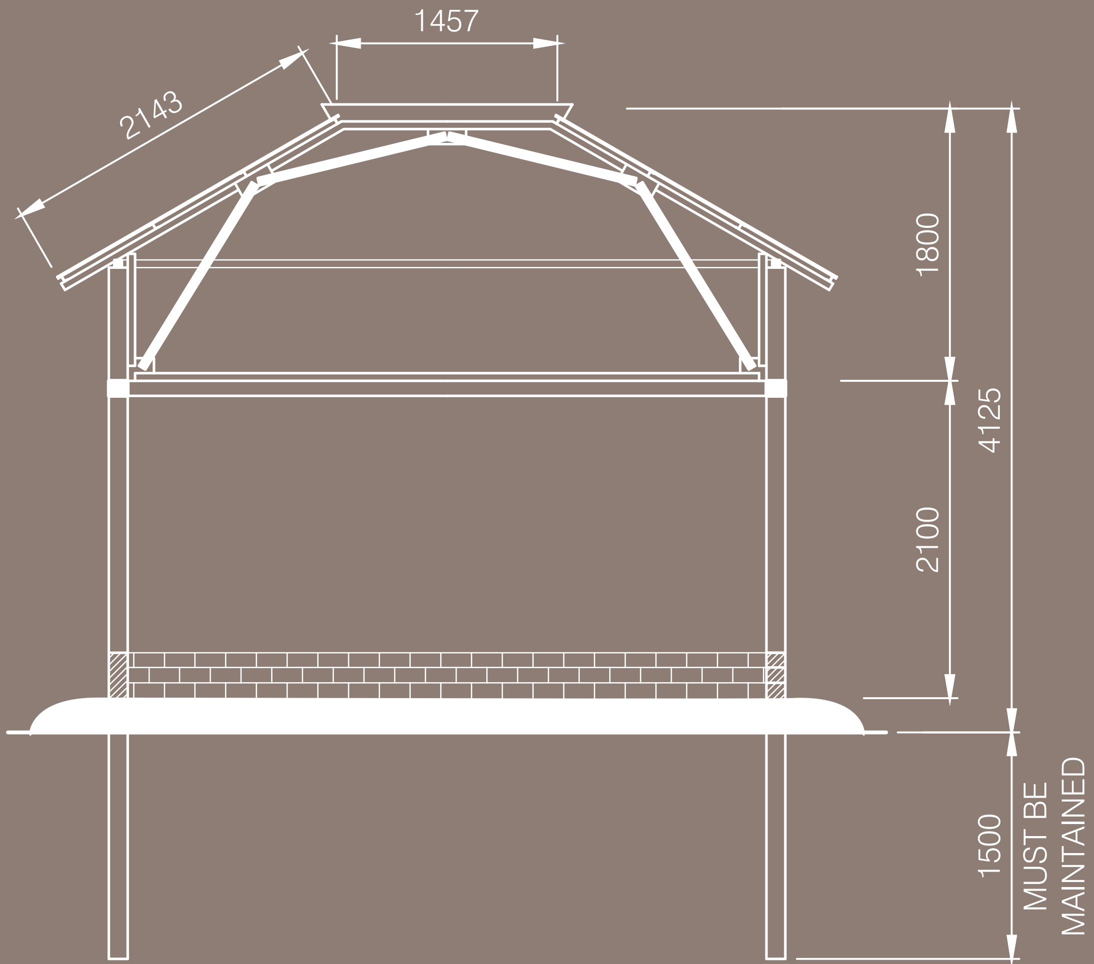

Post-disaster shelter:

Ten designs

www.ifrc.org
Saving lives, changing minds.

International Federation
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Post-disaster shelters: Ten designs

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Post–disaster shelter:
Ten designs

Strategy 2020 voices the collective determination of the IFRC to move forward in tackling the major challenges that confront humanity in the next decade. Informed by the needs and vulnerabilities of the diverse communities with whom we work, as well as the basic rights and freedoms to which all are entitled, this strategy seeks to benefit all who look to Red Cross Red Crescent to help to build a more humane, dignified, and peaceful world.

Over the next years, the collective focus of the IFRC will be on achieving the following strategic aims:

1. **Save lives, protect livelihoods, and strengthen recovery from disasters and crises**
2. **Enable healthy and safe living**
3. **Promote social inclusion and a culture of non-violence and peace**

IMPORTANT NOTICE:

The designs and information provided in this book must be treated as guidance and examples only and evaluated for suitability in the context of specific local conditions. Risk is inherent in shelter design after natural disaster, and caution must be exercised so as not to increase the threat to disaster affected persons. Users of this book do so solely at their own risk.

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Contents

Foreword

Meeting shelter needs in the aftermath of disasters and crises remains a major challenge for governments, humanitarian agencies and, most importantly of all, for the affected populations themselves. Beyond survival, shelter is an essential contributor to security, personal safety, protection from the climate and resistance to ill health and disease. Ensuring adequate shelter provides disaster affected households with a place from which they can address their other needs, promoting the use of existing capacities, resources and social networks. Although supporting self-recovery shelter activities by individual affected households is commonly recognised as being preferable, the context of a specific emergency may render such an approach impractical. The scale of the disaster and the resulting shelter need, the impact of the disaster on local resources and the local economy, and the need to address the inherent shelter or settlement risks as part of the sheltering process may require the use of interim solutions as a basis for temporary or longer term shelter. Any such interim shelter design needs to reflect the local context, and where possible local construction technologies and cultural preferences – and the time needed to develop and agree such solutions after the disaster has occurred including the required engineering and specification development can significantly delay the shelter response.

In 2011, leading National Red Cross and Red Crescent Societies compiled a "menu" of interim shelter solutions that had been successfully used following a number of disasters in different regions. In addition to fully engineered scheme designs, specifications and bills of quantity to enable rapid procurement, each solution was accompanied by guidance on how the shelter could be adapted to meet a range of different geographical contexts and design configurations, whilst retaining the required structural integrity and performance. Subject to the design, cost and performance parameters defined following a disaster, the technical information and guidance provided could also be utilised to develop alternative solutions in accordance with these parameters. It is important to acknowledge that any one shelter design will inevitably be a compromise between cost, performance, durability, cultural appropriateness and building technologies. The information provided should be used to inform the development of a disaster-specific shelter response and not to be used as a catalogue of "ready to use" designs for any context.

"Transitional shelter – Eight designs" was very well received on publication, being welcomed by both practitioners for its technical information and generalist decision-makers for its wide-ranging applicability. Although developed by the Red Cross Red Crescent Movement for its own internal use, the selected shelter designs reflected field-based solutions and are not proprietary. Shelter practitioners within leading international non-governmental organisations and United Nations agencies also welcomed this initiative, identifying additional shelter solutions for potential inclusion in a future edition and encouraging the regular technical cataloguing of the practice of emergency shelter in such an initiative.

This second edition – "Post-disaster shelter: Ten designs" – includes six shelter solutions from National Red Cross and Red Crescent Societies and four shelter solutions from other leading humanitarian agencies. A working group consisting of technical representatives from these and other National Societies and agencies was established to identify the preferred designs and to oversee the engineering review and detail guidance to be included. The schemes selected reflect a range of disaster contexts and climatic conditions, differing materials and building technologies, and different approaches to the process of sheltering including temporary, transitional, progressive and core shelter.

The development of the second edition has benefited from the contribution of AMEC, a leading engineering and construction project management company, as the technical partner and responsible for the structural analysis and technical guidance provided.

This publication and the technical guidance within is available for use by all interested practitioners and agencies. It is anticipated that this will generate yet more interest in a further edition, and IFRC will continue to collaborate with National Red Cross and Red Crescent Societies, humanitarian shelter agencies and interested technical and corporate partners to contribute to the knowledge, expertise and informed practice of the sector.

Graham Saunders
Head, Shelter & Settlements Department
International Federation of Red Cross
and Red Crescent Societies

Acknowledgements

This book was compiled and edited by Joseph Ashmore and Corinne Treherne (IFRC).

Technical assistance and shelter analysis was provided by AMEC. AMEC is a focused supplier of consultancy, engineering and project management services in the world's oil and gas, mining, clean energy, environment and infrastructure markets. Being involved in this book of shelter design analyses has allowed AMEC to apply many of the skills that they use every day for their customers and at the same time help people in need worldwide. The AMEC team, namely Justin Desjarlais, Edward Goulet, Colleen Haskell, Roger Jinks, Gary Lide, and Jeff Walker, has been proud to be able to support the International Federation of Red Cross and Red Crescent Societies in this important project.

This book was the output of the Transitional Shelter Task Group of the Red Cross and Red Crescent. It is based on the projects and contributions from the following national societies:

- American Red Cross
- Australian Red Cross
- Bangladesh Red Crescent
- Belgium Red Cross
- British Red Cross
- Canadian Red Cross
- Finnish Red Cross
- French Red Cross
- German Red Cross
- Haitian Red Cross
- Italian Red Cross
- Myanmar Red Cross
- Netherlands Red Cross
- Palang Merah Indonesia
- Pakistan Red Crescent
- Peru Red Cross
- Qatar Red Crescent
- Spanish Red Cross
- Swedish Red Cross
- Swiss Red Cross
- Vietnam Red Cross

Additional designs and information were kindly provided by the Norwegian Refugee Council (NRC), Catholic Relief Services (CRS) and Handicap International.

