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Sichere Unterkunft für heute und morgen in Syrien

MASTER THESIS

Safe Home for today and tomorrow in Syria

ausgeführt zum Zwecke der Erlangung des akademischen Grades
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unter der Leitung

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Abstract

Due to a disaster or a conflict many people will become displaced persons or refugees. Then they will be looking for one thing only:
a safe home.

And providing an appropriate post disaster home for refugees and displaced persons is a challenging topic.

This study is focusing on Syria and the internally displaced persons in Syria. Their Story started in 2012 and the number of the internally displaced people in Syria in 2021 according to UNHCR is 6.7 million.

Due to this huge number, the displaced people camps in Syria became cities of chaos and 69% of the shelters in these camps are tents, which are emergency shelters and provide no safety to Syrian displaced people.

The aim of this thesis is designing a safe and comfort shelter for the displaced persons in Syria in line with the technological development and by taking onto account friendly environmentally materials with low cost.
The first proposal aims to use local materials (Clay) for building low cost, climate responsive and environmentally friendly shelters, which provide appropriate living conditions in both cold winter and hot summer.
The second and third proposal aim to use 3D printers for printing two types of shelters, the first one is print on demand by using friendly environmentally materials and the second one is an eco-friendly printed module.

Kurzfassung

Wegen einer Katastrophe oder eines Konflikts werden viele Menschen zu Binnenvertriebenen oder Flüchtlingen. Dann suchen sie nur nach einer Sache:
einer sicheren Unterkunft.
Das Zurverfügungstellen einer geeigneten Unterkunft für Flüchtlinge und Vertriebene nach einer Katastrophe ist ein anspruchsvolles Thema. Diese Studie konzentriert sich auf Syrien und die Binnenvertriebenen in Syrien.
Die Geschichte der Vertriebenen hat 2012 begonnen und im Jahr 2021 beträgt die Zahl der Binnenvertriebenen in Syrien lt. UNHCR 6,7 Millionen. Aufgrund dieser enormen Zahl wurden die Vertriebenenlager in Syrien zu Städte des Chaos geworden und 69 % der Unterkünfte in diesen Lagern sind Zelte, die Notunterkünfte sind und den syrischen Vertriebenen keine Sicherheit bieten.
Ziel dieser Diplomarbeit ist es, eine sichere und komfortable Unterkunft für die Vertriebenen in Syrien zu entwerfen, die der technologischen Entwicklung entspricht und umweltfreundliche Materialien mit geringen Kosten berücksichtigt. Das Ziel des ersten Vorschlags für die Unterkunft ist es, eine günstige, klimagerechte und umweltfreundliche Unterkunft aus lokalen Materialien (Lehm) zu bauen, die sowohl im kalten Winter als auch im heißen Sommer angemessene Lebensbedingungen bietet.
Das Ziel des zweiten und dritten Vorschlags für die Unterkunft ist die Verwendung von 3D-Druckern für zwei Arten von Unterkünften: bei der ersten Art handelt es sich um Print-on-Demand mit Verwendung umweltfreundlicher Materialien und die zweite Art ist ein umweltfreundlicher printed Module.

Table of Contents

List of Abbreviations:

1. ACU Assistance Coordination Unit
2. GoS Government of Syrian Arab Republic
3. IDP Internally displaced person
4. NGO Non Governmental Organization
5. OCHA United Nations Office for the Coordination of Humanitarian Affairs
6. RW Reliefweb, a humanitarian information portal. Parent organization: OCHA
7. OHCHR United Nations Office of the High Commissioner for Human Rights
8. UNFPA United Nations Population Fund
9. UNHCR United Nations High Commissioner for Refugees
10. UNOSAT United Nations Operational Satellite Applications Programme
11. UN-Habitat United Nations Human Settlement Programme. Parent organization: United Nations
12. HRP Humanitarian Response Plan
13. FDM Fused Deposition Modeling
14. IFRC International Federation of Red Cross and Red Crescent Societies
15. NGO Non-Governmental Organisation
16. IOM International Organization for Migration
17. NRC Norwegian Refugee Council
18. EASO European Asylum Support Office
19. CCCM Camp Coordination and Camp Management
20. NFI Non-Food Items
21. SPGs Sphere Project Guidelines
22. WHO World Health Organization
23. EERI Earthquake Engineering Research Institute
24. MENA Middle East and North Africa

Definitions and terminology

IDP:
"Persons displaced from their habitual place of residence by disaster, fear of persecution or fear of physical harm, but remaining within the territorial limits of their country of origin. Unlike refugees, IDPs have no internationally defined legal status." (T. Corsellis, and A. Vitale, 2005).

Refugee:
"Refugee is any person who owing to well-founded fear of being persecuted for reasons of race, religion, nationality, membership of a particular social group or political opinion, is outside the country of his nationality and is unable, or owing to such fear, is unwilling to avail himself of the protection of that country; or who, not having a nationality and being outside the country of his former habitual residence as a result of such events, is unable or, owing to such fear, is unwilling to return to it." (UNHCR, 2011).

Emergency shelter:
"Short term shelter that provides life saving support, the most basic shelter support that can be provided immediately after the disaster." (Shelter Projects, IFRC, 2013).

T-shelter:
"A term often used to mean either Temporary Shelter or Transitional Shelter." (Shelter Projects, IFRC, 2013).

Temporary shelters:
"Post disaster household shelter designed as a rapid shelter solution. By prioritising speed and limiting costs of the construction, the llifetime of the shelter may be limited." (Shelter Projects, IFRC, 2013).

Transitional shelters:
"Rapid, post disaster household shelters made from materials that can be upgraded or re-used in more permanent structures, or that can be relocated from temporary sites to permanent locations. They are designed to facilitate the transition by affected populations to more durable shelter.
Transitional shelters respond to the fact that post disaster shelter is often undertaken by the affected population themselves, and that this resourcefulness and self-management should be supported." (Shelter Projects, IFRC, 2013).

Progressive shelters:
"Post disaster rapid household shelters planned and designed to be later upgraded to a more permanent status.
This is achieved by integrating future transformation and alteration possibilities in structural basis of the unit." (Shelter Projects, IFRC, 2013).

Core shelters / One room shelters:
"Post disaster household shelters planned and designed as permanent dwellings, to be the part of future
permanent housing, allowing and facilitating the future process of extension by the household, following its own means and resources.
The aim of a core shelter is to create one or two rooms, providing safe post disaster shelter that reaches permanent housing standards, and facilitates development, but not completing a full permanent house." (Shelter Projects, IFRC, 2013).

1. Introduction

It has been more than a decade since the conflict in Syria started. During these years so many people have died, so many have lost their loved ones, so many have been injured, so many are missed, so many have became internally displaced persons within Syria and so many have became refugees in other countries.

In 2010 the population in Syria was almost 20 millions. Due to this tough decade nearly half a million are dead, around five and half million are refugees and approximately six and half million are internally displaced persons.

These internally displaced persons are looking for safe shelters, where they can sleep safely during the cold nights in winter. Most of the available shelters in Syria are tents, which do not provide safety during the cold nights in winter and increase fire hazards.

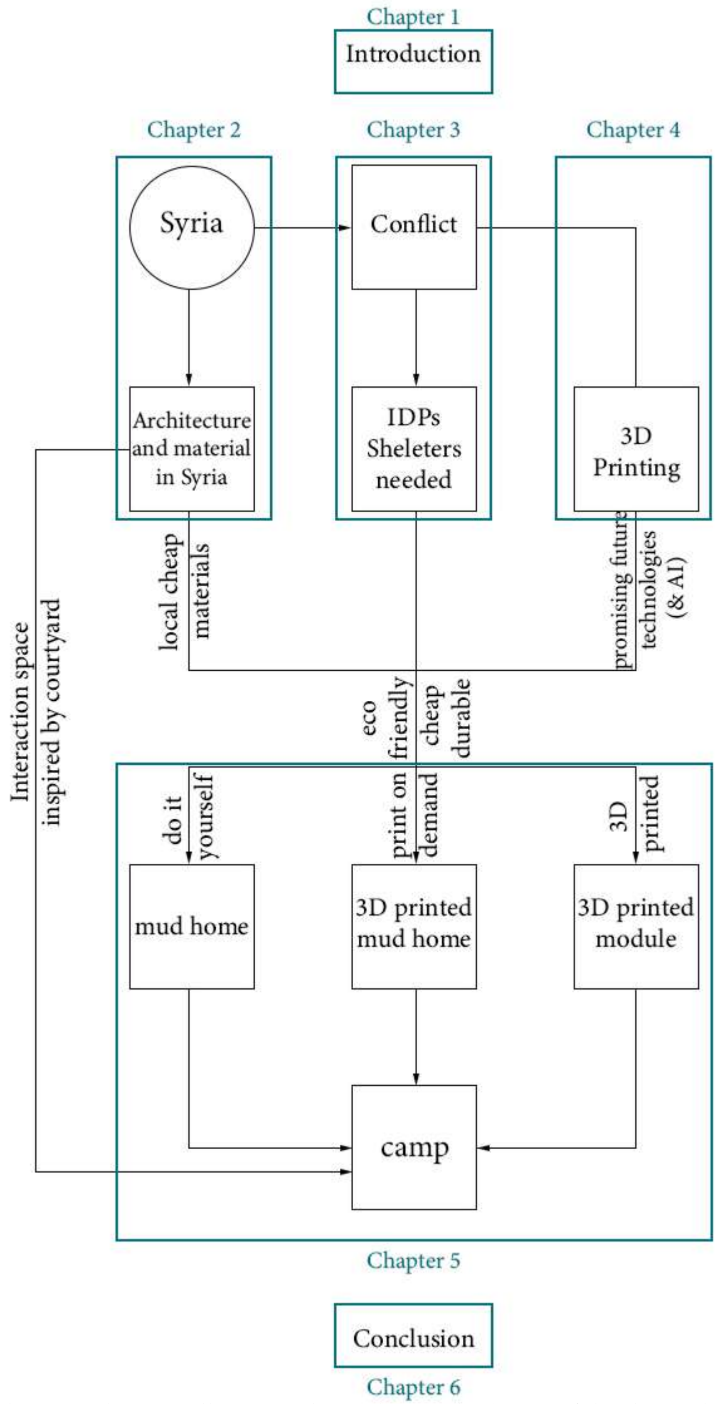
This thesis will walk through the history of architecture and the construction materials in Syria to the current situation in Syria. And on the way the advantage of promising future 3D printing will be discussed.

At the end of the way a bridge between the analysis and the proposed shelters will be crossed, a bridge overlooking environmentally friendly, cheap and durable materials.

Depending on the gathered information during this walk three cheap, durable and eco-friendly shelters will be proposed.

And one camp will be proposed as well. The camp has interaction spaces inspired by the courtyard house the most common house typology in Syria.

The next schematic diagram illustrates the outline and relation of the thesis chapters.



Schematic diagram illustrates the outline and relation of the thesis chapters.

2. Syria

“Because my love for you is higher than words, I decided to fall silent.” Nizar Qabbani

Fig.2.1. World map

2.1. Location

“We shall remember ...... Damascus, the 'Pearl of the East,' the pride of Syria, the fabled garden of Eden, the home of princes and genii of the Arabian Nights, the oldest metropolis on Earth, the one city in all the world that has kept its name and held its place and looked serenely on while the Kingdoms and Empires of four thousand years have risen to life, enjoyed their little season of pride and pomp, and then vanished and been forgotten.”

Mark Twain

Syria locates in Western Asia, bordering Turkey to the north, the Mediterranean Sea to the west, Lebanon and Israel to the southwest, Jordan to the south and Iraq to the east.

Fig.2.2. World map

The area of Syria about 185 km². It is a unitary state , but for administrative purposes, it is divided into fourteen governorates, Aleppo, Raqqa, Hasaka, Deir ez-Zor, Homs, Hama, Idlib, Latakia, Tartus, Damascus, Rif Dimashq, As-Suwayda, Daraa and Quneitra.
The governorates are divided into sixty districts, , which are further divided into subdistricts.

Fig.2.3. Syria map

Fig.2.4. Syria map

2.2. Climate

"Heaven is standing atop Mount Qasioun overlooking the Damascene sights with the wind carrying Qabbani's dulcet words all around you."
Kamand Kojouri

Syria has a Mediterranean climate, hot, dry, sunny summers from June to August, and mild, rainy winters along the coast from December to February.
Temperatures are influenced and moderated by proximity to the sea and elevation.

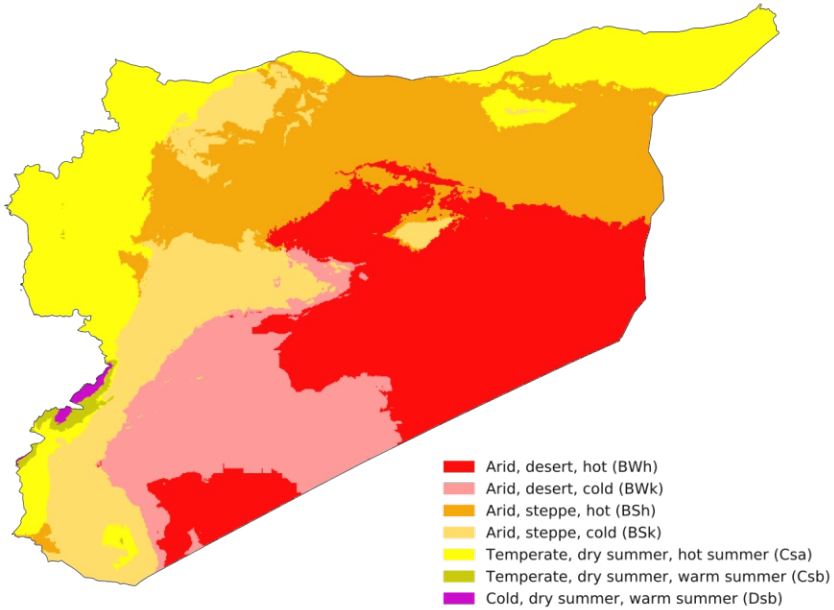


Fig.2.5. Syria climate classification zones

The mean daily maximum (red line) shows the maximum temperature of an average day for every month. The mean daily minimum (blue line) shows the minimum temperature. Dashed lines (Red and blus) show the the average of the hottest day and coldest night of each month of the last 30 years.

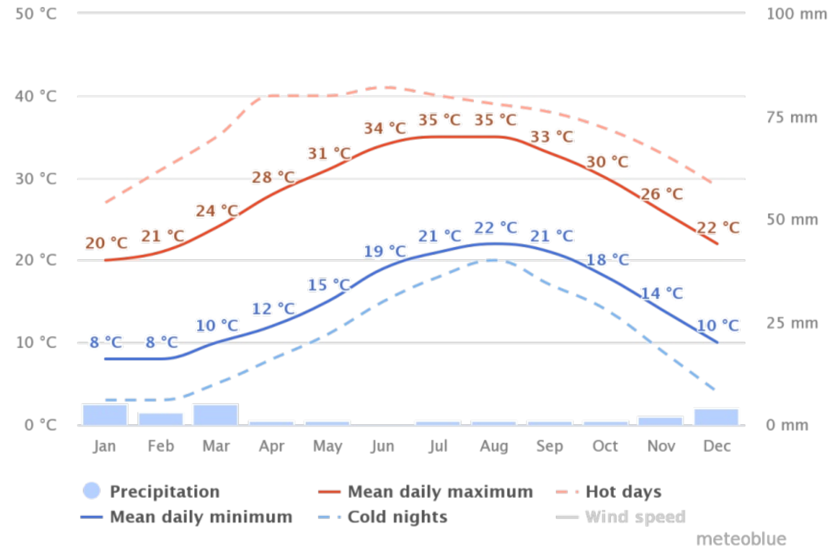


Fig.2.6. Syria Average temperatures and precipitation

The next diagram is the maximum temperture diagram. It shows how many days per month reach certain temperatures in Syria.

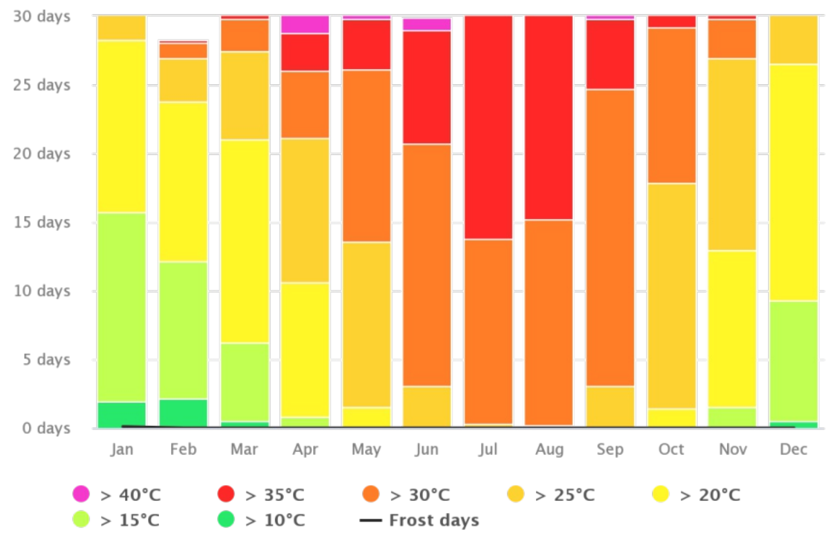


Fig.2.7. Syria Average temperatures and precipitation

Next digram is the precipitation diagram. It shows on how many days per month, certain precipitation amounts are reached.

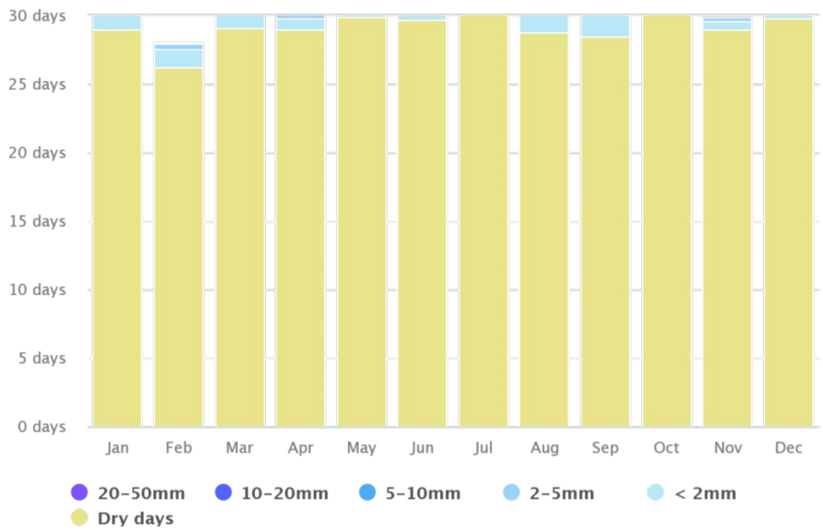


Fig.2.8. Syria precipitation amounts

Next Diagram shows the monthly number of sunny, partly cloudy, overcast and precipitation days

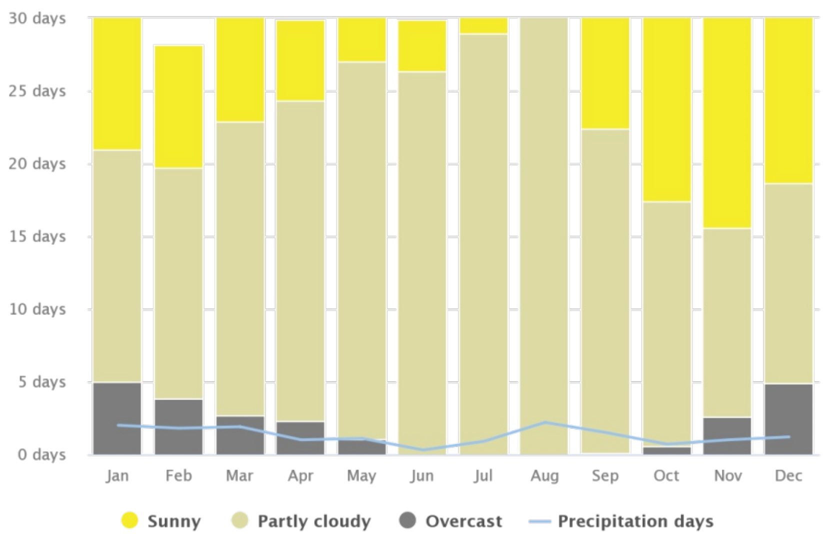


 Fig.2.9. Syria, Cloudy, sunny, and precipitation days

Next digram is the wind speed diagram. It shows the reached wind speed during every day.

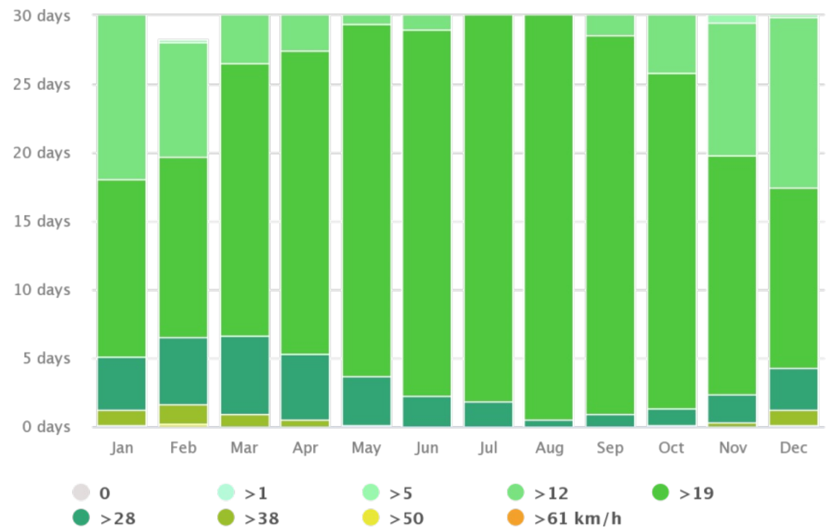


Fig.2.10. Syria, Wind speed

The wind rose shows how many hours per year the wind blows from the indicated direction.

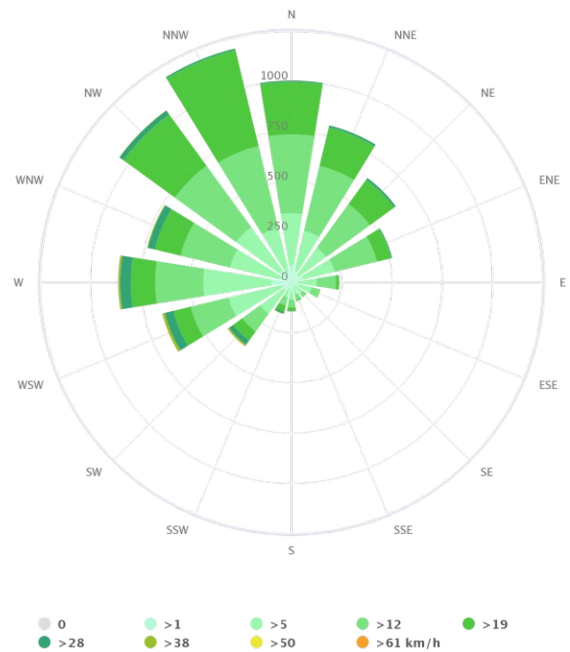


Fig.2.11. Syria, Wind rose

2.3. Traditional Architecture in Syria

“The Damascene House
Is beyond the architectural text
The design of our homes . . .
Is based on an emotional foundation
For every house leans . . . on the hip of another
And every balcony . . .
Extends its hand to another facing it
Damascene houses are loving houses . . .
They greet one another in the morning . . .
And exchange visits . . .
Secretly-at night . . .”
Nizar Qabbani

Typology of traditional buildings

There are many building types in Syria according to the region and people's lifestyle. But mainly two lifestyles are the reason of a major difference of construction and houses. These lifestyles are called nomadic and sedentary. Nomadic lifestyle depends on pastures and daily economic activity, it requires constant migration from one place to another to find water and pastures. Sedentary lifestyle is linked to cities and countryside. The types of houses in city or countryside are different.

The traditional house in a city is constructed by stones with different types and colors and variety of building topologies. It consists main courtyard surrounded by rooms for daily and evening activities.
The traditional house in the countryside consists main courtyard, which has been used as the garden of the house and it is surrounded in one side or more by rooms and the rest are bordered by a wall.

The tent

Tent is nomad shelter used by Bedouins. It is made from woven goat hair and easy to construct and take down and transfer. Nomad life depends on finding water and pastures, that is way the tent is linked to nomad lifestyle. Moving from place to another is very import and for Bedouins to find pastures and suitable environment for the community and its livestock.

Tent size

The size of the tent depends on the number of the middle poles, the more the poles the bigger the tent. The smallest tent has one pole. The medium size 2-3 poles. The biggest tent has 4-6 Poles.
The Poles help to divide the tent to several spaces with different usage and functions.

Tent Open

The opening of the tent has two types, the first type is the completely open tent in the front and closed in the back to the wind direction.
The second type is the completely closed tent to all sides with one door to enter and exit.

Interior space division

The main aim of division is to provide privacey and protection. There are various types of the division and the number of the spaces depends on many factors: number of central poles, family members, their needs, function of the space...

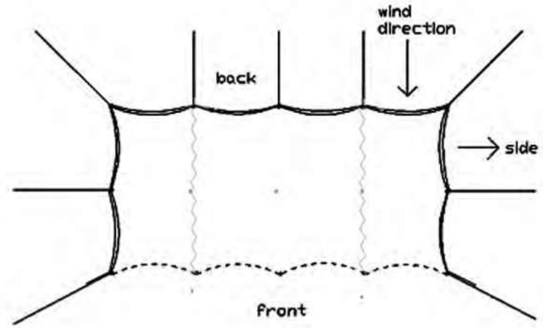


Fig.2.12. The Bedouin tent, Al Amaireh, 2011.

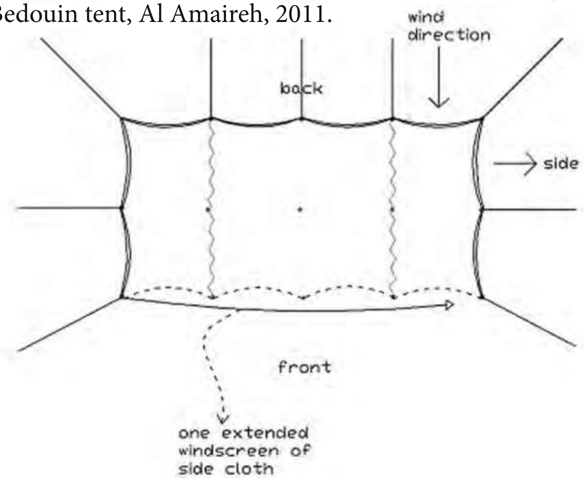


Fig.2.13. The Bedouin tent, Al Amaireh, 2011.

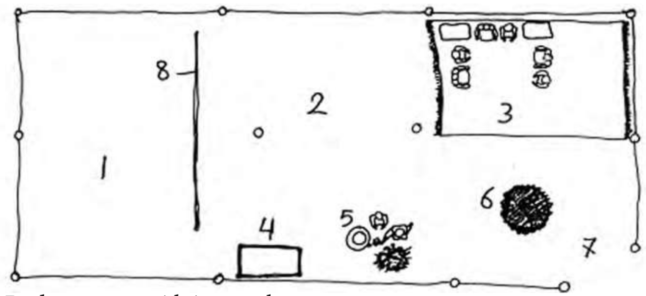
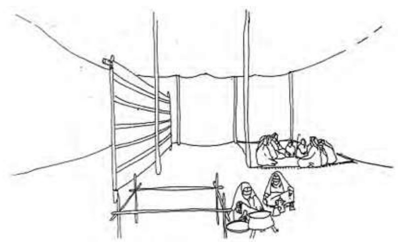


Fig.2.14. The Bedouin tent, Al Amaireh, 2011.



1. Parents sleeping area (Khidan)
2. Family section
3. Reception (Majles)
4. Store
5. Hearth
6. Dining Mat
7. Closed door
8. Wood partition

Fig.2.15. The Bedouin tent, Al Amaireh, 2011.

The basic house

The simplest and common typology in rural syrian areas.
It is consisted of four walls made of stone or mud and earth roofing.

There are two types oh this house:
The unit house, which has only one big rectangular room. This room offers a good living space and it could be divided according to the inhabitants needs, living area, storage area, sleeping area ...

The multiple units house which is simliar to the one unit house but it has many cubical rooms lined next to each other in the side of a land, open to the front and rarely open to each other. These rooms are open to open flat space, where the domestic life takes place.

In the urban areas the front side of the land is surrounded by walls to create a private space for the inhabitants.

This open flat space which defined by the rooms and the walls is the first potential space of the courtyard.

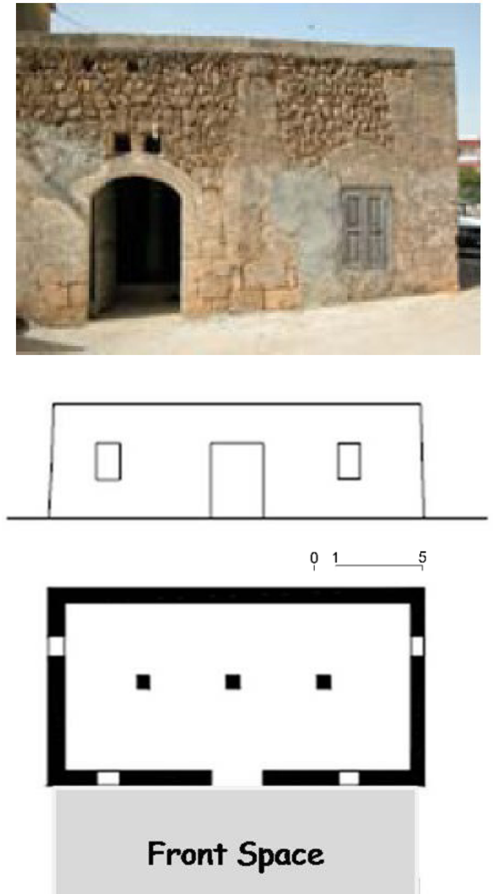


Fig.2.16. The basic house, Inceruh, 2011

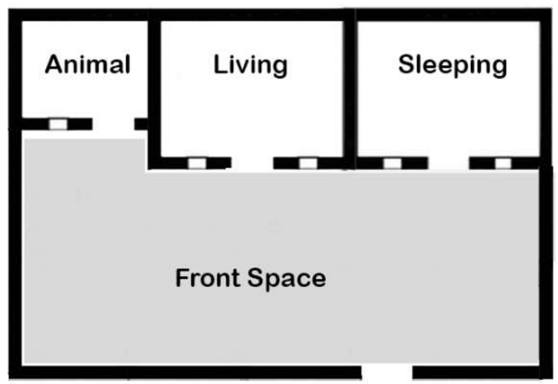


Fig.2.17. The basic house

The house with a Riwaq

The Arabic word "Riwaq" means gallery, loggia or portico.

