**

- **Lack of sufficient employment**
- **Lack of skills development**
- **Lack of local production**
- **Loss of traditional syrian craftsmanship due to movement**
- **Unbalanced distribution of the camp's commercial activity**

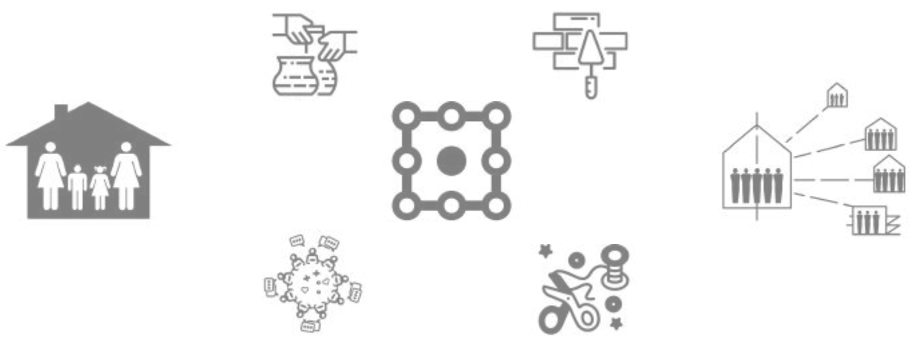
02.2 DESIGN APPROACH | Design Vision

One of the basic needs of people is the sense belonging. Syrian refugees who were brutally forced to flee their country out of the blue, abruptly find themselves in a camp in the middle of the desert feeling uprooted. Not able to move back to their home, they need to make a new reality in this unfamiliar ground.

Our design goal is to create a co-housing system mixed with decentralised "production hubs" where a neighborhood-based communal production of goods can take place.

We believe our design vision can help develop a sense of belonging in the following way. Firstly, the access to housing conditions that cover basic needs is achieved. Additionally to that, the cohabitation addresses both the problem of scarcity of space and infrastructure, and additionally brings the different families closer together. While the "production hubs" use their existing skills and help develop new ones providing also a potential for having economic growth. Finally, the housing configuration and architecture intends to serve as a connector to their living situation in their homeland and should also be adaptable to future needs and changes in population density.

Design Blocks of Neighborhoods where **co-housing units** are mixed with **decentralised makers hubs**



Communal Spaces/Activities

Merge families to live together sharing communal facilities.

Aliveness / Production

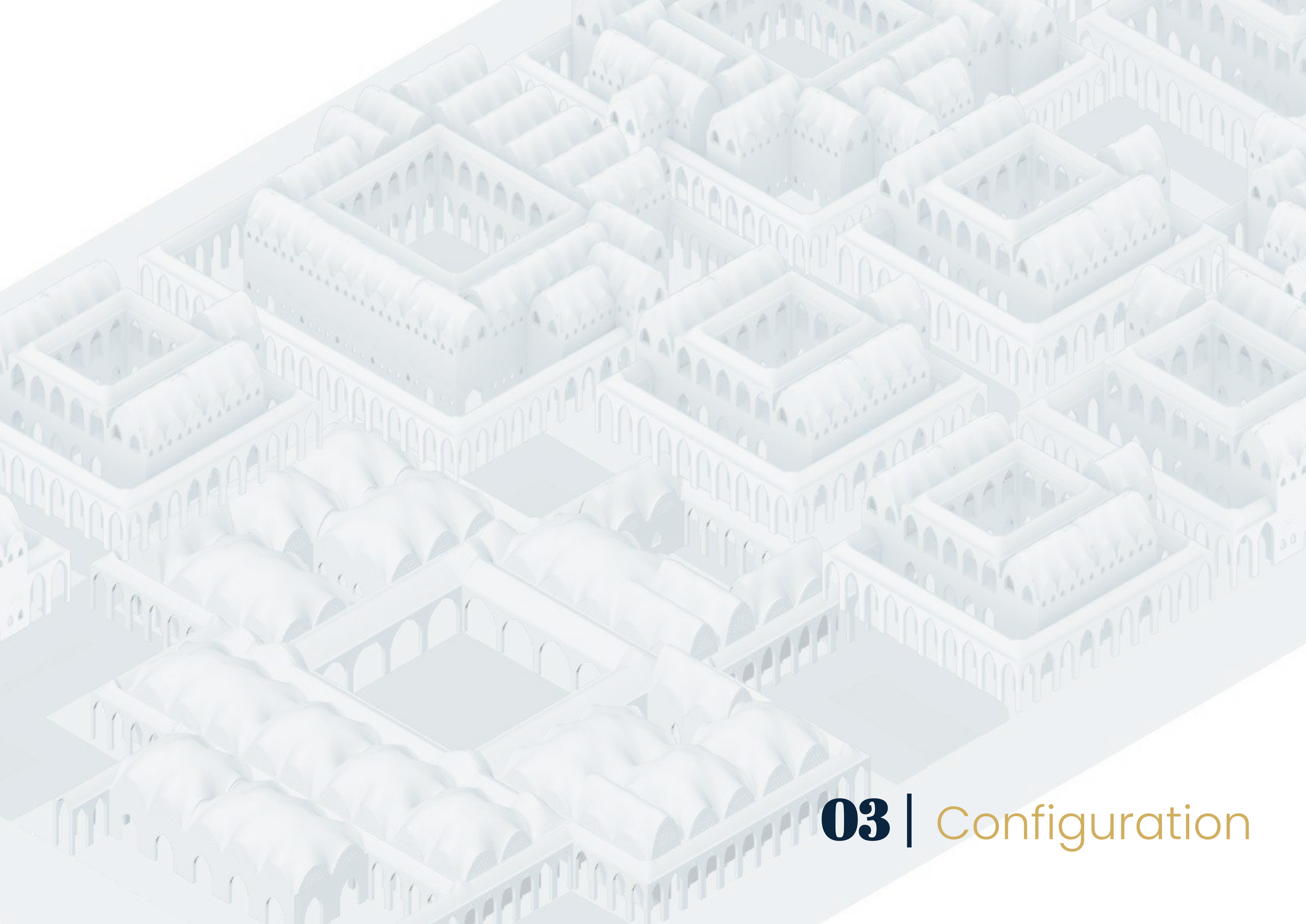
Develop Decentralised Production Hubs combined with housing units.

Meaningful Architecture

Design Modular Housing Units with references to familiar architecture.

Adaptive / Modular

Spaces that can be extended or repurposed organically.



03 | Configuration

03.1 CONFIGURATION | Overview

The priority was to create decentralised production units - **Maker's hub** in suitable areas around the camp. For the selection of location we move from the urban and district to the block and finally to the unit scale. At each level there are parameters to prioritize the locations. The first scale of selection is the urban scale.

The camp is analysed for the activity areas and infrastructure. The economic activities and employment areas are considered for the selection of influence areas in terms of walkability. After the development percentage is calculated, the least developed districts are looked into,The number of blocks selected depends on the development score of that districts (dia 03.1). The aim is that the design will be customised for the demographic of the particular block (further explanation in later chapters).

The desired outcome of the project is that after all the blocks have been selected and developed, the influence areas of the new hubs would increase the overall development of the camp and consecutively, the selection of the district can increase to 80% and so on.

Diagram 03.1 : District Scale Analysis

03.2 SPATIAL CONFIGURATION | Urban Scale

The urban Scale analysis is carried out to filter location for district scale. there are a number of parameters considered for the same. Firstly, the activity areas around the camp is identified. These activity areas are the source of employment for the refugees within the camp. The second step is to measure to influence areas of these activity spaces (dia. 03.2). The results of this analysis provides an overview of the development of the different districts in the camp. The aim is for all the districts to have higher than 70% development percentage. The districts with a lesser score is selected for the District scale. The steps are further explained in the flowchart (dia. 03.3)

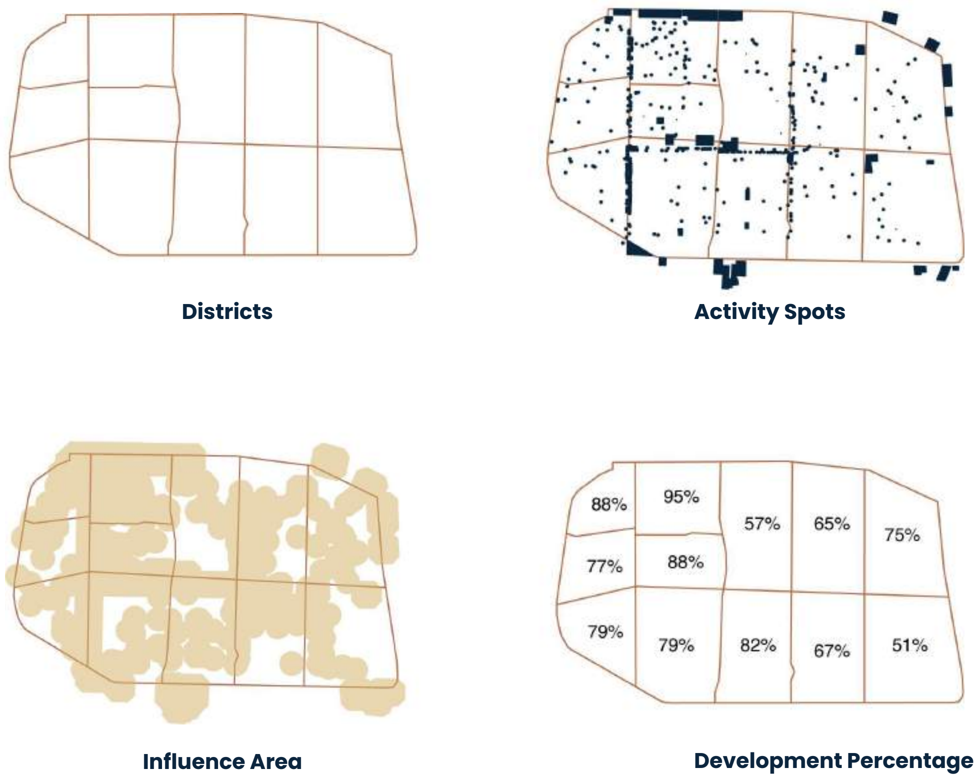


Diagram 03.2 : Urban Scale Analysis

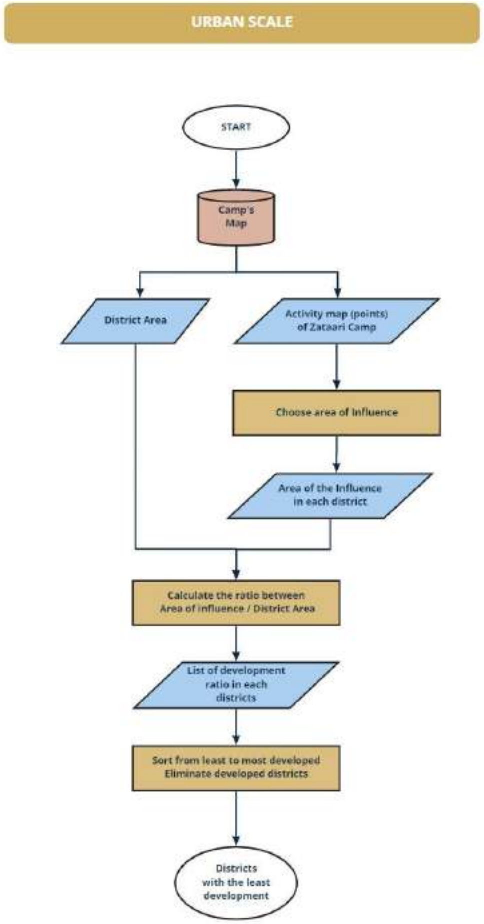
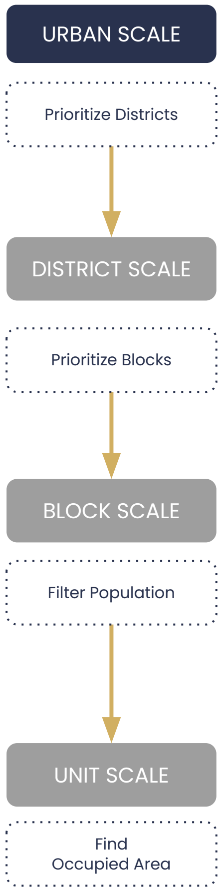
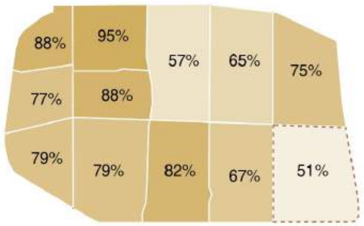


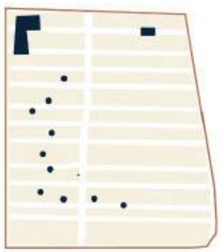
Diagram 03.3 : Urban Analysis Flowchart



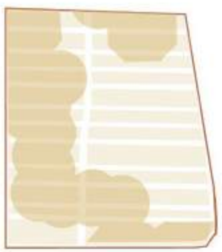
03.2 SPATIAL CONFIGURATION | District Scale

Zooming into the least developed districts, the next step is the selection of suitable blocks. Each block is further analysed for its activities and their influence areas, the shortest path to the gates-entrances of the camp, taking into account the commercial needs of the project and also the most direct road to the market-bazaar areas for the transportation of the selling products. After their evaluation the blocks that could developed further by placing our project are identified [dia 03.4]. The number of blocks selected in a district depend on the development score of that specific district. Depending on the demographic and density, the bumper of blocks selected can vary throughout the site. The details of the process is further elaborated in the flowchart [dia 03.5].

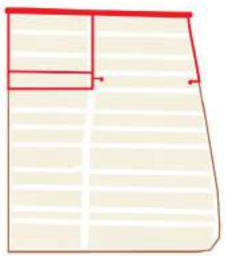




1. ACTIVITIES



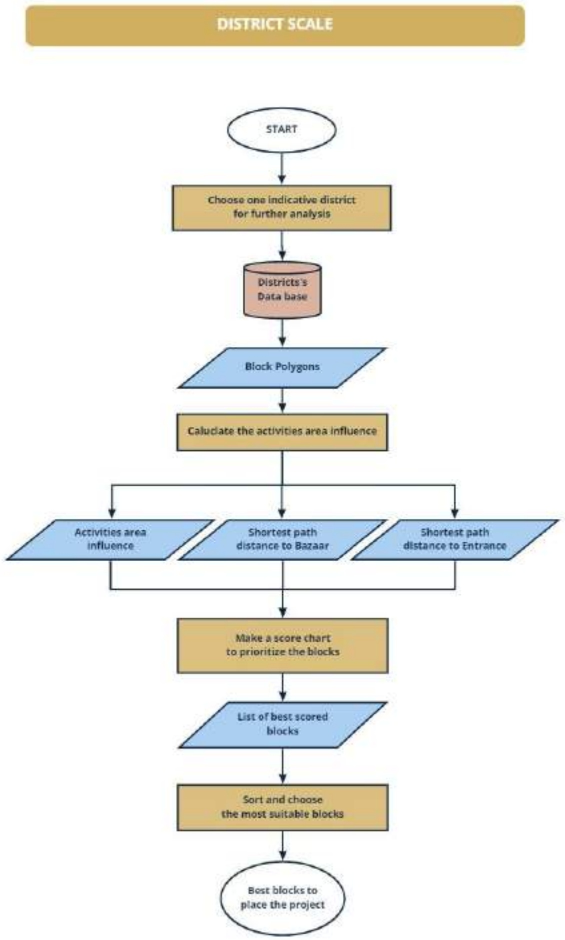
2 INFLUENCE OF ACTIVITIES



3. SHORTEST PATH TO BAZAAR AND ENTRANCE

4. SELECTION OF THE BLOCK

Diagram 03.4 : District Scale Analysis



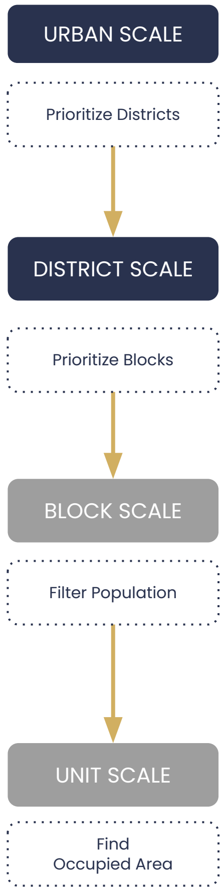


Diagram 03.5 : District Scale Analysis Flowchart

03.2 SPATIAL CONFIGURATION | Block Scale

The main aim of the project is to create decentralised production hubs along with housing. And the goal is to be able to customise the design solutions according to the context. For this reason, after the selection of the block, it is further analysed to inform the design in the unit scale.

The **first** step is to analyse the population of the block. n **second** step from the data the age group of people who can work (18-65) is filtered out. In the **third** step , the population is further segregated based on gender, to better inform the area programming in the unit scale. As the preference of typology of work varies with the gender. The **fourth** and final step, the unemployment percentage of the block is calculated and that gives the data for the size of the hubs [dia 03.6]

The number of hubs in a block depend on the number of unemployed people it needs to cater to. and depending on the preference and gender proportions, the area programming varies and that leads to unique context specific solutions.

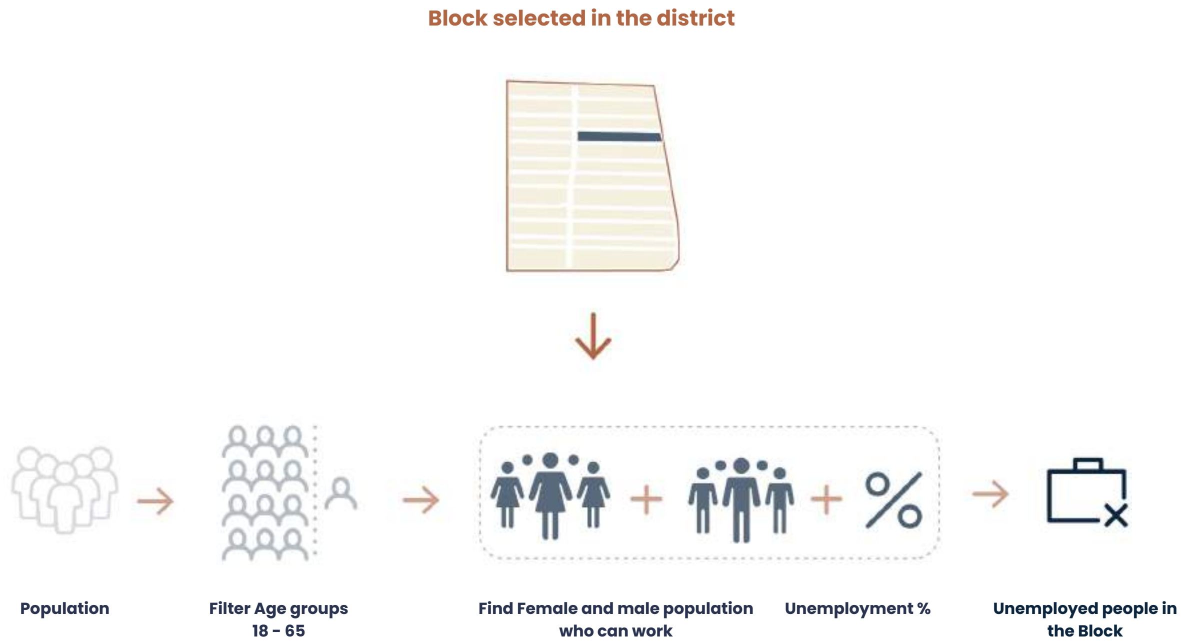


Diagram 03.6 : Block Scale Analysis

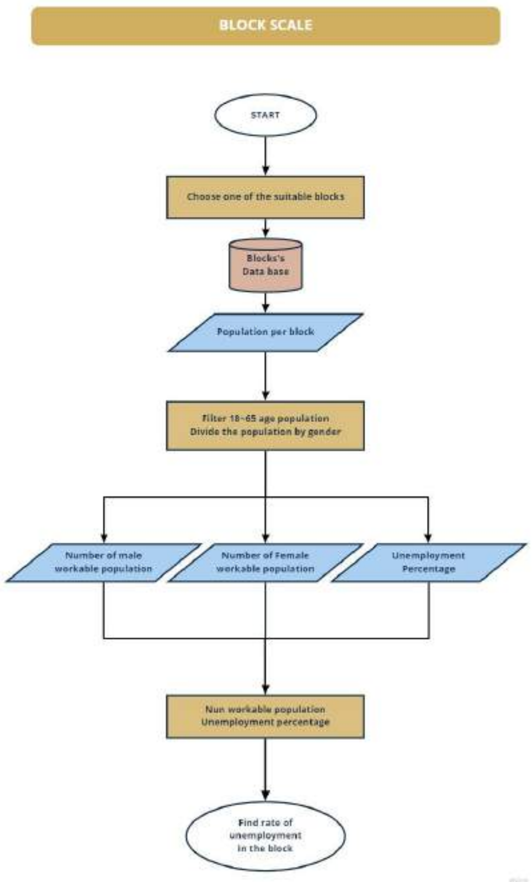
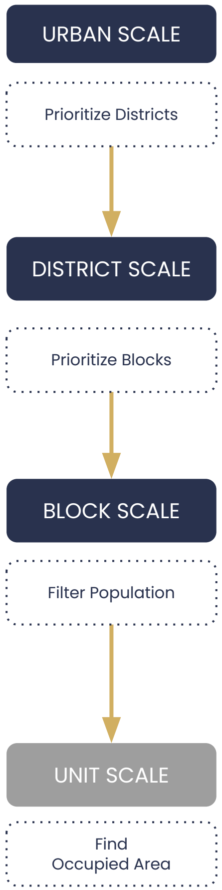


Diagram 03.7 : Block Scale Analysis Flowchart

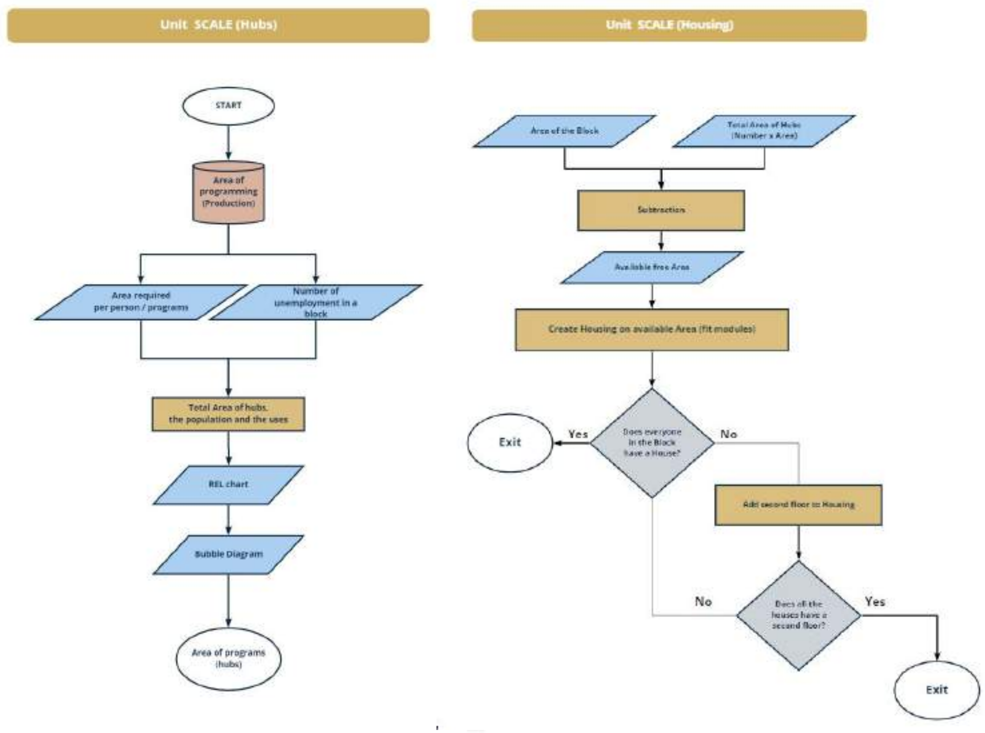


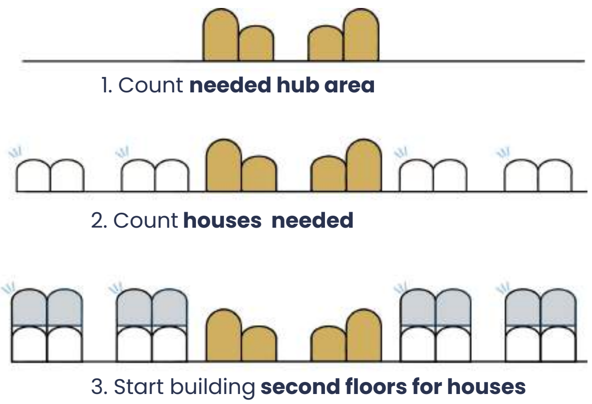
03.2 SPATIAL CONFIGURATION | Unit Scale

The final step is he configuration of the hubs and houses. From the Block scale we have the no of people that need to be accommodate in the hubs and also the number of people who need houses in a block.

The **first** step in the unit scale configuration is setting up the number of hubs required, the largest size of the hub in the design can accommodate 216 employees. if the calculated number of unemployed people is larger than 20% we add more hubs in the block. After placing the blocks, the **second** step is to add the houses in the remaining area. If the houses with ground floor cannot accommodate the population then in the **third** step second floors are added to the houses [dia 03.9].

There are two types of housing, private and communal in the project. The configuration of each hub, and housing is further gamified and explained in the following chapters.





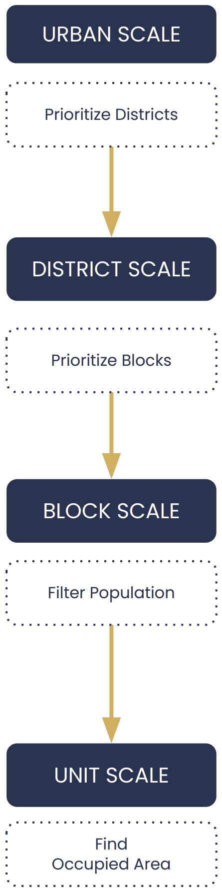


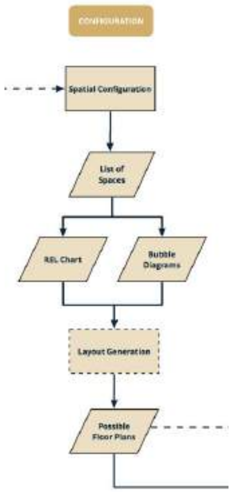
Diagram 03.8 : Unit Scale Flowchart (hubs and houses)

Diagram 03.9 : Unit Scale Diagrammatic representation

03.2 SPATIAL CONFIGURATION | Unit Scale

Logic and reasoning are the most important things in composing a space. Since it is a space for real people to use and live, Permacultura has taken a lot of effort in actuating the logic and reasoning of the programs. Various attempts and methods have been explored and the methods and examples will be introduced in this report. The general logic will be explained on this page and the details can be found on the following pages.

Permacultura's space configuration has three different spaces: **Maker's Hub, Communal housing, and private housing.** Here are the common rules and basic configurations. All of the spaces will follow the same flowchart and its methodology. it will be generated from the list of programs to REL and Bubble diagrams to layout generation of the floor plans.



0. Makers Hubs

Small decentralised hubs surrounded by housing, where people who live in the neighborhood are able to find creative employment and training related with brick production, pottery, sculpting and textile making.

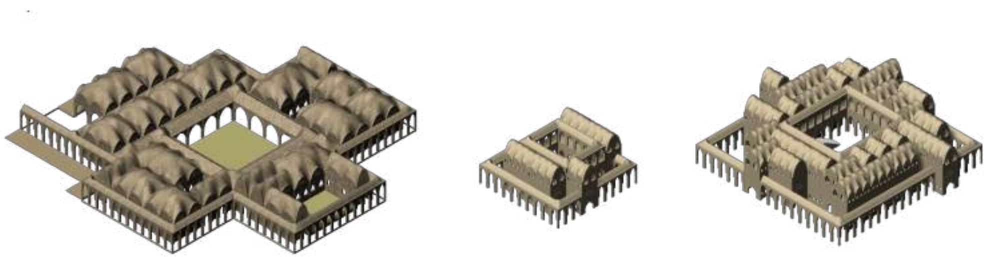
1. Private Housing

Houses that can host one big family at a time, consisting of 6 to 8 people.

2. Communal Housing

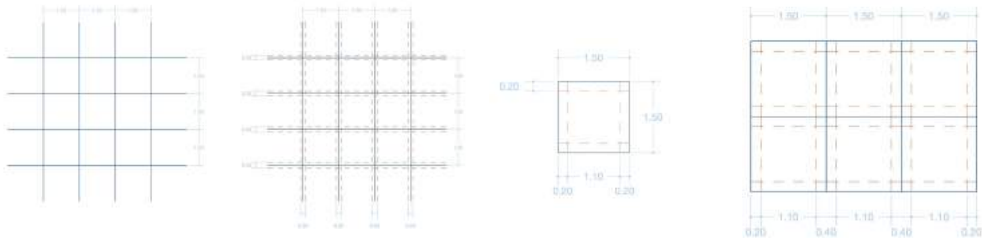
Houses that are capable to host at the same time multiple families of 2-5 people each, by sharing all the communal facilities.

Diagram 03.10 : Flowchart of configuration



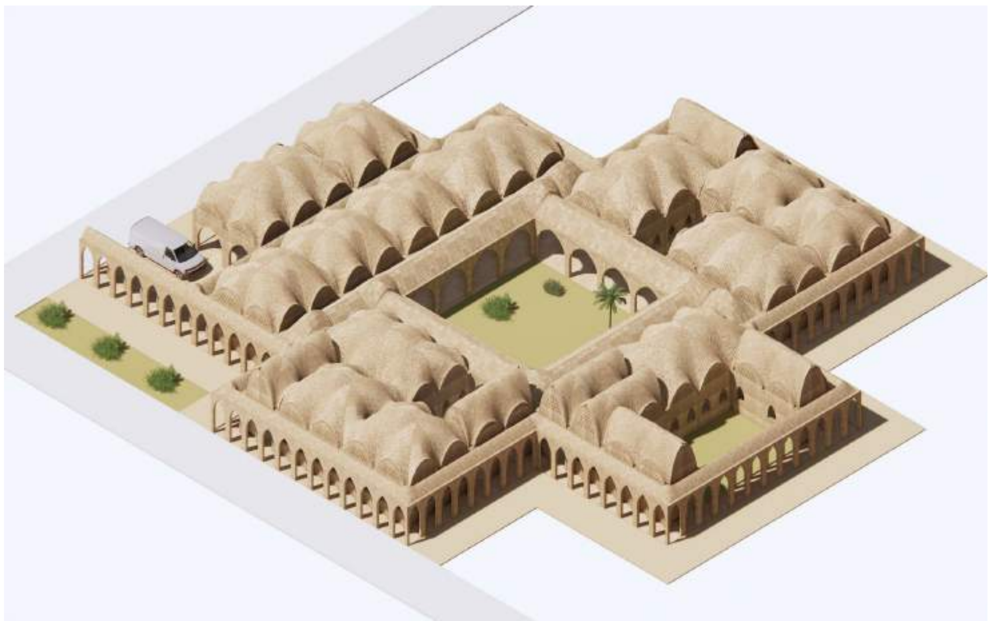
Picture 03.1 : configurations of all 3 spaces

Grid & Module sizes



All 3 space configurations will share the grid and module sizes.

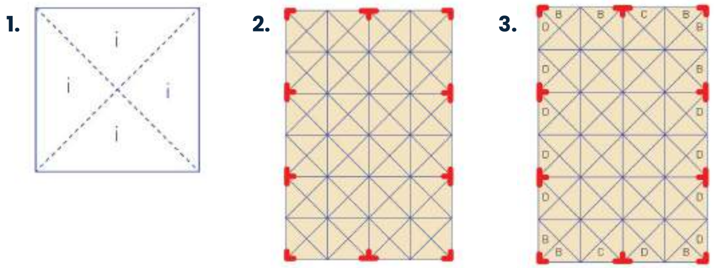
The tartan grid was designed as a modular coordination system to help in the creation and placement of the game modules and units. The original chosen grid size of 1.5m * 1.5 m is derived from the size of the basic living spaces. It was further evolved into a double tartan grid taking into consideration its translation into individual structural modules will certain wall thickness. **The module** refers to the smallest piece of the game, a rectangle of 1.5 m * 1.5 m with a 0.2 m offset internally.



Picture 03.2 : Visualization of Hub configuration

03.2 SPATIAL CONFIGURATION | Openings and Connections

OPENINGS TILE



OPENING TYPE

A open connection
B closed wall
C door
D window

Diagram 03.11 : Openings on grid

The Configuration Grid is divided into the smallest tile. This tile is then further subdivided into four parts which define the opening types. There are 4 types of openings. The catalog-code was developed according to the evaluation ran on the connections among the spaces of the enclosed, semi-closed and open areas of the typical houses' and various hubs' program. The connection Tiles are only present along the edges of the units, to inform about the edge and corner connections [dia 03.11]. and requirements which were previously analyzed. It is actually a combination of elements of that are connected with an arched opening. These are particularly useful for the user to choose according to their needs.

UNIT CONNECTIONS

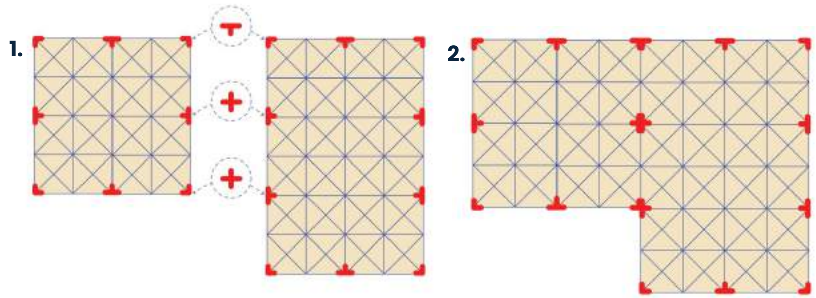
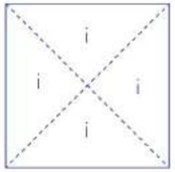


Diagram 03.12 : Opening syntax for Houses

The modules depending on the area requirements (explained in the later chapters) form the units for a specific program. The "+" is identified in a unit for columns and also used as a syntax for connection. The units always connect at the "+" with each other as shown in 1. and 2. of diagram 03.12 The units can be rotated and moved up and down as long as they connect at the "+".