This is the second compilation of shelter designs, and draws upon "Transitional shelter: 8 designs", in which the analyses were conducted by Arup International Department.

1 How to use this book

This book contains reviews by structural engineers of shelter designs built in significant numbers. It is intended that the information contined in this book will support the early stages of shelter programmes and inform shelter decision making.

The shelters in this book **should not be used without being adapted to the context**. Inclusion of shelter designs does not mean that they have been endorsed by IFRC.

Shelter is more than a design. Designs should be developed as part of the implementation of a shelter strategy.

Acceptable risk

As shelters are a balance of factors, including safety, lifespan, timeliness and cost (see section A.1 Deciding to build shelters), they are seldom perfect from a structural perspective (see analyses in Sections B.1 - B.8). However, designs that are not perfect structurally can be appropriate technical responses given the constraints of a situation.

Shelter practitioners must make informed decisions based on what is an **acceptable level of risk**. Critically, shelters must not increase the threat to those living within them.

1.1 What is in this book?

This book contains the findings of technical reviews of ten shelter designs. It is divided into sections:

- **Section A** discusses shelter design briefs, includes a programming checklist and explains how the shelters in this book were reviewed.
- **Section B** contains summary findings of the technical reviews for the ten shelters.
- **Annexes** contain details of materials, a template design brief, conversion tables, a glossary, and references.

1.2 What is not in the book

This book **is not a guideline on shelter programming**. However, A.3 Checklist for shelter projects provides an overview of key programmatic issues. Broader issues surrounding shelter projects such as community mobilisation, land, water, sanitation and hygiene promotion components of shelter programmes are not included in this book.

The book references external guidance wherever possible and does not focus on other aspects of the shelter programmes from which the designs came.

This book does not discuss shelter project processes. It focuses only on shelter design and specification issues

1.3 Audience

This book is targeted at people within the Red Cross and Red Crescent movement working in the emergency and early recovery phases after a natural disaster. The primary audience is shelter delegates. It is also intended to inform those planning and managing shelter programmes. It is assumed that readers have a strong understanding of the need for participation and experience in ensuring the close involvement of disaster affected people.

This scope of this second edition has been broadened to included designs from several other organisations.

1.4 Criteria for selection of designs

The following criteria were used to select the shelter designs in Section B of this book.

- The project had been implemented and significant numbers of the shelters were built.
- The designs would include post–disaster shelters but would not include complete permanent houses.
- Each shelter took a maximum of one month of construction on site.
- Accurate technical information was available.
- The shelters were appropriate for the people for whom they were built. They also illustrated flexibility of use, encouraged efficiency of design, and could withstand local hazards. They used materials which could be incorporated into longer term recovery shelter options.

2 Shelter terminologies

Sheltering as a process not a product

Terminologies such as “Transitional shelter”, “Progressive shelter” and “Core shelter” are often used for shelter after disasters and as a result of conflicts. Most terminologies relate to an approach rather than a phase of response, recognising that post–disaster shelter is often built, upgraded and maintained by the affected populations themselves, and this self-management should be supported.

However, this book focuses on the designs of the shelters themselves, and not the surrounding sheltering process. In so doing, we recognise that a shelter design cannot be transitional or progressive on its own- it is the context in which it is built that is critical. For example a design consisting of a simple timber frame covered in tarpaulin can be part of emergency shelter support, temporary shelter support, transitional shelter support or even progressive shelter support.

Definitions and terminology

For the purposes of this book, we use the following definitions for types of shelters. Each strongly refers to the context in which the structure is built:

Emergency shelter

Short term shelter that provides life saving support, the most basic shelter support that can be provided immediately after the disaster.

T-shelters

A term often used to mean either Temporary Shelter or Transitional Shelter.

Temporary shelters

Post disaster household shelter designed as a rapid shelter solution. By prioritising speed and limiting costs of the construction, the llifetime of the shelter may be limited.

Transitional shelters

Rapid, post disaster household shelters made from materials that can be upgraded or re-used in more permanent structures, or that can be relocated from temporary sites to permanent locations. They are designed to facilitate the transition by affected populations to more durable shelter.

Transitional shelters respond to the fact that post disaster shelter is often undertaken by the affected population themselves, and that this resourcefulness and self-management should be supported.

See Sphere Shelter and Settlement Standard 1: Strategic Planning, Guidance note 6 (📖 Sphere Project, Sphere)

Progressive shelters

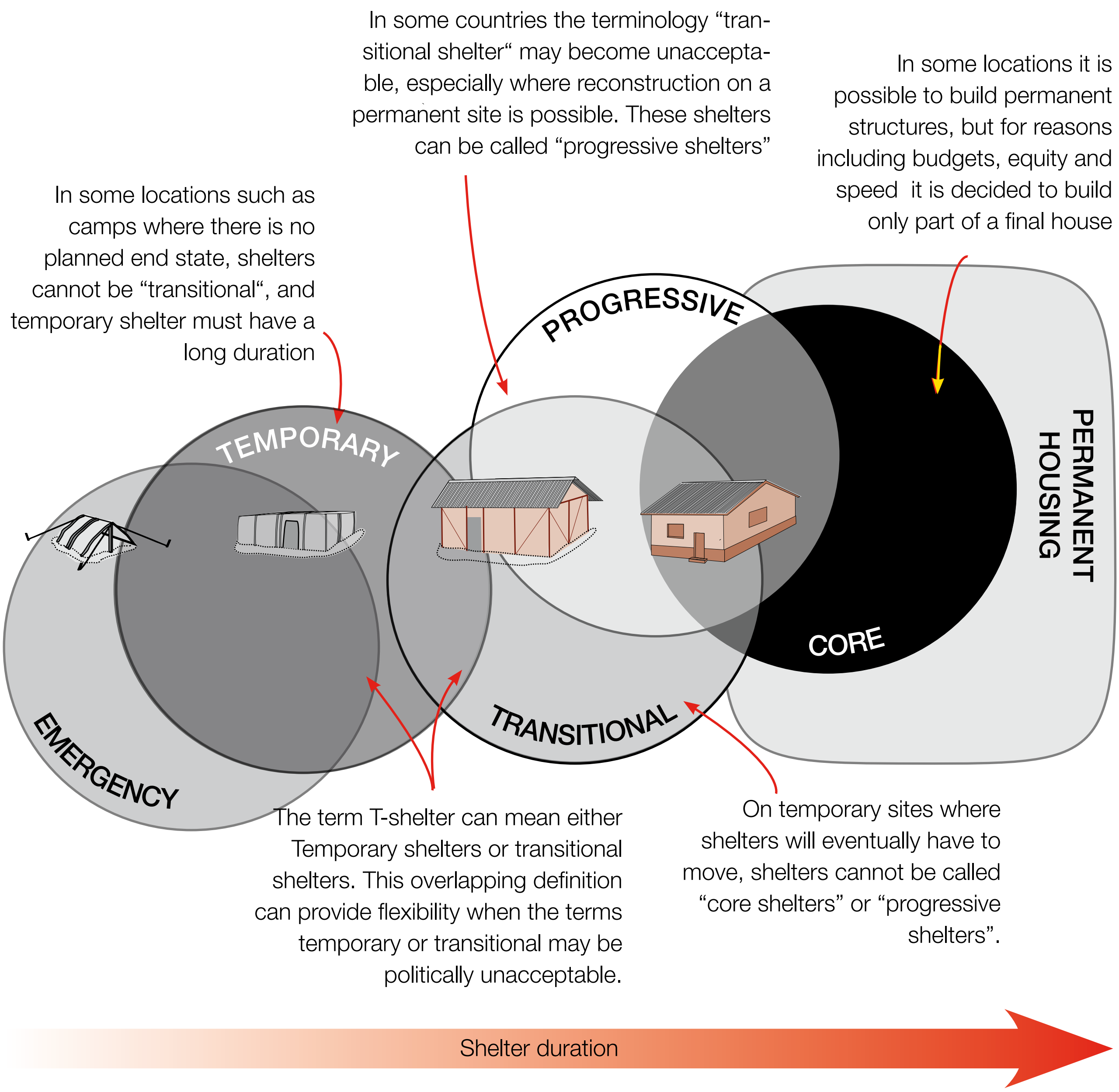
Post disaster rapid household shelters planned and designed to be later upgraded to a more permanent status. This is achieved by integrating future transformation and alteration possibilities in structural basis of the unit.

Core shelters / One room shelters

Post disaster household shelters planned and designed as permanent dwellings, to be the part of future permanent housing, allowing and facilitating the future process of extension by the household, following its own means and resources.

The aim of a core shelter is to create one or two rooms, providing safe post disaster shelter that reaches permanent housing standards, and facilitates development, but not completing a full permanent house.

