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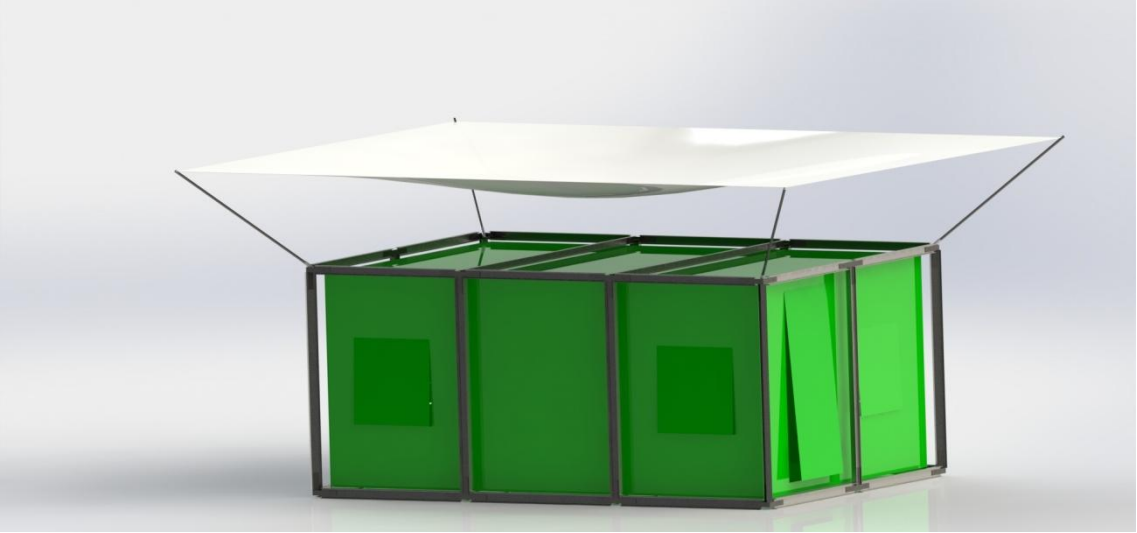
UNIVERSITAT POLITÈCNICA DE CATALUNYA

Design of a Basic Module For Emergency Situations:

Project Of A Fast Deployable Transitional Shelter Unit For Emergency Situations



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Acknowledgments

I would like to think that this project can set a leading path on my way of thinking and facing challenges. The project was breed on values that need to be transmitted in all fields in order to achieve great project results no matter where and what the situation is. This project would not have been possible without the help of my supporting teacher who guided me on the first steps of this project and then for his further empowering throughout the period of analysis and evaluation. I would also thank my supporter parents who gave me the conviction to start and finish this degree. The intention of this project is supply a need that may have been over looked for many but not strong solutions have been taken. This project has been the perfect case to review the four last years of knowledge gathering throughout the degree and demonstrate that humanitarian or social needs can fit on the engineering world.

Abstract

This Bachelor thesis attempts to give a better solution to a increasing problem due to permanent people relocation. A unit prepared to give shelter and comfort with standard living characteristics will be designed in terms of affordability, area to be assembled, climatology conditions and period of use. The unit will be tested theoretically for different areas, materials, purposes, configurations and energy needs. Nowadays refugees in camps, relocated populations after natural disasters and poor country citizens live in deplorable constructions consisting in tents that only offer a limited temporal solution with no dignity and comfort conditions. Therefore economical viability is taken to account in order to carry out the project in the actual market.

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1 Introduction

Every human being, to settle in some place, needs shelter, comfort and guaranties that this situation will stay still throughout time. Due to recent facts thousands of people have been forced to leave their homes and leave behind the security against surviving. Refugee camps and improvised poor build areas have grown in number and those also have increased the time they are operating. The lack of foresight on how long those settlements will be operating and also the lack of other options in the market have lead to weak constructions and poor adapted tents that can't last what it is need and don't offer the right conditions to live in.

By end-2013, 51.2 million individuals were forcibly displaced worldwide as a result of persecution, conflict, generalized violence, or human rights violations. Some 16.7 million persons were refugees. An estimated 10.7 million individuals were newly displaced due to conflict or persecution in 2013. During 2013, conflict and persecution forced an average of 32,200 individuals per day to leave their home and seek protection elsewhere, either within the borders of their own country or in other countries. This compares to 23,400 in 2012 and 14,200 in 2011. (pdf dades)

Refugee camps are usually planned by architects and planners of UNHCR. The standard model for a refugee camp is described in the "UNHCR Handbook for Emergencies. After site selection that take accessibility, climate and health risks into consideration, the handbook introduces the planning of the physical organization of the refugee camp. The refugee camp establishes an infrastructure and services, which outside of the camps are not provided. On a statistical level, live expectancies are higher in the refugee camp than in the rural areas. (web Africa)

Drinking water or sewage installations and proper thermal regulation and electrical grids are some of the characteristics that the unit will focus its attention and try to give a realistic implementation. Constructing a custom-built structure is too time consuming and expensive. But what if a structure could be created that combines the efficiency of a tent with the comfort and stability of a four-walled structure. Being that while tents do have their merits (they're cheap and fast to construct) they're not really meant to be more than just temporary relief.

Hence designing and making profitable a way of fast constructing decent dwellings for these people are the claims/goals of this project. Also the way any water or energy source is produced or used will be analyzed in order to offer a unit that requires the less to offer the most on comfort and hygiene. To summarize the result of this project will be an affordable and livable unit with the

lowest requires on maintenance and sustainable with its surrounding environment.

1.1 Motivation

The idea is evaluate and design an economical and functional shelter, that its modular characteristics make it deployable and can be sold anywhere world wide .This project has its roots on the realization of the growing number of refugees and relocated people all over the globe due to different causes, such as man-made or natural disasters and war conflicts, and mainly the inadequate solutions offered to those suffering in terms of shelter, also known as Transitional Shelter. The aim of providing and maintaining the rights of shelter for anyone who has been forced to move away from their homes and facing the reality that current solutions are temporary based, but need long-lifespan approaches, and offer poor living conditions, doing so with a plausible idea, that fits in the market reality and offers real solutions based on engineering knowledge, instead of fancy and expensive designs that shine bright on competitions but are not functional on the field.

Enrolling such a complex project allows me to dig in and be familiar with different fields like materials, heat transmission, structural design, regulations (international commercialization, customs, TS, camp planning…) and market study and evaluation. Some of those fields were courses from the degree I studied, hence I will be able to use all the background acquired throughout those years in the process of developing a product from ground level. Starting this project also gives me the chance to face the problems of a project by learning how to take the right decisions regarding advantages and drawbacks and eventually set a business opportunity on the real world economy.

1.2 Goals to achieve

The final goal of this project is to successfully design a transitional emergency shelter module. On doing so a sort of issues should be solved, achieved and taken to account:

- Low cost product (regarding existing solutions) reduction of material cost through intelligent design
- Reduction of material waste through efficient construction techniques
- Easy to assemble and deploy reducing time and manpower
- Low weight after packing the module
- Find the optimal measurements, the best shape and structure of the module
- Find the optimal wall, structure and sheathing materials
- Capability of being assembles worldwide by its adaptable characteristics
- Viability of different configurations to fit the market targeted
- Usage of coverings that will reduce outside environment conditions on the inside
- Energy Self-sufficiency of the unit
- Lifespan focused on permanent situations and reusable
- Find a universal ground secure unit system
- Achieve safety requirements of the unit fire retardant, smoke and gases ventilation and illness transmission animals.
- Weather and climate conditions resistant
- Viability of integrated grid and plumb installation
- Functional and reliable way of transportation and packing

1.3 Scope of the project

The scope of this thesis will be limited to the examination through a framework of theory of rational construction, of shelters built as a response to forced migration of those due to man-made or natural disasters at the present state of camp refugee and focuses on the primary need of adequate shelter. Self-build community generating practices based on given modular shelters and local building techniques will allow creating a long-term sustainable supply of dwellings. These principles aim to provide a new way that shelters can be constructed and then subsequently lived in, for the most cost-efficient manner. Existing buildings and construction methods will be analyzed on the bases of construction-cost and lifetime-use.

This project will be developed to provide dignity and human rights ensuring shelter for those who had to flee home due to adverse situations. From analyzing existing options, going through the design of new options and finally evaluation and developing the production of a solution as a product that could be sold are the stages that this thesis will face. The final product should fit all the requirements set on UNHCR handbook and should gather all the characteristics on which the goals are set or at least a high percentage.

Design, calculation and material characterizations will be also limited by worldwide regulations and its manipulation. Safety and product quality is the path to follow while developing this project.

Boundaries of the project, designing will allow a theoretical result be obtain but functional and real prototype of the product is not possible due to the low budget of this project and the short schedule available.

Hypothesis of the project (I guess something related to how much time is needed to deploy, materials and structure shape assumptions and fields reached during the project progress).

The criteria before exposed make the result a successful one only if a functional solution is obtained. The characteristics as far as they fit the requirements mentioned should allow the project to take in consideration other paths to finally succeed. A wrong or bad result would be the one that does not face reality boundaries and cannot be adaptable to multiple solutions.

1.4 Work Methodology

A research on bibliography and related documentation of emergency shelters solutions and its regulations throughout these years up to nowadays market options and involved organization advice set the basis and the fields that should focus the thesis. This data allows getting a close picture on this sector.
Documentation based on nongovernmental organizations gives an idea of how many need a solution and the problems that those have to face. Regulations made by these organizations or others in the field of camp deployment drive the path to follow on basic characteristics that these shelter units should cover. Finally analyzing nowadays solutions and purposes make it easy for new projects to success by trying to avoid certain errors occurred in the past.

Once searching for existing information some work must be done in order to point the direction of finding a new and functional solution.

The first part is focused on analyzing pre-existing low-income housing rational construction model solutions and detects its weakness, such as its problems towards long-term problems and its lack of coverage of human dignity and rights, in order to not let them take place in this project. This part is focused on analyzing existing unit structures, cladding materials, useful area, areas of appropriate and designed deployment and its other characteristics also involving the local repercussion. After the analysis chosen qualities and withdrawn options or solutions are exposed as a list of value assets to take to account in new designs.

The second part has the description and shows the designs that could be created using the methodology and principles written on the guidelines for refugee camp construction, published by UNHCR. Those designs contain the value qualities found on the part first and are new concepts from scratch. Next an analysis is made and one or a modular with few variations option is chosen. This selection is then fully characterized and designed fitting the goals set in the beginning in order to find a viable solution that fits the regulations and standards of those who will work in situ

The third part focuses on the description of the chosen unit solution its characteristics and gives a wide view of the potentials of the product created.

In the fourth part an economy study is carried out in order to find its viability. This is made by characterizing production, shipping and maintenance costs based on a target market evaluation on a real world economy.

Ultimately in the fifth part conclusions of the thesis are summed up and discussed. Also details of the proposed solution being accepted or developed by interested organizations or companies in the real world.

2 Background

2.1Actual situation

Currently there are millions of people living in refugee camps around the globe, each of which contains anywhere from a few hundred to many thousands of people, or more. These camps are meant to provide a measure of protection, shelter, and sustenance to individuals who have been forced to flee their homes in the wake of civil unrest, political persecution, or natural disasters. Unfortunately, a significant number of refugee camps are constructed rapidly with little regard for social aspects, provision of services, utilization of local materials, quality control, post-construction oversight, or the camp's potential permanence. 8 years is the average amount of time that people must reside in, but others have been standing over 50 years. Camps are mainly constructed with tents that degrade within a year. Inadequate continued oversight, and a lack of sustainable accommodation for the refugees makes them refugees often suffer from exposure, illness, assaults, and death.

Image: 1 Qaxootiga Soomaalida Camp

In the year 2004, the United Nations High Commissioner for Refugees (UNHCR) estimated that there were 20 million refugees living worldwide. In addition, 25 million people were displaced within the borders of their own countries and were thus classified as Internally Displaced Persons (IDPs). By end-2013, 51.2 million individuals were forcibly displaced worldwide as a result of persecution, conflict, generalized violence, or human rights violations. During 2013, conflict and persecution forced an average of 32,200 individuals per day to leave their home and seek protection elsewhere, either within the borders of their own country or in other countries. This compares to 23,400 in 2012 and 14,200 in 2011.

Refugee camps are usually planned by architects and planners of UNHCR. The standard model for a refugee camp is described in the "UNHCR Handbook for

Emergencies. After site selection that take accessibility, climate and health risks into consideration, the handbook introduces the planning of the physical organization of the refugee camp.

Overall, an image of low density and clear separation of functions and uses, suggests an idealized city with urban planning of the 1920s. The concept of hygiene shapes the refugee camp on a direct level (terms of health conditions, sanitation, transmittable diseases and vector control). This concept is applied all over the world no matter where or what is the situation. They are envisaged as perfect enclaves, representing a sort of utopian island within a context of dystopian conditions par excellence.

The refugee camp establishes an infrastructure and services, which outside of the camps are not provided. Live expectancies are higher in the refugee camp than in the rural areas. Provisions of food are generally stable and the level of physical safety is often higher. Often local population aims to enter the camps, trying to find security and support. The local population adopts a humanitarian ‘building style’ by adding leftover UNHCR tents to their typical clay huts or adopting plastic sheeting as cover material instead of their traditional thatched roofs.

Apart from the obvious beneficiary of the refugees, to whom they might represent a life saving resort, also local population; local politicians, UNHCR, the NGOs, armies and rebel groups, and international media take their share of profit from the camps, and thereby working towards perpetuating the camp. It becomes the permanentization of a space of temporality. (web Africa)

Architect Manuel Herz says: "We have several hundred refugee camps in every part of the world and in every kind of climate zone, but the same plans are used to build the camps". The Handbook for Emergencies defines how much living space a family should be allocated, and how the tents, streets and administrative buildings should be laid out based on crowdedness and sanitary and medical facilities.

No account is taken of cultural or ethnic aspects, such as living in an extended family.

The UNHCR is aware of the problem of not having enough space and work, but it points out that the standard plans allow them to plan to supply refugees with their basic needs as quickly as possible.

If the refugees were more involved in planning their new homes, they could develop a society that could administer itself. The aid organizations would have to withdraw a bit.

Over the years, these camps have transformed from temporary 'tent cities' into hyper-congested masses of multi-storey buildings with narrow alleys,

characterized by high concentrations of poverty and extreme overcrowding. The camps are considered to be among the densest urban environments in the world, but because camp structures were built for temporary use, over the decades the buildings have become overcrowded, critically substandard and in many cases life-threatening.

Image: 2 Zaatari Camp

As an example, after nearly two years in Gendrassa Camp, refugees have settled into a more appropriate and sustainable shelter. Refugee households were initially given 6.5m X 4m UNHCR tents as shelter upon arrival, and 80 per cent of households surveyed stated that they had built structures in addition to their tent.

The most common material used was wood, used by 94 per cent of households that built structures, followed by grass (81%) and tarpaulins (69%). Less than one percent used either flattened metal drums or corrugated iron in their structures. Refugees tend to use wooden poles as the frame of a structure, tarpaulins to waterproof the roof and grass and/or mud for walls.

The main sources of building materials for refugees were the bush areas around the camp (82%) and through the delivery of Non-Food Item. Twenty-two per cent of households acquired materials from refugee markets, 4 per cent from friends and less than one percent used host community markets. When markets are used, wood appears to be the most common material acquired from them.

Under international law, refugees have the right to an adequate standard of living, including housing, without prejudice to other rights they enjoy as refugees. Infrastructure and Camp Improvement Program (ICIP) adopts an integrated, comprehensive, participatory and community-driven improvement of the built environment of Palestine refugee camps, utilizing urban planning tools. (Example of conversion from tent camps to buildings)

A new way of thinking about how refugee shelters are constructed and managed should be put on the table. Logistics and long term solutions must be

addressed on provision of transportable, reusable, robust, modularized refugee shelters adaptable to varying environments and population that can be utilized during post-conflict scenarios.

Wherever practical, shelters should be constructed with local resources and simple technologies. Minimization of material transportation and construction costs is the key, but not at the expense of quality and reliability. This practice reduces dependence on outside sources, allows refugees to maintain a sense of purpose and dignity, and promotes long-term sustainability of the camp.

Image: 3 Zaatari Camp 2

2.2 Actual or current proposed solutions

This part will list some of the most significant solutions existing on the market nowadays. An analysis of its components, materials, the aim of its design and its weak or strong features will be held. The characteristics will be sort based on the UNHCR handbook regulations and its functionality after engineering evaluation. Hence, only engineering parameters and properties of the components and their materials will be taken to account, design features and module layouts will be purposed on the second part when the conclusions of this part will be extracted. Transportation and availability of the materials are also one key matter.

3 kinds of shelters will be analyzed the first ones involve current military or professional solutions and solid housing, which are the most expensive but also the most functional and well equipped. The second type of shelter analyzed will be the tents that are currently used or have been used as a solution and finally we will check the prototypes that have been designed but not used on the field. Finally some accessories or single parts which are useful to improve shelter features will be also shown and characterized.

The following section analyzes the three kinds of solutions (tents, professional housing and prototypes) and its most common characteristics. Each kind of solution is shown as an average of all of its options characterized and in the end an overall review is carried out in order to compare the three of them. By using charts and crossing values, a plot of what has been used the most and also which are the best options to give a positive and useful result, some conclusion is draft.

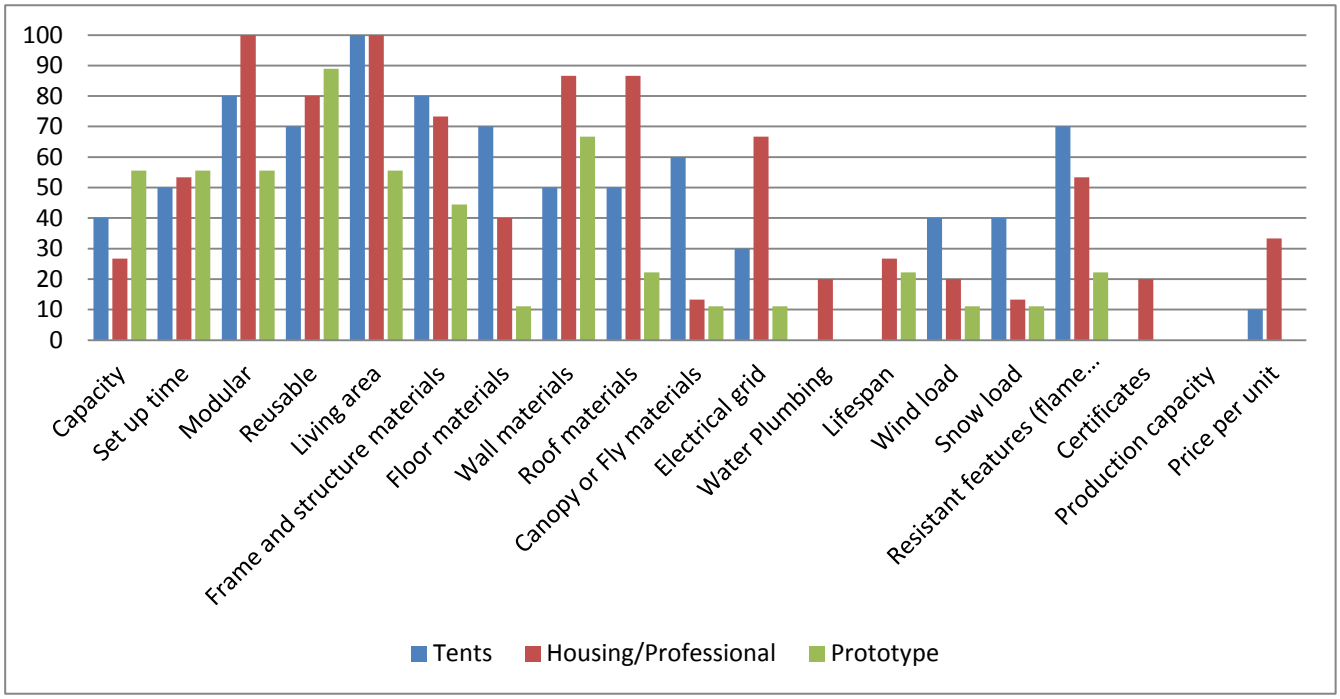


Table: 1 Actual Solutions Features %

The graph above shows a percentage of the characteristics that every solution has. Its intention is to summarize and compare the features that every kind of solution has. Due to a massive lack of information some important specs are grounded to 0. This allows having the bigger picture on where the companies focus its attentions. This graph just shows how much of the information that should be available is found in every category of solutions.

In order to start analyzing the graph the worst percentages will be explained. Afterwards an engineer deep review will show some of the possible extracted conclusions on materials based on the poor available information.

Every solution has the problem that doesn't show how many people can help or reach in terms of serial production or stock available. Hence production capacity is not taken to account and any try to evaluate transportation and delivery contexts is worthless.

Then certificates that show quality and could give any warranty don't appear in tents or prototypes but they do appear on some of the sorted professional solutions. This value just reaches the 20 % of all the professional solutions analyzed. These solutions focus mainly on army and fancy modular housing solutions where budget is not as important as in relief shelters.

Then one of the worst percentages of features is one of the two which covers basic needs like water plumbing. This characteristic is not an included option but just an accessory that can be added as an optional feature. It reaches the 20 % and once again just in professional housing solutions.

The other basic need is electricity and this appears in every kind of solution but once again the best percentage up to 60 % is shown on professional housing solutions. It is interesting that not all the prototypes offer this option in its solution and even though tents are not supposed to be heavy they also have some configurations with electrical grid. Those tents are also focused and aim to face army purposes.

The capacity of every unit varies and even though it is an important feature most of the options don't say how many people it can handle. Surprisingly the prototype is the category that gives the most information on this spec.

If any specification is crucial for the deploying of a functional and operative camp this is the set up time.

Although the tents are meant to be easy to assembly and place the modularity is even higher on professional solutions. This value goes up to 100%, so all the studied units can be in any way or another combined together.

In ecological issues all three categories have a high percentage of being reused once their job is done. The prototypes have the highest percentage about 90 % of them are reusable.

Information regarding living areas is only shown in existing solutions and then prototypes have lots of blank spaces on this issue.

The material area is deeply analyzed and explained in further chapters but for start a thing must be noticed. Tents as light solutions for short periods of need have the most information on canopies and flies. Tents also share with professional housing the highest value on frame and structure information. This is understood as the need of sturdy units and this comes from the part that attaches everything together. In order to finish with this section walls and roofs are the most important parts of sturdy units to be differentiate from tents and this can be seen in the graph with the highest values for professional solutions in this matter.

As the materials are shown but not in every solution specs regarding load limits and environment conditions are not mentioned and the once drafted are barely reliable.

Finally the price per unit is not mentioned in every solution and some of them are merely real state rated values. The prototypes are the category where a predicted price is not shown and neither do tents but some information regarding this can be found on professional solutions.

The next part shows the percentage of materials used and which are its theoretical characteristics. Estimation is made in order to be able to compare from one solution to another.

The category Tents has a few examples of materials used to face different problems and areas.

10 options were analyzed from this category. From all solutions just the 40% has information about the capacity of the unit, 50% about the set up time and none of them had any certification that ensured its quality. The price was found in just the 10% of the options and regarding the materials used on its different parts from 50 % up to 70% had the information. Those materials used are briefly commented and shown how much were they used. Neither loads nor flame, UV and mildew properties were massively described and those are really important for its lifespan and range of use.

Frame and structure most common materials:

From the 10 options selected only the 80% had some information on its structure used material. Metal was used in the 75% of the remaining options. Aluminum had the most applications. Aircraft aluminum kinds were the most

used for its light weight and its strength. Fiber glass poles was also used in 12.5% of the occasions also due to its light weight, mainly reinforced fiber tubes which stand long period medium-loads but not sudden stress. Finally Air beam was an option for larger tents due to its canopy light weight and small loads throughout the structure. But the need of an air pump running makes it expensive overtime.

Floor most common materials:

From the 10 options selected only the 30% had some information on its floor material. Polymer based materials were used in the 100% of the remaining options. Polyvinyl chloride was the most used. However nylon was also used for similar properties. Both are light weight and multiple layers make them stress UV and flame resistant. These features make them suitable for outdoor use and harsh environments.

Canopy and fly most common materials:

Due to light weight focused materials and structure no walls and roof are used on tents. From the 10 options selected only the 50% had some information on its canopy material. Plastics and polymers were used in the 80% of the remaining options. Polyester, Nylon and ASTM are an example of the used ones. These are light weight and multiple layers make them stress UV and flame resistant. These features make them suitable for outdoor use and harsh environments. The second solution was traditional cotton canvas that weights more and don't have such good features.

The category Professional has a few examples of materials used to face different problems and areas.

15 options were analyzed from this category. From all solutions just the 27% has information about the capacity of the unit, 53% about the set up time and just the 20% of them had any certification that ensured its quality. The price was found in just the 33% of the options and regarding the materials used on its different parts from 60 % up to 90% had the information. Those materials used are briefly commented and shown how much were they used. Neither loads nor flame, UV and mildew properties were massively described and those are really important for its lifespan and range of use.

Frame and structure most common materials:

From the 15 options selected only the 53% had some information on its structure used material. Metal was used in the 87.5% of the remaining options. Aluminum had the most applications. Steel beam kinds were the most used for its strength about a 57%. The weight wasn't an issue due to the purposes of those units mainly the army. Aircraft aluminum was also used in 43% of the occasions also due to its light weight compared to the steel. Finally Air beam

was an option for larger tents due to its canopy light weight and small loads throughout the structure. But the need of an air pump running makes it expensive overtime.

Floor most common materials:

From the 15 options selected only the 20% had some information on its floor material. Polymer or rubberized based materials were used in the 33% of the remaining options. Wooden sandwich panels were used in 33% of the solutions and aluminum-polyurethane sandwich was also used in 33% of the solution. Insulating panels have to do its task but those options show a focus on the weight they have. These panels are hard to bend and also lightweight but keep a high level of insulation. Multiple layers attached make them stress UV and flame resistant. These features make them suitable for outdoor use and harsh environments.

Wall most common materials:

From the 15 options selected only the 20% had some information on its wall material. Polymer or rubberized based materials were used in the 33% of the remaining options. Wooden sandwich panels were used in 33% of the solutions and aluminum-polyurethane sandwich was also used in 33% of the solution. Insulating panels have to do its task but those options show a focus on the weight they have. These panels are hard to bend and also lightweight but keep a high level of insulation. Multiple layers attached make them stress UV and flame resistant. These features make them suitable for outdoor use and harsh environments.

Roof most common materials:

From the 15 options selected only the 73% had some information on its roof material. Polymer or rubberized based materials were used in the 45% of the remaining options. Wooden sandwich panels were used in 9% of the solutions as cardboard based panels. Metal was also used in 27% of the solutions and composites were used in the 18%. Cardboard was used its cheap price but its properties regarding sturdiness and harsh environments resistance are below needed standards. Composites had fiber glass structures were light weight and pre-shaped panels are easy to assemble and show resistance and an acceptable lifespan. Then metals appeared in two different options high tech aluminum which makes it light weight and stress resistant but highly expensive and then the corrugated metal which is a cheap but heavier solution. Finally Polymer based panels appeared as PVC and Polyurethane sandwich panel. These panels are hard to bend and also lightweight but keep a high level of insulation. Multiple layers attached make them stress UV and flame resistant. These features make them suitable for outdoor use and harsh environments.

Canopy and fly most common materials:

Due to having a roof and walls the need of a canopy is reduced and only the 6 % of the solutions analyzed had it. PVC canopy is used due to its light weight, stress, UV and flame resistant. These features make them suitable for outdoor use and harsh environments

The category Prototype has a few examples of materials used to face different problems and areas.

9 options were analyzed from this category. From all solutions just the 55% has information about the capacity of the unit, 55% about the set up time and none of them had any certification that ensured its quality. The price was found in just the 10% of the options and regarding the materials used on its different parts from 11% up to 66% had the information. Those materials used are briefly commented and shown how much were they used.

Frame and structure most common materials:

From the 9 options selected only the 44% had some information on its structure used material. No metal is used in the remaining options. However some other options appear. Glass fiber is in the 25% of the solutions. As so does air beam, bamboo and polyethylene in the same percentage each of them. This use on prototypes is mainly based on their properties like their light weight and their strength. Even though some of them are quite expensive, their environment resistant qualities against mildew and rust make them suitable for a project of a unit like this. Glass fiber tubes can stand long period medium-loads but not sudden stress, just like bamboo. Finally Air beam was an option for larger tents due to its canopy light weight and small loads throughout the structure, this inflation based on a chemical reaction is bounded by its one and only use. After the foam hardens and the unit has done its job it can be reused.

Floor most common materials:

From the 9 options selected only the 11% had some information on its floor material. Wooden floor was used in 100% of the remaining options, which is just 1. Light weight compared to metals and great insulator but not as light as polymer based floors.

Wall most common materials:

From the 15 options selected only the 44% had some information on its wall material. Composite materials as a light and functional solution were in 25% of the remaining options. Wooden sandwich panels were used in 75% of the solutions. Insulating panels have to do its task but those options show a focus on the weight they have. These panels are hard to bend and also lightweight but keep a high level of insulation. Multiple layers attached make them stress

UV and flame resistant. These features make them suitable for outdoor use and harsh environments. However the ones based on cardboard are really weak against stress and wet climates trash the panels.

Roof most common materials:

From the 9 options selected none had any information regarding roof materials. In prototypes there were a few ones which had specific strong roof designs, but not a single material used on them was listed.

Canopy and fly most common materials:

From the 9 options selected only the 11% had some information on its canopy material. Metal and polymer combination was the solution of one of the solutions. The material was nylon aluminized polystyrene film that was light weight and had a few layers which make it stress UV and flame resistant. These features make it suitable for outdoor use and harsh environments.

Overall graph of used materials

Gathering all the materials listed the following graph is plotted.