03.2 SPATIAL CONFIGURATION | Roof Type Connection for Circulation Spaces

CONNECTION **CONNECTION TYPE**

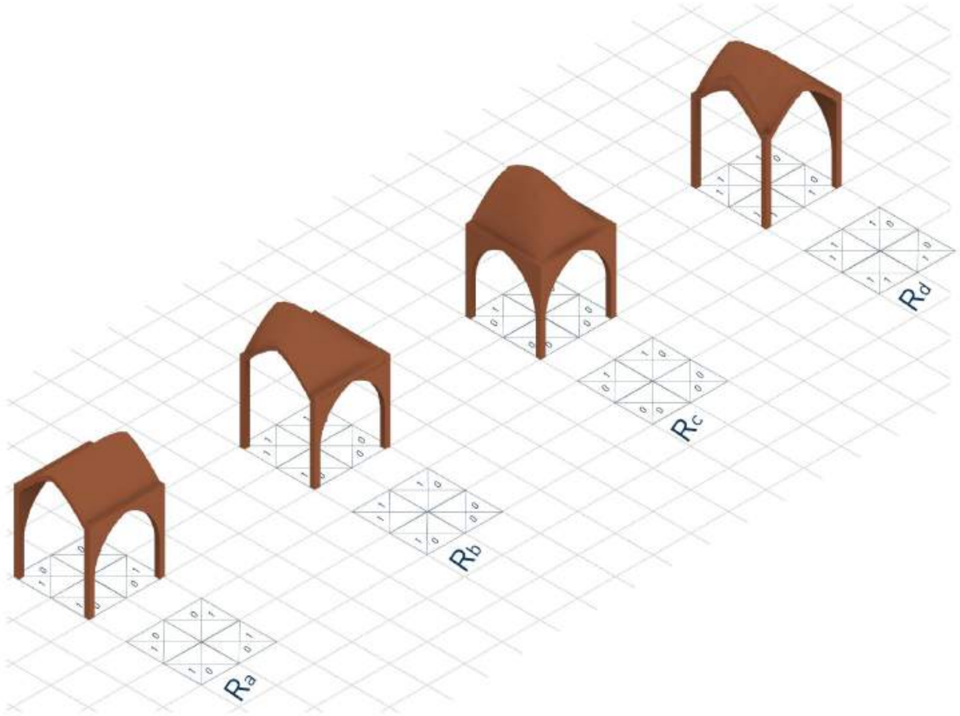


1 Connects to a similar circulation space (Riwaq or Corridor)

0 Does not Connect to a similar Circulation Space but can connect to other functional spaces.

The Circulation spaces namely Riwaq and Corridors have multiple connection options, and for that reason at junctions, the type of roof varies. There are 4 types of roofs for Riwaqs and 5 types for Corridors. The tile for Circulation spaces are further divided into 4 parts which are assigned the two connection types "1"or "o". Depending on the resulting configuration of a 1x1 module or 2x2 module of a circulation space, the roof type corresponding to that arrangement is added.

ROOF OF RIWAQ 3M X 3M (2X2 MODULES)



ROOF OF CORRIDORS 1.5M X 1.5M (1X1 MODULES)

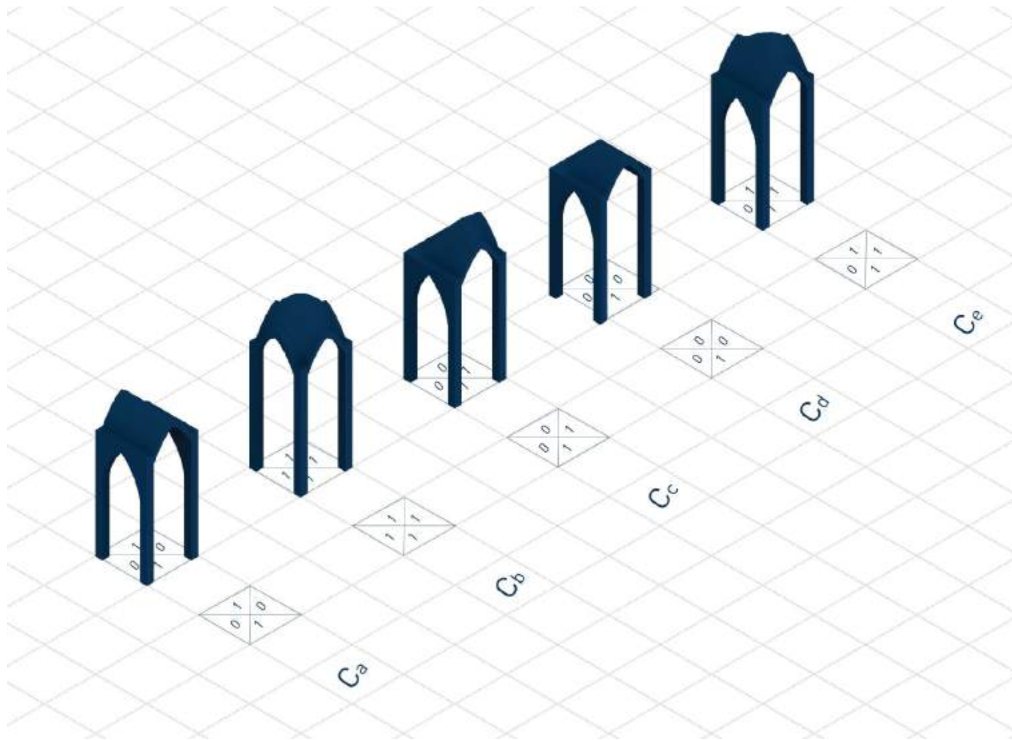


Diagram 03.13 : Roof modules with connection syntax for Riwaq

Diagram 03.14 : Roof modules with connection syntax for Corridors

03.3 CONFIGURATION HUB | Maker's Hubs

Maker's hub is the most central building of Permacultura, and it is an important building that has a brick production function and enables the growth of Permacultura based on bricks. Maker's hub consists of Brick, Textile, Pottery workshops, commercial and communal spaces.

The program can be divided into 3 categories depending on the type of function of each area. the first category is the commercial area which includes the truck area, exhibition area, and storage area. The workshop category is divided into 3 subjects of brick, textile, and pottery. within brick, the subject includes a brick press factory and storage. Within the textile subject, includes tread workshop, dyeing workshop, Al Aghabani workshop, a weaving workshop, and storage area. For pottery, the subject includes a wheel workshop, sculpture workshop, kiln workshop, glazing workshops, and storage area. Lastly in the communal spaces including Offices, toilets, training area, canteen and courtyard area. in the diagram below shows the relation of each area with the level of privacy.

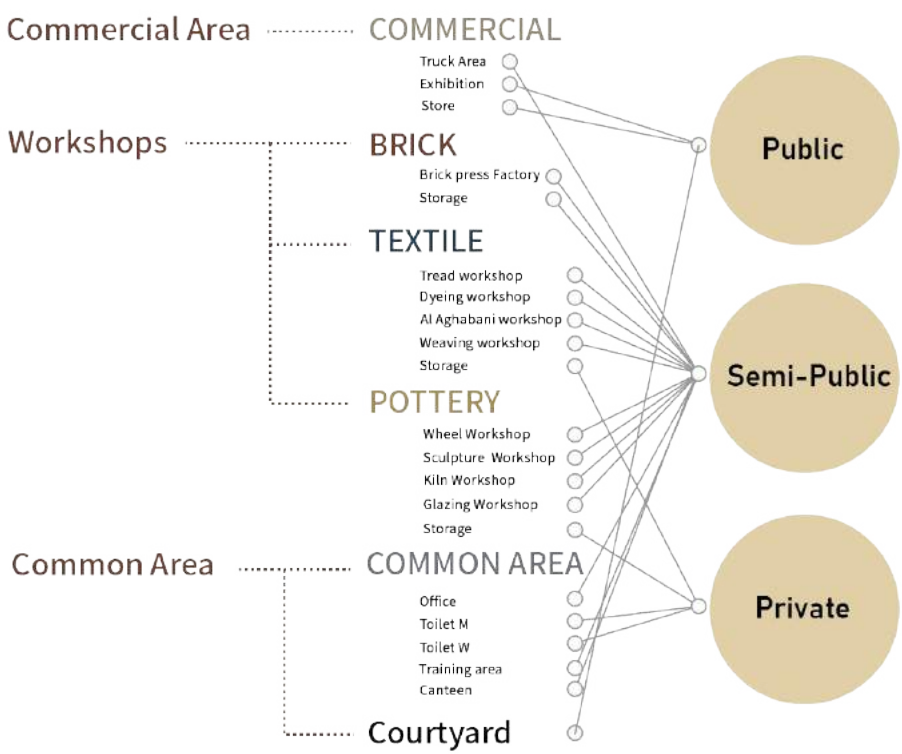


Diagram 03.15 : Classification of programs by categories and level of privacy connection

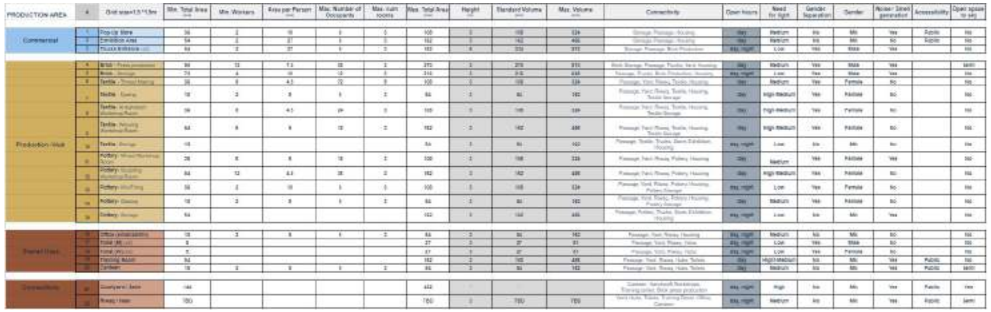
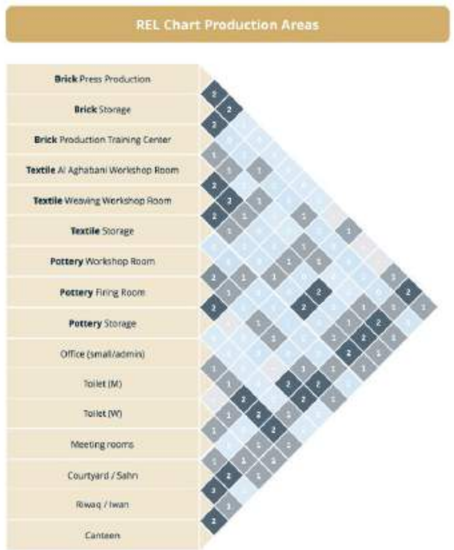


Table 03.1: Area of programming table

Based on the division of programs, to get a better understanding of our program of the area a table of programing was made. researches on the minimum and sufficient area for each program were done and the table directly translates into the area of distribution using python script in the next slides.

The area of programming table includes a data set of minimum total area, minimum employee, area per person, the maximum number of occupants, the maximum number of rooms, the maximum total area, ceiling height, standard volume, max volume, connectivity, open hours, need of light, gender separation, Gender uses, Noise/smell generation, accessibility and open space to sky.



With the information, the next step could be made to create the bubble diagram and REL chart on the left. the diagram helped us understand the general configuration idea and its connections.

Table 03.2 : REL chart of the Hub

03.3 CONFIGURATION HUB| Maker's Hubs

The bubble diagram on right shows the connections and proportion of programs based on the REL chart and area of the programming table. this shows how the general flow of programs and is also visualized in the right proportion of areas. The diagram on the right shows a depth diagram of the courtyard and truck area as the starting point, respectively.

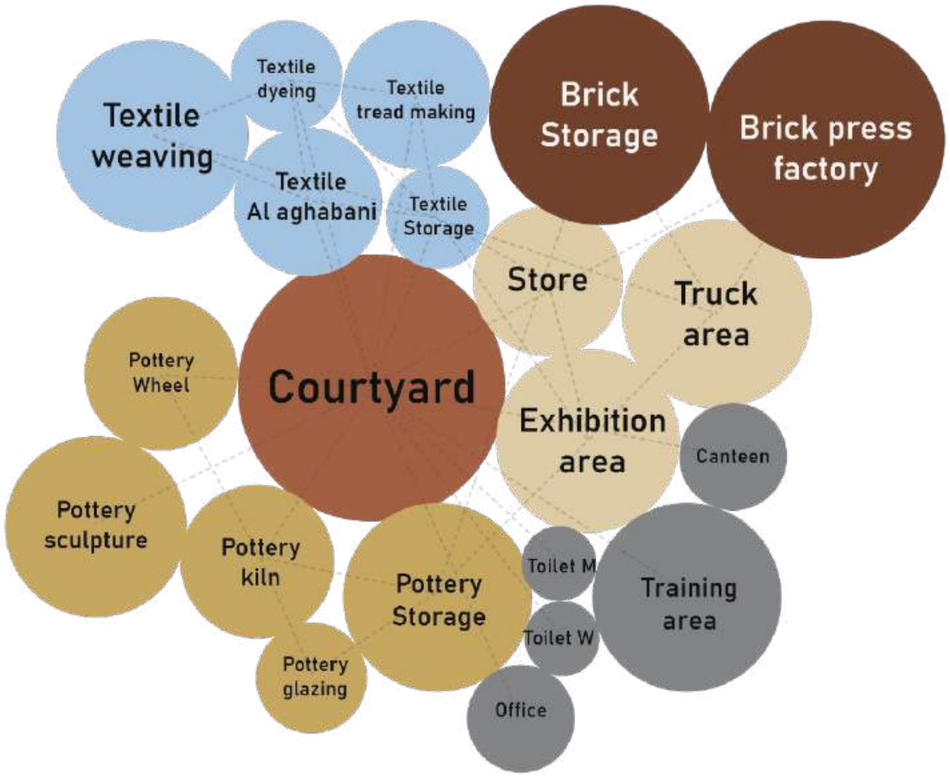


Diagram 03.16: Bubble diagram of the Hub Source : Authors

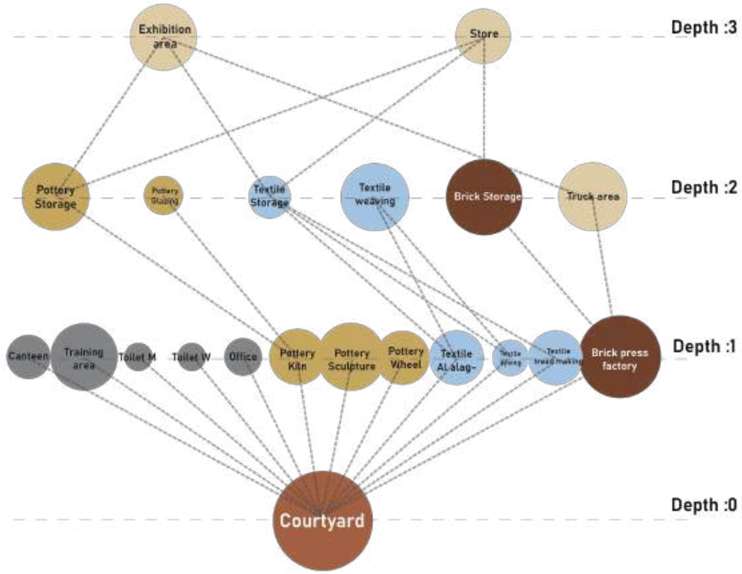


Diagram 03.17: Depth diagram of the Hub, Courtyard Source : Authors

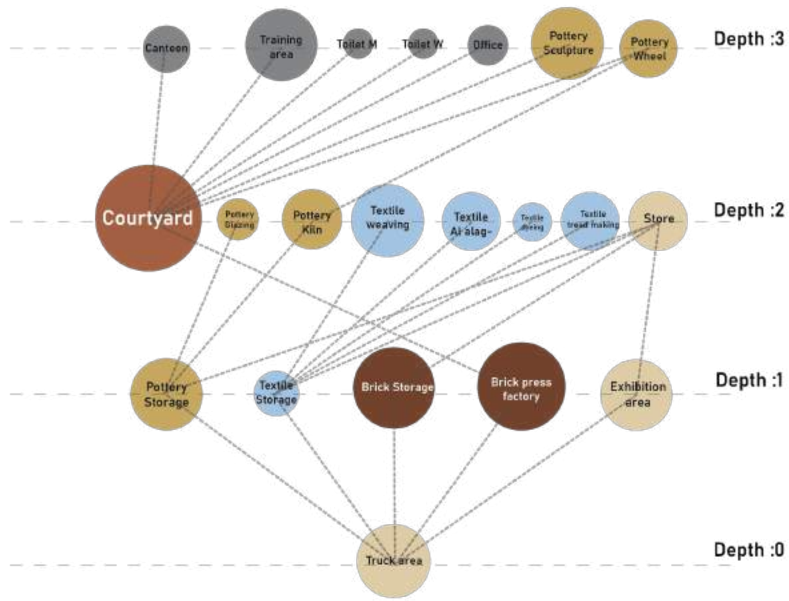


Diagram 03.18: Depth diagram of the Hub, Truck-area Source : Authors

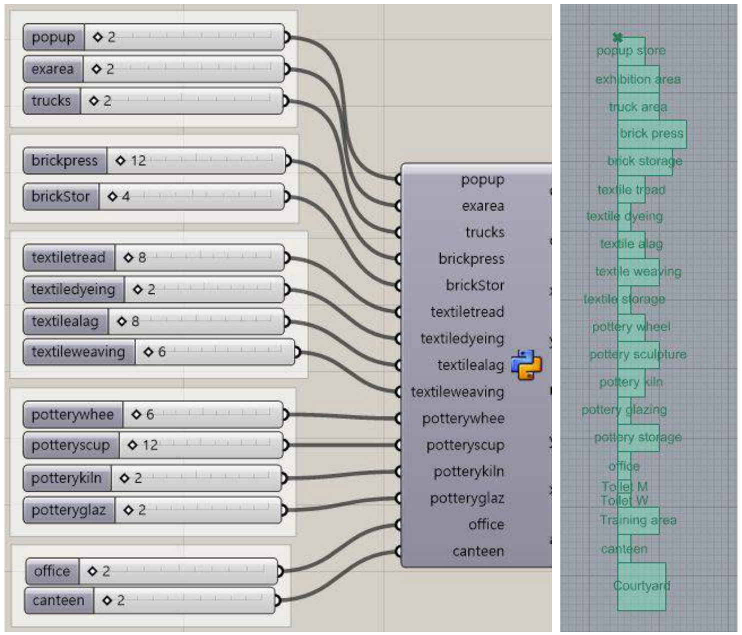
03.3 CONFIGURATION HUB |Area distribution

Hub's configuration depends on the number of employees assigned in each program. for that a python script is written to assign areas and generate plans from the numbers assigned.

First, different programs were listed in a large category, and as shown in figure 1, different numbers of employees were allowed to change numbers in the range specified by the slider bar. Also in the script same function is proceeded using a definition named **clip** to return only a number within a defined range.

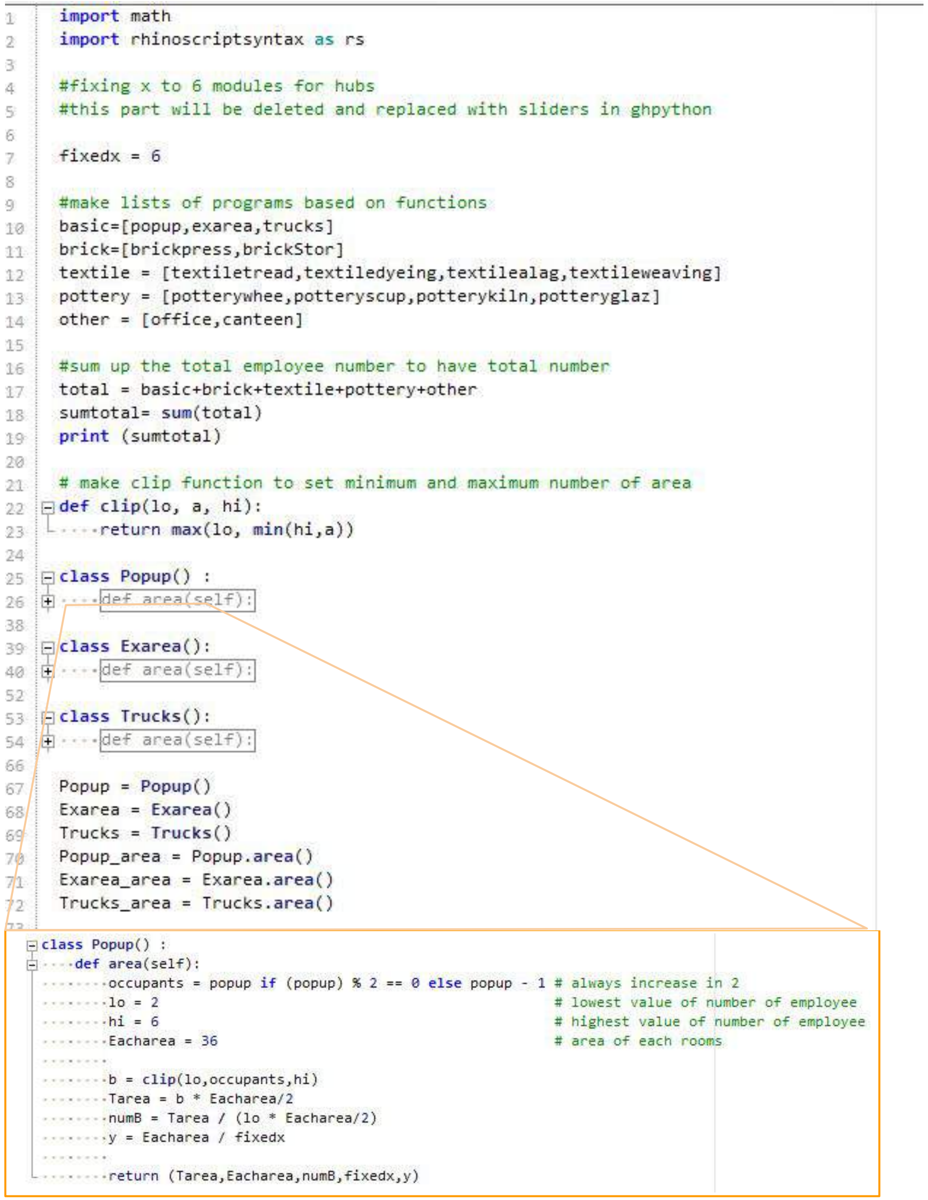
in each class of the programs, functions are given to generate the width and length of the program where the fixed x is hard-coded as 6 meters. If the employee number exceeds the number of people the room can accommodate, you can add a new room and designate the number of rooms.

Each program classes return, (Total area of the program, Each area of the room, number of the rooms, fixed axis width of 6 meters, and another axis that depends on the area) This is then translated into surfaces in grasshopper and arrayed with labels of the programs using the tag component.



Picture 03.3 : ghpython script with number sliders and how it visualizes after Source : Authors

Picture 03.4 : Part of the Python script showing the basic structure of the code



```
import math
import rhinoscriptsyntax as rs

#fixing x to 6 modules for hubs
#this part will be deleted and replaced with sliders in ghpython

fixedx = 6

#make lists of programs based on functions
basic=[popup,exarea,trucks]
brick=[brickpress,brickStor]
textile = [textiletread,textiledyeing,textilealag,textileweaving]
pottery = [potterywhee,potteryscup,potterykiln,potteryglaz]
other = [office,canteen]

#sum up the total employee number to have total number
total = basic+brick+textile+pottery+other
sumtotal= sum(total)
print (sumtotal)

# make clip function to set minimum and maximum number of area
def clip(lo, a, hi):
    return max(lo, min(hi,a))

class Popup() :
    def area(self):

class Exarea():
    def area(self):

class Trucks():
    def area(self):

Popup = Popup()
Exarea = Exarea()
Trucks = Trucks()
Popup_area = Popup.area()
Exarea_area = Exarea.area()
Trucks_area = Trucks.area()
```

```
class Popup() :
    def area(self):
        occupants = popup if (popup) % 2 == 0 else popup - 1 # always increase in 2
        lo = 2                                              # lowest value of number of employee
        hi = 6                                              # highest value of number of employee
        Eacharea = 36                                       # area of each rooms

        b = clip(lo,occupants,hi)
        Tarea = b * Eacharea/2
        numB = Tarea / (lo * Eacharea/2)
        y = Eacharea / fixedx

        return (Tarea,Eacharea,numB,fixedx,y)
```

Picture 03.5: Part of the script showing inside the class functions each class will have unique traits depending on sizes

03.3 CONFIGURATION HUB | Maker’s Hub - Tile set

A more detailed explanation of the 2d tileset from the previous Python scripting.

Users can increase the slider numbers to control the number of employees. If the capacity of each room is exceeded, the number of rooms increases on each program. Also, the storage of each category will increase according to the number of employees in each category, and the size of the courtyard will increase according to the size of the total number of employees.

when giving an area to the programs, the size of the room will have one side of 6 meters, and the size of the room will increase only on the other side by 3 meters. Each program is assigned with a minimum and a maximum number of employees even if the slider goes off the limit in both directions the result will still be within the range.

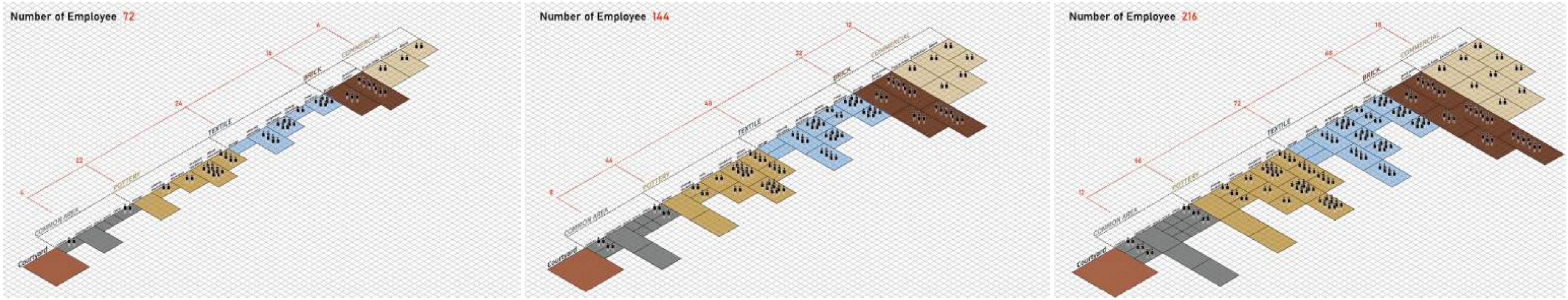


Diagram 03.6: Images of area growth of the Hub, 72 employee, 144 employee, 216 employee

After the 2d configuration of the tileset, 3d configuration can be added to make a 3d tileset as shown below. the structural set will further be explained in the structural part of the report. the premade structurally sufficient tiles with different sizes within the module size will be placed accordingly to the 2d tileset to have 3d configuration tile ready.

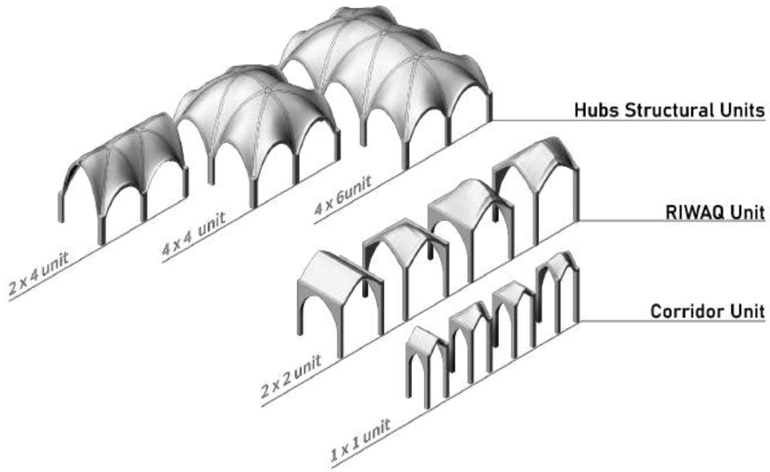
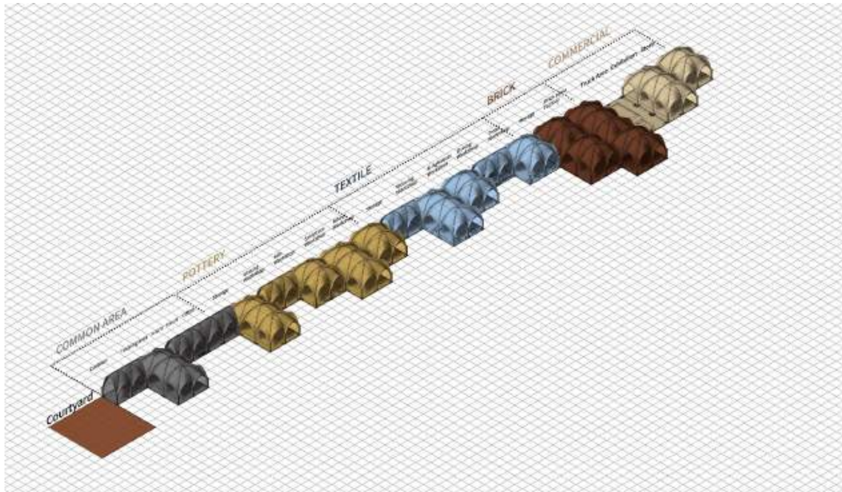


Diagram 03.7 : Diagram of Structural modules of Maker’s Hub



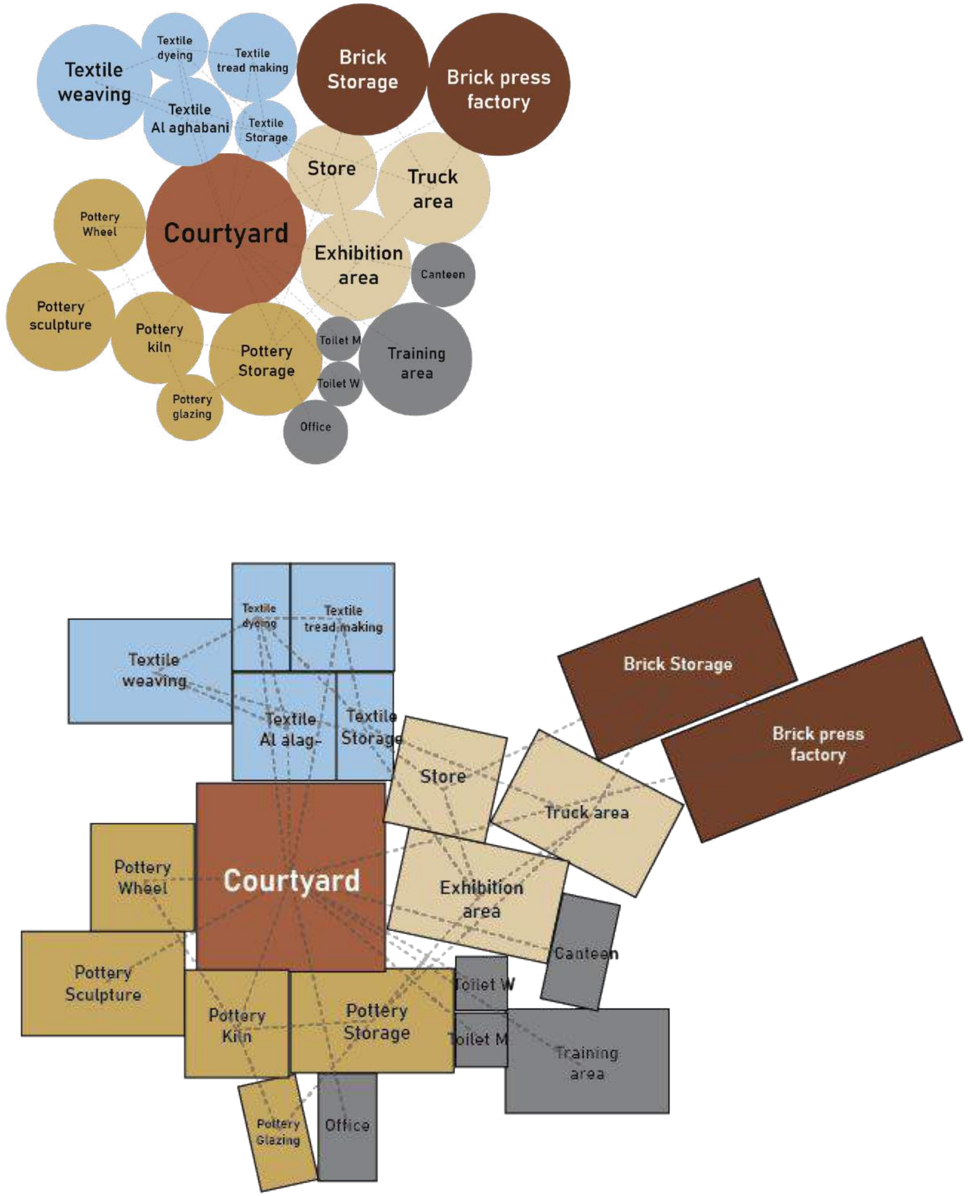
Picture 03.8 : Finalized Tileset of the Maker’s hub with employee number of 72

03.3 CONFIGURATION HUB | Space syntax & Kangaroo approach

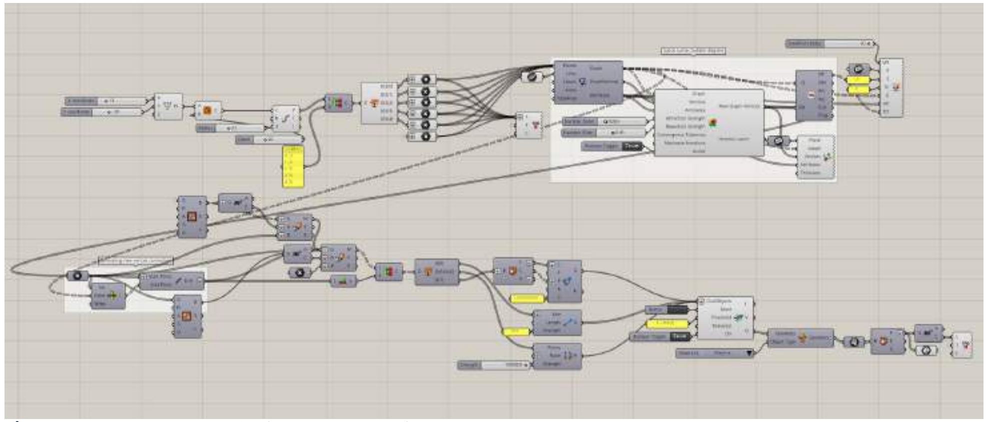
After area distribution is done through a python script and having a 2d tileset, our group further researched methods on how to configure spaces. In this report, two methods will be looked in to and one method is to use force pulling in the Kangaroo plugin. However, this method is not further proceeded until the end of the project.

Having made the 2d tileset, it is useful that it can be directly connected with the bubble diagram made previously. it is easily depicted that the picture on the right bottom has the same order as the picture on the right top in the script this is done by taking new nodes from space syntax and connecting them again with new lines and transferring it into Kangaroo force pull curves. this is a very direct approach and shows different results whenever the user changes the forces of space syntax or Kangaroo.

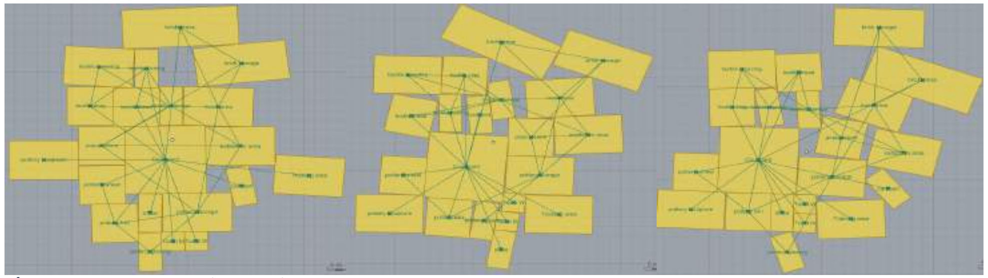
However, this method showed rather minor interactivity and less control over the configuration so the group decided to move on to the other method which is to gamify the configuration.