Overlapping definitions



Caption: Illustration of overlaps between some of the different shelter terminologies in use. Remember that individual designs might fall into many of the categories, it is the context that is important in agreeing the terminology.

Which terminology to use

The decision on which terminology to use is a mixture of contextual factors. These range from the level of permanence expected of the shelters and the materials from which they are made, the site on which they are built and local politics. In some locations governments might take a position against a certain terminology.

- Emergency shelters are usually provided in the aftermath of a disaster.
- T-shelters, Temporary shelters or Transitional shelters should usually be designed to be relocated and re-used.
- Progressive shelters and core shelters are built on permanent sites with the goal of becoming part of permanent solutions.

See *Sphere Project, Sphere*, and *Sheltercentre, UN, DfID, Shelter after Disaster*.

Section A
Context and Design

This section puts shelter design in context and focuses on the design brief for a post disaster shelter (A.2). The process that is used in this book for checking the structures of a shelter is summarised in A.4. Programmatic issues in shelter projects are briefly addressed in a checklist in A.3, but are not the main emphasis of this book.

Contents

A.1 Deciding to build shelters

A.1.1 Is construction the best shelter program?

Following a disaster, affected people often begin repairing their houses or permanently re-building. There might be many ways of supporting affected people to access suitable shelter. Building shelters might be one of them. Examples of different types of shelter projects can be found here: 🕮 UNHABITAT, IFRC, UNHCR, ShelterCaseStudies.org.

Successful assessments are required for all shelter projects. Issues such as land availability, hazard risks, access to livelihoods, water and community infrastructure (schools, health clinic, hospitals, community centres) must be assessed (🕮 IFRC, Guidelines for Assessment in Emergencies).

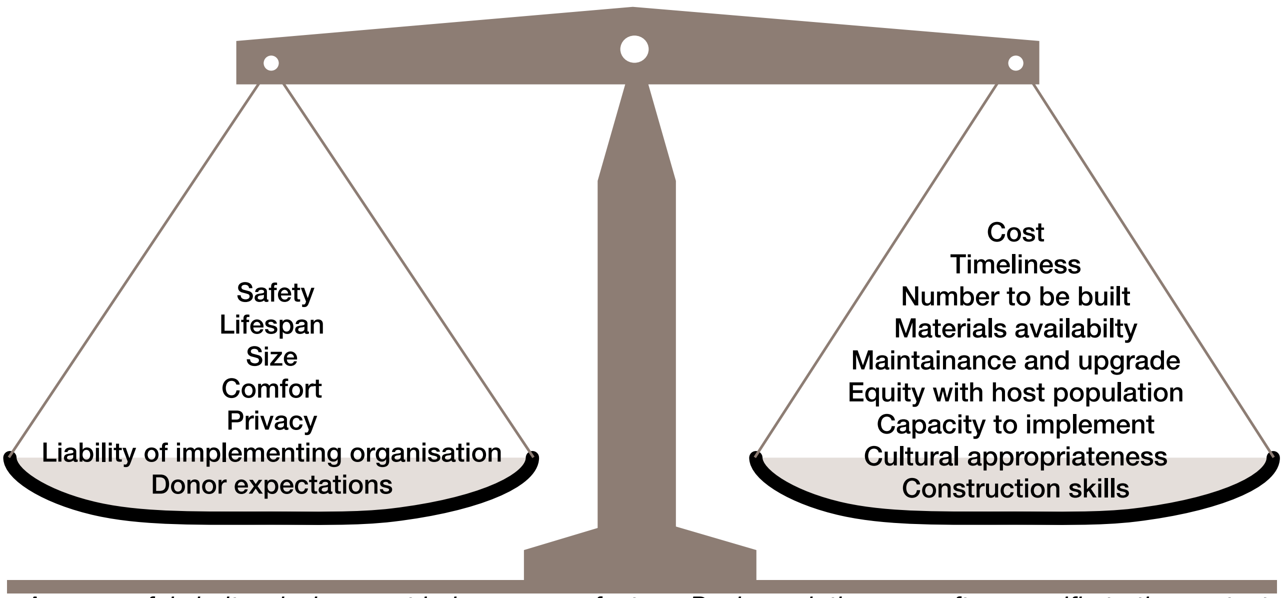
Have you thought of which other types of intervention might be appropriate?

"We built 200 beautiful shelters, but 500,000 people lost their homes.. We supported 0.2% of those in need of shelter. There was no money left to support durable reconstruction"

A.1.2 Settlement options and types of assistance

Before beginning a shelter construction programme, ensure that there is a strategy in place. The strategy should consider all settlement options such as those people who are staying with host families (🕮 Sphere Project, Sphere, or 🕮 Sheltercentre, UN, DfID, Shelter after Disaster).

Be aware that needs and strategies may change with time, and this may impact which shelter projects are the most effective forms of assistance.



A successful shelter design must balance many factors. Design solutions are often specific to the context, and as a result no single design is suitable for all responses.

A.2 Designing a shelter

A.2.1 Appropriateness

If a shelter design is appropriate, it reflects the needs, local culture, vulnerability and capacities of the affected community and the resources available.

As every context is different, so shelter designs must be adapted to each location, response and project. What might be a good solution in one location may not work in another. However, some shelters can be relocated, upgraded and the materials can be re-used, whilst others may be designed to be built on permanent sites.

Section B includes a diversity of shelter designs with structures using materials such as timber and plastic sheeting (B.2), wattle and daub (B.5), brick (B.9) and steel with reinforced concrete beams (B.9).

"Before the earthquake, my house was made of sticks with an iron roof. It was too lightweight to be damaged by the earthquake. My wealthier neighbour's house was made of cement block. My neighbours have now received a Transitional shelter that cost $3000. I have received nothing."
Is this response appropriate?

A.2.2 Developing a shelter design brief

What is a design brief? See Annex I.4 for a template for a design brief.

As soon as the decision to start a shelter construction project has been made, the first step is to develop a design brief. A design brief is a document that defines the performance of the shelter. The design brief allows shelter designs to be verified against key criteria such as safety, cost and durability. A shelter design brief must balance the ideal building from a structural perspective with constraints such as limited time and budgets, and will be dependent upon the overall shelter strategy adopted.

Participation, consultation and coordination

The design brief should be developed through consultation with people affected by the disaster. The design brief should also be developed in consultation with the government, the Shelter Cluster or any other coordination mechanism that might be in place, and reference existing building codes and standards.

Coordination is required to improve consistency between organisations and between sectors of response within organisations. For example, shelters should not be built without drainage, so coordination is required with Water Sanitation and Hygiene Promotion activities. Shelters will also require access to community infrastructure and income generated activities, so coordination is required with the livelihoods, health and education sectors.

Who builds

The shelter owners will have different skills and time pressures to build than a contractor or a supporting organisation will. As a result, the shelter design brief will have to take into account who is building the shelter and how the construction process will be managed (📖 CRS, Managing Post-disaster (Re)-Construction Projects, 2013). Some shelter designs will allow projects to specifically encourage income generating activities, or training of affected people in safer construction.

A.2.3 Relocation, re-use and maintenance

Once construction is complete, consider what longer term support will be required to maintain the shelters and support the people living in them. This support might include toolkits and trainings on maintenance or safer construction. It might also include lighting, solid waste management, livelihoods, or other forms of support.

When designing shelters, consider the financial capacity of households to maintain and upgrade them.

A.2.4 Hazards, risks and safety

Family shelters cannot usually be designed to withstand tsunamis, landslides, volcanos, or very serious flooding. Instead they must be built on safe sites.

Shelter designs must not increase the vulnerability of occupants to natural hazards such as earthquakes, storms or disease.

Location and hazards

Although choice of land (A.2.11 Land, sites and services) is often limited, the location of a shelter is often more important than its design (see I.1 Hazards and design details). Poorly located shelters can increase the risks faced by occupants, while well located shelters can reduce exposure to hazards such as fires, tidal surges or landslides.

Shelters must not increase risk of death or injury

Shelters must be designed so that if they do fail in a future disaster they are less likely to kill or injure the people living in them (A.4.2 Approach to codes and standards). As an example, organisations often build timber framed structures following an earthquake. This is because lighter weight timber structures are less likely to cause fatalities than collapsing masonry structures in future earthquakes. However, these lightweight structures can be more vulnerable to strong winds.

Designs should recognise that people occupying shelters will make extensions, upgrades and alterations. Ongoing guidance and monitoring is required to ensure that these alterations do not compromise the structure.

Defining acceptable risk

Design for hazard resistance should be based on the kind of event that is likely to occur within the lifespan of the shelter. If a one in 500 year event struck, another major disaster might have occurred and it may not be reasonable to expect temporary shelters to survive when the majority of the remaining housing stock also collapsed. However, if the area floods or has high winds annually, or the shelter will become part of a permanent home, this should be accounted for in the design (See also A.4.3 Classification of hazards).