This house is the developed type of basic house. And it has usually two stories. A sun shaded Riwaq in front of the rooms has been added to connect the rooms with each other. This typology has one floor or two floors.
The riwaq is an extension of the interior space and it is open to the outside through a series of supports.

This riwaq protected the house from rain and provided outdoor shaded area as living space for the habitants.
The most frequent orientation of the riwaq is north.
And the riwaq is a very important element in this typology, because it is providing excellent temperature regulation in hot weather. Syria

The ground floor has been used for animals, stores and service areas. The courtyard in the middle of the ground floor has a fountain and plants.
This type of architecture is very presence throughout the history of Syria.

This type is common in south of Syria and in north of Damascus.

one floor riwaq house
The rooms are open to the riwaq and used as living and sleeping spaces.

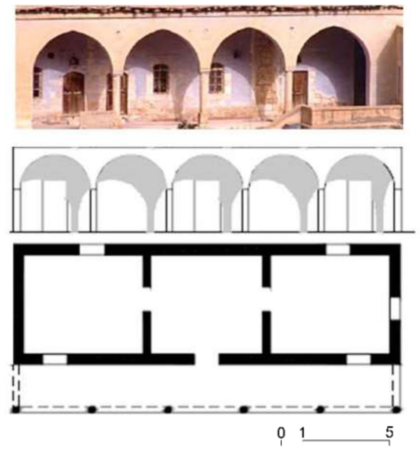


Fig.2.18. House with riwaq, Inceruh, 2011

1. Closed Rectangular House on the ground floor, arranged as two cross vaulted units
2. Cantilevered exterior staircase
3. riwaq, Riwāq House in the upper flooor
4. Adjoining rooms used as living and sleeping spaces

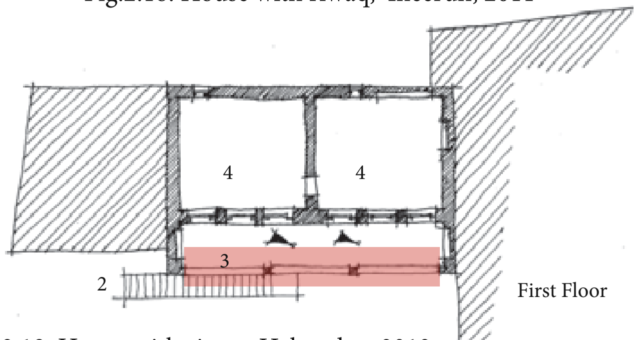


Fig.2.19. House with riwaq, Helmedag, 2012

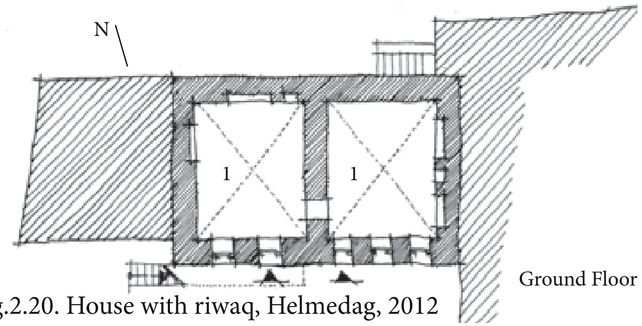


Fig.2.20. House with riwaq, Helmedag, 2012

Fig.2.21. House with riwaq, Helmedag, 2012

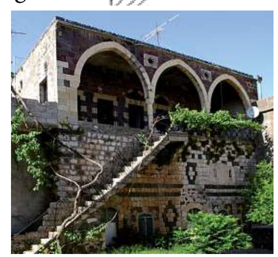


Fig.2.22. House with riwaq, Helmedag, 2012

The house with a Liwan

The term "Liwan" is originally Persian from Persian word "Aivan" which means open space, and it is very common in houses with courtyards.

The liwan in a central space defined by a large arch. It plays the central role of organizing and distribution the rooms. This central space in open on one side and surrounded by tow rooms.

There are some simple rural forms of liwan, which have been found in mountain areas close to the cities, like north of Damascus.
In this case the function is different from the urban form, because it open into the outside and it serves as entrance hall.

The Liwan is rest and relax area, and it plays very important role in providing shaded area during hot summer, that is why the liwan is oriented to the north side of the house.
Some houses have two liwans, one to the north to provide a shaded area, and one to the south to receive solar radiation during winter.

In both seasons liwans are used as living, eating, relaxing, setting, playing, sleeping and family gathering area.

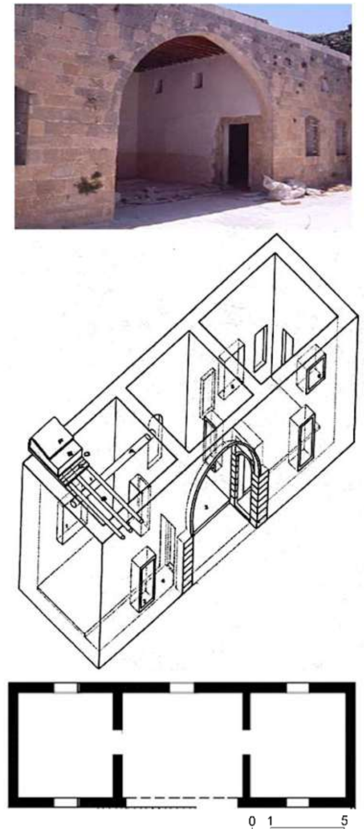


Fig.2.23. House with liwan, Inceruh, 2011

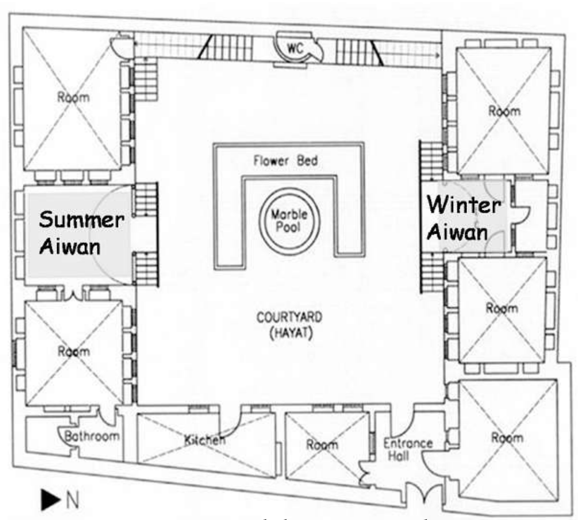


Fig.2.24. House with liwan, Inceruh, 2011

The rural house with courtyard

The difference between lifestyles in city and countryside has impacted the topologies, shapes and materials of houses. Lifestyle in countryside depends on agriculture and livestock farming. Due to this lifestyle a courtyard was attached to the house. It is used as a private. It has specific areas for animals and vegetables. It is common in the surroundings of Aleppo in Sfireh city, where mud structure and the use of mud cupolas in roofing are dominant.

This typology is based of main unit 5x5m approximately covered with cupola and repeated around the inner courtyard. These houses were mainly divided as following:
one or more rooms with various functions (living, sleeping or for visitors), kitchen, bath, store, stable, toilet, fences, garden, small store for hens and pigeons, earthen traditional bakery (Tannur), stage Mastaba, and well.

These houses never rise higher than ground floor.
Mud cupolas are also used in Tiara, on the outskirts of Aleppo, but the whole building take the shape of cupola, not just the roof as the building in Sfireh.

Some rooms in the house have flat ceiling, made of wood and earth.

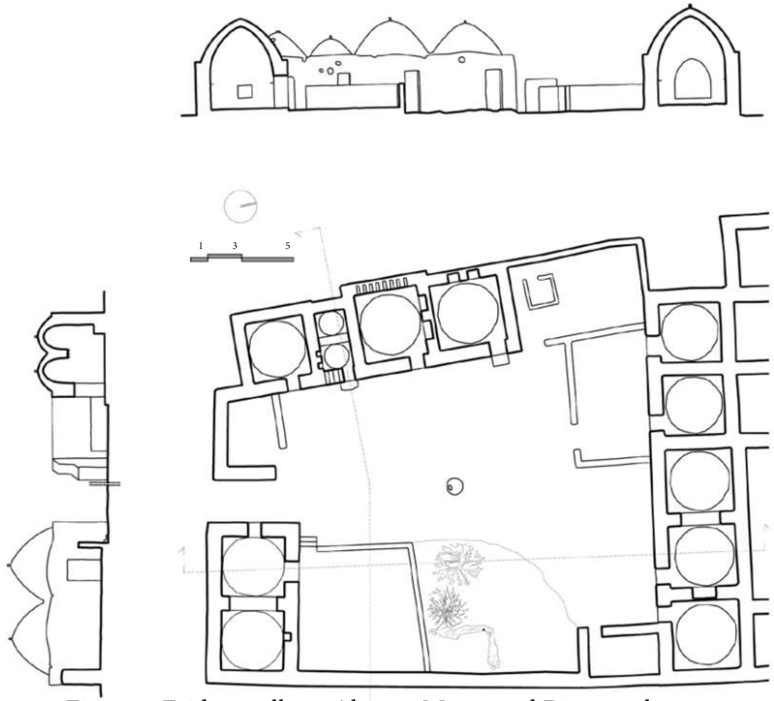


Fig.2.25. Fejdane village, Aleppo, Mecca and Dipasquale, 2009

D. Dwelling house
F. Animal fence
H. Stables, 'Hazera' or 'Qabu'
K. Kitchen, 'Matbakh'
S. Stores
T. Terrace, 'Mastaba'
W. Bathroom, 'Marhad'
Well

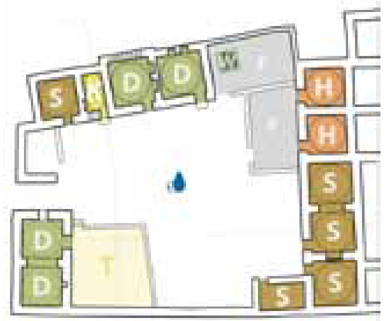


Fig.2.26. Fejdane village, Aleppo, Mecca and Dipasquale, 2009

Fig.2.27. Fejdane village, Aleppo, Mecca and Dipasquale, 2009

Fig.2.28. Fejdane village, Aleppo, Mecca and Dipasquale, 2009

The urban house with courtyard

The most common typology in Syria. It can be found in all syrian cities.

This Typology has small number of openings to the outside and large number of openings to the inside, to the courtyard. Theses houses differ in size and luxury level and they vary in number of inner spaces and their size in each house.

The main characteristic of these houses is the open courtyard, which provide the occupant a feeling of privacy.
This courtyard is the center garden of the house. The rooms are surrounding the courtyard and open into it.

In large and medium sized houses, a fountain is located in the center o the courtyard to freshen the air, trees are also grown in these courtyards to add shadow to these gathering areas.
These houses are often two floors with max. 10m hight. Living rooms and service rooms are in ground floor while the sleeping rooms are in upper floor. In large houses with many courtyards, the house is divided to areas, one for the owner, one for the guests and another for servants.

Traditional Arabic houses are environmentally friendly in both their design and structure.
For instance, Fountain and trees help to humidify the air, Iwan in courtyard is used as an open summer sitting area and facing north. The thick walls and roofs are good insulator and help to stable the room temperature. Many elements have been used to provide shading.

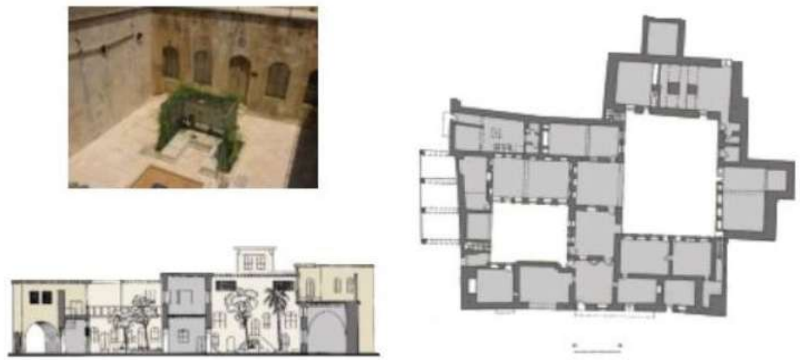


Fig.2.29. Courtyard house, CORPUS Levant, 2004

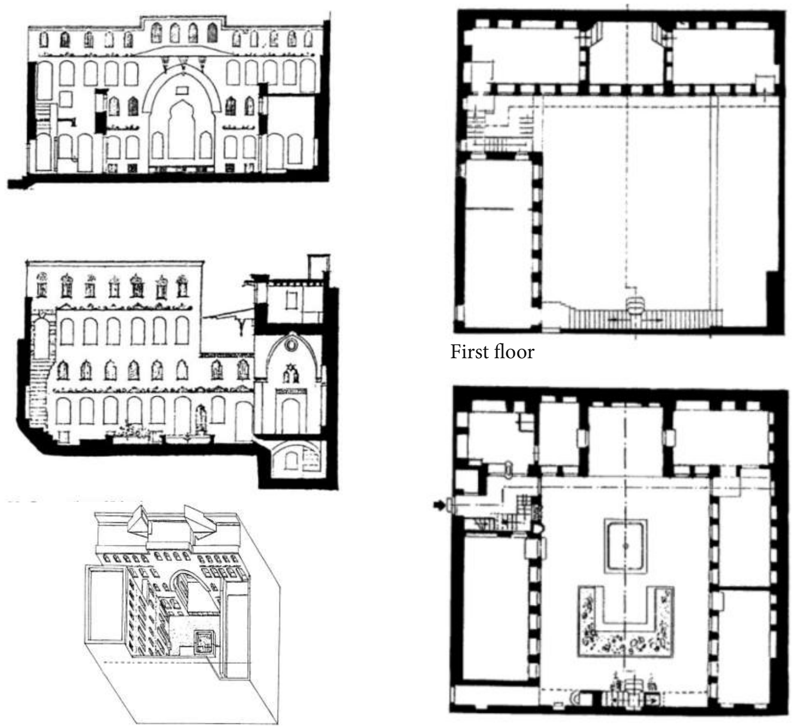


Fig.2.30. Baleet house, Aleppo, Edwards, Sibley, Hakmi and Land, 2006

2.4. Materials of traditional buildings

“In Damascus
The traveler sings silently to himself and I return from Syria
Neither dead, nor alive
But as clouds easing the butterfly’s burden
From my fugitive soul.”
Mahmoud Darwish

Stone walls

Stone was the main building material in most syrian cities. Stone has been used in some villages like Ezraa, where it was available locally.
Stone walls have been used in all types of buildings since the beginning of construction. They can be found in old cities, like Damascus old city, Aleppo old city...

There were many types of stones and they different from area to area and from city to city, limestone was used in Aleppo while limestone and basalt were used in Damascus.
And many other stones have been used, such as ashlar and dressed quarry. Another factor define the type of stone is the wall type and its function in the building, it could be internal wall or external wall.

The stones come in large random shapes then made into standard rectangular shape in the workshop.
The stone are laid in a mortar of mud and straw. The wall built in a stone foundation in trench around 1m deep. The wall is constructed with two stone layers, external and internal each about 30 cm width, with soil and rubble in between about 10cm width. The width of the wall about 70-80cm.

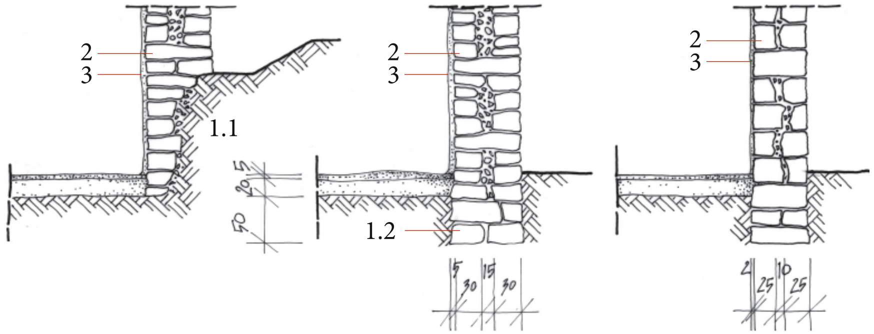


Fig.2.31. Stone wall construction, Helmedag, 2012

1.1. In-situ solid rock foundation
1.2. Rough foundation masonry
2. Double-walled made of natural stone of basalt or limestone
3. Interior plastering, whitewash

1. Transverse arch or other supporting structures
2. Corbel stone
3. Stone block
4. Superimposed load of framing stones
5. Thorny shrubs
6. 20-25 cm thick earth layer and chaff with lime finishing

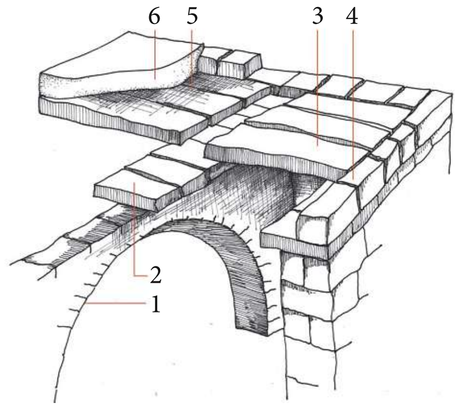


Fig.2.32. Stone roof construction, Helmedag, 2012

Fig.2.33. Stone house, Izraa, Syria, CORPUS Levant, 2004

Stone domes

It is one of the most important architectural features, it covers the main spaces in mosques, churches, bathes and some houses. Stone cupolas have been used in all Syrian cities and some villages, where the stone was available locally. They have different shapes semi spherical, onion shape or ribbed. Stone is cut and smoothed in a standard measures 30x30x25cm. The framework must be prepared to give a smooth surface from inside and outside. The binding material is lime mortar, and lime rendering is applied from inside.

Khan Assad pasha is a prime example of late Ottoman architecture and of the stone architecture in the old city of Damascus. The dome structures in the Khan is fascinating. The vast courtyard is divided by eight domes arranged around a circular aperture, which allows the light to spill into the fountain in the center of the courtyard.
These domes cover a central square area, which measures 27x27 m.
Each dome is ringed in twenty small windows that pull further light into the courtyard.

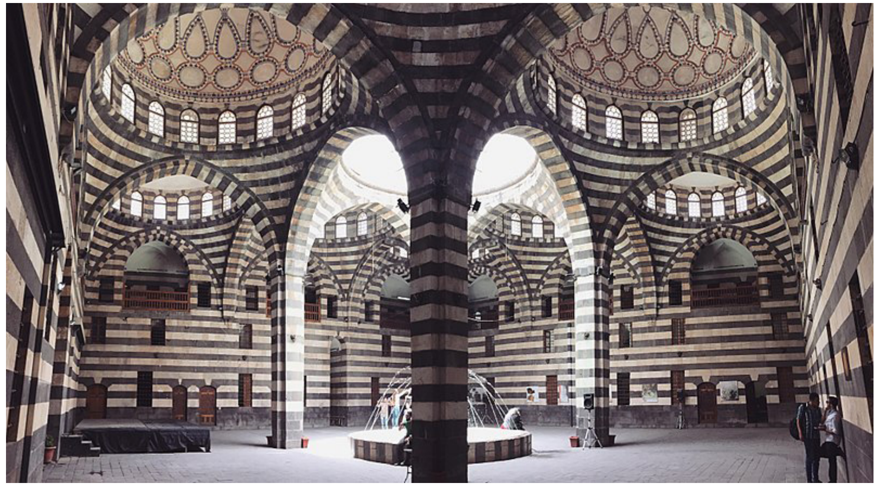


Fig.2.34. Khan Assad Pasha, Damascus

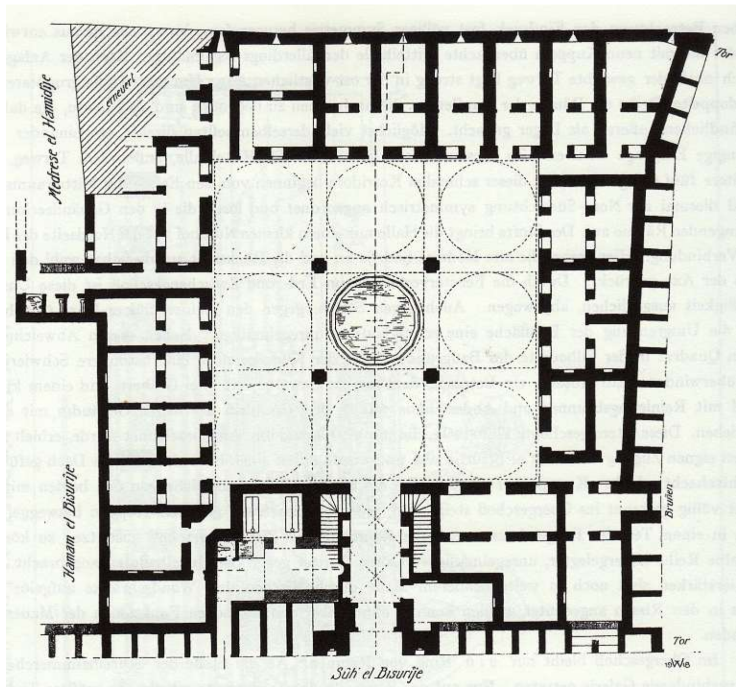


Fig.2.35. Khan Assad Pasha, Damascus

Earth Architecture

Earth architecture in Syria goes back to 11,000 years. The characteristics of this architecture depends on its history, place, economic, social and climatic environment.

Mud walls

Mud brick walls: These walls have been used in both cities and countryside, like some building in the old city of Damascus and Aleppo, Homs, Hama and most of syrian countrysides. This type of building is no more alive in the cities. And the mud house in the cities have turned into archeological monuments. But this type of architecture is still alive i countrysides.

The mud walls have been constructed by mud bricks and mud mortar. Mud bricks were prepared from mud mixed with straw to strength the mud blocks, and that by putting them in formworks, which measure 10x40x20cm, to form the mud bricks. Mud bricks and mud mortar have the same contents but mud mortar is sieved and refined to make it smooth and to apply it easier.
Mud walls are built on the ground if it is rock or on stone foundation if the ground is loose, these foundations about 50-75cm deep and rise about 50cm or more above the ground level. Thickness of mud walls around 60-70cm and the mud bricks are assembled alternately, every two long units for one wide unit and so on. The walls are covered with mud or lime rendering from outside to make them smooth.

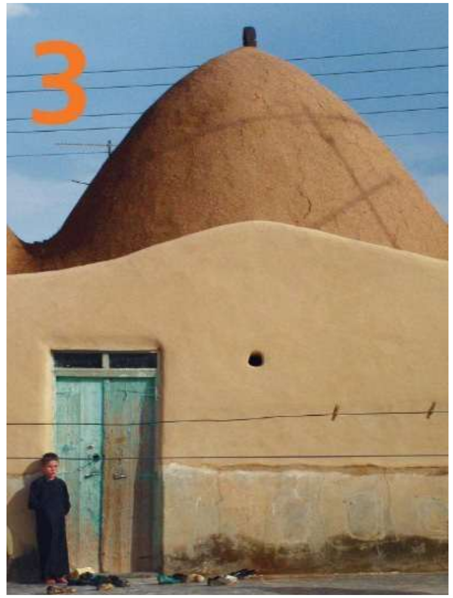


Fig.2.36. Mud house, Syria, CORPUS Levant, 2004

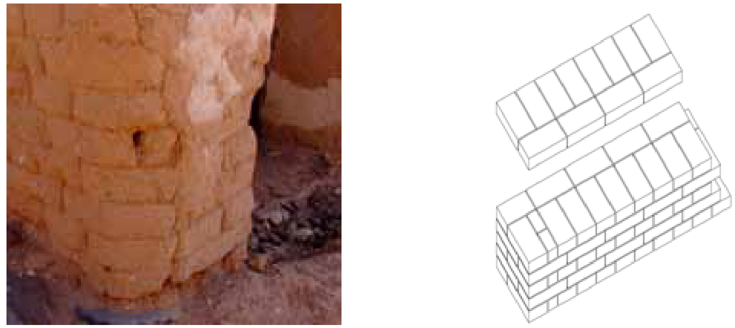


Fig.2.37. Mud wall built on the ground, Mecca and Dipasquale, 2009

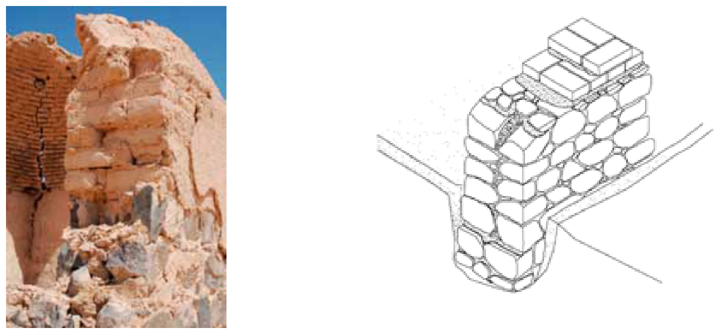


Fig.2.38. Mud wall built on stone foundation, Mecca and Dipasquale, 2009

Mud cupolas

It is used in mud buildings in many areas in Syria, for instance the countryside in north of Syria. Mud is the main used material in this type of buildings, which used in cupolas, walls, binding and covering.

Coarse earth is mixed with water and straw then shaped in formworks to make the mud bricks, 10x40x20cm. Then the mus bricks are dried and hardened in the sun. the thickness of cupola around 30-40cm and its height around 7m. The builder starts the constructing of the cupola from the four corners of the room, the courses are arranged above each other towards the center, and the mortar is used to bind the structure, The cupola covered from outside with earth rendering, which made from fine earth mixed with water and straw.

There are four type of mud domes:

Simple dome

The dome rests on a stone perimeter base that rises 30-60 cm centimetres from the ground. This type of dome can be founf in Hama.

Sultan dome

This dome rests on a mud wall which rises on a stone base between 30-80 cm. It can be found in Aleppo.

Transition dome

This dome is supported by stone base between 50-150 cm. It can be found in Aleppo as well.

Flat roof dome

This dome is supported by stone base between 50-180 cm. It can be found west of the Euphrates River.

Fig.2.39. Mud cupolas, Aleppo, Mecca and Dipasquale, 2009

After the emergence of reinforced concrete, cement and CMU (Concrete masonry unit), the roof became flat concrete roof. Walls were either traditional structure or constructed by stone or CMU.

This new solution dose not fulfill the needs of thermal insulation. Not like traditional buildings. They provide better acoustic and thermal insulation and more environmentally adapted. Since traditional walls are 70cm wide, and mud itself is an insulator that keep stable temperature in both winter and summer.

This typology has limited number of openings, limited to front door and small vertical long windows. Earth rendering is used to cover the outer walls, and limewash is used to cover the inner walls.

Mud has been used in many other rural areas with different topologies and shapes. Mud houses and rough stone houses can be founded in the areas surrounding Damascus and Ghouta: building are made with wooden frameworks and are often two floors.

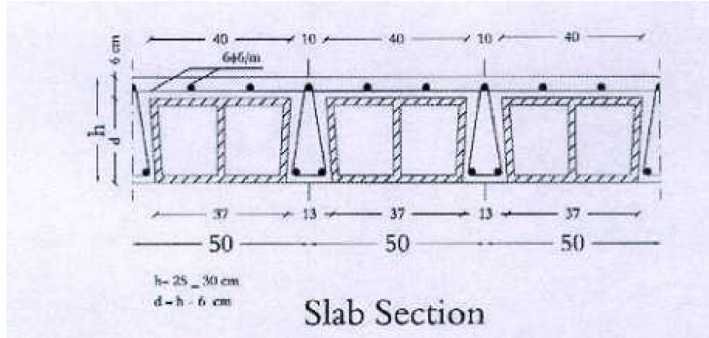


Fig.2.40. Slab section, EERI, Awad, Hwaija, Isreb and Ravi, 2002


Fig.2.41. Concrete hollow block, Helmedag, 2012

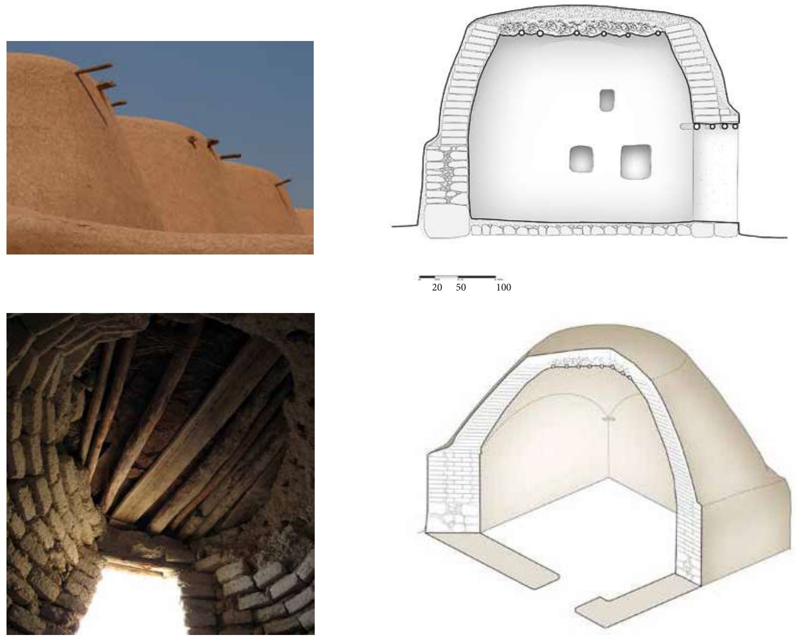


Fig.2.42. Wooden roof, Mecca and Dipasquale, 2009

Wooden roof

This type has been used widely in Syrian cities and villages, it has been used in roofs and upper floors.
Poplar logs has been used in roofs since it was available in large quantity. Cypress wood has been used as well, which known for its durability, solidity and quality.
The diameter of the logs about 15cm, they cover the width of the room and supported by walls in each side.
The waterproofing of the roof is made by a layer of earth on top of a wooden roofing.

Thatched roofing covered with mud

This type has been found in Damascus region with different shapes and styles accoring the availabe raw materials. It has basically main beam, secondary beam and covering layer of nutural materials, such as tree branches, cane, straw, reeds, wooden slats. Poplar and oak are the main materials.

