POST DISASTER TEMPORARY SHELTER

BASED ON THE SUSTAINABLE DESIGN PATTERN OF ANCIENT IRAN

"AFTER NATURAL DISASTERS MANY PEOPLE BECOME HOMELESS, IT IS VERY CRUCIAL TO PROVIDE STURDY TEMPORARY SHELTERS THAT CAN HANDLE COMPLEX STRUCTURES AND THESE SHELTERS ARE NEEDED QUICKLY.” HAKAN GURSU

AUTHOR: HIRBOD HATAMI
DIRECTOR: DAVID HERNANDEZ

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Abstract

This study has been conducted to design an emergency shelter for post-disaster in Iran especially post-earthquake circumstances. Destruction of houses, whether complete or partial is a consequence of earthquakes which results in homelessness. After destructive earthquakes, sheltering can last weeks to months and should be considered as one component of a defined long-term strategy. Iran, as one of the country in the world having most earth quick prolific, located on the belt seismic Alps - Himalayas and is under pressure from the Arabian tectonic plates, India, Eurasia and Turkey. On average, 3000 earthquake occur every year. To overcome the problems in the current settlement solution associated as objectives of this research, a new pre-fabricated semi-assembled design has been proposed that is adapted to the local climate of Iran specially in the regions with high risk of earthquake, providing ventilation system, taking advantage of local material in construction of units which gives mental comfort and physical convenience to the user. These shelters comparing to the current one, will take advantage of using local and more sustainable material in the construction process. During the design process, the shelters are also adapted to the culture and climate of Iran which makes it suitable for the people of suffering from displacement. The design at the meantime, would provide a good level of quality of life, privacy and security, appropriate infrastructure and proper ventilation system.

Keywords: Temporary shelter, post-disaster, Iran, sustainable design, Modular design
Chapter 1: Introduction
1.0 Introduction:

Natural disasters, such as earthquakes, tsunamis, hurricanes, floods, etc., cause loss of life and damage the property all around the world. Destruction of houses, whether complete or partial is a consequence of earthquakes which results in homelessness. In the past 10 years, up to 9 million people became homeless worldwide because of earthquakes. Sheltering, an essential phase in response to earthquakes, refers to the activity of staying in a place after the event even though daily routines are suspended. After destructive earthquakes, this process can last weeks to months and should be considered as one component of a defined long-term strategy. In many developed countries like United State, Emergency sheltering is usually designed for only one or two days after the event whereas temporary sheltering is for a longer period after the disaster. This period usually lasts for weeks or months.

In some communities, emergency sheltering is not limited to one or two days and may be used for several weeks. In this situation, emergency sheltering refers to both emergency and temporary sheltering. Moreover, in some situation; because of delay in recovery phase, this transitional phase can last longer and temporary shelters would be used as temporary houses or long-term settlements. Anyway, as an emergency situation and in combination with other earthquake consequences, it is important to shelter earthquake victims properly as soon as possible.

Temporary sheltering should provide at the very least residence, security and dignity for earthquake victims. So, it needs to be designated appropriately to decrease victims’ problems as far as possible. Such designing needs to define related and proper criteria.

Iran, as one of the country in the world having most earth quick prolific, located on the belt seismic Alps - Himalayas and is under pressure from the Arabian tectonic plates, India, Eurasia and Turkey. On average, 3000 earthquake occur every year and every 5 years, once the severe earthquake, that last of them was the Bam earthquake in 2003 would be killed tens of thousands. Iran, due to its location in a high seismic hazard zone and high vulnerability, it is considered a high-risk area. Existence of a large population at risk on the one hand and the lack of a suitable plan for resettlement of a large population based on experiences and actions in recent earthquakes on the other hand aggravates the situation and turns it into a crisis. The purpose of this study is to extract a suitable model for temporary sheltering after a possible earthquake.
1.1 Objectives:
Temporary shelters are built in order to fulfill the basic needs of the survivors rapidly with optimum convenience. There are different definitions of shelters but one of the most relevant definitions of shelter is “a habitable covered living space, providing a secure, healthy living environment with privacy and dignity to those within it” (Foster S. and Fowler J. (ed.), 2003). In this research the primary goal is to design a temporary shelter for the post-earthquake in Iran. According to the related definitions to the temporary sheltering, some criteria must be taken into account in the ideation and design process which are:

1. Bioclimatic design
   An approach applied in building and landscapes design which is based on local climate. In fact, the architectural design is linked to the physiological and psychological need for health and comfort. [1]

2. Sustainable Design
   concerned about excessive use of finite resources and the efficient management of the ecosystem, greenhouse gases, storm water pollution as well as fundamental concerns for social equity and social justice.