It is not always realistic to expect a temporary shelter to withstand a weather event or an earthquake of the scale that caused houses to collapse in the first place.
BUT - We MUST design and build the shelters not to risk lives if they fail

If the structural engineering standards are set too high, there is a real risk that the shelter project will be costly and slow to implement (see A.2.6 Life span). As a result, families will risk remaining in inadequate shelter, and become exposed to new risks such as oncoming rainy season or disease. There is also a risk that the shelters will be completed too late and no longer meet the needs.

Design to promote best practice

Simple hazard resistant details can be part of the design and can encourage learning. For example, in an earthquake zone, doors of even lightweight shelters should be built away from the corners of the shelter. This will promote good practice for when families move towards heavier construction.

A.2.5 Timeliness and construction speed

When planning to build shelters, talk to logisticians about the practical aspects of transport, storage and procurement of materials. This discussion should include an analysis of which materials can be procured in local markets and which need to be imported.

Review the supply of skilled labour. Even if a single shelter takes a few man-days to build, building a significant number of shelters will usually take many months.

The more complex a design is, the more training and resources will be required to build it, leading to delays. Many times shelters have been completed after families have rebuilt their own houses.

We should have spoken with the logisticians when we were designing the shelters. Now we are late...

A.2.6 Life span

The design brief should specify the amount of time that the shelter is intended to last, given the conditions at the locations in which they will be built. When agreeing the design life of the shelter, remember that if a shelter must last for a long time it may be more expensive and slower to build.

Where possible, materials should be reusable and upgradeable, even if families are relocated to different sites. For example, using more durable qualities of timber and bamboo will allow them to be re-used in the permanent house.

The specification of a shelter should include detail on the quality of materials required, so that the intended design life of the shelter can be achieved. Materials and design should allow for easy maintenance and upgrade.

If too long a lifetime is specified, the shelter risks being too expensive and too slow to build.

If the designs are not properly checked, the shelters might not last long enough

A.2.7 Size and shape

The amount of covered living space that a shelter must provide is a critical determinant of the shelter design, logistics requirements and cost. Organisations need to agree lower and upper bounds to reduce conflict between project sites.

A minimum of 18m² covered living space is often agreed in humanitarian responses. This is based on a family size of five and 3.5m² per person, quoted from Sphere indicators (Sphere Project, Sphere). However, providing 3.5m² per person does not imply that Sphere has been met, nor does Sphere demand that this amount of space must be provided in all circumstances.

Sphere says a lot more than what the size of a shelter should be... READ IT CAREFULLY!!

Example: Locally agreed standards, earthquake response in Haiti 2010

The space in urban centres was extremely limited. Building larger shelters would have forced people to move. This would have forced people to relocate away from their claim to land as larger plots would be required.

It was agreed that a transitional shelter kit for use with small groupings of shelters in urban areas should provide a minimum of 14m² per family. The provision of such small shelters could be considered as there was:

- A plan to mitigate against the impacts of crowded living conditions on inhabitants. This plan would include support with sanitation, drainage and hygiene promotion, access to livelihoods, health and child care.
- A plan to increase the covered shelter area to 3.5m² per inhabitant in an agreed time frame.

When agreeing the covered usable living space, the headroom should be consiered. Low ceilings may render a space unusable. Be aware that “covered living space” also includes external living areas such as verandas.

Shelters are often built by the affected population themselves. Support this re-sourcefulness and self-management.

A.2.8 Privacy, security and cultural appropriateness

Shelter designs, layouts and orientations differ between countries, and even between ethnic groups in the same country. As a result, shelter designs, their layout and their orientation must be adapted to the local culture.

In general, the design brief should aim to encourage flexibility in design such as by allowing occupants to add internal divisions for privacy. Remember to consider where activities such as cooking and cleaning take place and what allowances you can make for this in the design.

In many contexts, additional features such as lockable doors may be required to provide the most basic security.

Even a thin plastic sheet can help protect occupants and their belongings.

A.2.9 Ventilation and thermal comfort

The weather varies significantly between disaster locations and with seasons. For large scale disasters the weather can vary significantly across the disaster affected area.

People from different cultures will find different buildings comfortable, and be accustomed to different temperatures or humidities. Design details such as verandahs and high ceilings can make shelters cooler in hot weather, whilst taking care to reduce air gaps, or including a lobby area can help to keep shelters warmer in cold weather.

Shelter designs should provide protection from the anticipated extremes of weather. In the case of temporary, transitional or progressive shelters, they should be designed for upgrade with simple winterisation kits.

Design shelters for the climate and traditions

A.2.10 Environment

A large scale shelter construction project requires large volumes of materials. Consider the environmental impacts of materials being used for shelters, and look at ways to mitigate them. For example 5000 temporary shelters will require more than 2500m^3 of timber. Procuring the timber locally might negatively impact upon the local environment, but importing the timber, or using steel may only offset the impacts to another location.

A.2.11 Land, sites and services

I have an excellent shelter, but there is no water. I cannot live here...

Land ownership

Temporary and transitional shelters may be built as an interim solution until more formal land access can be established. As a result they may end up being built on marginal land.

For core and progressive shelters, the land identified must be agreed for a longer duration.

In some cases it may be necessary to sign agreements with the authorities to guarantee a minimum period of use. Wherever possible, funds should be set aside for follow up support in identifying land.

See 🕮 UNHABITAT, Land and Natural Disasters for more on land issues.

Access to Services and livelihoods

Do not forget that water will always be required, and access community infrastructure, livelihoods and other services such as electricity will be a necessity for most projects. Shelter projects will ultimately fail if people cannot find the means to live where their shelters are built.

A.2.12 Cost and budgets

The money available per household for each disaster varies, and is often a critical determinant of shelter cost and ensuing design. As a result, there are significant variations in costs of shelters between responses. To illustrate this, the materials costs of the shelters in this book vary from 500 CHF to over 2500 CHF per shelter.

When judging the cost per shelter, compare the cost of each shelter with the disposable income of affectees and host population. Support given to families in building shelter is usually many times higher than that provided to them in livelihoods programming.

Some risks of a shelter being at too high or too low a standard and cost

Too high	Too low
Risk being too slow, and shelters delivered too late.	Shelters risk collapse and inhabitants risk injury.
Number of shelters that you can afford to build is small, limiting the number of people that the project can support.	Shelters risk being refused by affectees. The materials of low quality and not sufficiently durable for use/reuse in a permanent house.
Shelters risk being to a higher standard than for households who will not receive a shelter. This can lead to divisions in society and increased dependance for future disasters.	The design life of the shelters will be too short.

A.3 Checklist for shelter projects

Be aware that the situation will change quite rapidly after a disaster as people help themselves, and markets and roads reopen. To deal with changing contexts:

- Shelters should be designed to be upgradeable, and components should be repairable.
- Shelter projects must be adjusted continually according to ongoing monitoring and evaluation.

Remember that for shelters to be useful, an informed decision to distribute them must be taken as quickly as possible.

A.3.1 Assessment

Needs

- Do the affected people need support with shelter construction?
- Would other types of support such as tool kits, vouchers, cash distribution, or supporting markets or rental meet shelter needs more effectively?
- Who will the shelters be for? Will there be social impacts of providing shelters free of charge to a selected population but ignoring others?
- What coping mechanisms do people already have?
- Have people been consulted as to what materials they most require?
- Are there any vulnerable individuals or groups within the community? Do shelters meet their needs?
- How do the shelters compare to how people were living before?
- What resources do people have and what can they salvage from their old homes?
- What is the cost in comparison to shelters used by the non-affected population and the affected population?

Organisational capacity

- Does your organisation have the capacity to properly assess the needs of the most vulnerable affectees?
- Does your organisation have the capacity to adequately and promptly implement the shelter construction project, considering your limitations?
- What additional staffing and training will be needed to implement the programme?
- Does your organisation have the funds to build sufficient shelters to make a significant impact?

Community capacity

- Who will build the shelters?
- Are local carpenters and masons available?
- What is the level of participation of the affected communities?
- Do all affected people have the skills to build the shelters?
- Do all of the affected people have the skills and resources to maintain the shelters?
- What support will be available to those who are not able to build their shelters?
- Is there a construction season? Are there times of year when people do not build as a result of weather or other livelihoods activities?

Strategy and coordination:

- Does shelter construction fit in with the activities of the government, coordination mechanisms, and other organisations?
- Do the shelters fit in with your organisation’s other sectors (such as livelihoods, water and sanitation)?
- For emergency, temporary and transitional shelter, would it be more effective use of resources to move straight into recovery?
- Is funding going to be made available in the future for permanent housing?
- Have relevant permits been obtained

Skills and staffing

- Do you have a team in place to implement or monitor the project?
- Are there other organisations that you could form partnerships with?

See also the checklist in the shelter and settlement chapter of Sphere...

Land and settlement

- Do the majority of the affected people have access to land on which to build?
  - Is the land safe?
  - Is the ownership of the land agreed?
  - Is the ownership of the shelters agreed?
  - How long will people be able to remain on the land?
- Are basic services such as water available at the shelter sites?
- For shelters intended as part of a permanent shelter, can
  - electricity be made available at the site?
  - basic community infrastructure such as schools or health clinic be made accessible for the people at the shelter site?