Picture 03.1: Diagrams showing the relationship between bubble diagram and Kangaroo configured layout.



Picture 03.9: Grasshopper script for Kangaroo configuration



Picture 03.10 : Iterations of the configurations Source : Authors

03.3 CONFIGURATION HUB | Manual Gamification 2d

The setup

1. The size of the units of each function is set according to the number of people
2. The units are coloured according to the zones of activity. As represented in the bubble diagram of depth.
3. The category of space divisions are:
   - Activity areas (Different colours for zones)
   - Circulation spaces (Corridors and Riwaq)
   - Courtyard

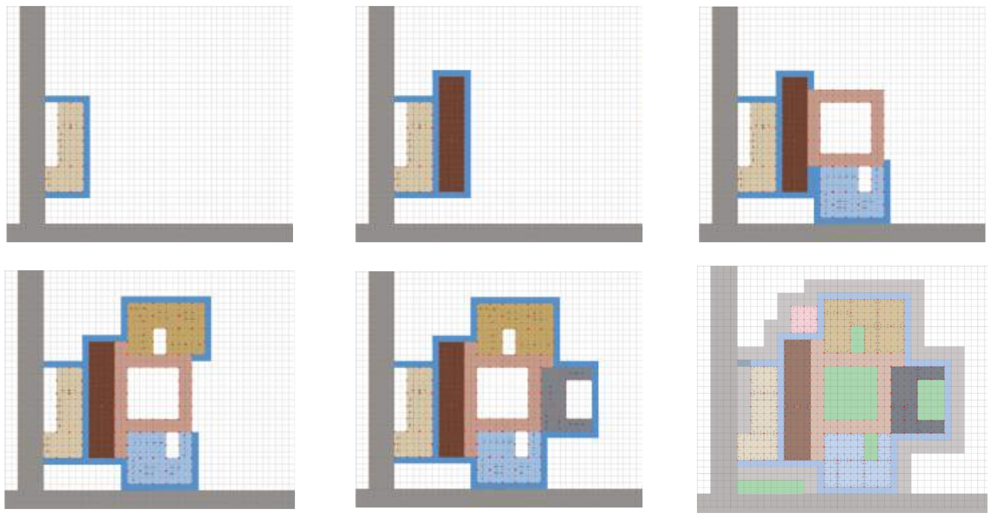
Defining the units and their identification:

1. The edge modules of a unit have information about connection and openings.
2. represented as **letters** identifying openings or partition walls.
3. Represented as '+' for connections. the "+" is identified every 2x2 module in a unit for columns.
4. For corridors the '+' is placed in every module and can connect with units when they are attached to them. The corridor completes the '+' for the units and where it's not connected there are no columns.

Picture 03.12: Final 2d configuration of the Board game

The Game Rule set

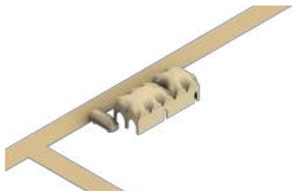
1. The sequence of placement of units depends on their location on the depth bubble diagram.
2. Once a unit is placed, all other units of the **same colour** should be placed in sequence.
3. The units should connect to complete '+'s .
4. Same color units **do not have corridors in between.**
5. All corridors should connect to the courtyard.
6. Similar colours if connected to the Courtyard, should stay on the side they connected with and within the courtyard extends. [create a second layer]
7. Set a rectangular zone boundary box once a zone is complete [including all the units.]
8. Wherever there is a gap inside the zone bounding box, create a courtyard.
9. Place corridors around the zone bounding box. And move on to the next colour according to the dept diagram.
10. After the layout is complete, add roads around external units.



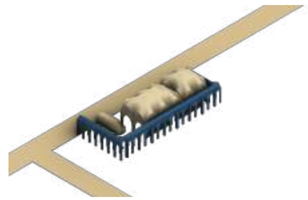
Picture 03.13: Diagrams showing sequence of the 2d configuration

03.3 CONFIGURATION HUB | Manual Gamification 3d

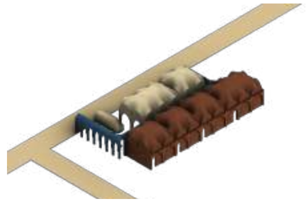
In this page step by step gamification of configuration will be explained. based on the ruleset from previous page, 3d configuration of the Maker's Hubs is generated in the following orders.



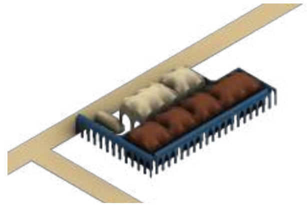
1.Place roads and Truck areas adjacently. Sequentially from the depth diagram place the other commercial spaces.



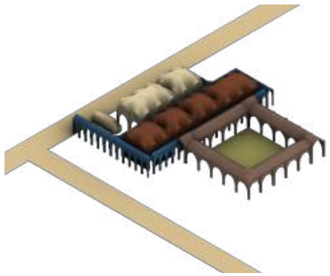
2. Place corridors around the bounding box of commercial areas



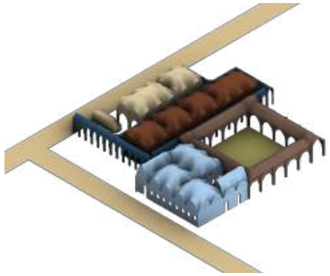
3. Place Brick storage nearest to the truck area and other brick workshop are adjacent to brick storage.



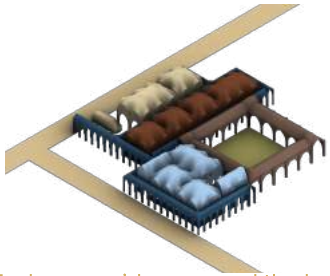
4. place corridors around the bounding box of brick areas.



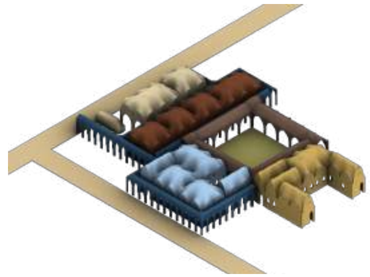
5. Based on depth diagram and connection rule of +, place riwaq and courtyard adjacent to brick areas.



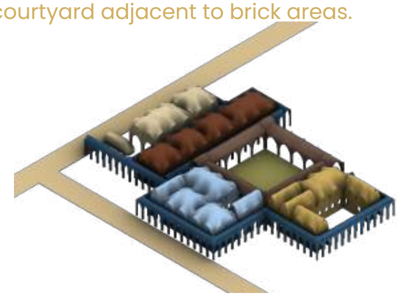
6. Placement of textile areas. Based on the rule set, second layer of places needs to take place.



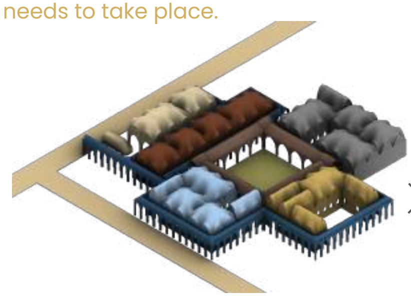
7. place corridors around the bounding box of Textile areas.



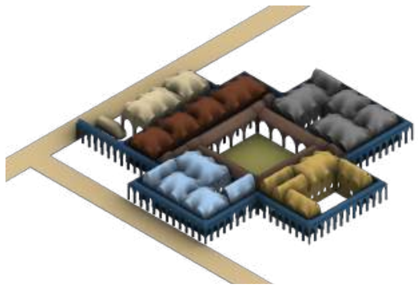
8. Place pottery areas based on the depth diagram, Storage needs to be firstly placed to be nearest to the truck area



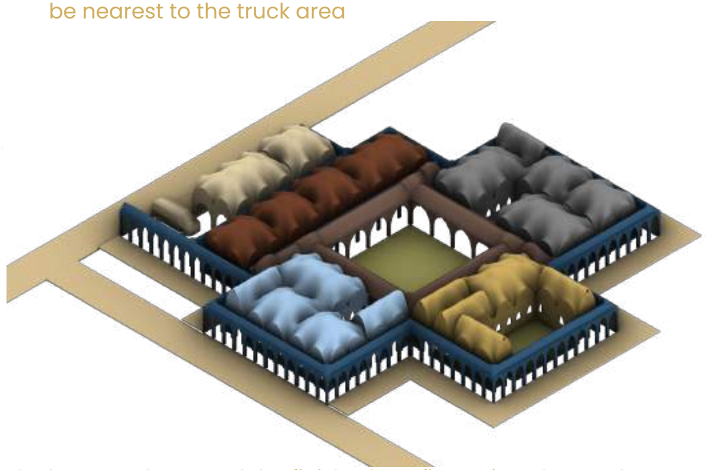
9. Place corridors around the bounding box of Pottery area



10. Placement of communal areas Communal area. Depending on the depth level of the area placement order is decided.



11. corridors are placed around communal spaces. **If two corridors are overlapping the corridors change to Riwaq**



12. Place roads around the finished configuration. the road connects with houses and empty area in between becomes green spaces

Picture 03.14: sequence of the 3d configuration

03.4 CONFIGURATION| Private Houses

The houses are divided into two subcategories, the private and the communal houses. The private houses host one family of 6-8 people, while the communal ones group together smaller families consisting of 2 until 5 persons each.

The manual configuration process has as a starting point the procedure of setting the areas needed for each function. The private housing uses are subdivided into common uses, private uses and connecting areas. Furthermore, the units of each function are categorised as fixed or incremental. The fixed units consist of a specific amount of modules which does not change according to the number of people. If more people need to be accommodated the unit will simply get multiplied. On the other hand, the incremental units are flexible as far as the number of their modules are concerned and more modules can be added in one unit.

PRIVATE HOUSING	Grid size: 1,5 *1,5m	Fixed (F) or Incremental (I) Unit	Area per Person (m2)	Min. Users - Occupants	Min. Total Area (m2)	Min. Number of Modules	Max. Number of Occupants	Max. Total Area (m2)	Max. Number of Modules
Connections	Entrance	F	-	6	9	4	8	-	-
	Inner Courtyard	I	4.5	6	27	12	8	36	16
Common Uses	Kitchen	F	-	6	13.5	6	8	-	-
	Dining Room	F	-	6	13.5	6	8	-	-
	Living Room	I	2.25	6	13.5	6	8	18	8
	Storage	F	-	6	13.5	6	8	-	-
Private Uses	Bathroom	F	-	6	9	4	8	-	-
	Bedrooms	F	-	2	13.5	6	-	-	-

able 03.3 : Area Programming for Private Houses

The following diagrams show the formation of the 2d units that comprise each space of the private houses. All units obey the 1.5 *1.5 grid and they always have a fixed number of 2 modules on the y axis, expanding according to the area needed towards the x axis.

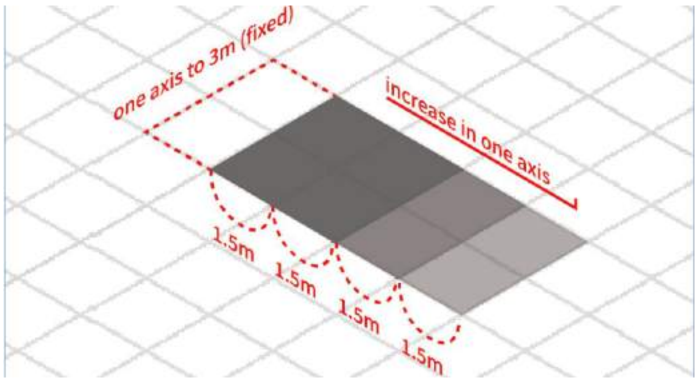


Diagram 03.18 : Rule of formation of each unit

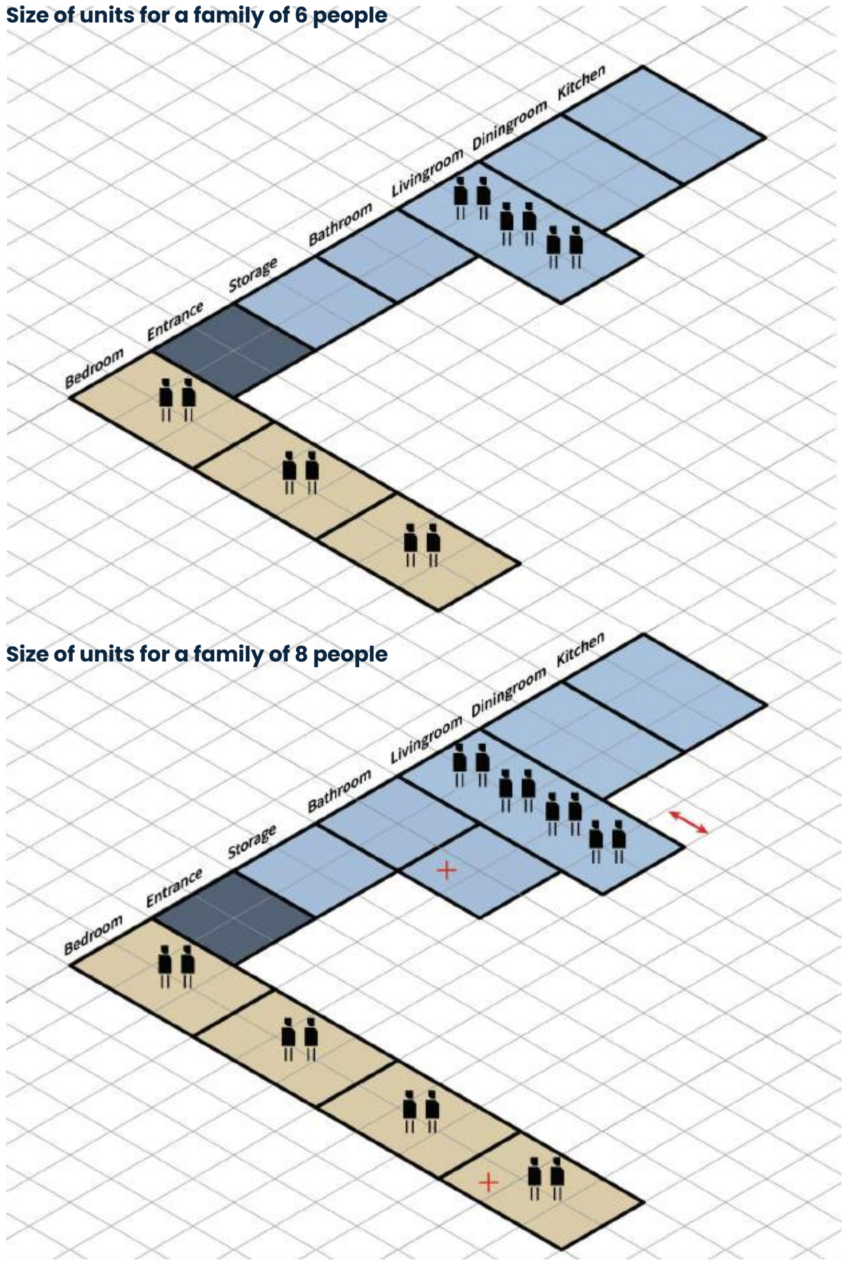
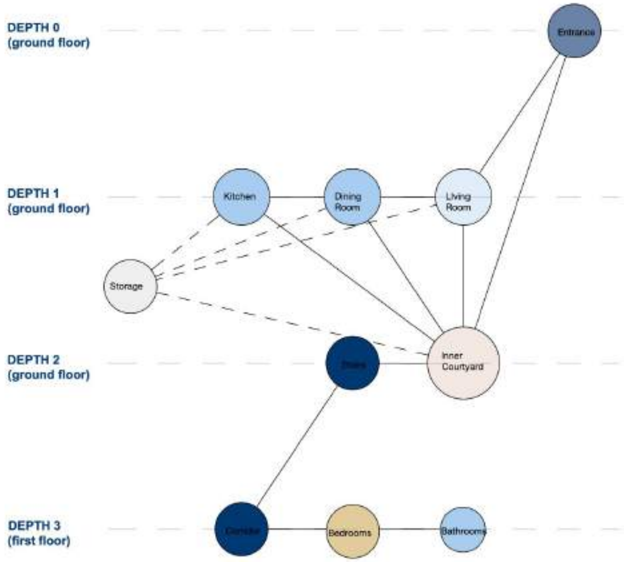


Diagram 03.19 : Rule of growth of units according to number of people

03.4 CONFIGURATION| Private Houses

The next step in the configuration process is to set the depth and bubble diagrams that define the space syntax. Based on the connections found necessary by these diagrams a set of rules is created that defines which spaces can be connected. There are three types of connections, a mandatory connection of a function with another one, an optional connection of two spaces and the connection of a space to at least one from a list of choices. In the diagrams 00 these rules for each function can be seen. At this point it is necessary to clarify that a connection between two different spaces means that at least one module of one function has an immediate connection with one module of the other function.



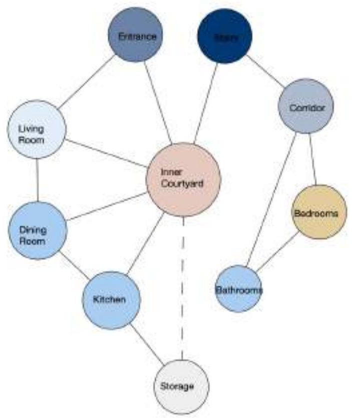


Diagram 03.20: Depth Diagram

Diagram 03.21: Bubble Diagram

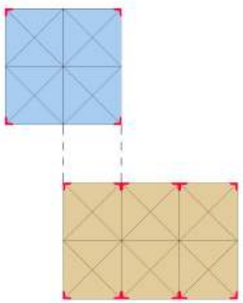
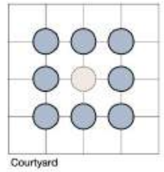
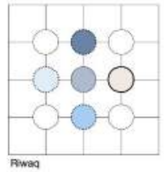


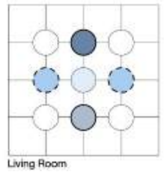
Diagram 03.22: Connection of two uses by at least one common module



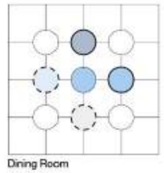
The Courtyard must be connected to a riwaq only.



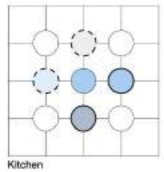
The Riwaq can be connected to Entrance, living room, kitchen and must be connected to courtyard



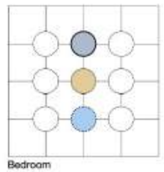
The Living Room must be connected to entrance and riwaq and must be connected to either kitchen or dining room



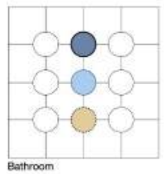
The Dining Room must be connected to Kitchen and riwaq and can optionally be connected to living room and storage



The Kitchen must be connected to dining room and riwaq and optionally be connected to either living room or storage



The Bedroom must be connected to corridor and can optionally be connected to bathroom



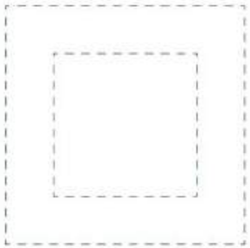
The Bathroom must be connected to corridor and can optionally be connected to bedroom

Rules of Connections

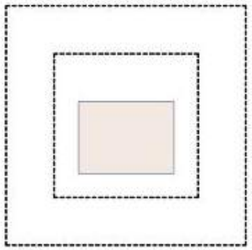
- mandatory
- optional
- at least one is mandatory

- Courtyard
- Riwaq
- Entrance
- Living Room
- Dining Room
- Kitchen
- Storage
- Bedrooms
- Bathroom

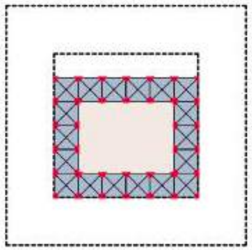
03.4 CONFIGURATION| Private Houses



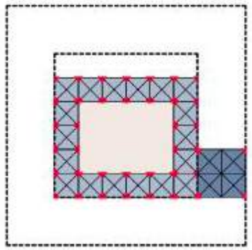
Bounding box



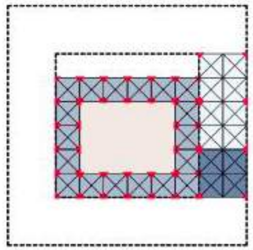
Placement of Courtyard



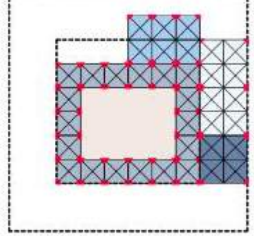
Placement of Riwaq around Courtyard



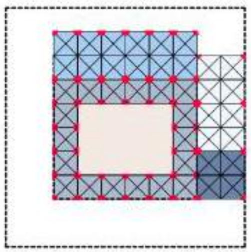
Placement of Entrance attached to Riwaq



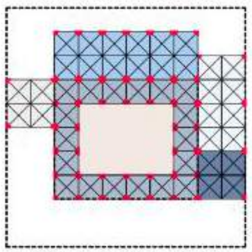
Placement of Living Room attached to Riwaq and next to Entrance



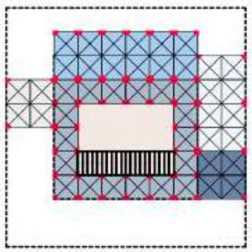
Placement of Dining Room attached to Riwaq and next to Entrance



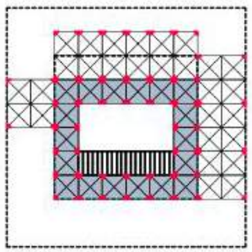
Placement of Kitchen attached to Riwaq and next to Dining Room



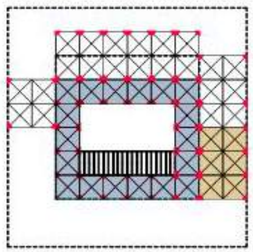
Placement of Storage attached to Riwaq



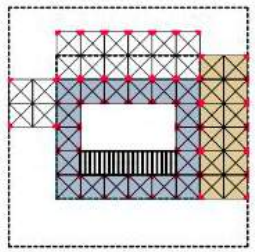
Placement of the Staircase inside the Courtyard



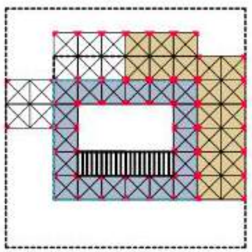
The red signs signal the structural columns that must be followed on the first floor



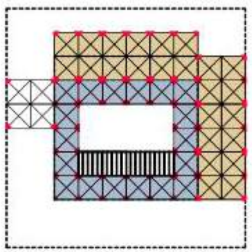
Placement of Bedroom 1



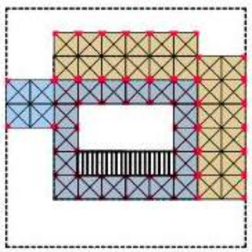
Placement of Bedroom 2



Placement of Bedroom 3



Placement of Bathroom 4



Placement of Bathroom

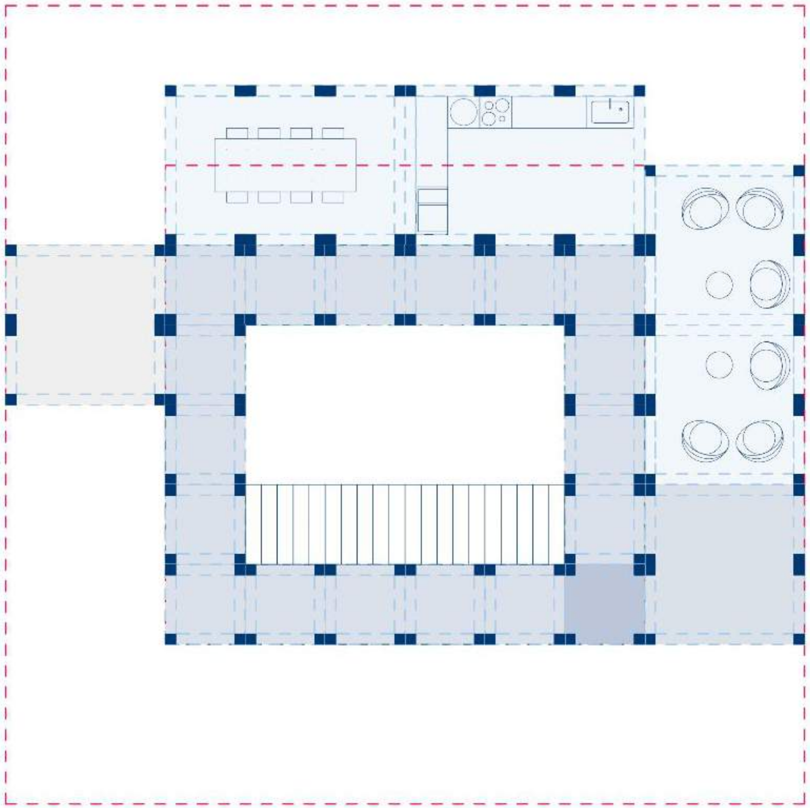
Picture 03.15 : An indicative Configuration of Private Houses

Once the rules regarding the necessary and optional connections of the different spaces have been set, a bounding box is set. This boundary is created consisting of 2 rectangles. The inner rectangle defines the area where most of the units should placed one next to the other. To allow for more possible configurations an outer rectangle is set creating a margin where the units that don't fit can be placed. This logic also helps to ensure a less strict connection and architectural outcome.

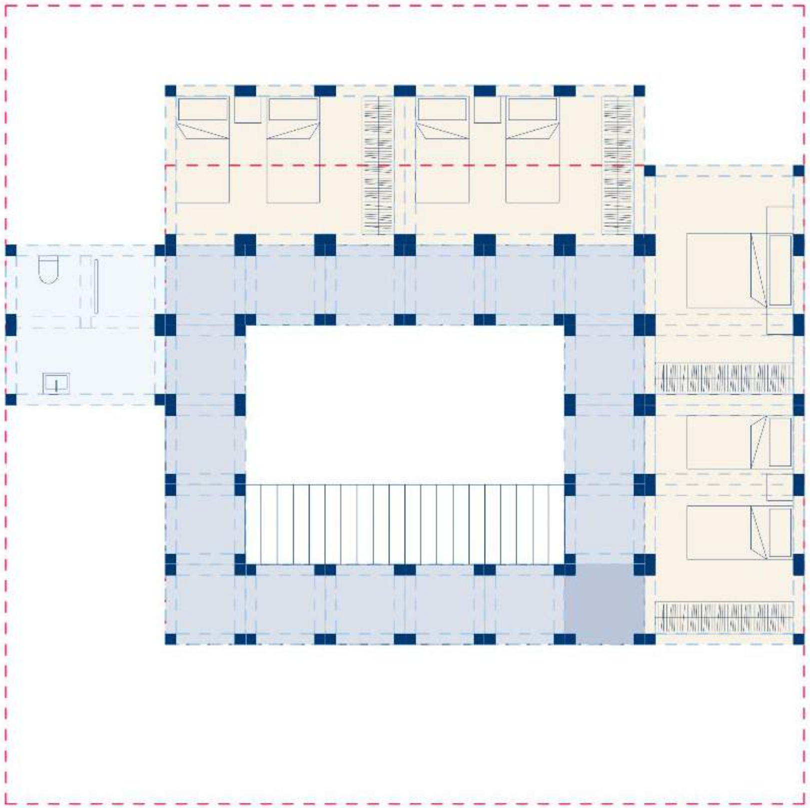
As a second step the courtyard is placed centrally, then the riwaq is placed around it and after that the functions that have been identified as suitable in the previous part are attached to the riwaq following the rules of connections.

When the ground floor configuration is complete a staircase is added inside the courtyard so the configuration can continue on the first floor. The placement of the functional units on the first floor must follow the structure of the ground floor. The red crosses signal the placement of structural columns. So when placing the units on the first floor an additional rule is that the units must be placed in a way that the red signs coincide.

03.4 CONFIGURATION| Private Houses

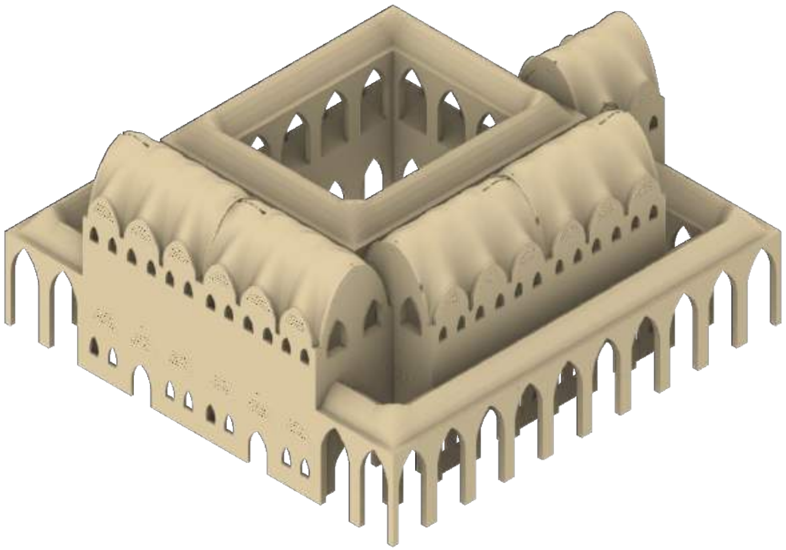


Picture 03.16 : Ground Floor Plans of one possible configuration of Private Houses

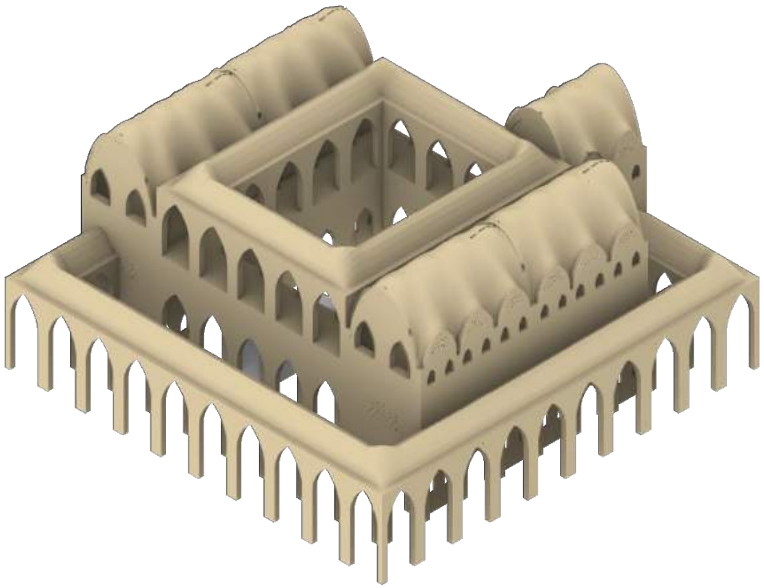


Picture 03.17: Ground Floor Plans of one possible configuration of Private Houses

03.4 CONFIGURATION| Private Houses



Picture 03.18: Ground Floor Plans of one possible configuration of Private Houses



Picture 03.19: Ground Floor Plans of one possible configuration of Private Houses

0.3.5 CONFIGURATION | Communal Houses

The communal houses as mentioned before are larger compounds where families of 2-5 people are grouped together sharing communal spaces as the kitchen, dining room, and bathroom. The logic behind the configuration of the Communal houses is similar to the one for the private houses.

The manual configuration process has as a starting point the procedure of setting the areas needed for each function. The subdivision into communal, private and connecting spaces expands here as well with a few differences from the private houses. In the connecting spaces a main entrance for the whole building is added, as well as Iwans are introduced which are semi-open spaces placed between private uses that belong to different families.

The categorisation of the units of each function as fixed or incremental is also applied here. The fixed units consist of a specific amount of modules which does not change according to the number of people. If more people need to be accommodated the unit will simply get multiplied. On the other hand, the incremental units are flexible as far as the number of their modules are concerned and more modules can be added in one unit. In the private sector, the bedrooms and living rooms are predefined according to the number of each family. In the communal uses the bathroom units are fixed and if more people need to be accommodated they are simply multiplied. The same logic applies to the iwans and individual entrances that are the same number as the number of families hosted. For the dining room and kitchen the rule of the incremental units applies, meaning that the space is expanded.

COMMUNAL HOUSING	Grid size=1,5 *1,5m	Fixed (F) or Incremental (I) Unit	Area per Person (m2)	Min. Users - Occupants	Min. Total Area (m2)	Min. Number of Modules	Max. Number of Occupants	Max. Total Area (m2)	Max. Number of Modules
Connections	Main Entrance	F	-	-	18	8	-	-	-
	Iwan	F	-	-	9	4	-	-	-
	Inner Courtyard	I	4.5	6	27	12	32	144	64
Common Uses	Communal Kitchen	I	1.6875	8	13.5	6	16	27	12
	Communal Dining Room	I	1.6875	8	13.5	6	16	27	12
	Communal Storage	F	-	-	13.5	-	-	-	-
Private Uses	Individual Entrances	F	-	-	9	4	-	-	-
	Private Living Room	I	4.5	2	9	4	5	22.5	10
	Private Bathroom	F	-	-	9	4	-	-	-
	Private Bedrooms	F	-	-	13.5	6	-	-	-

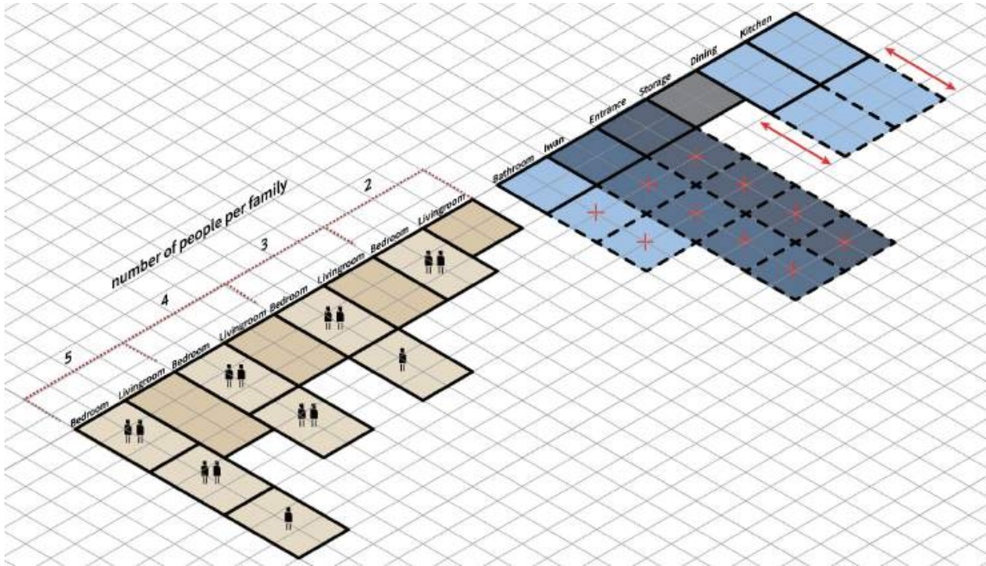


Table 03.4 : Area Programming for Communal Houses

Diagram 03.23 : Rule of growth of units according to number of people

0.3.5 CONFIGURATION | Communal Houses

The logic behind the configuration of the Communal houses is similar to the one for the private hoses. A set of rules regarding the allowable connections of different spaces is being created according to the bubble and depth diagram.