3. Adaption of local material in the process of construction.
   The material which will be used must be locally sourced and ethical to the environment. They must be feasible in terms of cost and availability.

4. Modular Architecture
   The approach that each module could be created independently and later, based on needs could be merged together to expand.

5. Flexible structure
   The structure must be prefabricated but un-installed to facilitate transportation and time-consumption. Victims in post disaster need to settle in the shortest period. So the time and quantity saving design in logistics and then easy-to-go installation (taking advantage of local citizens) would speed up this process.

6. Culture-centered design
   The approach that design must be adapted to the culture of target user which is citizen of Iran. The adaptation must be in each aspect including color, material, form and social aspects.
1.2 **Hypothesis:**
Designing post-disaster shelter also known as transitional shelters for the geographical location of Iran to facilitate affected population to more durable housing solution. These shelters comparing to the current one, will take advantage of using local and more sustainable material in the construction process. During the design process, the shelters are also adapted to the culture and climate of Iran which makes it suitable for the people of suffering from displacement. The design at the meantime, would provide a good level of quality of life, privacy and security, appropriate infrastructure and proper ventilation system.

1.3 **Context:**

1.3.0 **Inception of “Living in Emergency”**
The beginning of the house referred to emergency is connected to nomadic people who have to move from a place to another and it brought up the necessity of adequate shelter during the trip. Initially it was represented by makeshift places -such as caves- and later on to temporary housing units like tents.
The earliest form of shelter goes back to the paleolithic age -21,000 to 39,000 years ago- with the Aurignacian huts that inherits the name from the Aurignac cave in France. The hut had a self-supporting structure and branches represented the basic element of dome which were fixed in the ground within a circular distribution and the upper ends curved toward the centre and connected together where for the coating, often leather had been used to cover the frame. [2]

![Figure 1. Aurignacian shelters from Encyclopedia of the Great Plains.](image)
Following Aurignacian hut, Maddaleniann hut has been developed where the name is coming from the La Madeline cave in Tursac, in Dorgogna- France. The structure was made of wood within a double-pitched, central stiffening obtained to poles and stitched leather covering. [3]

![Figure 2. Magdalenian shelters by W G from Blendspace – Magdalenian culture](image)

Later on, Paleolithic housing inspired the most common form of nomadic dwellings like tents. It is made with a framed supporting structure where is covered by fabrics of leathers tended by tie-rods and it had to adapt to different types of climates.

Among all different types of tents, Yurt which is used until today, is technically the more advanced form in lightness and prefabrication points of view. [4] this type of shelters goes back to the Turkish and Mongolian tribes during trips. The structure of Yurt was self-supporting on a circular plant, having a diameter from four to ten meters and height of about 3 meters. The composition for basic frame is trellis of curved elements arranges in a lozenge and easiness in assembly. The ends of trellis elements culminated in a covering ring, left open to obtain the escape of the heat and during the night or in cold times, could be closed by curtains. The average weight for a Yurt is approximately 250Kg and the structure could be subdivided into group of components of 5 or 6 for the ease of transportation where the support of wagons or animals had been used.
1.3.1 Modern Experience

The agricultural-artisanal system left the society when economic evolution happened following the first industrial revolution and a considerable urbanization and transition to a modern industrial system happened in a process which could be recalled of “society industrialization”. In this period of time, increase in well-being and a technological innovation expansion has been observed which has a certain impact on building sector where one of the most important achievement was prefabrication – a process consists of preparation in a different place compared to the final location. [5]
1.3.2 From Worker Accommodation to war and post-war emergency shelter

In nineteenth century, increasing in industrial activities led plenty of workers to migrate to the cities. Along the migration faced housing problem of workers and their families was born. In this scenario, new building rules – addressed to guarantee the satisfaction of minimum spaces as well as the achievement of adequate conditions of physical and moral well-being and comfort – spread out. In those years, some models such as Garden City proposed in 1989 by E. Howard who which solved the overcrowding of cities and the migration from the countryside.[6]