Materials and alternatives

- Which materials do people already have available, or can they salvage? Many disasters will knock houses over but will not lead to all of the materials being lost.
- Will the shelter be suitable to integrate with the existing construction culture so that people can repair and maintain them?
- Where will the materials come from, and will people be able to maintain them?
- Is the design adapted to the available sizes and quantities of the materials?

Hazards

- Can people build safely with sufficient support?
- Are the shelters appropriate for the climatic conditions?
- Are proposed shelter locations safe? Often the only available land is vacant because it is hazardous.

Logistics and distribution

- Have you consulted with the logistics and procurement team concerning the best options and sources for procurement?
- Is local transport and warehousing available?
- Have you consulted with the logistics and procurement team concerning availability of materials, specifications and the time it takes to deliver?
- Have you consulted with the logistics team on how distributions of materials will take place?

Time

- How long will the shelters actually take to build (including materials transportation)?
- How long are the shelters expected to last?
- Will shelters be built soon enough for them to be useful?

A.3.2 Project planning and implementation

- Have you formed a project Plan of Action?
- What are the plans for procurement, construction and project management?
- Is there a design brief? See I.4 Template design brief
- What training and technical support will you be offering to project staff and to disaster-affected people?
- Have you budgeted for logistics and staffing costs?

Monitoring and evaluation

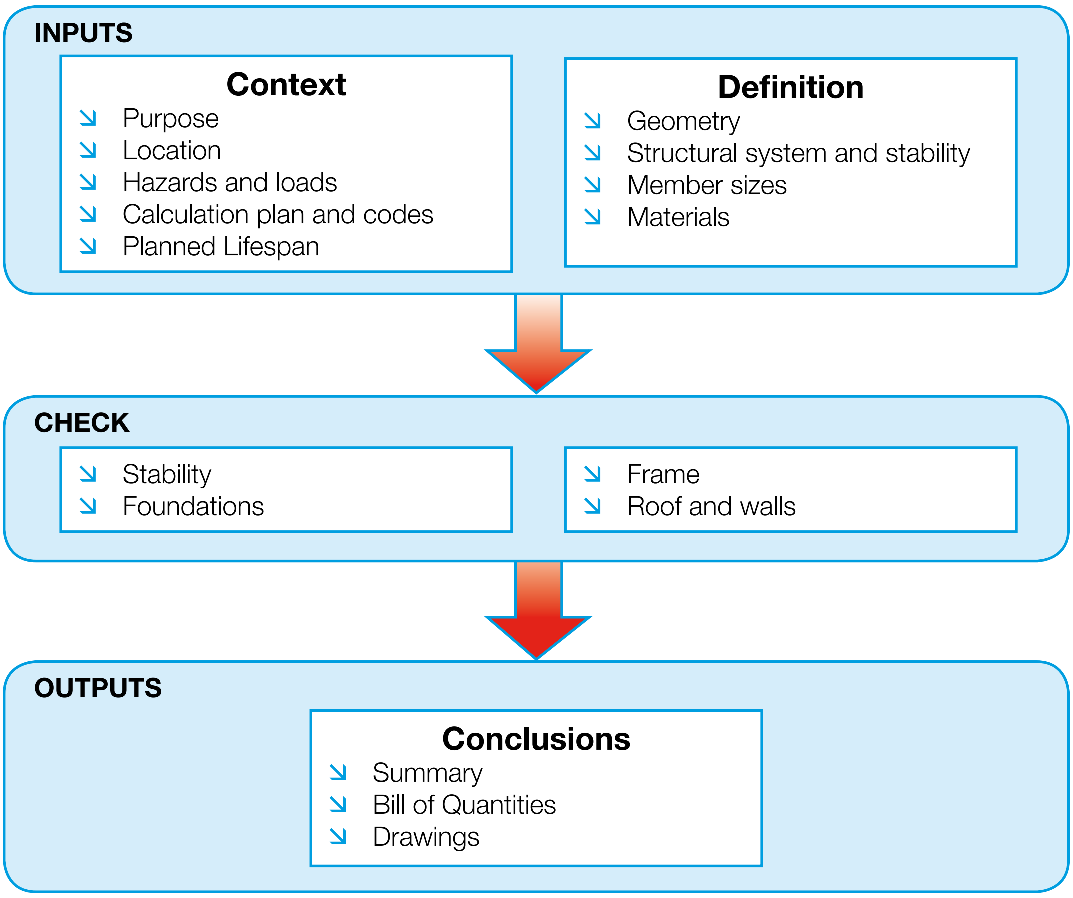
- Who will be conducting ongoing monitoring of the distribution and effectiveness of the transitional shelters?
- Who will evaluate and monitor the project?
- How will you monitor the project?
- How will you evaluate the project?
- Will you be conducting a survey to monitor satisfaction among those who receive the shelters?
- Based on monitoring and ongoing assessments, are you prepared to adapt your plan?

A.4 How the structures were reviewed

A.4.1 Process

This section discusses how the structural aspects of the shelters in Section B of this book were checked. To check the shelters a three stage process was used. This is illustrated below:

- **INPUTS.** Information on the shelter was gathered. This included information on the broader context including the purpose and proposed lifespan of the shelter and where it was built. This determined the hazards and loads it would be exposed to and which building codes and standards are relevant. The shelter was then defined in terms of its geometry, stability system, member sizes and materials. When information was not available, assumptions were made.
- **CHECK.** The performance of the main elements of the structure was checked against relevant codes and standards (A.4.2 Approach to codes and standards).
- **OUTPUTS.** Annotated drawings of the as-built shelter, an associated bill of quantities, a summary of structural performance and recommendations for improvements were produced as final outputs.



Caption: Illustration of the process by which shelters were checked

A.4.2 Approach to codes and standards

Codes used

The 🕮 International Building Code (IBC) 2009 (See Annex I.6) has been used as a reference for the design checks on the shelters. It is globally recognised and provides a good basis for calculating extreme loading cases such as earthquakes or strong winds. Other building codes were referenced when they were available or appropriate.

🕮 See annex I.6 for a more detailed explanation of how building codes were applied

Risk to life or risk of structure being damaged

The performance of each shelter in section B was assessed on whether or not the shelter was safe for habitation.

As an example, a major risk to people in shelters during extreme high wind is from wind-blown debris. For the most part, post disaster structures are not intended to be shelters during such events. Therefore, they are not only rated on the maximum wind velocity during which they will maintain their functionality but also their ability to be repaired and returned to functionality after an event that exceeds that maximum wind velocity.

As a structure may deform significantly under extreme hazard loading without posing a high risk to life, each shelter was also assessed on the risk of it failing or being damaged (A.4.4 Classification of performance).

Because most post disaster shelters are lightweight, the risk that falling parts of the building would severely injure people is reduced. However, if a shelter is damaged, it will often need to be repaired or rebuilt.

Regarding fire safety, simplified and comparative assessments of the flammability of materials were performed. Comments were based on the ability of occupants to escape from these small structures.

Applicability of building codes to post disaster shelters

For the shelter reviews in this book, design criteria have been developed based on the codes and standards discussed above. These criteria take into account the intended lifespans of the shelters.

Building codes are typically developed for permanent structures. They are not directly applicable to post disaster shelters. Therefore, to assess structures against a standard of complete code-compliance is unreasonable. The sections of the codes and standards referenced herein which apply to post disaster structures have been noted and are used as a guideline for assessing the structures. Key assumptions and reasoning for interpreting the standards are stated in the “assumptions” sections for each shelter review (see Section B).

Local codes and standards such as those listed above have been reviewed and utilized. It is understood that the local standards may be more applicable to post disaster structures than the IBC.

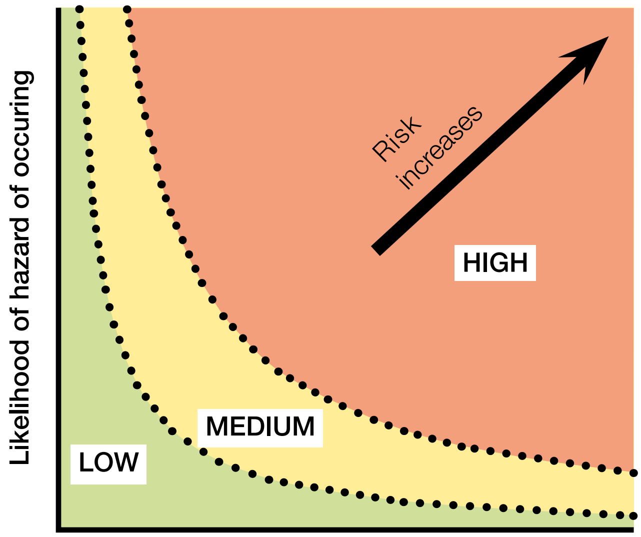
Connections and workmanship

In addition to the overall design, the performance of a shelter is dependent on the quality of workmanship and connections between elements. These aspects are not covered in this book but are important considerations in delivering a post disaster shelter programme.