The main beam made of poplar wood 25-30cm diameter, and above it is the secondary poplar beams (branches, 21-15cm diameter, parallel to each oher). Then the covering layer is applied from straw, reeds and leaves. On the top, a layer of rough wet earth is applied with thickness 15-30cm.

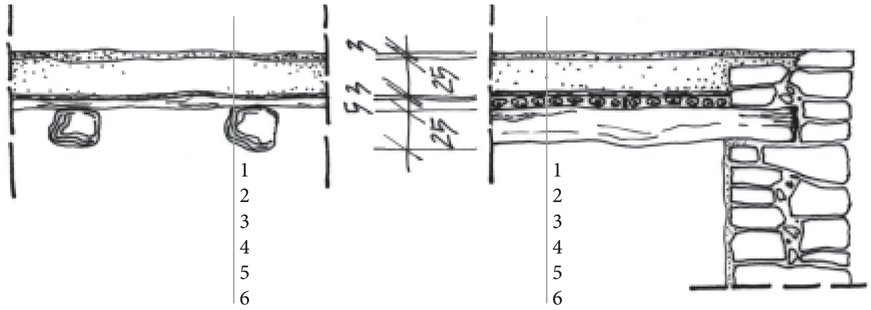


Fig.2.43. Wooden roof detail, Helmedag, 2012

1. Lime straw screed finishing
2. 20-25cm thick earth layer and straw
3. Reeds or branches
4. Thorny shrubs
5. Timber cross beam
6. Timber beam

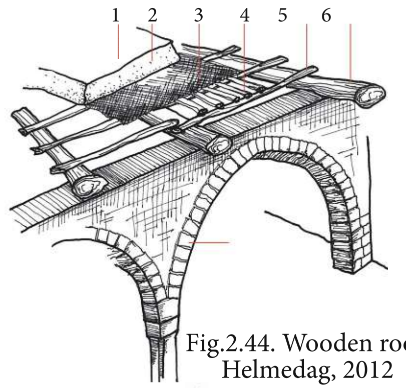


Fig.2.44. Wooden roof, Helmedag, 2012

Fig.2.45. Wooden roof, Mecca and Dipasquale, 2009

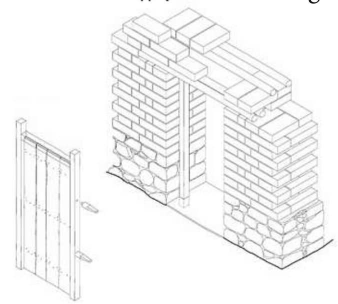


Fig.2.46. Opening, Mecca and Dipasquale, 2009

Fig.2.47. Wood roof, CORPUS Levant, 2004

Fig.2.48. Wood roof, CORPUS Levant, 2004

Wall coating

Lime plaster

It has been used as a rendering material for stone walls all over Syria.

It has been used as aesthetic element and to protect the walls from external effects, which may affect the durability and structure condition of the wall, reflecting sunlight and absorbing less heat during the hot seasons.

Lime plaster was applied in three layers

First layer: the bsmar layer, made of dust with hydrated lime, sand and water.

Second layer: the bitaneh layer, made of lime, hard sand, dust and hemp with water.

Third layer: the dahra layer, made of lime, fine sand, dust and water.

To apply these layers, the time between the application of each layer should be considered.

This plaster must be prepared in specific standards to ensure its cohesiveness and effectiveness. The dampening of the wall before the application of the first layer is important to ensure that the wall will not absorb the plaster´s water, in order to avoid cracks.

Lime plaster should be renewed and fixed every now and then since it is sensitive
to external effects.

Fig.2.49. Lime plaster, Aleppo, Mecca and Dipasquale, 2009

Fig.2.50. Lime plaster, Aleppo, Mecca and Dipasquale, 2009

Wall coating

Earth rendering

It has been used as rendering material for the external face of the mud buildings. It has been found in many cities and countrysides in Syria, such as Damascus and outskirts of Aleppo.

There are two types of traditional earth rendering:

Coarse rendering and soft rendering.

Both types consist of mud mixed with water.

In coarse rendering, there is an addition of straw to give it more cohesiveness (wheat straw or barley). Then the coarse rendering is covered with a layer of smooth rendering.

Mud rendering must be renewed and fixed regularly since it can not withstand climate conditions properly.

Washes

Whitewash has been used on stone and mud walls. It is liquid and made from limestone that is soaked in water for a couple of days until it is ready for use. The application of this whitewash in one layer and it gives a nice smell with bright white color. It has been used as a paint inside the rooms in some villages in Syria.

Fig.2.51. Earth rendering, Aleppo, Mecca and Dipasquale, 2009

Fig.2.52. Whitewash, Aleppo, Mecca and Dipasquale, 2009

2.5. Population in Syria

“Please
Respect my silence,
Silence is my best weapon
Did you feel my words
When I fell silent?
Did you feel the beauty of what I said
When I said nothing?”
Nizar Qabbani

Syria population

The population in Syria in 2010 was more than 21 000 000 millions people. Most of the population live in the big cities like Damascus, Aleppo, Hamah, Homs...
Few population live in east side of Syria since it is desert.
But due to the conflict in Syria the number has decreased to 17 500 658 people in 2020 according to UN data. Since 5.6 million sought refugee in other countries.
The number of population is changing every day. Because many people are still flee Syria every day.
6.7 million are displaced inside Syria according to shelter projects report 2017-2018.

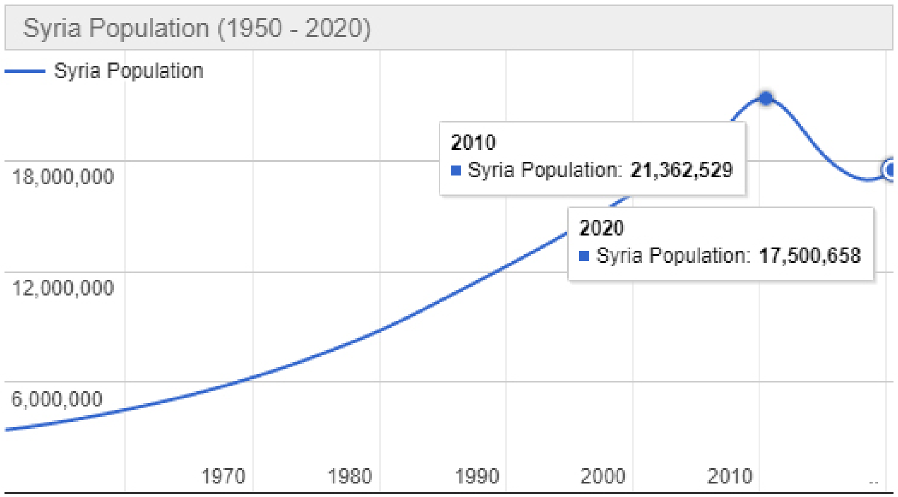


Fig.2.53. Syria population

Syrian refugees

5.6 million Syrian refugees:
- 3 576 344 in Turkey
- 914 648 in Lebanon
- 654 692 in Jordan
- 245 810 in Iraq
- 129 210 in Egypt
- 530 000 in Germany
- 110 000 in Sweden
- 50 000 in Austria
- 45 000 in Canada
- 33 000 in United States

Fig.2.54. Syrin refugees

2.6. Situation in Syria

"I cannot write about Damascus, without the jasmine climbing on my fingers.
I cannot say her name, without my mouth getting overcrowded with apricot juice, blackberries and quince"
Nizar Qabbani

Situation in Syria 2021

It has been more than a decade since the conflict in Syria started. During these years so many people have died, so many have lost their lovely ones, so many have injured, so many have been missed, so many have became internally displaced persons within Syria and many have became refugees in other countries...

In this decade, Syria has been divided to many parts, which has been controlled by many groups.

Next map shows who controls Syria and which portion?
In 2021, the syrian government has regained the control of the biggest cities in Syria and now it controls 63.38% of Syria.
The Syrian Democratic Forces (SDF) controls 25.64% of Syria.
The free Syria army controls 10.98% of Syria.
Islamic State does not control any part of Syria anymore.
Security corridor area is the observed area by Russia and Turkey.

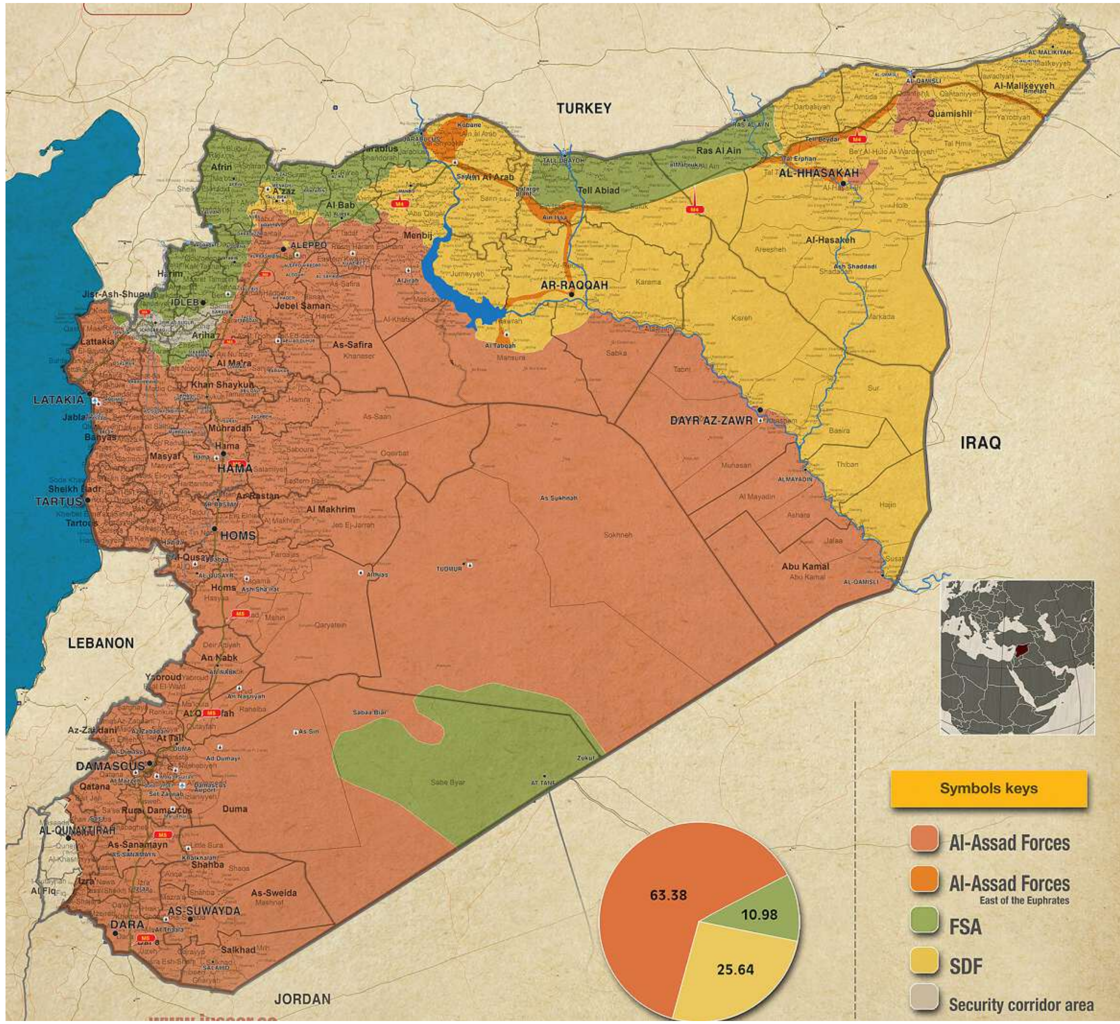


Fig.2.55. Syria control map

2.7. Damage in Syria

“In the summer
I stretch out on the shore
And think of you
If I told the sea
What I felt for you,
It would have left its shores,
Its shells,
Its fish,
And followed me.”
Nizar Qabbani

Damage in Syrian cities

Many syrian cities have experienced high or low damage during the last decade.
Aleppo and Eastern Ghouta (East of Damascus) have experienced the highest damage.
Number of buildings the experienced some damage or totally destroyed as following:
Aleppo 35722 buildings.
Eastern Ghouta 34136 buildings.
Homs 13778 buildings.
Ar-Raqqa 12781 buildings.
Hama 10592 buildings.
Deir-ez-Zor 6405 buildings.
Yarmouk and Hajar Aswad (west of Damascus) 5489 buildings.
Al Zabadani 3364 buildings.
Kobane 3247 building.
Dar'a 1503 buildings.
Idleb 1415 buildings.
Menbij 1198 buildings.
Tadmur -Palmyra 651 buildings.
Al Quaryatayn 525 buildings.
Tabqa 487 buildings.
Afrin 196 buildings.
As shown in the figure below.
Destroyed in purple. Severe Damage in red. Moderate damage in yellow.

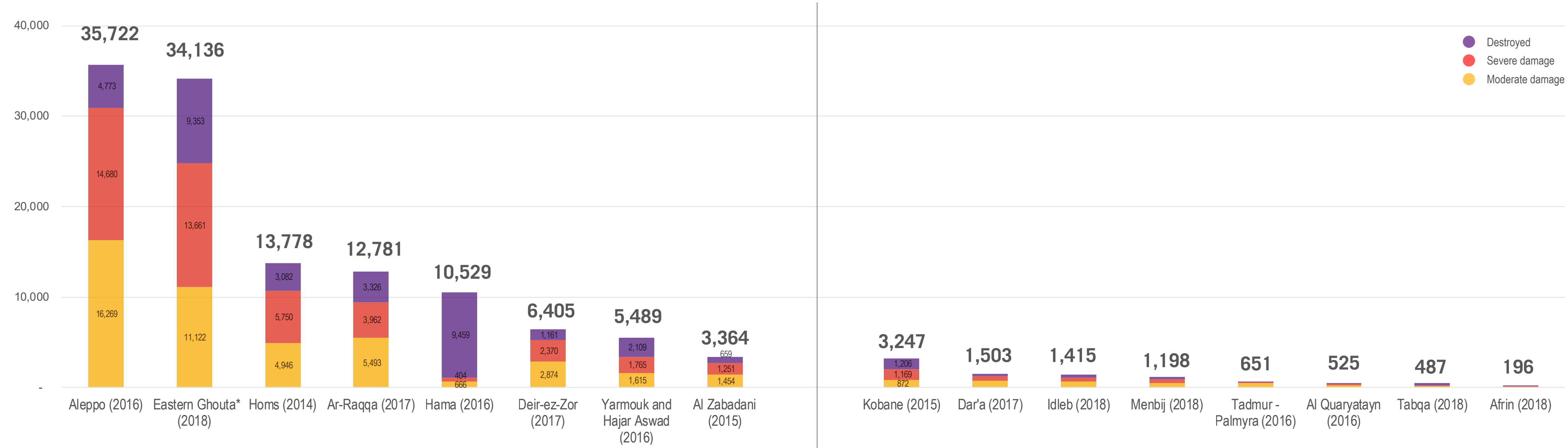


Fig.2.56. Damage comparison in syrian citeis, REACH, 2019

Damage in Aleppo

Aleppo city is the second largest city after the capital Damascus and it in known as the economic capital.
According to REACHUNOSAT sateliite damage analysis
all neighbourhood in Allepo had some damage except one neighbourhood. And the neighbourhoods within the central had high level of damage.

The buildings were classified in three categories

- Destroyed (purple color)
  4733 Buildings classified as destroyed
- Serve damage (red color)
  14680 Buildings classified as serve damage
- Moderate damage (yellow color)
  16269 buildings classified as Moderate damage

"On average, 4 buildings per hectare are classified as damaged or destroyed within Aleppo city. This ranges from 10 - 15 buildings per ha in the 10 most damaged neighbourhoods." REACH 2019

Aleppo satellite detected damage points shows the buildings which have been classified as destroyed or have experienced some damage as following:
Totally destroyed in purple color
Severe Damage in red color
Moderate damage in yellow color

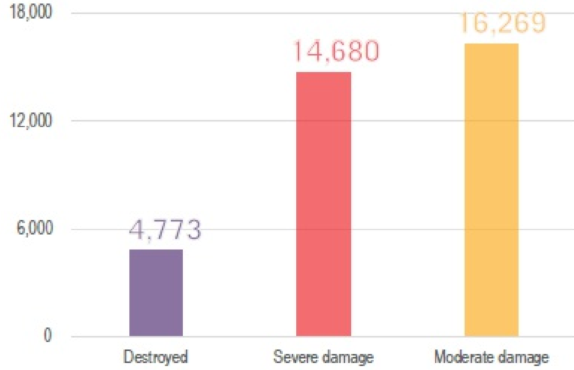


Fig.2.57. Aleppo Number of buildings classified into each damage category, REACH, 2019

Fig.2.58. Aleppo satellite detected damage points, REACH, 2019

Damage in Eastern Ghouta

Easter Ghouta is bordering Damascus (East side of Damascus) and located in Rif Dimashq governorate. It is the most damaged area.
93% of buildings in Jobar neighbourhood were destroyed or experienced some damage.
71% of buildings in Ein Terma neighbourhood were destroyed or experienced some damage.
"Jobar neighbourhood is empty of residents with almost all buildings destroyed. No one can return." Resident of Eastern Ghouta, interviewed by REACH, 07 March 2019.

The buildings were classified in three categories

- Destroyed (purple color)
  8606 Buildings classified as destroyed
- Serve damage (red color)
  10787 Buildings classified as serve damage
- Moderate damage (yellow color)
  12883 buildings classified as Moderate damage

Ghouta satellite detected damage points shows the buildings which have been classified as destroyed or have experienced some damage as following:
Totally destroyed in purple color
Severe Damage in red color
Moderate damage in yellow color

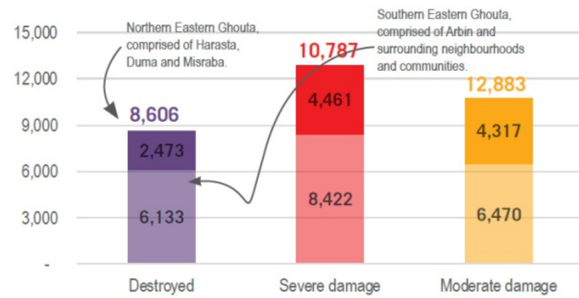


Fig.2.59. Ghouta Number of buildings classified into each damage category, REACH, 2019

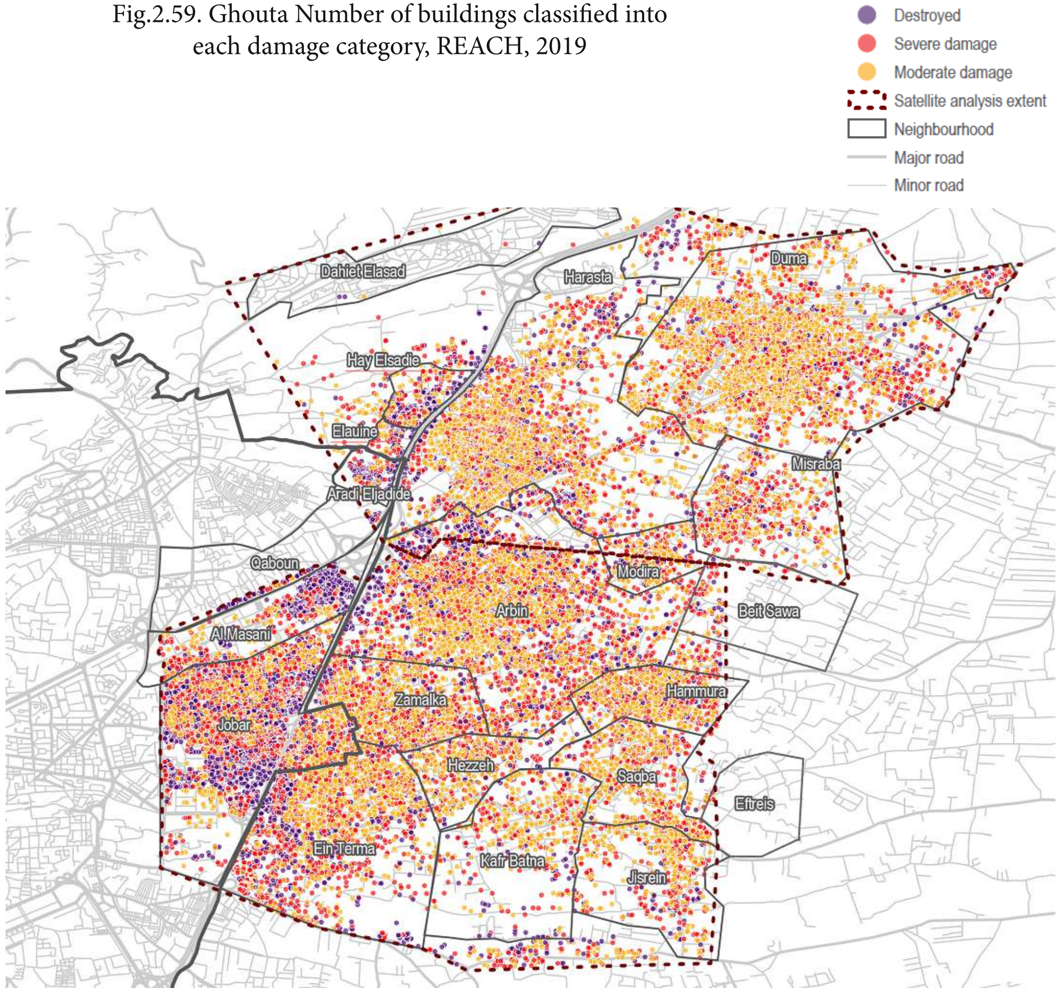


Fig.2.60. Ghouta satellite detected damage points, REACH, 2019

3. IDPs Camps in Syria

"These are the cities of tomorrow."
Kilian Kleinschmidt, German entrepreneur and former UNHCR official

3.1. IDPs in Syria

Due to the current situation in Syria a lot of people have fled from their homes within Syria itself and became IDPs (Internally displaced persons). This movement of IDPs has began in 2012.

6.7 million are displaced persons inside Syria according to shelter project report 2017-2018, the biggest internally displaced population in the World.

2.7 million of those live in Northwest Syria, in Aleppo and Idleb governorates.

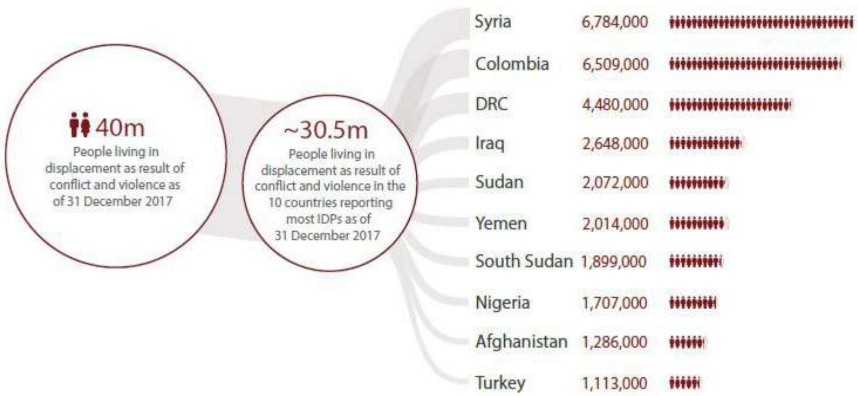


Fig.3.1. IDPs numbers by end the of 2017, Shelter projects 2017-2018, 2019

3.2. IDPs movement in 2020

The movement of syrian internally displaced persons has started in 2021 and some of them have changed their location more than three times.

1 822 000 IDPs movement has been recorded in Syria according to UNOCHA report. Most of this movements were in the governorates of Idleb, 1 070 000 IDPs movements.

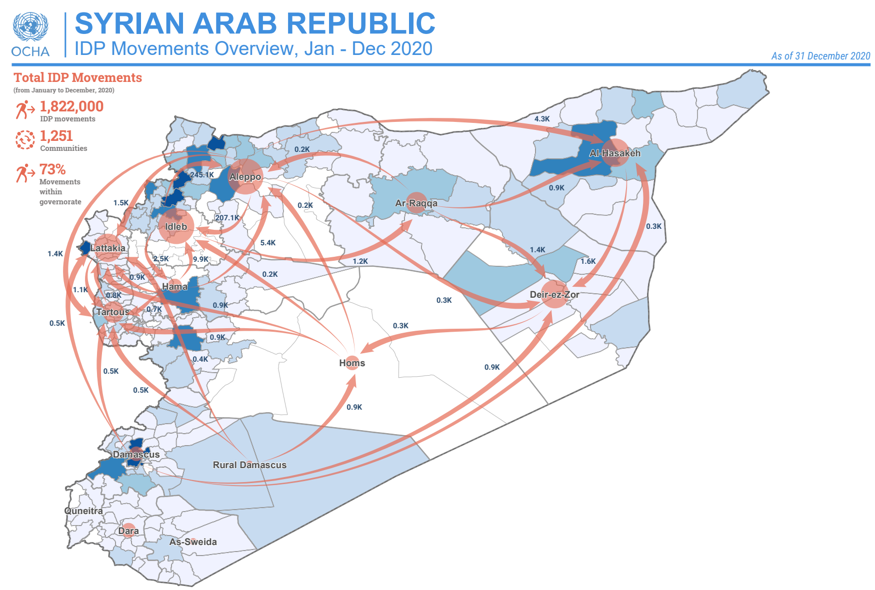


Fig.3.2. IDP Movements Overview, Jan - Dec 2020, OCHA, 2020

3.3. IDPs Camps in Aleppo and Idleb

According to the Assistance Coordination Unit (ACU) there are 320 camps within 14 sub-districted distributed in Aleppo and Idleb governorates.
221 camps in Idleb and 99 camps in Aleppo.

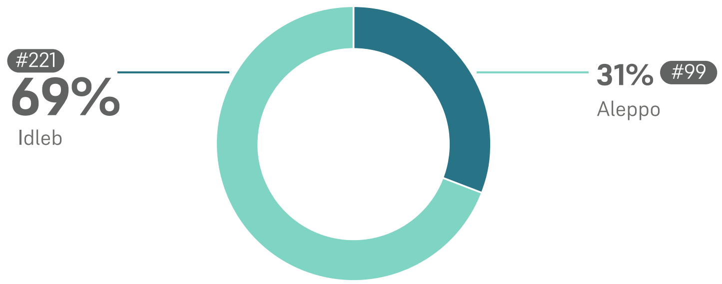


Fig.3.3. Number & Percentage of camps in Aleppo and Idleb, ACU, 2019

Camps in Aleppo governorate: (Sub-district Level)

1. Afrin sub-district
    - Jandairis: 2 camps
2. Jarablus sub-district
    - Jarablus: 17 camps
    - Ghandorah: 8 camps
3. A'zaz sub-district
    - A'zaz: 34 camps
    - Aghtrin: 8 camps
    - Suran: 3 camps
4. Al Bab sub-district
    - Al Bab: 21 camps
    - Ar-Ra'ee: 5 camps
    - Tadaf: 1 camp

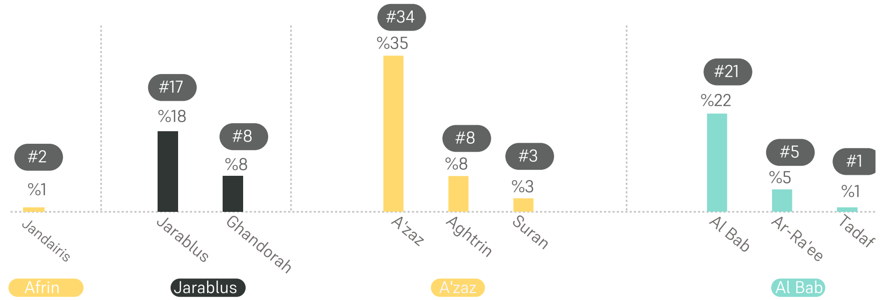


Fig.3.4. Number of camps in Aleppo, ACU, 2019

Camps in Idleb governorate: (Cluster Level)

1. Badama cluster
    - Kherbet Aljouz: 12 camps
2. Dana cluster
    - Atma: 79 camps
    - Al Rahma: 32 camps
    - Al Karama: 56 camps
    - Sarmada: 3 camps
    - Qah: 26 camps
3. Salqin cluster
    - salqin: 3 camps
4. Harim cluster
    - Harim: 6 camps
5. Ma'arrat An Nu'man cluster
    - Ma'arrat An Nu'man: 4 camps

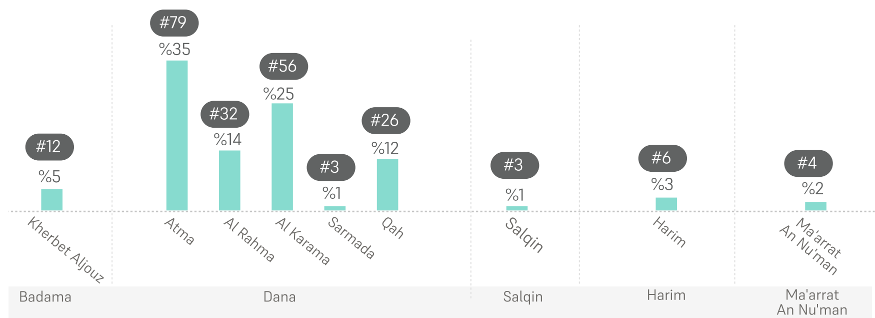


Fig.3.5. Number of camps in Idleb, ACU, 2019

Types of IDPs' shelters

According to the Assistance Coordination Unit (ACU), in Aleppo and Idleb governorates the percentage of shelters as following: 69% tents(57,917 tents), 23% rooms (19,101 rooms) and 8% caravans (6,425 caravans).

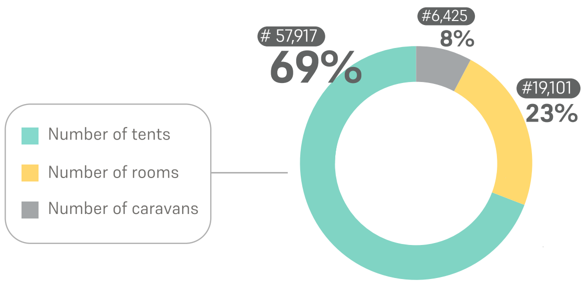


Fig.3.6. Types of IDPs shelters, ACU, 2019

Types of shelters in Aleppo governorate

In Aleppo governorate, all shelters in Suran and Ar-Ra'ee camps were tents. 97% of shelters in Albab sub-district were tents. 70% of shelters in Jarablus sub-district were tents. All shelters in Tadaf camp were caravans.