Between nineteenth to twentieth centuries, the idea of colonial housing in the case of housing for workers required functional living prototypes. This need has shown in 1930s within the expansionist of the Fascist regime in East Africa. The housing emergency faced by Italian government which was the construction of necessary houses in a brief time in 1938 in Libya. [7]

In the building field, war emergency caused the development of technological solutions which could be used in “shelter units” where comfortable, safe and rapid execution construction is a necessity. To overcome these requirement, these units – which can be used as residential or used as first aid- they were made of few material and components towards limited and simple steps, to reduce construction time and employ unqualified workers. This led to the birth of huts for military troops accommodation. In world war I, Nissen hut has been developed and used during war by American military forces and then has been developed to the T-Rib Quonset-Hut during second world war.

Figure 4. left to right, (a) Nissen Hut, (b) T-Rib Quonset Hut from Nissen building.com
1.3.3 Post-Disaster Shelter

Many famous designers and architects, in recent decades, have offered different types of shelters and models, including the works of Le Corbusier, Alvar Aalto, Paul Rudolph, Buckminster Fuller and Kisho Kurokawa. They tried to go for the mass and industrial production phase considering the complexities of designing a desirable emergency or temporary housing unit, within testing and evaluation some models in the affected countries. But in most cases, these efforts are neutralized by the reality of the disaster and the victims.

Figure 5. Top: Le Corbusier temporary shelter design, Bottom: Alvar Aalto temporary shelter design
1.3.4 Physical location of Iran:

Iran is situated in south-west Asia and has 1,648,000 square kilometres area. It is located on the world dry belt and 60 percent of it is covered with mountains and the remaining part is desert and arid land. Due to its geographical location, is subject to disasters. Amongst 40 different types of natural disasters in the world, 31 types have been identified in Iran. Major natural disaster occurring frequently in Iran include earthquakes, floods, droughts, landsides, desertification, deforestation, storm and etc. Earthquakes takes a heavy toll. Iran is part of the Alp-Himalaya orogenic belt. Resulting, Iran suffers certain economic and social damages from seismic activities. Earthquakes killed more than 180,000 people during the last 90 years. Reviewing historical seismic data shows that almost all parts of Iran suffers from earthquakes problem. [8]

![Image](maphill.com)

Figure 6. From left to right (a) Iran physical location in world map from maphill.com, (b) seismic Hazard zonation map of Iran from tavakoli and ghafory-ashtiany (2012)

1.3.5 Current post disaster needs assessment (PDNA) in Iran

The assessment included Social Sectors such as Housing, Education, Culture and Tourism; Agriculture, Fisheries and Livestock for the Productive Sector; Infrastructure Sectors such as Energy, Transport, Water and Sanitation and Community Infrastructure; and Cross-Cutting Sectors such as Disaster Risk Reduction, Environment, Employment and Livelihoods, and Gender and Social Inclusion but in this research we concentrate on the housing sector and related fields to it such as transport, energy and culture.
Iran is one of the five earthquake-prone countries in the world due to its location on the Alpine-Himalayan earthquake belt. Engineering statistics and probability show that on average, a strong earthquake occurs in Iran every four years, which results in the destruction of 71% of rural units in the earthquake zone.

Unfortunately, it seems that current situation in Iran for dealing with the phenomenon of temporary housing after devastating earthquakes is lower than the expected level, and temporary shelters are only as a place to settle the homeless rather than a place to live. Housing for a family should provide security and comfort and a sense of belonging.

In last three decades in Iran, post disaster shelter has been limited to the use of tents, shipping container(conex), prefabricated shelters and indigenous structures. But mostly, approximately 70% tents have been used and 17% containers have been used. The other 13% will be shared toward using prefabricated shelters for a share of 10% and only 3% goes for the indigenous shelters.