A.4.3 Classification of hazards

Magnitude, likelihood and risk

For the purposes of this book, the earthquake, wind and flood hazards in each location have been classified as **HIGH**, **MEDIUM** or **LOW**. These simplified categories are based on hazard criteria as applicable to lightweight, low rise buildings, and statistical assumptions about the likelihood of hazard occurring.



Caption: The risk is a combination of the likelihood of the hazard occurring and the magnitude of the hazard. Note that an event with a high likelihood can still be a low risk if the expected magnitude is low

	Hazard risk classification used in Section B for earthquake, wind and flood				
Classification used	**Earthquake**	**Wind (approximate)**		**Flood**	**Fire**
	Seismic Design Category *	Basic Wind Speed ** (km/hr)	Saffir/Simpson Hurricane Category		
LOW	B	< 113	< 1	Low risk	Low risk
MEDIUM	C	113 - 160	1-2	Medium risk	Medium risk
HIGH	D	> 160	3-5	High risk	High risk

* This is based on ASCE/SEI 7-10, Table 11.6-1 assuming Risk Category I (Table 1.5-1 representing a low risk to human life in the event of failure) and based on the modified PGA.

** The sustained 3 second gust speed at a height of 10m in flat open terrain for a 50 year return period (as defined in the International Building Code (IBC) 2009, Section 1609.

A.4.4 Classification of performance

The performance of each shelter has been categorised using a **GREEN**, **AMBER**, or **RED** scheme. This classification is for the risk of the structure failing or being damaged. It is not based on the risk of the structure injuring people if it does fail. (See annex I.7 Building codes and post disaster structures)

Classification used in Section B for the performance of structures	
Classification	Meaning of classification
GREEN	Indicates that the structural system fully meets the factors of safety and all other requirements of the International Building Code and local standards (if they exist) for the reduced design loads.
AMBER	Indicates that the structural system does not fully meet the requirement of the International Building Code, or local standards if they exist. However, the reduced design loads will not cause failure of individual members of the structural system or its overall collapse.
RED	Indicates that the reduced design loads will either cause complete failure of individual members or cause overall collapse of the structural system.

A.4.5 Performance analysis summaries

Each shelter review in Section B has a table titled 'performance analysis'. This table provides an overall summary of the robustness of the shelter. The table assesses the performance (A.4.4 Classification of Performance) of the shelter with respect to the hazards (A.4.3 Classification of Hazards) at the given location.

See A.4.4 Classification of Performance

See A.4.3 Classification of Hazards

Example of a Performance analysis	
Hazard	**Performance**
Earthquake LOW	**AMBER**
Wind MEDIUM	**RED**
Flood HIGH	**GREEN**
Fire LOW	**AMBER**

Structure is expected to deflect and be damaged under earthquake loads.

Structure is expected to fail under wind loads.

Section B
Analysis of the shelters

This section provides the summaries of structural analyses that have been conducted on eight transitional shelters. The analyses are based on the process outlined in section A.4. For each shelter, basic summary information and a bill of quantities is provided. Drawings are annotated with potential design improvements and details that should be checked or monitored. For each shelter design, a performance analysis table is included. This compares the performance of the structure with the hazards where the shelter was built. Finally notes on potential upgrades are provided.

Section Contents

B Overview of designs

Ten different shelter designs are summarised and technically reviewed in the following pages. These are in addition to the 8 shelters in Transitional shelter : 8 designs (2012). Criteria for inclusion can be found in the Introduction (1.4 Criteria for selection of designs).

The process by which the shelters were analysed can be found in Section A.4 How the structures were reviewed.

It is intended that the drawings and bills of quantities in this section are used to inform the design process. However, they should not be used as standard designs, and they must not be used without local adaptation.

Post–disaster shelter design is a balance of factors, including safety, lifespan, timeliness and cost. As a result, the shelters are seldom perfect from a structural perspective. However, designs that are not structurally perfect may well be excellent technical responses given the constraints of a situation.

Note: IFRC, Transitional shelter: 8 designs, 2011 contains additional shelters from Indonesia, Pakistan, Peru, Haiti and Vietnam.

B.1 Afghanistan – 2009 – 'Winterised Shelter'


Photo: Shaun Scales

Summary information

Disaster: Refugees returning from conflict, Winter 2009

Materials: Bamboo frames with plastic sheet walls and roof - to protect an existing tent

Material source: Internationally procured

Time to build: 3 days

Anticipated lifespan: 1 year

Construction team: 7 people fabricating frames, 5 people to assemble structures on site

Number built: 380. This design was later adapated and built in larger numbers in Pakistan following flooding

Approximate material cost per shelter: 270 CHF

Approximate project cost: 820 CHF - including all site winterisation works

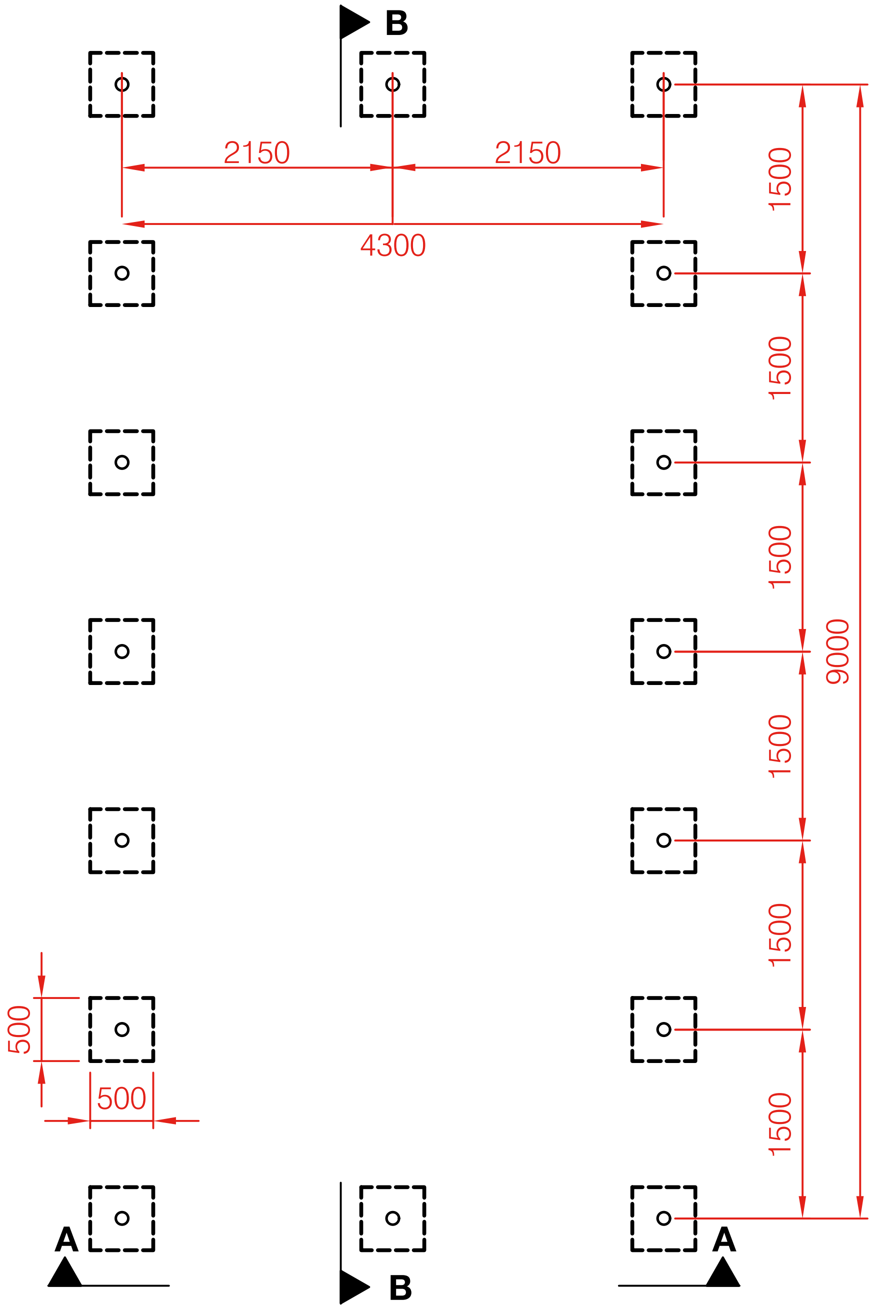
Shelter Description

This shelter was built to act as a shell to protect occupants living in tents. Each shelter contains one tent, erected inside the structure. It is rectangular in plan and has 1.8m tall side walls and a gable roof. The covered floor area is approximately 9m x 4.3m. The frames are constructed from bamboo poles. The frames are connected using plywood gusset plates and bolts. The walls and roof are plastic sheeting, and are supported on the bamboo frame and purlins. The floor is compacted soil. The shelter frames were shop fabricated in the camp and transported to the construction site. The frames are embedded into the ground for support.