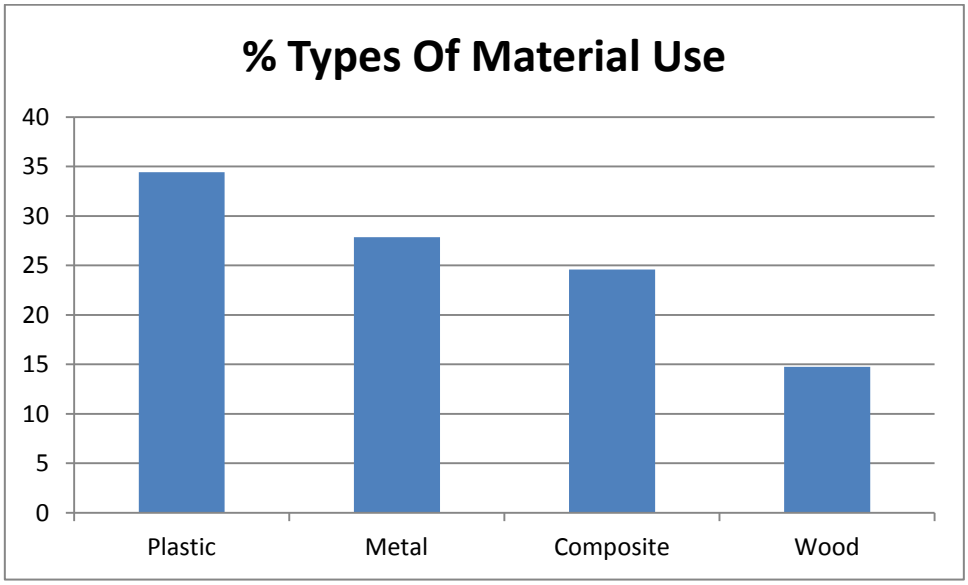


Table: 2 % of material types used in actual solution

This first graph shows us the materials used in a large type classification. Plastics are used in light structures, covering and flooring parts. Most of the panels used on sturdy options have layers of polymers to protect them from harsh environments. Metals are the most used mainly in professional solutions category and structure purposes. Composites are used as a light solution and preassembled options. Finally wood is mainly used as a panel solution for its insulating properties and it is also covered by some polymers.

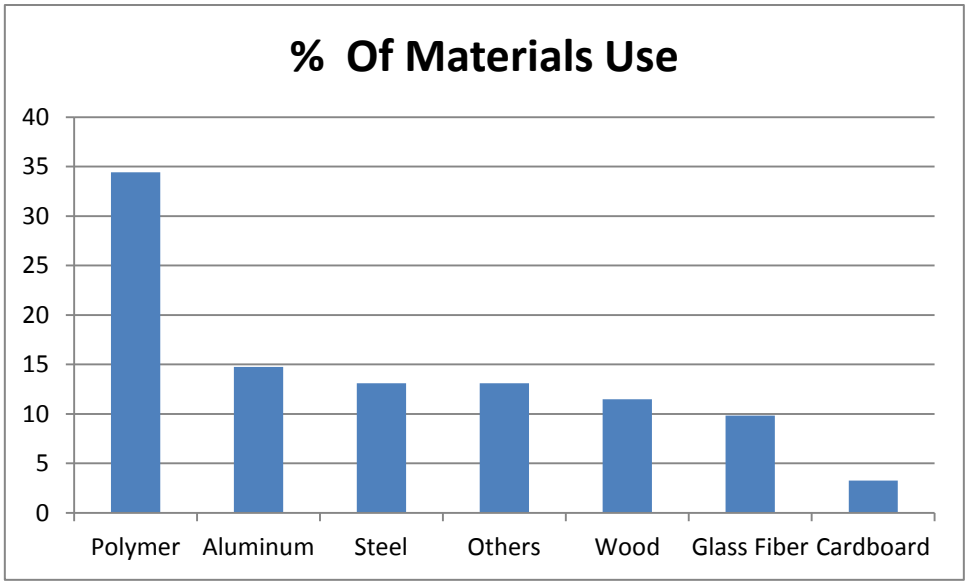


Table: 3 % of specific material use

Mainly polymers were used in every category of the listed solutions. Followed closely by metals where aluminum has the most use and also good has a significant reflection. The use of cardboard is really low due to its properties as so mechanical and chemical resistant ones.

These results help us to get an idea of what the industry or the designers are focused on and which kind of solutions they give. This allows us to compare directly with what world actually needs and where the focus should be. The standards and information gathered by organizations and governments give lots of clues on what should be considered to approach and solve those problems and leads the way on how to do so.

2.3 Actual or current proposed solution characteristics that fit the UNHCR handbook

From the options sorted on the section "actual or current proposed solutions" some are feasible and some are not, so for those which are they have to fit the regulation that the UNHRC handbook proposes to be considered shelter for emergency situations where humanitarian help is required and NGO are in charge. The other standards that those options should fit are USAID which is an American organization founded for military-humanitarian purposes that feces the guidance of emergency operation as well. On assessing so the regulation are explained and compared to the selected options. In the end of this section the conclusions show a list of characteristics that will be also applied on the new proposals on the next chapter.

The main standards that solutions should follow are the six summarized points listed below:

UNHCR Handbook for emergencies

- 3.5m^2/person.
- 1 latrine for every 20 people. There is no need on installing sewage pipes in every unit.
- 100m maximum distance to a water point. There is no need to install drinking water grids.
- 15-20 liters/person of water daily. Need of reservoirs.
- 50m fire brake every 300m.
- Multi-family shelter fits no more than 35 people.
- Shelters should be built by the refugees.
- 2m distance between shelters.
- Layout of shelter should avoid lines and rows configuration (this is not essential).

USAID Field Organization Guide

- 3.5m^2/person. The organization of the camp is dividing it in 1000 people communities.
- 1 latrine for every 20 people. There is no need on installing sewage pipes in every unit.
- 1 water tap for 200-250 people.
- 15-20 liters/person of water daily. Need of reservoirs.
- 50m fire brake every 300m.
- Minimum technical specifications per area’s season.

The requirements above are more or less the same in both cases but in some options what fits perfectly on USAID may not be as suitable for UNHCR standards. The graph bellow shows the percentage of units that meet the requirements listed above. The figure is divided by the three categories and the requirements are shown bellow each column.

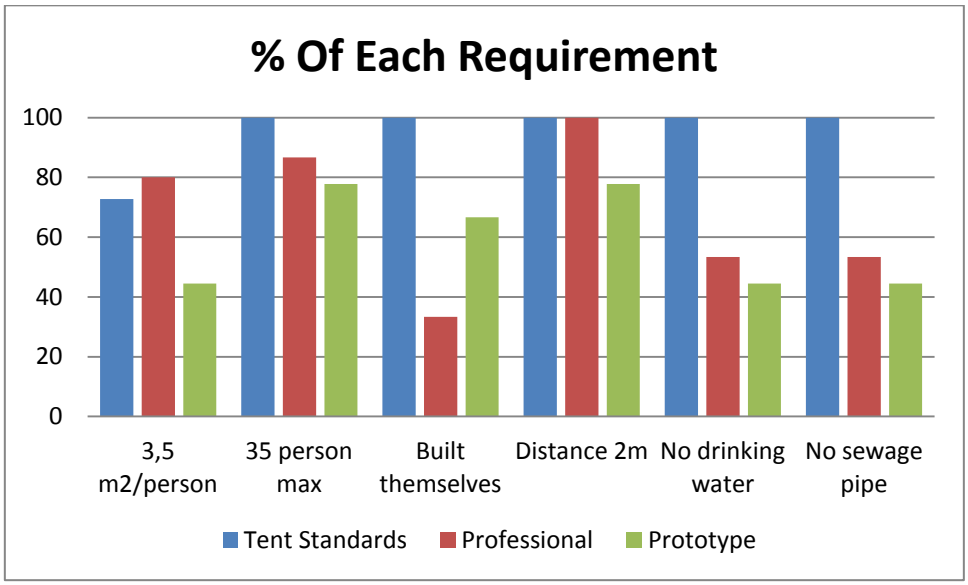


Table: 4 % of solutions that meet the UNHCR requirements

The thing to notice is that Tent category solutions meet the requirement purposed by UNHCR and USAID the most. They have full accomplishment on easy tasks as living space and assembling and they have no more than the essentials. Professional and Prototype categories have some strong accomplishment of some requirements but some other are poorly or barely covered.

The first requirement is the living space per inhabitant. It ensures comfort and at least some personal space for the refugee. As it is shown prototypes has the less focus on this one while professional solutions have it covered in about the 80% of them. Tents are known for being small and light weight and its living space it is quite limited but it has still 60 % of the options meeting this requirement what it is higher than Prototypes.

The limit of 35 people living in the same structure has its maximum on Tents category and for lack of information mainly has the lowest percentage in prototypes. The ease of building the structures it is the most important requirement because it allows the organizations cut on personnel deployed and also ease the transportation. Tents once again are on top and as professional solutions are sturdy and most of them are focused on comfort and army purposes they need to be assembled.

Finally the lack of any kind of installation as a mandatory option makes Tents the most suitable for a fast start.

The following graph shows the average percentage that every requirement compared has in the overall of the units.

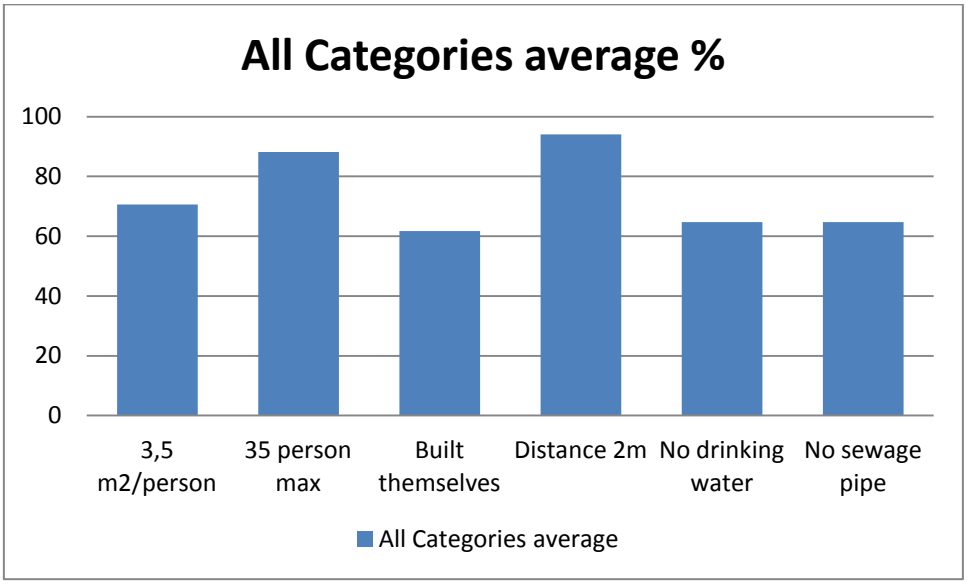


Table: 5 Average % of solutions that meet UNHCR meeting the requirements

As it is shown separation between 2 modular units is possible in the baste majority of the options. Not all of them can be built by refugees what makes them not suitable for fasts deploy need. Then more or less all the remaining requirements are covered. The graph bellow shows the percentage of options that meet all the requirements.

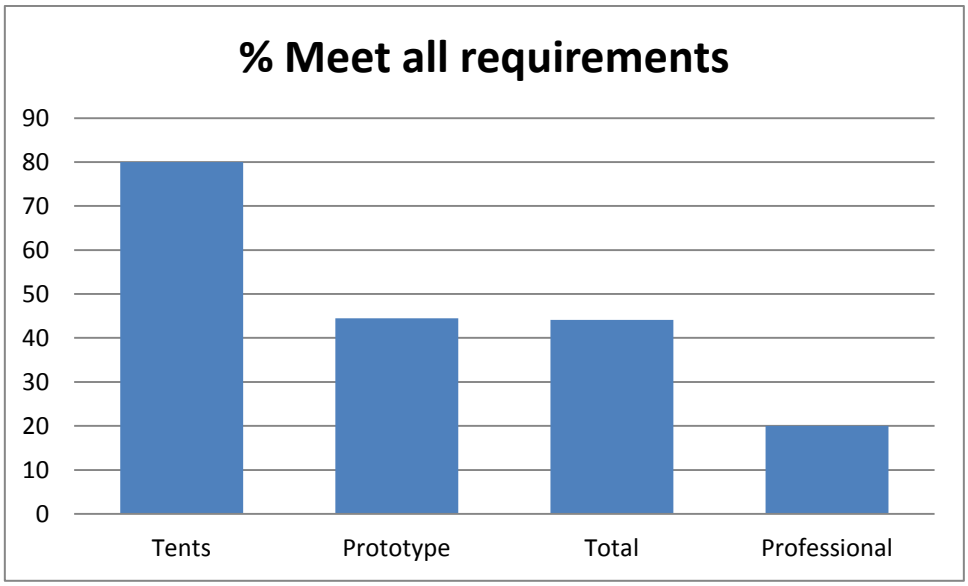


Table: 6 % of solutions that meet 100% UNHCR requirements

Most of the options don't meet the requirements due to some lack of information. Tents have the highest percentage because the points listed would

add weight and would not make this option practical. Prototype has both characteristics some are professional and others are tent based so the requirements are meet in half of the cases. Finally the professional housing solutions have the lowest percentage of achievement due to their huge range of need solving and comfort options. The most complex a unit is more specific requirements it has to cover in the opposite way of what an emergency situation seeks.

Conclusions

Tents seem to meet all the requirements but comfort and sturdiness are some characteristics that this option doesn't have for long term solutions. So bearing in mind that the goal of this project is to achieve a functional but feasible shelter unit the requirements that must fit are the following ones.

- 3.5 m2/person as a living area for the unit. This area can be bigger.
- Never reach the limit of 35 people in the same unit structure. This is not desired neither for design nor living conditions.
- The unit has to be assembled or ease the assembly for non qualified people.
- The unit must be easy to transport and carry.
- The possibilities of the unit layout must take in consideration stackable options and modular combinations.
- The unit needs neither drinking water nor sewage pipe installation. However some of this and other installation will be considered.
- All the requirements above should meet the further unit designs but can be missed if better features are brought to the unit and its users.
- Long term focus forces to think of unpleasant problems that might be accepted for a short period and must be solved.

3 Proposals and alternatives

This chapter is focused on analyzing new proposals of designs, configurations or characteristics of the shelter using or based on the features extracted as suitable for a feasible project on the former chapter. Once the set of new options are shown, and explained, another sorting is done. Hence some options are withdrawn and from those few that can be carried out only one are selected to do a thorough study.

3.1 New and feasible solutions

Material properties and its configuration in different solutions are carried out in this chapter. These features are analyzed through a chart comparing properties to each other and then combined together to make them less restricted and give them some options to play with.

Coming up next materials are listed and then each one has a chart with properties and few other information. Then the comparing chart includes and analyzes all of them. The list has the best performer highlighted. Afterwards the second group being analyzed is structures in shape, section, connections and stacking characteristics. Next and third group being analyzed are the cover, walling, roof and fly. Finally extra components like power grids or water plumbing and unit extra features (none essential parts) are also analyzed.

This first part is focused on the structure and its related issues. Beams are the main item. Cross sections, length, purposes, material and regulations are the characteristics that are gathered and compared. On the same topic (structures) corner fittings are also important, so the number of beams to fasten, its shape, also the material and the additional purposes are taken to account. This topic has to solve the way the structure can be combined and how will it be stacked and transport. Finally the unit shape gathers all the former variables and tries to fit them to a functional module.

Beams are evaluated in different areas. In order to set the analysis in a level where all the possible options fit, standards and mechanical characteristics of each purposed solution are sorted on a chart and compared. The variables that drive the study are moment of inertia, density or lineal weight and the yield stress. Those features are studied on crossing sections. The length of the beam is not a problem as long as standard measurements are needed. All the beams selected meet the requirements of different regulations and the manufacturer guaranties the certificates. By adding standard bit on the structure costs and calculations are cut down.

Metal beams are the first ones to be analyzed. Those are meant to stand a heavier covering than the regular canvas tent. This kind of unit should be long lasting and have rather thick walls and a good roof as well as a sturdy floor cover.

Beams	Material	Moment of inertia (cm^4)	Density LW (kg/m^3)	Yield stress (GPa)
HEA 100	steel	349,20	16,70	205
HEA 120	steel	606,20	19,90	205
HEA 140	steel	1033,00	24,70	205
HEB 100	steel	449,50	20,40	205
HEB 120	steel	864,40	26,70	205
IPE 80	steel	80,10	6,00	205
IPE 100	steel	171,00	8,10	205
IPE 120	steel	318,00	10,40	205
IPE 140	steel	541,00	12,90	205
IPE 160	steel	869,00	15,80	205
IPE 180	steel	1317,00	18,80	205
IPE 200	steel	1943,00	22,40	205
IPE 220	steel	2772,00	26,20	205
IPN 80	steel	77,80	5,94	205
IPN 100	steel	171,00	8,34	205
IPN 120	steel	328,00	11,10	205
IPN 140	steel	573,00	14,30	205
IPN 160	steel	935,00	17,90	205
IPN 180	steel	1450,00	21,90	205
IPN 200	steel	2140,00	26,20	205
UPN 30	steel	6,39	4,27	205
UPN 40x20	steel	7,58	2,86	205
UPN 40	steel	14,10	4,87	205
UPN 50	steel	26,40	5,59	205
UPN 65	steel	57,50	7,09	205
UPN 80	steel	106,00	8,64	205
UPN 100	steel	206,00	10,60	205
UPN 120	steel	364,00	13,40	205
UPN 140	steel	605,00	16,00	205
UPN 160	steel	925,00	18,80	205
UPN 180	steel	1350,00	22,00	205
UPE 80	steel	107,00	7,90	205
UPE 100	steel	207,00	9,82	205
UPE 120	steel	364,00	12,10	205
UPE 140	steel	599,00	14,50	205
UPE 160	steel	911,00	17,00	205
UPE 180	steel	1353,00	19,70	205

Beams	Material	Moment of inertia (cm^4)	Density LW (kg/m^3)	Yield stress (GPa)
UPE 200	steel	1909,00	22,80	205
UPE 220	steel	2682,00	26,60	205
UPE 80	steel	89,00	7,10	205
UPE 100	steel	174,00	8,60	205
UPE 120	steel	304,00	10,40	205
UPE 140	steel	491,00	12,00	205
UPE 160	steel	747,00	14,20	205
UPE 180	steel	1090,00	16,30	205
UPE 200	steel	1520,00	18,40	205
UPE 240	steel	2900,00	24,00	205

Table: 7 Considered I Beams mechanical properties

The crossing sections are made mostly from steel but those same can also be made out of aluminum. In the study no hollow metal sections have been showed due to their low mechanical properties and also due to its difficult to attach any structural accessory causing those leaks or not being suitable for maintenance.

The tables gather information regarding composites crossing sections, only based on products that are already manufactured, were not found. These profiles and materials are meant to stand low loads and being easy to carry them. These kinds of unit have a canvas canopy and do not stay in the same spot for a long time. Finally information regarding polymer tubes or pipes was not found. This profiles and materials are meant to stand low loads and being easy to carry them. This kind of unit has a canvas canopy and does not stay in the same spot for a long time. However just the most used and produced polymers are compared on the following section.

Now that the crossing sections are compared a thorough research on materials is carried out. This part gathers some materials and its properties in order to evaluate which one could be the suitable to use. The mechanical properties are important but the resilience against harsh environments makes the difference on its lifespan.

Name	Material	Yield Strength (Mpa)	Ultimate TS (MPa)	Modulus of Elasticity (GPa)
6061 t6	aluminum	276	310	68,9
7075 t7	aluminum	435	505	72
7075 t6	aluminum	503	572	71,7
AISI 1045	steel	585	__	205
Fiber Glass	fiber glass	130	__	32
Carbon fiber	carbon fiber	1730	__	142
PEEK	polyetrectoceton	93	__	3,6
PET	yethylene terephtha	88	__	3,63
PP	Polypropylene	30	__	1,2
PP APM-HMW	lypropylene APM-HM	28	__	1,2
UHMW	olyethilene ultra hig	19,5	__	0,5
PVC	Polyvinile clorhide	49	__	2,9
PA6	Nylon	78	__	2,8
Lamboo	Bamboo	386	__	16

Table: 8 Beam Materials Properties 1

Name	Shear Strength (Mpa)	Termal Conductivity (W/mK)	Specific Heat Capacity (J/gC)	Density (kg/m3)
6061 t6	207	167	0,896	2700
7075 t7	300	155	0,96	2810
7075 t6	331	130	0,96	2810
AISI 1045	__	58	0,49	7870
Fiber Glass	__	1,3	0,79	2110
Carbon fiber	__	15	0,71	1750
PEEK	__	0,256	1,05	1310
PET	__	0,291	1,05	1390
PP	__	0,221	2	910
PP APM-HMW	__	0,4	2	950
UHMW	__	0,41	2,26	930
PVC	__	0,17	1,3	1360
PA6	__	0,28	3,72	1140
Lamboo	__	0,14	__	673

Table: 9 Beam Materials Properties 2

In the table above can be seen that polymers have the lowest density which is suitable for lightweight structures but then their strength resistance is low compared to the metals. Bamboo has some interesting properties but its expensive price makes it dispensable also use of non standard materials adds difficulties in order to calculate the unit structure characteristics with a narrow range of deviation between units. Composites are the bridge between metals and polymers but no chain production or reasonable price makes it impossible for mass production cheap units and reliable structures. Finally metals looks like the material to use on structures for its mechanical properties but the weight has to be considered. The crossing sections play the role of letting us know which is the suitable. Metals have problems due to heat expansion and highly heat and electric conductors.

In order to protect the structure in the case of metals a sort of coatings are listed bellow with some of their characteristics. The use of anti-corrosion and abrasion coatings allows the structure to have a long lifespan without losing its properties.

Name	Material	Thickness	Temperature Resistance	Adhesion
Epoxy coating	epoxy	0,0001 m	148	ASTM D4541 13,3 Mpa
Polyphenylene sulfide coating	PPS	0,0001 m	260	__
Inorganic zinc coating	Zinc	0,0001 m	426	ASTM D4541 10,3 Mpa
Fluoropolymer coating	fluoropolymer	0,0001 m	260	__

Table: 11 Beam Coating Material Properties 1

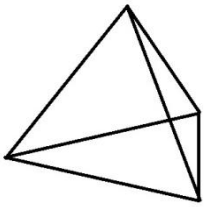
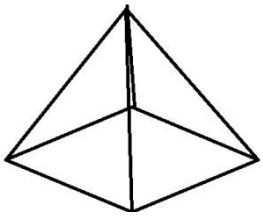
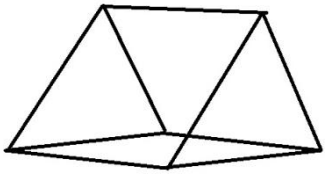
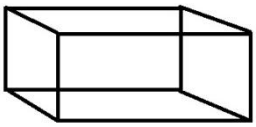
Name	Salt Resistance	Hardness	Chemical resistance
Epoxy coating	ASTM B117 (4000 h)	ASTM D3365	ASTM D543
Polyphenylene sulfide coating	ASTM B117 (4000 h)	__	ASTM D543
Inorganic zinc coating	ASTM B117 (4300 h)	ASTM D3365	ASTM D543
Fluoropolymer coating	ASTM B117 (4000 h)	ASTM D256	ASTM D543

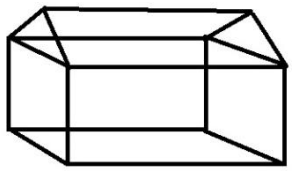
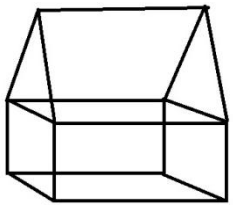
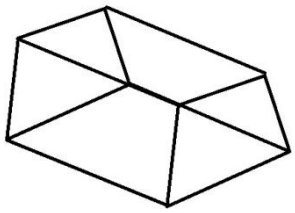
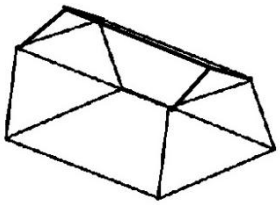
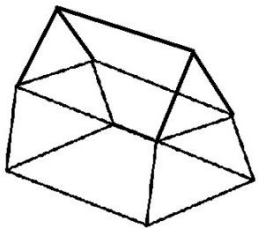
Table: 10 Beam Coating Material Properties 2 Standards

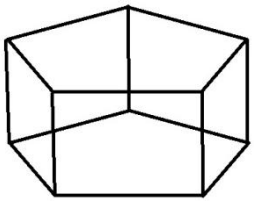
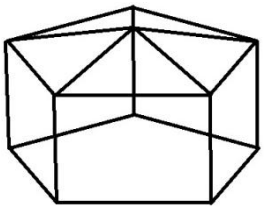
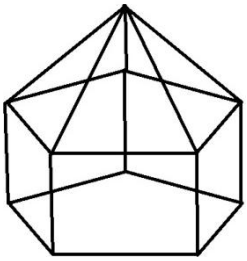
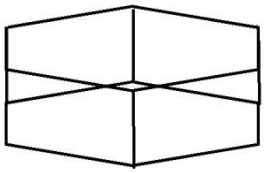
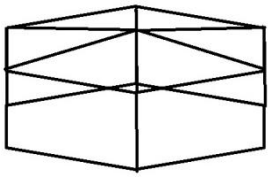
The tables above base their values on standards, so no explicit values to each feature are shown but the code allows finding the specifications in those standards. Temperature values are important because direct exposition with the sun can easily raise it to really high values. Salt resistance is a main issue to take to account in transportation requirements and environment conditions. Its thickness makes a difference in order to design the assembly bits that fix all the bits together.

In previous sections the crossing sections of the beams were analyzed, in order to have a better picture of the unit structure the combination of those is carried out and the unit shapes results and ideas are shown next.

- These drafts have to take to account 3 main variables:
    - The environment they can be set
    - The maximum useful living area
    - Ease to combine modules. This has also 3 issues:
        - The inner unit layout
        - Ease the assembly
        - Ease units combination (stackable or attachable)

Drawing	Shape	Pros	Cons
	Triangular	Easy to erect Easy to flat pack Loads equally spread. Evacuates loads on the roof faster. All the corners are the have specifications. Stands lateral loads.	Reduced living area. Combined on the base but not stackable.
	Triangular with squared base	Easy to erect Easy to flat pack Loads equally spread. Evacuates loads on the roof faster. Stands lateral loads.	Reduced living area. Combined on the base but not stackable. The corners have different specifications.
	Classic Canadian tent	Easy to erect Easy to flat pack Loads equally spread. Evacuates loads on the roof faster. All the corners are the have specifications.	Reduced living area. Combined on the base but not stackable. *The corners have different specifications.
	Square	100% useful living area. Easy to flat pack. Standard attachable parts. N stories high combination. Best option for stack combination. All the corners are the have specifications.	Lateral and roof load bad performance.
	Square tilted roof	100% useful living area. One way collecting roof. Standard attachable parts.	Different length hinders flat pack. The corners have different specifications. Lateral and roof load bad performance.

Drawing	Shape	Pros	Cons
	Square gable roof	100% useful living area. Two way collecting roof. Standard attachable parts.	No story combination possible. The corners have different specifications. Lateral and roof load bad performance.
	Square steep gable roof	100% useful living area. Evacuates loads on the roof faster. Standard attachable parts.	No story combination possible. The corners have different specifications. Lateral and roof load bad performance.
	Trapezoid	100% useful living area. Withstands lateral loads better than squared. Standard attachable parts.	Not good for stack combination. The corners have different specifications. Not as good as triangles lateral performance.
	Trapezoid gable roof	Like trapezoid. Less chance to get loads on the roof. Standard attachable parts.	No story combination possible. The corners have different specifications. Not as good as triangles lateral performance.
	Trapezoid steep gable roof	100% useful living area. Evacuates loads on the roof faster. Standard attachable parts.	No story combination possible. The corners have different specifications. Not as good as triangles lateral performance.

Drawing	Shape	Pros	Cons
	Pentagon	100% useful living area. N stories high combination. All the corners are the have specifications. Standard attachable parts.	Bad to combine modules. Lateral and roof load problems.
	Pentagon gable roof	100% useful living area. Standard attachable parts.	Too many bits to assemble. Bad to combine modules. The corners have different specifications.
	Pentagon steep gable roof	100% useful living area. Evacuates loads on the roof faster. Standard attachable parts.	Too many bits to assemble. Bad to combine modules. No story combination possible. The corners have different specifications.
	Hexagon	100% useful living area. Best shape to combine modules. N stories high combination. Standard attachable parts. All the corners are the have specifications.	Lateral and roof load problems.
	Hexagon gable roof	100% useful living area. Standard attachable parts. Best shape to combine modules.	Too many bits to assemble. No story combination possible. The corners have different specifications.

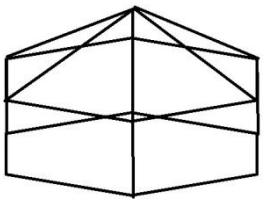
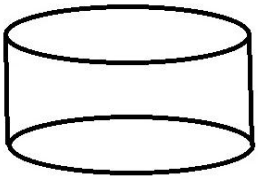
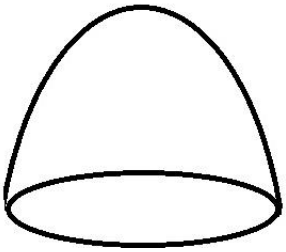
Drawing	Shape	Pros	Cons
	Hexagon steep gable roof	100% useful living area. Best shape to combine modules. Standard attachable parts. Evacuates loads on the roof faster.	Too many bits to assemble. No story combination possible. The corners have different specifications.
N base sides	More than 6 sides.	Can be useful and suitable for architecture designs.	Hexagon is the best shape to combine. Hence more base beams lead eventually to a similar cylinder shape.
	Cylindrical	Useful living area. Good performance on lateral loads.	Use of linear and bended beams. No standard part for covering. Bad performance on roof loads
	Igloo	Loads equally spread. The less cover material for volumetric dimensions. Evacuates loads on the roof faster. Good performance on lateral loads.	Reduced living area No use of linear beams. Fittings and connectors are bent. No standard part for covering.

Table: 12 Frame Structure Shape Evaluation

Now that the shapes the module can adopt, the way their beams are attached together has some options to evaluate. Some previous statements give a clue about what to do:

- The number of beams that one cornet fitting has to link together
- The shape of the beam determines the limits of the corner fitting
- The range of purposes that the fitting has to serve. This can gather:
    - External assembly bits and layouts
    - Loose bits or sheathing

The number of beams that has to link together depends on where this fitting is located. The number of beams attached and purpose of every corner is shown bellow.