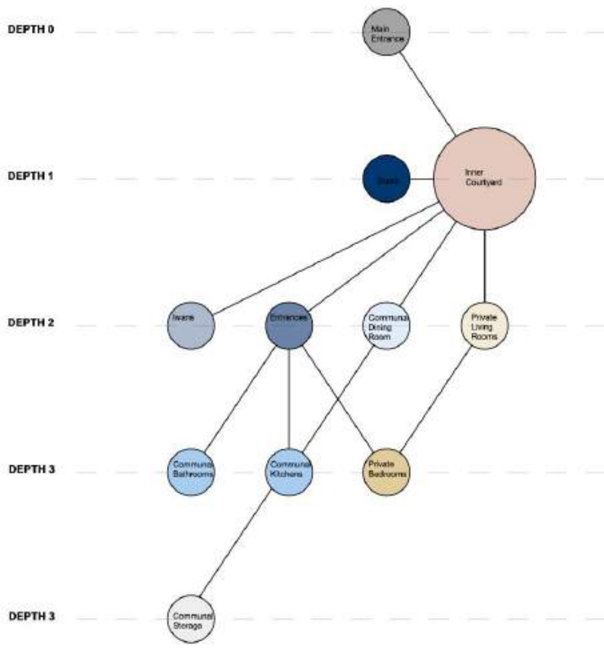


Diagram 03.24: Depth Diagram

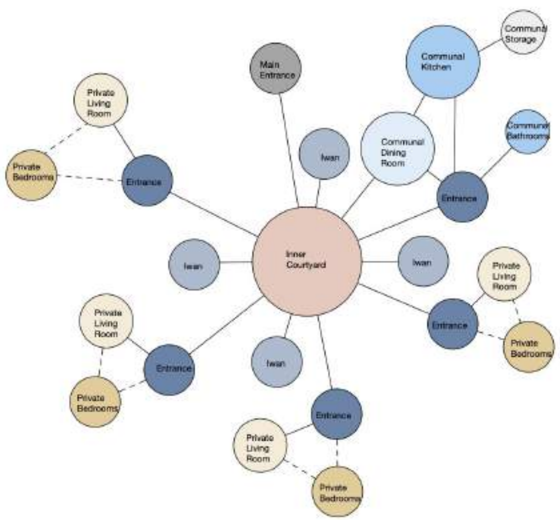
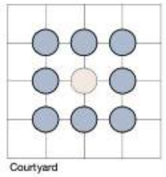
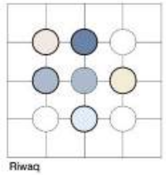


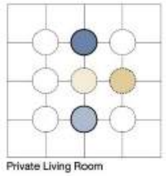
Diagram 03.25 : Bubble Diagram



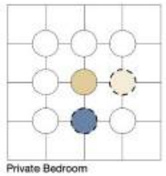
The Courtyard must be connected to a riwaq only



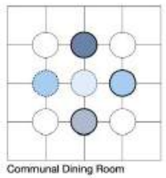
The Riwaq must be connected to Courtyard, Entrance, Iwan, Private Living Room, Communal Dining Room



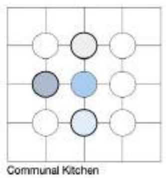
The Private Living Room must be connected to Entrance and Riwaq and can optionally be connected to Bedrooms



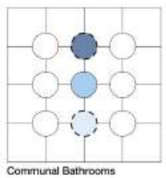
The Private Bedrooms must be connected to either Private Living Room or Entrance



The Communal Kitchen must be connected to Communal Dining Room and Riwaq and optionally be connected to either living room or storage



The Communal Kitchen must be connected to Communal Dining Room, Riwaq and Storage



The Communal Bathrooms must be connected to either Entrance or Communal Dining Room

Rules of Connections

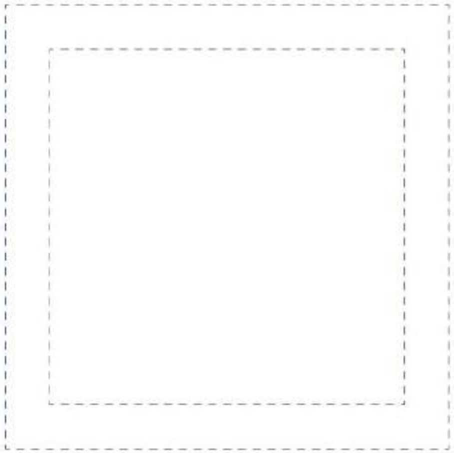
mandatory

optional

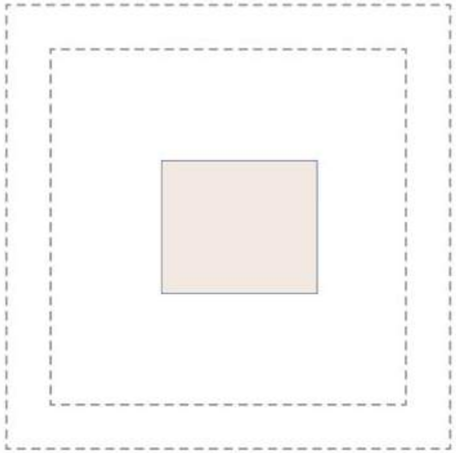
at least one is mandatory

- Courtyard
- Riwaq
- Iwan
- Entrances
- Main Entrance
- Communal Dining Rooms
- Communal Bathrooms
- Communal Kitchen
- Communal Storage
- Private Living Rooms
- Private Bedrooms

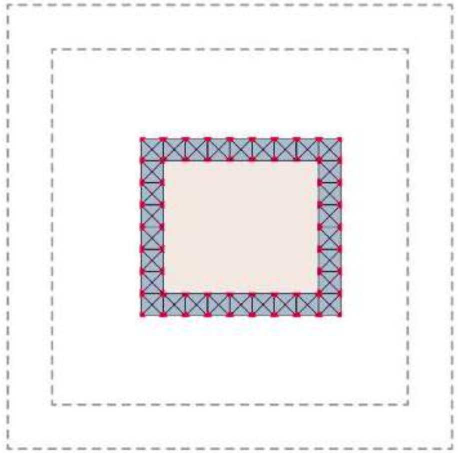
0.3.5 CONFIGURATION | Communal Houses



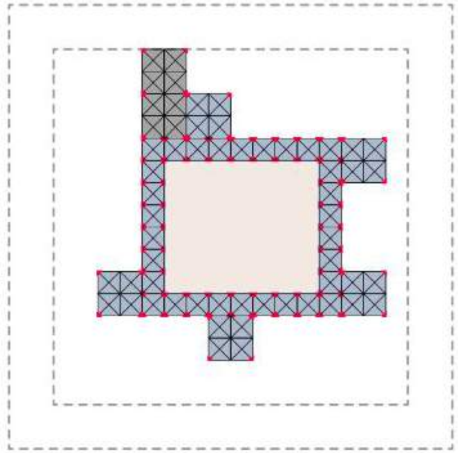
Bounding box



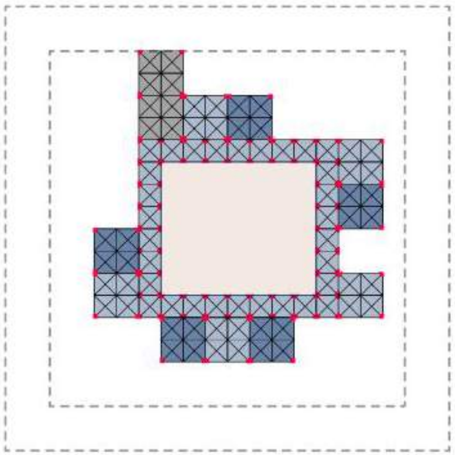
Setting the Courtyard



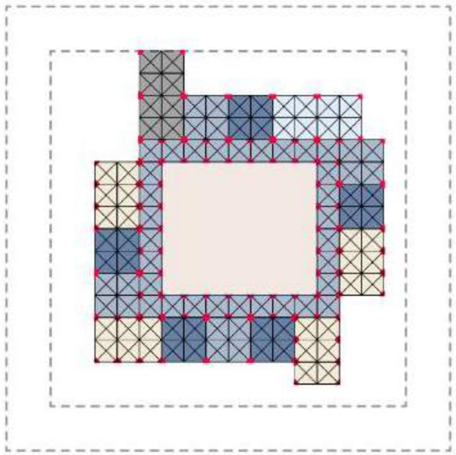
Placing Riwaq around Courtyard



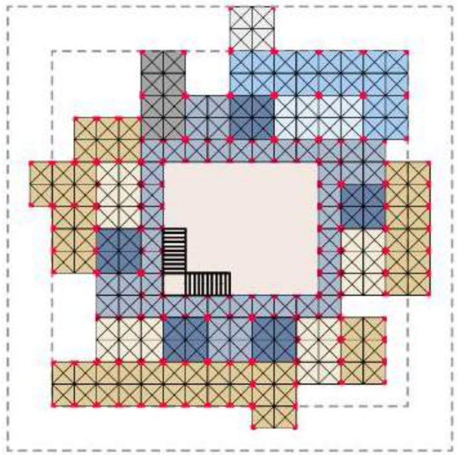
Placing Main Entrance and Iwans



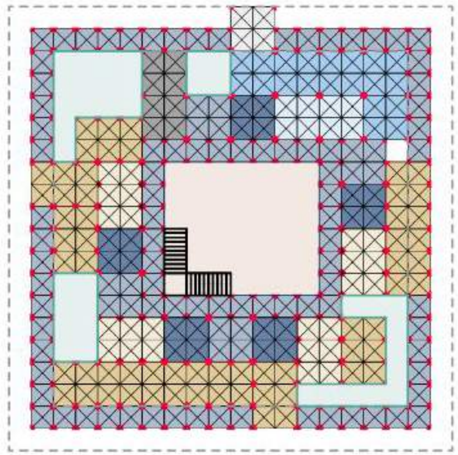
Placing Individual Entrances



Placing Functions of Depth 2



Placing Functions of Depth 3



Placing Riwaq around the whole building

Diagram 03.26: Configuration of Communal Houses

0.3.5 CONFIGURATION | Communal Houses

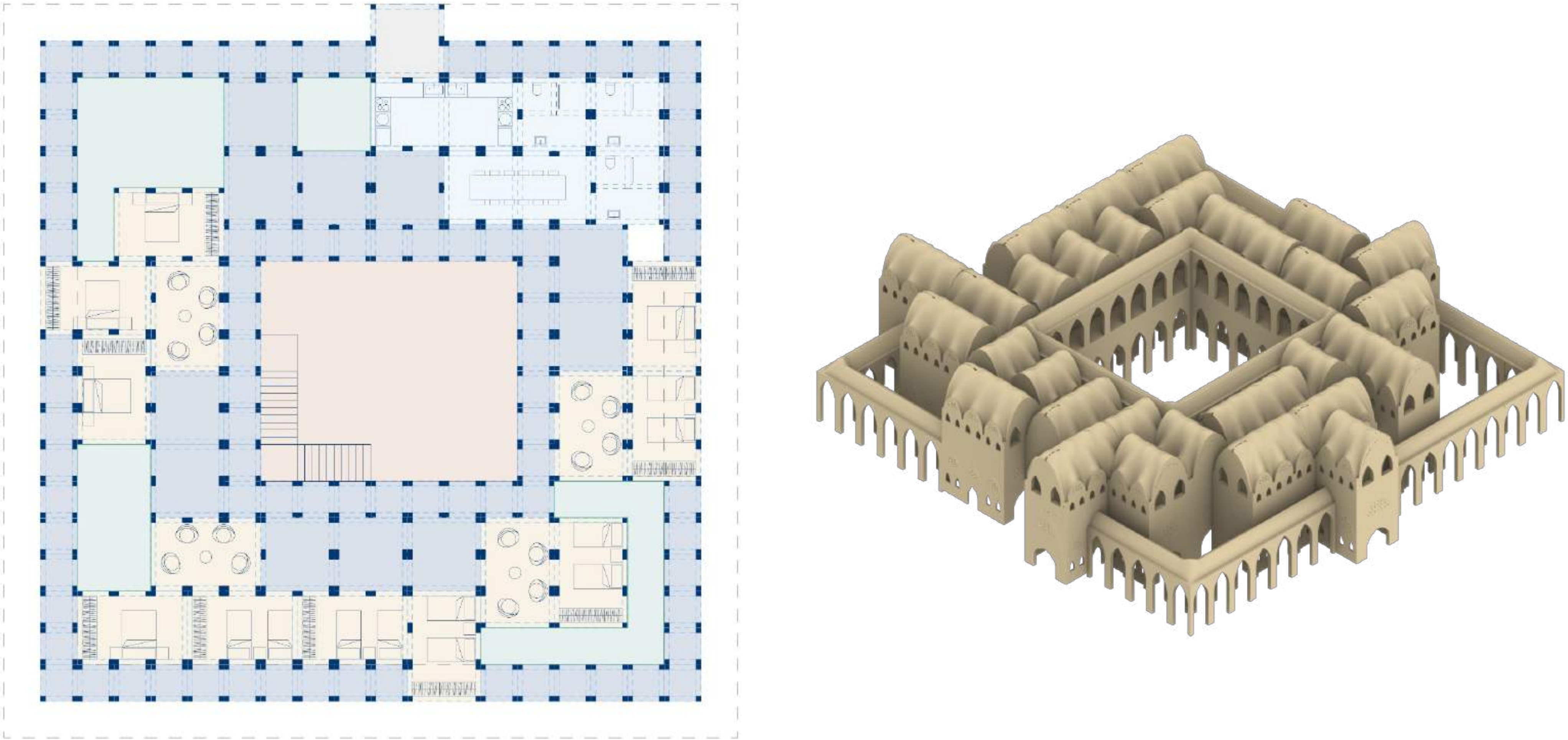


Diagram 03.27: Floor Plan with 3D visualisation

0.3.6 CONFIGURATION | Block Scale

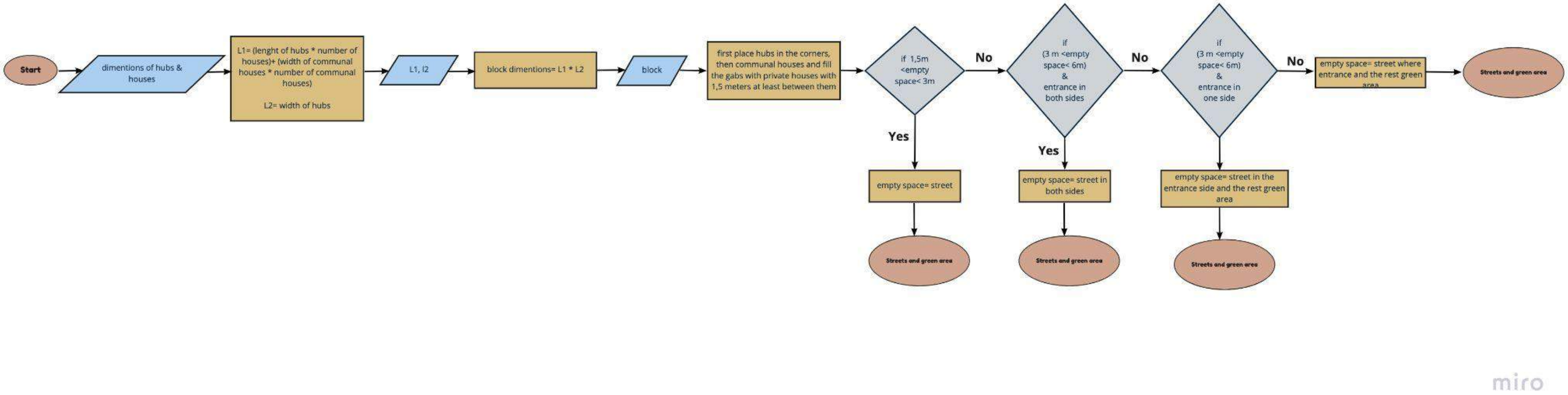


Diagram 03.28: Block Scale Configuration Flowchart

0.3.6 CONFIGURATION | Block Scale

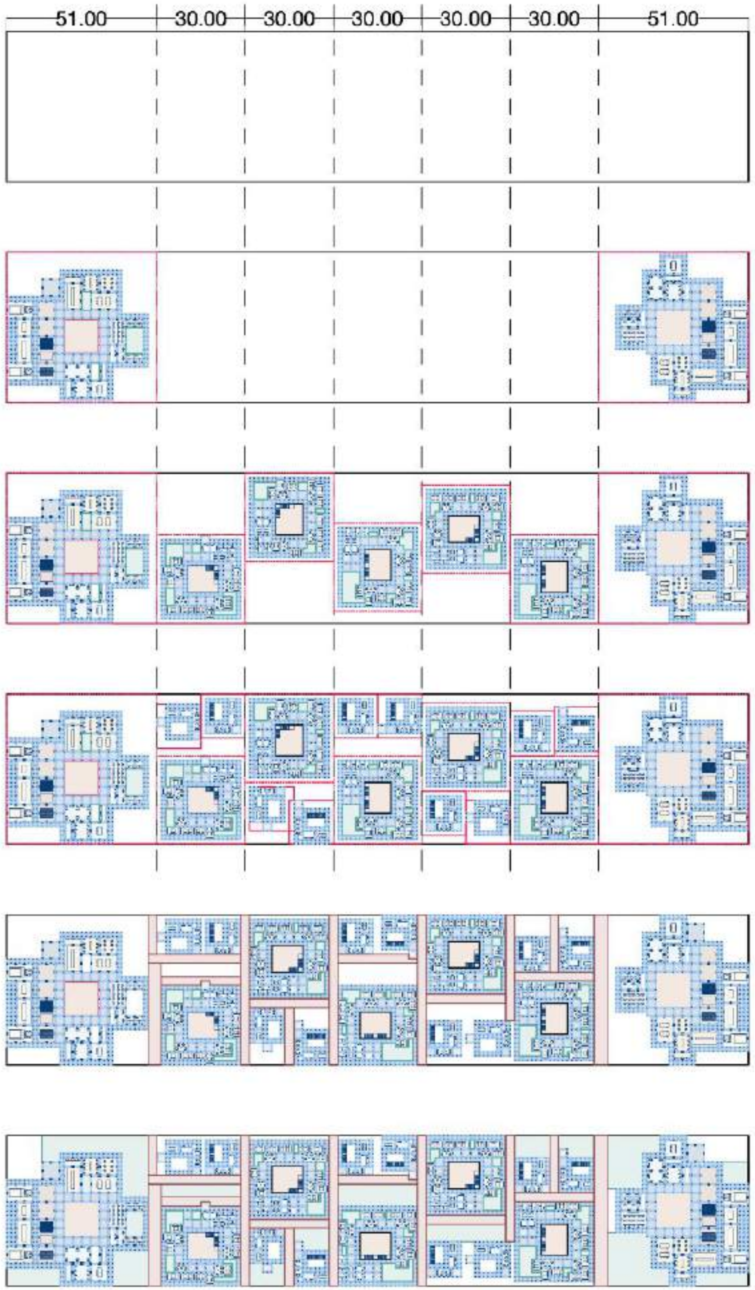
A crucial part of the configuration process was the need to define the relation between the 3 different kind of building units we are creating. The hubs, the communal and the private houses.

In order to do that he outer bounding boxes used for the configuration of each building are useful here for their placement in the block. Each block is divided into dimensions that correspond to the hubs and communal housing bounding box length.

Then Firstly, the hubs are placed in the edges of the block as access to the street is necessary. Then one communal house unit is placed in each inner division of the block having as an attractor the inner streets. And finally, the space left is covered by the smaller private houses in a more flexible way.

Once all the separate buildings are placed, streets and green spaces are added following some rules. The minimum distance between 2 different buildings is 1.5 m.

- If the space between 2 buildings is from 1.5-3 then a street is added.
- If it is from 3-6 and there is entrance in both sides a street is added, if not then a street and a green space is created.
- If it is more than 6 meters then a street is created to serve the entrances and the rest space is green.



Step 00_
Divide the block into dimensions that fit the individual buildings dimensions.

Step 01_
Set the main streets as attracting points for the hub placement and place one hub at each edge of the block.

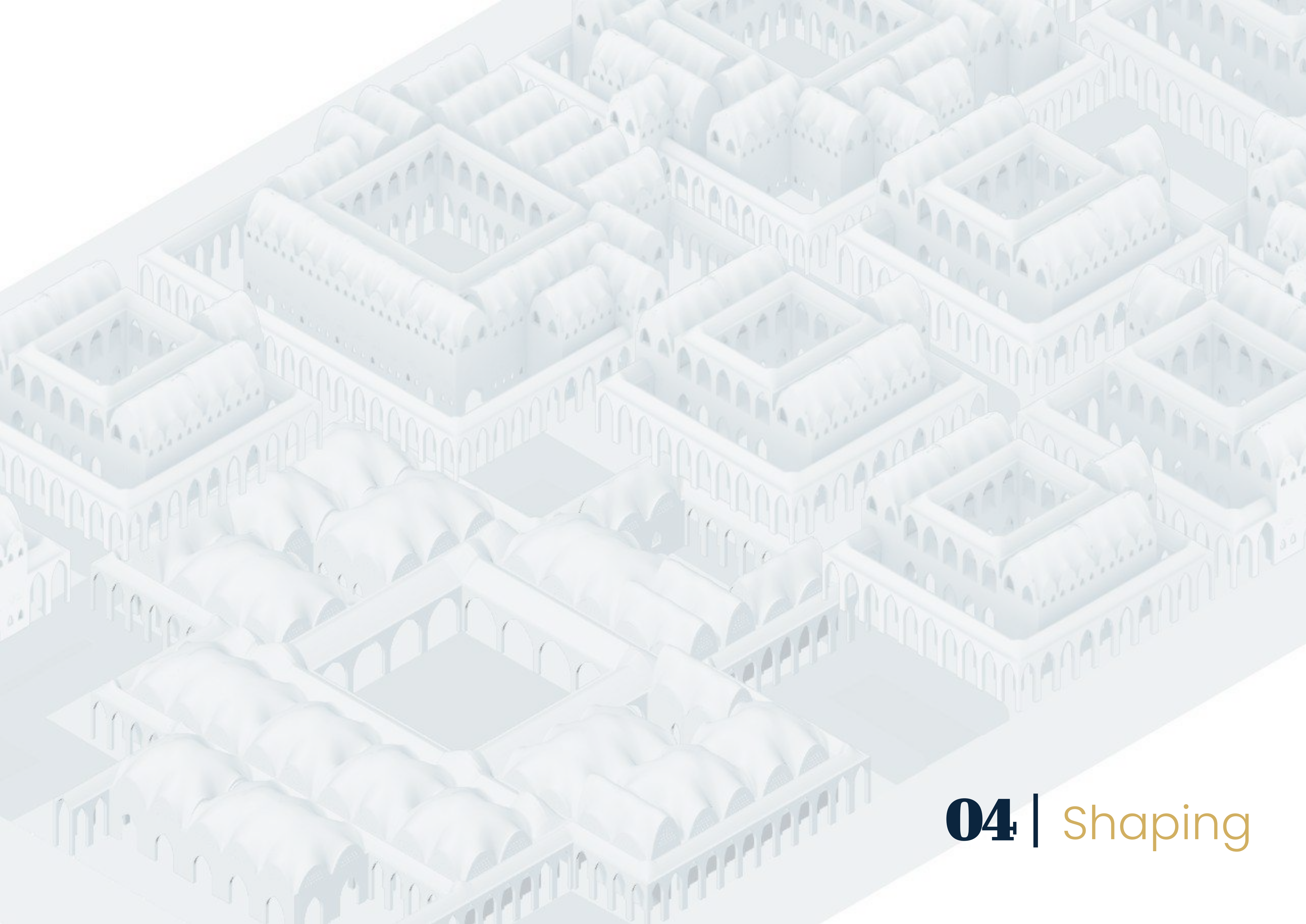
Step 02_
Set the inner streets as attracting points for the communal housing buildings and place one of these buildings per block division.

Step 03_
Fill the gaps between the communal houses buildings with private houses.

Step 04_
Place streets for inner circulation where necessary.

Step 05_
Place green spaces where possible.

Diagram 03.29 : Block Scale Configuration



04 | Shaping

04.1 SHAPING APPROACH

As to start working on the shaping procedure, some goals were set as to complete doable structures. These goals were based on not only to the proposal and the programme of our project but also to the overall configuration methodology and decisions that we took, which were explained in all the previous chapters of this report.

Based on the goals it was determined that the forming process should consider the aforementioned tartan grid that serves as the guideline of the design. The shape will come from the configuration and should be designed such that openings could be placed in all of the structures sides.

Next in our list was to create a library of elements, such as doors, windows, joints etc., that can be implemented in the main structure as to complete a whole building shape as the result of these main constraints, continuing in this way the forming process. Having this flexibility is vital for our project gamification because the user can choose how he/she wants their space to be creating in this way different patterns.

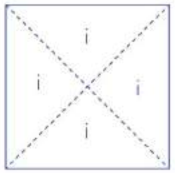
Finally, having the units' base we were able to generate the first tessellation lines. The aim of these margins was to get tessellation shapes with the aim of dynamic relaxation into vaults and domes, taking into account different parameters such the relation of height between the different units that must be combined in the spatial configuration.

After finalizing the ceiling tessellation for the various rooms, the tessellation was ready to be checked structurally as a whole structure and then proceed to the construction stages if they will be structurally safe elements.

04.3 SHAPING | Openings

OPENINGS TILE

1.



A open connection

B closed wall

C door

D window

Diagram 04.1 : Openings on grid

. The catalog-code was developed according to the evaluation ran on the connections among the spaces of the enclosed, semi-closed and open areas of the typical houses' and various hubs' program. The connection Tiles are only present along the edges of the units, to inform about the edge, corner connections[dia 04.1]. and requirements which were previously analyzed. It is actually a combination of elements that are connected with an arched opening. These are particularly useful for the user to choose according to their needs.

OPENING TYPE

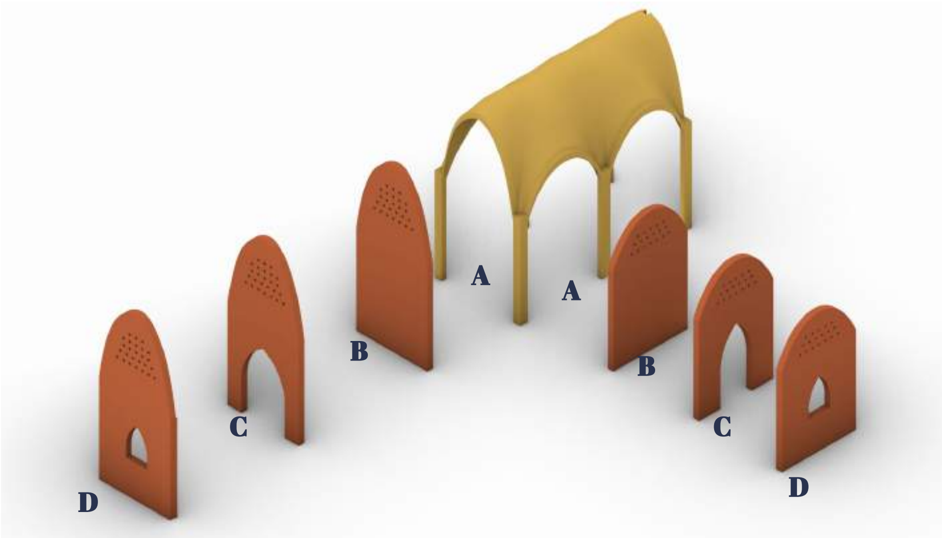


Diagram 04.2 : Openings Catalogue for Hubs

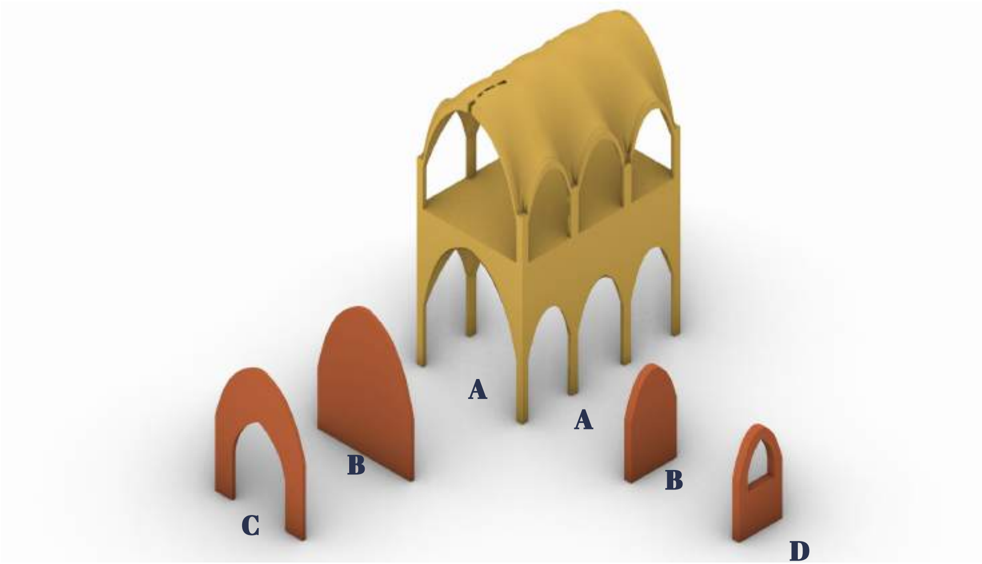


Diagram 04.3 : Opening Catalogue for Houses

04.4 SHAPING | Stairs

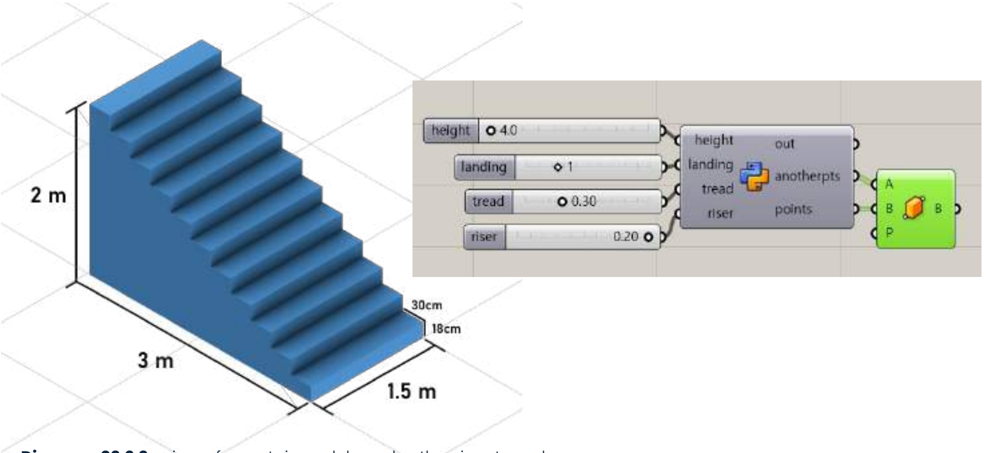


Diagram 03.2.3 : sizes of one stair module and python input numbers

A stair module is generated to fit in the grid size. Using python script, the user can control the height level, number of landings, tread size, and riser height. in our module, the size is fixed to 4m height, one landing, 30cm tread, and 18cm riser. the script calculates the number of steps from the riser height, in this case, was 11 steps for 18cm which sums up to 198cm for the height of the module. From the module, different combinations of stairs can be generated within the grid size (dia 03.03). The grid size it takes is 6~8. These are particularly useful for the user to choose according to their needs.

```
import Rhino.Geometry as rg
import math
import rhinoscriptsyntax as rs
import ghpythonlib.components as gc

points=[]
anotherpts=[]

# give numbers to landings, divsion for landing, number of steps in each modules
# module size 1.5

landings = landing+1
divsteps = height / landings
numsteps = math.floor(divsteps / riser)
module = 1.5


# will be the number of steps in one module
print(numsteps)


# make points on each steps and then take out the first point from a list to make two different set of pointlist

for i in range(int(numsteps)):
    edpoint1 = rg.Point3d(tread*i,0,riser*i)
    edpoint2 = rg.Point3d(tread*i,module,0)
    points.append(edpoint1)
    anotherpts.append(edpoint2)
points.pop(0)

a = points[-1]
b = anotherpts[-1]

if landing <= 1:
    landingstartpoint = rg.Vector3d(module,0,0)
    rs.MoveObject(a,landingstartpoint)
```

Diagram 03.2.3 : Python script for stair module generation

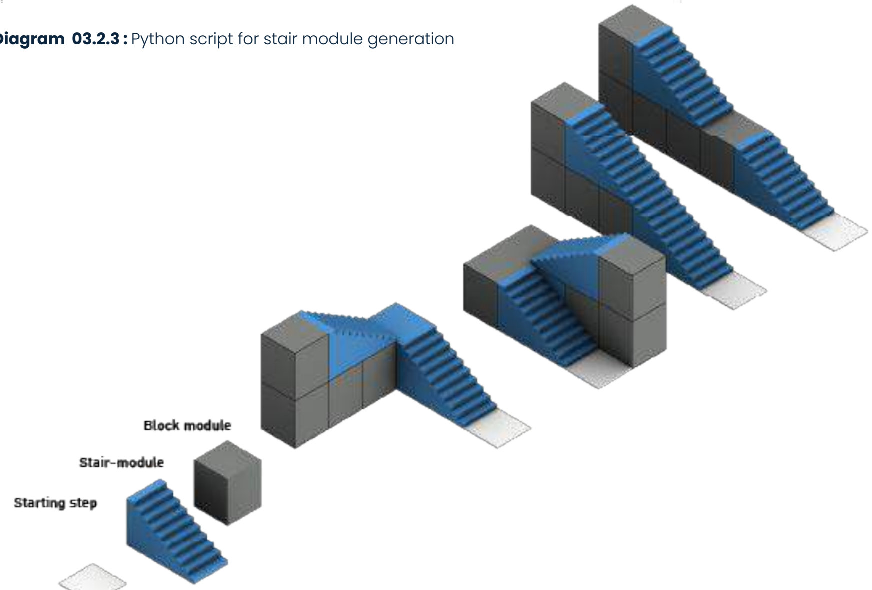
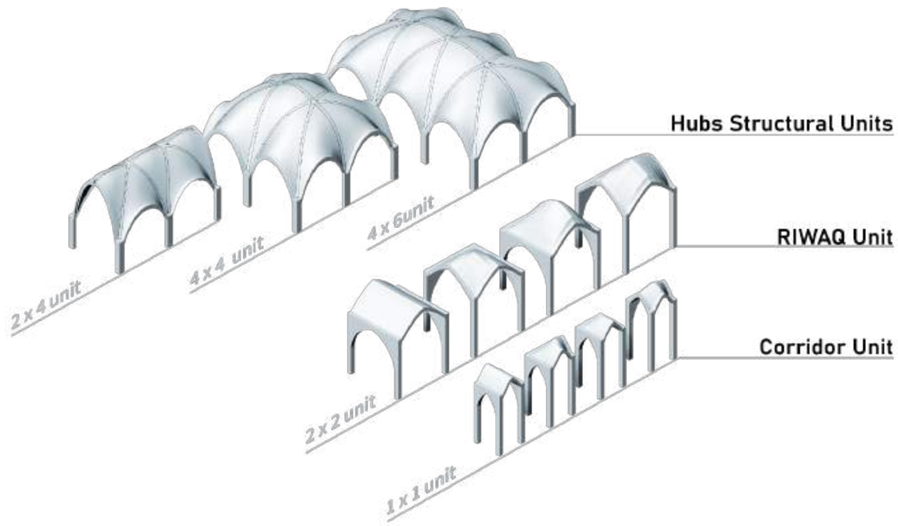


Diagram 03.2.3 : combination of stairs and stair modules.