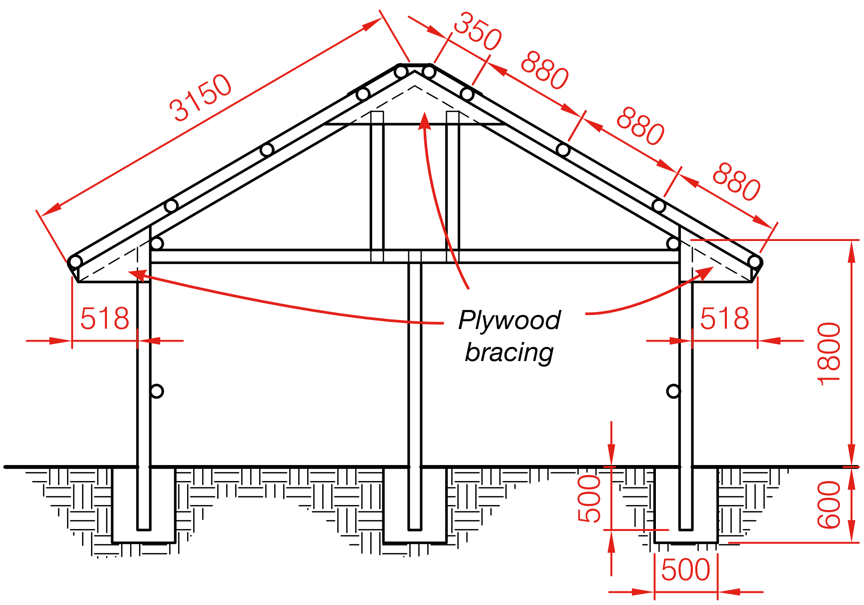
Shelter Performance Summary

This style of construction uses materials which create a lightweight shelter which can be quickly deployed in remote locations. The simple framing systems are well suited to mass fabrication using a mix of skilled and unskilled labour, and the light weight of the building framing does not require the use of heavy equipment for construction. Bamboo is a durable construction material, and is stronger than most wood species, but the plastic sheeting used for the walls and roof should only be considered temporary. The shelter frames should be able to resist the expected wind loads without failing the bamboo, but will most likely deflect significantly during strong storms. Given the relatively large span of the frames, snow loads can be problematic and occupants should be encouraged to reduce snow accumulation on the roof to prevent collapse.

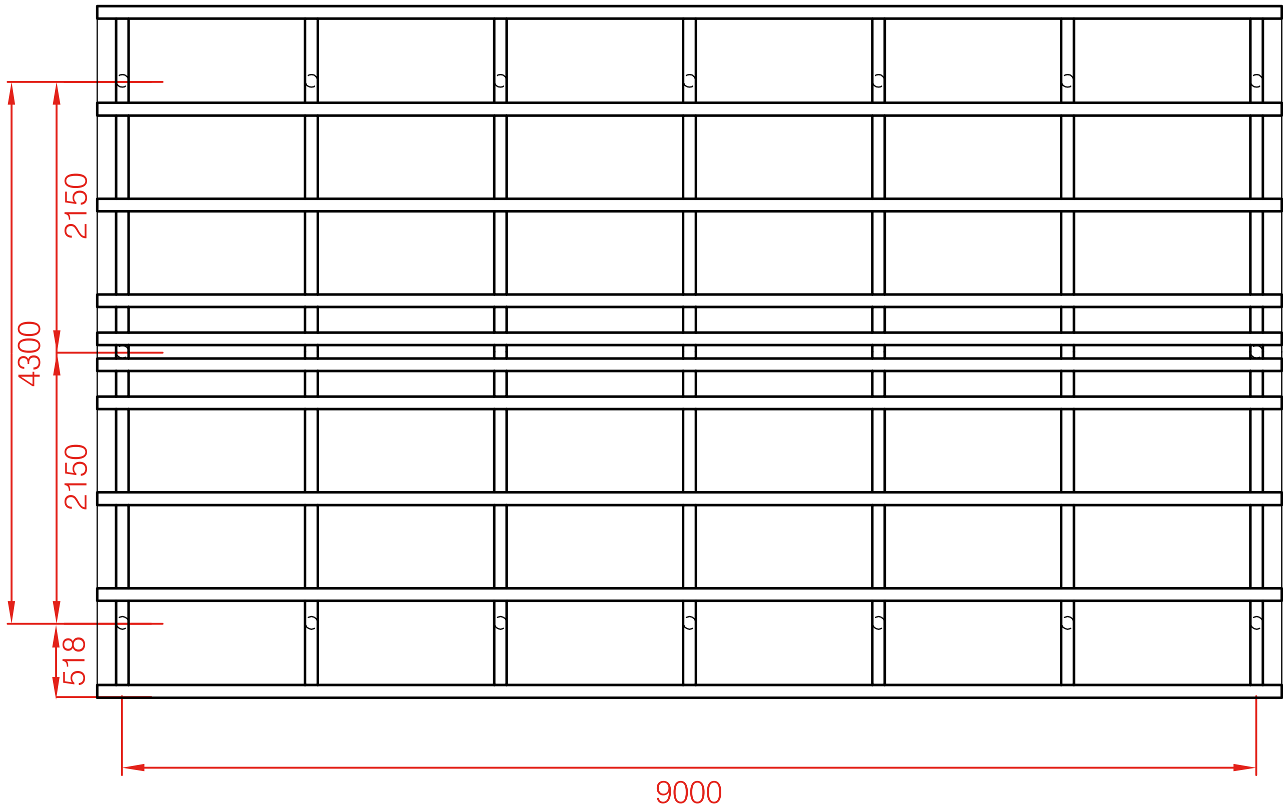
Plans



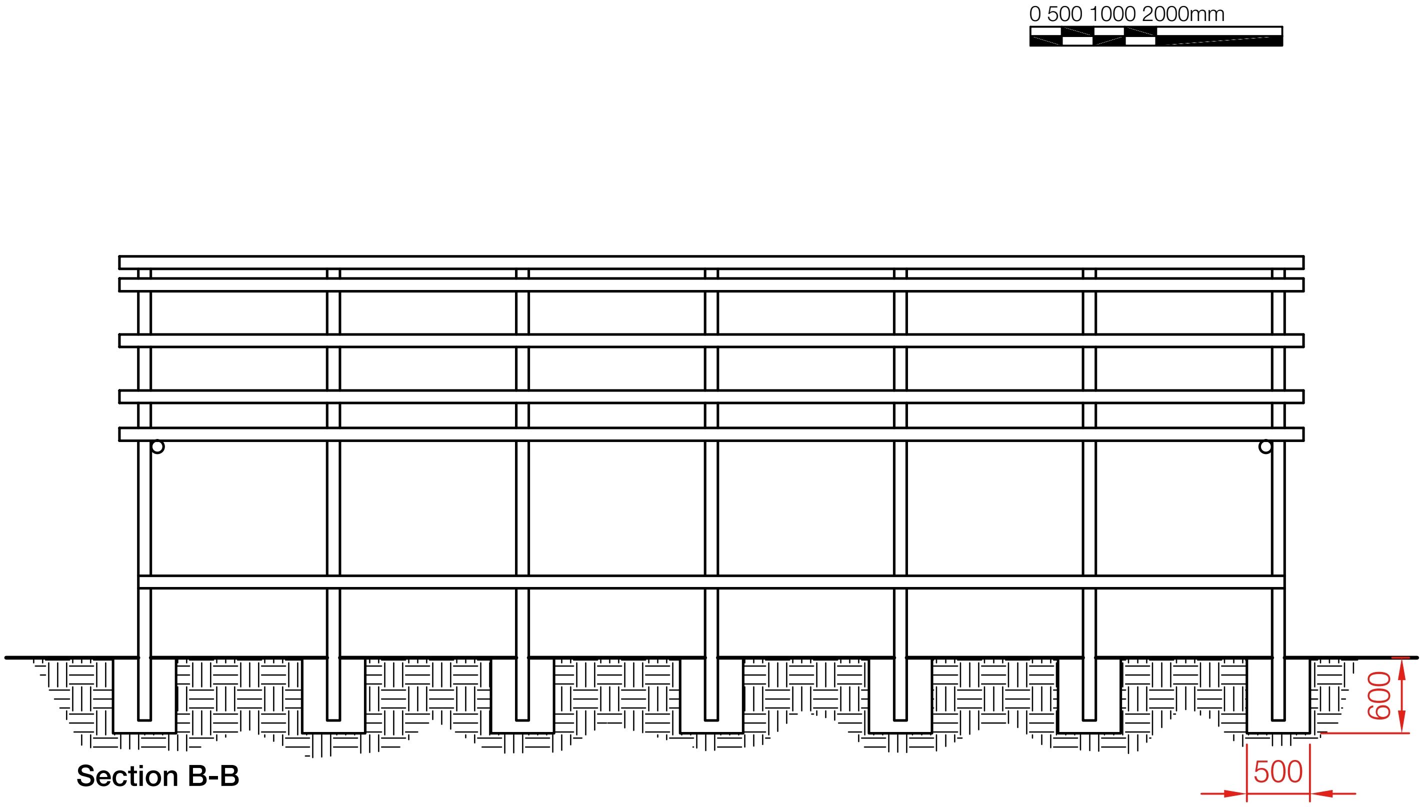
Floor plan



Section A-A



Roof Framing Plan



Section B-B

Durability and lifespan

The strength and durability of the shelter frames is dependent on constructing them with high quality and properly dried bamboo. While these shelters are intended to be temporary, the materials in the frame can potentially be re-used in permanent construction.