1.3.6 Tents

Tents as an emergency living space has been used from Mongolian and Turkish tribes’ times and only the material has been developed and upgraded. But tent as post-disaster housing has many disadvantages such as [9]:
- Inadequacy to protect of property and food
- lack of facilities for lightening and energy production
- Non-Resistant to variant weather conditions
- lack of Insulation against water infiltration
- Lack of proper ventilation
- Insufficient endurance against wind
- Lack of sufficient storage space
1.3.7 Shipping container

Shipping container in post disaster situation are being widely used in worldwide. They are mobile, secure and quickly deployed which is ideal for victims in need of emergency shelter but there are certain factors affecting suitability of using shipping containers for post disaster temporary housing which are:

- Number of displaced people and scale of disaster area,
- Mode of transportation which is limited to the aircraft, trucks, boat and rail and since in may locations in post disaster situation rail and boats are not accessible. Meanwhile time plays the key role, so the fastest way is to use aircraft.
Chapter 2:
Case studies
2.0 Woven Refugee Tents

“All throughout the planet there are more than 40 million refugee escaping natural disaster and political brutality. To manage compassionate emergencies, award winning architect and designer Abeer Seikaly has come up with a modest, basic, lightweight, functional, movable, and primarily strong refugee tents. These astounding tents give cover as well as fuse water assortment, sun based force age, and sun based water warming into the design. Inspired by conventional bin weaving procedures and the flexibility of snakeskin, Abeer Seikaly has created a tent design for temporary shelters. This great tent is ventilated and is adequately productive to give the neediest individuals essential necessities. She utilized weatherproof texture from durable, bended plastic components and an adaptable material skin that can hold pressure and strain loads. In addition, these double layered texture tent skins are empty which allow water pipes and electrical wires to run between the layers. The external layer helps in holding solar energy which is transformed into electricity form; nonetheless, the inward skin gives pockets for storage and there is additionally a water tank at the roof point of the tent for shower. [10]
2.1 TENTATIVE Design by Designnobis

"After natural disasters many people become homeless, it is very crucial to provide sturdy temporary shelters that can handle complex structures and these shelters are needed quickly." Hakan Gursu

Hakan Gürsu of Designnobis- Turkish design consultancy designed the Tentative shelter after facing the lack of accessible shelters lodging following quakes in his local Turkey. He was also touched by the statistics of 22 million displaced individuals in 2013 – multiple times more than war.

Tentative is a solution to disaster reaction tent that can be sent in practically any territory or environment. The design comprises of a climate safe material that is sewn together, with protecting perlite sandwiched between layers, held by an aluminium outline. Water is gathered through the rooftop, which additionally gives lighting and ventilation. Warmth protecting recyclable composite decks make up the floor, with legs keeping the floor over the ground to forestall heat misfortune.

The entire development implodes down into the rooftop and floor, which meet up to frame a 30-centimeter-high shell for transportation, empowering 24 units to fit onto a solitary semi-trailer truck. [11]
2.2 U-Dome shelter by World Shelters

the U-dome adjusts the modular geometry of buckminster more full's geodesic arch. U-domes have been utilized for disaster reaction, mobile clinical facilities, temporary housing and storages. the model could be instructed using local materials, and they are re-usable. world shelter is a non-benefit california based producer filling in as a private volunteer association. since 1986 they center around giving minimal expense, durable temporary shelter to those out of luck. the advantages are: lightweight transportation, easy assembly, minimal expense, withstand outrageous warmth and chilly, huge breeze, and light snow loads with legitimate establishment, hard dividers for strength. the plan highlights are: weatherproof layered polypropylene, fire resistant, UV safe, climate tight, shingled development, boards structure inward help swaggers. [12,13]
2.3 Just a Minute by Archello