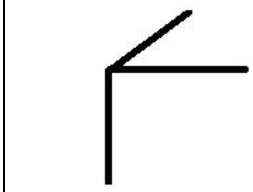
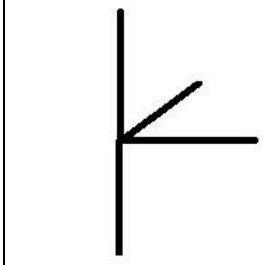
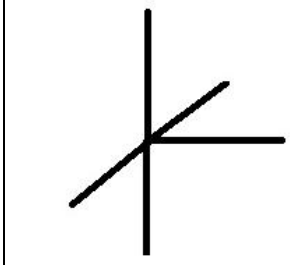
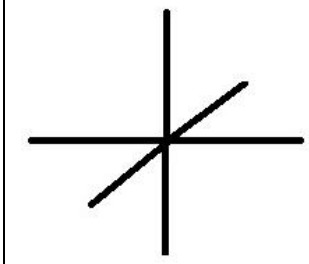
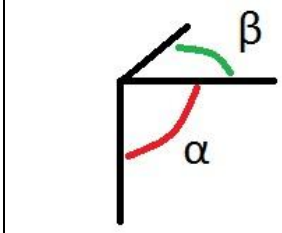
Drawing	N of beams	Purpose/Location
	3	Corner of a one story structure. Base corner or roof corner.
	4	Corner for 2 modules attached or 2 story connector corner. Roof or base corner to link 2 modules.
	5	Corner to connect 2 stories and 2 modules unit. Center connector for 4 modules and 1 story unit in base and roof levels.
	6	Central connector for 8 modules on 2 stories high units.
	N	Depending on the shape of the structure α, β and μ have the same value but on a range between 45° and 120°.

Table: 13 Corner Joints and fixing configurations

The table above shows which are the most used and functional shapes for beams joints. Those are the simplest examples of each variation. Those corners are based on the cubic structure and try to display how easy is to upgrade them in different situations. All of them can increase the number of beam connections, by reducing the angle between each arm, if the structure shape requires so.

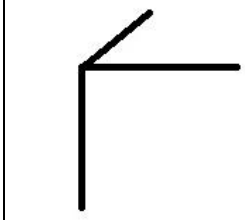
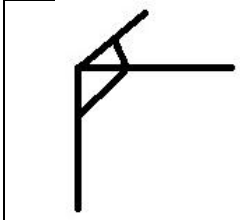
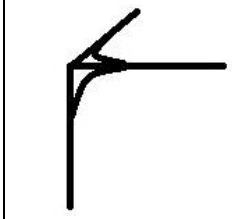
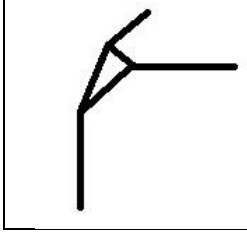
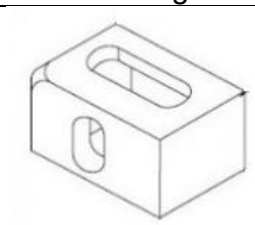
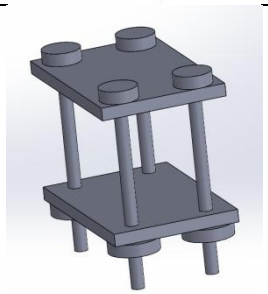
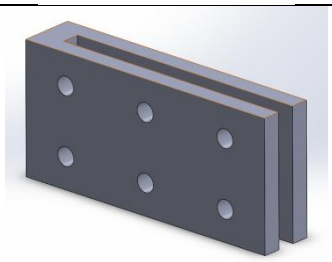
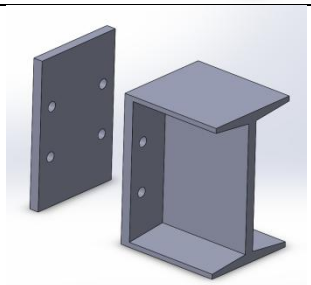
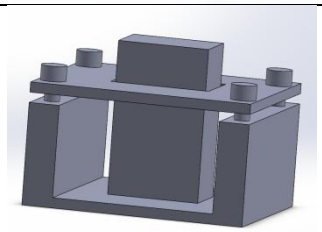
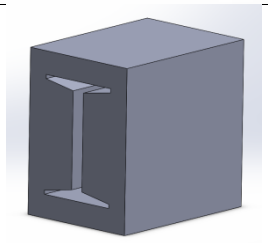
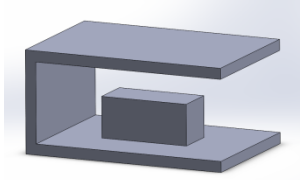
Drawing	Shape	Pros	Cons
	Square	Easy to produce. Light weight.	Limited resilience.
	Square and reinforced	Easy to produce. More sturdy than the square. Flat surface to attach extra parts.	More material.
	Round and pointy	Easy to produce. More sturdy than the square.	More material. Not enough flat surface to attach extra parts.
	Square and round	Light weight.	Difficult to produce.
	Square and flat	Flat surface to attach extra parts. Easy to produce.	Limited resilience.

Table: 14 Corner finish and properties

The list above sorts the designs of the corners that could be used on the structure. The most desirable combination is squared flat and squared and reinforced. It has the largest flat area where extra bits can be attached and has a high strength by using simple welded plates which allows the assembly to be easy to produce.

Fitting head and Fastening

The next table shows how the heads of the former corners can be shaped and which one has the best options.

Drawing	Purpose	Pros	Cons
	Link the beams on a single point.	Lightweight. Sturdy. ISO standard. Easy to produce. Fast assembly.	Does not fix the beams.
	Presses both flat parts of the beam and fixes it.	Easy to produce. Standards. Light weight. Number of pins can vary.	Lots of bits. Toilsome. Friction and pressure keeps it tight. Needs tools.
	Presses the beam and pins pass through the beam.	Tight secured. Number of pins can vary. Narrow and accurate. Easy to produce. Sturdy.	Medium weight. Needs tools. Load on the pins
	Plates share pins that tighten head and beam	Easy to produce. Lightweight. Sturdy. Number of pins can vary.	Loads on the pins.
	Block fits through the beam and it is secured by the cage.	Sturdy. Fixes the beam.	Difficult to produce. Heavy. Toilsome.
	Beam fitting	Sturdy.	Heavy. Do not secure. Friction parameters. Difficult to produce.
	Clamp wraps the beam and goes through it	Medium weight. No pins. No tools. Fixes the beam. Easy to produce	Bends. Looseness.

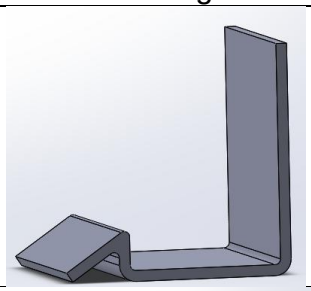
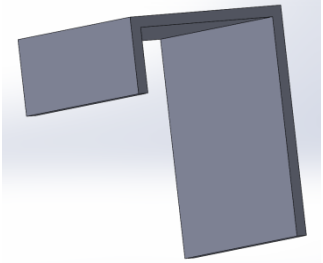
Drawing	Purpose	Pros	Cons
	Snap fit panel fastener. Pushed and fixed by the beam profile.	Lightweight. Fixed by pressure. No tools. No pins. Easy to produce	Needs foam or rubber to avoid looseness.
	Panel fastener. Hangs on the beam.	Lightweight. Fixed by pressure. No tools. No pins. Easy to produce	Needs foam or rubber to avoid looseness. Mounted on the beam and can swing.

Table: 15 Corner securing heads

The table above shows different ways to tight beams together with the corners. Among those options there are 2 fasteners focused on wall panels. The best option to get a sturdy and lightweight beam fixation is combining the clamp with a block that goes through the beam and can be fixed by a pin that tightens the block and the loose plate ones the beam is set on place.

Extra Parts

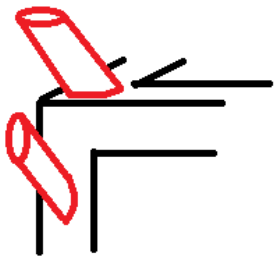
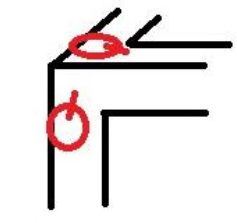
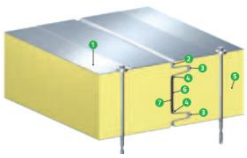
Drawing	Shape	Purpose
	Protrusions	In case any tube or rod has to be attached to hold another part or cladding over the unit. To give a variety of options of covers and extra bits supported on the structure.
	Rings	In case covering or other hanging options have to be attached to the unit. It allows wires of any kind to strap and cranes to hold. Accessory to fix things that do not belong to the structure.

Table: 16 Extra parts on the corner joint

The examples shown give a path on what in further chapters the calculations are carried out but it is possible that dimensions compared in the chart above are not the same as the ones on the final unit solution.

The second and most dense part is the cover and sheathing of the unit. This topic focuses on the covering of the 3 kinds of areas that the unit has, such as floor, roof and wall. A brief comment, regarding how those panels are attached on the structure, is that the fasteners shown in the former section of corners has 2 kinds of wrapping the panels on the structure by fixing those to the bare panel as it has no problem being drilled in some areas.

The fourth kind of covering that focuses on cladding cannot be carried out due to lack of information of those coverings and the companies that make them. This remaining part was supposed to be a thorough research about tent like outer fabrics and canvas materials. Neither properties nor specific products or companies were found.

IzoWall IPR / PUR	Core
	IPR core - stiff polyisocyanurate foam
Panel Drawing	PUR core - stiff polyurethane foam
	Layer Layout
	1. Steel lining, external, standard gauge 0.50-0.60 mm
	2. Polyurethane / polyisocyanurate foam core
	3. Protection strip preventing diffusion and water infiltration.
	4. Steel lining, internal, standard gauge 0.40-0.50 mm
	5. Polyurethane seal
	6. Available profile types: Linear, Grooved, Corrugated, Flat
	7. Double panel lock guarantees fire resistance.
	8. Edges facilitate assembly and seal

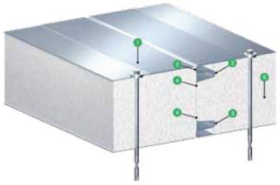
Mechanical Properties				
	Density	Weight	Fire Resistant	Acoustic
IPR core	ρ = 40 ± 3 kg/m3	9-12 kg	EI30	25
PUR core	ρ = 40 ± 3 kg/m3	10-13 kg	EI15	23

Thermal Properties			
	Conductivity	Insulation (W/m2K)	Width
IPR core	λ = 0,020 W/m*K	0,36-0,17	60-120 mm
PUR core	λ = 0,022 W/m*K	0,37-0,18	60-120 mm
IPR core	λ = 0,020 W/m*K	0,16-0,09	120-220 mm
PUR core	λ = 0,022 W/m*K	0,16-0,10	120-220 mm

Table: 17 IZOWALL thermal and mechanical properties

Panels are manufactured in accordance with PN-EN 14509:2010 IPU/MWF

IzoWall EPS	Core
	Polystyrene
Panel Drawing	



Layer Layout
1. Steel lining, external, standard gauge 0.50-0.60 mm
2. EPS expanded polystyrene core
3. Steel lining, internal, standard gauge 0.40-0.50 mm
4. Available profile types (panel widths 1150, 1080): Linear, Grooved, Corrugated, Flat
5. Available profile types (panel widths 1200): A, B, E
7. Double panel lock guarantees fire resistance.
8. Edges facilitate assembly and seal

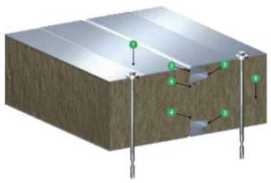
Mechanical Properties				
	Density	Weight	Fire Resistant	Acoustic
EPS core	ρ ≥15 kg/m3	8,3-11,4 kg	E60/EW60	23

Thermal Properties			
	Conductivity	Insulation (W/m2K)	Width
EPS core	λ = 0,040 W/m*K	0,86-0,16	40-250 mm

Table: 18 IZO WALL 2 mechanical and thermal properties

Manufacturing process according to technical approval AT-15-5340-2008 EPS

IzoWall MWF	Core
	Mineral Wool
Panel Drawing	

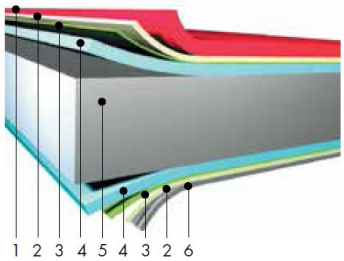


Layer Layout
1. Steel lining, external, standard gauge 0.50-0.60 mm
2. MWF mineral wool core
3. Steel lining, internal, standard gauge 0.50-0.60 mm
4. Capillary chamber
5. Internal side profile types as in IzoWall panels, one profile type available on the external side
6. Edges facilitate assembly and seal

Mechanical Properties				
	Density	Weight	Fire Resistant	Acoustic
MWF core	ρ = 100 ± 20 kg/m3	13-36 kg	EI 60/120	31

Thermal Properties			
	Conductivity	Insulation (W/m2K)	Width
MWF core	λ = 0,040 W/m*K	0,86-0,16	40-250 mm

Table: 19 IZOWALL 3 mechanical and thermal properties

Paroc AST	Core
	Paroc Structural Stone Wool
Panel Drawing	
	Layer Layout 1. Coil Coating steel sheet 0,5 mm 2. Primer 3. Passivation layer 4. Zinc 5. Steel 6. Epoxy coating

Mechanical Properties				
	Density	Weight	Fire Resistant	Acoustic
AST core	16-33 kg/m2	13-36 kg	EI 30/120	29-30

Thermal Properties			
	Conductivity	Insulation (W/m2K)	Width
AST core	__	0,5-0,25	80-120 mm

Table: 20 Paroc AST mechanical and thermal properties

Fibrebonded	Core
	Fiberbonded
Roof Drawing	
No Image available	Layer Layout 1. Coarse fibred 2. PP + PET

Mechanical Properties				
	Density	Weight	Fire Resistant	Acoustic
Fibrebonded	1,6 kg/m2	__	C	22

Thermal Properties			
	Conductivity	Insulation (W/m2K)	Width
Fibrebonded	__	0,11	3 mm

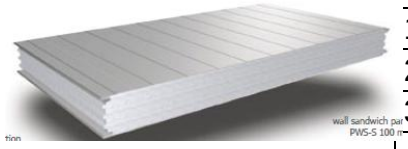
Table: 21 Firebonded mechanical and thermal properties

Vinyl PUR	Core
	Vinyl synthetic floor covering, heterogeneous, with PUR Eco System surface protection
Roof Drawing	
No image available	Layer Layout
	1. Coarse fibred
	2. PP + PET

Mechanical Properties				
	Density	Weight	Fire Resistant	Acoustic
Vinyl PUR	2,8 kg/m2	__	B	5

Thermal Properties			
	Conductivity	Insulation (W/m2K)	Width
Vinyl PUR	0,25 W/mK	0,011	2,25 mm

Table: 22 Vinyk PUR mechanical and thermal properties

PWS	Core
	Styrofoam
Roof Drawing	
	Layer Layout
	1.polyester glossy/matt
	2. Polyurethane
	3. PVDF
	4. zinc, aluzincred

Mechanical Properties				
	Density	Weight	Fire Resistant	Acoustic
PWS	16,2kg/m3	8,5-10 kg/m2	E60/120	25

Thermal Properties			
	Conductivity	Insulation (W/m2K)	Width
PWS	0,25 W/mK	0,75-0,13	50-125 mm

Table: 23 PWS mechanical and thermal properties

Balextherm PU	Core
	Mineral Wool
Roof Drawing	Polyurethane

Layer Layout
1. Cladding exterior thickness 0,5 mm
2. Cladding interior thickness 0,4 mm
3. Zinc PN-EN 10346:2011
4. STAINLESS STEEL PN-EN10088-1:2007

Mechanical Properties				
	Density	Weight	Fire Resistant	Acoustic
PU	__	10-12 kg/m2	E60	25
MW	__	17-25 kg/m2	__	33

Thermal Properties			
	Conductivity	Insulation (W/m2K)	Width
PU	λobl = 0.023 W/mK	0,5-0,22	40-100 mm
MW	λobl = 0.04 W/mK	0,47-0,26	80-120 mm

Table: 24 Belextherm PU mechanical and thermal properties

The panels have to meet some requirements on two subjects. One of them is their mechanical properties and the other main characteristics are thermal properties. Ones gives us the practical information for structural analysis and construction parameters and the thermal features allow us to compute how the unit behaves on different environments regarding living conditions on the inside and the installation requirements needed for that live to be comfortable. It can be seen that most of the coating or external sheathing are polymers. The inside of all the panels is also polymers but on a foam structure. Fastening of the mentioned panels are established by the manufacturer and can be easily adaptable.

The next table shows the maxim load that each of the panels displayed above can stand. That information is given in meter length load. The longer the panels are the lower the maximum load they can stand.

PANEL NAME	Max. Load
IzoWall IPR / PUR	1kN/m2 per 2,4-4,9 m
IzoWall EPS	1 kN/m2 per 2,5-4,5 m
IzoWall MWF	1 kN/m2 per 2,5-4,5 m
Paroc AST	2,5kN/m and 1,5 kN/m2
PWS	1-0,6 kN/m2 per 2,1-3,3 m/ 2,8-1,49 kN/m2 per 2,4-3,3 m
Balextherm PU	1,9-1,38 kN/m2 per 2,4-3,3 m
Balextherm MW	1,9 kN/m2 per 3 m

Table: 25 Panels maximum load resistance

The following table displays a list of coating materials used on panels. No properties are shown due to there are part of what the former panels are made of.

Panel Coating
Glossy Polyester
Matt Polyester
PVDF
Polyurethane
Colorcoat HPS200
Foil PVC
Calamine PET
CESAR PUR 55®
ALUCYNK + Easyfilm®

Table: 26 Panel Coating Materials

Now the materials options and their properties section is finished and none specific engineering variables will be discussed on the next chapter.

Finally installations regarding power and services are taken to account. Ventilation, health risks, water supply and energy production are features that will be analyzed and evaluated if they have to be included or not.

Some requirements that the camp has to meet in order to allow the unit to be settled on place with the most possible likelihoods to accomplish its commitment are gathered below. The comments are sorted by topics and gather reasons that can add or withdraw features on a unit and its design.

Environmental conditions:

- Area free of environmental health hazards.
- Pollution must also be considered.
- Filters and special materials on cladding need to be arranged in areas where air and soil conditions are health risky.
- Increase the cost of the unit.

Soil and Ground Cover:

- Water absorption and the retention of human waste.
- Groundcover (vegetation) provides shade and reduces erosion and dust.
- During the construction of the unit cause as little damage as possible to the vegetation and topsoil

Cultural Requirements:

- Housing should meet the cultural and social requirements of the refugee's home.
- Single-family shelters preferably.
- Vector cutting layouts that reduce the risk of communicable diseases.

Logistics:

Accessibility:

- The site must be accessible by vehicles and close to communication links and sources of shelter material supplies.
- This allows an easier and less costly transportation of all the parts of the unit.
- Cutting down time on delivery.

Deployment, Employment, Sustainment and Redeployment:

- Procurement of Construction Materials
- Appropriate material selection. Fitting environment and function requirements.
- Materials procuring through military supply channels (slow and costly but reliable), local procurement (fast and not costly but difficult to guarantee

quality) or can be produced locally (infrastructure, can be costly in the beginning and quality and running time issues).

Contract Support:

- Professional engineering services and infrastructure support.
- The construction of the unit shouldn't require the labor of qualified personnel but the supervision of layouts and living conditions should be carried by engineers.
- Maintenance and repair is arranged to offer security and fast response to undesirable situations.
- Environmental management services regarding permits and HAZ.MAT. and/or waste management and disposal.

Local Procurement:

- Procuring construction materials locally from countries within or near the AOR.
- Maximize its benefits, local procurement should occur as close as possible to the actual construction site in order to minimize transportation requirements.
- Use of local building materials and techniques. Avoids problems of unit adaptability. Unnecessary technology is not used due to the simplicity but effective results of the former times validated solutions.
- Large quantities materials are more economical to purchase on local suppliers.

Property Control:

- All goods must be received with a signed receipt at time of arrival and entered into the appropriate property control system to ensure proper use and storage.
- Property control must also include procedures for tracking and controlling issue of materials.
- Periodic inventory to track the parts or full unites available.

Transportation:

- Ensure fully coordinated operations in advance with local customs and immigration officials.
- Have a complete understanding of all documentation and fee requirements.
- Reducing bureaucracy unknown issues reduce delivery time and unexpected expenses.
- Host nation infrastructure and transportation capabilities may be par with developed nations or they may have been severely damaged.
- Avoid high value shipments due to security lack reasons.

- Political considerations on postures held by countries involved can conflict and result in significant delays.
- Less expedient methods and routes of travel may be required. Reducing the probability of unexpected situations
- Currency requirements. Entry fees of the host country.
- Waterborne movements may require the use of container ships, bulk transport vessels, roll on/roll off (RO/RO) vessels and ferries to transport materials.
- Moving resources by water will not be as fast as air shipments, but far less expensive.
- Demobilization and return of excess inventory temporarily imported into the host nation is essentially accomplished in the reverse order of the process to import the resources.
- Not careful numeration of need may lead to huge volumes of transportation goods and expensive fees and shipments.
- Logisticians must consider which equipment and supplies may be left behind at the completion of the mission.

Planning Considerations:

1- The operational threat environment.
2- Locally available resources.
3- Local support available.

Those three points have a common variable that is the government. Lack of a functioning government affects planning and level of support from local population (hostile, cooperative, etc.) can take apart the whole operation.

The surrounding area must be also characterized. These are some topics to be faced and below each one a brief explanation of the reasons why they are so.

- Soil type/percolation rates on construction.
    - The unit has to be placed where the refugees seek help but constructions have to be fixed in a secured soil that can stand the structure.
- Potential impact of natural and/or cultural resources on the mission.
    - The use of non conventional or local materials could lead to changes on housing construction techniques and surrounding areas due to previous none existing needs.
- Impact of vectors and poisonous or dangerous rodents and animals.
    - All kinds of population concentration lead to waste production. Hence health threats may appear and the unit should be a protection.
- Potential for site contamination from previous occupation/activities.

    - The site may have been used for other purposes in former times so information regarding its past use helps layout and site planning.
- Potential for contamination from off-base/local industrial plants.
    - Polluted soil could reduce the life span of the fixing structure unit and also any kind of soil activity related for those who live in.
- Potential for air pollution from the site or nearby industrial activities.
    - Filtration and unit protection for these kinds of issues is expensive and reduces the life span of the covering materials.
- Potential for noise pollution from the site or nearby local activities.
    - Well insulated unit allows personal space and reduces psychological problems.
- Resources needed/available to support wastewater management.
    - UNHCR requirements do not force the unit to have pipe solutions for fluids, but as dignifying values are attached to the project basic services are studied.
- Climate conditions of the region, including seasonal weather hazards.
    - Well chosen materials and specifications may offer useful solutions.

The unit has to face the challenge to be suitable for habitation throughout the whole year. In order to achieve a practical and useful unit some of the most common climate zones and its characteristics are drafted.

Temperate Zones Characteristics:

Intermediate Hot-Dry Regions:

- Air temperature of 42ºC.
- Maximum ground temperature of 54ºC
- Wind velocity of 2,5- 5 m/s.
- Rains may be accompanied by intermittent wind velocity of 16 m/s. Sites may be subject to winds of 23 m/s for a 5-minute period; gusts may reach 33.5 m/s.
- Snow and icing conditions are not uncommon in parts of the area designated intermediate hot-dry.

Intermediate Cold Regions:

- In the winter, the ambient temperature may drop to -31ºC for six continuous hours.
- Infrequent wind velocities greater than 5 m/s can be expected when temperatures are that low.
- Soils:
    - The free-draining, coarse-grained soil exhibits almost no tendency toward high compressibility or expansion.

- Solar Orientation:
    - Hot- Dry Orienting the facility's longer side along a north-south axis should minimize shelter wall exposure to the sun.
    - Cold region orient facilities so the longer sides of the shelters are along an east-west axis to provide maximum solar radiation on walls.
- Foundation Requirements:
    - Spread or strip footings
    - Carry depth below the frost line
    - Use a thickened edge slab with lightweight structures where some slab cracking is permissible.

Tropical Zone Characteristics:

- Wet-hot conditions, characterized by high temperature and humidity and intense solar radiation.
- Solar Orientation:
    - Tree cover, man-made screening, camouflage netting, or a combination of these methods can produce the desired effect.
    - On flat terrain, shelters should be sited in an east-west direction, which minimizes wall area exposure to the low angles of early morning and late afternoon sun.
- Wind Orientation:
    - Wet regions in the tropical zone are characterized by mild trade winds blowing in the same direction for most of the year.
    - High velocity winds occur from several directions during the monsoon season.
- Interior Electrical:
    - Use porcelain or fungus- and corrosion-resistant plastic switches and receptacles.
    - Request salt spray test certification for equipment used in a salt-ladened atmosphere.
- Foundation Requirements:
    - The raised-point foundation is the best solution for the tropics.
    - Absorbs much less of the stored heat from the ground.
    - Allows the floor system to be cooled by natural ventilation and separates the structure from the high moisture content of the ground.
    - Aluminum alloys are excellent for use in the tropics. When in contact with concrete, mortar, or plaster, aluminum gives better service if coated with synthetic or rubber-based paint.
    - Use galvanized steel fasteners. Plain steel corrodes rapidly and promotes wood decay.

- Use only paints, primers and enamels containing a fungicide to inhibit mold growth.

Frigid Zones Characteristics:

- Frequent high winds and either very short or very long periods of daylight prevail.
- Six continuous hours with an ambient temperature of -45ºC can be expected.
- Summer maximum temperature expectancy is 35ºC well inland.
- Winds velocities above 46m/s have been recorded.
- Snow and silt begin drifting with winds above 4.1 m/s.
- Plan to use trees, shrubs, snow fences, or even structures to keep drifting snow from reaching the site proper.
- In a non-dispersed layout, leave enough space between shelters to permit snow removal and locate structures in rows perpendicular to the wind.
- Dispersed shelters should be oriented with their longest axis parallel to the wind.
- Solar Orientation:
    - In subarctic areas, the long axis of shelters should be an east-west direction to take advantage of the maximum solar exposure.
    - The direction of prevailing winds decides the sitting factor.

Desert Regions Characteristics:

- Temperatures of 58ºC.
- Nighttime temperatures are moderate: 20ºC in the summer and 5ºC in the winter.
- Wind velocity of 18m/s.
- Storm winds 23m/s for a 5-minute period with gusts to 34m/s.
- Prevailing winds blow from northwest or southeast almost exclusively.
- Solar Orientation:
    - Their long axis in a north-south orientation to minimize exposure to the low-angled sun.
- Wind Orientation:
    - The wind carries fine soil particles, which clog mechanical systems, accumulate on every surface.
    - Wind can be lifted, deflected and guided with a perimeter berm to shelter height, particularly on the prevailing wind side.
    - Consider placing the long side of shelters perpendicular to the prevailing wind.

Ventilation Considerations:

- Take advantage of winds for ventilation.
- Hot, dry daytime winds must be lifted, deflected, or guided away from shelters.
- In low humidity regions with large variations between day and night air temperatures, ventilation should be as high as possible at night to cool down the interior walls.
- During the day, the ventilation should be as low as possible so that hot air will not raise the temperature of interior surfaces.
- In high humidity (coast desert) regions with little change between day and night air temperatures, there should always be ventilation for facilities not served by air conditioning.

That information above was a generic and no specific locations where mentioned. In order to expose the most common regions where shelters are always deployed a set of images gathering those areas and its most important weather characteristics are displayed next. This part focuses on module characteristics and layout.

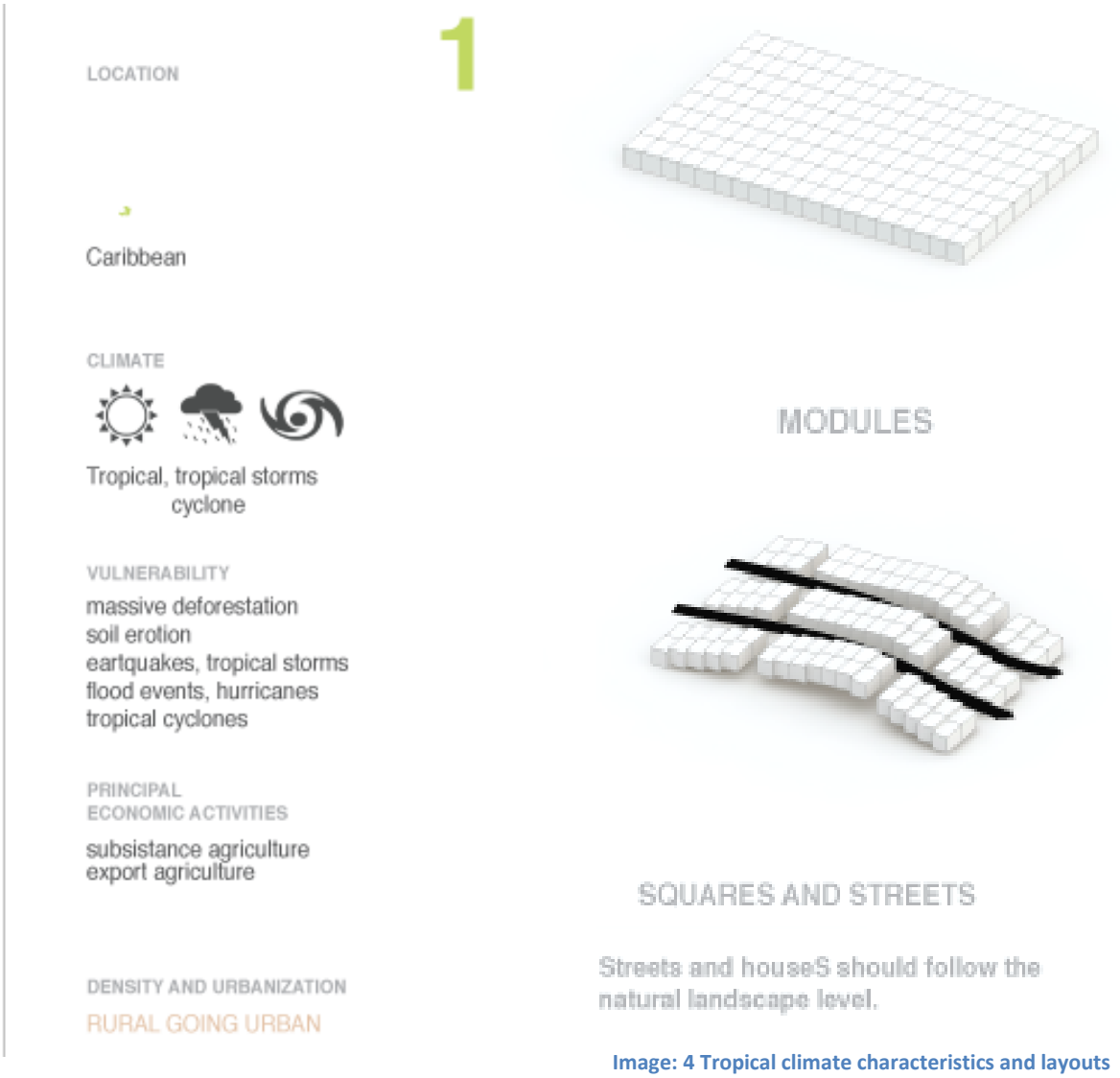


Image: 4 Tropical climate characteristics and layouts

VENTILATION

Water flows down when settlements are located on higher ground level.
Buildings should be located on the shaded sides of hills, the settlement will benefit from breezes.