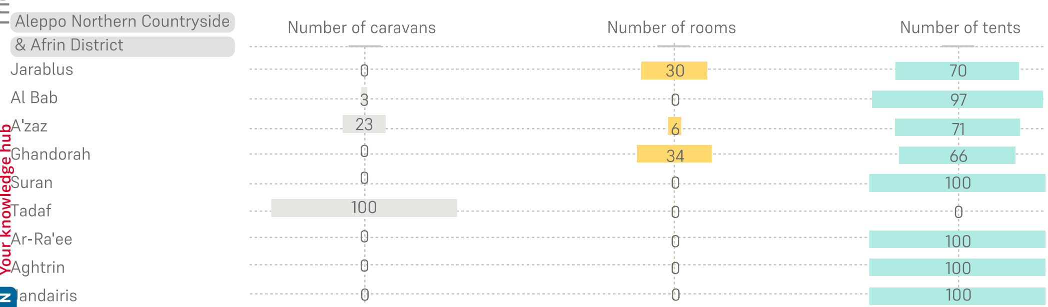


Fig.3.7. Types of shelters in Aleppo, ACU, 2019

Types of shelters in Idleb governorate

In Idleb governorate, all shelters in Salqin and Kherbet Aljouz camps were tents. 80% of shelters in Sarmada camp were tents. 72% of shelters in Ma'arrat An Nu'man camp were tents. 71% of shelters in Alrahma camp were tents.

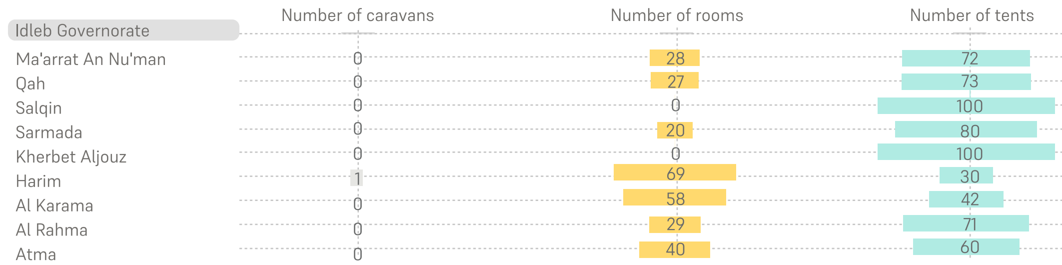


Fig.3.8. Types of shelters in Idleb, ACU, 2019

Shelters require maintenance in Aleppo and Idleb

The study shows that 9% of room (1,629 rooms), 25% of total tents (14,578 tents) and 26% of total caravans (1,675 caravans) need maintenance. And 29% of total tents need replacement. The slope of land was suitable only of 56% of total camps. 70% of camps included paved or surfaced roads with gravel.

Fig.3.9. Shelters that need Maintenance, ACU, 2019

IDPs' camps location

The following map shows the location of the mentioned camps in Aleppo and Idleb governorates and the number of affected IDPs by flood.

January 2021, 67 647 people were affected by heavy rain in Northwest Syria. At least 196 IDP sites were affected as well. According to OCHA report 2021.

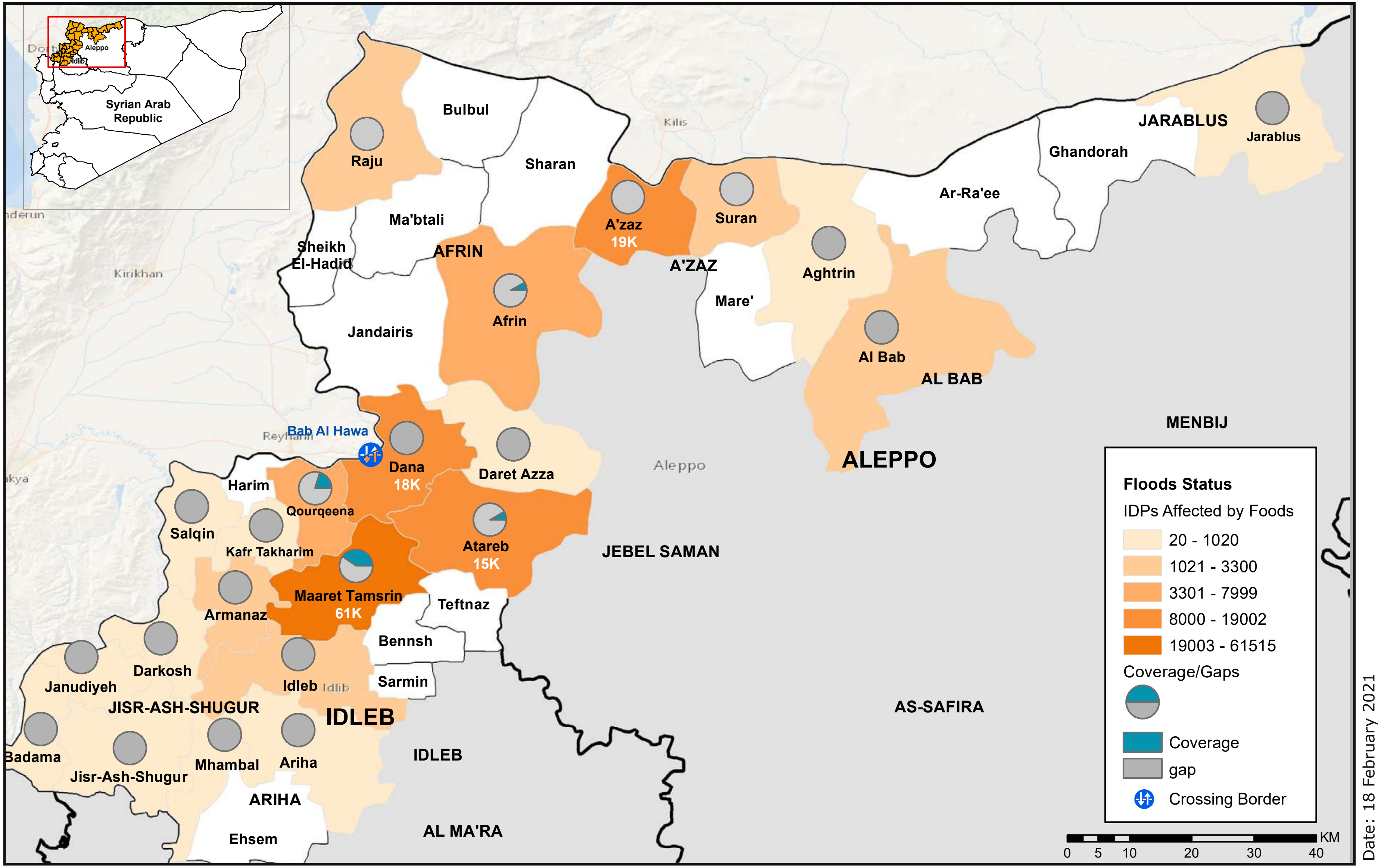


Fig.3.10. IDPs camps in nortwest Syria , Reliefweb, 2021

IDPs camps in Syria

"These are the cities of tomorrow." Kilian Kleinschmidt, German entrepreneur and former UNHCR official who served as the director of the Zaatari refugee camp.

Rapid Growth of Syrian Refugee Camps, which became cities of chaos.
And that requires an urban planning of these camps to provide the IDPs there an appropriate living spaces.
The following map shows Al Karama camp, which has been planned randomly and without consideration the minimum required area per person in these camps.

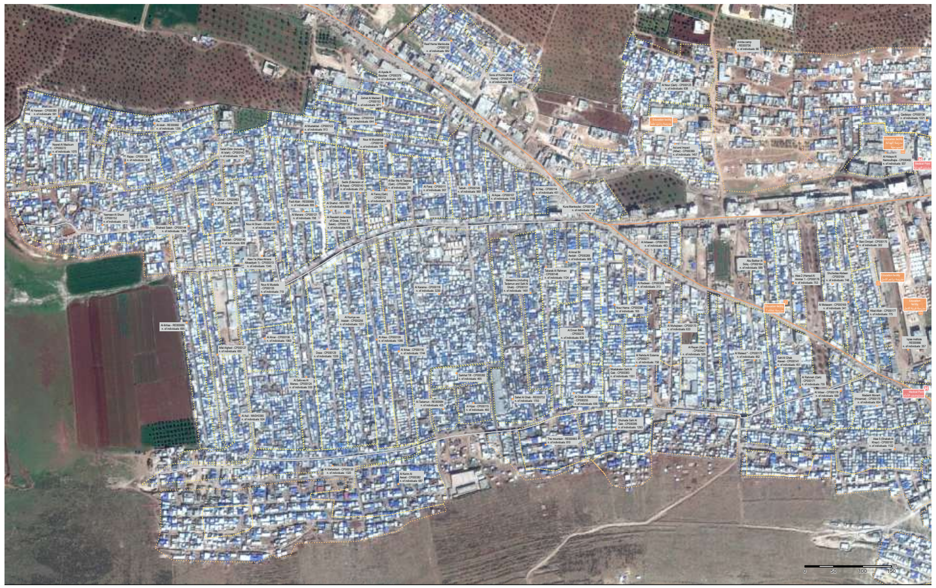


Fig.3.11. Al Karama camp, Dana cluster, Idleb , REACH 2020

Tents are not enough in cold nights during winter to provide a safe and warm shelter.
Moreover, many IDPs have been died due to fire outbreaks in IDP camps. The main reason was the fabric material of the tent. Building a safe shelter require choosing an appropriate material.

Fig.3.12. Dana cluster, Idleb , 2021

4. Refugee Shelters

“The key thing will be to design and construct shelter where no or little technical supervision is required, and use materials that are locally available and eco-friendly. It’s important that the houses can be easily maintained by inhabitants.” Pritzker Prize winning architect Shigeru Ban

4.1. Post Disaster Shelter

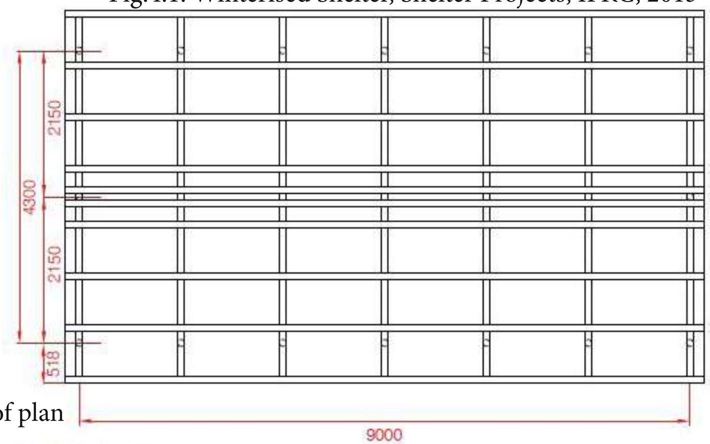
“I believe that the way people live can be directed a little by architecture.” Tadao Ando

Afganisan 2009, Winterised Shelter

This shelter was built as a shell to protect occupants living in tents.

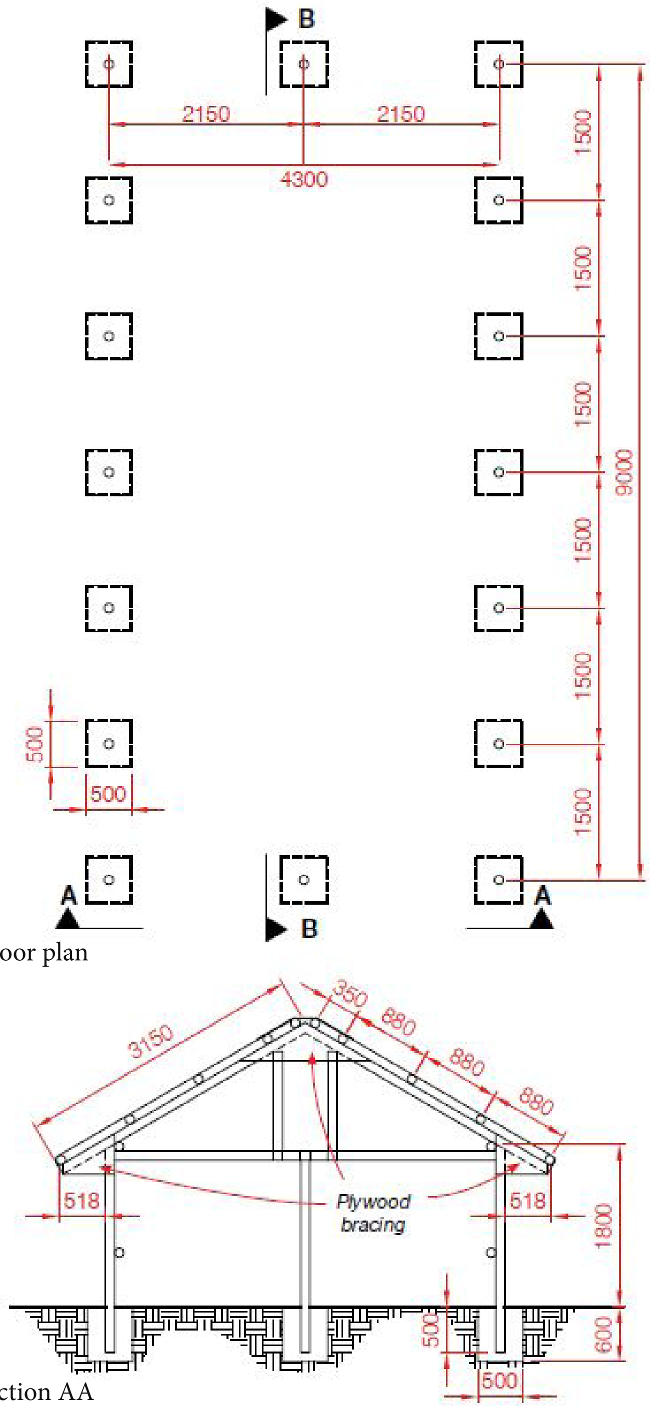
The tent has been erected inside the structure. It is 9m x 4.3m and 1.8 height. The frames from bamboo poles. They are connected using plywood gusset plates and bolts. The walls and roof are plastic sheeting. The floor is compacted soil. These shelters are temporary solution, and the frame can be re-used in permanent construction. The plastic sheet roof and walls are simple to install, but will not withstand many seasons.

Fig.4.1. Winterised Shelter, Shelter Projects, IFRC, 2013



Roof plan

Fig.4.2. Winterised Shelter, Shelter Projects, IFRC, 2013



Floor plan

Section AA

Fig.4.3. Winterised Shelter, Shelter Projects, IFRC, 2013

Indonesia - Sumatra 2009, Timber frame

After the earthquake in Sumatra at 2009 almost 7000 shelters have been built. It 4x4.5m and 2.4m to 3.35m height.
The Shelters are timber framed structure with palm roofing and walls.
There is no bracing, but some stability is provided by three portal frames.
It can be quickly constructed after a disaster and offers a good short term solution. The columns are embedded into concrete foundations.
The shelters have been built from locally sourced materials and can be quickly constructed because no t specialist tools or equipment are required. Therefore this shelter is a good short term solution. And it provides a good performance for both high winds and seismic.
Many improvements can be applied such replacing the matting with roof sheeting, strength the foundations.

Fig.4.4. Timber frame, Shelter Projects, IFRC, 2012

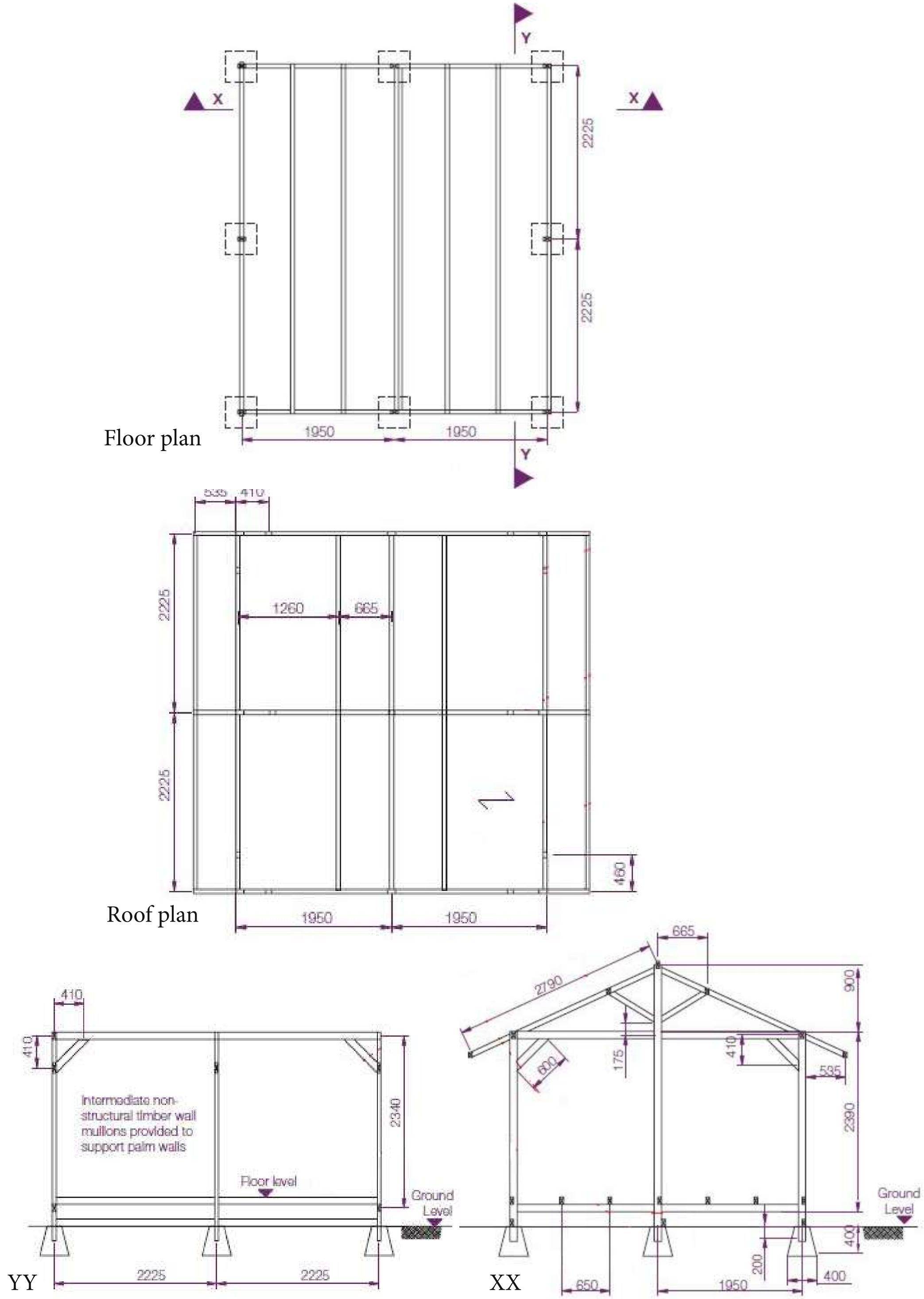


Fig.4.5. Timber frame, Shelter Projects, IFRC, 2012

Haiti 2010, T-Shelters

Approximately 1.3 million people were displaced in Haiti due to Earthquake on 12 January 2010.

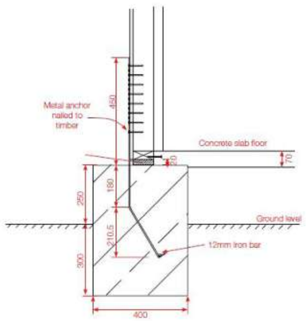
Formal and informal camps were built in open areas throughout Port-au-Prince for the internal displaced people, known as tent cities.

By 2012, 93% of the camps were T-Shelters. And 7% Tents and makeshift shelters. Transitional shelters built by Catholic Relief Services are expected to last between three to five years.

Haiti used a design similar to the one that has been used in Sri Lanka after the Indian Ocean tsunami.

This shelter is a rectangular timber framed structure with a gable roof and a floor area of 21 m². Wall consists of wood studs with plywood sheathing and metal roofing on wood purlins and trusses. The wood trusses can be pre-manufactured and shipped to the construction site. The foundation consists of concrete piers in the four corners and a stone masonry wall in-between the piers.

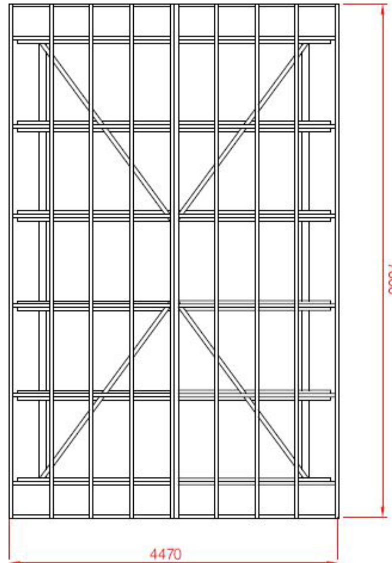
The Structure of this shelter is very durable with lifespan much larger than the typical transitional shelter provide the basis for permanent housing.



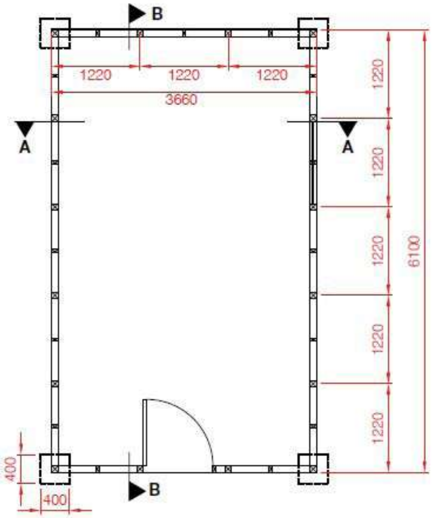
Foundation Detail

Fig.4.6. Haiti T-Shelter, Shelter Projects, IFRC, 2013

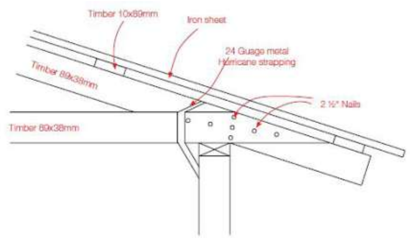
Light timber and plywood framing, which can provide with some modification to the anchoring details a good performance for both high winds and seismic. The stone masonry foundation wall raises the floor above the surrounding ground surface, which provide resistance to flood damage.



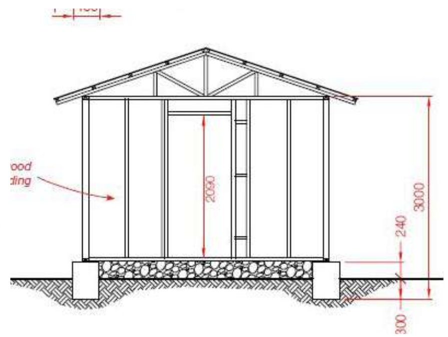
Roof framing plan



Floor plan



Roof fixing detail



Section AA

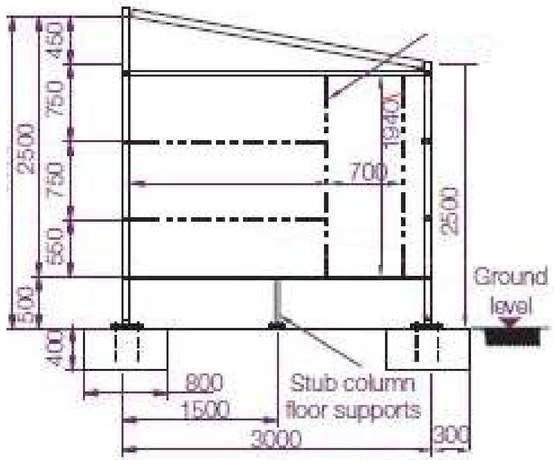
Fig.4.7. Haiti T-Shelter, Shelter Projects, IFRC, 2013

Haiti 2010, Steel Shelter

The shelter consists of a galvanized rectangular steel frame with an 8.5 degree mono-pitch roof and a suspended floor. It is 3 x 6 m and 2.55 to 3m height. It has reinforced concrete foundation with a 300x300x6mm baseplate and four ordinary bolts per base. The raised floor is also supported by 13 additional stub columns on 100x100x6mm base plates bearing directly on to the soil.

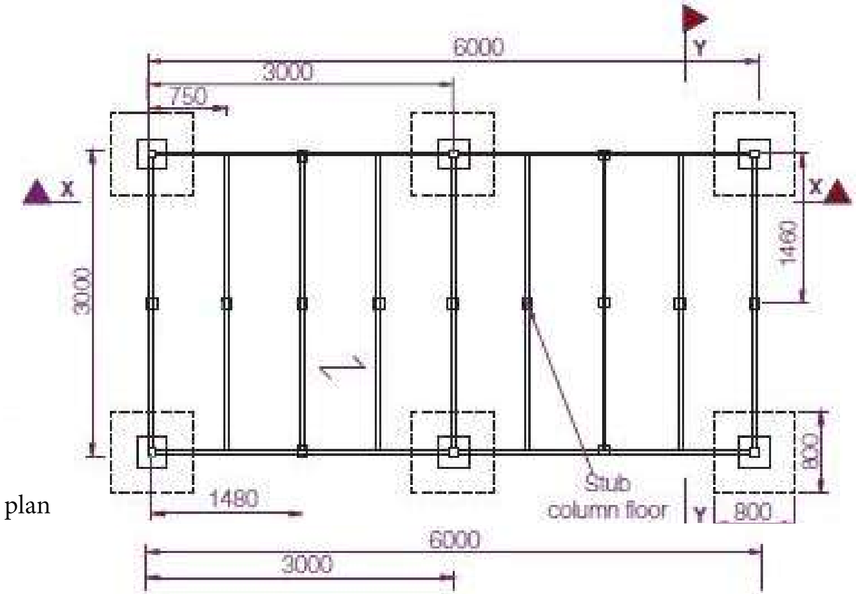
The main structure is three primary frames with rectangular hollow section columns. The roof cladding is corrugated steel sheeting and the walls are plastic sheetings.

This pre-fabricated steel frame structure is relatively expensive but quick to construct. Limited stability because there is no bracing in the walls or roof, which cause a low performance for both high winds and seismic. Many alterations are required to improve its performance such modifications to foundations, steel members and bracing in the walls and roof.

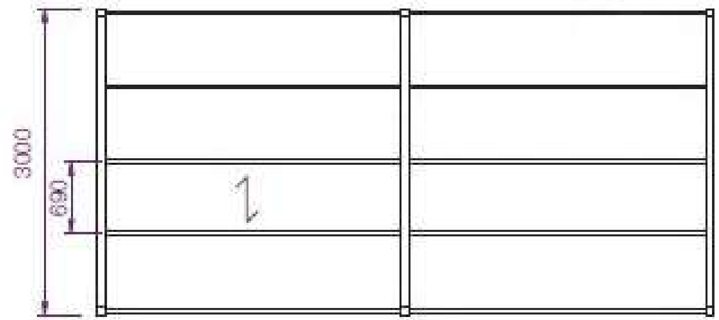


Section YY

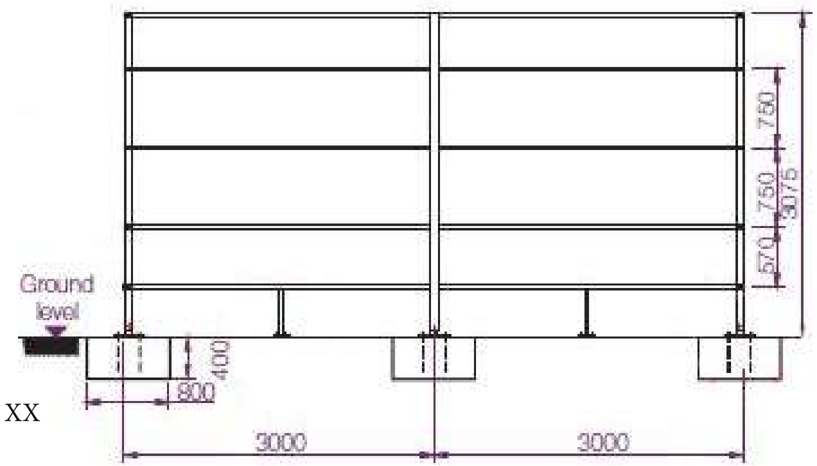
Fig.4.8. Haiti Steel Shelter, Shelter Projects, IFRC, 2012



Floor plan



Roof framing plan



Section XX

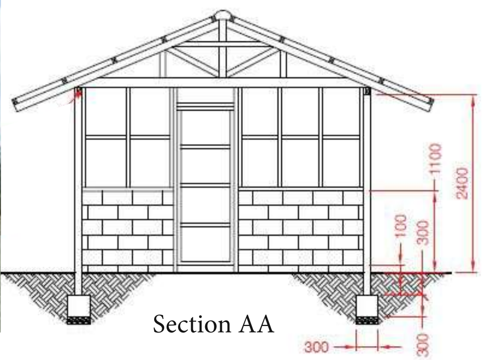
Fig.4.9. Haiti Steel Shelter, Shelter Projects, IFRC, 2012

Philippines 2011, Transitional-Shelter

Rectangular structure with a gable roof. It measures 6.5 x 4 m. The exterior walls have a half height concrete masonry wall with wood framing above. The roof consists of timber trusses and metal roofing.

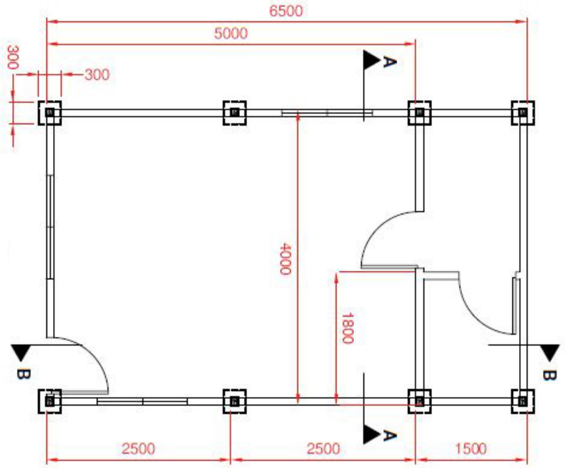
Eight precast concrete columns located within the exterior walls support the roof framing. The floor is a cast in place concrete slab. Expansion in both horizontal directions is possible due to the modular construction for the shelter. The shelter can be deconstructed for relocation and/or to be included in permanent construction.

The concrete and masonry components are durable materials. The use of precast concrete columns provides a quick construction of the roof. The weight of shelter is not enough to resist uplift loads for full wind speeds.