"Just a minute" means to assemble another life for nepalese individuals, giving them a straightforward however effective house, exceptionally open to customization and future exchanging into a steady house. The primary thought of the task is to utilize neighborhood Nepalese materials, or from close nations, to make a house that can be assembled rapidly, lightweight and minimal to move, strong (in spite of it is brief) and monetary. The utilization of a deployable construction made of bamboo and material structure envelope, permits transport the house shut possessing an impression of 2.5 x 4 meters and, when open, to get a 4 x 7.11 meters’ house. Its creation doesn't need complex advances or gifted work, however a progression of basic tasks helpful to set up the different parts to be gathered all into one place. The particularity of the design permits to coordinate the development cycle in stages, as in a mechanical production system. Profoundly, another can deal with the material envelope, etc. Clearly, a few sections can be pre-assembled, to show up on the creation site currently pre-worked, accelerating the cycle. At the focal point of the house there is an extremely durable part, made of coverable wooden OSB boards, outfitted with every one of the administrations (restroom and kitchen), which estimates 1.5 x 4 meters. On the sides of the focal square, are sent the two primary rooms (living region and dozing region) which measure 4 x 4 meters, in addition to a little covered outside space of 1 x 4 meters. The two side rooms comprise, truth be told, of even (floor), vertical (upstanding) and slanted (rooftop) bamboo posts with a breadth of 6 cm, supported by bamboo shafts organized in X, with a width of 3 cm. These shafts are bored at the middle and at the finishes, to permit the design to unfold. The fixing of the shafts, in the wake of opening the design, is guaranteed by butterfly screws. [14]
Figure 11. Just a minute design by archello
Chapter 3:
Methodology
To accomplish a final design that meets each of the goals and necessities for the target user, this work has been divided into five main stages which are:

1. Problem Definition,
2. Emphasize target user
3. Ideas Analysis and Brainstorm
4. Develop Ideation
5. Improve the design

In the very first stage an interview has been conducted with victims of natural disasters and displacement and all the related information has been collected to identify and frame the problem. Then, in the second stage, identity and characteristics of the victims has been identified which forms the target user for the design. Moving toward the next stage, “Ideas analysis and brainstorm” the case studies has been investigated and a solution has been coming up to the mind. The last two stages have been focused on ideation and defining elements of design and then improving the model.

Each stage will be explained fully in details in the following chapter.

Figure 12. Flowchart of methodology
3.0 Problem Definition

3.0.0 Interviews

There have been quite plenty of post-disaster interviews with the victims but the main content of these interviews could be classified into two main subjects of the problems and the necessities. Below four of these interviews have been chosen to demonstrate their initial necessities and problems they are facing in post disaster settlement.

1. Interview with a woman after Bam earthquake in 2003

   After 3 months We are still living in a difficult situation in a tent on these hot days. We survived a magnitude 5 earthquake, but we are dying from diseases or infection due to lack of sanitation and adequate facilities. [15]

![Figure 13. Bam earthquake in 2013](image)

2. Interview with a family after Kermanshah earthquake in 2018

   We are living within difficult nights because tents and also sitting next to the fire do not work in these bone-chilling cold nights. we need lighting and electricity to turn on heaters. [16]
3. Interview with a mother after Sarpol-e Zahab earthquake in 2018
   If each family were given a Conex, our problems would be much less. My children talk
during sleeping at nights and do not sleep properly due to the fear of earthquakes. [17]
4. Interview with a family after Iran-Iraq earthquake 2017

We can't stay home because of the aftershocks. They gave us tents and heating equipment, but heavy rain seeped into the tent. We expect them to provide a safe haven for every family. [18]

![Figure 16. Iran-Iraq earthquake in 2017](image)

All the interviews have a common point where victims are complaining form the characteristic of the temporary shelters such as ventilation system of shelter, resistance to the wind and rain, temperature insulation, lack of storage place and many other factors which could conclude to the lack of safety and convenience.

3.0.1 Problem Statement

Based on the standard definition of temporary shelter in UNHCR (The UN Refugee Agency) the current shelters being used in Iran for post disaster suffers from lack of privacy, psychological comfort, emotional safety, adequate ventilation system and being adapted to the weather regardless of seasonal pattern. So, a new design that is fitted to all of these requirement and is also locally sustainably sourced and constructed, must be presented. [19]
3.1 Emphasize Target User

The scope of target user for the post disaster shelter will be specifically population of Iran which is a wide selection. In fact, it will consist of all the citizen of a region with risk of earthquake which include men, women, children in different ages with variety of health condition and life quality.

3.2 Ideas Analysis and brainstorm

3.2.0 Current solution for post disaster settlement

As mentioned before, the current facilities that has been used mostly in Iran during post disaster settlement are tents and shipping containers. They are the most basic solutions and unfortunately does not provide even basic needs and necessities for the victims. As it can be seen current tents are non-resistant to rain and wind, short long lasting, lack of ventilation and insulation to temperature. Moreover, lack of safety and privacy is one of the major disadvantage of tents. Shipping containers, although are more resistant to weather conditions such as rain, wind and snow but suffers from lack of ventilation system and also temperature insulation. The other disadvantage is transportation method, containers are prefabricated models and they occupy large amount of space in transportation which makes them expensive and difficult in logistics.