Humidity does not accumulate when walls are thin.
Combining thin walls with thick walls keep buildings from collapsing at an eartquake.

WALLS

FLOOR

Elevated ground floor avoids the earth's humidity, the house will be safe when floods occur.

ROOF

Sloped roofs to evacuate the rainwater

OPENINGS

Large windows will improve ventilation.
An upper opening allows the hot air to exit while the cool air enters the lower window.

Image: 5 Tropical climate characteristics and layouts 2

GROUP
2

LOCATION

Sub-Saharan Africa

CLIMATE

Dry and hot, almost
no rainfall

VULNERABILITY

desertification
soil erotion
droughts
flooding rivers
epidemic

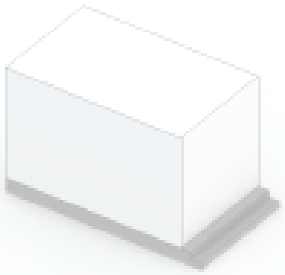
PRINCIPAL
ECONOMIC ACTIVITIES

subsistance agriculture
export agriculture
mining
livestock

DENSITY AND URBANIZATION

RURAL — RURAL GOING URBAN

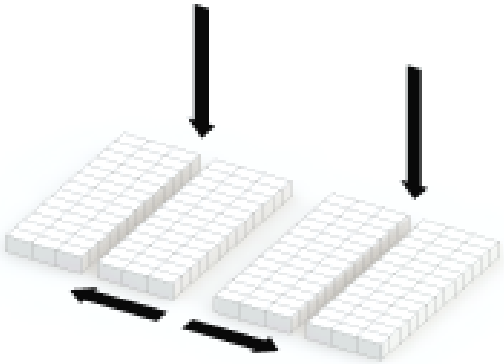
MALI — BURKINA FASO
NIGER
CHAD



FLOOR

The house should rise at least 30cm to prevent the infiltration of humidity.

MODULES



SQUARES AND STREETS

Main streets running north-south are preferable so one side is always in the shade.
Narrow secondary streets prevent the walls from solar radiation.

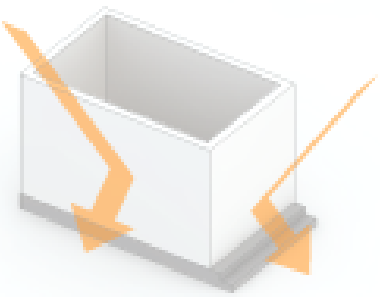
COURTYARDS

The houses should have shaded courtyards to cool the air. The wind must have spaces to move through to cool facades and roofs.

Image: 6 Sub sahara climate characteristics and layouts

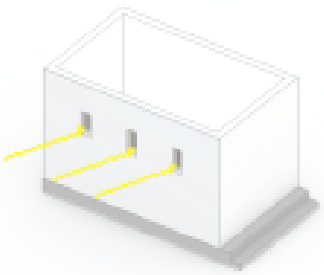
ROOF

In dry areas flat roofs are the best option. Roofs with a gentle slope can also be built to drain the rain water.



WALLS

Thick walls for heat rejection.



OPENINGS

Small openings prevent heat gain, the interior of the house will be more comfortable.

GROUP
3

LOCATION

Eastern and Western Africa

CLIMATE

Tropical rainforest, jungle,
hot and humid

VULNERABILITY

sea level rising
salt water intrusion,
thunderstorms,
high precipitation
harmattan

PRINCIPAL
ECONOMIC ACTIVITIES

subsistance agriculture
export agriculture
fishing, mining
livestock

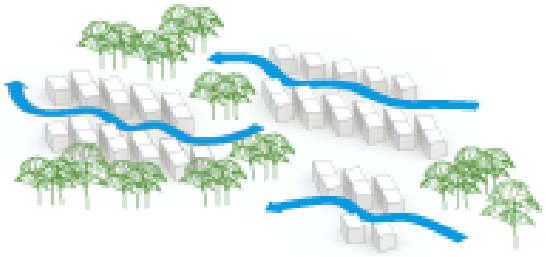
DENSITY AND URBANIZATION

RURAL	RURAL GOING URBAN	URBAN
GUINEA	NIGERIA	D.REP. OF THE CONGO
GUINEA-BISSAU	BENIN	CONGO
LIBERIA	CENTRAL AFRICAN REP.	
EAST TIMOR		

MODULES

SQUARES AND STREETS

Deforesting to make large clearings can destroy the local ecology. Small clearings connected by paths through the forest is better.



VENTILATION

Houses sould be separated for better ventilation.

Image: 7 Western Africa climate characteristics and layouts

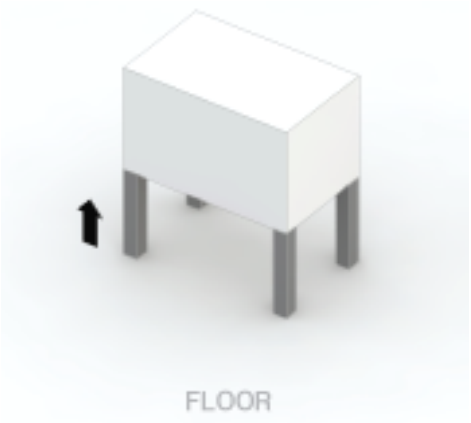


Image: 8 Western Africa climate characteristics and layouts 2

GROUP

4

LOCATION

Eastern Africa

CLIMATE

Temperate Rainforest
Marshy Areas

VULNERABILITY

landslides
overpopulation
epidemic

PRINCIPAL ECONOMIC ACTIVITIES

subsistance agriculture
export agriculture
livestock
mining

DENSITY AND URBANIZATION

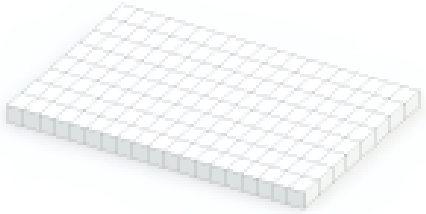
RURAL

UGANDA

RWANDA

BURUNDI

overpopulated



MODULES

SQUARES AND STREETS

Houses and streets can be built on sloped sites increasing density when the areas are overpopulated.

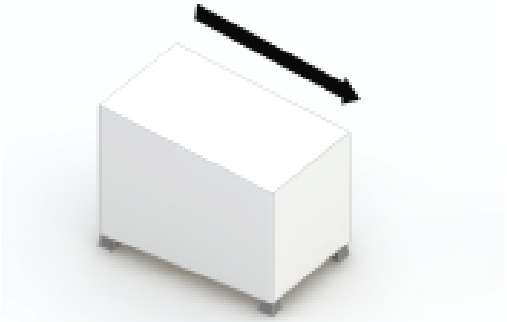
COURTYARDS

During the cold season the hill works as a natural barrier against the cold winds.
Shared Courtyards allow the sun light to enter all the houses.

Image: 9 Eastern Africa climate characteristics and layouts

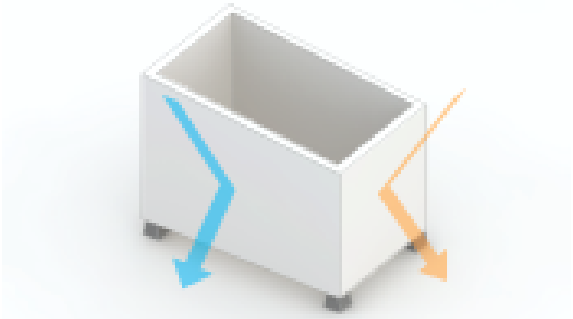
FLOOR

It is recommended to build the house on footings where the ground surface is irregular.



ROOF

A gentle slope is enough when precipitation is moderate.



WALLS

Thick walls protect from cold or heat in temperate tropics.

OPENINGS

Openings should be flexible allowing solar heat to enter in cold seasons, during warm seasons an opening on the top allows the hot air to exit and the cool air to enter.

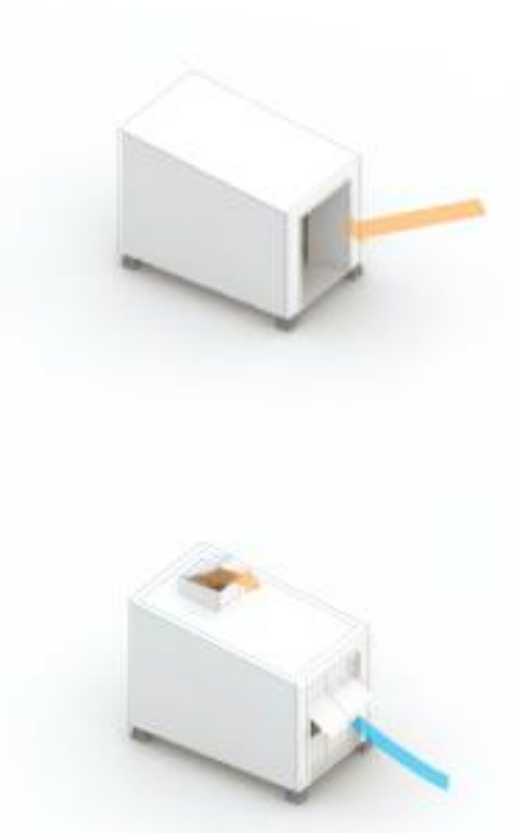


Image: 10 Eastern Africa climate characteristics and layouts 2

GROUP 5

LOCATION

South Asia

CLIMATE

Hot and Humid
Monsoon

VULNERABILITY

flood events, tropical cyclones, tornadoes, tidal bores overpopulation, soil degradation and erosion, deforestation

PRINCIPAL ECONOMIC ACTIVITIES

subsistance agriculture
export agriculture
mettalurgy, service sector
mining, textile industry
fishing farming

DENSITY AND URBANIZATION

RURAL RURAL GOING URBAI

BANGLADESH * INDIA

CAMBODIA

LAOS

GROUP 6

LOCATION

Southern Africa
Central Asia

CLIMATE

Desert
sand storms

VULNERABILITY

Lack of water, droughts, floods
epidemic, extreme temperature

PRINCIPAL ECONOMIC ACTIVITIES

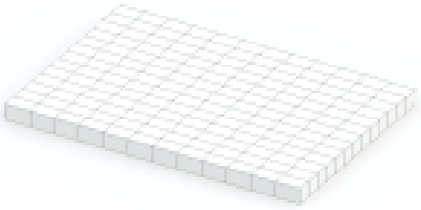
subsistance agriculture
export agriculture
minig

DENSITY AND URBANIZATION

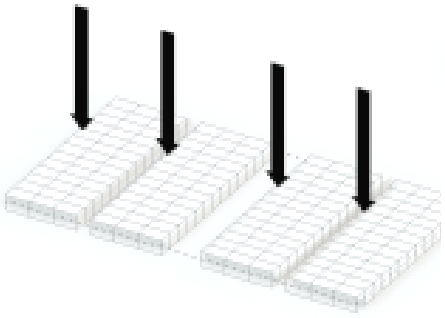
RURAL RURAL GOING URBAN

NAMIBIA UZBEKISTAN

Image: 11 South Asia and Africa climate characteristics and layouts

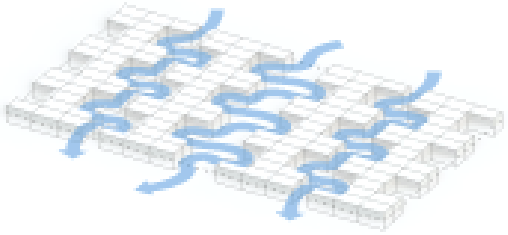


MODULES



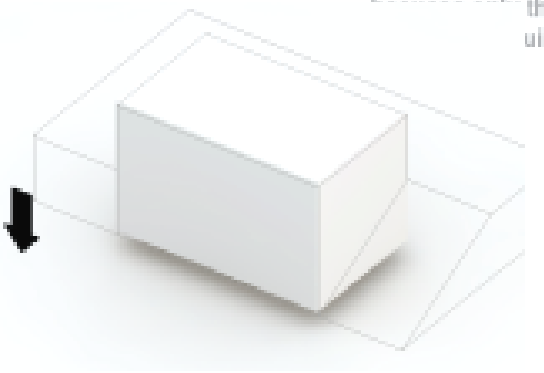
SQUARES AND STREETS

Excavated areas are useful to insulate the houses from heat.
Burying the house partially is cheaper
the top half of the walls
uilt.

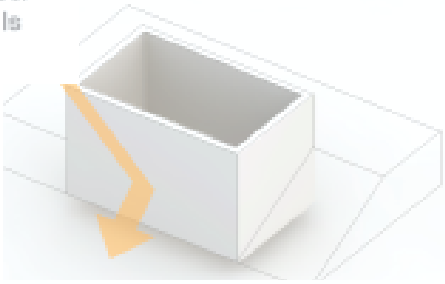


VENTILATION

The houses should have shaded courtyards to cool the air. The wind must have spaces to move through to cool facades and roofs.

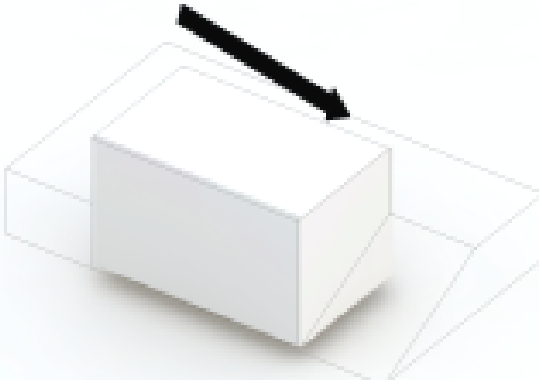


Partially buried houses are protected from heat by using the earth as an insulation.



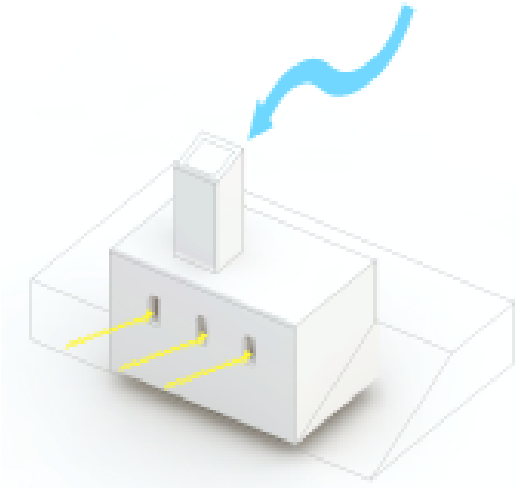
WALLS

Thick walls for heat rejection.



ROOF

In dry areas flat roofs are the best option.
Roofs with a gentle slope can also be built to drain the rain water.



OPENINGS

Small openings prevent heat gain, the interior of the house will be more comfortable.
An open windcatcher collects breeze or wind to cool the house interior.

Image: 12 South Asia and Africa climate characteristics and layouts 2

Now that all of the possible climates are explained a brief comment on the walling characteristics of each one is drafted.

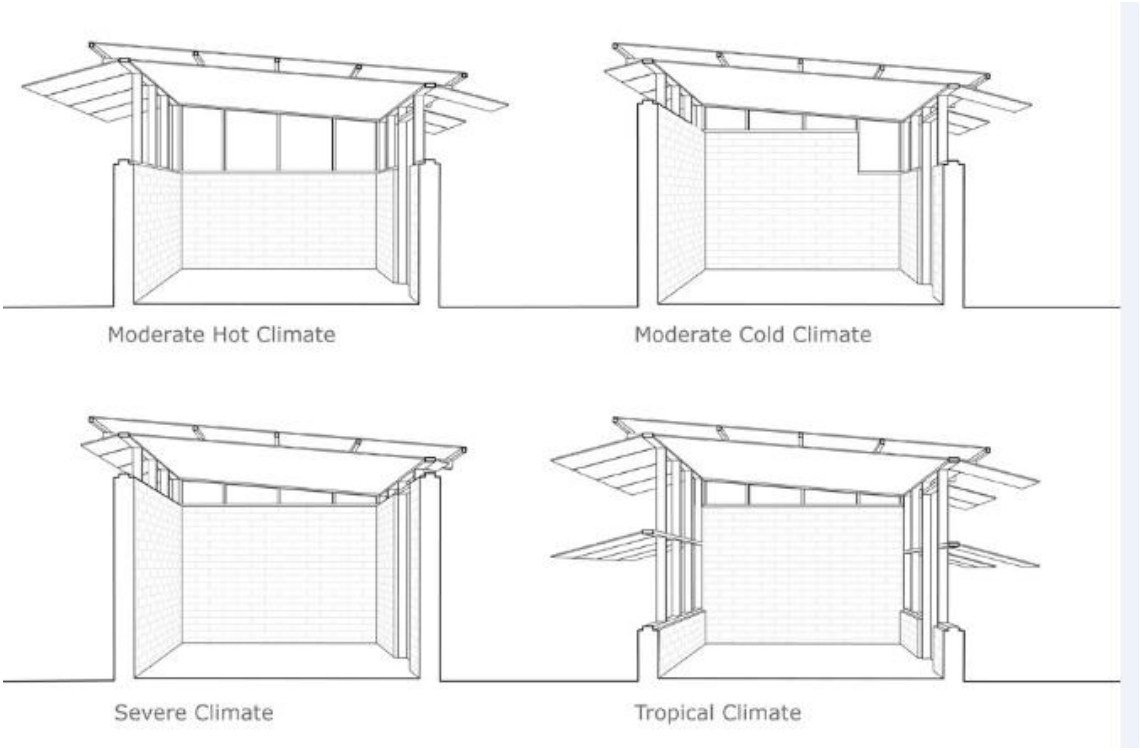


Image: 13 Wall configuration depending on the climate region

As it is shown in the image above hot and medium cold climates have a wall composed by thick construction material and a windows area that allows ventilation. As the temperatures that can be reached vary between a range of few below zero and high above zero it has to combine the qualities of thermal mass and solar heating interior. On the contrary sever climates do not allow easy air recirculation in order to keep a narrow range of temperatures on the inside as high as possible compared to the outside of the dwelling. On the other hand a fully breathable dwelling is arranged in tropical climates where air recirculation is intended and thermal mass is avoided. Windows are transparent in colder climates and opaque on hotter climates to avoid solar radiation but allowing ventilation.

This ventilation has to come from convection natural stream. The wanted objective on hot climates is to drag out the warm air and fill in with fresh air. The path that must follow is the one showed beneath.

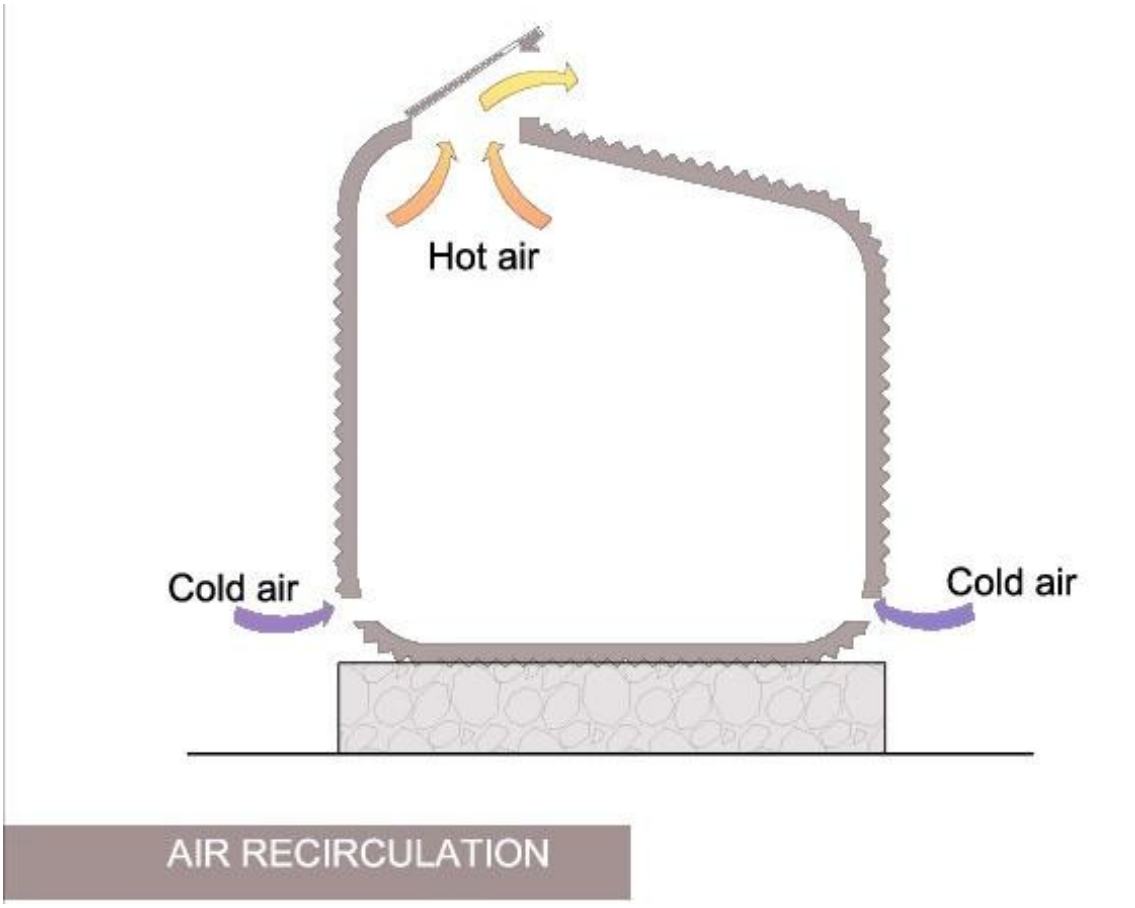


Image: 14 Natural air convection stream

Power and grids:

After environment and logistics considerations some of the main issues on a dwelling unit are how to power any device that could make life easier for those who live in it.

Power has two main parts, one it is production and the other is transportation. The first one has multiples options but as the main idea of this dwelling is to be the less dependent conventional power generation methods are dismissed. Hence none petrol or gas related energy generators for electric power are proposed.

Renewable energy offers the possibility of reducing pollution on camps and grid investments. Wind solutions are not feasible due to its expensive transportation, its huge needed area to work and its noise. Biomass is considered in case of heating needs but as shown in further chapters this is not the desirable way to keep the dwelling environment comfortable for a living. Also deforesting the place where refugees settle their camp is not a good decision. Doing so erase any wind natural defense and dust becomes an issue.

The only remaining option for electric power producing is relay on photovoltaic panels. This option allows noise free generation compared to wind turbines and petrol engines, reduces the needed area for energy production due to its ease to be installed on any surface (mainly misused roof area) and does not generate any kind of harmful emission which reduces the pollution on the refugee camp.

As the energy needs to be send to the interior of the unit a sort of sockets are placed along boundaries of the structure to allow easy and safe plugging.

The same kind of connections has to be done with pipe installation. Drinking water on the dwelling must be available. This water will not be used for personal cleaning but some house cleaning or drinking.

Health risks:

Another consideration refers to how health threats are faced. On a modular dwelling unit planed for temporary living some standards must be accomplished.

Some areas have poison or disease transmitting insects which have to be held outside the tent, doing so by raising the unit above the ground or maybe sealing with nets the openings on the tent. The unit has to be easy to clean by the dwellers and has to avid mildew creation and fungus adherence. Sharp edges or any cutting profile must be redesigned in order to avoid wounds that could lead to an infection. Rodents are always around human food waste or where suitable conditions allow them to set their den. By avoiding empty cavities and inaccessible spaces this chance will be put away.

3.2 New and feasible solutions that fit UNHRC and USAID standards and the aims of the project

In order to keep in mind the standards and requirement that the projected unit has to meet a list is sorted below. These requirements, the UNHRC and USAID, are first shown, and then goals or objective of this project are also displayed to make it easy to understand why the following conclusions and decisions are made. These conclusions are focused on three different main parts of the project.

UNHCR Handbook for emergencies

- 3.5m^2/person.
- 1 latrine for every 20 people. There is no need on installing sewage pipes in every unit.
- 100m maximum distance to a water point. There is no need to install drinking water grids.
- 15-20 liters/person of water daily. Need of reservoirs.
- 50m fire brake every 300m.
- Multi-family shelter fits no more than 35 people.
- Shelters should be built by the refugees.
- 2m distance between shelters.
- Layout of shelter should avoid lines and rows configuration (this is not essential).

USAID Field Organization Guide

- 3.5m^2/person. The organization of the camp is dividing it in 1000 people communities.
- 1 latrine for every 20 people. There is no need on installing sewage pipes in every unit.
- 1 water tap for 200-250 people.
- 15-20 liters/person of water daily. Need of reservoirs.
- 50m fire brake every 300m.
- Minimum technical specifications per area's season.

The following ones are the conclusions extracted after all the existing solutions evaluation. These are based on the UNHRC requirements also.

- 3.5 m^2/person as a living area for the unit. This area can be bigger.
- Never reach the limit of 35 people in the same unit structure. This is not desired neither for design nor living conditions.
- The unit has to be assembled or ease the assembly for non qualified people.
- The unit must be easy to transport and carry.

- The possibilities of the unit layout must take in consideration stackable options and modular combinations.
- The unit needs neither drinking water nor sewage pipe installation. However some of this and other installation will be considered.
- All the requirements above should meet the further unit designs but can be missed if better features are brought to the unit and its users.
- Long term focus forces to think of unpleasant problems that might be accepted for a short period and must be solved.

Finally the project goal in order to design a successfully and functional transitional emergency shelter module are listed below.

- Low cost product (regarding existing solutions) reduction of material cost through intelligent design
- Reduction of material waste through efficient construction techniques
- Easy to assemble and deploy reducing time and manpower
- Low weight after packing the module
- Find the optimal measurements, the best shape and structure of the module
- Find the optimal wall, structure and sheathing materials
- Capability of being assembles worldwide by its adaptable characteristics
- Viability of different configurations to fit the market targeted
- Usage of coverings that will reduce outside environment conditions on the inside
- Energy Self-sufficiency of the unit
- Lifespan focused on permanent situations and reusable
- Find a universal ground secure unit system
- Achieve safety requirements of the unit fire retardant, smoke and gases ventilation and illness transmission animals.
- Weather and climate conditions resistant
- Viability of integrated grid and plumb installation

- Functional and reliable way of transportation and packing

As the deep analysis pays attention to three main topics the conclusions extracted are separated on those topics. Those conclusions can be seen below:

Conclusions regarding the structure part:

- The structure has to be shaped as a cube or rectangle based. This is the most useful shape due to its ease to be assembled and the possibility of using just 2 or 3 different parts which lowers the cost and the needed calculations.
- The use of steel or aluminum before composites raises the weight but allows heavier load to the unit.
- The use of standard crossing sections allows reducing the calculations and reduces the cost.
- The use of a sturdy structure allows construction materials to be attached on the structure.
- Life span is more important that weight and due to medium loads and long period use composited or polymers are not suitable.
- The shape is easy to understand and few tips are needed to assemble the unit.
- The joints where the beams are linked is the mixture of the combination of a 90º angle direction fitting head, secured one to another by a triangle plate that gives strength to the unit and a flat surface edge where poles fittings and rings can be attached in order to fix loose parts.
- The head of the fitting has a peg end that clamps the beam and then a pin is put through to secure the beam to the joint.
- The edge has holes drilled to allow the canvas for the initial tent to be hold.
- Base lifters are needed either to secure the structure to the ground or protect the dwelling from external hazards.
- The beams need a coating to avoid rust during transportation and its used life time.

Conclusions regarding the sheathing part:

- Three options have to be faced.
    - Canvas or canopy used on a tent for the first days/weeks
    - Hard panels that allow insulation and resist loads:
        - Insulating manufactured panels filled with foam. Give the best insulation ratio with a really low weight and stand medium loads depending on their length.

        - Empty panels that once they are assembled can be filled with any available material. Lighter that the ones above and can be slimmer once flat packed. Unknown insulation value.
    - Local materials that fit in the structure but have an unknown insulating value and load resistance. No need to be transported but unknown results.
        - Also standard known thermal mass values can be showed to give a simple idea on what could happen.
- The panels shape depends on where they will be set. Hence a sort of different modular panel with different features has to be evaluated.
- Wind, snow and rain loads are the main variables but hanging and hitting are also included.
- Canvas for the first days has an excess part to be attached to the structure.
- Fasteners used on the panels are snap fit ones and link the panel on the inner part with the beam on the structure.
- Noise and heat are the main variables on the panel use.

Finally the conclusions regarding the installation part:

- Electric power supply base on photovoltaic panels.
- No internal wiring but connector socked to link the generator and the outlet.
- Water installation it is not needed regarding UNHCR standards but installation drafts can be done in order to future implementations.
- Ventilation issues regarding surrounding environment and climate zone are taken to account in the thermal analysis.
- Stackable options and layouts have to be evaluated for structure analysis.
- Solar and wind orientation vary the loose parts assembly.
- The whole unit has to gather health and construction regulations.
- The whole structure can fit in a single pallet and can be easily moved through countries and transportation methods.

4 Description and design of the proposed solution

This chapter faces the design of the unit. By doing so a first part is based on calculations and parameterization of the three main topics mentioned on the former section, then a display of the characteristics is listed and finally all the related regulations and requirements are drafted on a third section.