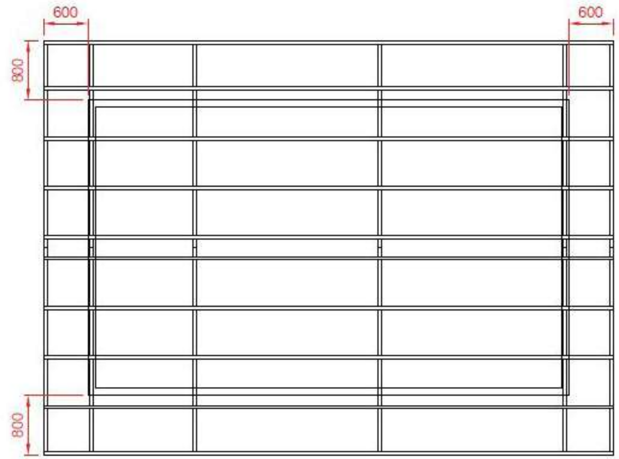


Section AA

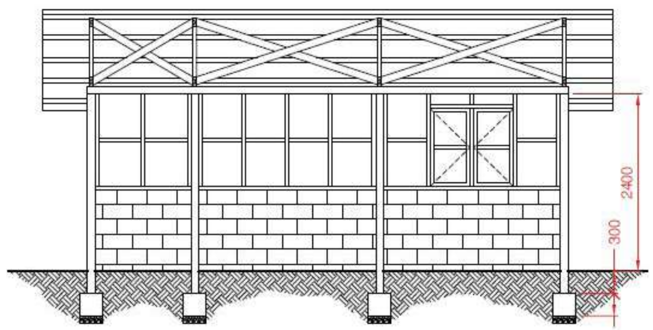
Fig.4.10. Philippines Transitional Shelter, Shelter Projects, IFRC, 2013



Floor plan



Roof framing plan



Section BB

Fig.4.11. Philippines Transitional Shelter, Shelter Projects, IFRC, 2013

Nasma, Najjar Architects

Prototype of low-cost, climate-responsive school.
Due to lack of educational opportunities in syrian refugee camps in Lebanon, Najjar architects proposed a refugee school, that provides the syrian children supportive learning conditions. Prototype has been built in The Bekaa valley, which has dry weather, cold Winter and hot Summer. Therefore the concept was to build a prototype with low cost, good learning conditions, appropriate thermal and air conditionings, environmentally friendly by using local materials. Funding: 20,000 $.
Exterior walls are made of stacked-earth bags assembled on site and braced by eco-beams, which provides a sufficient thermal insulation. The roof made of timber covered by thatch for insulation covered by metal sheets. The prototype can be disassembled with no footprint on the site. The ventilation of the school is provided through earth ducts. Stale air will be exhausted through roof vents. The vents and the sun-absorbing panels are creating a chimney effect. The project involved refugees in the construction process in order to give them a sense of ownership.

Fig.4.12. Completed school unit, Najjar, 2017

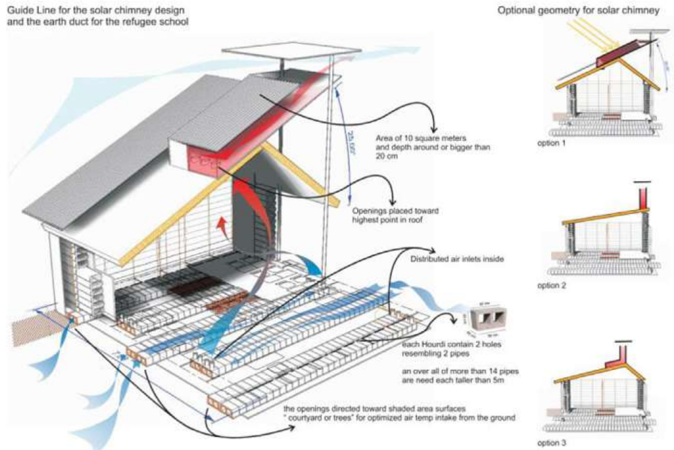


Fig.4.13. Climate concept, Najjar, 2017

Fig.4.14. Assembling earth ducts, Najjar, 2017

Fig.4.15. Sand bag stacking and assembling Eco-beams, Najjar, 2017

Better Shelter, Refugee housing unit

Temporary shelter has been produced by IKEA and designed for refugees and displaced persons.
The expected life span of better shelter about three years. Better shelter is designed to be more durable and better insulated than traditional refugee tent.
Better shelter has 17.5 m² area, 140 kg weight. It is suitable for five people and can be assembled by four people in five to six hours. This shelter has Modular design, which means sections can be added and removed to create different structures. It can be dismantled, moved and remounted. It is flexible wit low cost, app.1250$.
It made of steel frames and covered by lightweight polymer panels laminated with thermal insulation.
Panels, pipes, connectors and wires all come in two flat-packed in cardboard boxes like IKEAs furniture.
It includes four windows, four ventilation openings and a lockable door.
A solar panel on the roof generates power to illuminate a built-in lamp, as well as power for the charging of electronic devices.
It has a led lamp as well.

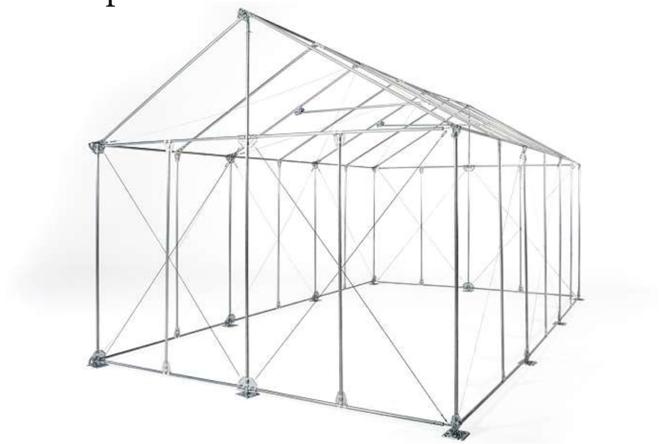


Fig.4.16. Better Shelter's frame, BetterShelter.org, 2018

Fig.4.17. Better Shelter 1.2, BetterShelter.org, 2018

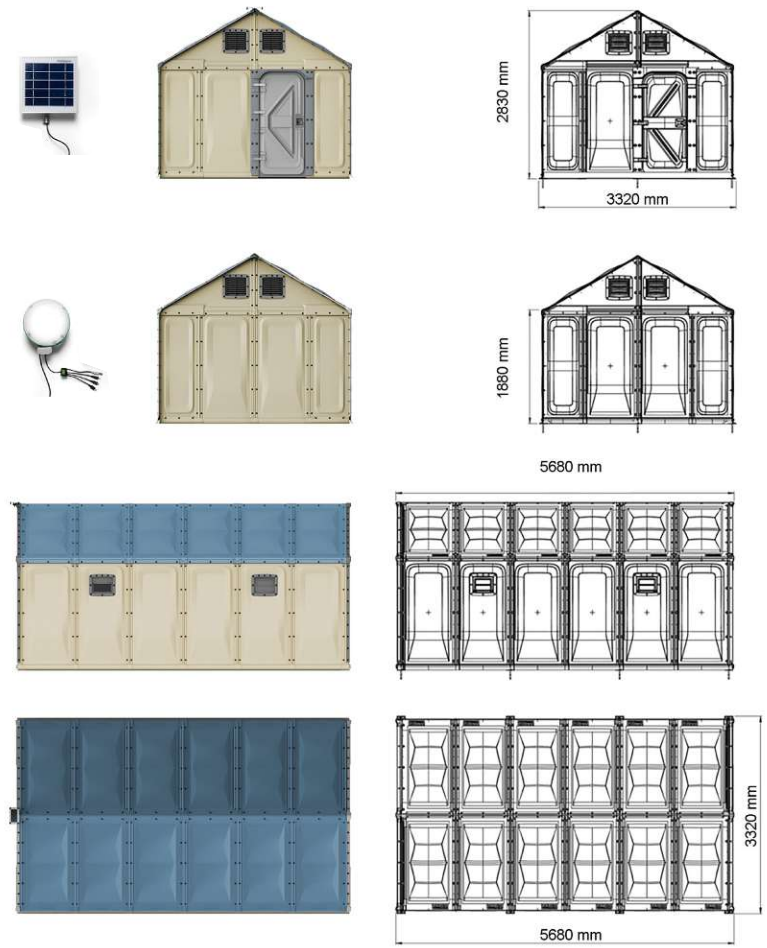


Fig.4.18. Lamp, solar panel and elevations, BetterShelter.org, 2018

Turkana Houses in kenya

Pritzker Prize winning architect Shigeru Ban.
Agreement with UN-Habitat to design up to 20,000 new homes for refugees in Kenya's Kalobeyei Refugee Settlement.
"The key thing will be to design and construct shelter where no or little technical supervision is required, and use materials that are locally available and eco-friendly. It's important that the houses can be easily maintained by inhabitants."
Type B3 is a house built by earth bricks and wood, local material.

Fig.4.20. Mud bricks, UN-Habitat, 2020

Fig.4.21. Turkana House Type B3, UN-Habitat, 2020

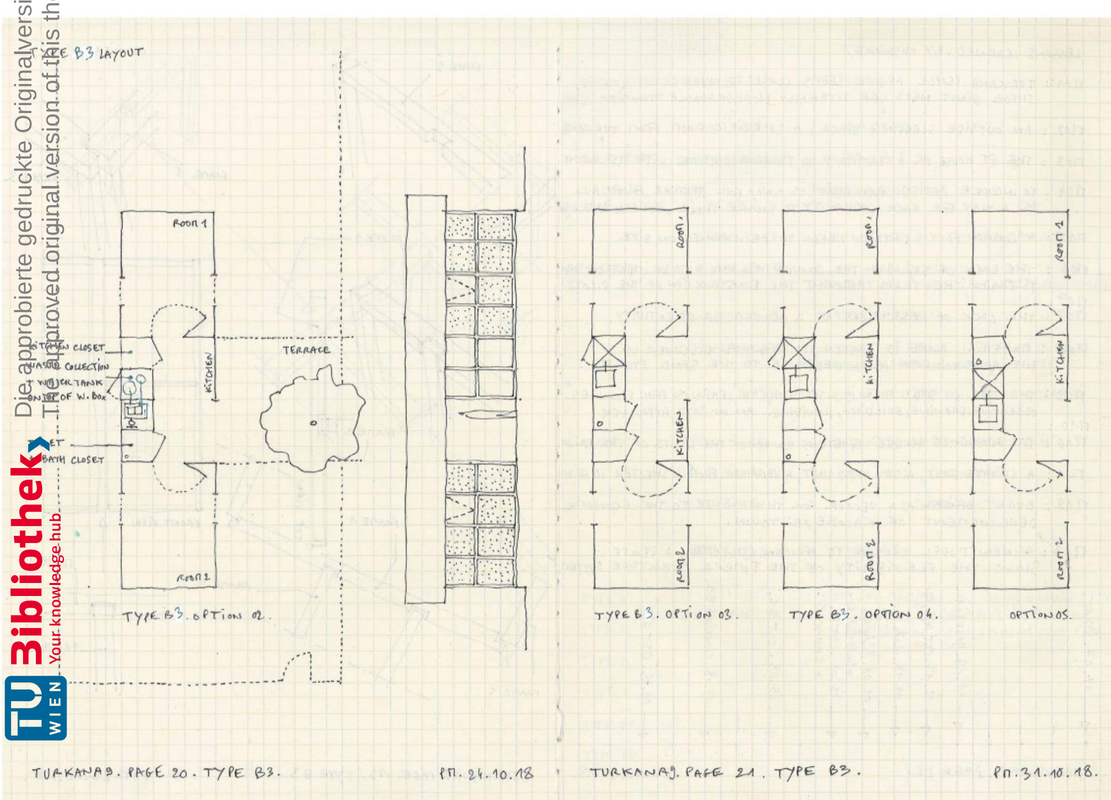


Fig.4.19. Turkana House Type B3, UN-Habitat, 2020

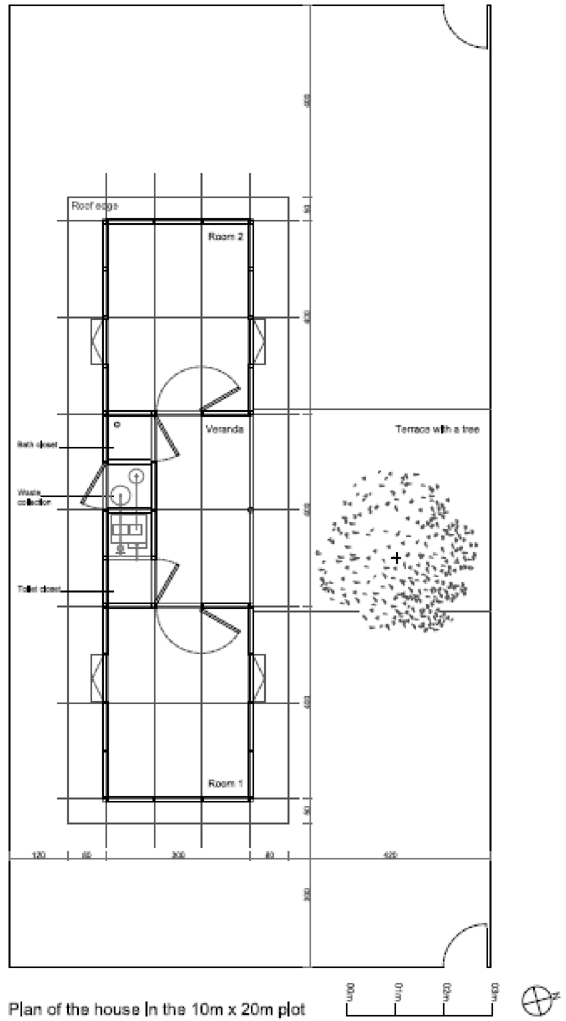


Fig.4.22. Turkana House Type B3, UN-Habitat, 2020

4.2. 3D Printed Shelters

The improvements in manufacturing technologies
provide a solution for
Eco-sustainable, cheap and
fast printed post-disaster houses

WASP

WORLD'S ADVANCED SAVING PROJECT

Company located in Italy produces and sells 3D printers. It has printed GAIA house, a new eco-sustainable house model. Raw soil has been used as the main binder of the constituent mixture. WASP has developed a compound composed of 25% of soil (30% clay, 40% silt and 30% sand), 40% from straw chopped rice, 25% rice husk and 10% hydraulic lime. The mixture has been mixed through the use of a wet pan mill, able to make the mixture homogeneous and workable. Rice husks were also used as layer of insulation.

Fig.4.23. GAIA house

Fig.4.24. Chopped rice husks and straws for insulation

In 2018 Wasp released Crane WASP, the infinite 3d printer, a collaborative 3d printing system able to print Houses. WASP and DAKU participated in the project "Exporting Reconstruction - Innovation and new materials for post-war reconstruction in the MENA Region". It took 10 days to print the casing, 30m² wall, whose thickness is 40cm and total cost of the used materials is 900€. "Gaia is a highly performing module both in terms of energy and indoor health, with almost zero environmental impact," said the design team. Due to its comfortable temperature it does not need a heating or an air conditioning system neither in winter nor in summer.

Fig.4.25. WASP 3D printer

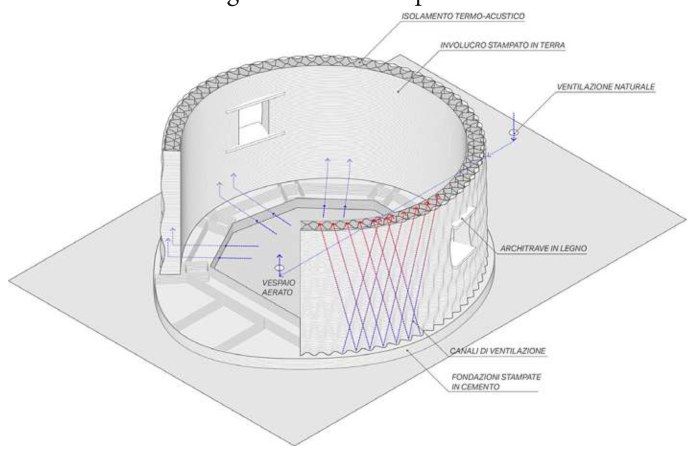


Fig.4.26. GAIA ventilation concept

apis cor

A San Francisco-based company that specializes in 3D-printing used a mobile 3D printer to construct an exceedingly affordable 38m² home in 24 hours, which has bedroom, bathroom and hall in the Moscow. It costed 10134 $, app. 275$/m².
The company says their buildings will last up to 175 years.
The printer is easily transportable using a regular truck and does not require a long preparation procedure to start construction.

Fig.4.27. apis cor 3D printer

Fig.4.28. 3D printed wall and the added fiberglass

apis cor opens a new round of revolution, horizontal fiberglass reinforcement.
They have developed their own material mix, which is an extrudable concrete consisting of cement, sand, geopolymers and fibers. They left a small gap between the interior and exterior of walls, where they can place fiberglass reinforcements and sprayed a polyurethane-based mixture for insulation.
Another advantage is the absence of construction waste.

Fig.4.29. Plaster finishing

Fig.4.30. White interior

ICON

World's 1st 3D Printed Community

The U.S.-based nonprofit (New Story) founded in 2014 and since then has built more than 2,700 homes in haiti, el salvador, bolivia, and mexico. It recognized that new technology could help it work more effectively, therefore it has teamed up with the tech company ICON to build the world's first community of 3D printed homes. It's part of their project working to combat global homelessness. A community of 50 3D printed homes in rural Tabasco, Mexico.

Instead of traditional methods, they used robotic technology to face large scale disasters and rebuild shelters quickly.

The 3D printer starts layering the cement all the way to top where the roof is placed. It takes 24 hours to print.

This home can withstand hurricanes or earthquake.

Each 3D printed home has two bedrooms, living room, kitchen and bathroom, app. 46,45m².

Fig.4.31. 3D printed home, ICON and New Story

The walls are made of a proprietary concrete mixture called Lavacrete.

As a proof of concept a prototype has been built in with 10 000$ cost.

ICON 3D printer, known The Vulcan, is built to be easily transported via truck. It can print the structure with almost zero waste.

Fig.4.32. The Vulcan, ICON 3D printer, Rendering

Fig.4.33. 3D printed community, Rendering

4.3. 3D printed modules

“Each new situation requires a new architecture.”
Jean Nouvel

winsun, units combat covid19

Winsun has printed isolation houses in Xianning in China to face the corona virus outbreak. These units hosted medical stuff. The units are built to withstand extreme temperatures, wind and even earthquakes.
Moreover, the units are easy to transport and set up and can easily be connected to a power supply. And they can be reused. WinSun is changing how emergency shelters are made by using 3D printing technology.
Winsun has designed these units as mobile home and it adapted the design as isolation unit during the covid19 pandemic.
And it was able to print the walls of 15 houses in just 24 hours, less than 2 hours for each house. Area of each house $10m^2$ and height 2,8m. Extrusion process was used to print the houses, Robotic arm deposits successive layers of concrete that hardens quickly to ensure stability. Environmentally friendly, recyclable material has been used such as sand and construction rubble. Twice stronger as concrete.
One unit can be printed in two hours. It costs app. 4000$.

Fig.4.34. winsun 3D printed isolation houses

Fig.4.35. winsun 3D printed isolation unit

Fig.4.36. winsun 3D isolation unit internal perspective

winsun, units combat covid19

Another example of isolation homes , Winsun has shipped 15 units to Islamabad in attempt to help Pakistan facing the covid-19 pandemic.
Due to the humid and subtropical climate of Pakistan, Winsun come up with a specific airtight and thermally insulated design, by employing the most benefits of 3D printing. Not only that, Winsun was able to print 100 units per day, with the interior fabricated in one piece.
Water, electricity, doors, and windows had to be installed.
Designers of these units have outlined that these units after they have outlived their use can be use as park restrooms, small cafes, security guard structures, disaster relief emergency rooms, tiny homes or tiny hotel rooms.
Recycling is a possible as well, these homes can be returned to Shanghai for "crushing, sorting, grinding, and high-temperature treatment."
Afterward, the materials can be shredded and made into more 3D printing filament for further construction of homes.

Fig.4.37. winsun 3D printed isolation houses

Fig.4.38. winsun 3D printed isolation unit

Fig.4.39. winsun 3D isolation unit internal perspective

Mighty House

Mighty building, Start up in California offered the construction market four accessory dwelling units (ADU) 32m² to 65m². These ADUs are prefabricated housing units, known as Mighty Mods, built in the factory, transferred then positioned by crane.

The ADUs are fully furnished.
"Our modular units arrive fully finished with everything needed to move in, including washer/dryer, fridge, dishwasher, etc.," Mighty Building CSO Sam Ruben.
Mighty Mod 32m² costs around 183,750$.

Mighty Building is working on a new innovation in the construction field, UV-curable resins.
"not only speed up the construction process and improve the sustainability of the process, but to also open up new ways of designing buildings," Mighty Building CSO Sam Ruben.

Fig.4.40. Mighty ADU

This innovation has found a new material called Light Stone Material (LSM).
"We have created a proprietary printing material and technology which allow us to UV cure an extrudable gel that cures quickly enough to be able to support its own weight, unlocking the ability to print unsupported spans and organic shapes," Mighty Building CSO Sam Ruben.

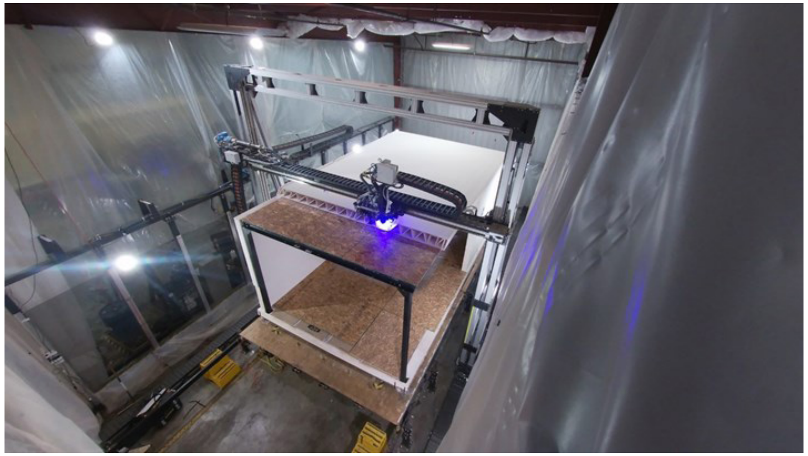


Fig.4.41. Mighty 3D printer

Fig.4.42. Mighty Modules

4.4. Cost of Shelters

The cheaper the better

Shelter	Total Cost per shelter in $	Time to Assemble		Estimated Lifespan	Material
Afganisan 2009, Winterised Shelter	$300,00	3 Days		1 year	Bamboo frames with plastic sheet walls and roof - to protect an existing tent
Indonesia - Sumatra 2009, Timber frame	$898,00	2 days		6 to 12 monthes	Timber frame, palm fibre roof, concrete bucket foundations and palm matting wall panels
Haiti 2010, T-Shelters	$2.560,00	2-3 days		3 to 5 years	Wood framed walls with plywood sheathing, metal roofing on wood trusses, concrete slab floor
Haiti 2010, Steel Shelter	$6.339,00	2 days		2 years	Galvanised steel frame, timber studs, plastic sheeting walls, corrugated steel roof sheeting, concrete foundations, bolts, screws and nails
Philippines 2011 Transitional-Shelter	$2.230,00	12 days		5 years	Reinforced concrete columns, masonry and timber walls, timber roof framing with metal siding
Better Shelter	$1.250,00	4 to 8 hours		3 years	Steel
GAIA house	$1.000,00	10 days		more than 5 years	25% soil(30% clay, 40% silt and 30% sand), 40% chopped rice, 25% rice husk, 10% hydraulic lime
Winsun 3D unit	$4.000,00	less than 2 hours		more than 5 years	recycble, sand and construction rubble
ICON	$10.000,00	24 hours		more than 5 years	concrete mixture called Lavacrete
apis cor	$10.134,00	24 hours		more than 5 years	Concrete consisting of cement, sand, geopolymers and fibers

Table.4.1. Shelters comparison

The previous table shows the most important informations regarding the cost, assembly time, lifespan and the material of the shelters, which have been mentioned in this chapter.

The aim of this analyzing is to find the best solution for cheap, durable and environmentally friendly shelters. These futures are exactly the ones, which the three proposal shelters have. As shown in the next table.

Shelter	Total Cost per shelter in $	Time to Assemble	Estimated Lifespan	Material
Mud Home	less than 1000$	5-6 Days	more than 5 years	Mud bricks (mud and hay) local cheap material
Mud 3D printed Home	less than 1000$	7-8 Days	more than 5 years	25% of soil (30% clay, 40% silt and 30% sand), 40% from straw chopped rice, 25% rice husk and 10% hydraulic lime
3D Module	app. 4000$	less than 3 hours	more than 5 years	Environmentally friendly, recyclable materials such as sand and construction rubble

Table.4.2. Proposed shelters comparison

5. Design Strategy

“All fine architectural values are human values, else not valuable.” Frank Lloyd Wright

Shelter?

Security
Winter
Summer

Safe

Comfort

Privacy
Health
Psychological considerations
Interaction spaces, socialising.

the longer the better

Durable

cost

The cheaper the better
Local material

Scalable

5.1. Shelter Standards

“All architecture is shelter, all great architecture is the design of space that contains, cuddles, exalts, or stimulates the persons in that space.” Philip Johnson

Design Standards

The standards of providing emergency shelters have been defined in many books and researches, like The Sphere Handbook published by group of NGOs and the Red Cross and Red Crescent, 4 editions have been published (200,2004,2011,2018). Shelter Projects is a series of case-study compilations through annual (2008, 2009, 2010) or biannual (2011-2012, 2013-2014, 2015-2016, 2017-2018) publications. The participating agencies in Shelter Projects: IFRC, UNHCR, UN Habitat, IOM, Habitat for Humanity, InterAction, USAID-OFDA, CARE International UK, CRS, DRC, NRC and World Vision International.
Transitional shelter guideline published by Shelter Centre 2012.
Handbook for Emergencies published by UNHRC 2007.

Safe Shelter
It is necessary, that the shelter is providing protection from the weather, providing security to the people in their home, people have privacy within their home, protecting people form getting sick, providing a safe place for people to live and engage with each other.
Living Space
Minimum 3.5 square metres of living space per person, excluding cooking space, bathing area and sanitation facility.
4.5–5.5 square metres of living space per person in cold climates or urban settings where internal cooking space
and bathing and/or sanitation facilities are included.
Internal height 2.6m in wam climates. Minimum 4.5m² to

5.5m² of living space per person in cold climates including kitchen, because most of the time will be spent inside the shelter. Internal height floor to ceiling 2m in cold climates.
Privacy and dignity
Privacy is very important for the people in their home. Therefore privacy should be considered during the design process, sleeping areas, rest areas, etc.

“Engage the affected people in calculating and organising space to support existing social and cultural practices.” “Involve affected communities and households as much as possible in determining the type of assistance to be provided.” (The Sphere Handbook).

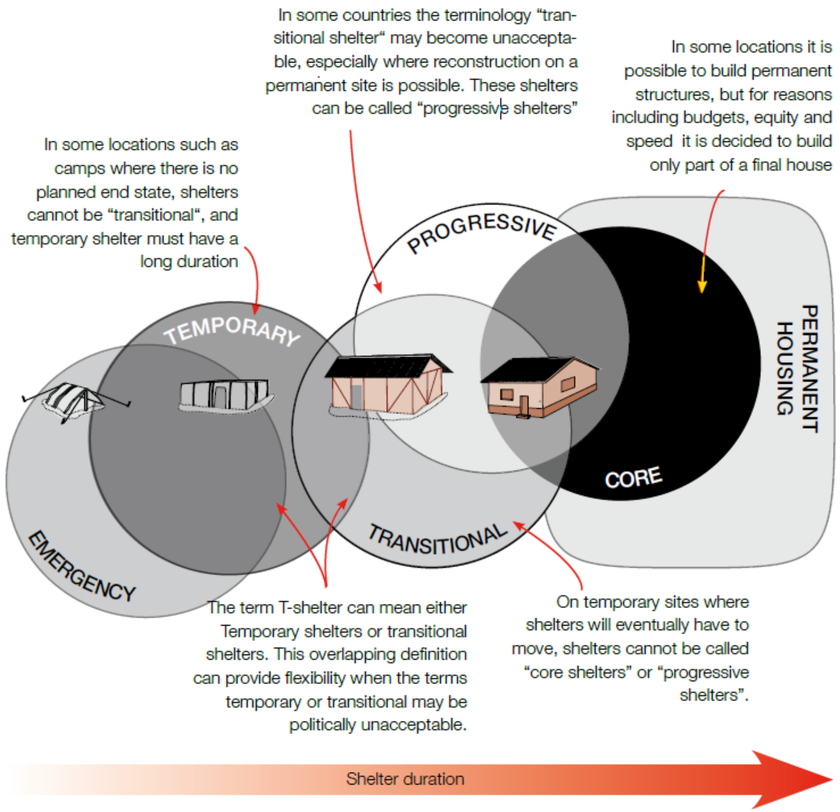


Fig.5.1. Shelter overlapping definitions, Shelter Projects, IFRC, 2013

Design Standards

Temperature, Ventilation and Comfort

The effect of temperature should be considered in both summer and winter. Therefore the shelter design should be appropriate to temperature variation.

Replacing the air within the shelter in important and affect the temperature of the shelter. Successful ventilation design can improve the shelter quality.

"Comfort is subjective and it is therefore difficult to specify "optimal comfort". Instead, "comfort zones" can be defined for specific climates using a range of indices such as the corrected effective temperature (CET) and operative temperature (OT). Factors affecting personal thermal comfort include environment" ((The Sphere Handbook 2018, IFRC and NGOs)

Fire protection

Fire is a common hazard in temporary shelters made textile materials (tents).

Preferable distance between the shelters at least twice the height of the shelter to reduce the fire spreading. The distanve shoud be increased to three or four times the height in heighly flammable materials. The impact of wind should be considered as well to prevent fire spreading.

Earth quake

"Simple building layout plans are recommended for future upgrades and extensions. Asymmetrical, L-shaped, H-shaped or T-shaped designs are more vulnerable and should be avoided" (Shelter Centre transitional shelter guidelines).

Earthquake can caused formation of cracks and/or significant rise and fall of land. That is why simple building layout plans are recommended. Asymmetrical, L-shaped, H-shaped or T-shaped should be avoided.