3.2.1 Contemporary solutions in user cases

Displacement after a natural disaster refers to a global issue and always needs improvement in solution to provide healthy and secure living environment with privacy and dignity. In study cases that have been provided in this design, woven refugee tent is a contemporary form of tents. The materials used in tents are weather proof and more durable. Each tent has its own water collection system and also cabling space which gives privacy to users. Tents are very suitable solution as their transportation and installation conserve cost and time. U-dome design also follows the form of tents but with a more durable and weather resistant material. They are least expensive and easy transportable design among others but do not provide water and electricity system. The other study case is tentative that is inspired by shipping container but has ventilation system inside and is disassembled for ease of transportation but could be assembled easily. Tentative has been manufactured within material those are resistant to weather condition.
3.2.2 Solution

To overcome the problems in the current settlement solution associated as objectives of this research, a new pre-fabricated semi-assembled design has been proposed that is adapted to the local climate of Iran specially in the regions with high risk of earthquake, providing ventilation system, taking advantage of local material in construction of units which gives mental comfort and physical convenience to the user.
3.3 Design Ideation
3.3.0 Mind Map

Figure 17. Mind Map
3.3.1 Inspiration

Figure 18. Inspiration mood board
3.3.2 Initial Sketch

Figure 19. Initial sketch
3.3.3 Concept Development

The initial concept is a modular box which is similar in form to the shipping containers but different in the connections, assembly and installation. The initial design is made up 6 pallets which will be assembled on site. For the ease of installation and taking leverage of local people, the connection will be using hinge connections.
The initial design has been modified to the concept in figure 21 which will be adapted to needs and culture of user in Iran. The ventilation system design has been inspired by shotorgaloo wind catcher design [], and sustainable material from local environment.
3.3.4 Technical Drawing

Figure 22. Technical drawing
3.3.5 Elements of Design

3.3.5.0 Structures

Each side has been covered with a frame to strength the structure. Victims in most of the times prefer to set the shelter close by to their destructed house. As the ground will still be expecting other earthquakes, the module should be secured to the maximum safety as possible. This structures will make the module stronger and reduce its vulnerability.

The structures are made of Light steel frame (LSF) which is lightweight and very resistant to earthquake. [20]
3.3.5.1 Connections

The main structure of concept is designed as that can be connected smoothly and effortlessly without expert prior knowledge within ordinary people [local people] with simple training. A cubic module is made of six square pallets which are prefabricated in the factory, and each pallet is connected to others like a puzzle using spring latches. It is possible to attach other modules with the same method to make more needed space. To connect each pallet to others by pulling the spring latches and then releasing them after connecting the two pallet pieces together.

Figure 24. Connection detail plan
3.3.5.2 walls

Walls are in the form of pallets composed of light steel framing (LSF) for the frame, polyurethane board as the internal board which is fire resistant plasterboard and composite of wood-plastic for the external boarding as it is weather defense externally. There have been considered to provide windows in the wall palate to use the light of the day and for the ventilation of the air as well. The detail analysis for the walls has been described fully in concept analysis chapter.
3.3.5.3 Ventilation System

Ventilation system in this studies has been inspired the Wind catcher of Yazd, Iran since before 19\textsuperscript{th} century which is an ancient Persian natural or passive way in air ventilation system. The designed ventilation system has openings that are facing the wind and trap it inside the shelter and when there is no wind it would work as chimneys to let the hot air to rise and escape.

[21]

Figure 26. designed ventilation system inspired by Yazd wind catcher
Chapter 4:
Concept Analysis
4.0 Dimensions

Based on the minimum standards have been defined in the UNHCR, the dimensions for an emergency shelter per person should follow:

1. Minimum 3.5 m² covered living space per person in tropical or warm climates, excluding cooking facilities or kitchen (it is assumed that cooking will take place outside)

2. Minimum height of 2 meter at the highest point.

Following minimum requirement, the area for each module which corresponds to a person, will be 7.3 m² and the height will be 2.7 meter. The equality in length make it easier and more user friendly for packaging and installation. It also facilitates the modularity of concept. [22]
4.1 Material

The material used for this design could be divided into material has been used for the structure, walls, windows and their frames.