4.1 Calculations and design

In this chapter a combination of engineering concepts and related software is explained step by step. Three topics are evaluated in this chapter: structure, covering and installation which gathers power and water grids and some specific requirements that the unit has to meet. Concepts are explained and then the calculations and sketches are shown.

The first parameters to calculate are the ones regarding the structure, its joints and the fasteners.

Structure analysis

First of all the loads and variables that interact with the structure have to be listed and evaluated. This structure deals with a few possibilities that have to be introduced correctly. Those assumptions lead the calculations and its conditions. The structure has to resist inner and external loads.

- The structure has to bear its own weight which is a spread load along the beam and has a reflection on the joints.
- The structure has to stand external loads which have its roots on natural phenomenon.
- Different length of some beams may offer a range of slender crossing sections depending the purpose and location. Length of 2.5, 3, 3.5, 4, 4.5, 5, 5.5 and 6 are the once that will be evaluated.

Once the structure is characterized on its own some other values have to be summed to those initial loads.

- The panels attached to the structure weight and its load has to be spread along the beam.
- The panels offer high resistance to wind and snow creating heavier loads.
- The shade canopy has its own weight and it also offers resistance to weather phenomenon.
- The tent canvas as well as panels can act as a sail transmitting loads to the structure but its weight is really low.

- The tent canvas and the panels can be combined and then their weights can be summed but just one load due to external environment issues is taken to account.
- The use of other materials for covering the walls of the structure that are heavier than the ones purposed has to be considered in order to avoid safety problems in future uses of the unit.

Now that all the possible and worth situations are listed it is time to give values to those loads. The loads come from different sources:

- Regulations dictate which are the load limits or deformations and which safety coefficient is used.
- Depending on the area of use some of the loads are dismissed and others are taken as the main reference. Natural provenance for example.

The former information allows to set a path on where and how to evaluate the structure.

A previous simple calculation gives us certain values on loads and combined with beams characteristics the sort of crossing sections is reduced to a few that meet the needs.

In order to clarify calculations and where they are based on a brief explanation on that topic comes up next. Loads can occur for different situations and reasons and they are sort in different types with specific conditions.

Permanent loads are the ones that are there all the time and the structure has to bear them for its life time. Permanent loads are multiplied by a coefficient that equals to 1.35.

- Own weight of the structure, wall and stuffing. Depends on material properties and dimensions.
- Prestressed structure.
- The loads that the soil can put through the foundations of the unit.

Variable loads are the ones that can occur in addition of the permanents and are evaluated so the structure does not collapse on sudden or long term stress situations. Variable loads are multiplied by a coefficient that equals to 1.5.

- Use overload purposes of that unit and what is stored on the inside.
- Those are sorted on categories and the ones used on this study are the following ones:
    - Use category A1 dwellings and room area Uniform load of 2 kN/m^2.

- Wind loads takes in to account slender construction characteristics. The value for the load is 0.5 kN/m^2, but it also depends on the exposition coefficient that varies from 2,2 on flat areas to 1,6 in rural areas and the wind coefficient depending on that varies from 0.7 to 0.8.
- Wind loads showed above are also compared to the ones registered on common refugee camp areas.
- Joints and beams of the same material allow avoiding stress due to thermal expansion.
- Snow loads can take standard number of 1 kN/m^2 in low areas but 1.5 kN/m^2 is recommended on higher locations.

The following section explains and shows how wind values have been calculated and which the taken value for further evaluation is:

In order to know the load that a surface is resisting a simple calculation is carried out. The formula below is used on the next calculations.

$$Pressure = v^2 \cdot \rho \cdot \frac{1.17}{2}$$

V is the wind speed in m/s.

ρ is the air density which in room temperature is about 1.20 kg/m^3

Pressure is the load the wall bears N/m^2.

1.17 is the coefficient for a flat perpendicular surface.

Wind loads on temperate zones where set between 2.5 and 5 m/s but rains can raise that value up to 23 m/s and gusts of 33 m/s. To compute he biggest value is used.

$$Pressure = 33^2 \cdot 1.2 \cdot \frac{1.17}{2}$$

$$Pressure = 734.5\ N/m^2$$

Wind loads on tropical zones where set between 2 and 18 m/s but storms can raise that value up to 70 m/s. To compute he biggest value is used.

$$Pressure = 70^2 \cdot 1.2 \cdot \frac{1.17}{2}$$

$$Pressure = 3440\ N/m^2$$

Wind loads on frigid zones where set on 4.1 m/s and can reach 48 m/s. To compute he biggest value is used.

$$Pressure = 48^2 \cdot 1.2 \cdot \frac{1.17}{2}$$

$$Pressure = 1617\ N/m^2$$

Wind on desert zones is set on 18 m/s and due to storms can reach 23 m/s and a 34 m/s gust limit. To compute he biggest value is used.

$$Pressure = 34^2 \cdot 1.2 \cdot \frac{1.17}{2}$$

$$Pressure = 811.5\ N/m^2$$

The values extracted have a range between 0.7 and 3.5 kN/m^2 the value established on the Spanish regulation applying the coefficients reaches is almost the same as the lowest calculated above. Hence it will not be considered as a characteristic value. Between those two values a mean load is 2.1 kN/m^2. Therefore the use of this load is suitable for almost all the situations.

Now the canopy weight and its load due to wind values are calculated. These values have the same result on wind load effect because the same area is covered but as it can be seen material weights are quite different so an observation must be done. The estimated volume and whence its weight equals to the area of the structure and the thickness of the fabric layer.

Cotton canvas:

- ρ density is 1 kg/m^2

Generic polymer:

- ρ density 0.7kg/m^2

The table beneath gathers a combination of measures to see which the best option is for a specific living area by analyzing the weight

		Living area						
		24 m^2	21 m^2	18 m^2	19,25 m^2	20 m^2	22,5 m^2	20,25 m^2
	Size	6x4	6x3,5	6x3	5,5x3,5	5x4	5x4,5	4,5x4,5
Weight	Cotton	98	89,5	81	83,5	85	92,5	85,5
	Polymer	68,6	62,65	56,7	58,45	59,5	64,75	59,85

Table: 27 Weight of the canopy due to tent size and living area

The formulas used where the following ones:

$$Volume\ of\ fabric =$$

$$(2 \cdot side1 \cdot height + 2 \cdot side2 \cdot height + 2 \cdot side1 \cdot side2) * Thickness$$

$$Weight = Volume\ of\ fabric \cdot \rho$$

- The considered height is 2.5 m

	Ratio kg/m^2						
Cotton	4,08	4,26	4,50	4,34	4,25	4,11	4,22
Polymer	2,86	2,98	3,15	3,04	2,98	2,88	2,96

Table: 28 Density per squared meter of the canopy

As the best ratio for Kg/m^2 is for the unit made out of 2.5, 4 and 6 meter beams the loads will be computed based on this selection. Its weight depends on the material used. Hence polymers will be the used ones because they are lighter and have better strength and thermal properties.

The load values for the unit covering are not lineal loads. The cover is attached to the structure using pins on the joints so it will be considered as a sort of point loads. Those values are:

$$Point\ Load = Weight \cdot 9{,}81 \cdot \frac{1}{4}$$

$$Point\ Load = 68 \cdot 9{,}81 \cdot \frac{1}{4}$$

$$Point\ Load = 166\ N$$

Apart from the canopy a shade is also needed in some areas. This fly covers the entire roof surface and has to ensure a wide shadow area around the unit. In order to avoid load reactions or lifting episodes due to wind gusts the shade is holed to let the air flow go through. As those holes may let the sunlight pass through as well a second layer should be arranged holed as well but out of phase compared to the first one.

Cotton canvas:

- ρ density is 1 kg/m^2

Generic polymer:

- ρ density between 0.7 kg/m^2

The formulas used where the following ones:

- Porch is the extra length added to living area size measurements.
- n is the number of layers.

$$Volume\ of\ fabric = \big((size1 + porch) + (size2 + porch)\big) \cdot Thickness$$

$$Weight = Volume\ of\ fabric \cdot \rho \cdot n$$

	Porch addition		
	1 m	1,5 m	2 m
Weight (kg)	67,2	88,2	112

Table: 29 Additional weight by porch addition

The chosen material was the polymer and as a result of a 2 layer shade the weight increases rapidly. Even though the lighter is the 1 m extension the one chosen in the 2 m. It reduces the wall exposure to the sunlight and its consequent warming and offers a shadow for external activities.

Extra porch covers can be attached to the main structure but poles are needed to fix them on the ground.

The loads due to shade fabrics are not lineal loads. The shade is pinned on to a added tubular structure on the joints so it will be considered as a sort of point loads. Those values are:

$$Point\ Load = Weight \cdot 9{,}81 \cdot \frac{1}{4}$$

$$Point\ Load = 112 \cdot 9{,}81 \cdot \frac{1}{4}$$

$$Point\ Load = 275\ N$$

Finally on external loads due to cladding the panels and local resources are analyzed. As those materials are not fabrics loads will increase compared to the former calculations but these parts have to be assembled on the structure for life span purposes and comfortable features.

The insulating panel has been chosen for its thermal properties in a later chapter. Hence the given values are a result of the selection of that used option.

- ρ density of the panel material

Depending on the position and configuration the loads need to be calculated in different ways:

- Panel vertical on the beam
- Panel horizontal between 2 beams

The calculations of the vertical panels are related to the ones behaving as a wall. Those selected as roof materials will be calculated depending on the width between the larger walls of the unit. The less span gap the panel is hanging between heavier loads can resist and less weight the beam has to support. The loads compared are the following ones:

	Density kg/m^3 or *kg/m^2	Min Width (m)	Max Width (m)	Bad U-value (W/m^{2}K)	Good U-value (W/m^{2}K)
Methyl methacrylate	1192	0,002	0,020	5,8	5,3
PWS roof/wall	16	0,05	0,125	0,75	0,13
Wood	800	0,05	0,08	2,9	2,6
Metal Plates	8.42*	0,001	__	8,5	__
Dirt/Mud/Brick	1800	0,12	__	2	__
Polymer Canvas	0,7*	0,003	0,206	4,5	2,6

Table: 30 Mechanical and thermal properties of selected wall materials

	Density kg/m^3 or *kg/m^2	Density kg/m2
Methyl methacrylate	1192	2.38-23.84
PWS roof/wall	16	2
Wood	800	40-64
Wood sheet	800	2.4
Metal Plates	8.42*	8.42
Dirt/Mud/Brick	1800	216
Polymer Canvas	0,7*	0,7

Table: 31 Surface density of selected wall materials

The load for the beams must take to account the heaviest combination possible.

- The PWS foam panel, wood and metal plates (corrugated) are the ones that can be used on the roof. The heaviest of all of them is the wood.
- The PWS foam panel, wood, metal plates, metrhacrylate and Bricks are the ones that can be used on the siding the heaviest one is brick, dirt and mud but as this kind of construction lays on the ground the frame structure will not have to bear the load just hold it in case of upholder. The chosen for calculations is wood.
- Floor may have the possible combination of wood or wood sheet and PWS foam panel due to insulation and comfort needs. Hence both are selected for calculations regarding floor.

The materials about which the structure has its calculations based are:

	Density kg/m2	Vertical load for 2,5 m height (kg/m)	Vertical load for a 4 m span (kg/m)
PWS roof/wall	0.8-2	2-5	1.6-4

	Density kg/m2	Vertical load for 2,5 m height (kg/m)	Vertical load for a 4 m span (kg/m)
Wood	40-64	100-160	80-128
Wood sheet	2.4	6	4.8

Table: 32 Preselected final wall materials

Eventually due to its weight the main variable is just the wood that could be used for every kind of cladding.

	Density kg/m2	Vertical load for 2,5 m height (kg/m)	Vertical load for a 4 m span (kg/m)
Wood	40-64	100-160	80-128

Table: 33 Finall selected wall material for calculation purposes

The use of the worst condition for the structure to bear makes sure that other possible combinations resulting on lower loads are feasible.

Wall Wood	80-128 kg/m	0.79-1.26 kN/m
Roof and floor Wood	100-160 kg/m	0.99-1.57 kN/m

Table: 34 Panel weight loads due to selected material for calculations

Also regarding the photovoltaic panels that could be installed on the roof have to be taken to account:

- Photovoltaic characteristics:
  - Weight 19-27 kg
  - Area 1.6-2 m^2
  - Density 11.9-13.5 kg/m^2

$$Point\ Load = Weight \cdot 9{,}81 \cdot \frac{1}{4}$$

$$Point\ Load = 27 \cdot 9{,}81 \cdot \frac{1}{4}$$

$$Point\ Load = 66\ N$$

*The load result is just for one panel installed.

Now that all external variables have and empiric number the study of a simple beam profile must be carried out to understand which crossing sections are suitable or in these firsts evaluations which are useful. Using the tables below and comparing the loads a starter beam profile is selected.

Loads summary:

- Wall Panel: 1.26 kN/m
- Roof/Floor Panel: 1.57 kN/m
- Flooring: 2 kN/m^2 or 4kN/m
- Canopy: 166 N
- Shade: 275 N
- Wind: 2,1 kN/m^2 or 3.15 kN/m
- Snow load: 1.5 kN/m^2 or 3kN/m
- Photovoltaic panel: 66 N

Load summary with applied coefficient:

- Permanent Wall Panel: 1.7 kN/m
- Permanent Roof/Floor Panel: 2.12 kN/m
- Permanent Flooring: 5.4 kN/m
- Permanent Canopy: 224 N
- Permanent Shade: 371 N
- Variable Wind load: 4.75 kN/m
- Variable Snow load: 4.5 kN/m
- Permanent Photovoltaic panel: 89 N

The loads to be considered for base beam calculations must be all the listed above but for roof beams just Permanent Roof and Variable Snow Loads are the only ones to be evaluated.

Calculations of suitable I-Beam

Given all the load values some simple calculations must be carried out to verify that the right profile is chosen. The loads that affect the unit base beam can be gathered as follows:

- Distributed load: 13.8 kN/m y-axis and 4.75 kN/m x-axis
- Point load: 684 N o 0.68 kN
- Beam material:
    - module of elasticity: 210 GPa
    - S275JR
    - Density 7800 kg/m^3

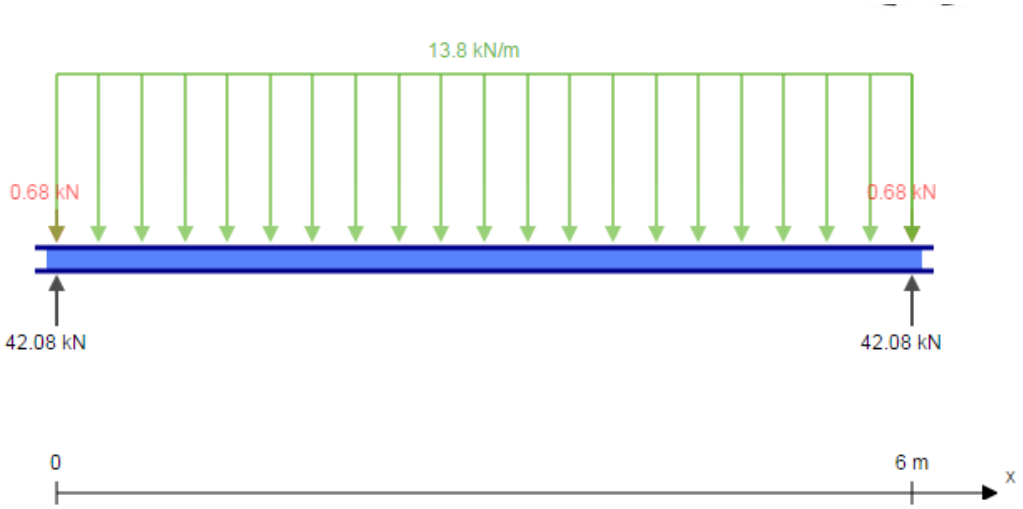


Image: 15 Load draft for simple beam 1

The point of analysis is the center of the beam where the maximum stress and displacement will appear. The evaluation is done at 3 m from the origin set in one edge of the beam. This layout and values are common in all cases.

The I-beams characterized are IPE crossing sections; these offer the best ratio between linear weight and resistance. High moment of inertia and low weight make them suitable for an assembled structure trying to avoid professional or machinery involved on its construction.

A quick way of choosing the IPE profile is using the table below:

	kg/m²		Distributed load (kN/m)																
			0,5	1,0	2,0	3,0	4,0	6,0	8,0	10	15	20	25	30	35	40	50	60	80	100
IPE	80*	6,0	4,3	3,3	2,5	2,6	2,1	1,8	1,7	1,5	1,4	1,2	1,1	1,0	1,0	-	-	-	-	-
	100*	8,1	3,5	4,3	3,4	3,1	2,8	2,4	2,2	2	1,7	1,5	1,4	1,3	1,3	1,2	1	-	-	-
	120*	10,4	6,8	5,3	4,2	3,5	3,3	2,9	2,6	2,4	2,1	1,9	1,8	1,7	1,6	1,5	1,3	1,2	1,0	-
	140*	12,9	8,1	6,3	5,0	4,5	4,0	3,5	3,1	2,9	2,5	2,3	2,1	2,0	1,9	1,8	1,6	1,4	1,2	1,1
	160	15,8	9,5	7,4	5,8	5,2	4,8	4,0	3,7	3,4	3,0	2,7	2,5	2,3	2,2	2,1	1,9	1,7	1,5	1,3
	180	18,8	11,0	8,5	6,7	6,0	5,5	4,7	4,3	3,9	3,5	3,1	2,9	2,7	2,5	2,4	2,2	2,0	1,7	1,5
	200	22,4	12,5	9,7	7,5	7,0	6,0	5,3	4,8	4,5	4,0	3,5	3,3	3,1	2,9	2,8	2,5	2,3	2,0	1,8
	220	26,2	13,5	10,9	8,5	7,5	7,0	6,0	5,5	5,0	4,5	4,0	3,7	3,4	3,3	3,1	2,9	2,6	2,3	2,0
	240	30,7	15,5	12,2	9,6	8,5	7,5	6,5	6,0	5,5	5,0	4,4	4,1	3,9	3,7	3,5	3,2	3,0	2,6	2,3
	270	36,1	17,5	14,0	13,0	10,0	9,0	7,5	7,0	6,5	5,5	5,1	4,7	4,4	4,2	4,	3,7	3,4	3,0	2,6
	300	42,2	20,0	15,8	13,5	11,0	10,0	8,5	7,8	7,0	6,0	5,7	5,3	5,0	4,7	4,5	4,2	3,9	3,4	3,0
	330	49,1		17,7	15,0	12,5	11	9,5	8,8	8,0	7,0	6,4	6,0	5,6	5,3	5,1	4,7	4,4	3,8	3,4
			Beam lenght (m)																	

Table: 35 Load distribution for profile selection 1

Purposed Initial beam results: IPE 300

Max Displacement	0.013595 m
Max Shear	41.400 kN
Max Moment	62.100 kN-m

Table: 36 Initial beam selection results

As it can be seen the displacement using this beam is around 1.4 cm/ 6m. This value works for structural purposes but the beam and therefore the structure are not easy to handle or carry. This value is reached due to bending on the middle point of the beam. In order to decrease this value another beam with a higher Moment of inertia must be chosen. However as the outcomes of the calculation gives a acceptable small deflection and the objective of this project is light weight or at least the lowest weight possible a lighter beam should be considered.

Unit System

English (inches, kips, ksi)

Metric (meters, kN, kPa)

Constants

Young's Modulus, *E (kPa)*

205000000

Moment of Inertia, *I* (m^4)

0.00008356

Load & Dimensions

q (kN/m)

13.8

L (m)

6

point of interest, x (m)

3

Table: 37 initial beam selection parameters

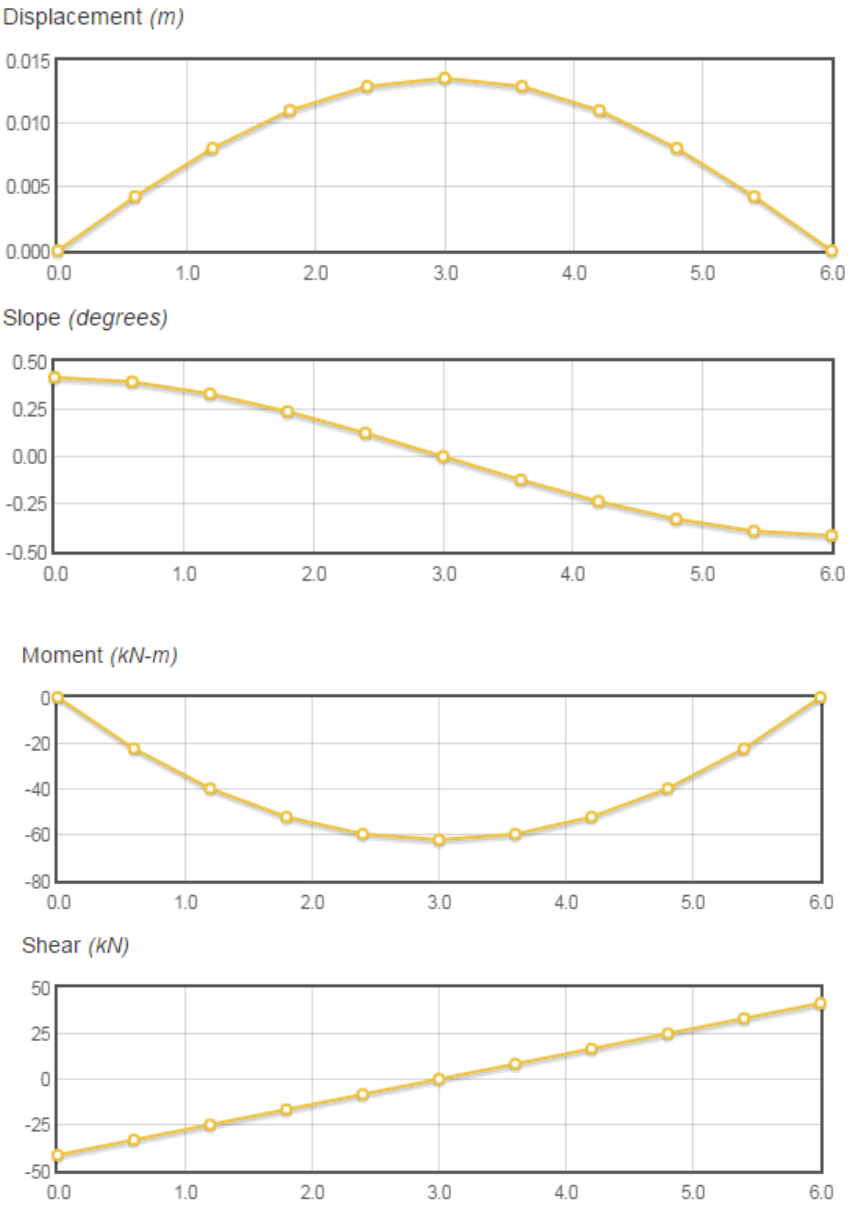


Table: 38 Initial beam ploted data

Based on the table same table as the calculation above the next section analyzes the second beam. As the load is placed between the 10 and 15 kN/m the IPE crossing section could also be the 10 kN/m but for a longer span. This can even the difference between the profile characteristics and the load applied.

	kg/m²		Distributed load (kN/m)																
			0,5	1,0	2,0	3,0	4,0	6,0	8,0	10	15	20	25	30	35	40	50	60	80	100
IPE	80*	6,0	4,3	3,3	2,5	2,6	2,1	1,8	1,7	1,5	1,4	1,2	1,1	1,0	1,0	-	-	-	-	-
	100*	8,1	3,5	4,3	3,4	3,1	2,8	2,4	2,2	2	1,7	1,5	1,4	1,3	1,3	1,2	1	-	-	-
	120*	10,4	6,8	5,3	4,2	3,5	3,3	2,9	2,6	2,4	2,1	1,9	1,8	1,7	1,6	1,5	1,3	1,2	1,0	-
	140*	12,9	8,1	6,3	5,0	4,5	4,0	3,5	3,1	2,9	2,5	2,3	2,1	2,0	1,9	1,8	1,6	1,4	1,2	1,1
	160	15,8	9,5	7,4	5,8	5,2	4,8	4,0	3,7	3,4	3,0	2,7	2,5	2,3	2,2	2,1	1,9	1,7	1,5	1,3
	180	18,8	11,0	8,5	6,7	6,0	5,5	4,7	4,3	3,9	3,5	3,1	2,9	2,7	2,5	2,4	2,2	2,0	1,7	1,5
	200	22,4	12,5	9,7	7,5	7,0	6,0	5,3	4,8	4,5	4,0	3,5	3,3	3,1	2,9	2,8	2,5	2,3	2,0	1,8
	220	26,2	13,5	10,9	8,5	7,5	7,0	6,0	5,5	5,0	4,5	4,0	3,7	3,4	3,3	3,1	2,9	2,6	2,3	2,0
	240	30,7	15,5	12,2	9,6	8,5	7,5	6,5	6,0	5,5	5,0	4,4	4,1	3,9	3,7	3,5	3,2	3,0	2,6	2,3
	270	36,1	17,5	14,0	13,0	10,0	9,0	7,5	7,0	6,5	5,5	5,1	4,7	4,4	4,2	4,	3,7	3,4	3,0	2,6
	300	42,2	20,0	15,8	13,5	11,0	10,0	8,5	7,8	7,0	6,0	5,7	5,3	5,0	4,7	4,5	4,2	3,9	3,4	3,0
	330	49,1		17,7	15,0	12,5	11	9,5	8,8	8,0	7,0	6,4	6,0	5,6	5,3	5,1	4,7	4,4	3,8	3,4
			Beam lenght (m)																	

Table: 39 Load distribution for profile selection 2

Purposed second beam results: IPE 270

Max Displacement	0.019620 m
Max Shear	41.400 kN
Max Moment	62.100 kN-m

Table: 40 Second beam selection results

As it can be seen the maximum displacement of the beam reaches almost 2cm/6m meaning this that the value is beyond the limit. Even if the value is accepted the characteristics of the beam are still far from the desired objective. Trying to reduce the weight of the beam by choosing a lighter but less resistant crossing section leads to a worst performance against the loads.

Unit System

English (inches, kips, ksi)

Metric (meters, kN, kPa)

Constants

Young's Modulus, *E (kPa)*

205000000

Moment of Inertia, *I* (m^4)

0.00005790

Load & Dimensions

q (kN/m)

13.8

L (m)

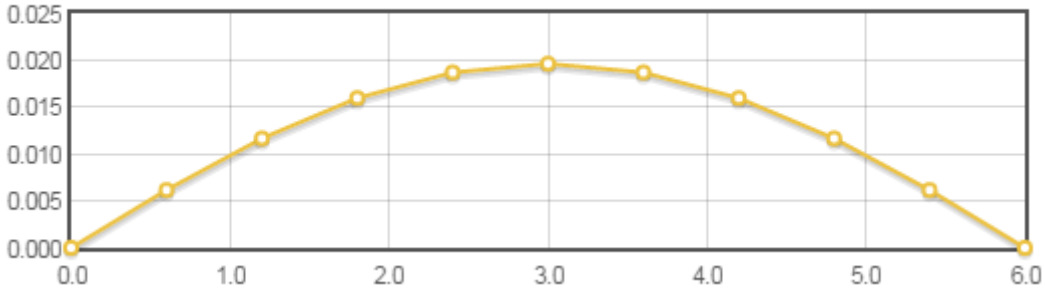
6

point of interest, x (m)

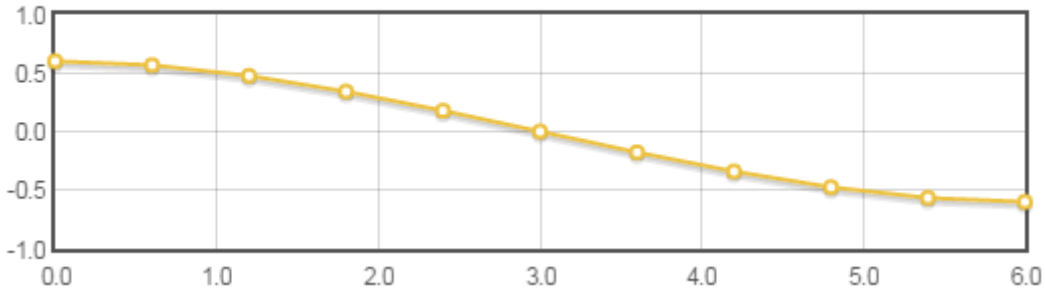
3

Table: 41 Second beam selection parameters

Displacement *(m)*



Slope *(degrees)*



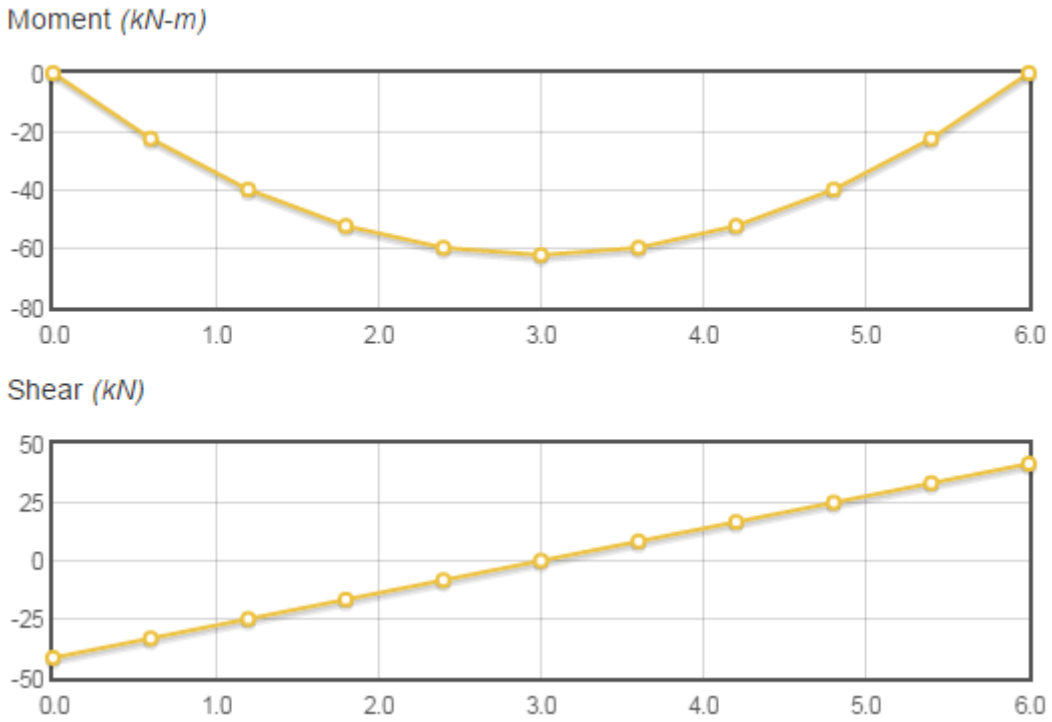


Table: 42 Second beam selection ploted data

Now some options have to be considered and can be seen in the following list.