04.2 UNITS | House and Hub

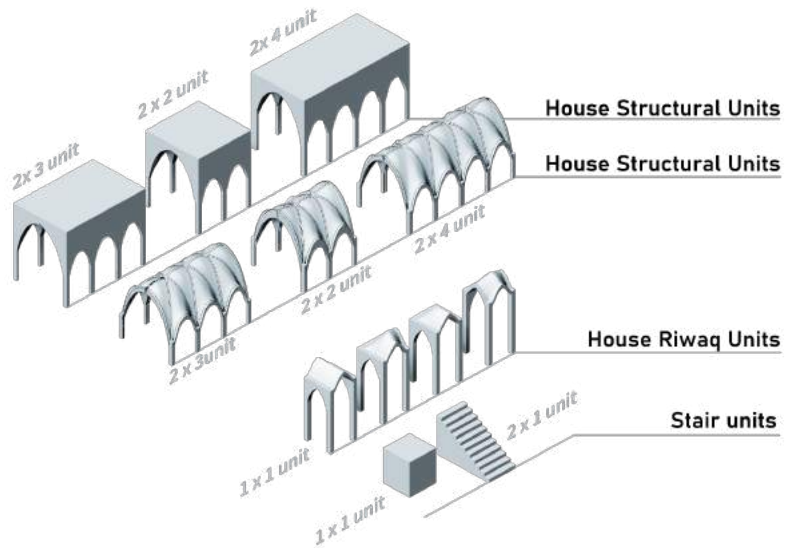
For the shaping structurally independent 3d units are designed, that can be combined in different ways to suit the 2d configuration.

The game uses 3 types for the main hub area , 4 types for the riwaq unit and 4 for the corridor unit.



Picture 4.1 Hub Units

In the house area there are also structural units 3 for the first and upper floor, 4 types for the riwaq units and 2 types for the stair units

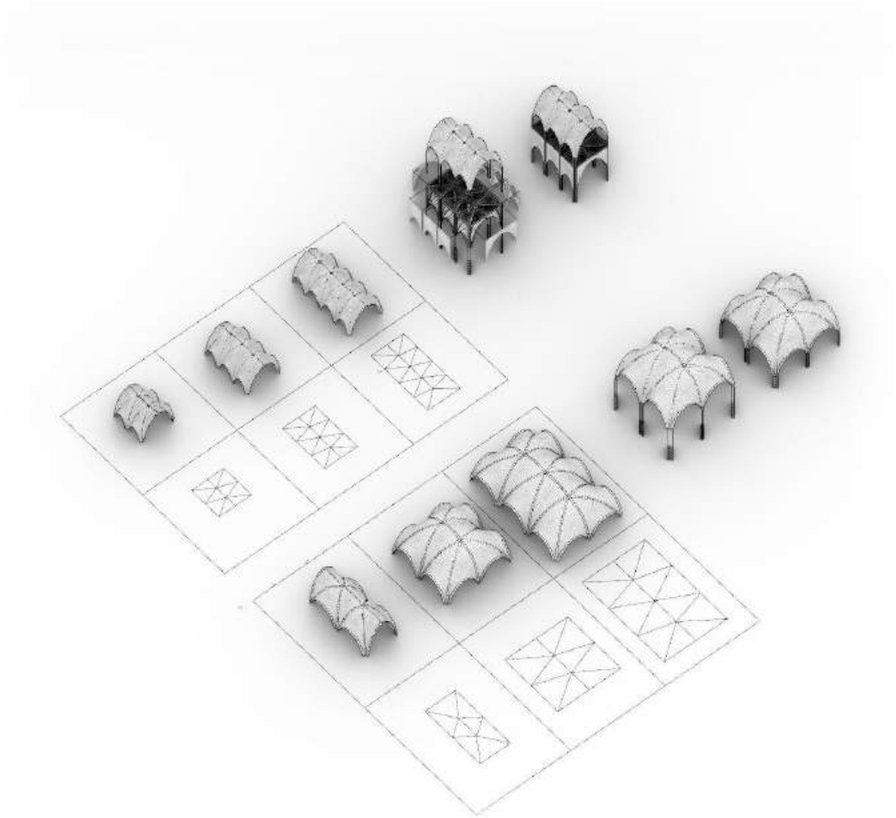


Picture 4.2 : House Units

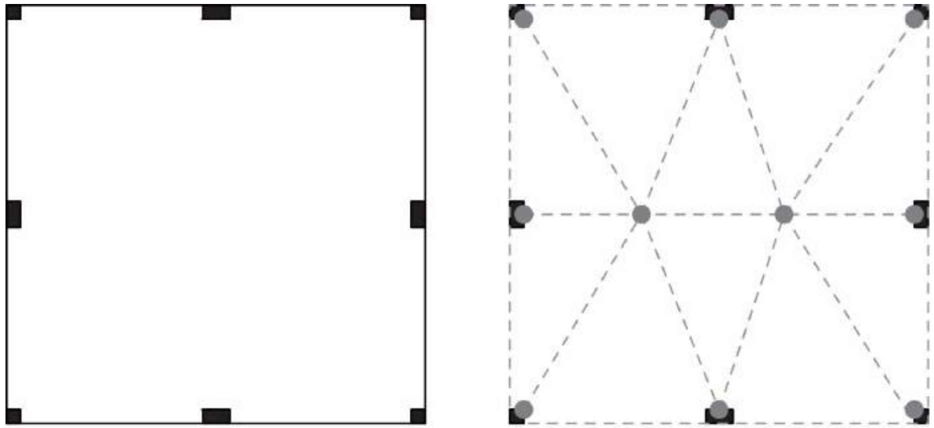
04.5 TESSELLATIONS

For the subdivision pattern of our units we looked into gothic vaulted ceilings trying to analyze the subdivision patterns. From the plan configuration we get the position of the columns. Then we subdivide the an initial mesh in the middle. The outer edges are divided by the number of columns and the inner middle edge is divided by the number of columns plus 1. From that we get a triangulated pattern.

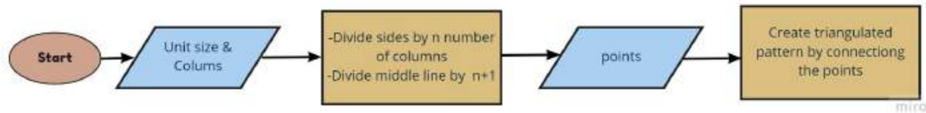
Then we create hexagonal meshes in the division points of the middle edge. Their edges are connected with the outer edges creating quad faces used for the ribs. The inner triangulated faces at divided n times through constant quad division while the quad faces are divided by n multiplied by 4 times

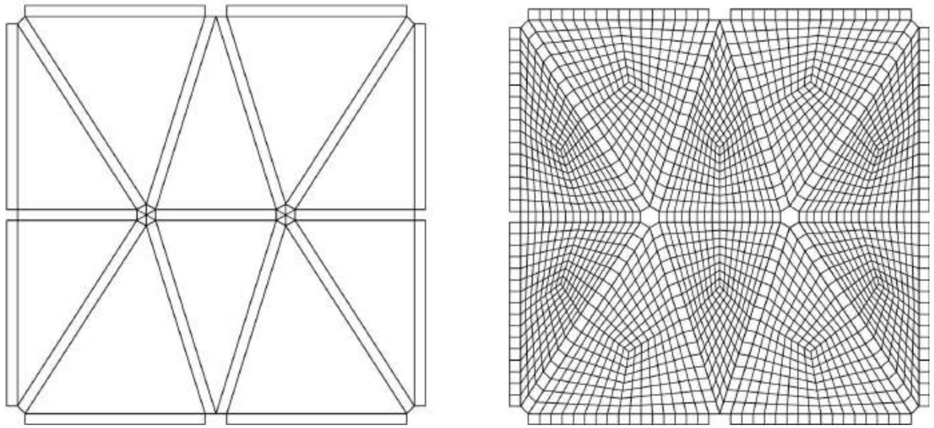


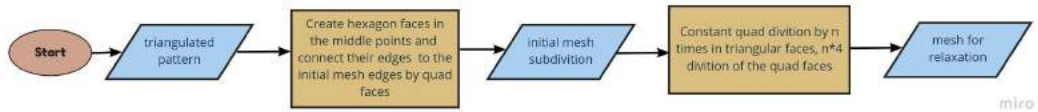
Picture 4.3 : Mesh subdivision and relaxation



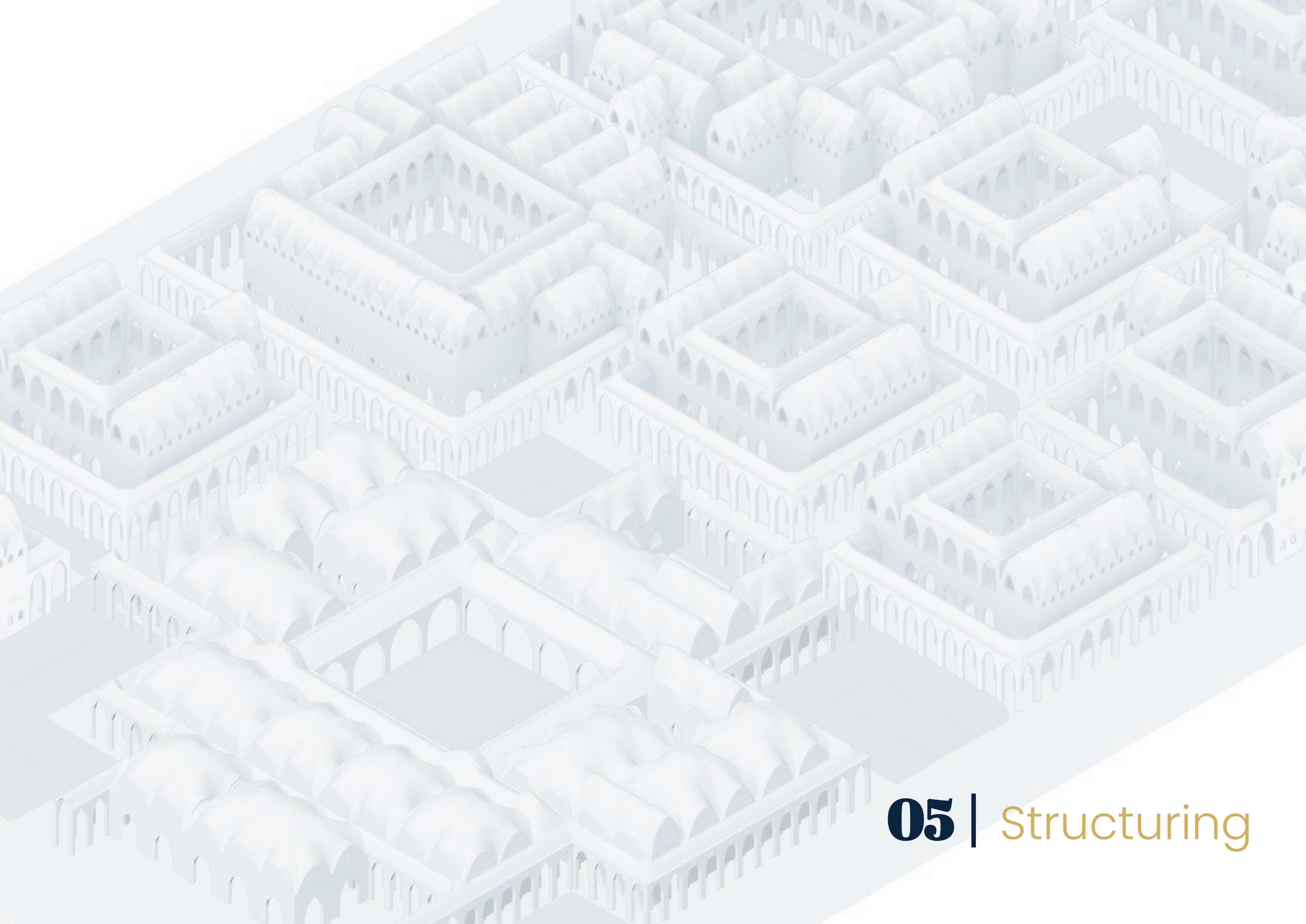
Picture 4.4: : Mesh triangulation







Picture 4.5 : Mesh subdivision



05 | Structuring

05.1 STRUCTURAL APPROACH

Considerable schemes from our building modules language have been considered for a deeper structural evaluation and analysis.

Our first priority was to define the materials properties of the adobe blocks, such as inputs and limit values, in order to carry out a veritable structural analysis and optimization of the shape and the thickness of each building element.

The second step to set up the analysis environment was to determine the three different loading conditions and the safety factors to create the proper load combinations as the last input of the structural survey.

Main purpose of our steps is to create greater possibility for variations in the units' configuration. Thus, the simplification of the structure is a milestone to provide the desired freedom and flexibility in the tessellations' formation and the simple constructability and replicability; matters that are of elemental importance for our proposal.

Moreover, a systematic approach of several structuring rules was taken as to obviate any difficulties in the construction phases. This set had to do with the module's dimensions, its multiplications and combinations to create variations in the different units' generation in the production and housing zones, and finally their configuration on the horizontal and vertical axis.

After the essential rules of structuring were designated and the form for every module configuration and its tessellations were structurally analyzed, the structural variations required were specified accordingly.

The structural analysis was carried out in parallel with the design of the various unit types of the uses, their form finding and constructability. Main target was to reach a desired and efficient solution within the material requirements and following the same modular systematic approach in having easily repeatable parts. However, this approach came to an answer through many trials and errors. Finally, the results were considered as the feedback to enable decision-making and possible shaping or structural improvements.

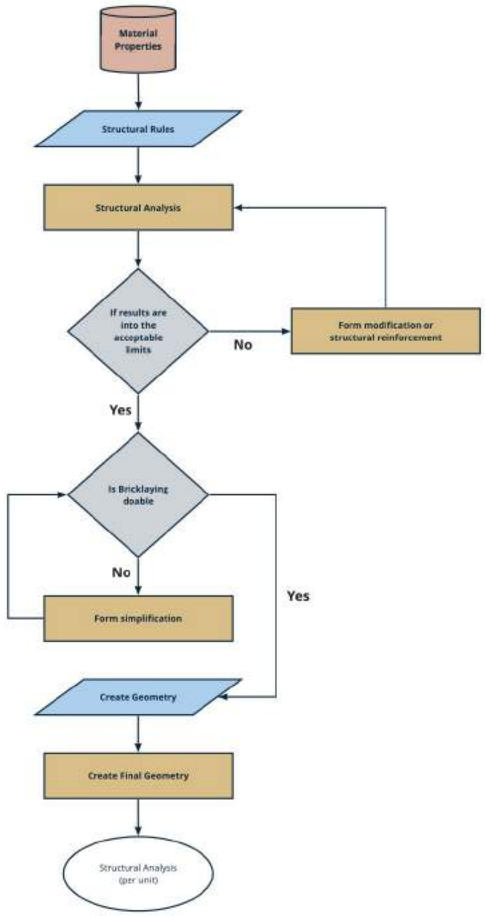


Diagram 5.1 : Flowchart of the Structural Analysis Process and Methodology

05.2 MATERIAL PROPERTIES

Significant scenarios from our building units design have been considered for a deeper structural evaluation and analysis. Main step, that is actually mandatory to perform a realistic simulation analysis and optimization of both the shape and thickness of each structural element of the building, has been determining the material properties for adobe bricks. Since, we didn't have the opportunity to produce, test and study the properties of our own earth mixtures and blocks, we execute a research in the existing literature and the previous years reports of Earthy as considerable references in order to find the most suitable block's composition.

After a research of the various blocks properties and their production systems evaluation, we concluded that the unstabilised compressed earth blocks (CEB), which are manually pressed, has shown all the advantages of using them. They were chosen for their balance between its mechanical properties and its production procedure, even if they had a slightly higher cost and complexity in their manufacture, since the design of the proper molds are necessary.

Young's Modulus	250 MPa
Density	1700 kg/m3
Compressive Strength	0,3 kN/cm2
Tensile Strength	0,03 kN/cm2

Table 5.1 : Material Properties of Compressed StabiliZed Earth Blocks

The final composition that will be used is the aforementioned adobe in combination with straw. This composition has a compressive strength of 0,3 kN/cm2. The tensile strength is kN/cm2 and the Young's modulus is 250 MPa. The density of the adobe with straw is 1700 Kg/m3.

For the load bearing ceiling in the house units gypsum gravel was used along with gypsum blocks for binding. In the structural analysis a density of 1.100 kg/m3 was assumed.

Finally, the roofs will be provided with an extra layer of earthen plaster. This is done to make the roofs waterproof. The composition of the earthen plaster will be the same as the composition of the adobe bricks. In addition, lime is added to the composition. This makes the earthen plaster water-resistant (Owens, 2015). Despite the fact that the earthen plaster is water-resistant, the plaster layer will have to be replaced after a few years due to wear and tear.

BLOCK TYPE	FORMI PROCEDURE	MECHANICAL PROPERTIES	BIOBASED MIXTURE	PRODUCTION COST	PRODUCTION EASE	TOTAL EVALUATION
Unstabilized Adobe Brick	Handmade Shape	--	+	++	++	+++
Unstabilized Compressed Earth Block (CEB)	Manual Press	+	+	+	+	++++
Unstabilized Compressed Earth Block (CEB)	Mechanical Press	++	+	-	-	+
Stabilized Earth Block	Manual Press	+	-	-	+	+
Stabilized Earth Block	Mechanical Press	++	-	--	-	--

Table 5.2 : Block's Production System Evaluation

05.3 STRUCTURAL RULES

In order to prevent any difficulties in the construction phase, several structural rules were taken. Based on our module size of 1.5 meters, the variations on the room configurations are derived through the module multiplication for both the hubs and housing areas.

Generally, a rule of mirroring modules was created for the units' generation. For instance, the smallest room size is 3.0 * 3.0 meters. One module is mirrored to create the inner length of the room and then the length is again mirrored to get the final unit of 3.0 * 3.0 size. While a module side is 1.5 meters, a gap of 1.1 meters, with adjacent wall of 0.2 meters on both sides of it, is created in the edges of the new unit to accommodate the variations of the opening elements.

For rooms with bigger size, we combine or mirror the modules is order the are to be their multiples. For example, the 3.0 * 3.0 room and the initial mirrored modules together create the 3.0 * 4.5 meters room size. Resulting consequently to a larger length rectangular room, thus keeping the opening size the same.

Thus the whole process could be further repeated for larger room sizes, while always maintaining the 1.5 meters module size with the 3.0 meters high section.

To sum up, this systematic approach of room generation, contributing to create greater possibility for variations in the unit configuration, thus providing the desired freedom and flexibility in cluster formation.

5.4.a Thickness of elements

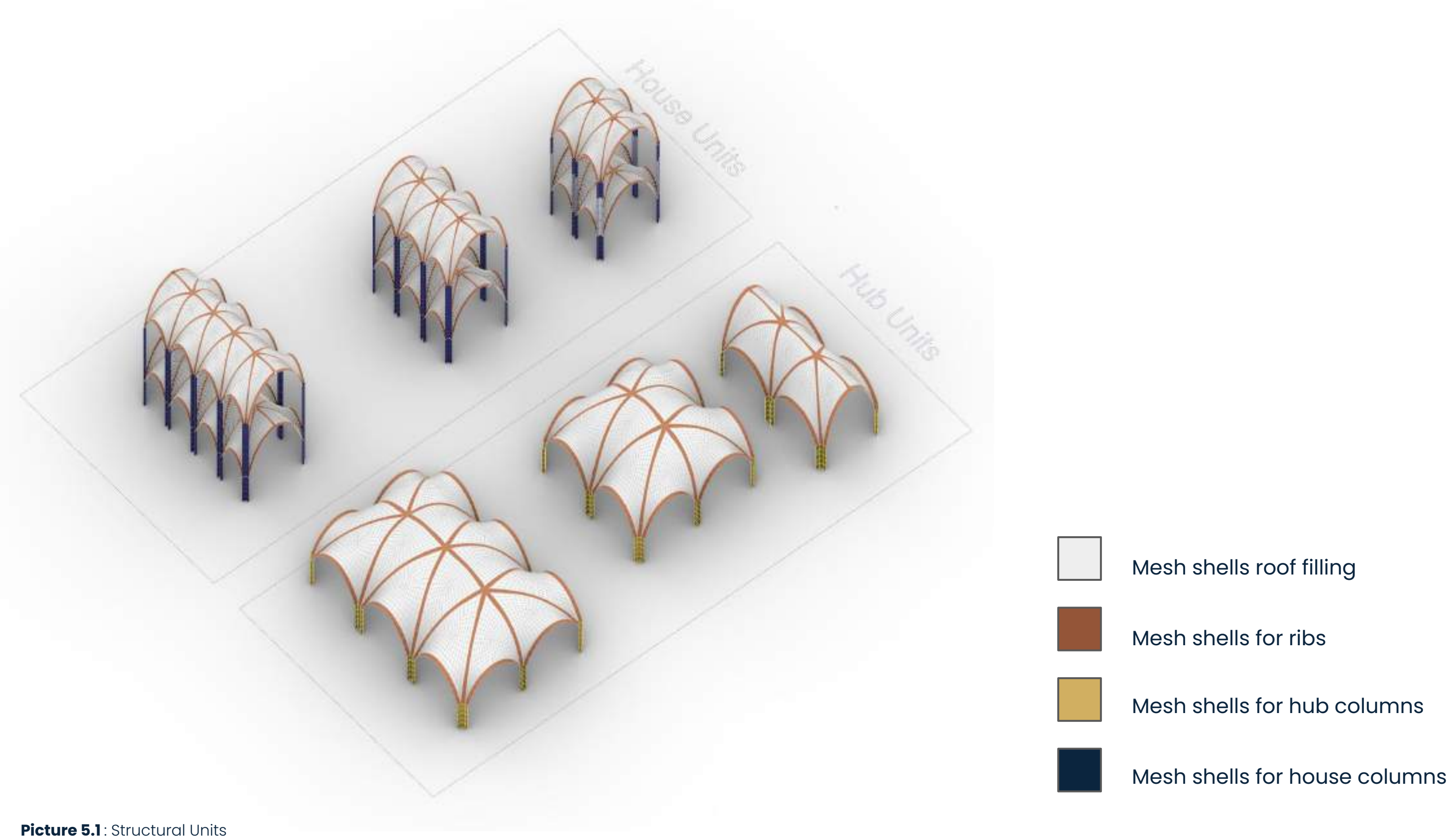
For the structural simulation mesh shells are used and various thickness is applied:

Roof ribs: The thickness for the mesh of the roof ribs is 20cm

Roof filling: The thickness for the roof filling is 10 cm

Columns in hubs: For the hub units a thickness of 25 cm is assumed which results in columns 50x50 cm.

Columns in houses: For the house units a thickness of 15 cm is assumed which results in columns 30x230 cm.



Picture 5.1: Structural Units

5.4.b Hub Units- Load Cases

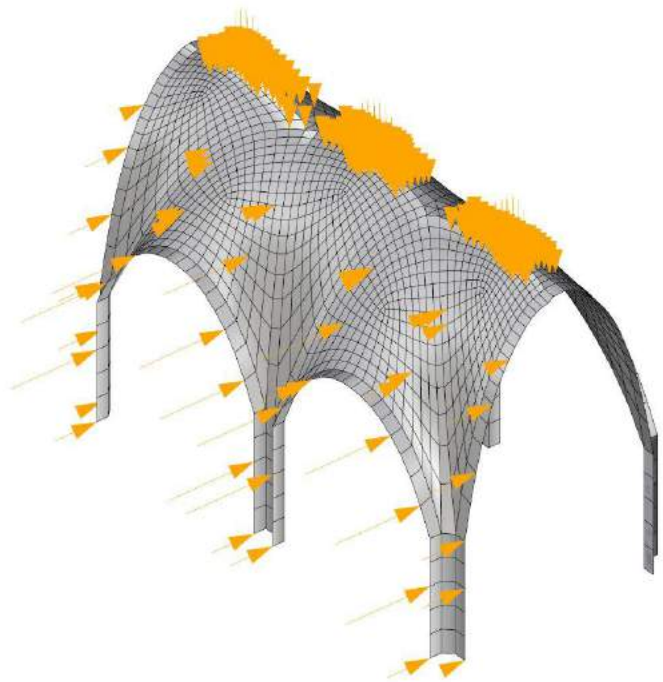
Dead Loads

L1: Gravity
For the gravity load we took into account the weight of the material taking into account the research of Earthy groups from 2020.
Safety factor for dead loads: 1.35

Live Loads

L2: Wind load
The columns were tested as mesh shells for ease purposes. Therefore uniform line loads could not be applied. For this reason a mesh load was used instead. The value **1kN per square meter** was used multiplied by 1.5 which represents the span of the columns , representing the wind load applied in the side walls.
L3: Service load
A load of 1 kN per square meter is considered for roof access for future service repairs

Safety factor for live loads: 1.5



Picture 5.2 : Load cases

5.4.c Hub Units- Columns

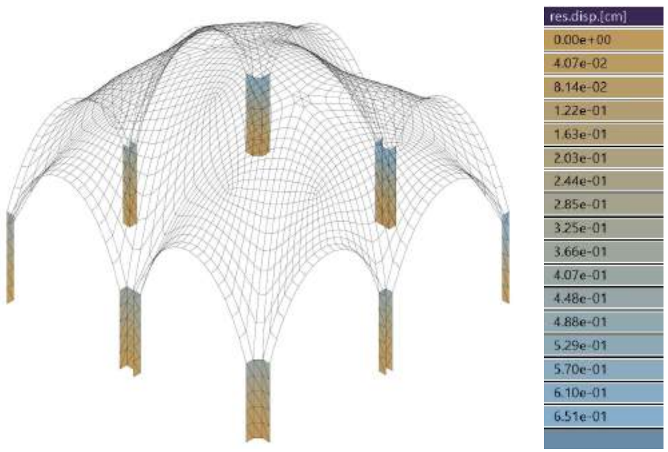
The following diagrams demonstrate the displacement of the mesh shells and the principal stresses at the columns of one of the production hub units. Structural results for the rest of the units can be found at the Appendix B.

The deflection allowed is the 1/200 of the smallest length which is 1.8 meter, therefore 0.9cm.

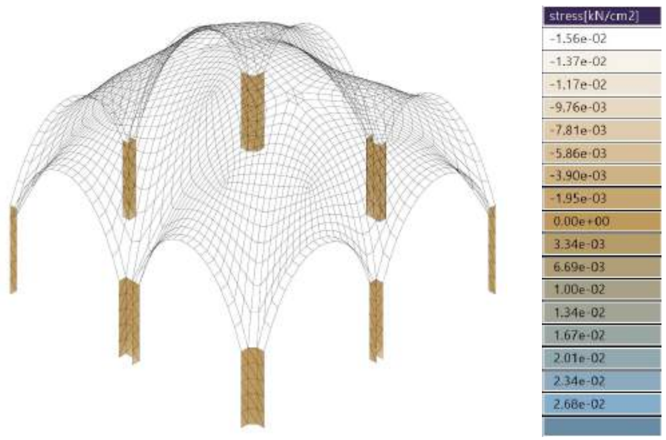
For the principal stresses the values on the legend that are not rendered on mesh shell do not exist.

Principal Stress 1		Material Strength
Maximum Compressive stress	0.0017 kN/cm2	0.3 kN/cm
Maximum Tensile stress	0.001 kN kN/cm2	0.03 kN/cm2
Principal Stress 2		
Maximum Compressive stress	0.0026 kN/cm2	0.3 kN/cm
Maximum Tensile stress	0.00022 kN/cm2	0.03 kN/cm2
Displacement		
Maximum displacement	0.65 cm	0.9 cm

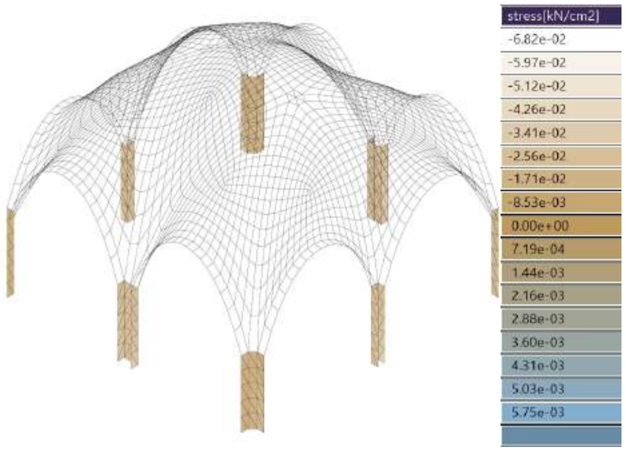
Table 5.3 : Structural Analysis of the columns for the hub unit



Picture 5.3 : Displacement of columns



Picture 5.4: Principal stress 1 for columns



Picture 5.5 : Principal stress 2 for columns

5.4.d Hub Units- Roofs

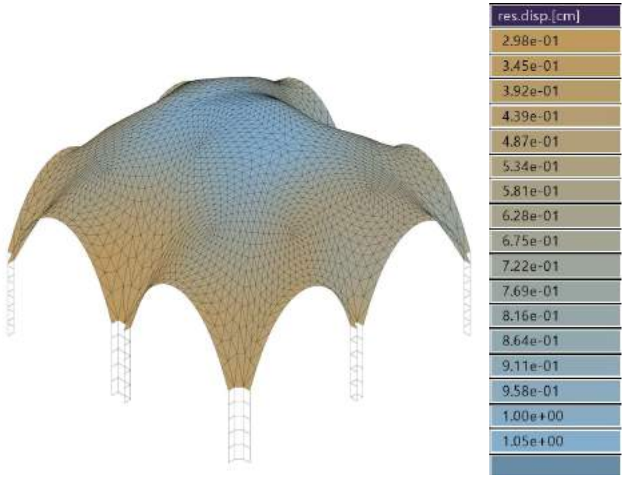
The following diagrams demonstrate the displacement of the mesh shells and the principal stresses at the roofs of one of the production hub units. Structural results for the rest of the units can be found at the Appendix B.

The deflection allowed is the 1/200 of the smallest length which is 3 meter, therefore 1.5cm.

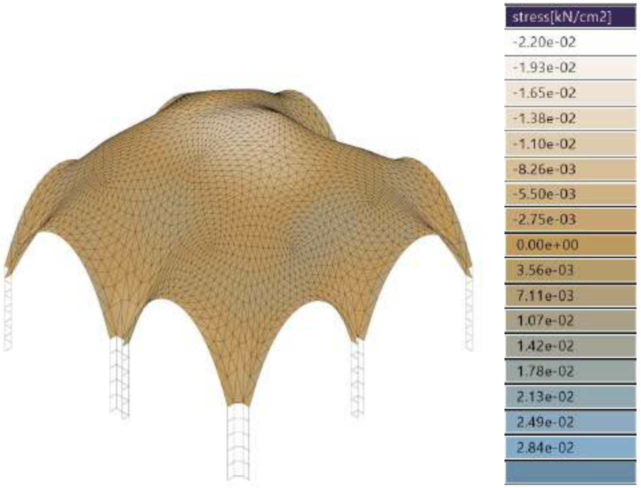
For the principal stresses the values on the legend that are not rendered on mesh shell do not exist.

Principal Stress 1		Material Strength
Maximum Compressive stress	0.019 kN/cm2	0.3 kN/cm
Maximum Tensile stress	0.001 kN kN/cm2	0.03 kN/cm2
Principal Stress 2		
Maximum Compressive stress	0.05 kN/cm2	0.3 kN/cm
Maximum Tensile stress	0.0017 kN/cm2	0.03 kN/cm2
Displacement		
Maximum displacement	0.3 cm	1.5 cm

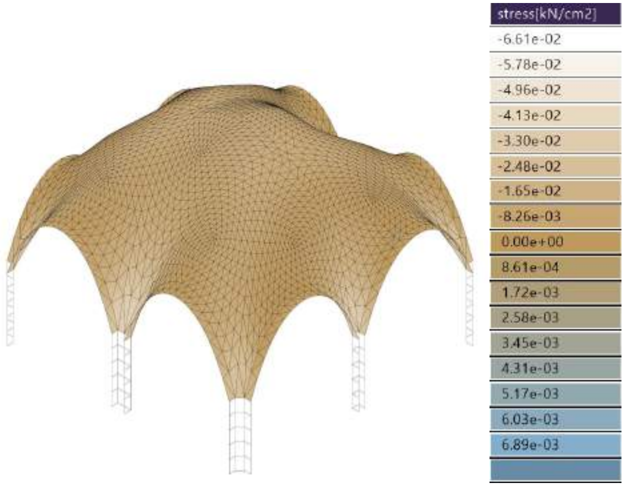
Table 5.4 : Structural Analysis for the roof of the hub unit



Picture 5.7 : Displacement ot the roof



Picture 5.8: Principal stress 1 of the roof



Picture 5.9 : Principal stress 2 of the roof

5.4.e House Units- Load Cases

Dead Loads

L1: Gravity
For the gravity load we took into account the weight of the material taking into account the research of Earthy groups from 2020.

L2: First floor load
For this particular load case there are two things considered:

- The dead load of the first floor slab which has a thickness of 10 cm and Earth compressed blocks are used.
- The material filling between the roof of the ground floor and the first floor slab. That consists of gypsum gravel along with gypsum blocks for binding. For this case a mesh load is used that allows the application of various surface load vectors, one of each mesh face. For the values first the center points of the mesh faces (for the slab and the first floor roof) are connected to form lines. The length of each line is multiplied with the area of the mesh face that belongs to and then by the density of the gypsum material (7 kN/m3). Finally these values are assigned to the mesh faces.

Safety factor for dead loads: 1.35

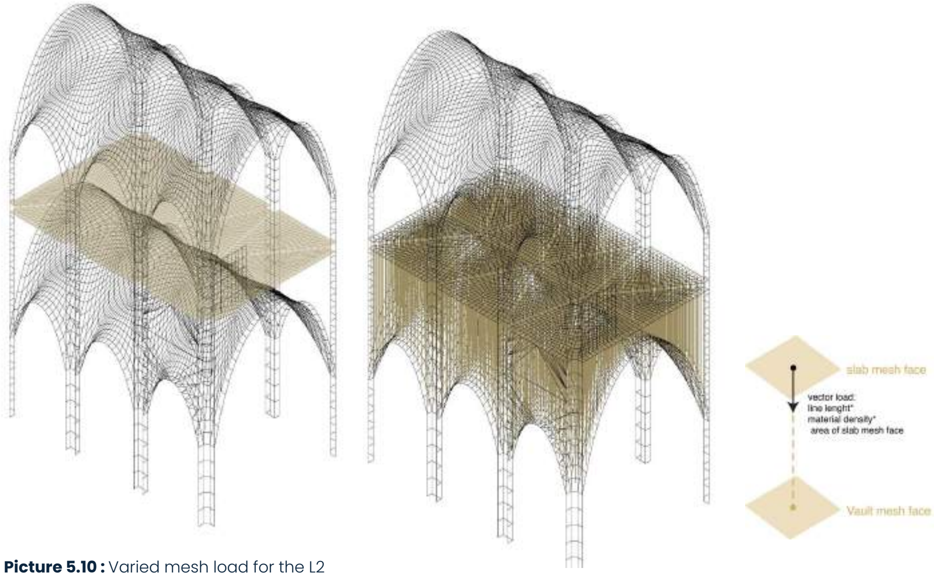
Live Loads

L3: First floor people
For the first floor **3kN per square** meter are considered

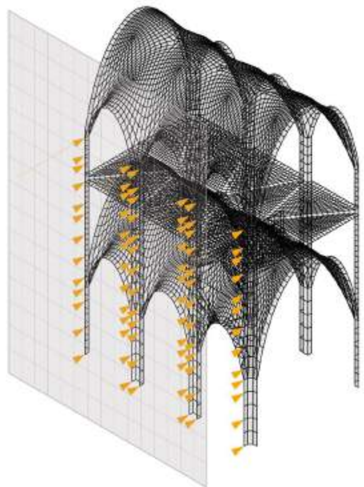
L4: Wind load
The columns were tested as mesh shells for ease purposes. Therefore uniform line loads could not be applied. For this reason a mesh load was used instead. The value **1kN per square meter** was used multiplied by 1.5 which represents the span of the columns , representing the wind load applied in the side walls.