- **The structure** is made of LFS (light steel framing).
- **The walls** are composed of LSF, wood-plastic composite and Polyurethane.
- **The windows** are made of double glazed glass and the frames are metallic frames.

Each material will be fully described in the following section.

Figure 28. Material Exploded plan
Light Steel Framing (LSF):
LSF structures are a type of structures that are produced for the construction of light buildings in the factory and installed at the project site. LSF stands for LIGHT STEEL FRAME, which is equivalent to light cold rolled steel frames. Usually, these structures are produced with sheets with a thickness of 0.7 mm to 3 mm and in sizes of 89 to 308 mm.
These shelters made of LSF are very light. They weight one-sixth of concrete buildings and one-fifth of metal buildings. The lower the weight of a building, the less force it absorbs and the less damage it will suffer during an earthquake. In this type of structure, instead of a few strong and limited columns, a number of scattered hails are used that can withstand a large force.
The structures of the module will be made of LSF. The details for the joining the LSF’s has been shown in the figure 29. [20]
The walls are composed of LSF, wood-plastic composite and polyurethane.

Wood plastic composite is panel product made from recycled plastic and small wood particles or fibers. Wood plastic composites are new products compared to the long history of natural lumber or traditional wood composites such as particleboard or fiberboard. WPC manufacturing is a two-step process which is Combination of wood and thermoplastic such as high density polyethylene (HDPE), low density polyethylene (LDPE) and polyvinyl chloride (PVC) being mixed together dough-like-consistency. In addition to the main ingredient wood with grain size ranging from 20 to 60 mesh, plastic coupling agents, stabilizer, foaming agents or dyes also are added to enhance properties of the final product for a particular use.[23]

Polyurethanes are a large class of polymers more commonly known for liquid coating and prints but could vary from soft and flexible forms to rigid and insulation based on the application needed. In this design has been used for the purpose of insulation which is a modern and highly effective method for the thermal insulation of the building. [24]
4.2 Ventilation System

The functionality of the ventilation system could be described as below:

1. Multidirectional wind-towers capture prevailing wind that may change seasonally or daily. The X configuration of interior panels channel wind from the prevailing direction.
2. The tunnel helps accelerate the descending air into the shelter. Wind exerts a high positive pressure on walls facing its flow.
3. A circulation of air conveys a cooling breeze. The breeze helps cool the body by increasing moisture evaporation from the skin.
4. Strong up draught of air maintains the circulation. And opposite effect is created on the other sides, causing air to be sucked through the shelter and out of the other vents. [25]

Figure 31. Ventilation system functionality
This concept has been designed based on the modular design approach. Each shelter has been designed for an individual but based on the needs, two or more modules could be merged together and produce a bigger shelter for families or people they wish to stay together. Individual shelters could be expanded in different form such as linear, L shape and Z form. [26]

The corresponding table shows the number of the modules joined together, their functionality in terms of number of individual living and required space for.

Figure 32. Modular concept description
Figure 33. Final executed design
Chapter 5: Conclusion
5.0 conclusion

This study has been conducted to design a new form of emergency shelter for post-disaster situations such as earthquake in Iran. The design has several advantage comparing to the current shelter being used in Iran which could be pointed out as:

- Sustainable design as it will be designed using the local and recycled material in the fabrication process.
- Modular architecture form where it could be expanded into bigger shelters for the family and group usage.
- Bioclimatic design as the air flow will be designed based on the natural ventilation system inspired by Persian ancient ventilation system.
- Convenient and low cost transportation as the pallets are prefabricated and occupies small space in the logistic, thereby the transportation would be cost and time effective.
- Installation would be on site using the local people as it does not require complex training and equipment for the process.

It could be concluded that all the objectives of the design have been achieved and the concept have more advantage comparing to current case studies.

5.1 Future work

This concept has been designed for the post-disaster circumstances but it could be modified for the co-housing purpose. The modular architecture of the concept could satisfy the need for the co-housing needs.
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