- Reducing the beam weight a loss of properties makes it non-viable.
- Choosing a strong beam makes it heavy and not a feasible option.
- Length reduce may offer strength and lower weights.

Considering the last option, the selection of the new beam crossing section must take to account weight and its limits. Hence smaller profiles are chosen and the new span to evaluate is 2m in order to make it easy and applicable to all the frames of the structure.

	kg/m^2		Distributed load (kN/m)																
			0,5	1,0	2,0	3,0	4,0	6,0	8,0	10	15	20	25	30	35	40	50	60	80	100
IPE	80*	6,0	4,3	3,3	2,5	2,6	2,1	1,8	1,7	1,5	1,4	1,2	1,1	1,0	1,0	-	-	-	-	-
	100*	8,1	3,5	4,3	3,4	3,1	2,8	2,4	2,2	2	1,7	1,5	1,4	1,3	1,3	1,2	1	-	-	-
	120*	10,4	6,8	5,3	4,2	3,5	3,3	2,9	2,6	2,4	2,1	1,9	1,8	1,7	1,6	1,5	1,3	1,2	1,0	-
	140*	12,9	8,1	6,3	5,0	4,5	4,0	3,5	3,1	2,9	2,5	2,3	2,1	2,0	1,9	1,8	1,6	1,4	1,2	1,1
	160	15,8	9,5	7,4	5,8	5,2	4,8	4,0	3,7	3,4	3,0	2,7	2,5	2,3	2,2	2,1	1,9	1,7	1,5	1,3
	180	18,8	11,0	8,5	6,7	6,0	5,5	4,7	4,3	3,9	3,5	3,1	2,9	2,7	2,5	2,4	2,2	2,0	1,7	1,5
	200	22,4	12,5	9,7	7,5	7,0	6,0	5,3	4,8	4,5	4,0	3,5	3,3	3,1	2,9	2,8	2,5	2,3	2,0	1,8
	220	26,2	13,5	10,9	8,5	7,5	7,0	6,0	5,5	5,0	4,5	4,0	3,7	3,4	3,3	3,1	2,9	2,6	2,3	2,0
	240	30,7	15,5	12,2	9,6	8,5	7,5	6,5	6,0	5,5	5,0	4,4	4,1	3,9	3,7	3,5	3,2	3,0	2,6	2,3
	270	36,1	17,5	14,0	13,0	10,0	9,0	7,5	7,0	6,5	5,5	5,1	4,7	4,4	4,2	4,	3,7	3,4	3,0	2,6
	300	42,2	20,0	15,8	13,5	11,0	10,0	8,5	7,8	7,0	6,0	5,7	5,3	5,0	4,7	4,5	4,2	3,9	3,4	3,0
	330	49,1		17,7	15,0	12,5	11	9,5	8,8	8,0	7,0	6,4	6,0	5,6	5,3	5,1	4,7	4,4	3,8	3,4
	Beam lenght (m)																			

Table: 43 Load distribution for profile selection 3

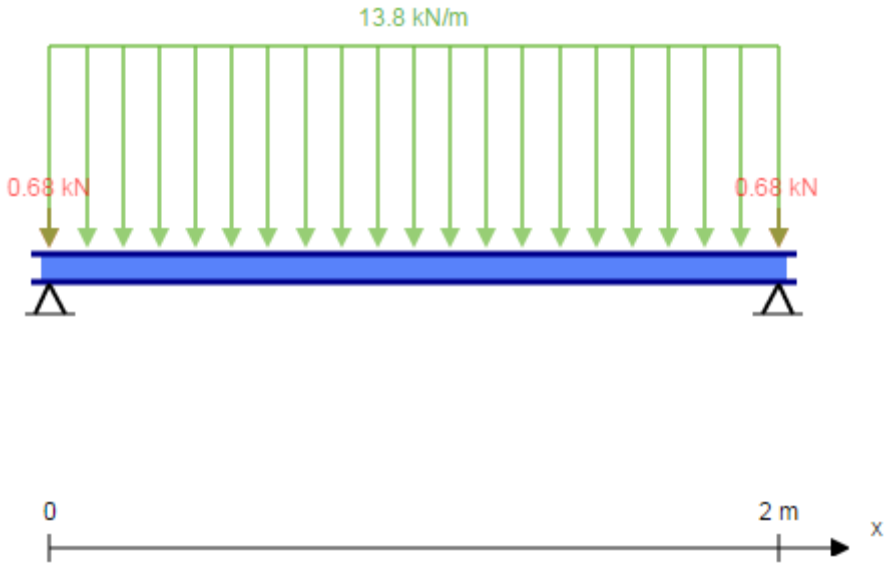


Image: 16 Load draft for beam selection 3

The point of analysis is the center of the beam where the maximum stress and displacement will appear. The evaluation is done at 3 m from the origin set in one edge of the beam. This layout and values are common in all cases.

Purposed third beam results: IPE 120

Max Displacement	0.0043052 m
Max Shear	13.800 kN
Max Moment	6.9000 kN-m

Table: 44 Load beam selection results 2

As it can be seen the displacement using this beam is around 0.43 cm/ 2m. This value works for structural purposes and unlike the former evaluations this option is easy to handle and carry. This value is reached due to bending on the middle point of the beam which is shorter now. As the possibility to make the displacement decrease is based on higher moments of inertia, and heavier weights drive this condition, no further beam sections need to be evaluated.

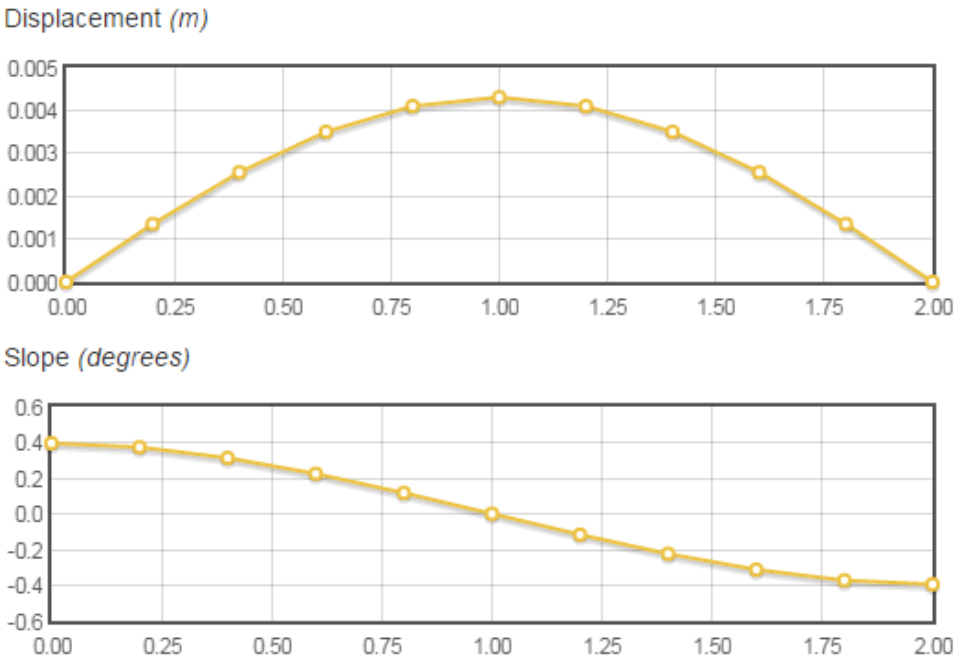
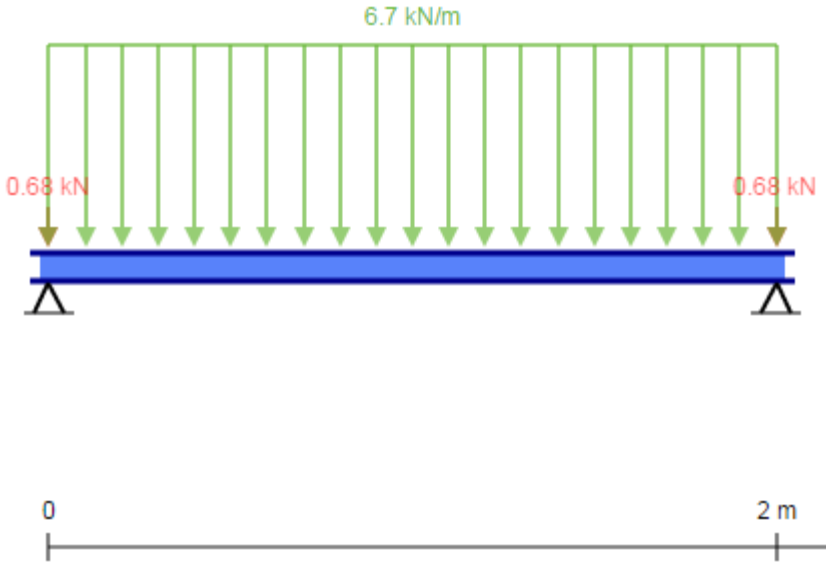


Table: 45 Thirds beam selection ploted results

Now that the base beam is characterized it is turn for the roof beam which will bear a lower load and therefore the section can be reduced as well as the weight.

The loads taken for the analysis are:

- Distributed load: 6.7 kN/m y-axis and 4.75 kN/m x-axis
- Point load: 684 N o 0.68 kN
- Beam material:
    - module of elasticity: 210 GPa
    - S275JR
    - Density 7800 kg/m^3



	kg/m²		Distributed load (kN/m)																
			0,5	1,0	2,0	3,0	4,0	6,0	8,0	10	15	20	25	30	35	40	50	60	80	100
IPE	80*	6,0	4,3	3,3	2,5	2,6	2,1	1,8	1,7	1,5	1,4	1,2	1,1	1,0	1,0	-	-	-	-	-
	100*	8,1	3,5	4,3	3,4	3,1	2,8	2,4	2,2	2	1,7	1,5	1,4	1,3	1,3	1,2	1	-	-	-
	120*	10,4	6,8	5,3	4,2	3,5	3,3	2,9	2,6	2,4	2,1	1,9	1,8	1,7	1,6	1,5	1,3	1,2	1,0	-
	140*	12,9	8,1	6,3	5,0	4,5	4,0	3,5	3,1	2,9	2,5	2,3	2,1	2,0	1,9	1,8	1,6	1,4	1,2	1,1
	160	15,8	9,5	7,4	5,8	5,2	4,8	4,0	3,7	3,4	3,0	2,7	2,5	2,3	2,2	2,1	1,9	1,7	1,5	1,3
	180	18,8	11,0	8,5	6,7	6,0	5,5	4,7	4,3	3,9	3,5	3,1	2,9	2,7	2,5	2,4	2,2	2,0	1,7	1,5
	200	22,4	12,5	9,7	7,5	7,0	6,0	5,3	4,8	4,5	4,0	3,5	3,3	3,1	2,9	2,8	2,5	2,3	2,0	1,8
	220	26,2	13,5	10,9	8,5	7,5	7,0	6,0	5,5	5,0	4,5	4,0	3,7	3,4	3,3	3,1	2,9	2,6	2,3	2,0
	240	30,7	15,5	12,2	9,6	8,5	7,5	6,5	6,0	5,5	5,0	4,4	4,1	3,9	3,7	3,5	3,2	3,0	2,6	2,3
	270	36,1	17,5	14,0	13,0	10,0	9,0	7,5	7,0	6,5	5,5	5,1	4,7	4,4	4,2	4,	3,7	3,4	3,0	2,6
	300	42,2	20,0	15,8	13,5	11,0	10,0	8,5	7,8	7,0	6,0	5,7	5,3	5,0	4,7	4,5	4,2	3,9	3,4	3,0
	330	49,1		17,7	15,0	12,5	11	9,5	8,8	8,0	7,0	6,4	6,0	5,6	5,3	5,1	4,7	4,4	3,8	3,4
			Beam lenght (m)																	

Table: 46Load distribution for beam section 4

The point of analysis is the center of the beam where the maximum stress and displacement will appear. The evaluation is done at 1 m from the origin set in one edge of the beam.

Purposed first roof beam results: IPE 100

Max Displacement	0.0038870 m
Max Shear	6.7000 kN
Max Moment	3.3500 kN-m

Table: 47 Load beam results 4

As it can be seen the displacement using this beam is around 0.39 cm/ 2m. This value works for structural purposes and like the former evaluations this option is easy to handle and carry. This value is reached due to bending on the middle point of the beam which has a total length of 2 m. As the possibility to make the displacement decrease is based on higher moments of inertia, and heavier weights drive this condition, no further beam sections need to be evaluated.

Unit System

English (inches, kips, ksi)

Metric (meters, kN, kPa)

Constants

Young's Modulus, *E (kPa)*

210000000

Moment of Inertia, *I* (m^4)

0.00000171

Load & Dimensions

q (kN/m)

6.7

L (m)

2

point of interest, x (m)

1

Table: 48 beam load parameters 4

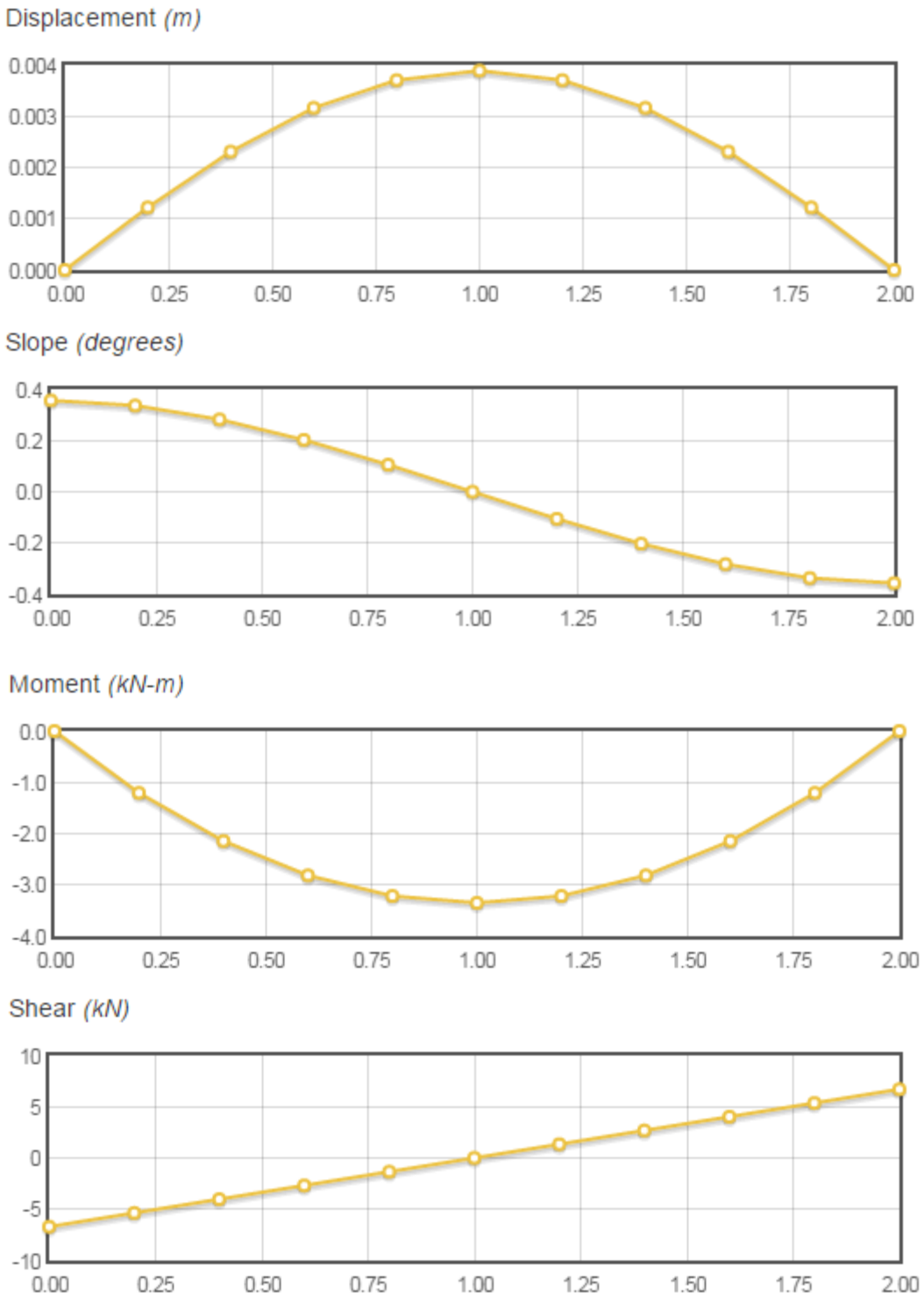


Table: 49 Load beam ploted data

After the single beam analysis has been done a whole structure beam frame evaluation with the right configuration of load is carried out. The analysis using CAD software to analyze the simply supported beam can be found in the annex with all the structure results.

CAD structure analysis:

The use of Computer Assisted Design software eases the task of analyzing the whole structure and makes it possible to quickly arrange layouts and beam sizes for each specific area of the unit. Based on the former results a simple combination of beams and shape has been arranged. From a first analysis the weakness of the structure are faced and then in next evaluations some changes are done. The main shape and beams attached does not change but some profiles are changed. As a way to show this only the first and last evaluations are explained.

The material used on the corner fittings, the junctions and the I beams is the structural steel S275JR.

First study:

- 20 IPE120
- 10 IPE100
- Supported on the base on each corner
- Red arrows: 13.8 kN/m
- Green Arrows: 6.7 kN/m^2
- Blue Arrows: 4.75 kN/m
- Purple Arrows: 0.68 kN
-

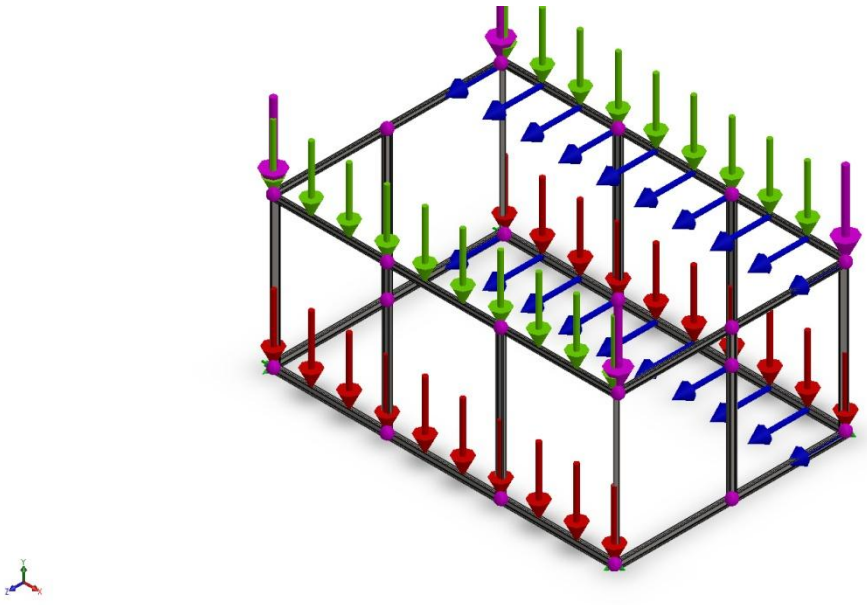


Image: 17 Frame structure load distribution

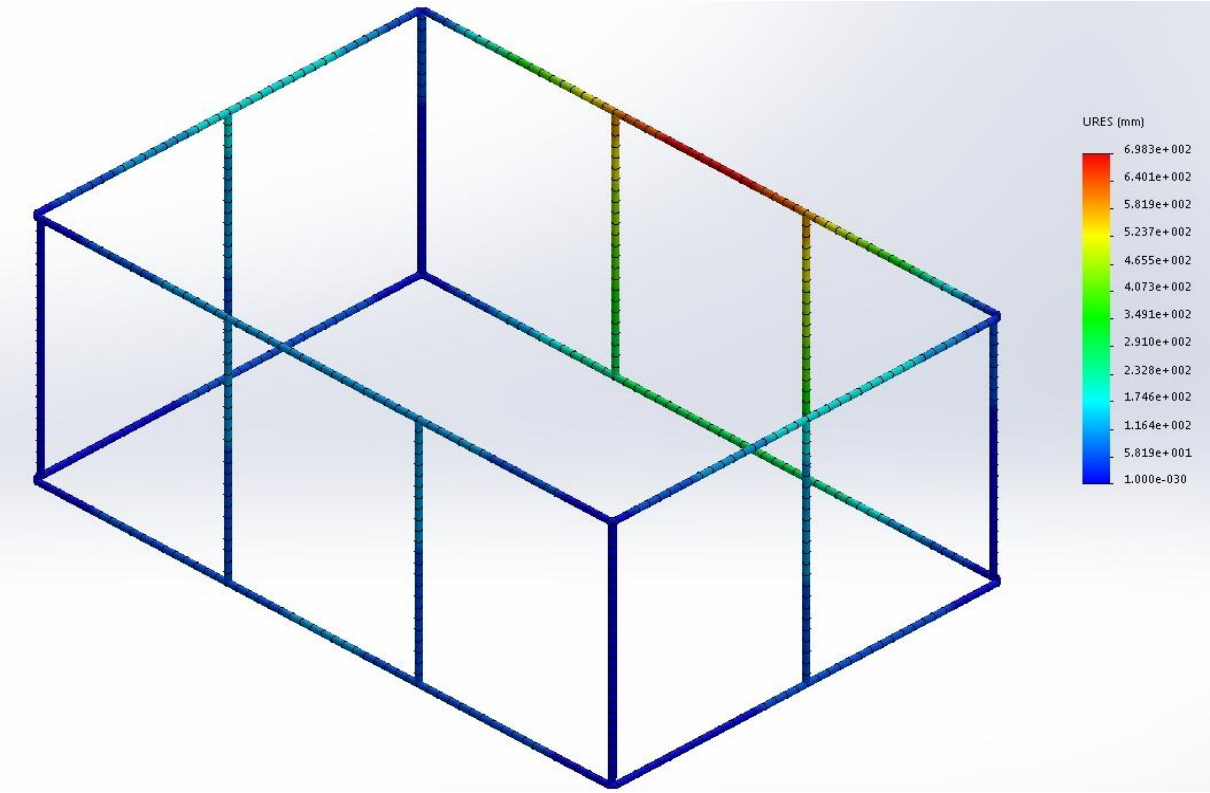


Image: 18 Displacement due to loads first frame study

As it can be seen on the picture above the red section shows a high displacement equal to 0.68 m which makes the structure not suitable and most of all dangerous for its dwellers. The reason of this high displacement is due to lateral loads which the section is not designed for.

The loads bared by the rest of the structure are not significant and as designed the frame structure behaves perfectly vertical and point loads. The displacement due to lateral loads is the major problem on the structure. The further analysis taken focused just on avoiding or reducing its bending. All structure analysis can be found on the annex. The final result sum up can be seen next.

Last study:

- 20 IPE 120
- 10 IPE 100
- 4 IPE 80
- The structure is supported on the base on each corner and the middle joints are also fixed to the ground.
- Red arrows: 13.8 kN/m
- Green Arrows: 6.7 kN/m^2
- Blue Arrows: 4.75 kN/m
- Purple Arrows: 0.68 kN

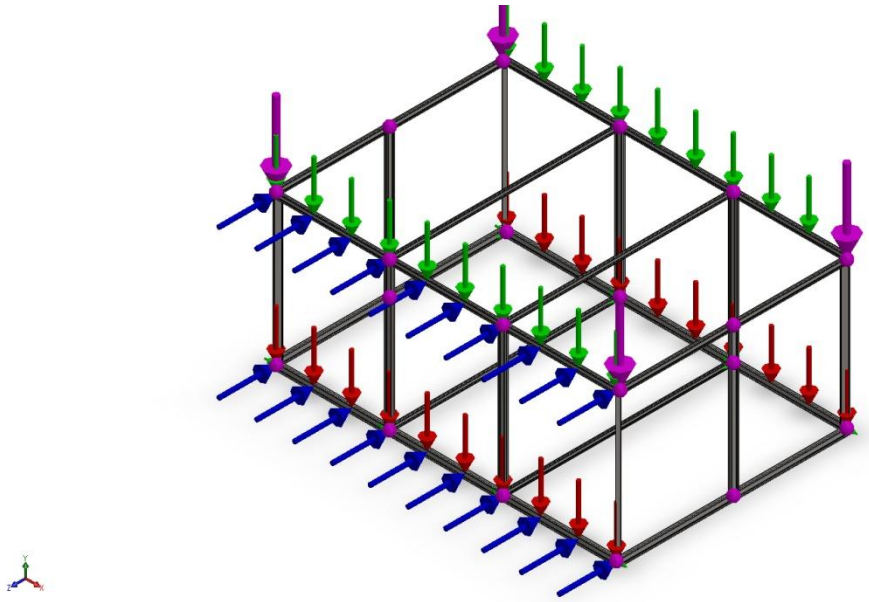


Image: 19 Frame structure last study load distribution

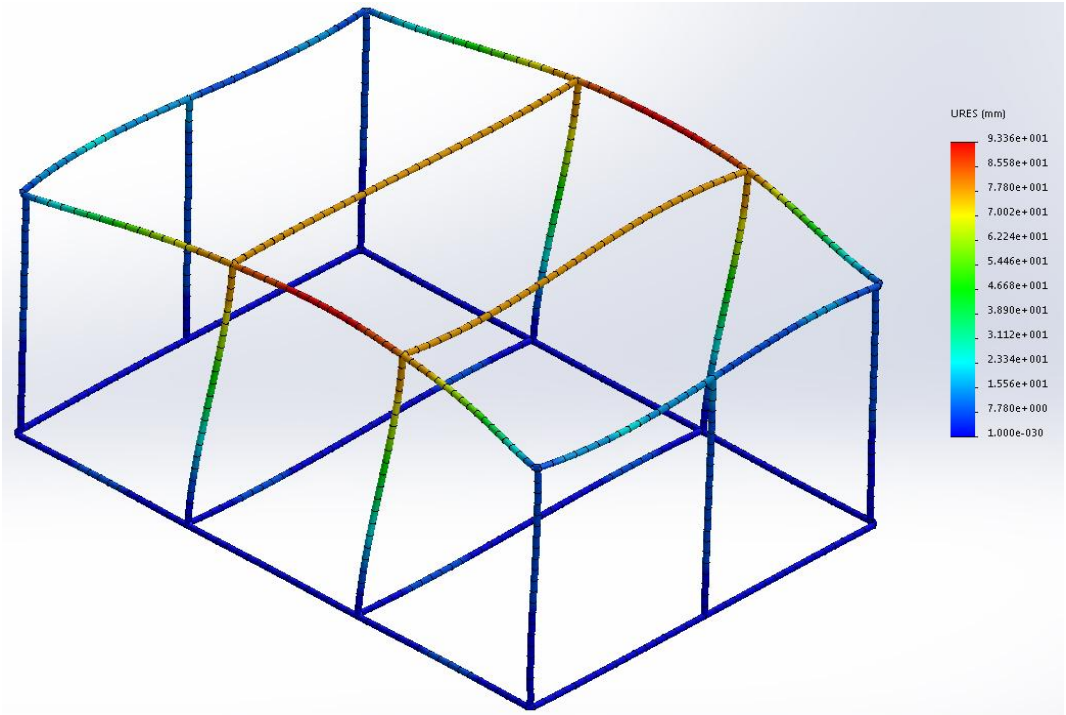


Image: 20 Displacement due to last study loads

As it can be seen in this last analysis the displacement values due to vertical loads are minimized as much as has been possible (0.01m) but even with all the changes made on the frame structure adding beams has not been enough to avoid lateral displacement. Even though lateral displacement has to be considered as a low probable situation the results obtain do not fit the highest safety demands but the structure can be deployed and fully functional in higher levels than the solutions nowadays.

After the analysis is concluded the resultant structure is the shown below:

Image: 21 Final frame structure design

Corners, junctions and fittings:

Now that the structure has all the sections defined, how those are attached together has to be evaluated. Three options are chosen and each one has its commitment explained next.

- The first joint is the 3-axial joint:

This joint is used to fix 4 beams together in the middle area of the unit. It links an IPE80 beam, which hangs on the span between the two sides of the beam. Then an IPE120 is linked on the vertical direction and finally the 2 remaining horizontal fixtures can be attached to two IPE120 on the base of the structure or two IPE100 on the roof of the structure.

Image: 22 Trixial joint

- The second joint is a flat joint:

This joint is used to fix 3 beams together in the middle area of the unit. It links an IPE120 on the vertical direction and finally the 2 remaining horizontal fixtures can be attached to two IPE120 on the base of the structure or two IPE100 on the roof of the structure.

Image: 23 Flat joint

- The third joint is the corner joint:

The corner joint has 2 configurations. The first one is used on the base of the structure a lever jacks can be used to raise the structure on that point. The second one is used on the roof part of the structure where the poles that support the shade fabric are attached. They both link an IPE120 on the vertical direction and finally the 2 remaining horizontal fixtures can be attached to two IPE120 on the base of the structure or two IPE100 on the roof of the structure. This corner fitting has also a flat plate where the locker for the tents canopy is fixed. It is the T hole.

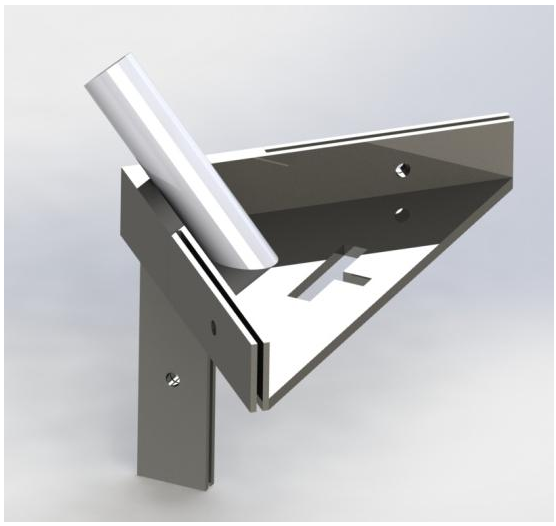


Image: 24 Upper roof corner

Image: 25 Upper roof corner location

Image: 26 Base corner

As it can be seen the plates that mate the beams have a profile and a hole drilled. All plates are separated by the same gap distance but the ones that are attached to the bigger beam sections have a thicker protuberance to fit and fix the thicker web plate. The width of those plates is the same on all the connections to make them standard. Once the beam web plate is fixed a pin is tight to secure the junction.