L5: Service load
A load of 1 kN per square meter is considered for roof access for future service repairs

Safety factor for live loads: 1.5



Picture 5.10 : Varied mesh load for the L2



Picture 5.11 : Wind Load

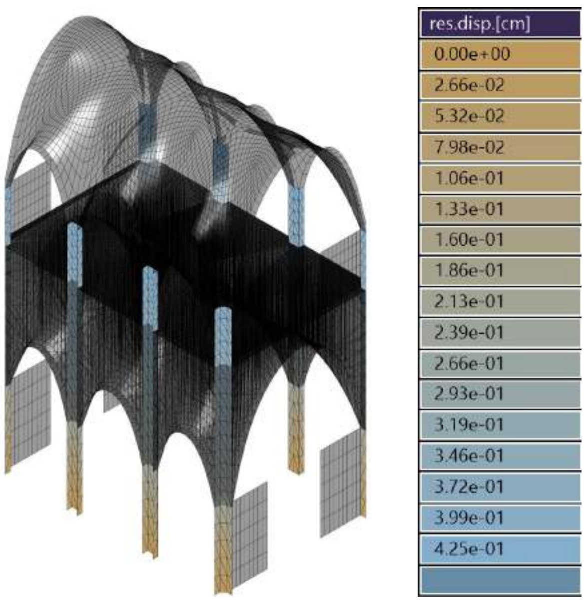
05.4 STRUCTURAL ANALYSIS | Hub and House Units

5.4.f House Units- Columns

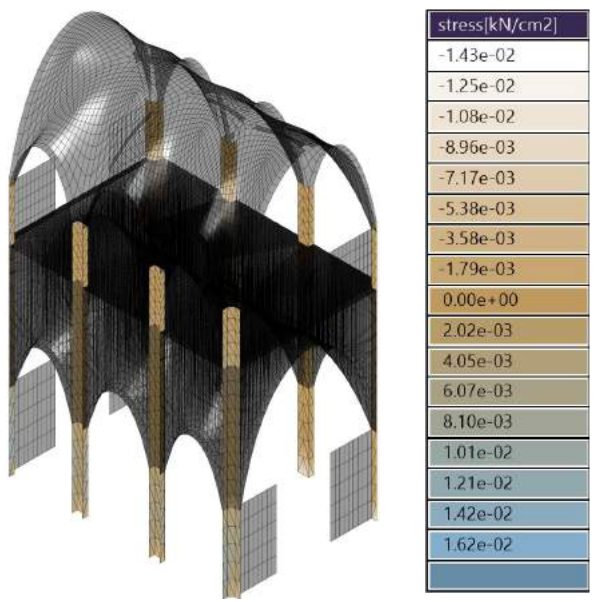
The following diagrams demonstrate the displacement of the mesh shells and the principal stresses.
Small side walls on the ground floor are considered along with the sidewall between the roof of the ground floor and the first floor slab.
The deflection allowed is the 1/200 of the smallest lenght which is 1 meter, therefore 0.5cm.
For the principal stresses the values on the legend that are not rendered on mesh shell do not exist.
In this report and indicative unit is analyzed. More units can be found in the appendix

Principal Stress 1		**Material Strength**
Maximum Compressive stress	0.089 kN/cm2	0.3 kN/cm
Maximum Tensile stress	0.0081 kN kN/cm2	0.03 kN/cm2
Principal Stress 2		
Maximum Compressive stress	0.016 kN/cm2	0.3 kN/cm
Maximum Tensile stress	0.0012 kN/cm2	0.03 kN/cm2
Displacement		
Maximum displacement	0.425 cm	0.5 cm

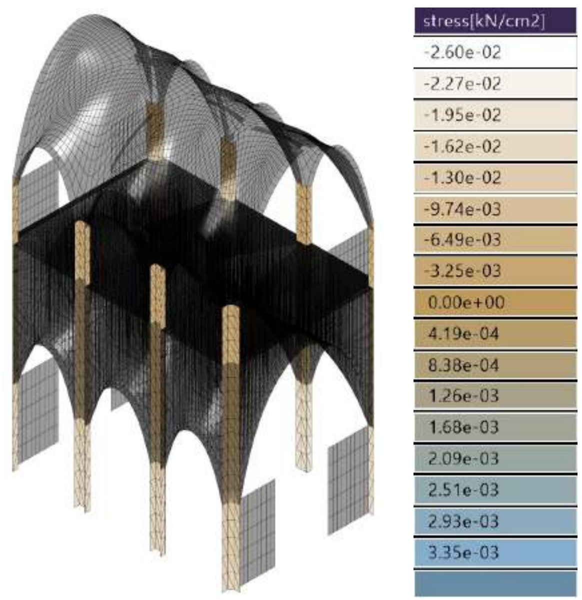
Table 5.5 : Structural Analysis for the columns of the house unit



Picture 5.12 : Displacement of columns



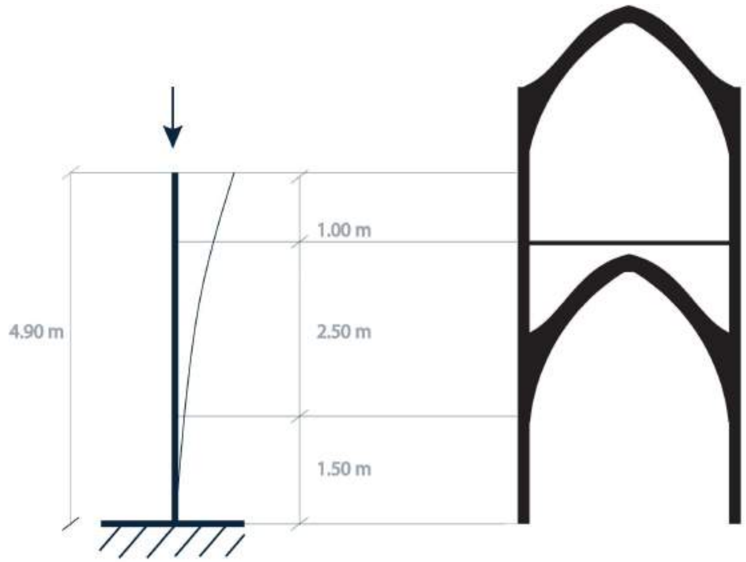
Picture 5.13 : Principal stress 1 for columns



Picture 5.14 : Principal stress 2 for columns

5.4.g House Units- Columns

Buckling of the columns is checked with hand calculations.
The maximum reaction force on the column's supports is calculated and as seen on the table does not exceed the Pcr therefore the columns do not fail because of buckling.



Picture 5.15 : Section of the house Unit

Section area	1.6E+05mm2
Young's Modulus	2.50E+02 Mpa
Moment of Inertia	2.13E+09 mm4
Length	4.90E+03 mm
Pcr	54.8 kN
Maximum Reaction Force	48 kN

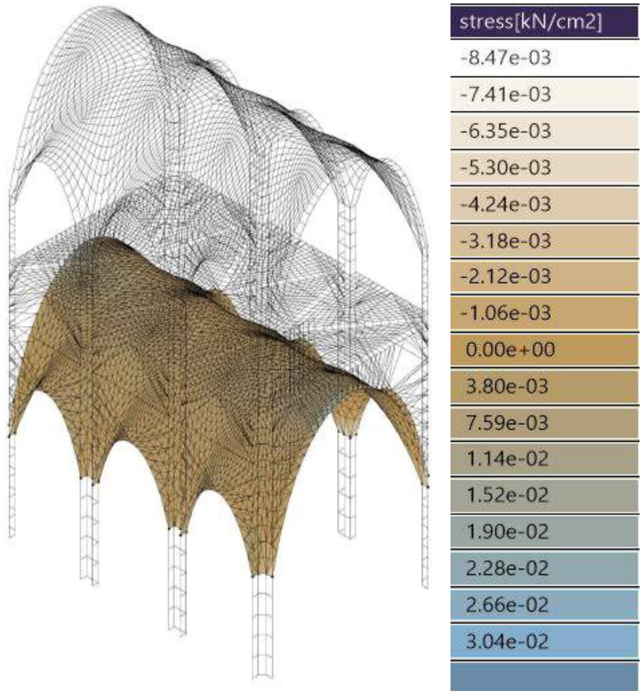
Table 5.6 : Hand Calculations for the buckling verification.

5.4.h House Units- First roof

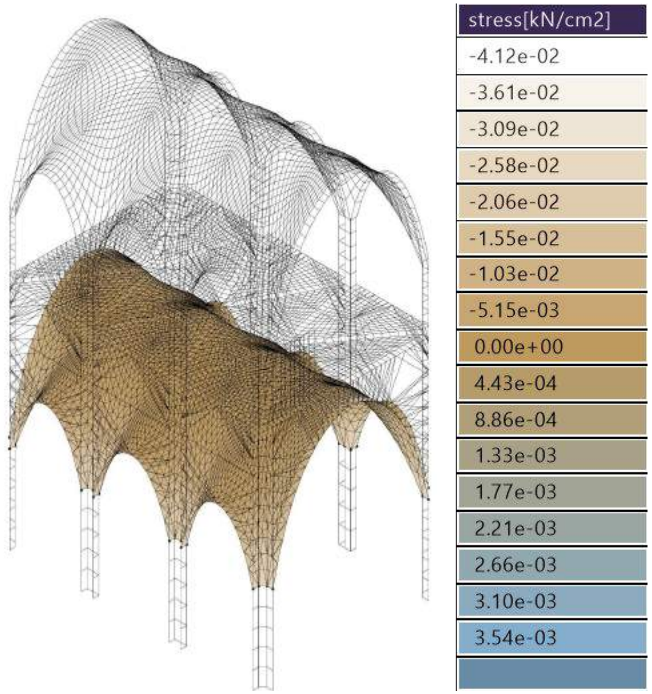
The following diagrams demonstrate the displacement of the mesh shells and the principal stresses at the roof of the ground floor.
The deflection allowed is the 1/200 of the smallest span which is 1.5 meter, therefore 0.75 cm. For the principal stresses the values on the legend that are not rendered on mesh shell do not exist.

Principal Stress 1		Material Strength
Maximum Compressive stress	0.0001 kN/cm2	0.3 kN/cm
Maximum Tensile stress	0.0019 kN/cm2	0.03 kN/cm2
Principal Stress 2		
Maximum Compressive stress	0.01 kN/cm2	0.3 kN/cm
Maximum Tensile stress	0.00133 kN/cm2	0.03 kN/cm2
Displacement		
Maximum displacement	0.294 cm	0.75 cm

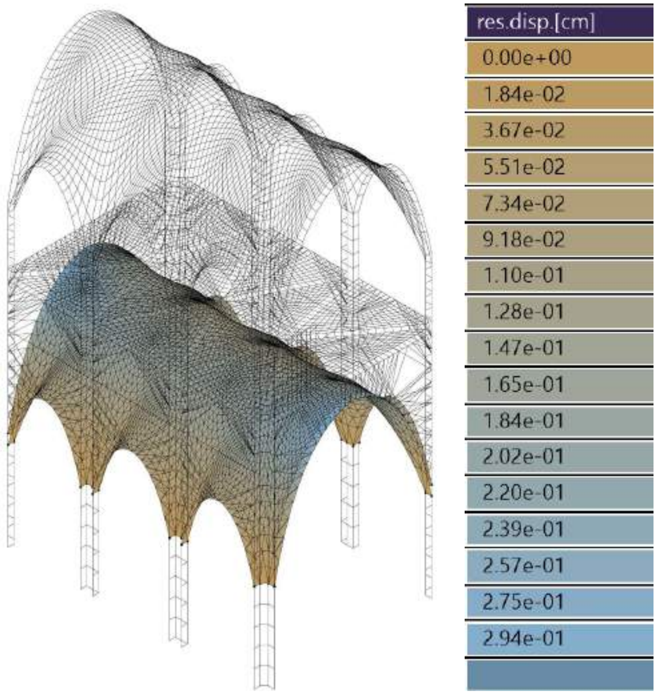
Table 5.7 : Structural Analysis for the roof of the ground floor of the house unit



Picture 5.16 : Displacement of the first roof



Picture 5.17 : Principal stress 1 of the first roof



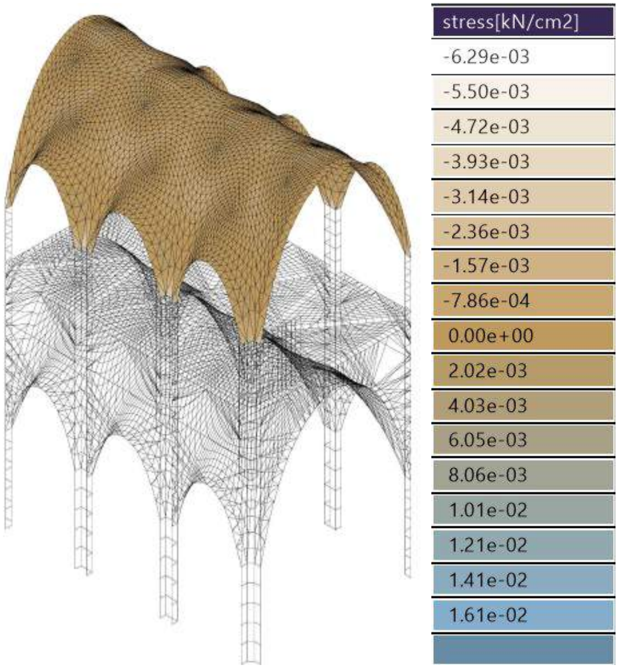
Picture 5.18 : Principal stress 2 of the first roof

5.4.i House Units- Second roof

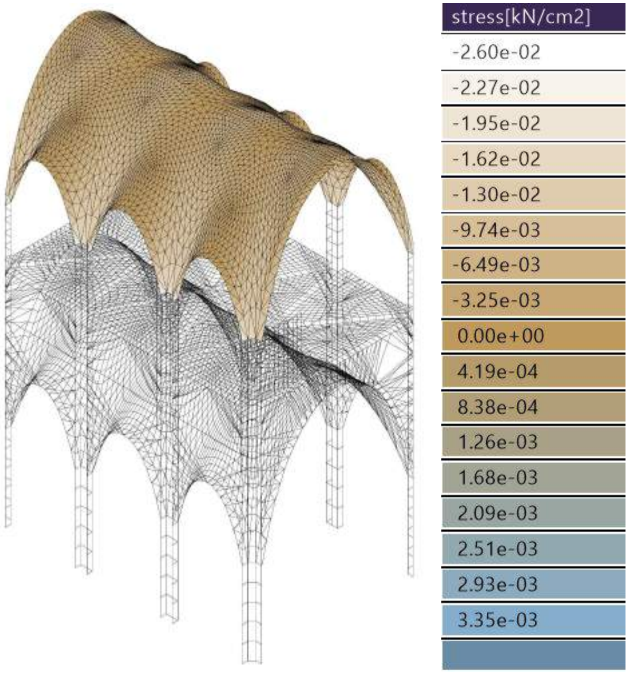
The following diagrams demonstrate the displacement of the mesh shells and the principal stresses at the roof of the first floor.
The deflection allowed is the 1/200 of the smallest span which is 1.5 meter, therefore 0.75 cm.
For the principal stresses the values on the legend that are not rendered on mesh shell do not exist.

Principal Stress 1		**Material Strength**
Maximum Compressive stress	0.0024 kN/cm2	0.3 kN/cm
Maximum Tensile stress	0.002 kN/cm2	0.03 kN/cm2
Principal Stress 2		
Maximum Compressive stress	0.013 kN/cm2	0.3 kN/cm
Maximum Tensile stress	0.00126 kN/cm2	0.03 kN/cm2
Displacement		
Maximum displacement	0.181 cm	0.75 cm

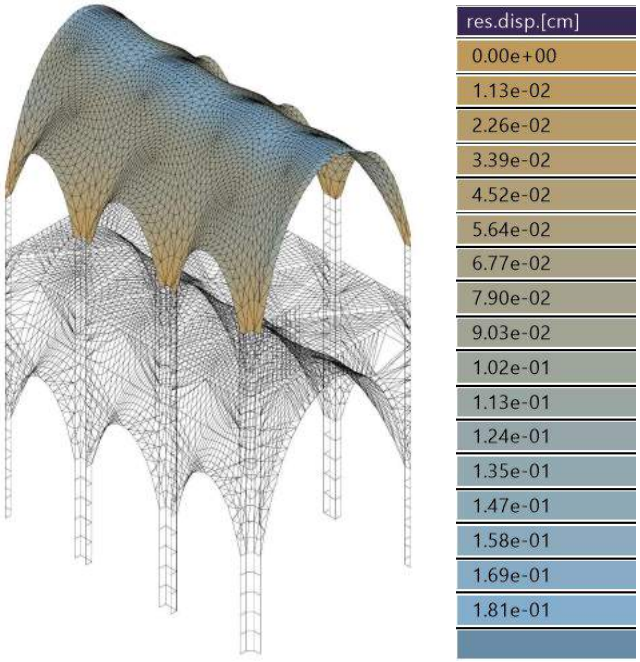
Table 5.8 : Structural Analysis for the roof of the first floor of the house unit



Picture 5.19 : Displacement of the second roof



Picture 5.20 : Principal stress 1 of the second roof



Picture 5.21 : Principal stress 2 of the second roof

5.5.a Corridors- Load Cases

Dead Loads

L1: Gravity
For the gravity load we took into account the weight of the material taking into account the research of Earthy groups from 2020.
Safety factor for dead loads: 1.35

Live Loads

L2: Wind load
The columns were tested as mesh shells for ease purposes. Therefore uniform line loads could not be applied. For this reason a mesh load was used instead. The value **1kN per square meter** was used multiplied by 1.5 which represents the span of the columns , representing the wind load applied in the side walls.
L3: Service load
A load of 1 kN per square meter is considered for roof access for future service repairs

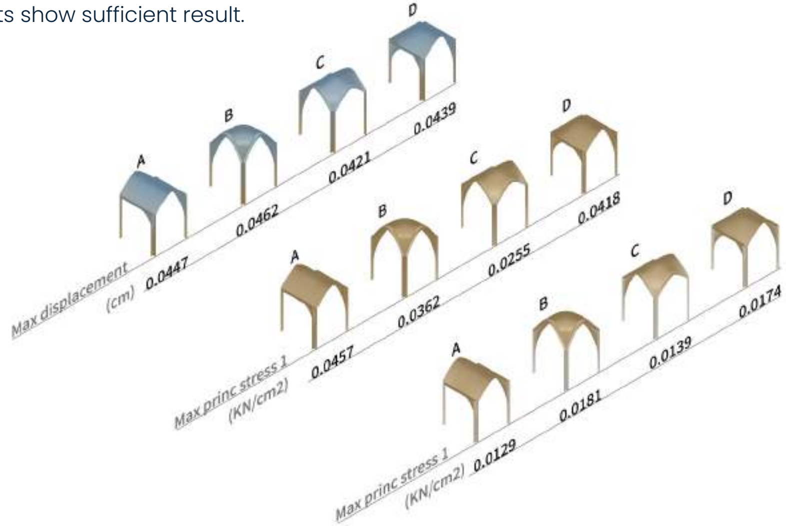
Safety factor for live loads: 1.5

Thickness of Mesh Shells
A thickness of 20 cm was applied in the mesh shells of the corridors and the riwaqs.

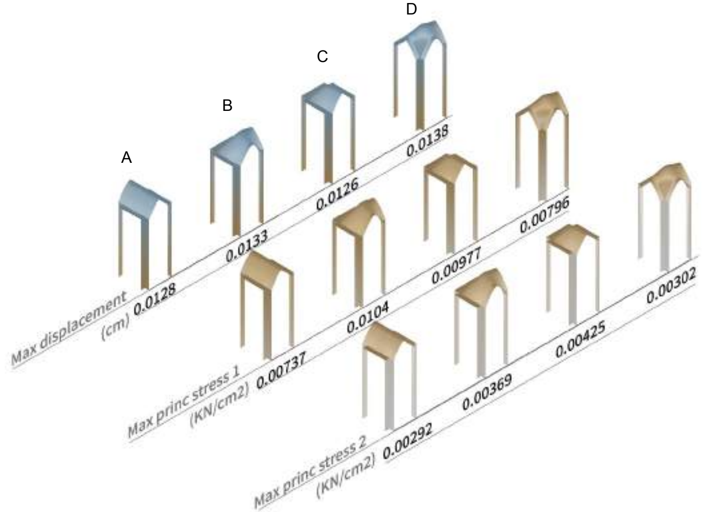
05.5 STRUCTURAL ANALYSIS | Riwaq and Corridors

5.5.b Results

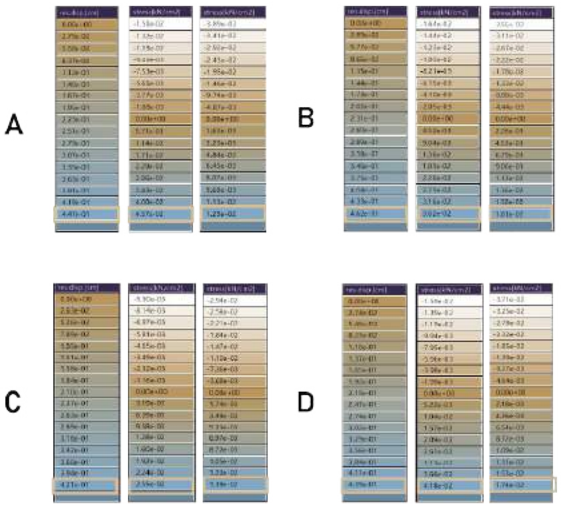
The following diagrams demonstrate the displacement of the mesh shells and the principal stresses at the Riwaq and corridor modules. the tesselation for the two modules is basic quad mesh tessellations with nodes fixed on the x and y-axis.
The deflection allowed is the 1/200 of the smallest span which is 1.5 meters, therefore 0.75 cm and all results show sufficient result.



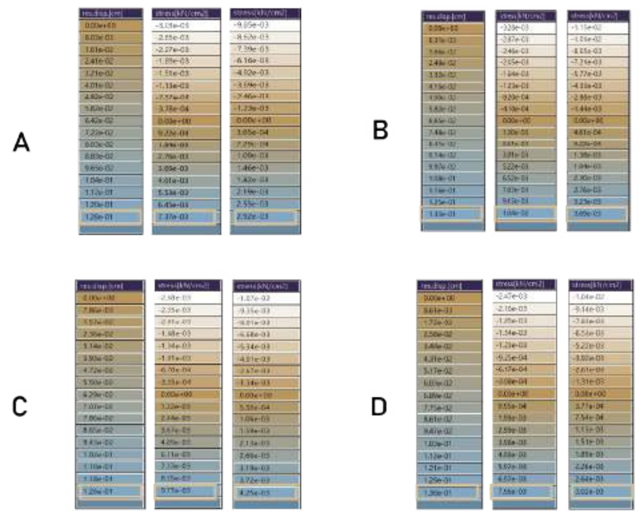
Picture 5.22 : Displacement and principal stresses of Riwaq modules



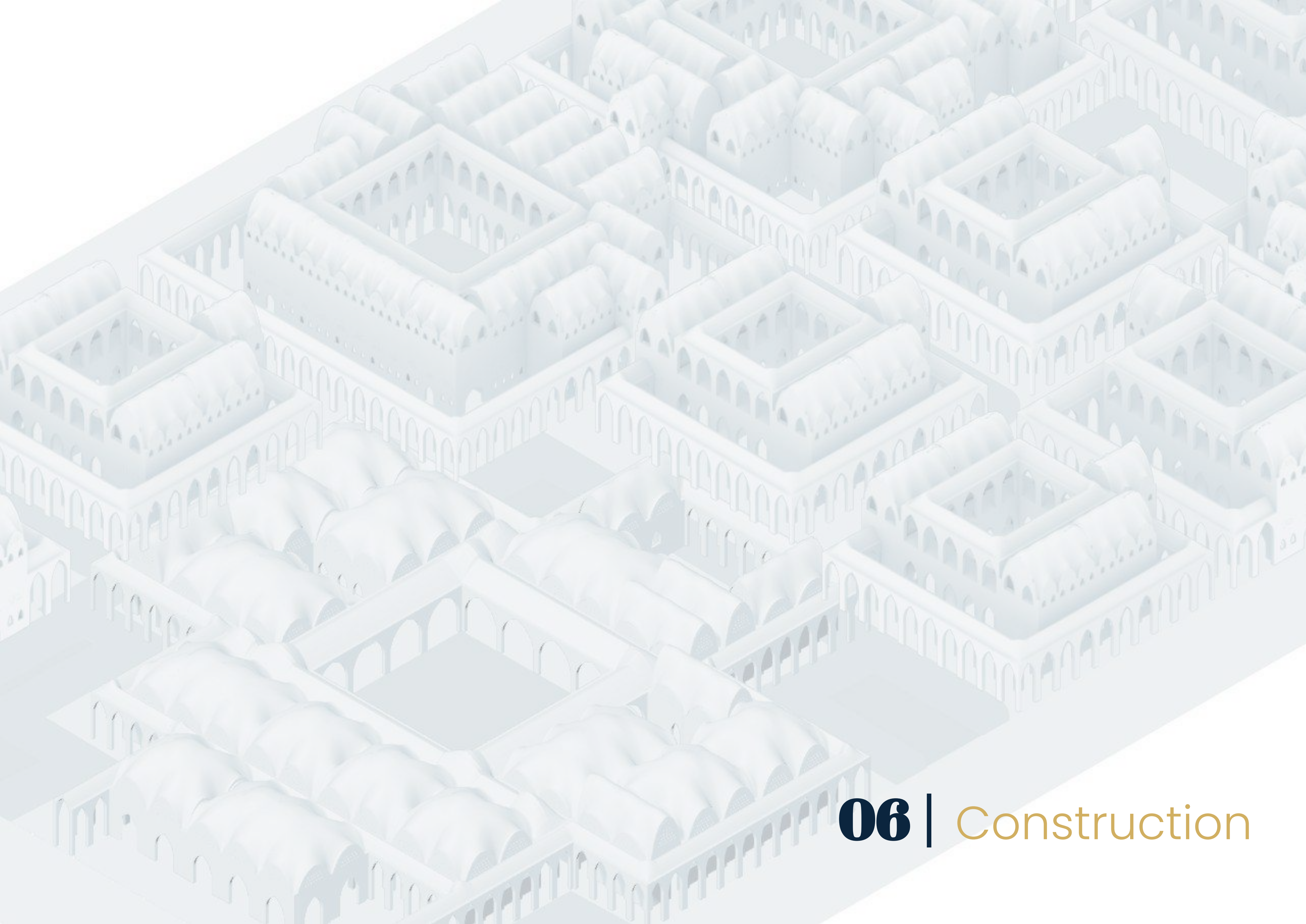
Picture 5.23 : Displacement and principal stresses of corridor modules



Picture 5.24 : Displacement and principal stresses of Riwaq modules



Picture 5.25 : Displacement and principal stresses of Corridor modules



06 | Construction

06.1 CONSTRUCTION APPROACH

Since we run structural analysis for the variations in the roof shapes and we validated their efficiency, the construction order of the units was defined. Each phase of construction of the room was structurally analyzed to ensure a proper and safe construction process.

Prior to this, the different brick sizes and shapes were designed in order to fulfill our design need to create a simple construction procedure for the user-builder. This step gave us guidelines on how to position the bricks in the construction. At the same time, the units' bricklaying was created with the aim of a grasshopper script as to be structurally self-stable and can be configured to cover the whole space's area.

Our main priority in the whole design process was everything to be easily produced on site from the refugees with all the available resources. So, the context of the project contains limitations since the pores for the construction must be found within the Al Zaatari camp. So the hubs units as the housing one should be completed with only the essential materials and techniques that can be easily replicated throughout the camp by the unskilled labor. Also, simple and modular tools needed were designed as to be easily created and assembled on the construction site.

Since the different spaces have different requirements such as bigger or smaller spans, number of supports, single or second levels on top, all the units alternatives are designed to be structurally independent.

In the same logic, the openings design was settled on, based on a catalogue of elements that can be constructed according to the refugees wills and needs.

Next to the shaping and constructing phase of our design, an initial process of detailing has been performed on it. In this part, alternative topics have been addressed, as to ensure the feasibility and success of the project.

Picture 06.1 : Auram press 3000, multi mould manual press
Auroville (source)

Picture 06.2 : Iran, Adobe making
Auroville (source)

Picture 06.3 : Adobe paste with straws
Auroville (source)

Picture 06.4 : Libya Adobe making
Auroville (source)

06.2 BLOCK COMPOSITION

Altogether, material properties are related to the analogy of ingredients that are used to form the final product, as far as the curing time and conditions to be made.

Literature research indicated that conventional mixtures of adobe blocks are generally composed by sand (40-70%), clay (15-60%) and water (8-12%). For consistency, previous Earthy reports were considered to come up to a final decision about the recipe that we were about to follow. In this way, the ingredients and the quantities for the standard brick composition were settled on as 30% clay, 30% fine sand, 40% coarse sand and 10% water of the total weight of the dry raw materials.

Firstly, the structural analysis of our structures had been performed with the basic materials' properties not only to understand their behavior and to ensure safety, but also the possibility to add an extra ingredient to bind together the recipe of the most stressed adobe blocks. So, the extra reinforcement helped us to amplify ductility and compressive strength to the blocks.

For the purpose of choosing the type of reinforcement inside the bricks, a survey of the composition of the solid waste flows within the camp had been take into account (Saidan 2016). According to that, the most common categories in the whole Zaatari camp that can be used as reinforcement were plastics (12.85%), textiles (10.22%), paper and cardboard (9%) and metal (4.82%) **[1]**. Based on the availability, straws are suggested to be added for its tensile quality in the percentage of 2% of the total mixture. Additionally, additives can be applied on the bricks to waterproof them such as seed oil, lime, and animal fat (Makers Bazaar, Earthy 2020).

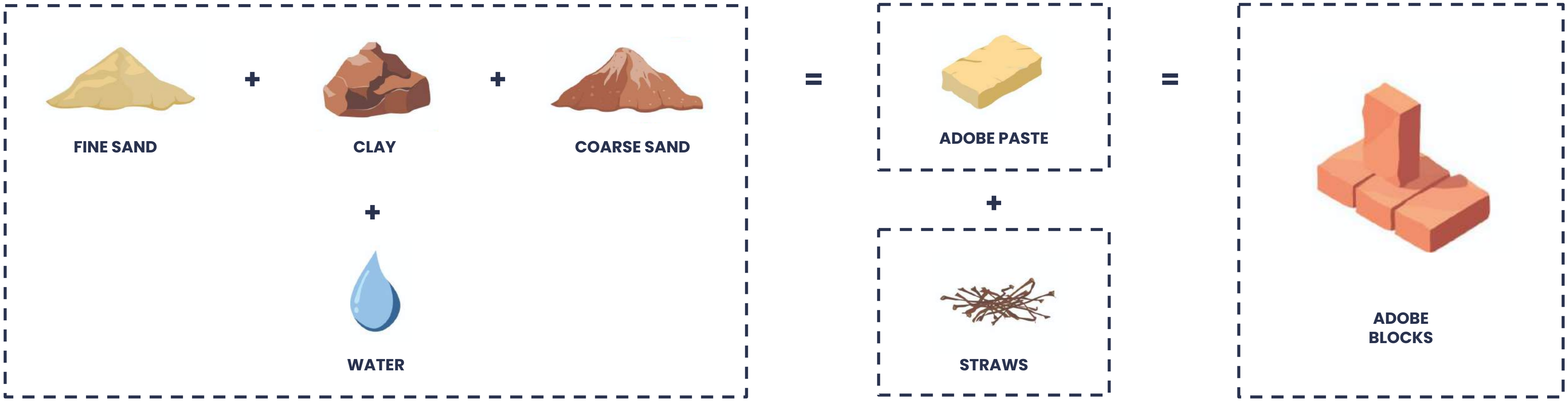


Diagram 06.1 : Block Composition illustration

06.3 BLOCK MANUFACTURE PROCESS

Our main priority was the adobe blocks to be constructed on site from the refugees in the brick production hub of our project, with the aim of the available material that can be found in the surrounding area.

The final mash, raw soil, is slightly moistened, poured into the steel press and the compressed manually into the moulds, which can be in different shapes and sizes (Auroville). Then, the required shaped paste is allowed to dry firstly for 7 days in the shadow and then for approximately 30 days in the sun to harden as to create the blocks, following a linear production process **[2]**.

Finally, the mortar, that keeps the bricks together in the structure, was also prepared with the same basic composition but with a higher water percentage as required to produce a sticky mixture.

INGREDIENTS	MIXTURE	MOULD	PRESS MACHINE	SHAPING	DRYING
Clay 30% Fine Sand 30% Coarse Sand 40%	Mix Dry Ingredients	Choose Mould	Manually Pressed	Dry in the Shadow	Dry in the Sun
Reinforcement 2%	Add Water	Add Mixture		Cured for 7 days	Cured for 30 days
Water 10% (of the total mixture)	Mix them together				

Diagram 06.2 : Block Manufacture Process Illustration

06.4 BLOCK TYPES

The set of rules that were stated in the previous pages introduces the main steps, which have to be followed as to manufacture the compressed earth blocks. Those instructions were further developed, based on parameters such as the hand the press that is used in the manufacturing process and the more specifically curing conditions for the formation of the bricks.

In order to make efficient structures of arches, vaults and domes and a convenient construction procedure, the brick making logic has been further evolved into different forms of compressed unstabilized earth bricks. Different measurements and brick patterns were designed.

The kit of the adobe blocks is divided according to the tiles' destination.

- Starting point in this process is the typical brick, which is used for the columns and the walls of the structures. It is the most typical brick of our collection while its size derived from the desired wall thickness.

- Next part of our kit are the adobe blocks that help to design the arches of the structure. In this one, we have the main brick, which is also used for the ribs and it is slightly thinner compared to the typical brick.. The key brick is also added in this kit and it is actually the piece that locks and bind together the arches with the one side to be narrower compared to the other.

- Another variation on the size has been done to design bricks for roofs. A lightweight brick that is works as a tile to cover the vaults and domes.

- Last collection includes the ribs' bricks and mainly the three different types of the key bricks.

These brick components are used to develop, detail and accomplish the building systems of which the design for the production and housing units are made of.