Fig.5.2. Fire in IDPs Camp, Idleb, 2020

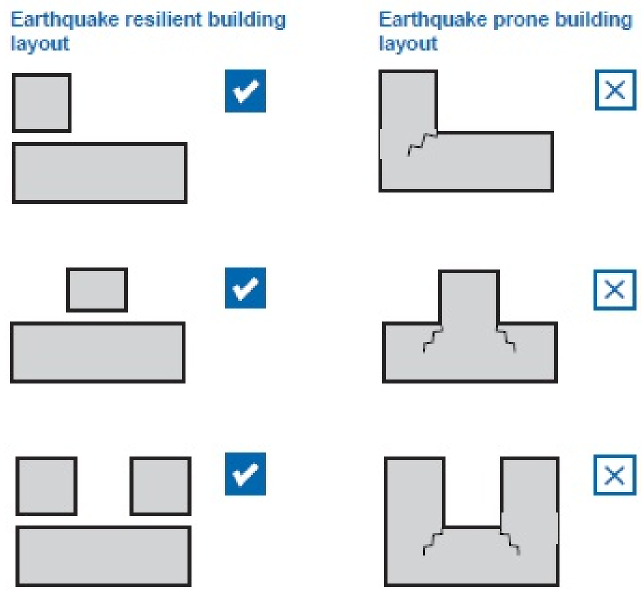


Fig.5.3. Improve earthquake resilience, Shelter Center, 2012

Camp Planning

Recommended area
45 square metres for each person in camp-type settlements, including household plots.
30 square metres for each person, including household plots, where communal services can be provided outside the planned settlement area.

Shelter footprint
The recommended ratio shelter footprint to plot size is 1:2 or 1:3 to provide sufficient space for outdoor activities, a ratio closer to 1:4 or 1:5 is preferable.

Drainage system
poor drainage system of rainfall or floodwater can restrict the people's movement, their living spaces and the access to service facilities.
Site selection and infrastructure development are important factors for planing a large scale drainage system.

Access
providing appropriate roads to supply of relief assistance and other goods. Avoiding damaging the local road infrastructure.

" The site and any primary storage and
food distribution points must be accessible by heavy trucks from an all-weather road. Other facilities must be accessible by light vehicles. Provide safe, secure roads and pathways within settlements, and all-weather access to all individual dwellings and communal facilities. Consider the needs of people facing mobility or access barriers" (The Sphere Handbook 2018, IFRC and NGOs)

5.2. Do it yourself

“The key thing will be to design and construct shelter where no or little technical supervision is required, and use materials that are locally available and eco-friendly. It’s important that the houses can be easily maintained by inhabitants.” Pritzker Prize winning architect Shigeru Ban

Mud home

The aim of these houses is using local materials to build low cost, climate responsive and environmentally friendly shelters, which provide appropriate living conditions in cold winter and hot summer.

These shelters will be built of clay bricks, which has been used in old syrian houses. Clay bricks can be easily prepared by mixing mud and hay and placed in molds then left out in the sun for several days. The molds have different sizes, for instance 45x 25 x 20 cm, 38 x19 x 9,5 cm or 40 x 20 x 10 cm...

The thickness of the clay brick walls around 60 cm: These thick walls trap in the cool and keep the sun out as well.

The roof will be built of wood and clay layer above.

The refugees can prepare these clay bricks and even build their own shelters by themselves, which give them a sense of ownership.

Fig.5.4. Clay bricks molds, Mecca and Dipasquale, 2009

Fig.5.5. Clay bricks, Mecca and Dipasquale, 2009

Wall structure

The Foundation
The type of foundation in Syria depends on the nature of the ground of the construction area.
Rocky ground, the wall can be built without a foundation.
Clayey earth, a foundation should be built underneath the wall as following:
The mason digs until a solid layer (depth around 40 cm) then build the foundations of irregular rough stones and earthen mortar, making sure the gaps between the bigger stones are filled with smaller stones or mortar.

The Socket
It is the part above the foundation, which built of similar size large stones in order to have constant height and create horizontal laying level, where the clay block will be placed.
The interface between socket and ground is covered by a thick layer of clay to protect the wall from water.

The clay brick wall
The bricks are laid in a specific arrangement called bond, no brick should be laid directly on top of another. Each block should be laid above two blocks and below two blocks so there are no straight joints.
Bricks can be cut to different sizes for building corners.

Mud brick doesn't resist atmospheric weathering well, therefore a lime rendering is applied.

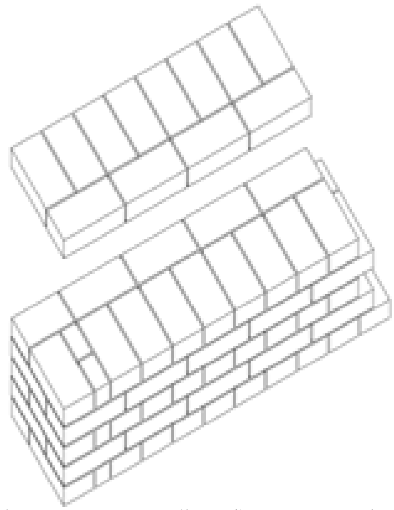


Fig.5.6. Clay bricks arrangement (bond), Mecca and Dipasquale, 2009

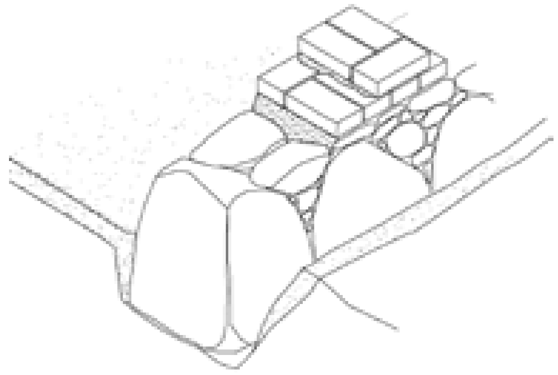


Fig.5.7. Clay wall on stone foundament, Mecca and Dipasquale, 2009

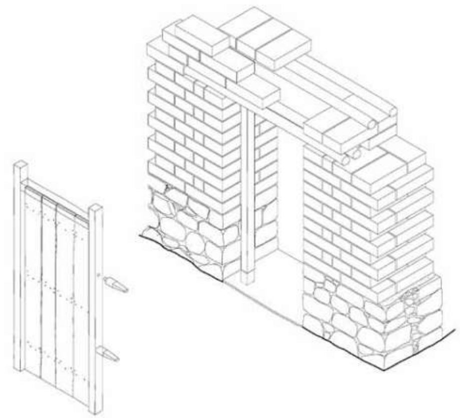


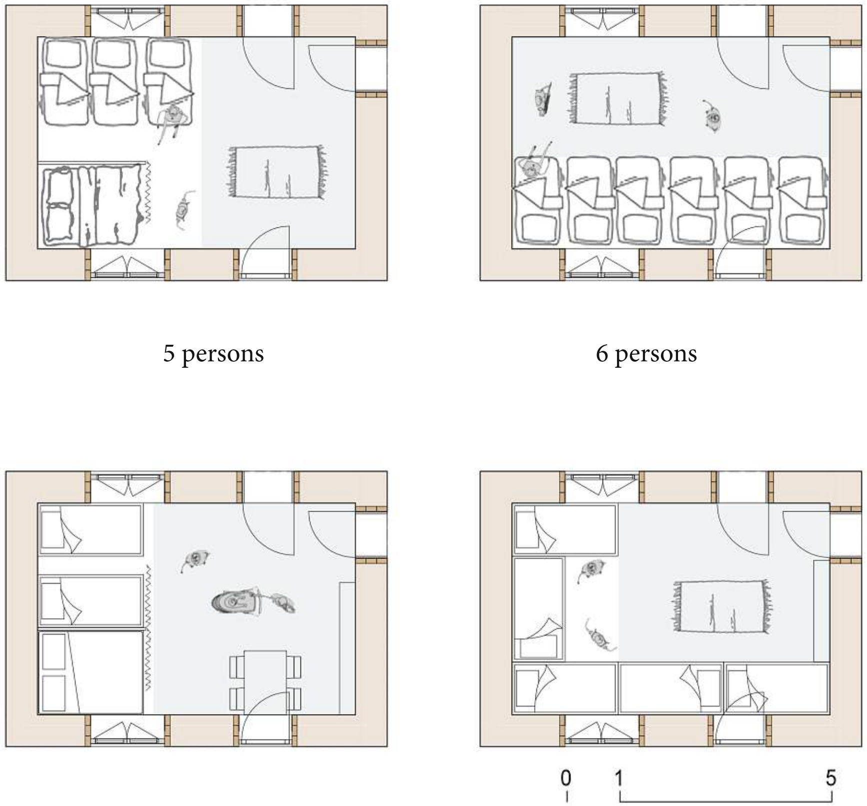
Fig.5.8. Opening, Mecca and Dipasquale, 2009

Mud home

According to The Sphere Handbook (2018), minimum 3.5 square metres of living space per person, excluding cooking space, bathing area and sanitation facility.
Lehmhaus area 24 m² (4x6 m) for 5-6 persons.
4 - 4.8 m²/Person

Each mud home will have a led light and a solar panel on the roof, which generates power to illuminate the led light and charge electronic devices.

Flexibility:
The mud home can be easily divided into different using areas by using wood partitions, folding partitions or even a curtain.
The sleeping areas can be furnished with beds or mattresses.
As shown in the eight types below.



5 persons | 6 persons | 4 persons | 5 persons

5 persons | 6 persons | 4 persons | 5 persons

Fig.5.9. Mud home types

Mud home

The walls and the roof are covered by Lime plaster as aesthetic element and to protect the walls from external effects, which may affect the durability and structure condition of the wall, reflecting sunlight and absorbing less heat during the hot seasons.

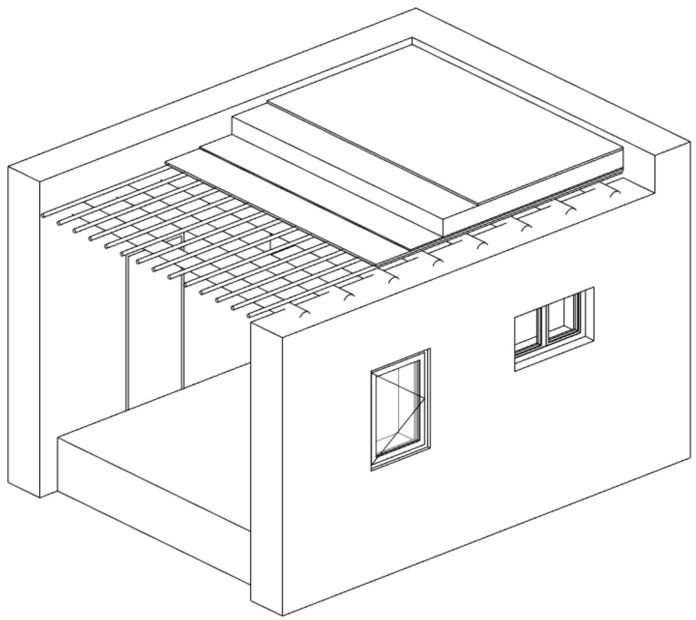


Fig.5.10. Wooden roof perspective

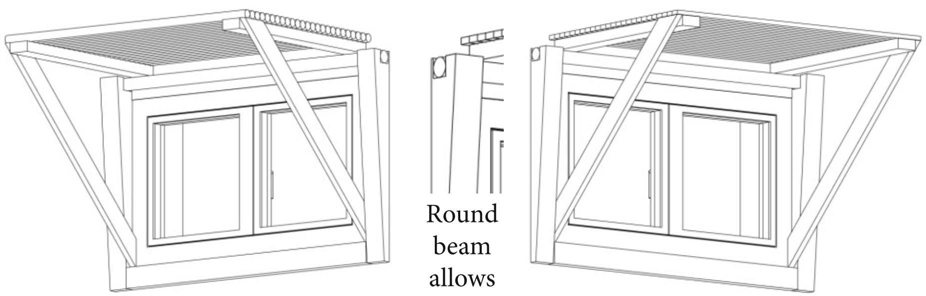
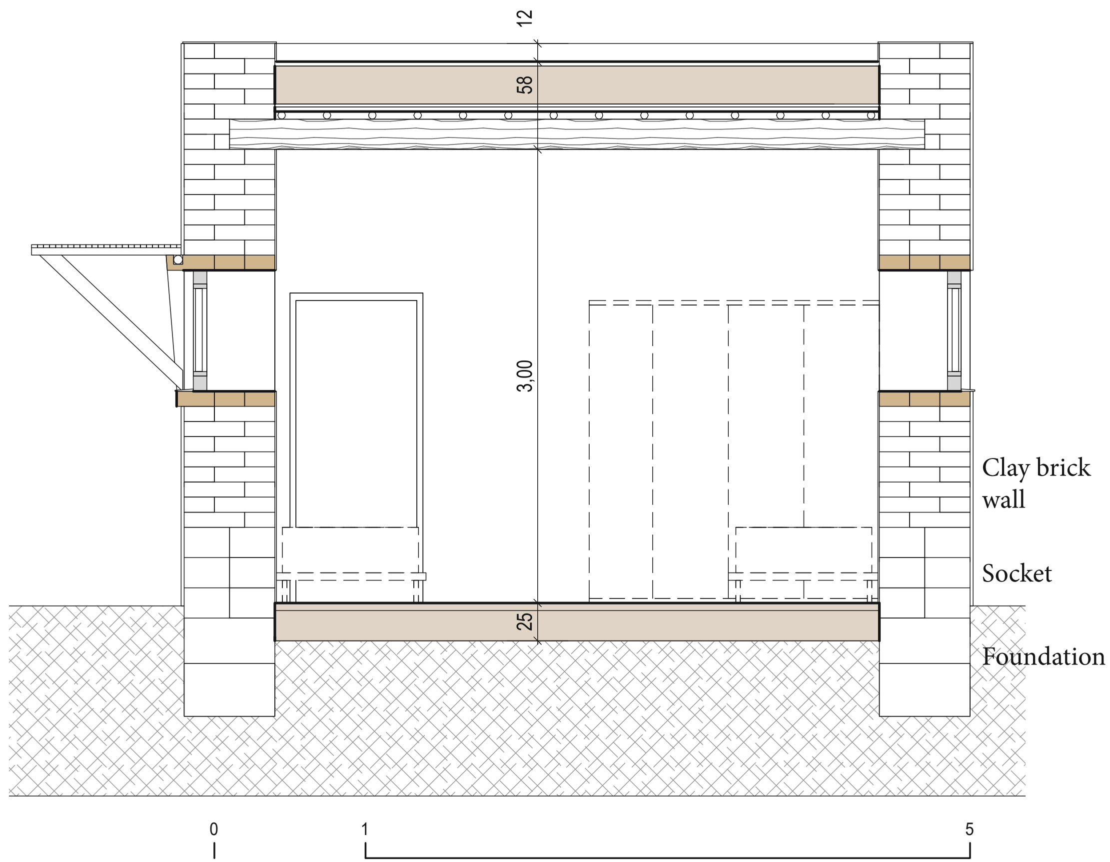


Fig.5.11. Wooden sunshade, movable, easy disassembled

58 cm	Wooden roof
3	Lime plaster
25	20-25cm thick earth layer and straw
2	Reeds or branches
3	Thorny shrubs
5	Timber cross beam
20	Timber beam



25 cm	Floor
5	Floor covering (earth)
20	Packed earth layer
	Earth

Fig.5.12. Mud home section

5.3. Camp Proposal

“We should attempt to bring nature, houses, and human beings together in a higher unity.”
Ludwig Mies van der Rohe

Location

Sarmada camp in Dana cluster in Idleb, close to Turkey border.

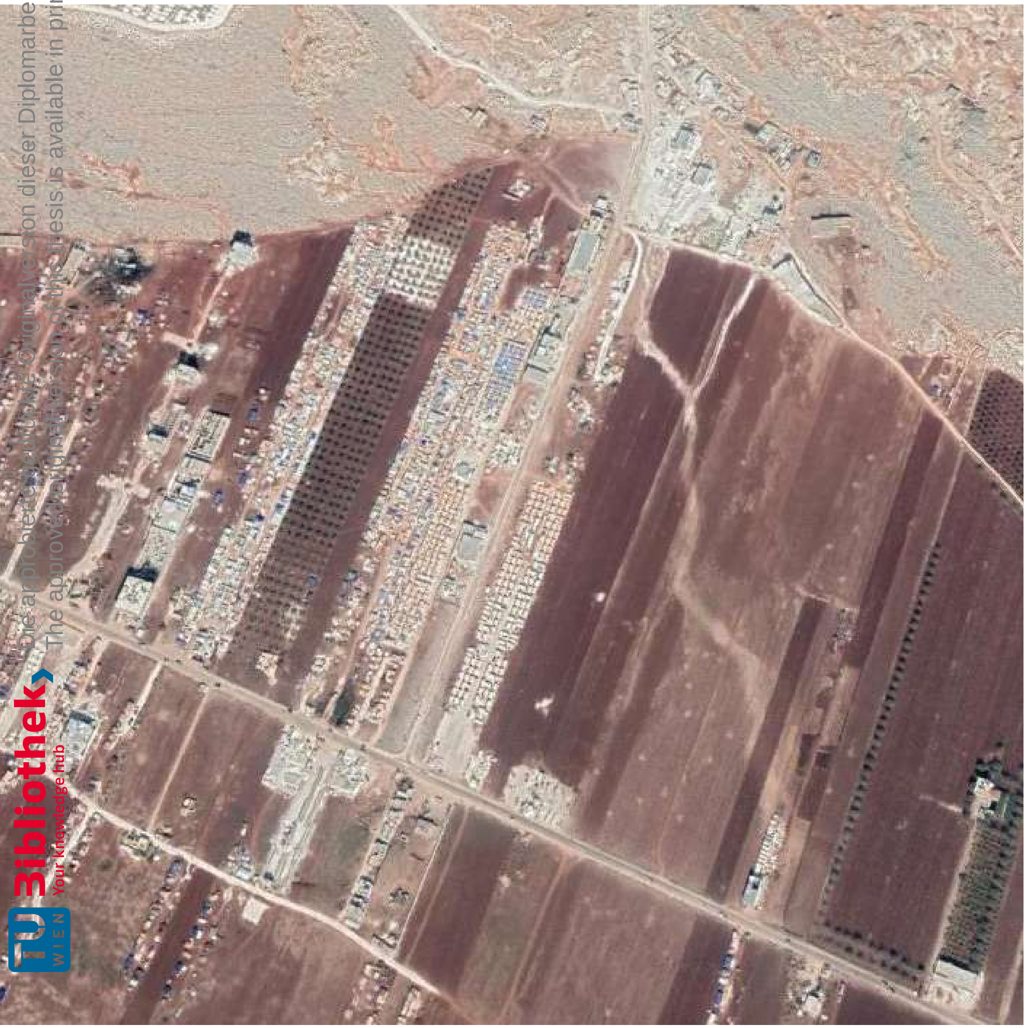


Fig.5.13. Sarmada camp in Dana cluster, Google Earth

Fig.5.14. Sarmada location, Google Earth

Location

Sarmada camp in Dana cluster in Idleb, close to Turkey border. Rapid Growth of Sarmada camps as shown in the next two figures.

Fig.5.15. Sarmada satellite photo

Fig.5.16. Sarmada satellite photo

Concept

The main idea of planing the camp was dividing the camp into blocks and forming the blocks in a way, that creates a central living open space in the middle of the camp similar to the courtyard in the courtyard house.

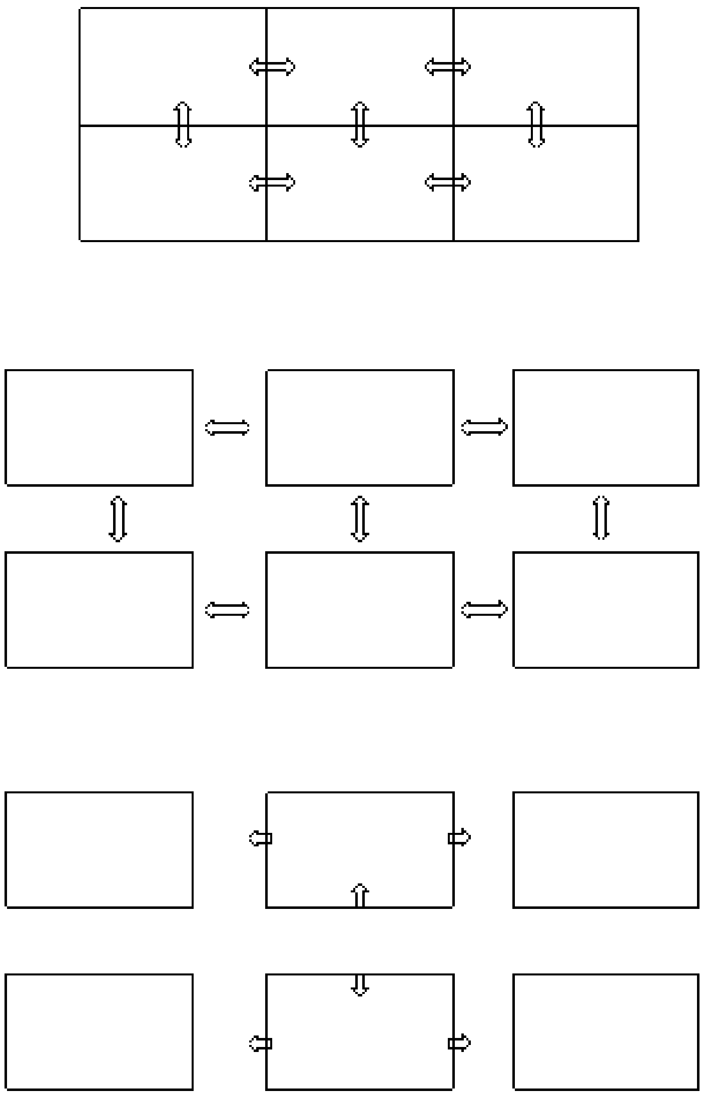


Fig.5.17. Camp blocks concept

The camp has a central interaction space and 6 blocks. And each block has its own interaction space as well. The pedestrian paths represent the main axes towards the central interaction space.

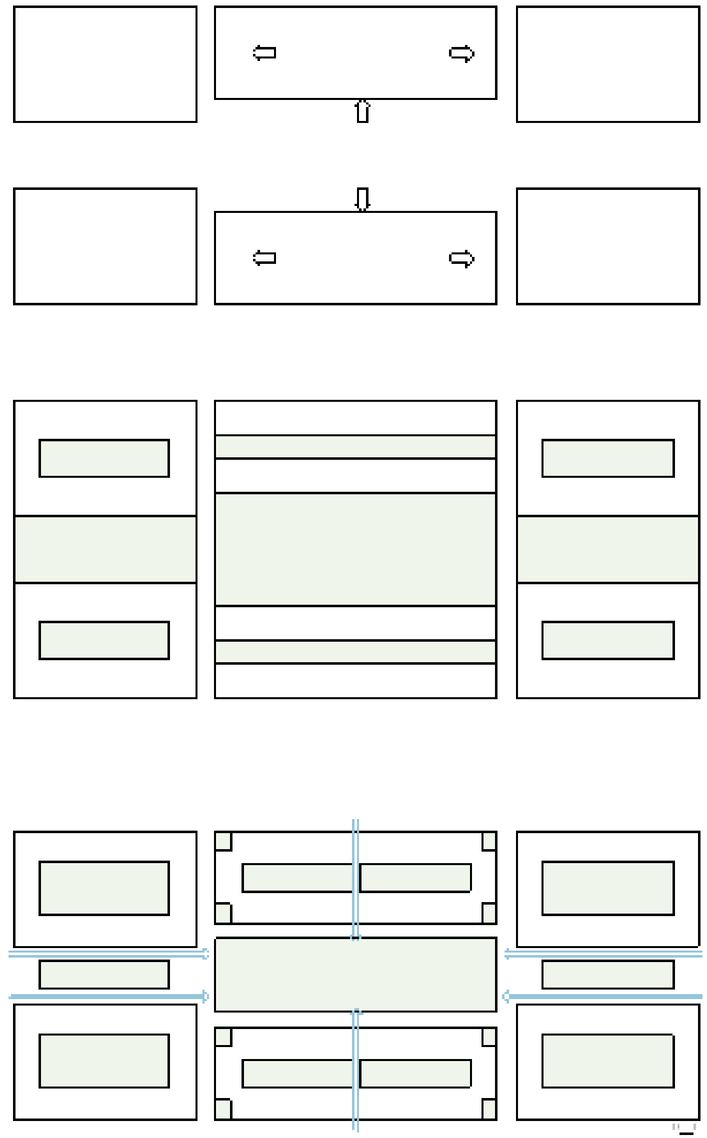
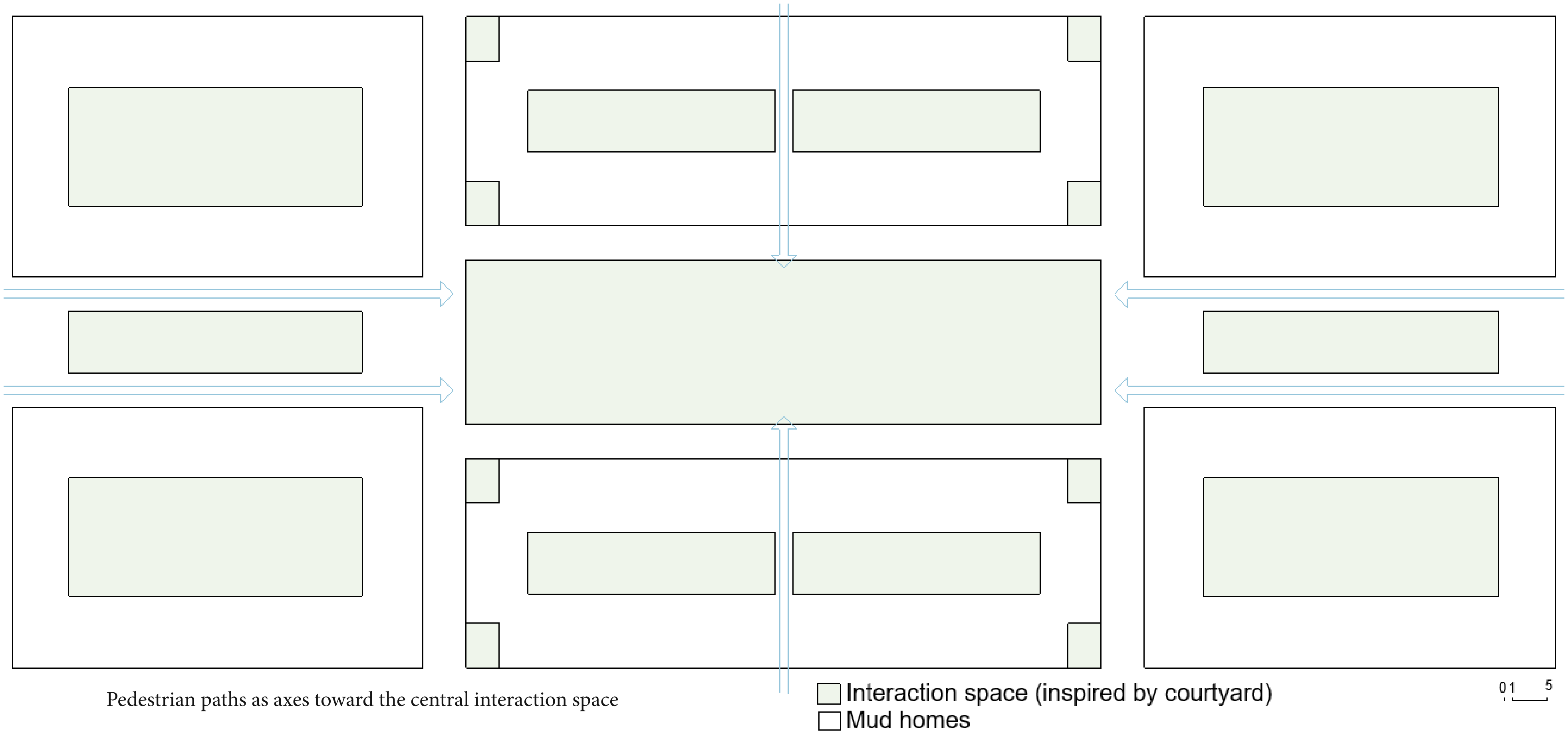


Fig.5.18. Interaction spaces concept

Concept

The courtyard house is the most common typology in Syria and it represents Syrian architectural and cultural concepts.
The idea of the interaction spaces in the camp was inspired by the courtyard in a courtyard house.
That makes every block like a courtyard house on a big scale.
All these blocks are combined in one bigger courtyard house, the camp.
Pedestrian paths as axes toward the central interaction space.

These open spaces are the living areas for IDPs, where they can do common activities, relax, play...
Each interaction space has its unique feature. It could be sculpture, tree, form or fountain....
The IDPs can decide that and do it themselves.
That will give them a sense of ownership and help avoiding psychological illness.



Pedestrian paths as axes toward the central interaction space

Fig.5.19. Interaction spaces and pedestrian paths

Lighting

Arranging the shelters parallel towards south and north and providing appropriate distance between the shelters to optimize the lighting in winter time.
Simple building layout plans to improve earthquake resilience.