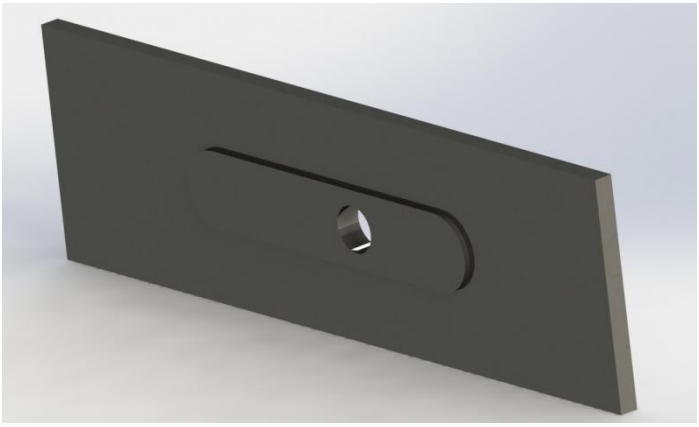


Image: 27 Single plate used on the beam head junctions

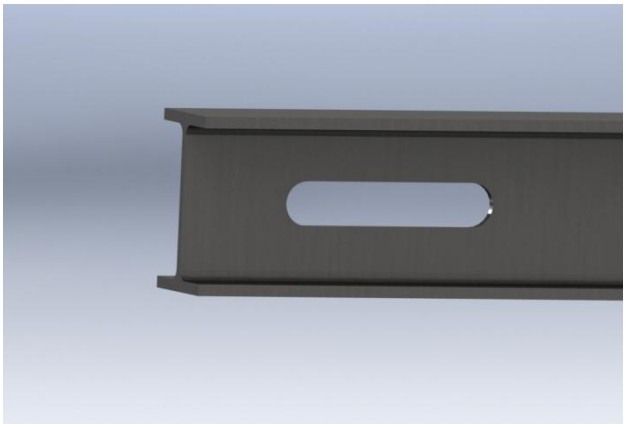


Image: 28 Beam head hole for fixation

Fastening and span fitting:

The structure has its ways to connect and secure loose parts. In order to secure parts to that structure, but those which are not part of it, a design of a fitting that can attach the panels to the beams must be done. The resultant design and its characteristics are shown next.

The material used is the same S275JR as it has been used in all the components of the unit. The use of this standard material allows safety due to its associated regulations and a cheaper way to characterize and purchase materials compared to customized ones.

The locker that secures the tent canopy to the structure has been design to resist the weight and easy to hang on the spot.

Image: 29 Tent-structure locker

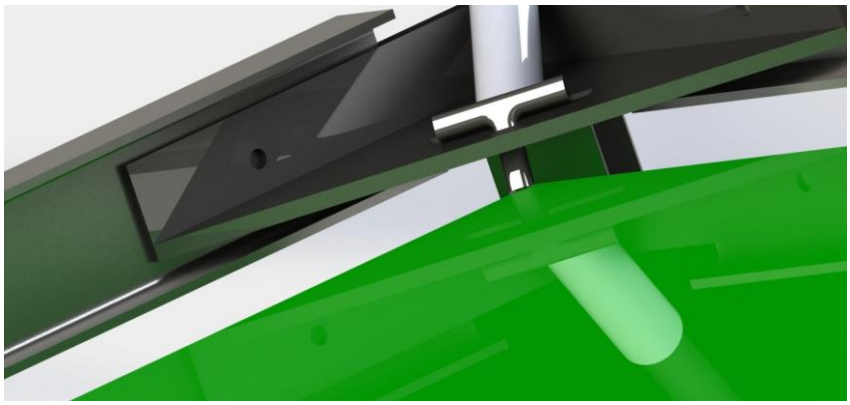


Image: 30 Location and configuration of tent-structure locker

Image: 31 Location and configuration of tent-structure lockerroof corner

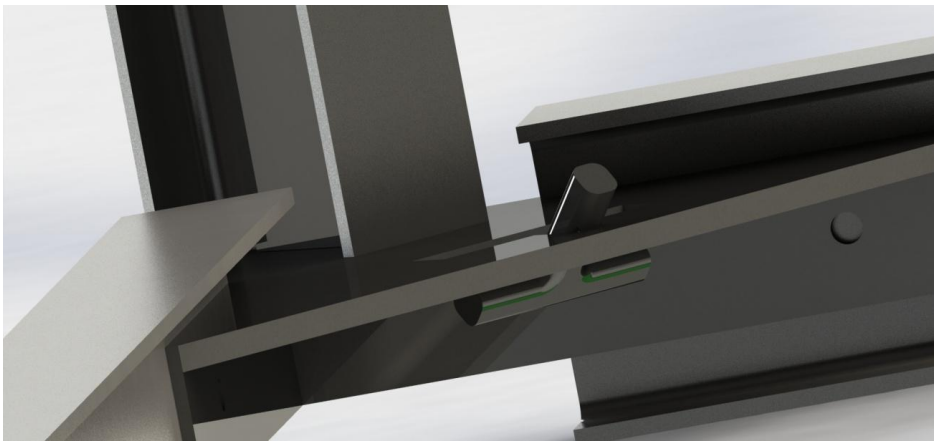


Image: 32 Location and configuration of tent-structure locker base corner

In order to secure the panels used to insulate the unit and also the roof and floor parts a sort of span fittings have been designed. They are base on the same width and shape but the securing part varies depending on which beam or area of the beam they need to be attached. The way they are joined with the panels it is by using pins.

The first and the smallest one is the used for securing the vertical panel with the IPE100 beam bottom flange on the roof.

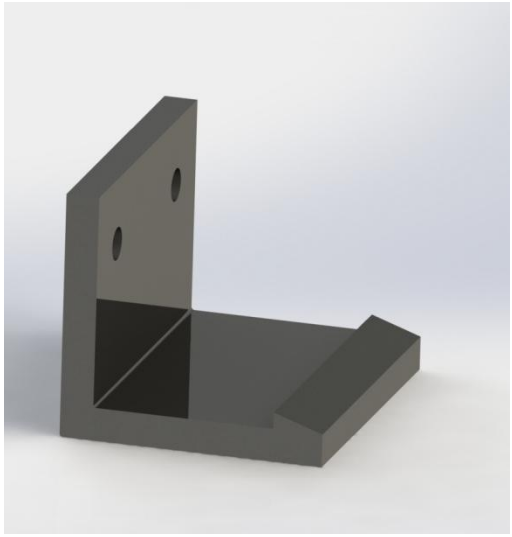


Image: 33 57mm snap fit

The second one is the used for securing the vertical panel with the IPE120 beam top flange on the base.

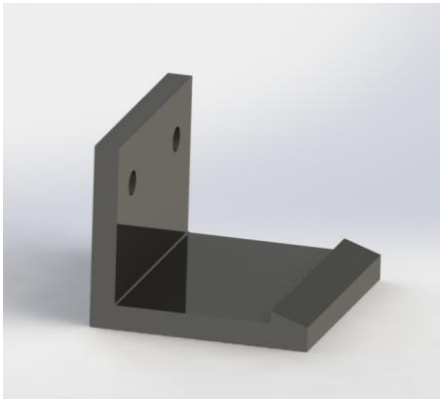


Image: 34 63mm snap fit

The third and fourth one are used for securing the horizontal panels with the IPE100 or 120 beam. The fastening has the depth of the flange distance of each beam.

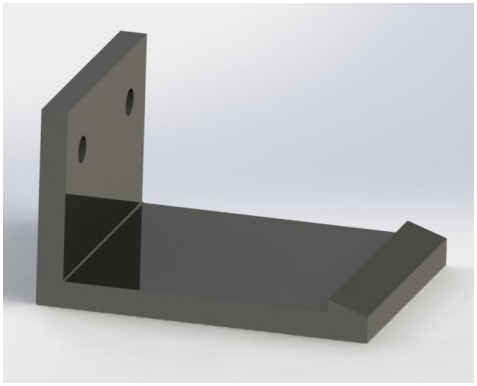


Image: 35 100mm snap fit

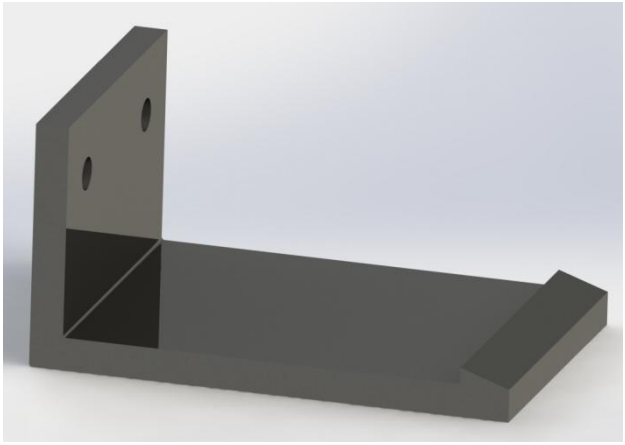


Image: 36 100mm snap fit

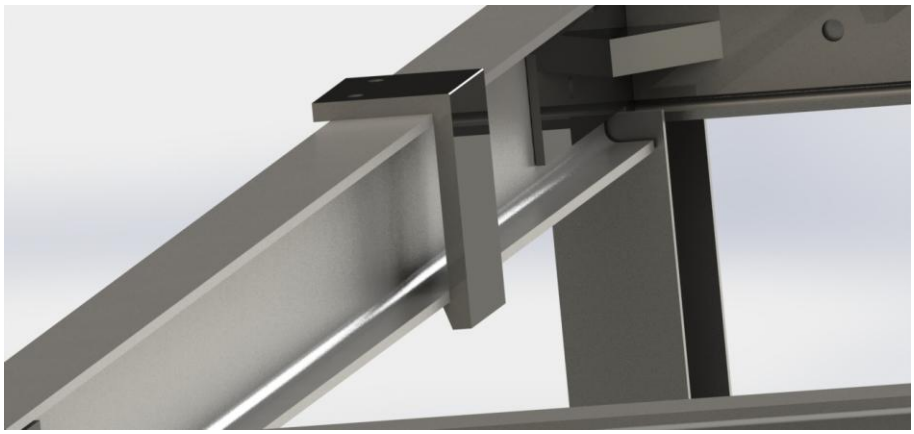


Image: 37 flange to flange snap fit configuration

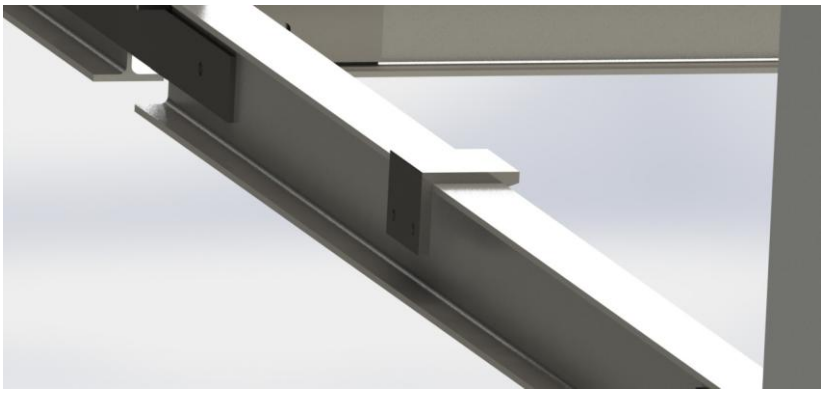


Image: 38 Singel flange snap fit configuration

The structure analysis and components design is finished. On conclusions of this chapter the features and properties of the unit are gathered and compared to the initial project aims.

Thermal Evaluation

The second main topic regarding the unit design is thermal analysis of the panel or cladding covering. A few possibilities allow some combinations that must be comment before starting the calculations. Those variables must be considered to lead the different evaluations and its proper conditions.

The unit can be settled in different climate zones, these where mentioned and explained in former sections. Due to its needs and environmental characteristics the unit has to face different arrangements of its parts:

- The panels have different design and materials
- The unit has to be insulated to keep warm temperatures
- The unit has to be insulated to keep cold temperatures
- Environment hazards constrain the insulating properties
- The panel size or shape depends on the area.

  - Wide open for tropical climates (high ventilation)
  - Openings for ventilation but low temperatures on the inside on desert
  - Openings for ventilation but high temperatures on the inside on frigid zones
  - Temperate areas where both low and high temperatures are needed
  - Thermal mass against insulation designed preassembled panels
  - Predesigned material or local material
- Use of extra covering to reduce the needs of panels

The possible materials combination is based on the few following options:

- Glass
- Insulating panel
- Thermal mass (constraining panel)
- Shade
- Local construction material

The analysis is based on the unit so the shape and volume are equal to those. Fist an area heat transmittance and insulation evaluation is made and then the full walls of the unit are taken on the calculations.

	Density kg/m^3 or *kg/m^2	Min Width (m)	Max Width (m)	Bad U-value (W/m^2K)	Good U-value (W/m^2K)
Common Glass	2600	0,005	0,015	5,6	5,6
Methyl methacrylate	1192	0,002	0,020	5,8	5,3
Izo IPR/Pur wall	43	0,06	0,12	0,36	0,17
Izo Eps wall	15	0,04	0,25	0,86	0,16
Izo MWF wall	100	0,04	0,25	0,86	0,16
Paroc AST wall	23*	0,08	0,12	0,5	0,25
Roof cover	1,6*	0,003	__	0,11	__
PWS roof/wall	16	0,05	0,125	0,75	0,13
Balextherm PU R	11*	0,04	0,1	0,5	0,22
Balextherm MW R	22*	0,08	0,12	0,47	0,26
Wood	800	0,05	0,08	2,9	2,6
Metal Plates	7820	0,005	__	8,5	__
Dirt/Mud/Brick	1800	0,12	__	2	__
Polymer Canvas	0,7*	0,003	0,206	4,5	2,6

Table: 50 Mechanical and thermal properties of wall materials for thermal evaluation

The selected materials for further the further climate calculations are the following ones:

	Density kg/m^3 or *kg/m^2	Min Width (m)	Max Width (m)	Bad U-value (W/m^{2}K)	Good U-value (W/m^{2}K)
Methyl methacrylate	1192	0,002	0,020	5,8	5,3
PWS roof/wall	16	0,05	0,125	0,75	0,13
Wood	800	0,05	0,08	2,9	2,6
Metal Plates	7820	0,005	__	8,5	__
Dirt/Mud/Brick	1800	0,12	__	2	__
Polymer Canvas	0,7*	0,003	0,206	4,5	2,6

Table: 51 Final materials selection for thermal analysis characteristics

Now that the materials that could be used on the structure are known the calculation of a theoretical case must be carried out. The evaluation conditions are:

- 198 W/m^2 of solar irradiation.
- Depending on the climate zone external temperatures and winds vary:
  - Desert conditions wind 18 m/s (gusts m/s) and temperatures 58 ºC day time 15 ºC night time.
  - Temperate conditions wind 5 m/s (gusts 23 m/s) and temperatures 40 ºC
  - Frigid conditions wind 40 m/s (gusts m/s) and temperatures -45 ºC
- The internal accepted temperature is about 21 ºC.
- The same calculations but a reduction of 80% of sunlight irradiation.

As the incident radiation from the sun can raise the inside temperature it must be taken to account.

Heat evaluation of 3 surfaces of the unit:

- Side area of 15m^2
- Side area of 10m^2
- Roof area of 24m^2

Total area: 49m^2

Image: 39 Tent and frame structure configuration

This first option is the initial fabric tent and as can be seen direct sun radiation hits the surface. The walls have no insulating properties and therefore the tent and inner volume heat up fast. To face temperature rising openings must be arranged, air circulation allows heat to escape and air renovate. Air recirculation helps decreasing temperature but constant radiation makes it merely significant. As it is a temporary solution until the sturdy construction is arranged this option can be used on cold and temperate climates.

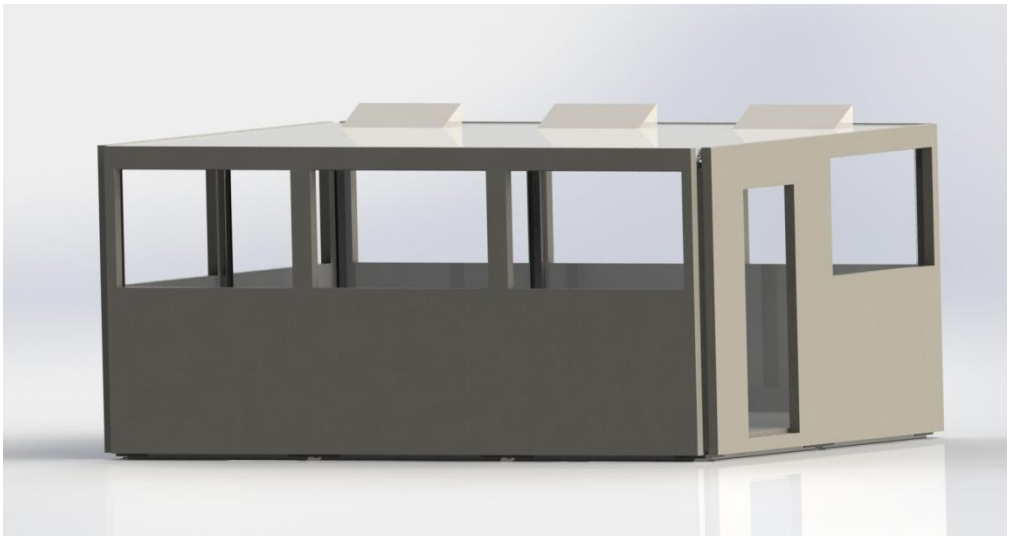


Image: 40 Frame structure and wall panel configuration

This second arrangement is also exposed to direct sun radiation but as the panels are insulating the heat on the inside is significantly reduce. However the temperature is not suitable for comfort living if ventilation is not allowed. To both options former shown a shade component is missing. Hence the final configurations should be the ones next. As it is a temporary solution until the sturdy construction is arranged this option can be used on cold and temperate climates.

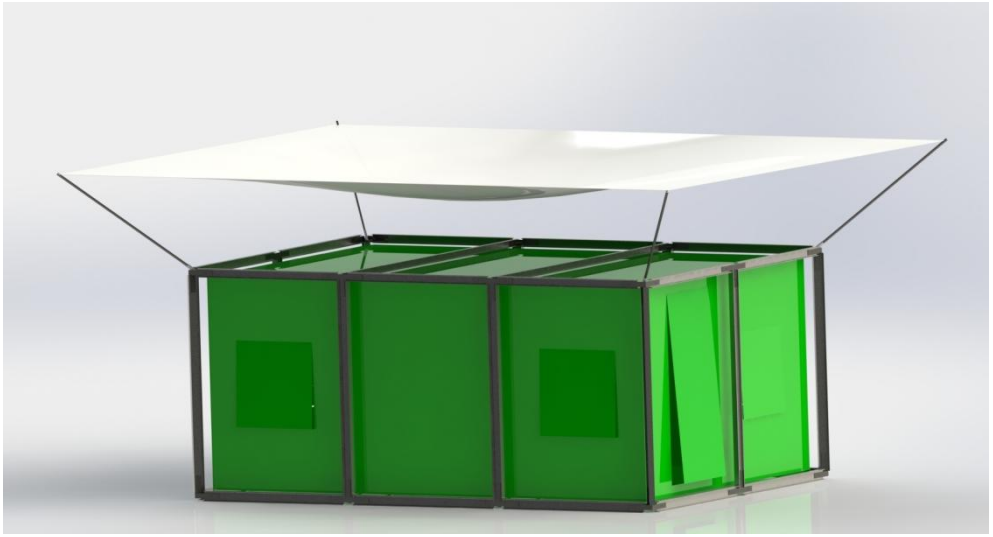


Image: 41 Tent and frame structure configuration with shade

Even though the fabric wall are not suitable for any insulating demand the use of a shade reduces the solar radiation exposure and allows air to cool the surfaces. As it is a temporary solution until the sturdy construction is arranged this option can be used on temperate and desert climates.

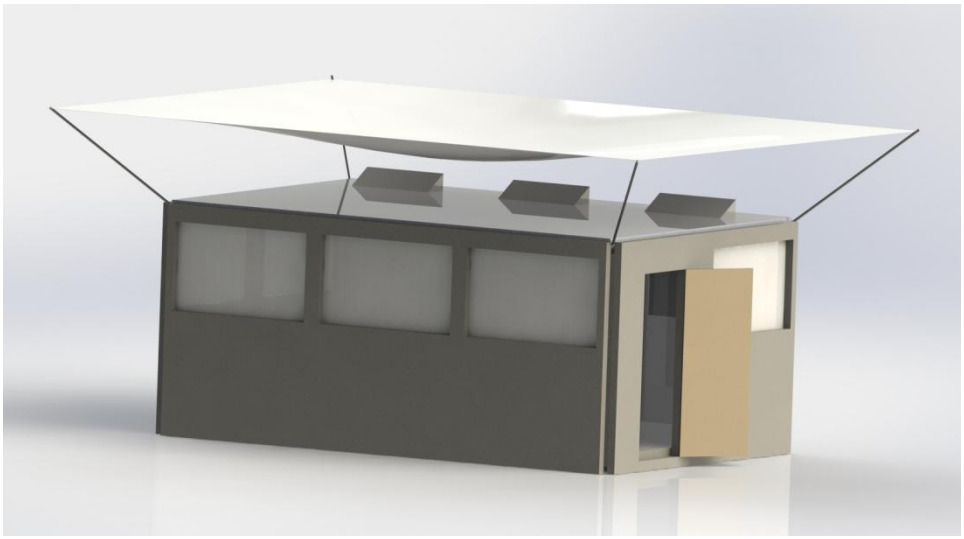


Image: 42 Frame structure and wall panel configuration with shade

This is the final and most versatile configuration. Due to its thermal insulating properties of the panels and the sturdiness of its structure can be set in any climate and environment conditions. The openings allow air circulation and shade blocks the sun reducing incident radiation and lows the temperature on the inside of the unit.

The R-values of the panels make them suitable for hot or cold climates. The use of shade is mandatory for hot climates otherwise the module will not work as it is supposed.

Area of Home	Good	Better	Best
2x4 Walls	R-13		R-15
2x6 Walls	R-19		R-21
Floors	R-19	R-25	R-30

Table: 52 R values for walls sizes

The solar radiation factor is important but a tool to reduce its effect is ventilation. As the unit is considered a bedroom and living room based on minimum ventilation standards the obtained air renovation result is extracted. Those values are used in conventional building and sometimes external power must be used to achieve those exchange rates. The unit is focused on a five member family dwelling. Following a brief calculation on the air exchange volume is done. The formula beneath shows the air volume needed to declare the unit as suitable. The constant wind was taken from the lowest values of prevailing winds available and finally the need and the obtained are compared. The ventilation has been considered for the panel construction and the smallest perpendicular area and its openings,

- Standard rate per person: 5L/sec
- Nº of dwellers: 5
- Unit volume: 60 m^3
- Volume exchanged: 90 m^3/h
- Constant wind: 5 m/s
- Opening area: 1.9 m^2

$$Air\ volume\ through\ the\ unit = Area \cdot Wind\ velocity$$

$$Air\ volume\ through\ the\ unit = 1.9 \cdot 5$$

$$Air\ volume\ through\ the\ unit = 9.5 \frac{m^3}{s}$$

As it can be seen, even with the half of the speed and the area, the air flow through the tent fits widely the requirements of ventilation standards.

Installation

The last part of the unit analysis is addressed to installations and its characteristics. The place where all the small bits and unions are. The extra parts that some of the areas of the unit must have. The most focused comfortable and services features are gathered in this section.

Power

The unit power source was set on photovoltaic panels. Hence connections to the grid or to the inner part of the tent must be arranged.

The power supply provided by the panels equals to 245 W and a peak of 28V and a current of 8.2 A. This value covers the consumption of 4 led lights, which will provide the enough light for the entire dwelling, and let charge some electronic devices.

Element	Characteristics	Units
Solar panel	245 W	1
Led Bulb	15 W	4
Sockets	IP44 protection	7
Battery	12V	1 or 2
Regulator	6 A and 12 V	1

Table: 53 Installation components for electric generation

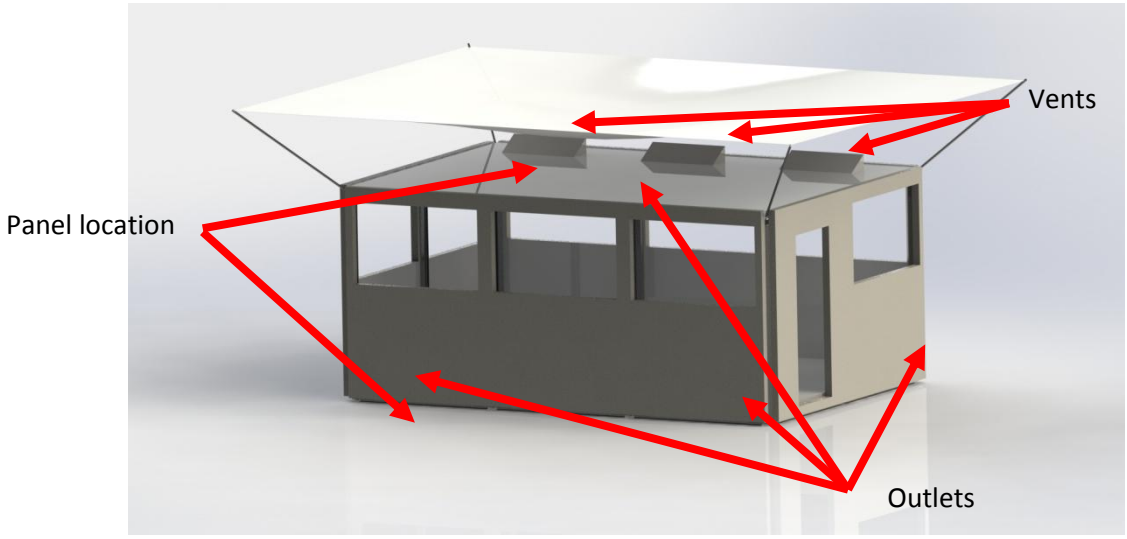


Image: 43 Location of installation parts

The solar panel could be placed on the roof of the unit or if it is not possible in the ground level taking shadows in to account.

On the pictures above the sockets or power outputs are pointed out to make clear where they are. The sockets and power outputs are placed in order to satisfy all the necessities the dwellers could use. The ones in the lower part are

mainly for appliances or charging device use while the ones above let the power produced on the solar panel to be transmitted to the inner part of the home and to be used by lights that can be attached to the top.

Vent openings are place on the roof of the panel unit to let combustion gases or harmful particles drift away.

In such areas hazards must be taken to account. Due to animals or environment and its related illness some measures have to be taken. Regarding openings and inside conditions the purposed solutions are the following ones.

Openings allow any small particle to get inside the unit and as any particle can be considered also any animal. There are two kinds of openings that has to face two different situations.

- Openings above the ground
- Openings on ground level

The first kind makes it difficult for animals which cannot fly to enter the unit, so small and medium size animals should not be considered as a problem. Those openings are windows or ventilation areas where air goes through. This let flying animals or insect an easy way in.

- To avoid animal invasion a sort of nets are attached to those openings.
- Dust is also a problem in arid areas but as filters are expensive and need maintenance this option is withdrawn.
- The use of nets should reduce the amount of environmental particle that can get inside the unit and block and stop completely the entrance of bugs and bigger animals.

The transmittance of illness by bugs or insects is common on refugees areas.

The second kind has a difficult approach due to its high activity and its position. Those openings are doors which have a constant use and therefore a high probability to let environmental particle and animals in from the outside. The net is a solution for permanent openings, for example to ease ventilation, but conventional doors which are most of the time closed a net would be a disturbance for the users. Then the solution should consider elevate the unit to avoid rodents and other animals get in as they are considered a health threat and probable unpleasant encounter.

The best option to elevate the unit and keep stability is using leveling jacks as is has been shown in former sections of this chapter. This additional part to the unit allows it to be raised above the ground and therefore natural ventilation can flow through the bottom surface of the unit empowering temperature control on the inside.

Once the health aspects are arranged the safety must take a consideration. The main issues are fire detection and prevention and natural phenomenon resistance.

Natural phenomenon due to weather conditions have been take to account in former sections such as the structure calculation and its covering. Environmental threats where considered for the parameters used to characterize the unit, the sturdiness of the frame and the bending resistance of the walling panels and shade components.

The UV, rust and mildew resistance are not considered as a specific section or chapter but those features are the qualities of the materials used on cladding mainly and then coating for those bits where rust could become a problem on the long term. Reducing mildew and rust avoids contagious fungus origin diseases.

One of the most feared unfortunate mishaps is fire. Crowded layouts and narrow separations between units could worsen the situation, but the focus must be put on the starting point which could be a unit.

As technology and safety protocols are not common in those areas and would be quite expensive, to do maintenance on smoke detector or temperature systems, the easiest and functional solution has been to use fire resistant materials. They need the lowest maintenance and are not that expensive on the long term. All the materials used as coating, shade or sheathing solution are fire resistant and meet the requirements of European regulations. The use of fire extinguish installations is also not a feasible option most of the places neither have a suitable water grid nor enough water resources.

Logistics:

As it was mentioned in former chapters once the unit is designed and after that eventually produced the most important issue focuses on how this product can be distributed and send in the easiest way possible to the place where it needs to be used.

The most usual way are the three conventional and well known air by plane, road by truck and finally see by cargo ship.

Some considerations before extracting the method and its implementations have to be displayed to understand which are the options and possible combinations that this product offers.

- First and most important weight and volume. The density of the whole unit varies depending if it is stewed or deployed. This differentiation must be understood because it can lead to wrong conclusions. The stowed unit is heavier compared to a conventional tent but sturdiness of the

dwelling designed is beyond comparing to a weak and non lasting solution. Once it is deployed the area and volume filled by the unit makes it reasonable.