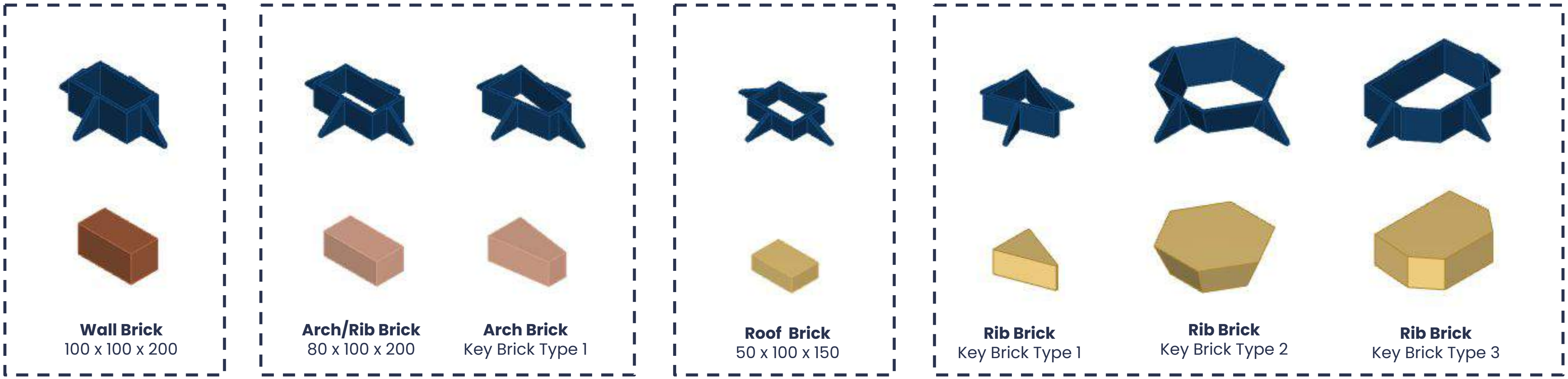


Diagram 06.3 : Brick Types

06.5 TOOLS & METHODS

The constructability of the buildings plays a major role in the design of the different unit structures. Every design choice for one of the buildings is thoroughly checked whether it's constructable or not.

The factors that are taken into account for this procedure are:

- The occupants of the camp must be able to build such structures..
- The materials have to be available on site or nearby.
- No tensile stresses are permitted to occur on the structure during the building process.
- The use of scaffolding should be avoided due to safety reasons.
- The use of formwork and guides should be kept at a minimum range and must be always reusable due to the the resources in the area.

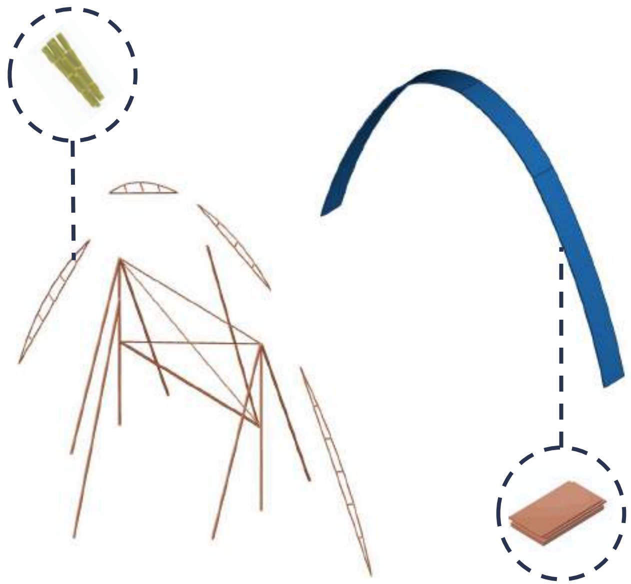
The focus of the constructability was mainly on how to construct it with a minimum of the available materials instead of how to construct it fast or in an efficient way. It is also assumed that the labor costs are low and that there are not very strict safety rules for the workers. This pushed this project in a way to come up with creative solutions instead of the obvious solutions.

Various construction systems were studied to construct domes and vaults with minimal or no form work. The chosen was the free spanning technique, a process that allows construction of individual components, which can be combined in different ways to create the desired roof geometry.

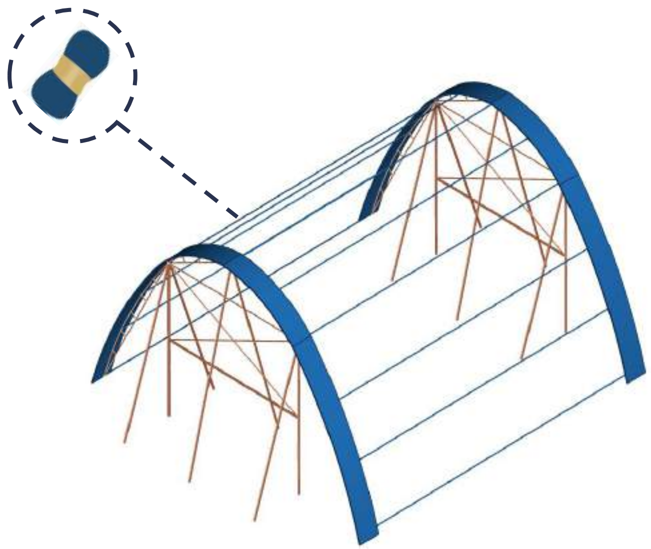
This method with the aim of jigs bind together, we were able to create the desired shape of the catenary arches. On top of them a cardboard surface was placed as a guide for the arches formation.

Moreover, strings were used as to assist the proper shape and form of the vaulted structures, in order to lead the blocks on truck.

The aforementioned tools came out from an analysis of the resources present in the camp.These elements, together with other basic instruments and methods have been collected and illustrated to provide the workers with a clear toolset for the construction of the earthy buildings.



Catenaries Guides for Arches & Ribs



Curverature Guides String for Vaults

Diagram 06.4 : Guide tools illustration

06.6 FOUNDATION

As any other building, brick structures need foundation.

1. The tartan grid that defined the wall for the units is first marked as to create the **structures margins** on the site using chalks and marking ropes.

2. An offset of 0.5 meters is then excavated creating a **hole in the ground** up to a minimum depth of 1 meter, while the soil that is dug up will also be used for preparation recipe of the adobe blocks.

3. The first half-meter is filled with **rammed stones**, because they soak less water than adobe bricks and they can be found in the area around the camp.

4. On the top of them, the **shoe footing is constructed**; as the previous layer prevent any capillary action in adobe while it provides additional stability to the columns and the walls.

5. Then, **rammed earth filling** is used beneath the footings to keep everything in place and to flatten the floors.

6. Finally, the floor at the higher levels is equalized with brick tiles as to make a **flat surface** and covered with the mud plaster that doesn't contain animal fat.

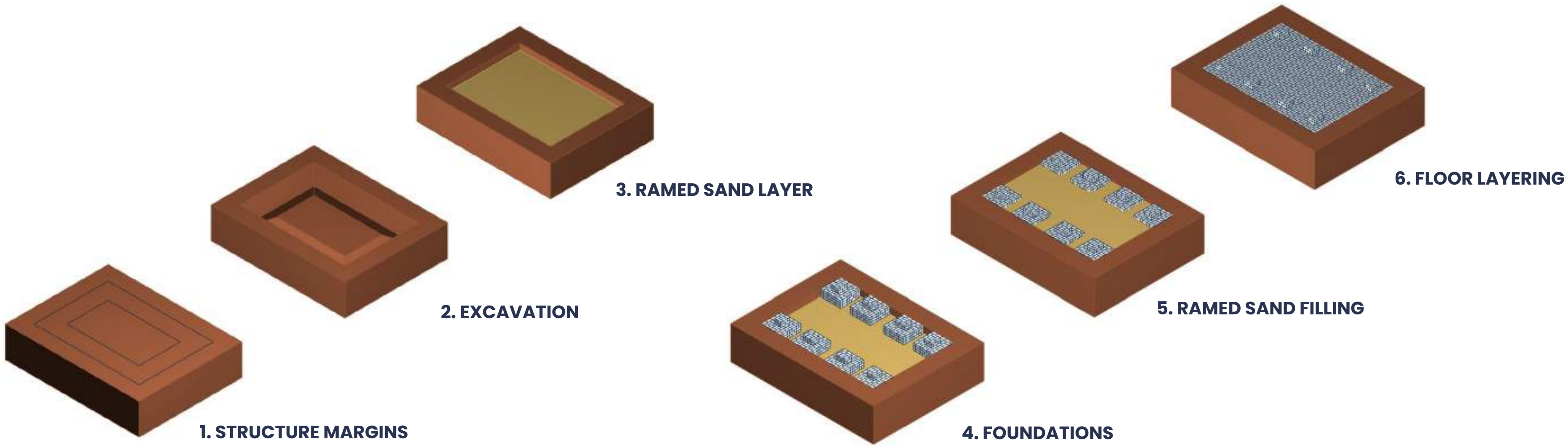


Diagram 06.5 : Foundation construction order illustration

06.7 ASSEMBLY ORDER | Single-floor

A construction manual with the assembly order of the different designed unit is created as to guide easily the unskilled refugees about the necessary construction stages that must be followed in order to complete the structures. This will also explain the steps and methods to create tools and guides that was previously mentioned from the locally available resources.

In the following diagram, the construction phases of the single-storey building unit are illustrated step by step.

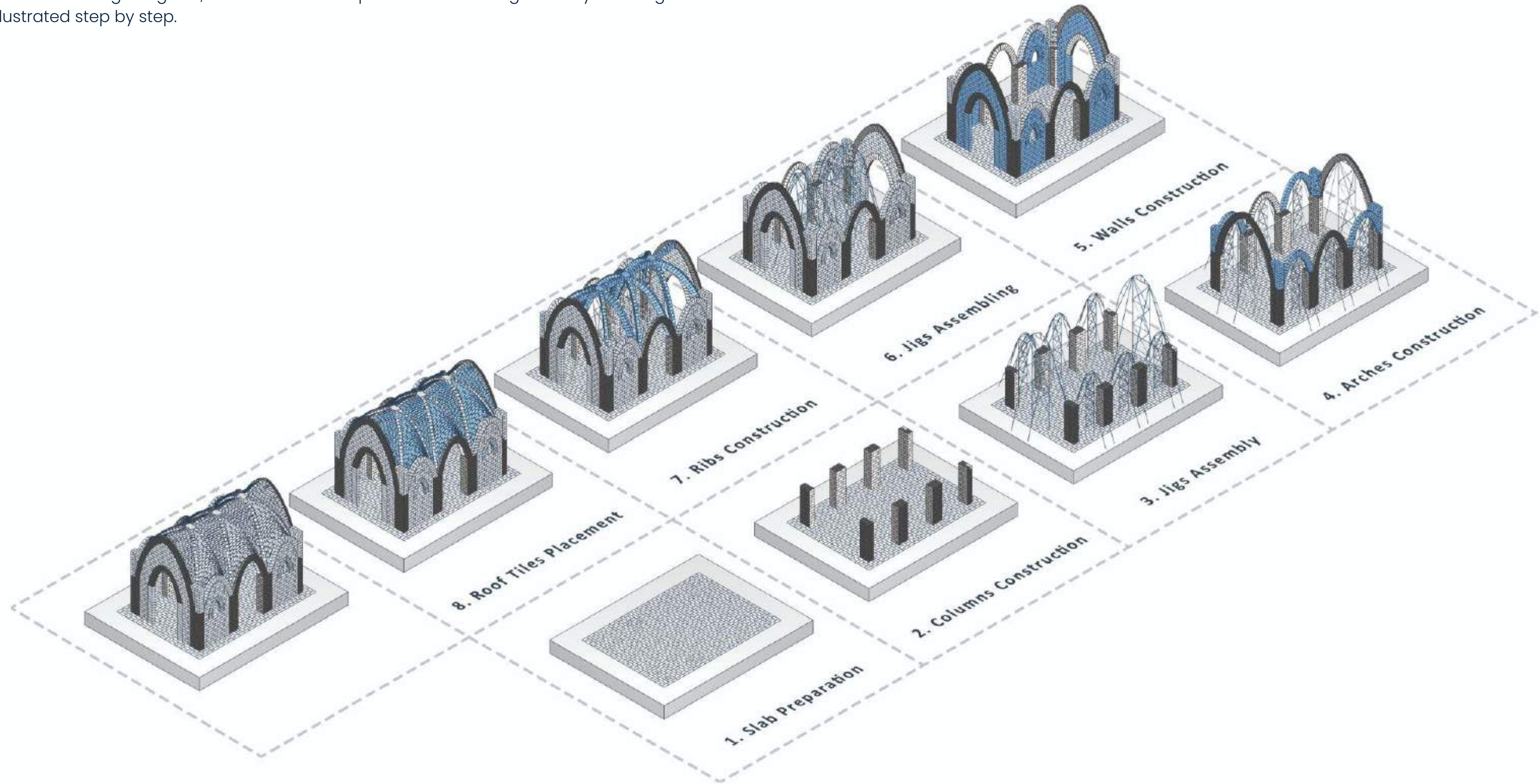


Diagram 06.6 : Construction Phases of Single-floor Unit

06.7 ASSEMBLY ORDER | Double-floor

Especially in the housing part of our project the second floor addition was necessary. For this reason in the next diagram the construction phases of this addition is depicted.

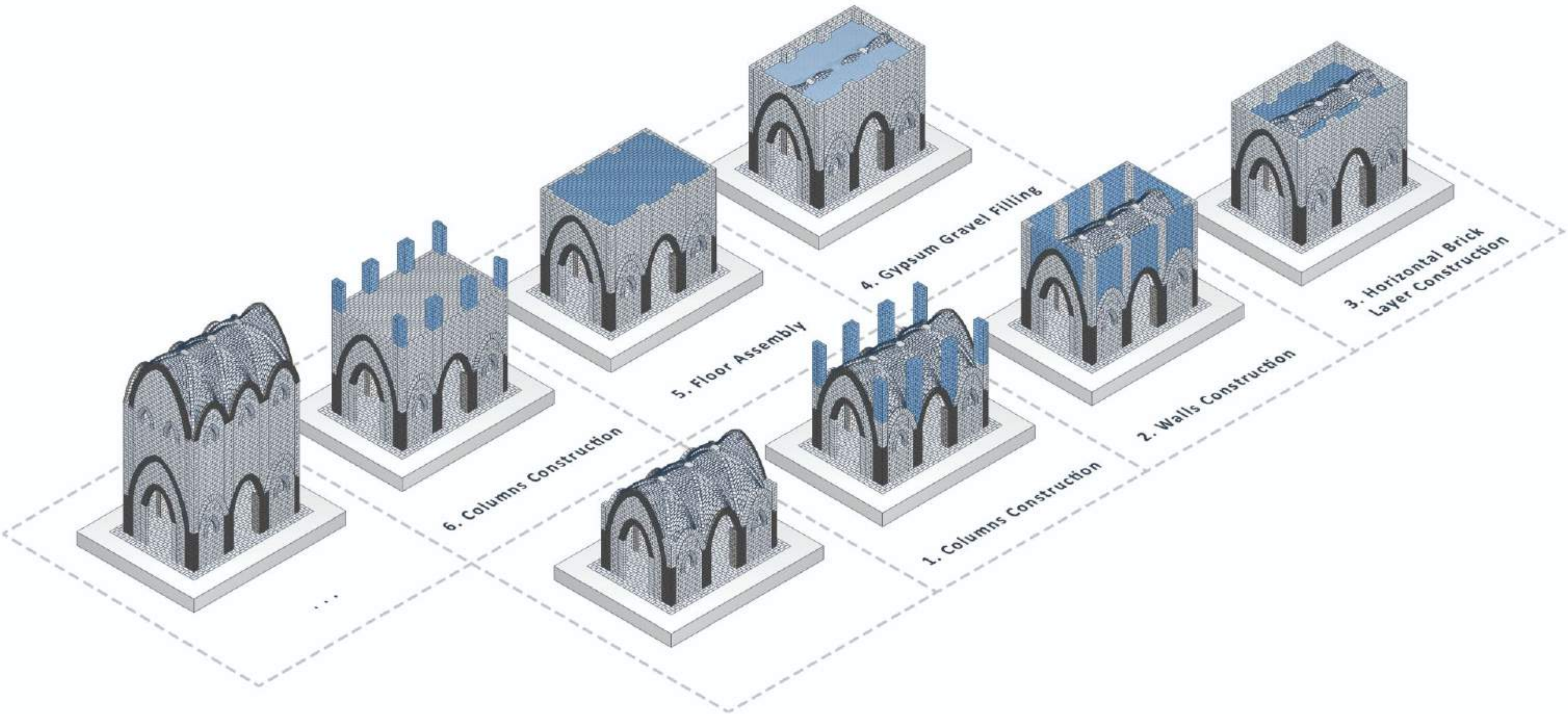


Diagram 06.7 : Construction Phases of Double-floor Unit

06.8 DETAILS | Rainwater Management

The Zaatari refugee camp of Jordan is located at the border of the Arabian Desert, where precipitation levels are really low. However, if it rains, the water needs to be removed from the unit structures as fast as possible, since the remaining water is able to cause damages on the earthy adobe bricks and therefore the buildings.

For the roofs of the building system in particular, rainwater management solutions has been defined as necessary and crucial. Knowing that such a strategy could be potentially integrated in the computational logic with which our layout tool assigns roofs to wall modules, the research has been limited to more standard and easiest options that could represent a tangible solution to this problem.

For this reason, a network of gutters on the ceiling surfaces were made to lead the water of the structure, while the lengths of the gutters are minimized, and the roofs are placed in such a way the water can always finds its way to a gutter. Also the valleys of the roofs are filled with mud plastering as finishing layer in order to cover any gaps. At the same time, it creates the proper angle in order to redirect with their inclination the water in the exit to the yards.

One of the first ideas to collect and discharge water at the valleys generated when four roof modules meet on top of a column has been to integrate a gutter into them, so that the water could then flow through pipes located in the floor. However, even this solution meets our design goals, it isn't that practical from another point of view, which shows many drawbacks related to their maintenance. Bringing rainwater inside the building and being the integrated gutter, we create difficulties to access and maintain this area, while moisture could deteriorate the material status.

Moreover, we designed a unique brick to serve the role of an external gutter on the walls and the columns as to guide the water flow. Both this surface and the outside of the building will be plastered with a waterproof layer. This layer consists the same materials as the adobe bricks, including animal fat as extra additive. This animal fat will provide the material a protection against water.

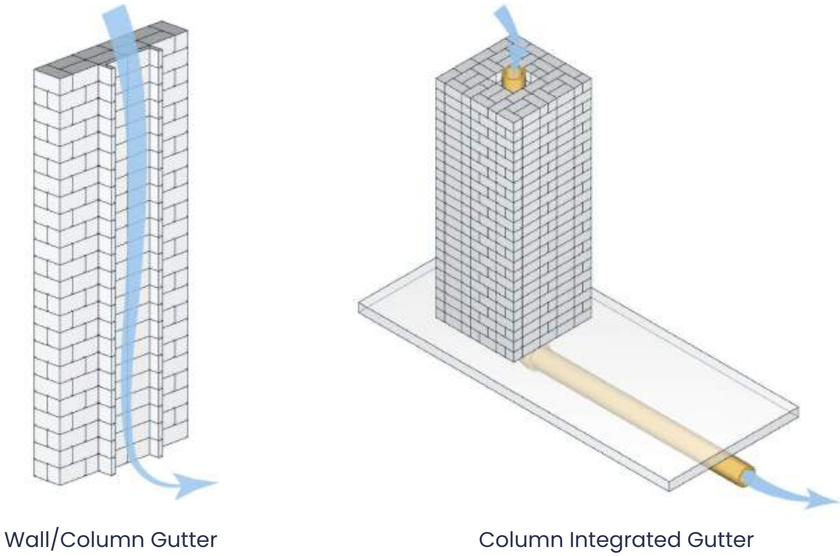


Diagram 06.8 : Drainage System Details

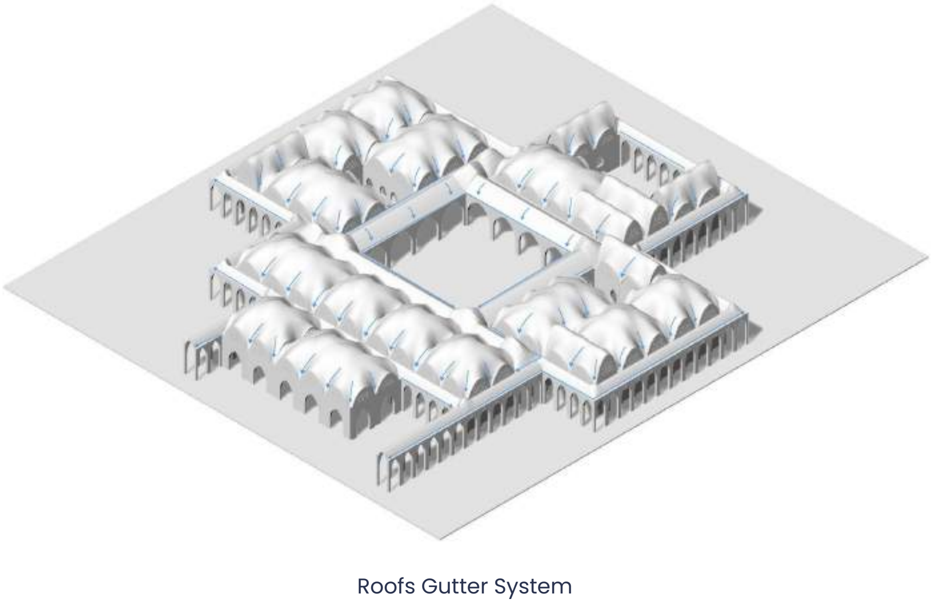


Diagram 06.9 : Drainage System

06.8 DETAILS | Slab

Initially, during the design procedure of the structure, we looked and designed various block types in size and shape in order to achieve efficient and doable construction. In that process, we came up with adobe bricks that could serve as gutter in the ribs and the roof tiles of the units when they doesn't have a second floor.

Nevertheless, when a second floor is needed, a slab is created with a gap space in between. This hollow area would be filled with another special brick type on layers in distance, although their space between this horizontal brick layers will be filled with gypsum gravels.

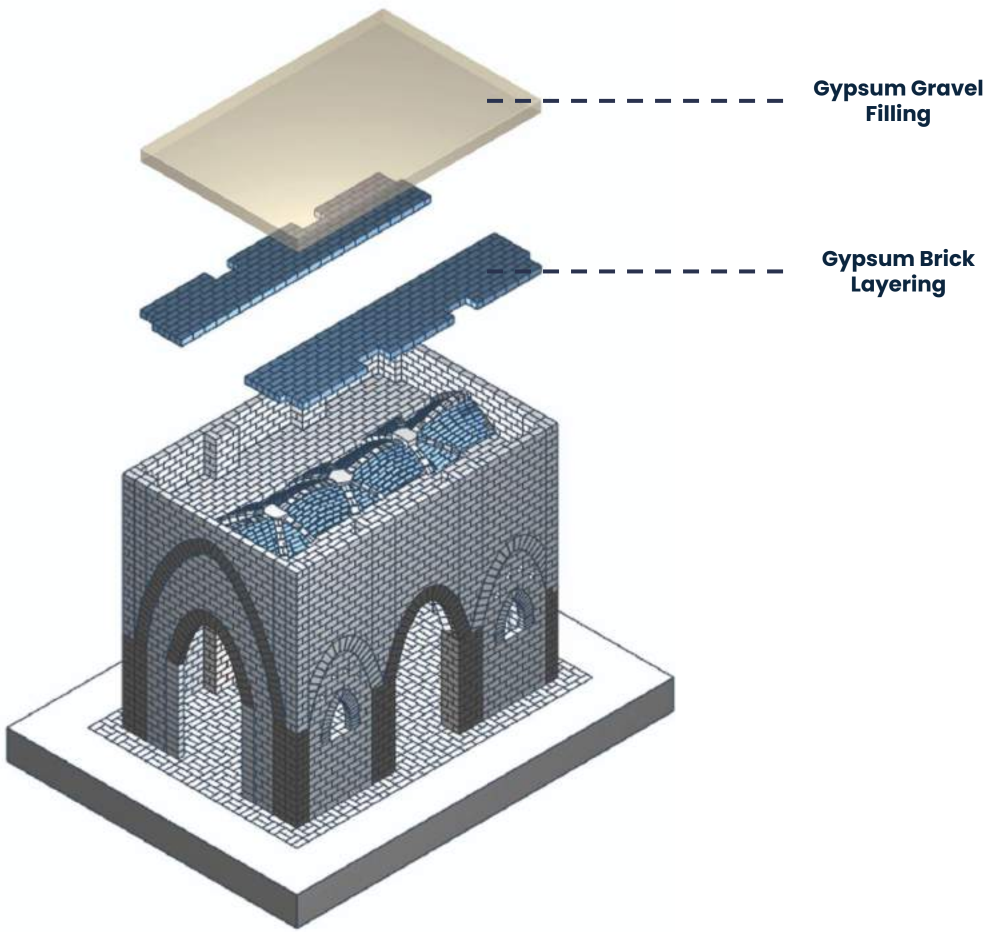


Diagram 06.10 : Inner Slabs System

06.8 DETAILS | Irrigation System

in Permaculture Project, the yards and the gardens are always connected to the households even they are referred to the private or the communal one, so the vegetation is mainly around the house. So, it would be a great idea to adapt the grey water collection combined with gardening in certain parts into these yards as to upgrade their own living environment. Consequently, grey water can be used as a solution for high water demands, especially in semi-arid zones like Zaatari camp.

Grey water management is a really promising tool to use directly for irrigation purposes. Trees can absorb the contaminated water by reusing it in their root zone. So, developing a system to irrigate the gardens, it firstly saves a lot of treatment costs. and moreover the water is the only essential source for greening Zaatari.

In this way, the following system has been developed:

1. Grey water is collected in a whole on the yard of the house.
2. This hole is filled with rocks, while the space in between them has enough space to accommodate the water.
3. This hole is also filled with a layer of gravel.
4. An overflow hole is made next to the previous hole, where the filtered water flows after it's overuse.
5. Trees are plant on the top of the gravel surface, as they suck up the polluted water for irrigation purposes.
6. In the remaining space of the yard vegetables and herbs can be plant, since the overflow hole delivers filtered water that can be used for the gardening.

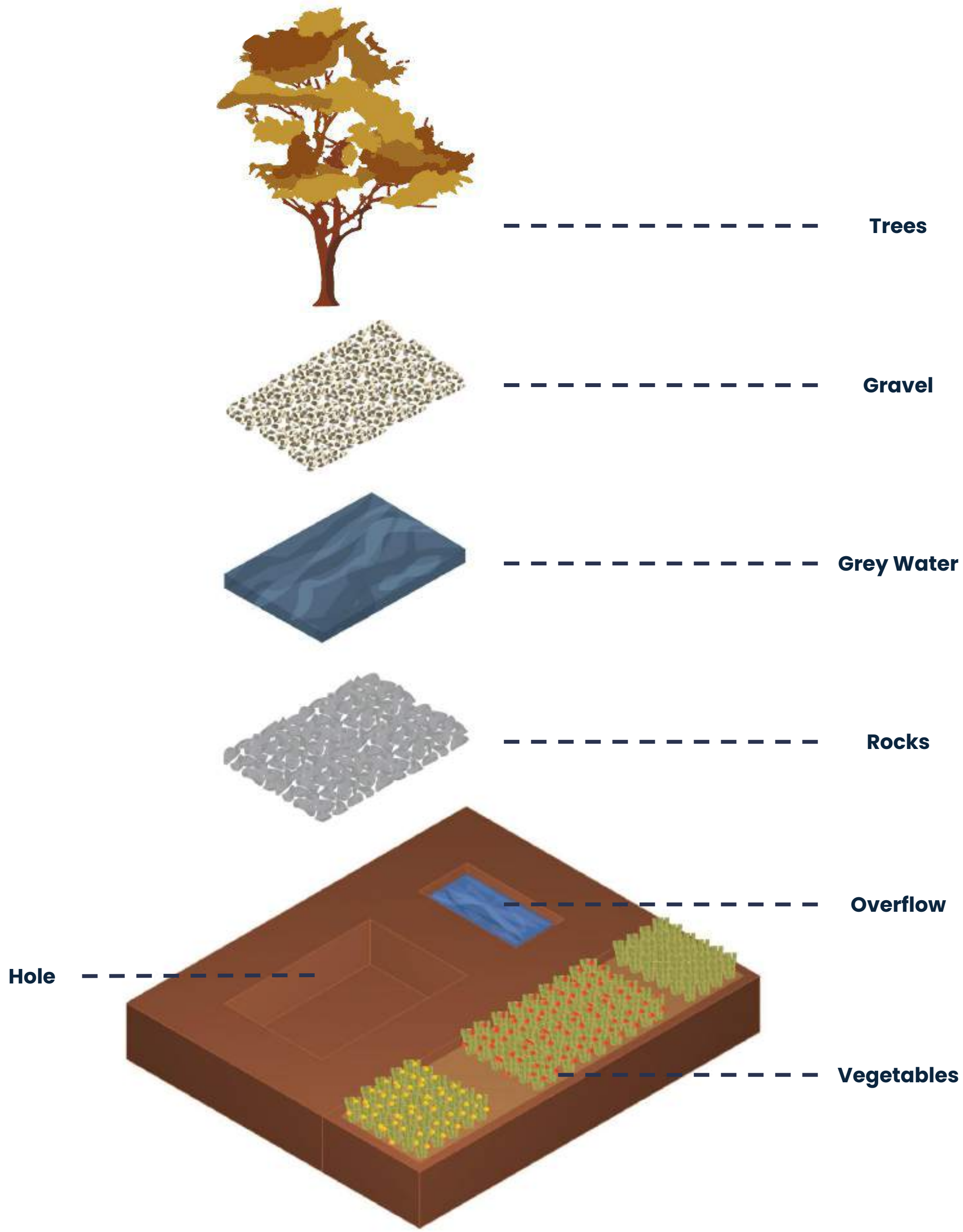


Diagram 06.11 : Irrigation System

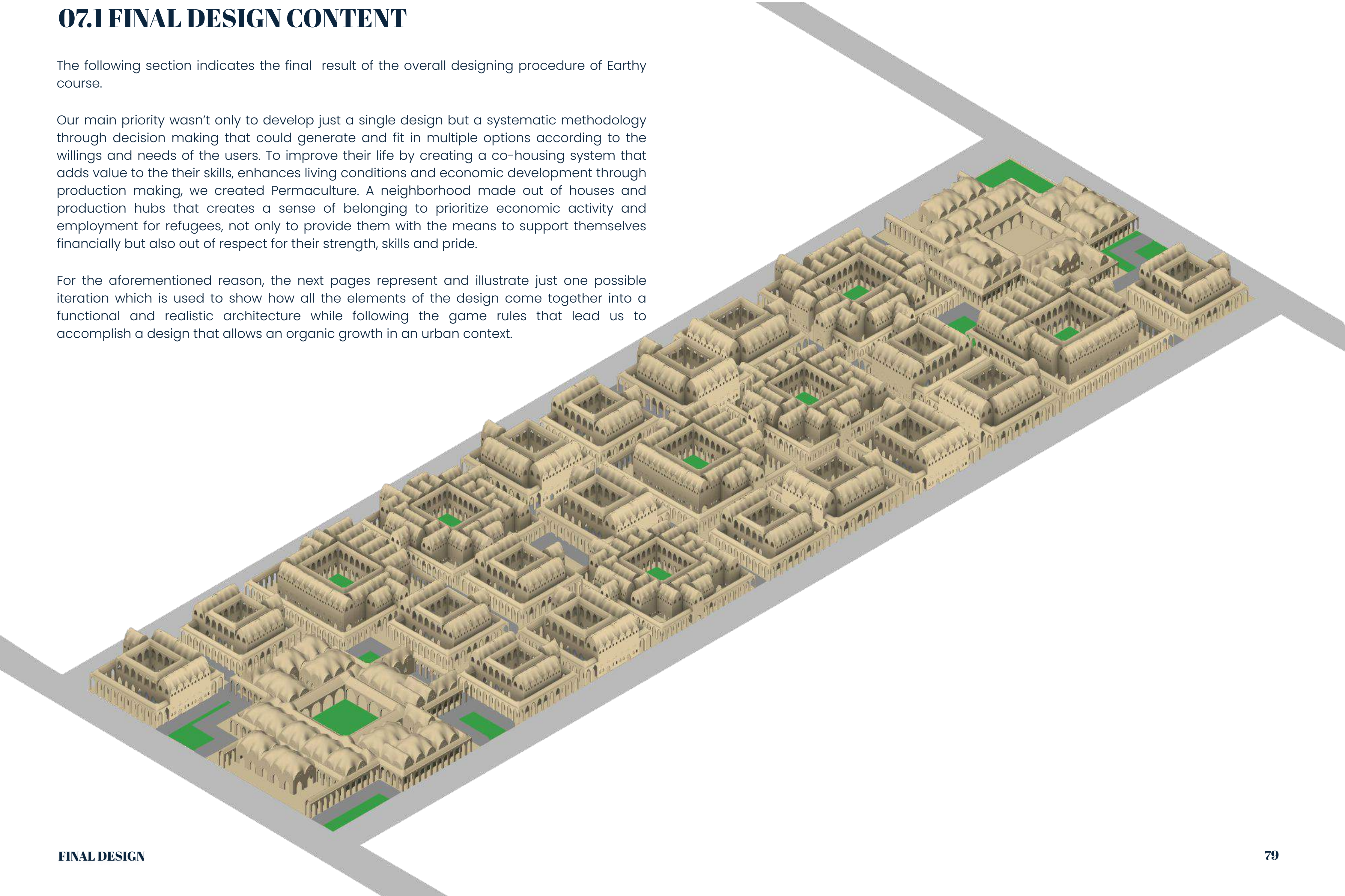
07 | Final Design

07.1 FINAL DESIGN CONTENT

The following section indicates the final result of the overall designing procedure of Earthy course.

Our main priority wasn't only to develop just a single design but a systematic methodology through decision making that could generate and fit in multiple options according to the willings and needs of the users. To improve their life by creating a co-housing system that adds value to the their skills, enhances living conditions and economic development through production making, we created Permaculture. A neighborhood made out of houses and production hubs that creates a sense of belonging to prioritize economic activity and employment for refugees, not only to provide them with the means to support themselves financially but also out of respect for their strength, skills and pride.

For the aforementioned reason, the next pages represent and illustrate just one possible iteration which is used to show how all the elements of the design come together into a functional and realistic architecture while following the game rules that lead us to accomplish a design that allows an organic growth in an urban context.