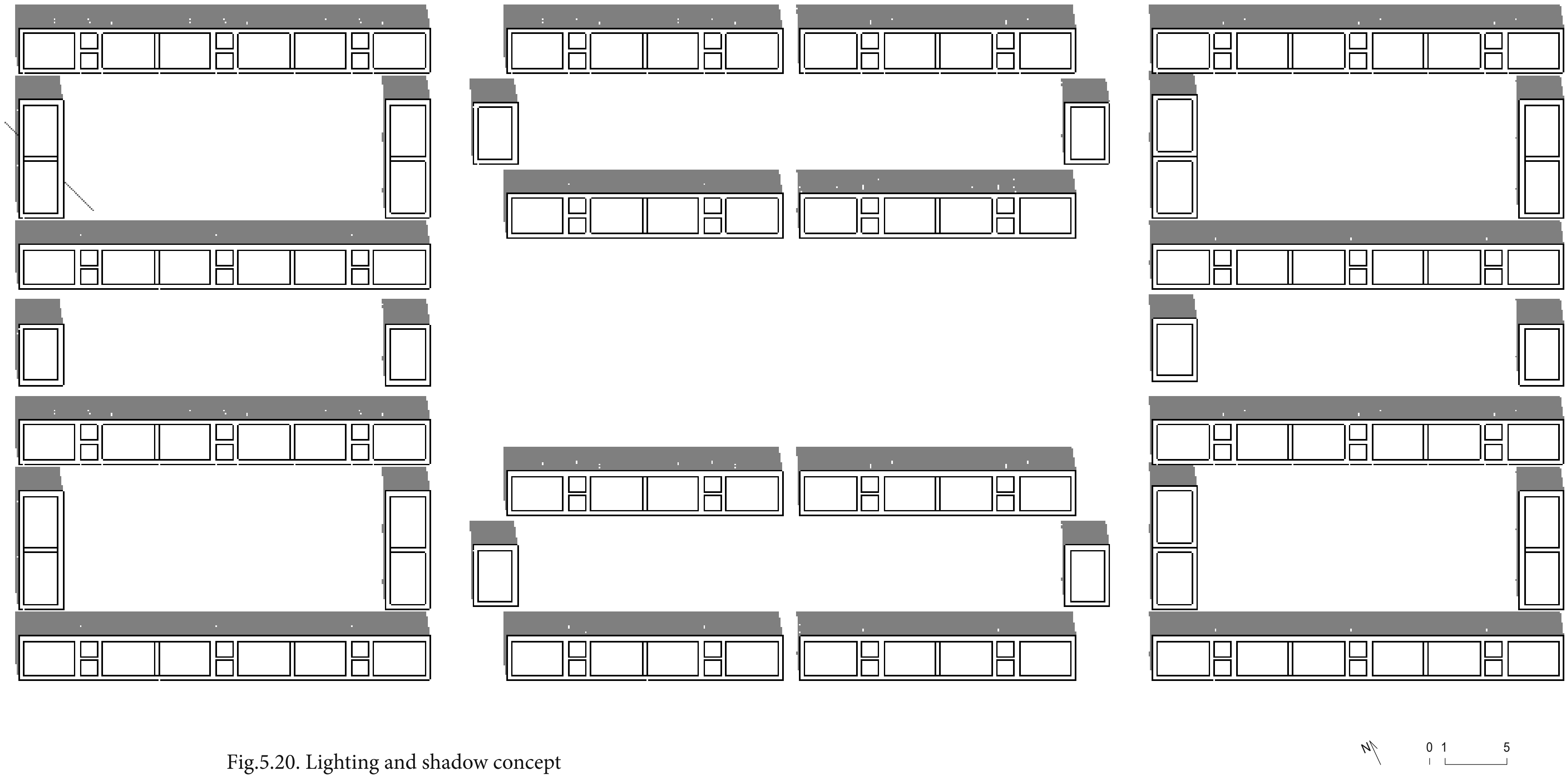


Fig.5.20. Lighting and shadow concept

Camp

According to The Sphere Handbook (2018), 30 square metres for each person, including household plots, where communal services can be provided outside the planned settlement area.
Cluster's area 13740 m² for app. 400 persons,
34 m²/person.
The camp has fourteen kitchens and four washing rooms and six multipurpose rooms (kid's room, rest room, etc).
Simple building layout plans to improve earthquake resilience.

Each block has central interaction space, which reflects the concept of the courtyard in a courtyard house. This open space is a living area for IDPs.
This interaction space aims to promote socialising activities. The residents of each block will do the work in the green areas and they can decide what to build in the center of their block, or where ever they want, could be fountain, tree, art work or what ever they like. That will give them a sense of ownership and help avoiding psychological illness.

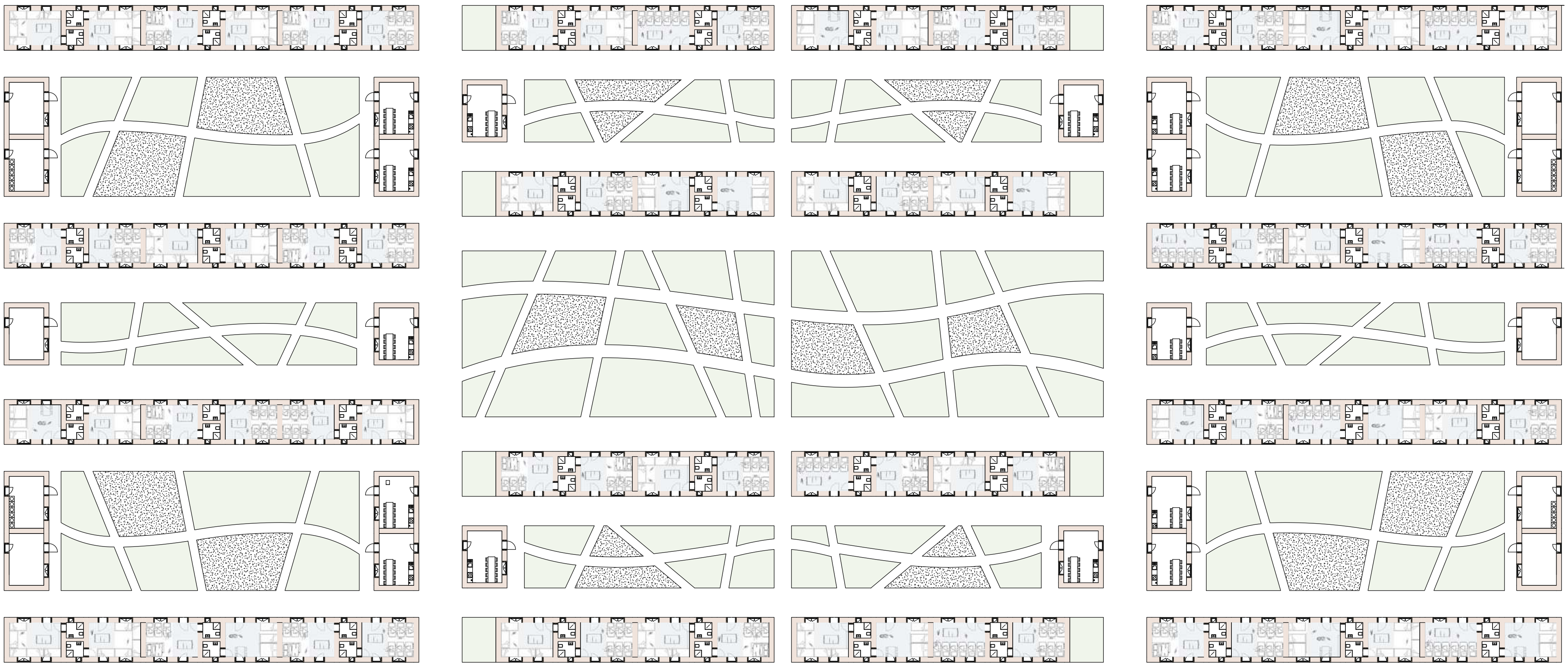


Fig.5.21. Camp plan

Play areas (local soil) Green areas N 0 1 5

Block 1

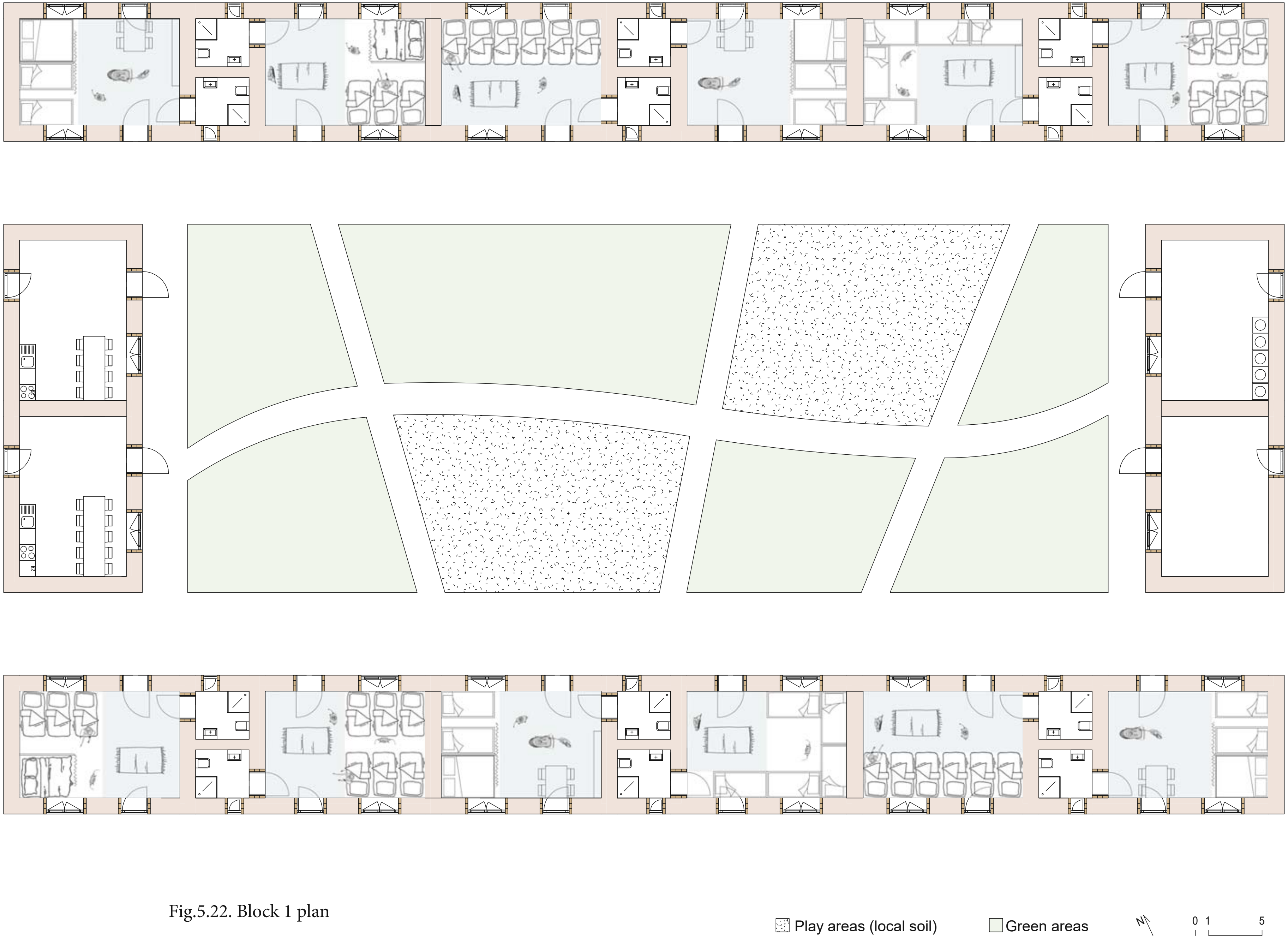


Fig.5.22. Block 1 plan

Block 2

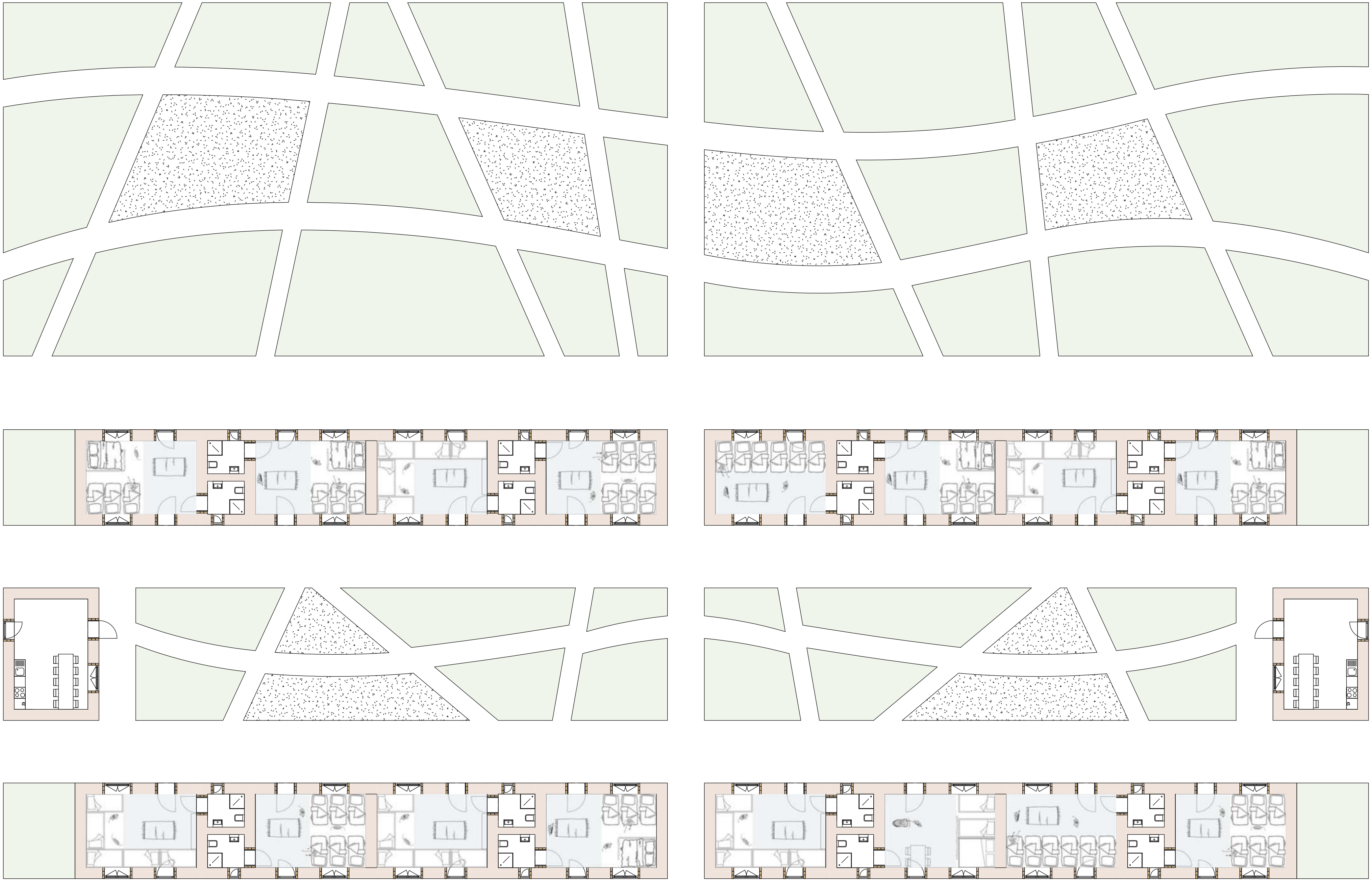
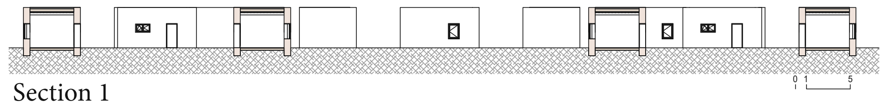


Fig.5.23. Block 2 plan

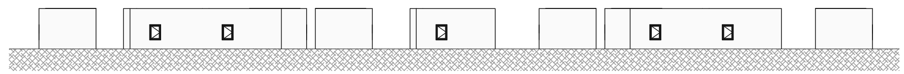
Play areas (local soil)   Green areas   N   0 1 5

Opening

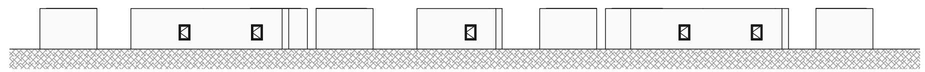
The size of windows is defined depending on the use of each part. Windows for living parts are bigger than windows for sleeping parts.
The windows and doors made of translucent plexiglass sheets, which are cheap, easy to transport and to cut, very efficient in lighting transmission and shatter resistant. In case it is broken, it will not break into dangerous parts. That will provide privacy and allow lighting transmission.
Movable wooden sunshade can be easily installed in south side of buildings to provide protection against the sun. And it is easy disassembled.
IDPs can build their sunshades or disassemble them themselves.



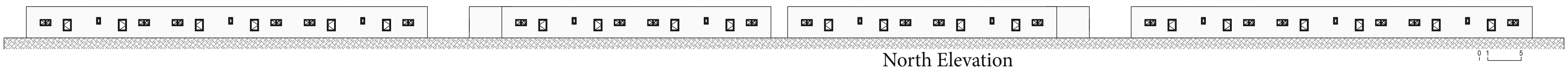
Section 1



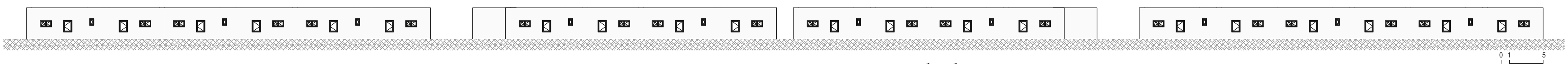
West Elevation



East Elevation



North Elevation



South Elevation

Fig.5.24. Section and elevations

5.4. Print on Demand

“Robotic manufacturing will enable us to eliminate the loss in translation from data to matter and allow us to fabricate homes at great speed, with less waste, and with higher accuracy than today,” Bjarke Ingels, founder and creative partner of Bjarke Ingels Group (BIG).

3D Printing?

Save Time

Low environmental impact

Save Materials

Print on demand

buy one printer
print thousands of homes

Cost reduction

3D printed module

cheap
fast

Flexibility

Accurate

3D printed mud home

3D printing is already playing an important role in Architecture. For instance GAIA house , eco-sustainable house printed by using WASP 3D printer. WASP has developed a compound composed of 25% of soil (30% clay, 40% silt and 30% sand), 40% from straw chopped rice, 25% rice husk and 10% hydraulic lime

This 3D printed mud home can be printed by using 3D printer: Crane WASP.
Eco-sustainable homes, local soil as the main binder of the constituent mixture.
The wall's gaps will be filled by straw as a layer of insulation.

3D mud home area 24 m^2, it takes 5-6 days to be printed. And the lifespan of this home is more than five years
Less than 1000$ is needed to have this 3D home built.

Using such of method to build shelters for refugees and IDPs, after a disaster or because of a war, will save Non Governmental Organizations a lot of money. The point is, buying a 3D printer once and using it thousands of times to print thousands of homes.

According to The Sphere Handbook (2018), minimum 3.5 square metres of living space per person, excluding cooking space, bathing area and sanitation facility.
Lehmhaus area 24 m^2 (4x6 m) for 5-6 persons.
4 - 4.8 m^2/Person

3D printed mud home has the same eight types of mud home as shown previously. It is flexible and can be easily divided into different using areas by using wood partitions or folding partitions.

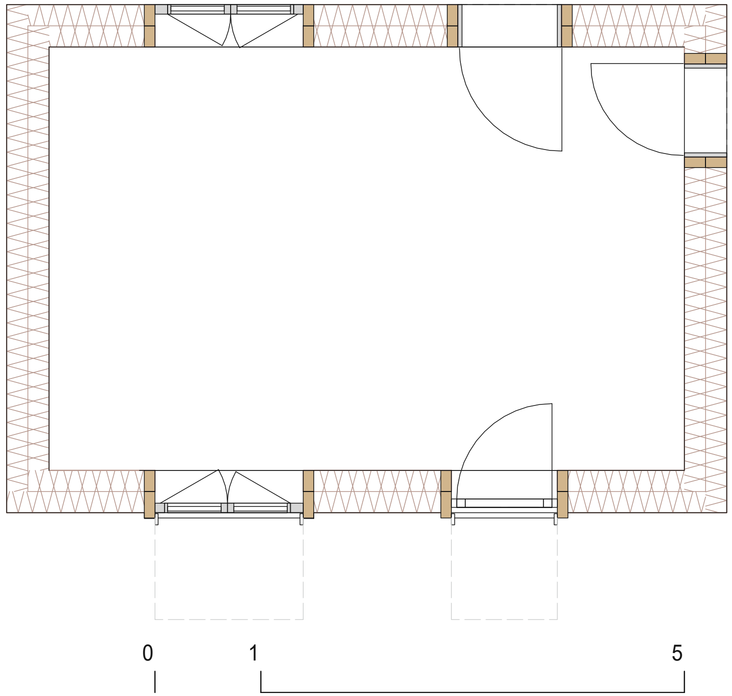


Fig.5.25. 3D Mud home

3D printed Mud home

According to The Sphere Handbook (2018), minimum 3.5 square metres of living space per person, excluding cooking space, bathing area and sanitation facility.
Lehmhaus area 24 m² (4x6 m) for 5-6 persons.
4 - 4.8 m²/Person

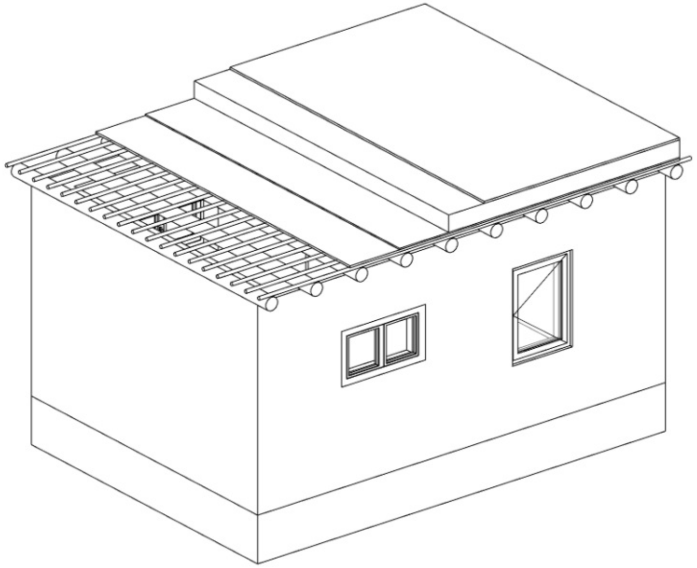


Fig.5.26. Wooden roof perspective

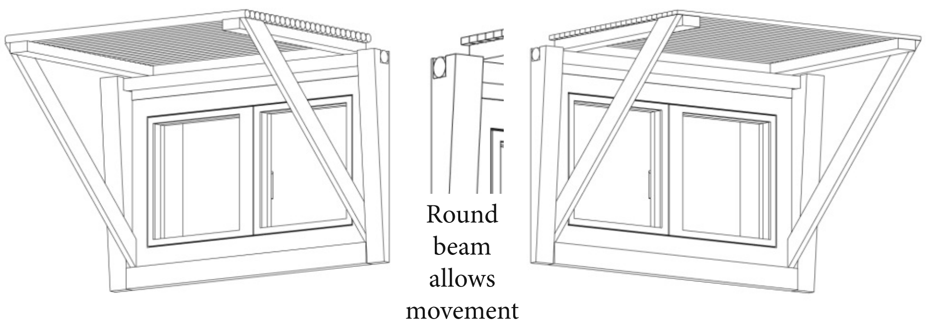
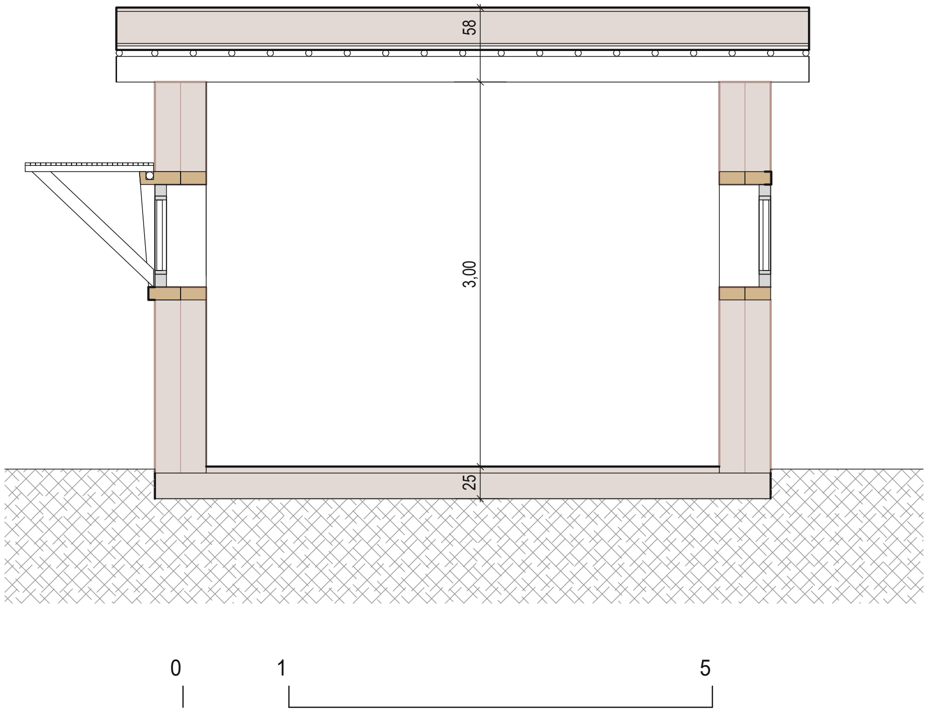


Fig.5.27. Wooden sunshade, movable, easy disassembled

58 cm	Wooden roof
3	Lime straw screed finishing
25	20-25cm thick earth layer and straw
2	Reeds or branches
3	Thorny shrubs
5	Timber cross beam
20	Timber beam



25 cm	Floor
5	Floor covering (earth)
20	Packed earth layer
	Earth

Fig.5.28. 3D Mud home section

3D printed Cluster

According to The Sphere Handbook (2018),30 square metres for each person, including household plots, where communal services can be provided outside the planned settlement area.
Cluster's area 13129 m^2 for app. 400 persons,
32.8 m^2/person.
The camp has fourteen kitchens and four washing rooms and six multipurpose rooms (kid's room, rest room, etc).

Each block has central interaction space, which reflects tho concept of the courtyard of old arabian house, which was the central living area.
This interaction space aims to promote socialising activities. The residents of each block can decide what to build in the center of their block, could be fountain, tree art work, or what ever they like. That will give them a sense of ownership and help avoiding psychological illness.