- Minimum length and areas. Depending on which and how the unit components are packed the minimum sizes can vary.
- Material treatment or problems. Some of the materials need to be carefully treated due to fragility or loads resistance and others such as metals due to its rust problems need to be securely packed to avoid unfit material on arrivals.
- Parts of the unit can be purchased in local businesses. No need of sending material reduces cost and weight of the package and allows other parts to be massively sent.
- Sending system due to transportation method. A way to unify and ease the packing and transport of the stowed unit.

Regarding the first of the considerations above the result density of the stowed unit is 105 kg/m^3 and deployed the value can go down to 22.86 kg/m^2.This gives the answer of how much the unit will need from the transportation method carrying maximum. The full unit has the total weight of 1371.66 kg but as different configurations and combinations of the unit parts can be made the resultant weights are listed below.

	Parts	Weight (kg)	Volume (m^3)
Frame structure	54	1027,6	0,8
Panels	16	203,7	11,8
Shade	1	35,6	0,0
Tent	1	68,6	0,3
Installations	7	36,2	0,1
Frame structure + Tent	55	1096,2	1,0
Frame structure + Panels	70	1231,3	12,6
Frame structure + Shade	55	1063,2	0,8
Frame structure + Installation	61	1063,8	0,9
Tent + Shade	2	104,2	0,3
Panels + Shade	17	239,3	11,8
Tent + Panels	17	272,3	12,1
Tent + Panels + Shade	18	307,9	12,1
Tent + Panels + Installation	24	308,5	12,1
Tent + Panels + Shade + Installation	25	344,1	12,2
Frame structure + Tent + Shade	56	1131,8	1,1
Frame structure + Panels + Shade	71	1266,9	12,6
Frame structure + Tent + Panels	71	1266,9	12,6
Frame structure + Tent + Panels + Shade	72	1335,5	12,9
Frame structure + Tent + Panels + Installation	78	1336,1	12,9
Frame structure + Tent + Panels + Shade + Installation	79	1371,7	12,9

Table: 54 Unit parts combinations and characteristics

The combinations above do not add any trouble and cost to any deploy operation because it allows reducing shipment sizes and makes packing more efficient. And a way to see the amount of packages that can fit on a standard ISO cargo container is the following table. The table displays the package weight, the volume and depending on which container the amount of packages that fit.

	Max load (kg)	Volume (m^3)
20 ft	30400	33
40 ft	30400	67,5

Table: 55 Sea freight containers specifications

The first column depends on the volume of the package and the second one on the weight.

	20ft W	20ft V	40ft W	40ft V
Frame structure	29,6	42,6	29,6	87,1
Panels	149,2	2,8	149,2	5,7
Shade	853,9	1100,0	853,9	2250,0
Tent	443,1	132,0	443,1	270,0
Installations	839,8	423,6	839,8	866,4
Frame structure + Tent	27,7	32,2	27,7	65,9
Frame structure + Panels	24,7	2,6	24,7	5,4
Frame structure + Shade	28,6	41,0	28,6	83,9
Frame structure + Installation	28,6	38,7	28,6	79,2
Tent + Shade	291,7	117,9	291,7	241,1
Panels + Shade	127,0	2,8	127,0	5,7
Tent + Panels	111,6	2,7	111,6	5,6
Tent + Panels + Shade	98,7	2,7	98,7	5,6
Tent + Panels + Installation	98,5	2,7	98,5	5,6
Tent + Panels + Shade + Installation	88,3	2,7	88,3	5,5
Frame structure + Tent + Shade	26,9	31,3	26,9	64,0
Frame structure + Panels + Shade	24,0	2,6	24,0	5,3
Frame structure + Tent + Panels	24,0	2,6	24,0	5,3
Frame structure + Tent + Panels + Shade	22,8	2,6	22,8	5,2
Frame structure + Tent + Panels + Installation	22,8	2,6	22,8	5,2
Frame structure + Tent + Panels + Shade + Installation	22,2	2,5	22,2	5,2

Table: 56 Number of units that fit on the container depending on the weight and volume

The chosen option is the one that fits less depending in the volume against the weight. Hence the best table shows the cargo option for each package.

	20ft W	20ft V
Frame structure	29,6	
Panels		5,7
Shade	853,9	

	20ft W	20ft V
Tent		270,0
Installations		866,4
Frame structure + Tent	27,7	
Frame structure + Panels		5,4
Frame structure + Shade	28,6	
Frame structure + Installation	28,6	
Tent + Shade		241,1
Panels + Shade		5,7
Tent + Panels		5,6
Tent + Panels + Shade		5,6
Tent + Panels + Installation		5,6
Tent + Panels + Shade + Installation		5,5
Frame structure + Tent + Shade	26,9	
Frame structure + Panels + Shade		5,3
Frame structure + Tent + Panels		5,3
Frame structure + Tent + Panels + Shade		5,2
Frame structure + Tent + Panels + Installation		5,2
Frame structure + Tent + Panels + Shade + Installation		5,2

Table: 57 Selected units value for container

When the weight limits the package the 20 ft option is better but on volume issues the use of the 40ft container is the best. The numbers show the amount of packages that can be shipped on the container.

	20ft	40ft
Frame structure	29	
Panels		5
Shade	853	
Tent		270
Installations		866
Frame structure + Tent	27	
Frame structure + Panels		5
Frame structure + Shade	28	
Frame structure + Installation	28	
Tent + Shade		241
Panels + Shade		5
Tent + Panels		5
Tent + Panels + Shade		5
Tent + Panels + Installation		5
Tent + Panels + Shade + Installation		5
Frame structure + Tent + Shade	27	
Frame structure + Panels + Shade		5

	20ft	40ft
Frame structure + Tent + Panels		5
Frame structure + Tent + Panels + Shade		5
Frame structure + Tent + Panels + Installation		5
Frame structure + Tent + Panels + Shade + Installation		5

Table: 58 Real number of units for sea freight container

Image: 44 W&K sea freight container example

Now that package sizes have been set and configurations displayed the third consideration must be faced. The transportation may require some extra cares in order to keep all the materials in well shape until their use on its destination. Different materials and properties are considered in the following points.

- As shipment may take different ways the considerations on each one for metals is drafted next.
    - Air shipments are considered to be the fastest and the safest for materials. Neither extreme conditions nor heavy duty loads due to transport moving. Hence beams will be packed in the simple layout explained in former sections
    - Water shipments maybe the longest time option but the most useful for large loads and number of units. Water and salt may be drawbacks to metal beams so a plastic covering for each beam or group of beams should be arranged. Also careless treatment of the package should be considered so protections on the package or on the most delicate parts of the beams should be arranged.
    - Road and train transportation are maybe the most common way of shipment once the unit needs to be delivered in the exact deploying site. As this is usually the last step on shipments the protections considered may be the same as the shipment by sea methods. Road conditions on countries in seek of need may be

really damaged and therefore material bad treatment can be considered.

- Considerations regarding panels and tents canopy.
    - As polymers in fabric or foam state are used, no need for antirust measures has to be taken.
    - In all ways of shipments fabrics have to be packed on hard bags due to its weak resistance to scraping against sharp edges.
    - In all ways of shipments panels due to its limited load resistance have to be on the top of the package or packed all together.

Maintenance can be easily done by the dwellers just following the instructions enclosed with the package delivered. On the Tender of Specifications a thorough explanation is shown related to this subject and functionalities in order to use the unit and its characteristics the best way possible.

4.2 Resultant solution characteristics

This section gathers all the parameters extracted for the design of the dwelling shelter unit. This can be considered the brochure of the unit. The only two brochures available are the ones about the full tent and the full unit deployment.

Shelter unit Brochure:

The Refugee Transitional/Permanent Dwelling is a project to design a better refugee shelter, aimed on offering a place to call home for displaced families fleeing war zones, natural disasters or areas of political unrest. I am trying to create a more dignified life for the people who have had to flee their own homes.

The shelter unit designed gives a long-lasting alternative to currently-used refugee tents, which typically have a life span of only six months and don't face the reality of camps still running after 12 years.

The shelter unit lasts a span of 6 years and has been designed towards both durability and dignity, giving refugee families a more comfortable and secure place. It is upgradable, repairable and re-usable enabling significantly reduce life-cycle costs. . A better security is offered, ventilated and each has a renewable energy source if needed and demanded.

The shelter unit uses automated/chain production processes that ensure high production quality and minimal use of materials.

FLAT-PACKED/PILLAR-PACKED
Refugee camps are situated remotely and logistics are a challenge. Shipping takes time and cost can go up high. So reducing weight and volume is essential to reach as many people as possible in one shipment on aftermath situations. The shelter unit is flat-Packed in a maximum stowed volume of 12.9 m3 and a weight about 1372 kg .

MODULAR AND ADAPTABLE
Fly-in existing solutions are often functionally, culturally and socially inappropriate. Nowadays shelters don't take to account the need for family, community, social, and cultural expression. The shelter unit is designed around a modular framework and it can be upgraded with local materials. Temporal or transitional elements should be put out of the equation and focusing in long term or permanent situations. Frequently challenge for humanitarian shelter programs is structures resembling permanent housing solution that are not allowed by the land owner or host community. The shelter unit is modular and can easily be dismantled due to none require of concrete foundation.

The project is only a prototype and has never been tested in real situations. A feedback program could be set-up to get user insight, questionnaires, video recordings and interviews, technical monitoring: continuous measurement of technical performance including temperature (inside/outside), moisture (inside/outside), oxygen/CO2 levels, air transmittance, wind load, sun load (UV) and rain.

The shelter is an efficient and easily to assemble solution to the problem of housing people displaced by any circumstance. This kind of solution fills the gap between temporary tent shelter and permanent home.
The shelter unit is made out of S275JR structural steel frame structure build around a tent that can be upgraded to a solid cladding and also can be the base for a construction with local materials. The tents draped in the basic structure prevent water penetration until stronger covering or local materials can be gathered to create a solid cladding. As a result of its several sheathing possibilities the shelter adapts easily to almost every climate on Earth.

Options and characteristics:

Shelter Prototype:

Concept: Tent canopy attached to the steel frame structure as a first solution that can be upgraded with local or sandwich panels to make the shelter a permanent solution. The need of foundation is not required.
Features:

The measurements of the deployed shelter unit are:

- Length: 6 m
- Width: 4 m
- Height: 2.7 m
- Volume: 64 m^3
- Weight: 1372 kg
- Living area: 24 m^2

Functional characteristics:

- 5 person unit
- 2 hours assembly
- UV resistant
- Mildew resistant
- Fire resistant
- 6 years minimum lifespan
- 1kN/m^2 Snow load
- Stands prevailing winds of 48 m/s and 72 m/s gusts

Steel Frame Structure of S275JR structural steel composed by:

- 4 IPE 120 beams of a length of 1.835 m
- 6 IPE 120 beams of a length of 1.846 m
- 4 IPE 100 beams of a length of 1.835 m
- 6 IPE 100 beams of a length of 1.846 m
- 10 IPE 120 beams of a length of 2.5 m
- 4 IPE 80 beams of a length of 4 m
- 4 Roof corners with pole adapter
- 4 Base corners
- 8 Triaxial joints
- 4 Flat joints
- 8 Tent lockers
- 4 Shade poles
- 48 Snap fits:
    - 12 57mm
    - 12 63mm
    - 12 100mm
    - 12 120mm

Panel and covering:

- 16 Insulating PVC insulating panels:
    - 1 Door panel (2x2.5x0.1m)
    - 9 Windows panels (2x2.5x0.1m)
    - 3 Roof panels with a vent (2x4x0.1m)
    - 3 Floor panels (2x4x0.1m)
- 1 Shade of PVC fabric (8.2x6.2x0.002m)
- 1 PVC tent canopy (6x2.5x4m)
- 9 Methacrylate windows (1.05x1.8x0.002m)
- 1 Pine wood door (0.9x2.2x0.03m)

Power generation & consumption:

- 1 245W Capacity solar panel
- 2 12V Batteries
- 4 18W Led lights
- 7 Outdoor outlets/sockets
- 1 12V/24V Regulator

Logistics:

- Flat packed unit storage and transport.
- 5 Full unit shipment on a 40ft container

Possible Modifications:

- Use of local not standard materials for covering with a maximum distributed load of 1.57kN/m
- Standard parts can be purchased on local business
- Royalties for not send parts but to give access to drafts

5 Economic evaluation

The following chapter gathers the cost of producing and assembling the unit characterized in former sections. The transportation costs are not 100% reliable but give an idea of what means to move the product quantity on a range that may be the real one. First a product cost of the entire unit is calculated and a second part regarding a sales estimation tells the viability of the unit.

5.1 Production costs

This section has a computation of the cost of the unit. The process to compute the cost is set as follows. First each part has an associated price. Once all the parts have an associated price by material or acquisition a second revaluation of that part is done. This part adds costs regarding manufacturing or maybe assembly. After the single part value is finished cost estimation on the different combinations is computed. Eventually a price per unit and configuration is displayed. As every configuration has different weights and dimensions transportation costs are also listed.

The unit parts are the listed below:

Elements	Nº Parts
IPE 120x1,835	4
IPE 120x1,846	6
IPE 120x2,5	10
IPE 100x1,835	4
IPE 100x1,846	6
IPE 80x4	4
Roof corner	4
Base corner	4
3Axis joint	8
Flat joint	4
Door panel	1
Windows panels	9

Elements	Nº Parts
Floor panel	3
Roof panel	3
Shade	1
Shade pole	4
Snap fit 57	12
Snap fit 63	12
Snap fit 100	12
Snap fit 120	12
Locker	8
Canopy	1
Windows	9
Door	1
Solar panel	1

Elements	Nº Parts
Battery	2
Led Bulb	4
Sockets	7
Regulator	1

Table: 59 Unit components list

Now that the parts are known a research on prices and budgets must be carried out. First the needs of material of every part are drafted and then a purposed bugged are considered. Finally the result budget is accepted and taken for further estimations on further sections.

Elements	Nº Parts	Part Weight (kg)
IPE 120x1,835	4	18,9
IPE 120x1,846	6	19
IPE 120x2,5	10	23,8
IPE 100x1,835	4	14,8
IPE 100x1,846	6	14,86
IPE 80x4	4	23,9
Roof corner	4	7,8
Base corner	4	7,69
3Axis joint	8	5,12
Flat joint	4	3,77
Door panel	1	6
Windows panels	9	6
Floor panel	3	13,2
Roof panel	3	12,7
Shade	1	35,6

Elements	Nº Parts	Part Weight (kg)
Shade pole	4	11
Snap fit 57	12	1,15
Snap fit 63	12	1,2
Snap fit 100	12	1,5
Snap fit 120	12	1,65
Locker	8	0,2
Canopy	1	68,6
Windows	9	11,3
Door	1	20,2
Solar panel	1	19
Battery	2	8
Led Bulb	4	--
Sockets	7	--
Regulator	1	--

Table: 60 Unit components and associated weight

Most of the information on producing price was found in Chinese based websites and some European ones were withdrawn due to the price and conditions. The searched offers can be found on the annexes. After the comparison of the prices and offers found the resultant prices are gathered on the list below.

	Element	Material	Kg price	M.O.Quantity (kg)
Structure	Beams	S275JR	0,720	25000
	Plates	S275JR	0,630	10000
	Pipe	S275JR	0,650	100
		Material	liter price	M.O.Quantity (L)
	Coating	Epoxy	20	No

	Element	Material	Kg Price	M.O.Quantity (kg)
Covering	Locker	Stainless steel	4,500	1000
	Fastening	S275JR	0,720	1000
	Windows	Polymethyl methacrylate	2,970	1000
	Wood	Pine	0,52	19300
		Material	m2 price	M.O.Quantity m2
	Panel	PVC foam	21	500
	Canopy/shade	PVC	2,8	1000

	Element	Unit price
Installation	Sockets	3,58
	PV panel	318
	Light Bulb	32
	Battery	15
	Regulator	35

Table: 61 Structure, covering and installation material price

The tables above show which the values are and what they are referred to. Next a display of the total cost per element is shown.

Elements	Nº Parts	Part Weight (kg)	Unitary price	Total Cost
IPE 120x1,835	4	18,9	0,72	54,432
IPE 120x1,846	6	19	0,72	82,08
IPE 120x2,5	10	23,8	0,72	171,36
IPE 100x1,835	4	14,8	0,72	42,624
IPE 100x1,846	6	14,86	0,72	64,1952
IPE 80x4	4	23,9	0,72	68,832
Roof corner	4	7,8	0,63	19,656
Base corner	4	7,69	0,63	19,3788
3Axis joint	8	5,12	0,63	25,8048
Flat joint	4	3,77	0,63	9,5004
Door panel	1	6	21	105
Windows panels	9	6	21	945
Floor panel	3	13,2	21	516,6

Elements	Nº Parts	Part Weight (kg)	Unitary price	Total Cost
Roof panel	3	12,7	21	516,6
Shade	1	35,6	2,8	134,4
Shade pole	4	11	0,63	27,72
Snap fit 57	12	1,15	0,63	8,694
Snap fit 63	12	1,2	0,63	9,072
Snap fit 100	12	1,5	0,63	11,34
Snap fit 120	12	1,65	0,63	12,474
Locker	8	0,2	4,5	7,2
Canopy	1	68,6	2,8	274,4
Windows	9	11,3	2,9	294,93
Door	1	20,2	0,5	10,1
Solar panel	1	19	318	318
Battery	2	8	15	30
Led Bulb	4	--	32	128
Sockets	7	--	3,6	25,2
Regulator	1	--	35	35

Table: 62 Unit elements price

Now the same elements are majored due to either manufacturing process or earning percentage on raw material. The addition to raw materials is the 20% of its initial cost and the additional rate for manufactured parts is the 60%

Elements	Nº Parts	Total Cost (€)	Total cost with added value (€)
IPE 120x1,835	4	2,88	65,3184
IPE 120x1,846	6	4,32	98,496
IPE 120x2,5	10	7,2	205,632
IPE 100x1,835	4	2,88	51,1488

Elements	**Nº Parts**	**Total Cost (€)**	**Total cost with added value (€)**
IPE 100x1,846	6	4,32	77,03424
IPE 80x4	4	2,88	82,5984
Roof corner	4	2,52	31,4496
Base corner	4	2,52	31,00608
3Axis joint	8	5,04	41,28768
Flat joint	4	2,52	15,20064
Door panel	1	105	126
Windows panels	9	105	1134
Floor panel	3	172,2	619,92
Roof panel	3	172,2	619,92
Shade	1	134,4	161,28
Shade pole	4	2,52	33,264
Snap fit 57	12	7,56	13,9104
Snap fit 63	12	7,56	14,5152
Snap fit 100	12	7,56	18,144
Snap fit 120	12	7,56	19,9584
Locker	8	36	11,52
Canopy	1	274,4	329,28
Windows	9	26,1	353,916
Door	1	0,5	12,12
Solar panel	1	318	381,6
Battery	2	30	36
Led Bulb	4	128	153,6
Sockets	7	25,2	30,24
Regulator	1	35	42

Table: 63 Unit elements with added value

Each item of the unit as has been shown in former sections has its price and to obtain a total price just the sum of all the components has to be carried out. However due to transportation facilities and also components combination the price cannot be summarized in only one value. Each configuration has its own specific characteristics but for those parts that have been designed and produced specially for this unit and are not shipped because they can be manufactured or purchased locally can be compensated by royalties for unit sold as the drafts can be sent to let local producers manufacture them. The rate for each part that has not been sent is the 10% of the cost the shipped part is.

Each unit combination has transportation costs that have to be added. The next chart shows shipping conditions and characteristics of each combination. The shipping conditions characteristics are based on a simulated shipment to Sudan. Two other places where evaluated but where cheaper and as what it is intended to do here is check the most unfavorable but plausible situation the distance from Barcelona to Port Sudan is evaluated.

- Sending from Barcelona, Spain
- Delivery to Port Sudan, Sudan
- Delivery time: 22 days
- 20ft container: 2.530€
- 40ft container: 4.434€

Table with containers and the packages that fit

	20ft	40ft
Frame structure	29	
Panels		5
Shade	853	
Tent		270
Installations		866
Frame structure + Tent	27	
Frame structure + Panels		5
Frame structure + Shade	28	
Frame structure + Installation	28	
Tent + Shade		241
Panels + Shade		5
Tent + Panels		5
Tent + Panels + Shade		5
Tent + Panels + Installation		5
Tent + Panels + Shade + Installation		5
Frame structure + Tent + Shade	27	
Frame structure + Panels + Shade		5
Frame structure + Tent + Panels		5
Frame structure + Tent + Panels + Shade		5
Frame structure + Tent + Panels + Installation		5

	20ft	40ft
Frame structure + Tent + Panels + Shade + Installation		5

Table: 64 Units that fit on a container

	20ft price per package (€)	40ft price per package (€)	Price after transportation (€)
Frame structure	87,2		786,4
Panels		886,8	3752,7
Shade	3,0		197,5
Tent		16,4	357,2
Installations		5,1	648,6
Frame structure + Tent	93,7		1237,3
Frame structure + Panels		886,8	5425,9
Frame structure + Shade	90,4		1074,3
Frame structure + Installation	90,4		1525,3
Tent + Shade		18,4	573,1
Panels + Shade		886,8	4837,0
Tent + Panels		886,8	4996,7
Tent + Panels + Shade		886,8	5194,2
Tent + Panels + Installation		886,8	5645,3
Tent + Panels + Shade + Installation		886,8	5842,8
Frame structure + Tent + Shade	93,7		1434,8
Frame structure + Panels + Shade		886,8	5623,4
Frame structure + Tent + Panels		886,8	5783,1
Frame structure + Tent + Panels + Shade		886,8	5980,6
Frame structure + Tent + Panels + Installation		886,8	6431,7
Frame structure + Tent + Panels + Shade + Installation		886,8	6629,2

Table: 65 Price of each package depending on container use

Now that the combinations and its transportation characteristics are defined the final price has to be computed. The following charts display the items of each unit combination and the final price for the most complete units.

	Price after added VAT 21% (€)
Frame structure	951,6
Frame structure + Tent + Shade	1736,2
Frame structure + Panels + Shade	6804,3
Frame structure + Tent + Panels + Shade	7236,6
Frame structure + Tent + Panels + Installation	7782,3
Frame structure + Tent + Panels + Shade + Installation	8021,3

Table: 66 Most useful package combinations price after transport added cost

The prices displayed above show the final price for one single unit or a bulk of packages that could be shipped on a container. However if the conditions can be escalated a forecast of a 10% saving could be arranged on 1000 and a 20 % in orders of 20000 units. The resulting prices would be the following ones.

	Price after added VAT 21% (€)	Forecasted price for 1000 units	Forecasted price for 20000
Frame structure	951,6	856,4	761,2
Frame structure + Tent + Shade	1736,2	1562,6	1388,9
Frame structure + Panels + Shade	6804,3	6123,9	5443,4
Frame structure + Tent + Panels + Shade	7236,6	6297,8	5598,05
Frame structure + Tent + Panels + Installation	7782,3	7004,1	6225,8
Frame structure + Tent + Panels + Shade + Installation	8021,3	7219,2	6417,0

Table: 67 Price forecast after VAT of 1, 1000 and 20000 units order

The estimated cost of the full equipped unit is about:

- Single unit: 334.2 €/m^2
- 1000 units: 300.8 €/m^2
- 20000 units: 267.4 €/m^2

5.2 Sales estimation

Now that the price per unit is known a brief evaluation on which the optimal bulk shipment and number of units to sell is carried out. As sales are arranged with governments and NGOs the forecasts used to determine those parameters are the same statistic data they generate and gather.

As UNHCR affirm on their reports regarding refugees and internal displaced population the raw numbers are about a 51.2 million people seeking for house and help in 2013. This data has not been updated yet but that gives an idea of the volume of potential units that could be sold.

The forecasted amount of displaced population due to actual conditions has been set in a 30000 people per day in 2014. The former years that displaced population rate was 32000 people per day in 2013 a rate of 23400 people per day in 2012 and a rate of 14200 people per day in 2011.

The forecast or gathered data regarding this rate in 2015 have not been updated yet but as it can be seen either is higher or the level has a lower variation.

So if just a 10% of that displaced population or even a lower 5% had the chance to get a unit the result would be the following one.

- 30000 people per day make a total amount of nearly 11 million people on a year.
- The 5% of that amount is 547500 people.
- Each unit could fit 5 people which can be seen as a need of 109500 units.
- The budget for those units, basing the calculations on the most expensive option, is a total of 878M €.
- This could be lowered due to the high amount demanded on a budget of 703 M €.
- The forecast means that this should not and could not be paid neither produced nor arranged in a single move. But gives an idea of the opportunities that this field can offer for a good product at a good price.

6 Conclusions

The design of the shelter for refugees is concluded and therefore a general evaluation must be done. In order to extract the proper conclusions the goals set in the beginning of this project are drafted again and a brief comment that shows the realization or not of the task is written. Each former section had a brief comment on its topic and the steps forward achieved on each end of the chapter. Now the goals and its evaluation are listed below:

- Low cost product (regarding existing solutions) reduction of material cost through intelligent design
    - As it may seem that the price is quite high for a modular and transitional shelter, it is not. The price has a relation on materials used and thermal and mechanical characteristics of the unit. As many of the current solutions just meet the requirement to cover from the environment, the designed unit provides a safe area form natural phenomenon and weather conditions in a large range of variations.
    - The earnings by selling royalties of custom parts for the unit when those can be produced on the local industry reduce the cost.
- The method of sending to the needed area just what has been asked, from the sort of possibilities that are offered, reduces both the weight of the unit and the production price. The use of standard parts makes it easy to find a local business that can offer parts of the module on the spot.
- Reduction of material waste through efficient construction techniques
    - Most of the materials used are manufactured ones. Hence no material waste cost need to be evaluated. The only manufacturing

process that can be observed on the unit parts is welding of elements that are already sized for the maker.

- Easy to assemble and deploy reducing time and manpower.
    - The use of a clamp fastener that needs just the beam to be pushed against it and then pinned is the fastest way that a secure structure can be assembled. The uses of just pin plates that do not have any protuberance are toilsome and need a lot of bits that can be lost.
    - On panel fixation the snap fit system that secures the panel to the beam needs just a gentle push to obtain a reliable wall.
    - The most important part that is erecting the structure allows it to be assembled by areas or modules and as those weights can be easily carried by 2 or 3 man no difficulties or long labor hours to build the unit are needed.
    - Once the unit has done its commitment the same way it was assembled it can be disassembled, no heavy duty equipment or tools are needed to do so.
    - The part that needs from external equipment is the one the packed unit is unloaded from the transportation method to the spot where it is erected.
- Low weight after packing the module.
    - This one has not been achieved. The mechanical requirements a functional and safe shelter need make it heavy when the unit is stowed. Once the unit is erected that density decreases rapidly.
    - The options were not the whole unit

- Find the optimal measurements, the best shape and structure of the module.
    - Rectangle design makes it the easy to understand when it has to be assembled.
    - Standard and cheaper parts can be used.
    - Sizes of components can be used in different parts and purposes.
    - It is not the strongest shape for lateral loads as can be seen on the structure analysis.
    - All the inside space can be used due to no changes on height throughout the sections.
- Find the optimal wall, structure and sheathing materials
    - The use of a fabric for the tent canopy is not the best solution against natural phenomenon of any kind but gives the chance to put a temporary covering while the panel permanent solution is arranged.
    - The panel selection has been a full success due to its insulation properties and it is lightweight.
    - The use of a shade allows reducing solar effects.
    - The structural material (S275JR) was chosen by its properties and by construction codes recommendation.
- Capability of being assembles worldwide by its adaptable characteristics
    - As it has been said the use of standard parts makes it suitable for any place where the need strikes and the material properties that take climate areas in to account work well.
- Viability of different configurations to fit the market targeted

  - This subject of different configuration has not been treated due to its associate cost. Even thought the unit has to be assembled different combinations need different or a higher range of parts that add weight and cost to the product.
  - On the configuration topic just some different options where analyses but just one is selected. The variability of the actual unit was not considered.

- Usage of coverings that will reduce outside environment conditions on the inside.
  - The use of insulating materials allows temperature and sound reduction whichever the environment is.
  - The tent canopy does not have any effect on environmental conditions. Just some weather protection.
- Energy Self-sufficiency of the unit
  - As the unit does not need any energy for interior environment control the possible produced energy can be low and not essential.
  - The use of a solar panel if it is desired allows to power a set of lights and charge or power home devices.
- Lifespan focused on permanent situations and reusable
  - The life span has not been analyzed as a specific matter but as each product supplier has a range of 6-10 years or lifespan on each product a considered 6 years of safe and useful unit is granted.

  - The unit is heavy due to the material used, but each component was either tested or selected to be useful but not over evaluated.

- Find a universal ground secure unit system
  - As the unit weight can make it sink on the ground the corner shapes and junctions can be used as the ground secure system.
  - Specific lever jacks are not design for the unit as it difficult the unit stability.
- Achieve safety requirements of the unit fire retardant, smoke and gases ventilation and illness transmission animals.
  - The unit has a range of indirect and passive measures for avoiding and reducing hazards.
  - Animal risks depend on the area of deployment but nets are provided in order to decrease illness transmittance.
  - The vent locations on the roof and the wide windows opening areas allow a high rate of air circulation and renovations.
  - The materials used on covering are fire retardant tested by the manufacturers and UV resistant as well as mildew resistant.
- Weather and climate conditions resistant
  - The tent canopy is water proofed and the sandwich panels as well.
  - The use of the shade makes it easier for the covering to work and wind and snow are taken to account on the components resistance.
  - The unit can be deployed everywhere except on extreme cold zones.

- Viability of integrated grid and plumb installation
    - As UNHCR requirements do not consider any important electric grid or a plumbing installation no considerations or analysis were done
- Functional and reliable way of transportation and packing.
    - The best way of transportation for the stowed unit is by sea freight.
    - Sea fright has the lowest cost per container and huge loads as well as large amount of units can be shipped in a single shipment.

The major conclusion is that against the actual solutions the unit designed has better performance in any climate and situation. It weight may seem excessive but its mechanical and thermal features are above the average of any solution that is focused on humanitarian help. The cost in the sort term compared to conventional tents is too high but on the long run is an option that can meet both requirements being a temporary solution with guaranties and comfort. Due to the price and maybe the shipment need is the best option for developed countries emergency needs instead of poor and needed countries. The comfort and characteristics of the unit could be considered as positive and necessary for an emergency occurred in Europe or North America, where the budget will not be an issue and resources and solutions need to meet standards and requirements.

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