07.1 FINAL DESIGN CONTENT

SECTIONS

Diagram 0.1 : Section Through The Site

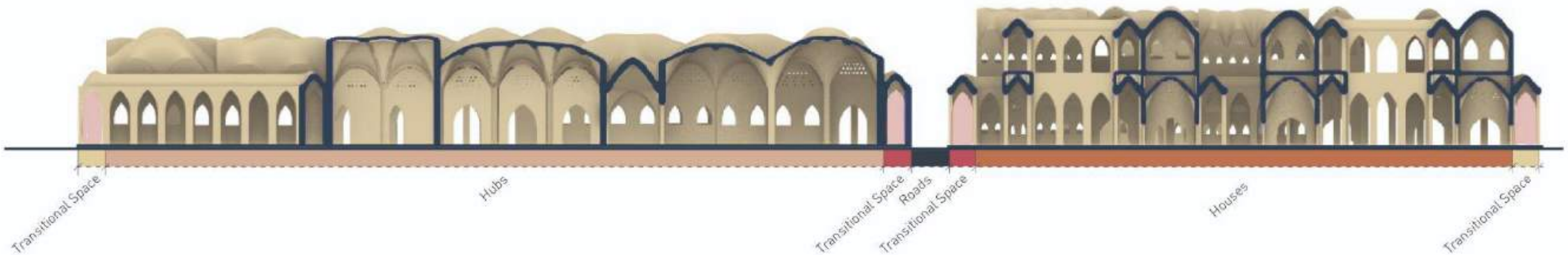


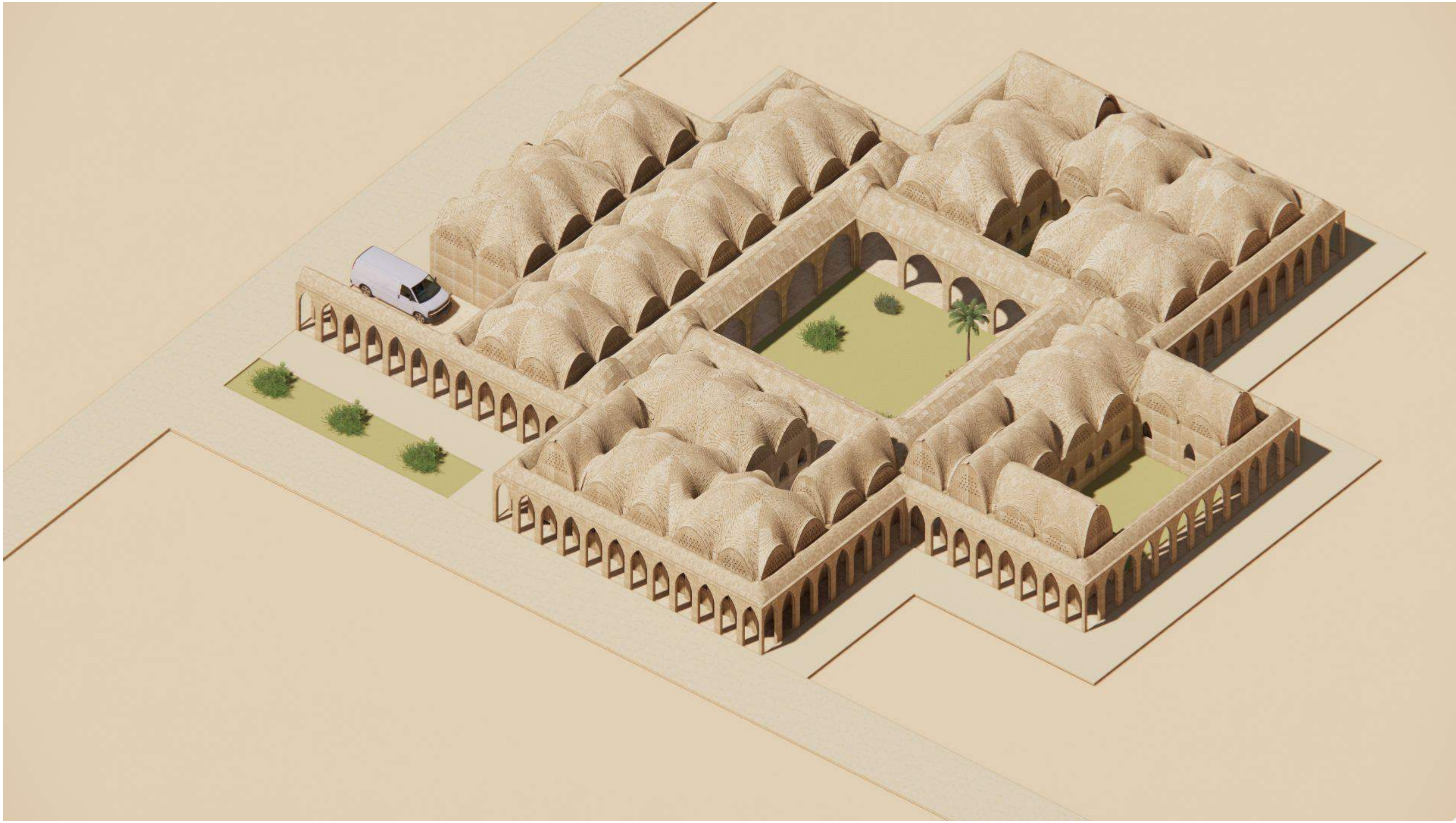
Diagram 0.2 : Section Through The Site showing the zones of transitional Spaces between uses.

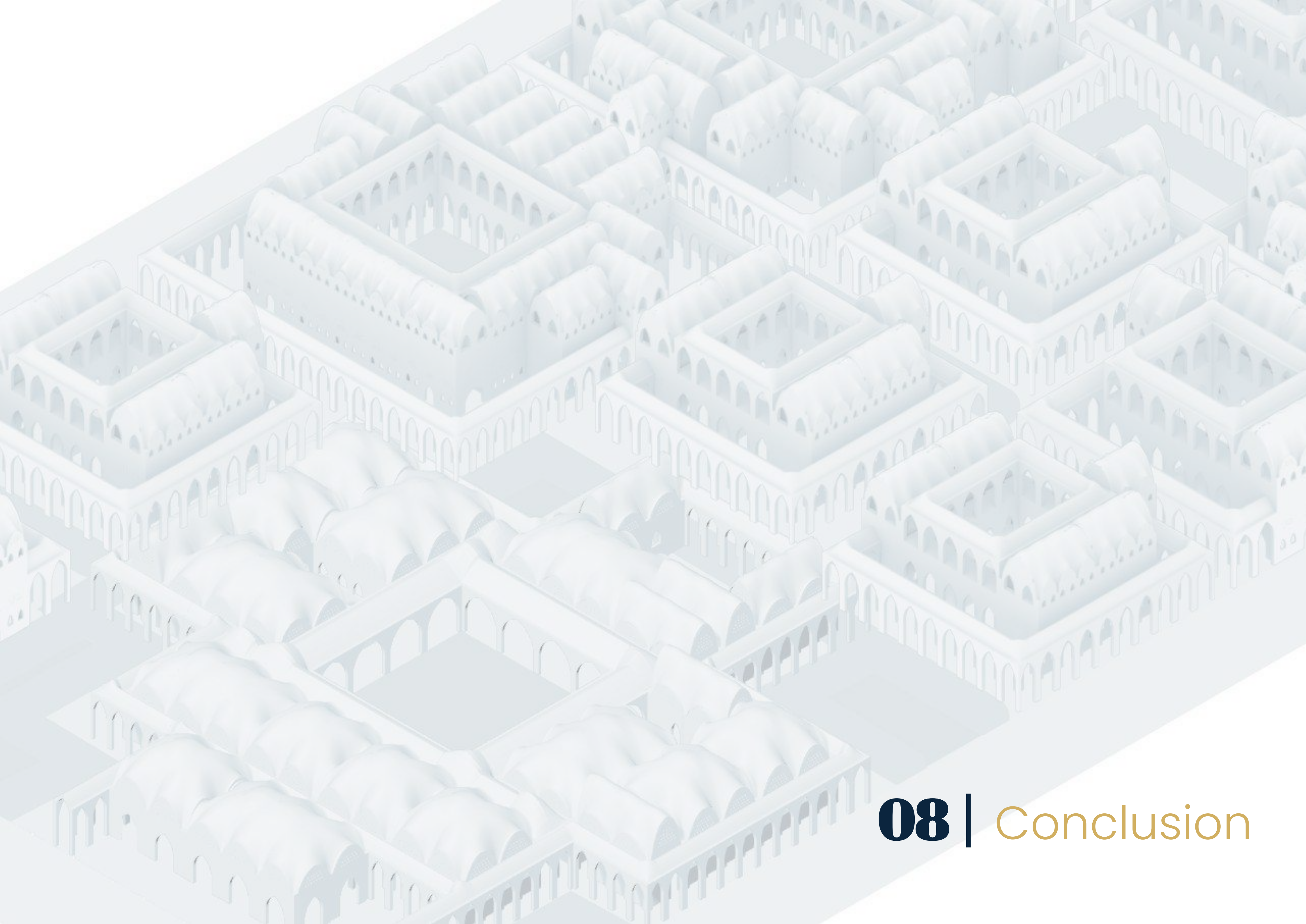
07.1 FINAL DESIGN CONTENT

VISUALISATION

07.1 FINAL DESIGN CONTENT

VISUALISATION





08 | Conclusion

08.1 CONCLUSION | Limitations & Further Development

As it is in every project and research and considering the limited amount of time that was available to create this project, there are always things and parts that could be improved or further developed. These could range from the configuration to the detailing part in order to consider Permaculture Project as completed in this instant point.

For this reason, this final section covers some of the possible directions or redirections of research, design and testing that we didn't have the proper time to explore properly. So, a detailed recount of elements within our project that should be improved will be listed for every step of the design procedure.

CONFIGURATION
The configuration was done manually, and a board game approach was taken. though it was interesting to solve the logic and come up with the rule sets; the configuration would be interesting to develop as a computational scripting using python and pygame. this could not have been done since all members in the group were new to the programming.

SHAPING
The tessellation pattern changed a lot throughout the course. Initially a triangulation method was used, however it was changed to a quad subdivision.

A further improvement would be to develop a code for subdividing the initial mesh according to its size and need of columns.

A further improvement would be to develop a code for stair generation script to generate stair modules based on the sizes of the housing and connecting points.

STRUCTURING
The Structural Analysis took into account the allowable deflection limits and principal stresses. Hand calculations were performed for the buckling check. Initially the thickness of the columns was less, but had to be increased due to the deflections. For ease of designing and optimizing speed, the columns were checked as mesh shells. However, a structural verification by considering them as beams would be preferred. This can be performed by measuring the reaction forces resulting by the roof load.

Another improvement would be to consider the excess load due to the water absorption of the bricks.

Finally, the structural verification did not consider the wall filling between the columns, therefore the final structures, after placing the wall partitions, are expected to perform better.

CONSTRUCTION
As far as construction is concerned a lot of research had to be done in a really short timeframe. This year, we didn't have the opportunity to construct our own bricks and test them as to have a better understanding about the different materials composition's behavior.

About the materiality, more investment had to be done on the gypsum brick composition and its potentials in the as structural element for the ceilings.

A further and more detailed approach was needed on the integrated drainage systems into and the columns and their material that had to be done. A part that showed some drawback but it had a lot of potentials to be further analyzed.

The rulebook logic of the wall elements such as openings, windows and doors had to be developed on its assembly order and logic. Something that was designed but it didn't explained because of the narrow timeframe.

08.2 INDIVIDUAL REFLECTIONS

Namrata Baruah

It was an interesting and intense course. The lectures at the beginning of the course were very informative but we couldn't become proficient enough to use those tools in our project. Additionally, we as a group had a fairly large scope and because of which we could not go into details, but we did enjoy the process and tried our best. I personally had a lot of fun creating the group avatars and working on the gamification of the hub configuration. Nevertheless, there are a lot of areas that still need improvements but it was a very new challenge and a good base for further exploration!

Sofia Kouvela

Earthy 4.0 was an intense and quite challenging course. So many new concepts and tools were introduced in terms of lectures and way of thinking and approaching the design challenge through gamification. I personally felt that the new information given to us at the first part of the course compared to the time we had to absorb it were really proportional. I that sense I would have liked to be able to have more time to practice what i was taught in the lectures. As far as the second part of the course is concerned I enjoyed a lot approaching the design goal in a gamified way, it was something new and eye opening. Working in a big team was quite challenging in order to make proactive decisions at the right time and not waste time discussing.

Stella Pavlidou

I feel that we faced a lot of challenges throughout the course and even though I appreciate the introduction of the new tools, I think that we took too seriously the request to challenge ourselves more. Putting a lot of rules on our table resulted in limited time to experiment with the tools. I would also like to have enough time to apply the voxelization system in the structural design, which in our case was not applicable due to the initial design and the time.

Solkyu Park

While feeling a lot of pressure from the word 'computational design', I came to earthy class with great anticipation for introduced computer languages such as python. I feel like I'm still learning the basics, but the python classes that were conducted in the beginning had good classes that served as a foundation, and I think I will have to study alone based on these. The workload set by the group was huge compared to other groups, and the result did not reach python deeper. However, the consultation went in-depth and pointed out many things I was curious about. It's a pity that I couldn't put in a little more time and effort, but I learned a lot and it seems to have become a good foundation for writing my thesis.

Isidora Matskidou

Earthy 4.0 has been a course like no other before! Designing a project that combines elements of earth architecture with computational methods, strategies and tools, and finally come up with a structurally sound design is not something that we were accustomed to. At the same time, it was a really hectic and overwhelming course while the information storms didn't really help us to concentrate in specific parts and develop our skills.

However due to our different backgrounds, we used each other's strengths to come to a successful design. The road to this has not been easy. Our design choices posed various challenges that had to be solved within a relatively limited amount of design space and time as well. Apart from that, our different views had to be aligned at every meeting, while we had to divide the different project parts to be developed and completed at the same time.

Throughout the process, this has manifested itself in the fact that the project has always been a compromise between methodology, decision making, architecture and engineering approach. Apart from the final result, the process has been a steep learning curve.

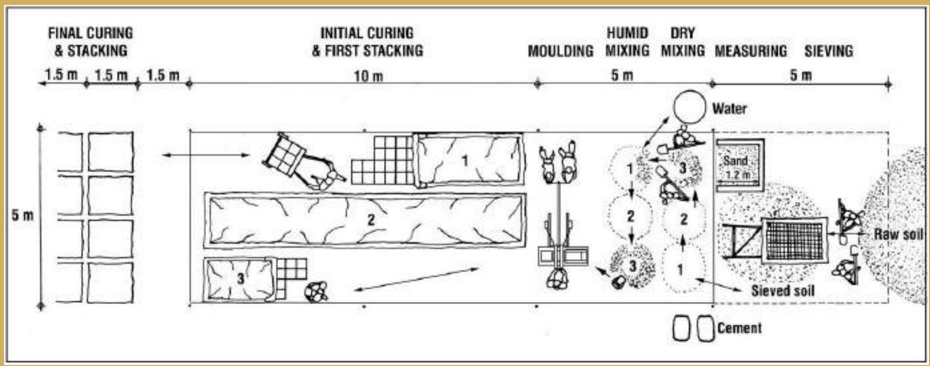
APPENDIX A

[1] For the purpose of choosing the type of reinforcement inside the bricks, a survey of the composition of the solid waste flows within the camp had been take into account (Saidan 2016). According to that, the most common categories in the whole Zaatari camp that can be used as reinforcement were plastics (12.85%), textiles (10.22%), paper and cardboard (9%) and metal (4.82%). Based on the availability, straws are suggested to be added for its tensile quality in the percentage of 2% of the total mixture. Additionally, additives can be applied on the bricks to waterproof them such as seed oil, lime, and animal fat (Makers Bazaar, Earthy 2020).

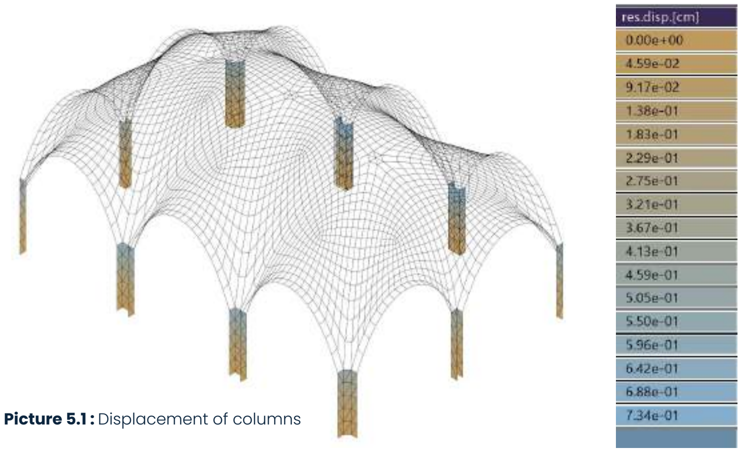
Waste categories (%)	High populated Districts	Low populated Districts	Commercial Area	Zaatari (Average)	Average MSW in Municipalities[a]
Organics	55.84	52.60	49.65	52.70	59
Paper and cardboard	5.60	3.74	17.67	9.00	14
Plastics	11.39	13.23	13.91	12.85	10
Leather, wood, textile and rubber	11.57	13.99	5.10	10.22	10
Metal	3.69	3.70	7.08	4.82	5
Aluminum	0.27	0.32	0.65	0.41	
Glass	0.90	0.81	2.04	1.25	4
Inert material	0.04	0.37	0.23	0.22	5
Special Waste (Hazardous, etc.)	0.17	0.45	0.20	0.28	6
Miscellaneous-Bread	0.35	0.41	3.09	1.28	
Miscellaneous - Nappies	10.18	10.38	0.38	6.97	
Total	100.00	100.00	100.00	100.00	

[a] Average MSW compositions percentages in the 100 Municipalities in Jordan.

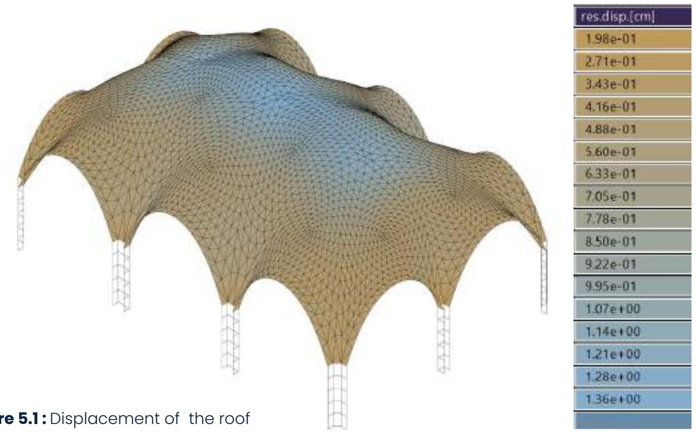
[2] Typical blockyard layout for press blocks production, represented as a linear process. (Auroville)



APPENDIX B | Structural verification the hub units

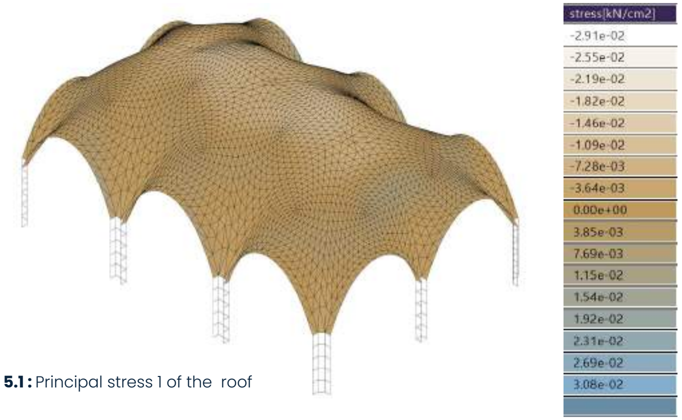


Picture 5.1 : Displacement of columns

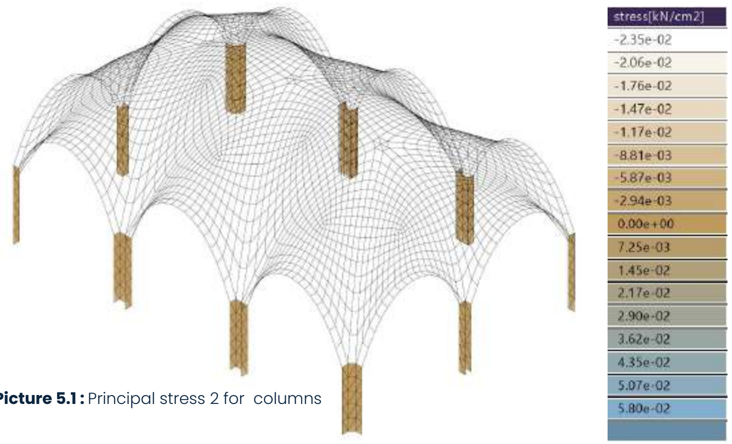


Picture 5.1 : Displacement of the roof

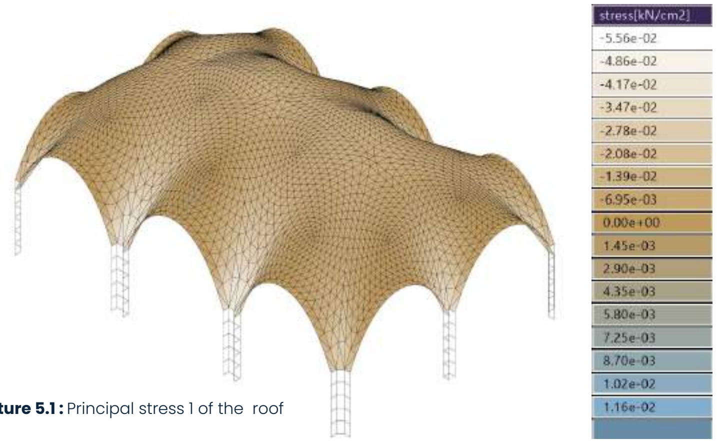
Picture 5.1 : Principal stress 1 for columns



Picture 5.1 : Principal stress 1 of the roof

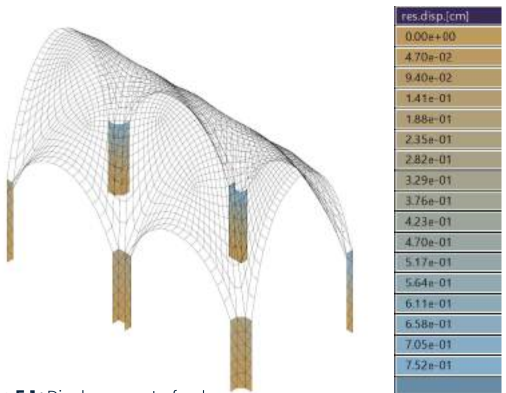


Picture 5.1 : Principal stress 2 for columns

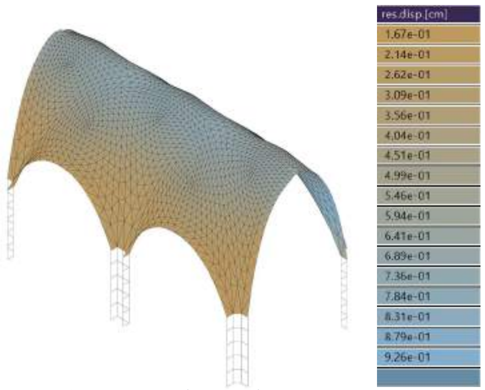


Picture 5.1 : Principal stress 1 of the roof

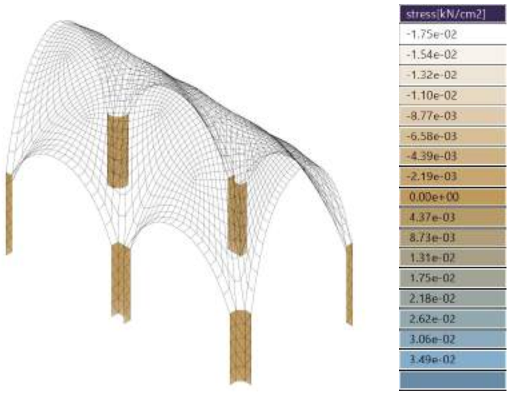
APPENDIX B | Structural verification the hub units



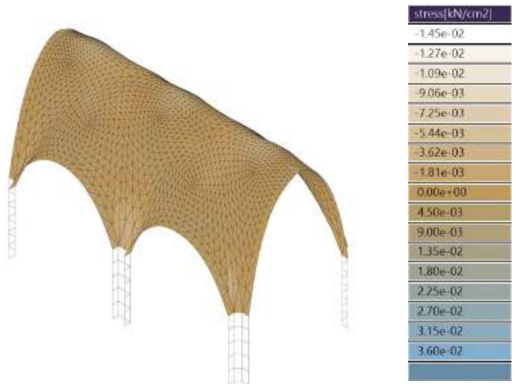
Picture 5.1 : Displacement of columns



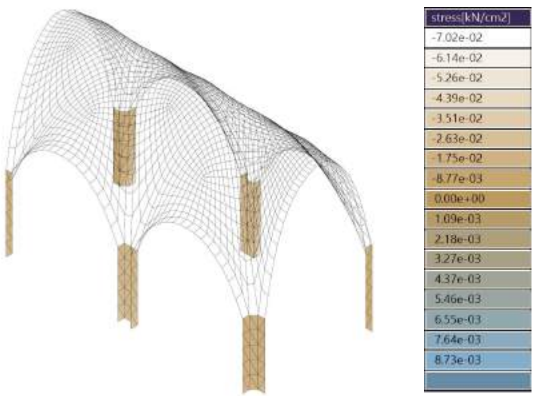
Picture 5.1 : Displacement of the roof



Picture 5.1 : Principal stress 1 for columns



Picture 5.1 : Principal stress 1 of the roof



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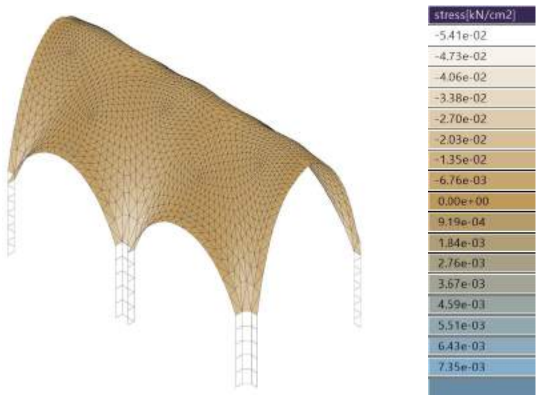
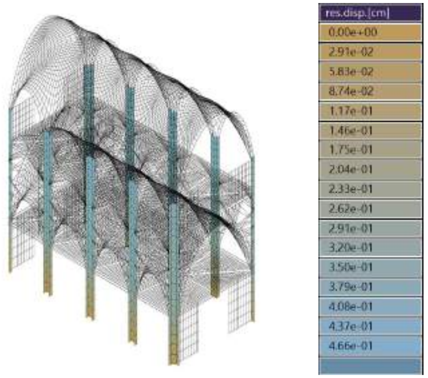
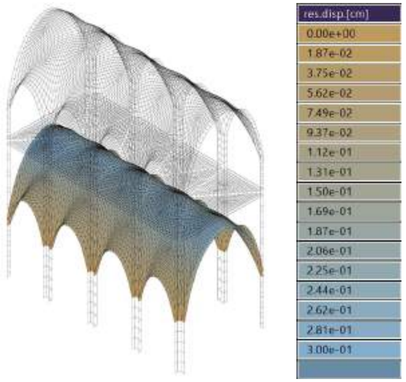


Picture 5.1 : Principal stress 2 of the roof

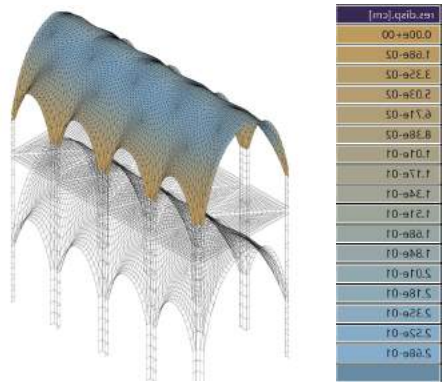
APPENDIX B | Structural verification the house units



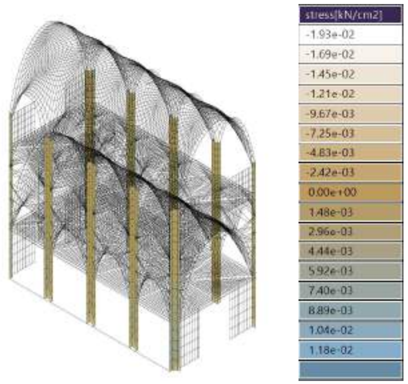
Picture 5.1 : Displacement of columns



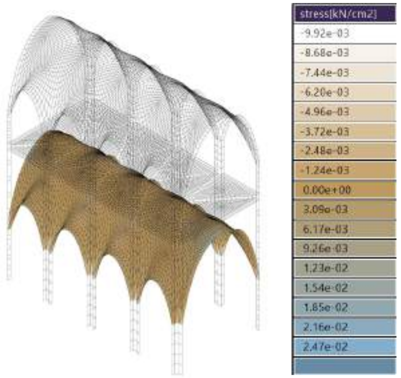
Picture 5.1 : Displacement of the first roof



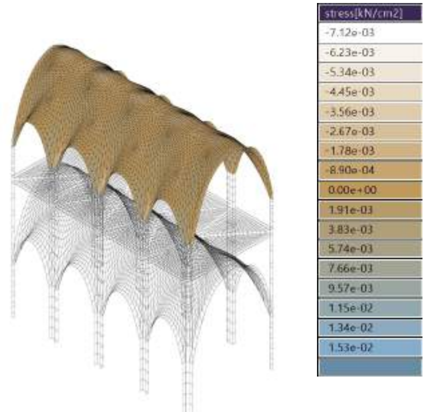
Picture 5.1 : Displacement of the second roof



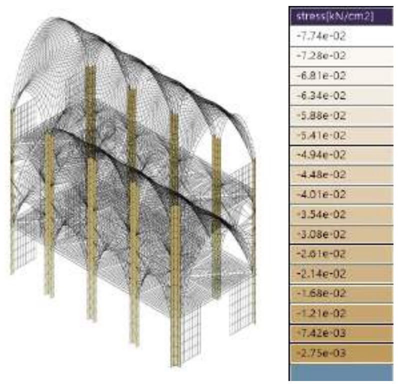
Picture 5.1 : Principal stress 1 for columns



Picture 5.1 : Principal stress 1 of the first roof



Picture 5.1 : Principal stress 1 of the second roof



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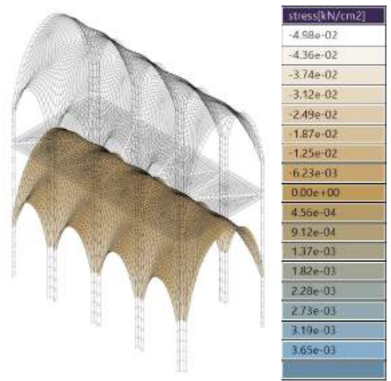

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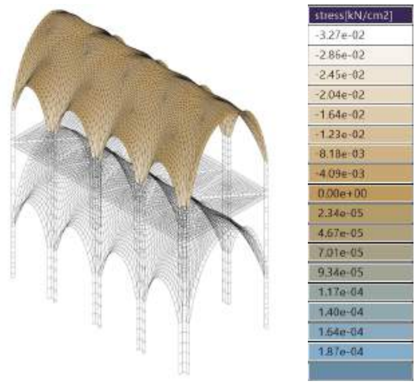
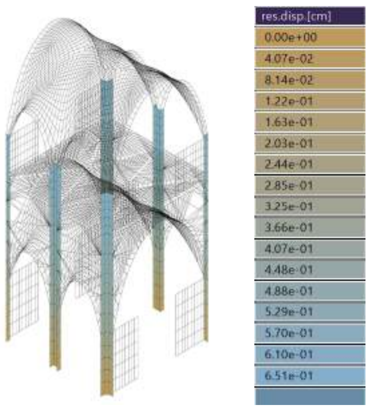
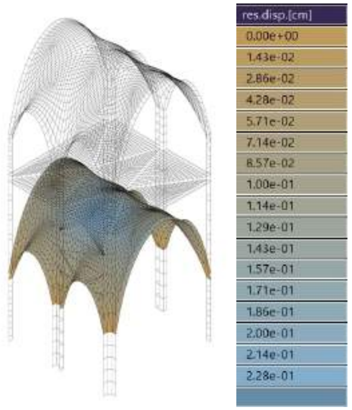


Picture 5.1 : Principal stress 2 of the second roof

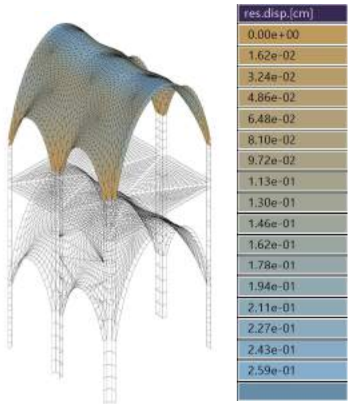
APPENDIX B | Structural verification the house units



Picture 5.1 : Displacement of columns



Picture 5.1 : Displacement of the first roof



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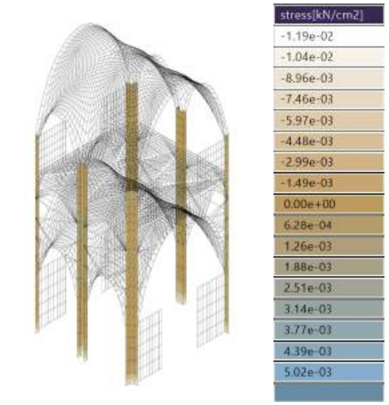

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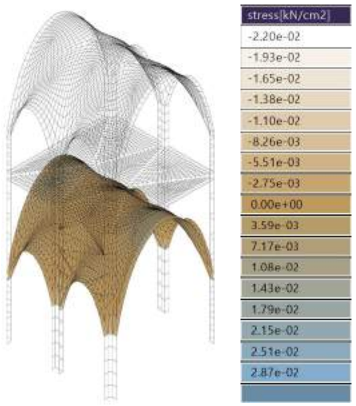
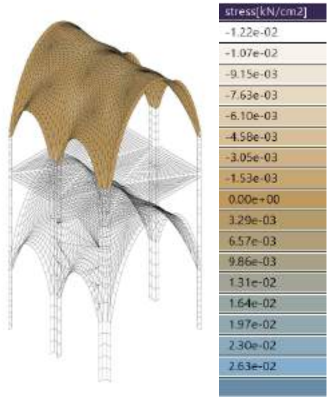
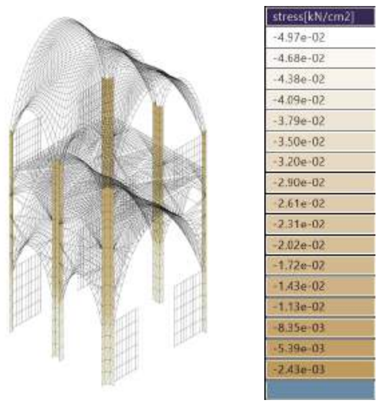


Picture 5.1 : Principal stress 1 of the first roof



Picture 5.1 : Principal stress 1 of the second roof



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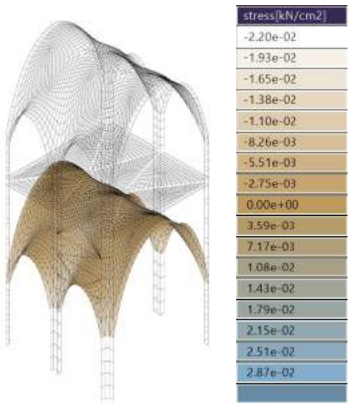

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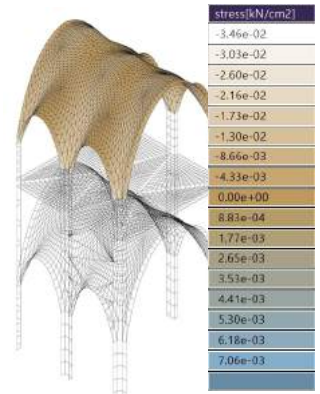

Picture 5.1 : Principal stress 2 of the second roof

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