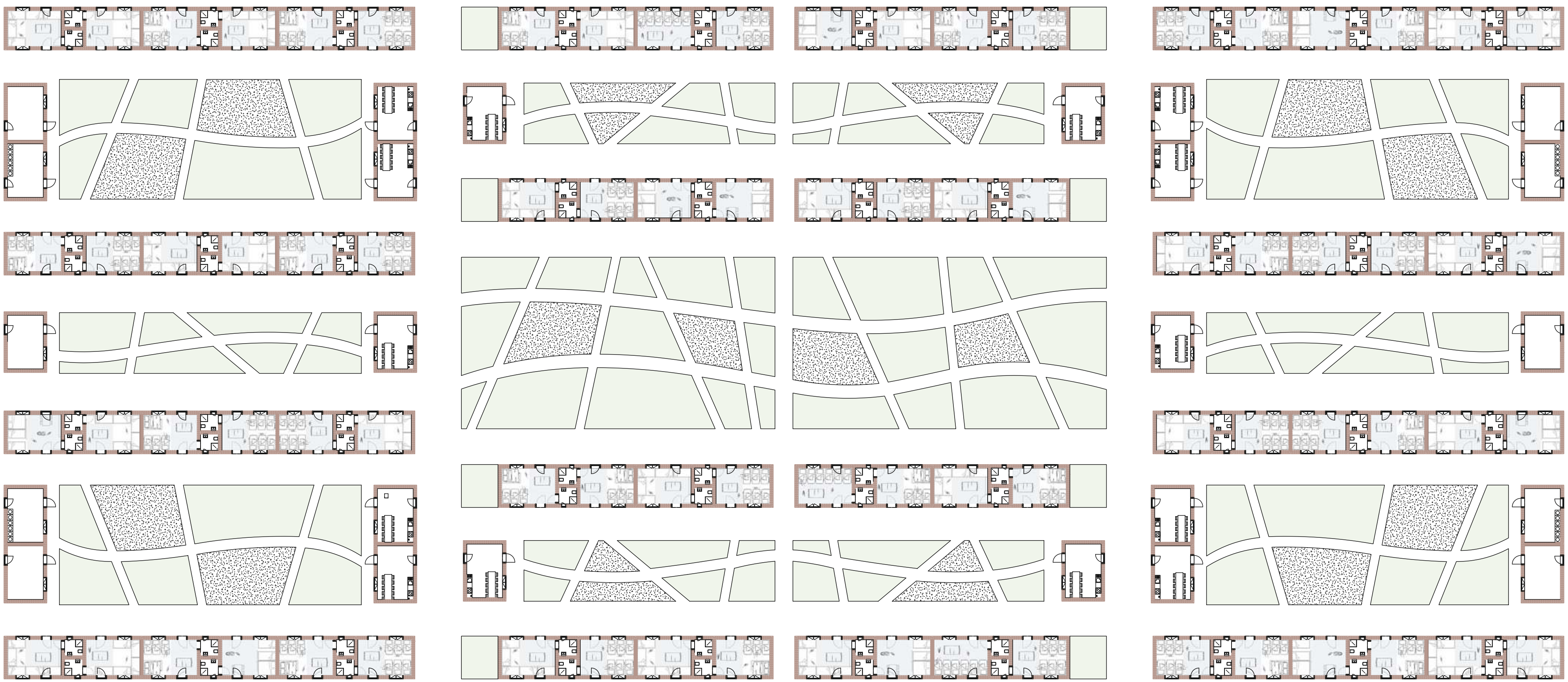


Fig.5.29. Camp plan

Play areas (local soil) Green areas N 0 1 5

3D printed Block 1

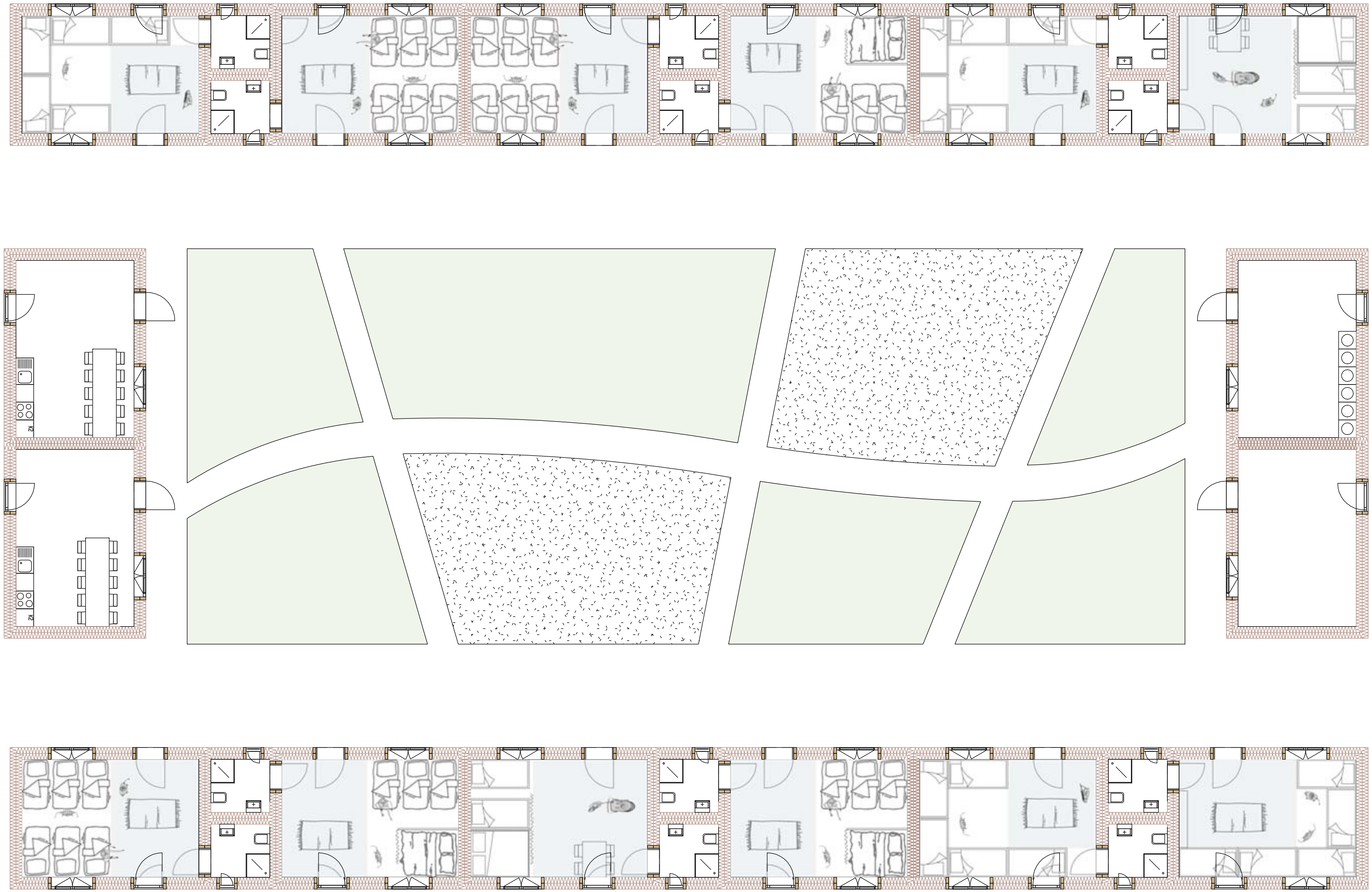


Fig.5.30. Block 1 plan

Play areas (local soil)   Green areas   N   0 1 5

3D printed Block 2

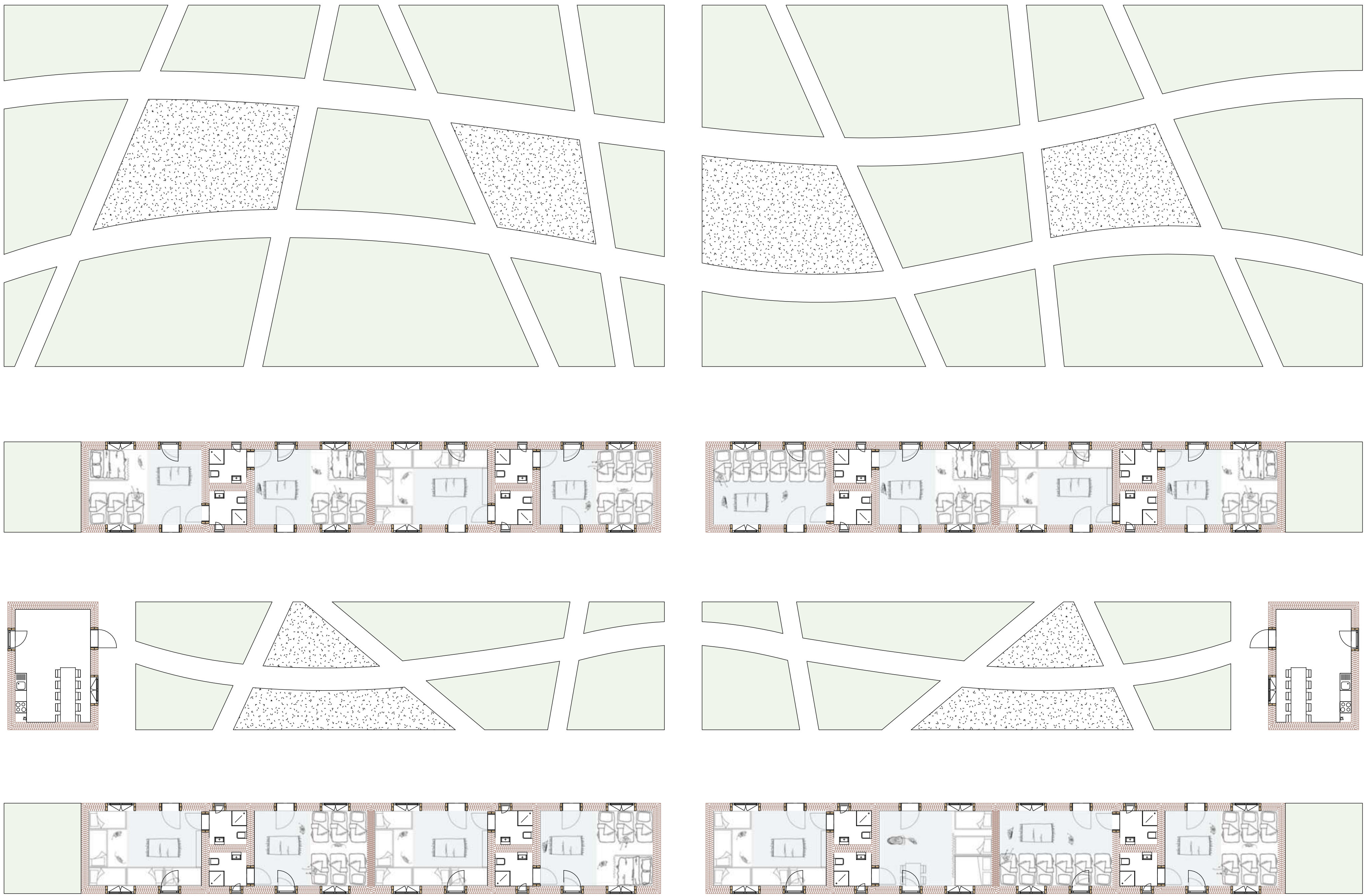


Fig.5.31. Block 2 plan

5.5. Printed Module

“Right now we have problems because there are hundreds of thousands of refugees, and building houses for them is very complicated. If you use bricks or wood or concrete, it takes a while. But if you 3D print prefabricated parts and use robots to put them together, it is very economic and very fast.” Himmelb(l)au founder Wolf D Prix

3D Printed Module

This module can be printed by using winsusn 3d printer. Environmentally friendly, recyclable materials such as sand and construction rubble. Winsun 3D printer can print one module in less than 3 hours. It is easy to transport and set up the module. It can be reused in other places as well.
Moreover, this module can be returned to the factory and recycled.

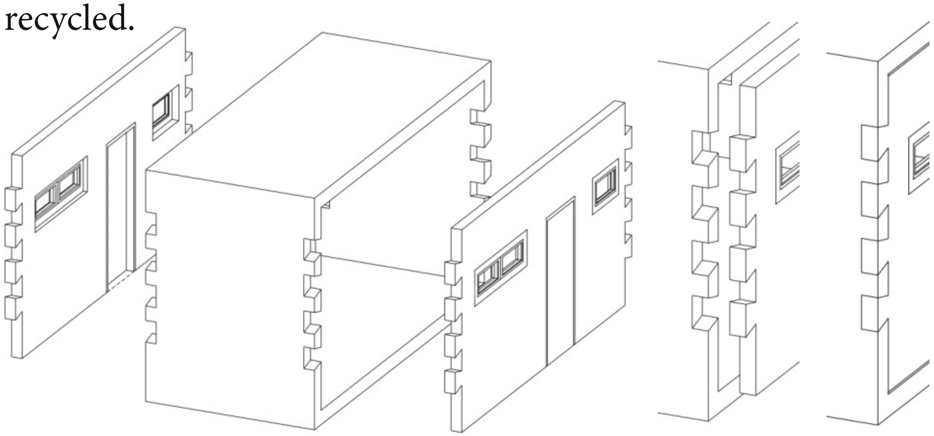


Fig.5.32. 3D printed Module consists of three parts

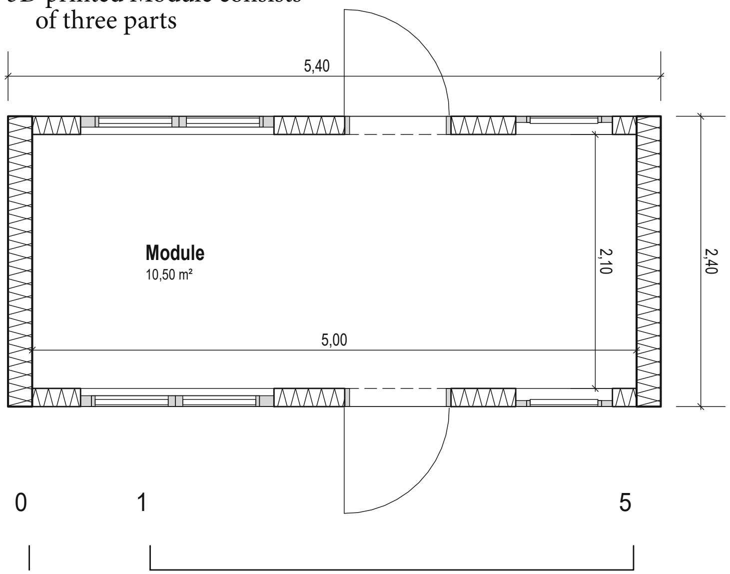


Fig.5.33. 3D printed Module

Module Z

Minimum 3.5 square metres of living space per person, excluding cooking space, bathing area and sanitation facility.
Module area 10.5 m^2
Living area 8.34 m^2 for 2 persons, 4.17 m^2/Person.
Module height 2.8 m.

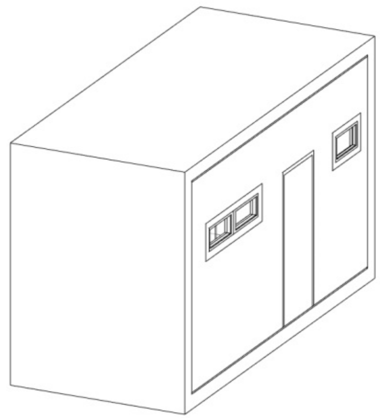


Fig.5.34. Module Z perspective

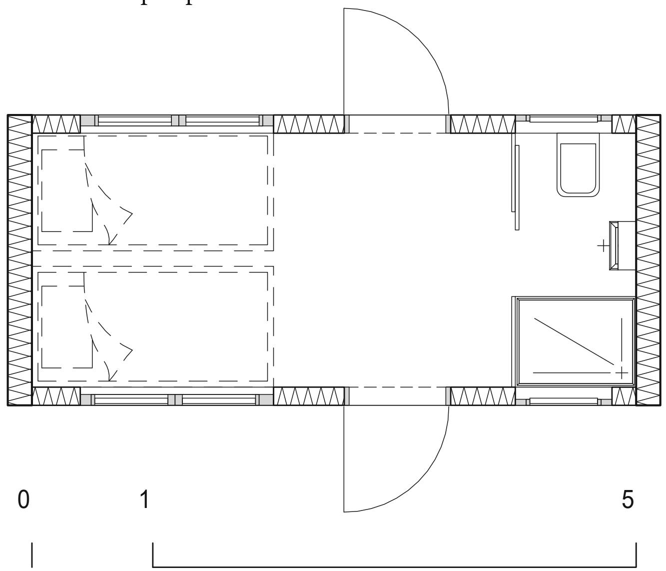


Fig.5.35. Module Z

Module X, Y

Minimum 3.5 square metres of living space per person, excluding cooking space, bathing area and sanitation facility. Module area 10.5 m² for 3 persons, 3.5 m²/Person.

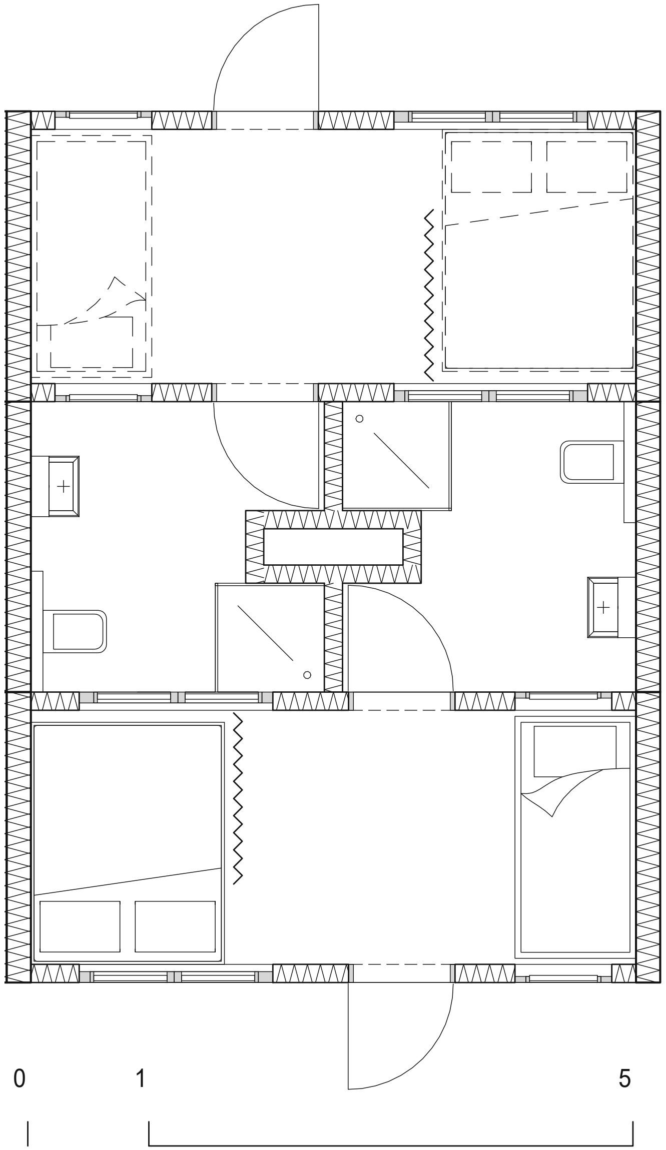


Fig.5.36. Modules X & Y combined

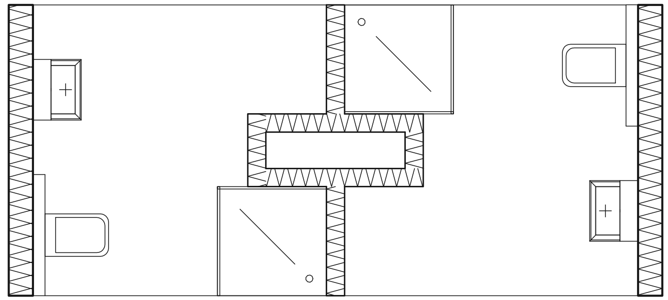


Fig.5.37. Modules Y

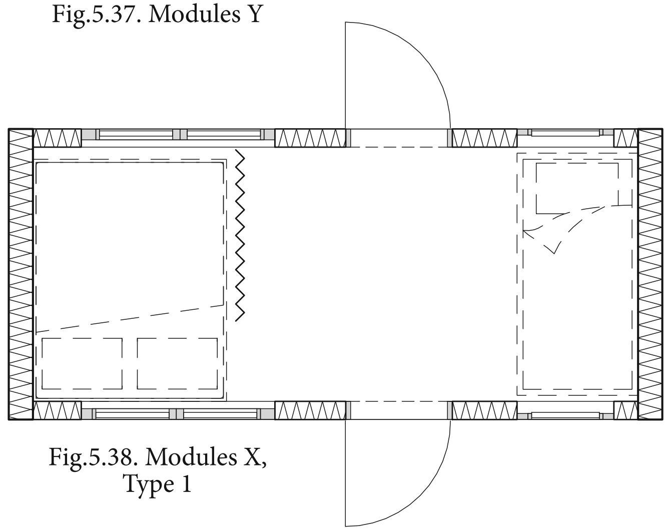


Fig.5.38. Modules X, Type 1

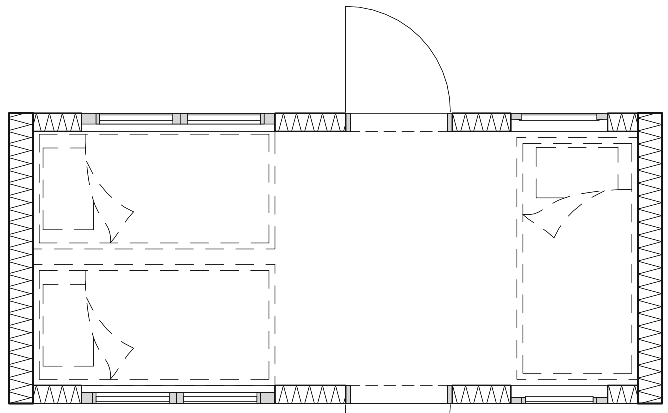
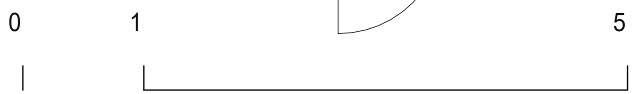
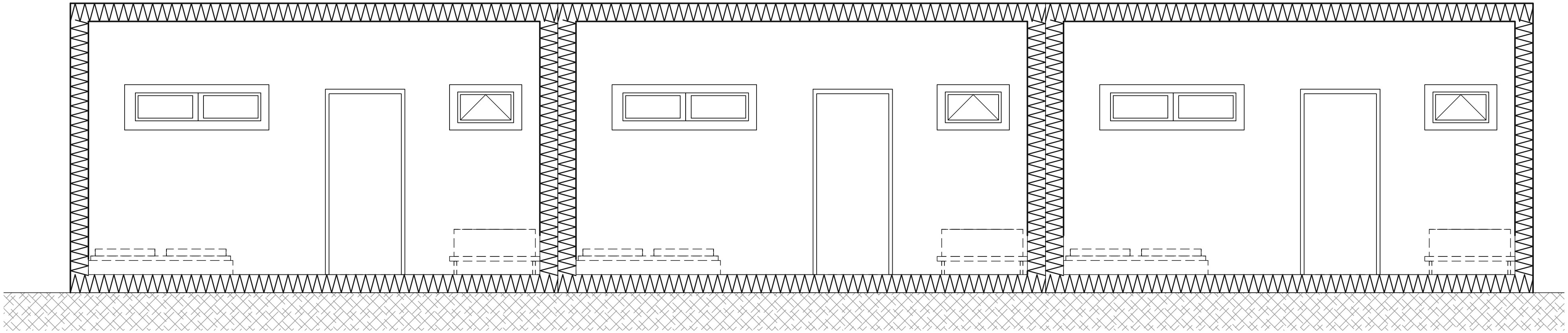
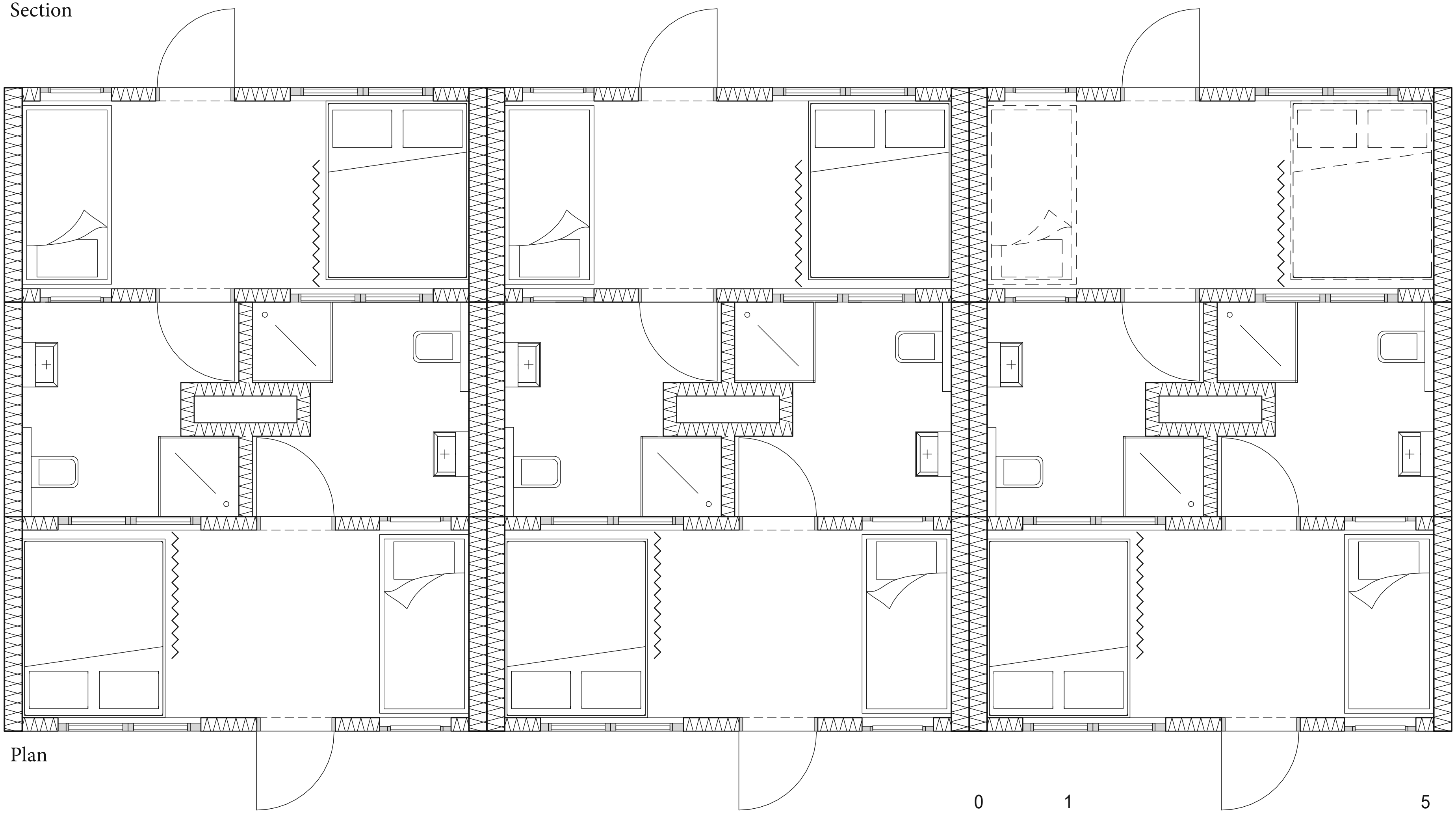


Fig.5.39. Modules X, Type 2





Section



Plan

0 1 5

Fig.5.40. Scalability of Modules X & Y combined

6. Conclusion

"When we build, let us think that we build forever."
John Ruskin

Designing a safe shelter for affected people by a conflict or a disaster requires understanding the architecture and knowing the available materials in the affected area to provide these people an affordable shelter, that can be built easily and fast using local materials.
The affected people should take part in construction process and it is better if they can build them shelters themselves, because that will decrease the required construction time tremendously.
The faster the shelters can be built is the better, as long as the affected people have no safe place to stay in.

The proposed mud home is an example of using local materials and letting the affected IDPs do the construction work themselves.

On the other hand, we live in the tech era. And taking advantage of this technology, 3D printing to be more specific, in the construction field is a good choice.

3D printing has provided the construction industry a solution to build more environmentally friendly projects. Because it has many advantages like less material waste, lower carbon footprint, more robust structures, less time, less human errors, flexibility, print on demand, 3D printed module, cost reduction, low environmental impact, and so forth.

The proposed 3D printed mud home in this thesis is an example of an environmentally friendly 3D printed home, printed of local material almost zero environmental impact, soil.
And the proposed 3D printed module is an example of an environmentally friendly 3D printed module, printed of recyclable materials.

3D printed technology is the key to friendly environmentally projects and it will allow safe and affordable homes faster than ever.

The three proposed shelters are cheap and durable. Moreover, they are safe shelters during the cold nights in winter and the hot days in summer.

Planing a camp is like planing a village or a city if the scale is bigger. To do so, taking onto account the required areas per person is very important and providing green areas and interaction spaces in this camp is very useful to avoid psychological illness and to promote socialising activities.

References:

[01] F. E. Boafo, J.H. Kim and J. T. Kim, "Performance of modular prefabricated architecture: case study-based review and future pathways." Sustainability 8.6 (2016): 558.

[02] U. Knaack, S. Chung-Klatte and R. Hasselbach, Prefabricated systems: Principles of construction. Walter de Gruyter, 2012.

[03] P. Bell, "Kiwi prefab: Prefabricated housing in New Zealand: An historical and contemporary overview with recommendations for the future." (2009).

[04] J. Jovanović, J. Grbić and D. Petrović, "Prefabricated construction in former Yugoslavia. Visual and aesthetic features and technology of prefabrication." GRAUE REIHE DES INSTITUTS FÜR STADT-UND REGIONALPLANUNG (2012): 175.

[05] T. Corsellis and A. Vitale. "Transitional Settlement Displaced Populations, Published by Oxfam GB in Association with University of Cambridge." (2005).

[06] Cleveland, LTG Charles, M. M. Dalton, A. F. Hof, K. Kagan, M. Karlin, M. Kirk, and M. C. Tuttle, "SYRIA STUDY GROUP." (2019).

[07] A. Al Amaireh, "The Bedouin Tent in Comparison with UAE Housing Provision." open house international (2011).

[08] C. Inceruh, "A Chronological Study on the Changing and Vanishing Form and Concept of Courtyard Houses in the Near East." (2011).

[09] I. Helmedag, J. Jäger, T. M. Weber, N. Abu-Jaber, A. Suleiman, B. Burkhardt, O. Reiter, M. Louderback and A. Khammash, "Stone and architecture in the mountainous regions of Jordan and Syria." DAAD, (2012).

[10] S. Mecca L. Dipasquale, "de l'article/du chapitre Earthen domes et habitats/Villages of Northern Syria: An architectural tradition shared by East and West." distributeur Edizioni ETS, (2009).

[11] B. Edwards, M. Sibley, M. Hakmi, P. Land, "Courtyard housing: past, present and future." Taylor & Francis, (2006).

[12] CORPU Levant, "Traditional Syrian Architecture." Handbook for the maintenance and rehabilitation of traditional Syrian architecture. France (2004).

[13] K. Najjar,, B. Madi and A. Nouraldeen. "Nasma; Sustainable climate-responsive schools for Syrian refugees in Lebanon." International Journal of Computational Methods and Experimental Measurements 5.4 (2017).

[14] OCHA, UN. "Humanitarian Needs Overview: Syrian Arab Republic." (2019).

[15] OCHA, "syr_idp_movement_overview_jan_to_dec_2020_final." (2020).
https://reliefweb.int/sites/reliefweb.int/files/resources/syr_idp_movement_overview_jan_to_dec_2020_final.pdf

[16] OCHA, "Recent Developments in Northwest Syria, Situation Report No. 24 - As of 26 January." (2021).
https://reliefweb.int/sites/reliefweb.int/files/resources/nw_syria_sitrep24_20210126.pdf

[17] UN-Habitat, "Turkana Houses: Housing Prototypes in Kalobeyei New Settlement." (2020).
by Shigeru Ban and Philippe Monteil, with UN-Habitat support
https://unhabitat.org/sites/default/files/2020/12/turkana_houses_larger.pdf

[18] Traditional Mediterranean Architecture, House with Liwan, Syria. (2003).
http://www.meda-corpus.net/arb/fitxes/F1/eng/sy_t05.pdf

[19] Shelter Centre, "Transitional shelter guidelines." (2012).
https://www.sheltercluster.org/sites/default/files/docs/20120522_tsg_onlinedoc_0_0.pdf

[20] Shelter Projects
https://www.sheltercluster.org/working-group/shelter-projects#1

[21] Shelter Projects 2017-2018, , "compiling 35 new case studies and overviews of shelter and settlement responses to crises worldwide." (2019).
https://www.sheltercluster.org/shelter-projects-working-group/documents/shelter-projects-2017-2018

[22] Shelter Projects, IFRC, "Post-disaster shelter: Ten designs" (2013).
https://shelterprojects.org/tshelter-8designs/10designs2013/2013-10-28-Post-disaster-shelter-ten-designs-IFRC-lores.pdf

[23] Shelter Projects, IFRC, "Transitional Shelters Eight designs." (2012).
http://shelterprojects.org/tshelter-8designs/8designs2012/Transitional-Shelters-8Designs-2012.pdf

[24] Handbook for Emergencies published by UNHRC (2007).
https://www.ifrc.org/PageFiles/95884/D.01.03.%20Handbook%20for%20Emergencies_UNHCR.pdf

[25] The Sphere Handbook (2018).
https://spherestandards.org/handbook-2018/

[26] EERI, Awad, Hwaija, Isreb and Ravi ,"World Housing Encyclopedia Country: Syrian Arab Republic, Housing Type: Reinforced concrete frame with concrete shear walls - dual system." (2002).
https://www.eeri.org/lfe/pdf/syrian_arab_republic_reinforced_concrete.pdf

[27] ACU (Assistance Coordination Unit), "Northern Syria Camps DYNAMO Report." (2019).
https://reliefweb.int/report/syrian-arab-republic/northern-syria-camps-dynamo-report

[28] Reliefweb, "Emergency Flood Response Dashboard , Flood Response Snapshot - Northwest Syria, Issue #4 (19 February 2021)."(2021).
https://reliefweb.int/report/syrian-arab-republic/emergency-flood-response-dashboard-flood-response-snapshot-northwest-0

[29] REACH, "Syrian Cities Damage Atlas - Eight Year Anniversary of the Syrian Civil War: Thematic assessment of satellite identified damage." (2019).
https://www.impact-repository.org/document/reach/c403830d/reach_thematic_assessment_syrian_cities_damage_atlas_march_2019_high_quality_3.pdf

[30] REACH, "REACH_SYR_MAP_Karama_Qah_Cluster_Camp_March2020_A0_landscape_en_versio." (2020).
https://reliefweb.int/sites/reliefweb.int/files/resources/REACH_SYR_MAP_Karama_Qah_Cluster_Camp_March2020_A0_landscape_en_version5.pdf

[31] BetterShelter.org, "Shelter 1.2 product information." (2018).
https://bettershelter.org/wp-content/uploads/2018/09/Better-Shelter-1.2-Product-Specification.pdf

[32] United Nations High Commissioner for Refugees (UNHCR). "UNHCR resettlement handbook." (2011).

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