The plastic sheet roof and walls are simple to install, but will not withstand many seasons before they deteriorate due to UV exposure. It should be expected high winds and/or windblown debris will rip or tear the sheathing. Plastic sheets can be expected to last less than two years.

Performance analysis

The performance of the shelter is good for seismic loads, and should be able to withstand most wind storms without collapse. Snow should not be allowed to accumulate more than 300mm on the roof at any time. Proper site analysis is necessary prior to construction to provide any mitigation of flood hazards.

Hazard*	Performance
Earthquake HIGH	**GREEN:** The light weight construction of the frames are adequate to resist expected seismic events, and even if failure occurs it is unlikely to seriously injure the occupants.
Wind HIGH	**AMBER:** The bamboo frames should be able to resist expected wind pressures without collapse, but will likely deflect significantly, and permanent damage to the frames which will require repairs should be expected after strong storms. The wall and roof sheathing is not very durable, and will possibly require frequent replacement. The light weight shelter does not offer significant resistance to uplift loads, and could be picked up off the ground.
Flood LOW	**RED:** The floor of the shelter is the ground surface, and will not prevent flood water from entering the shelter. The only defence against flood damage will be site selection and adequate drainage provisions.
Fire LOW	**AMBER:** The components of the structural system are flammable, and will not offer significant fire resistance. The plastic sheeting is not fire retardant or fire resistant. Fortunately the small floor plan and two exits make it easy for occupants to escape before being harmed.

* See section A.4.5 Performance analysis summaries

Notes on upgrades

The walls and roof should not be upgraded with more permanent materials, as the bamboo frames are only adequate for a short expected design life, and would require significant reinforcement for use as a long term shelter.

The bamboo columns could be embedded into concrete piers to provide uplift resistance for wind loads.

In areas where flooding in a significant risk, the design can be easily modified to add more fill inside the shelter to raise the elevation of the floor above the surrounding grade. Care should be taken though to ensure the ceiling height is sufficient for the occupants.

Low height mud walls could be built to improve the thermal performance of the structure in cold weather.

Raised floors or platforms could provide protection against flooding.

It is not recommended to upgrade the plastic sheeting with more permanent materials. The tent frame is not sufficient for a shelter with a design life longer than 2 years

Assumptions

- The bamboo poles are assumed to be 8cm in diameter and have a 5mm wall thickness.
- Plastic sheeting is sufficiently attached to the bamboo framing to transfer wind loads to the frames. The capacity of the plastic or its connections to resist wind and snow loads was not analysed, given the temporary nature of this type of construction
- Lateral foundation loads are resisted by lateral soil bearing, and uplift loads are resisted by the shelter weight alone.
- Structural analysis does not include roof live loads.
- There is no building code for Afghanistan, so this shelter was only analysed using the International Building Code (IBC) 2012.

Potential Issues

Site Selection

- Site selection is the best way to mitigate flood hazards. Select sites on higher ground and away from flood hazards.
- Provide proper drainage around shelters to prevent accumulation of rain water.

Materials

- Inspect bamboo to ensure that pieces are straight, of uniform diameter, and free of cracks or other defects.

Foundation

- Verify poles are embedded in the soil the correct amount.
- Make sure the frames are in their proper location and plumb before soil is compacted around them.
- Verify that the soil under the shelter is free of organic material and compacted before construction of the structure.
- On sites at risk of flooding, elevated platforms could be built.

Bamboo Framing

- Ensure the plywood gussets are installed with the proper number, size, and location of screws and bolts.

Wall and Roof

- Plastic sheeting wall and roof sheathing should be installed neatly and tightly to the bamboo framing. The plastic sheeting should not flap in the wind, as it can be damaged by flapping against the framing.
- Ensure sheeting is fastened to the framing with battening strips or fasteners with large heads or washers to avoid fastener heads pulling through the plastic sheeting.

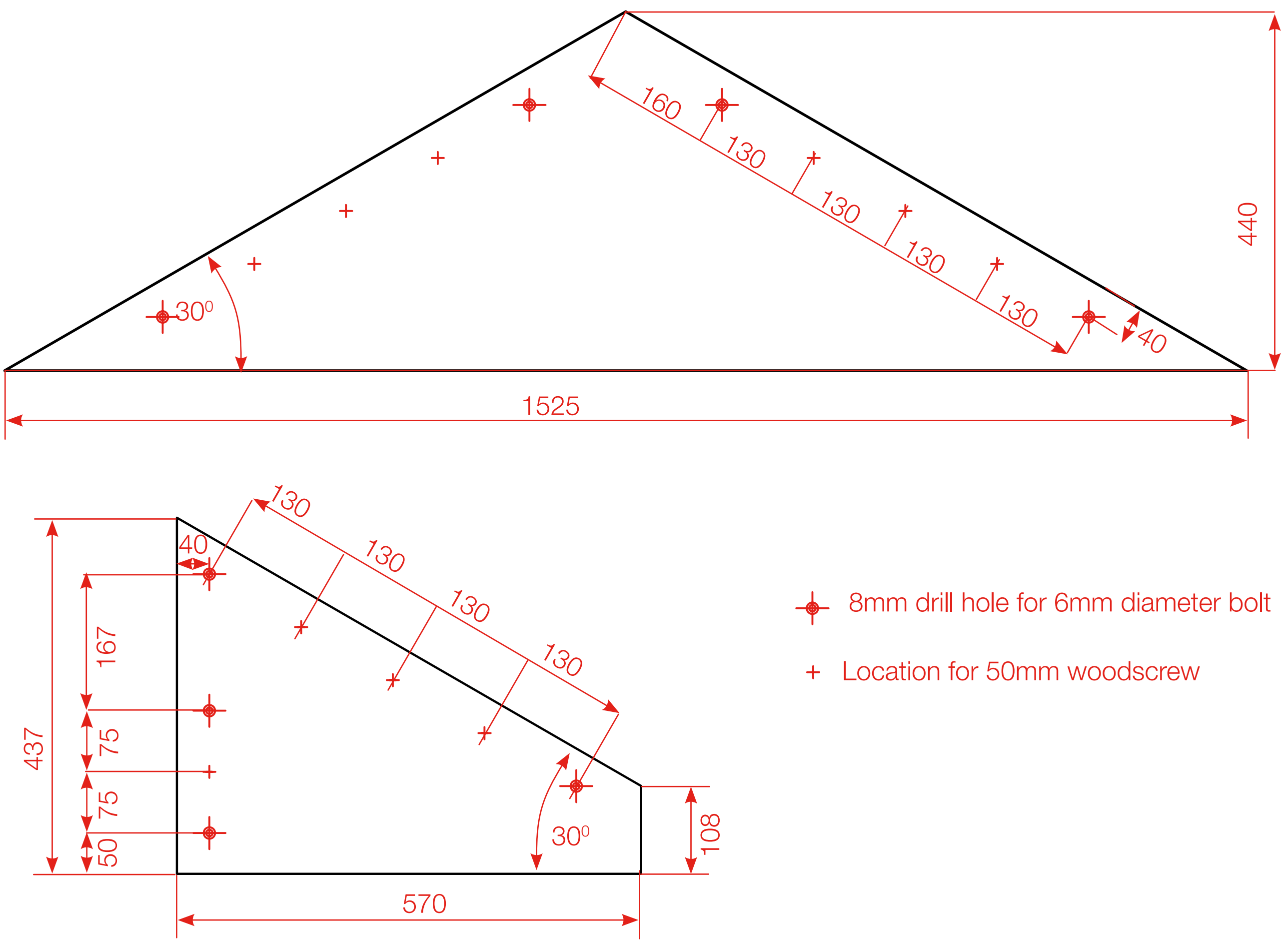
Bill of quantities

The bill of quantities in the table below is for the shelter as it was built, without the design alterations suggested here. It does not take into account issues such as which lengths of timber are available and allowances for spoilage in transport and delivery.

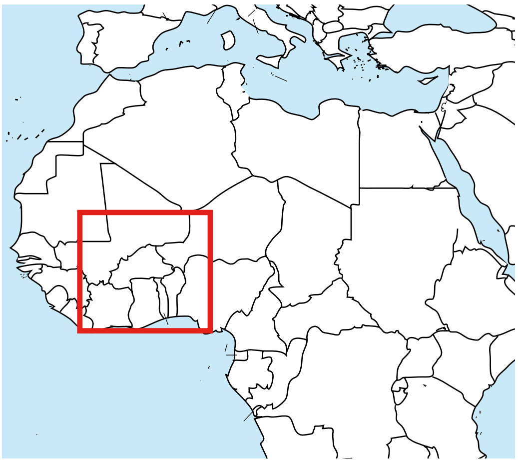
Item See annex I.1	Additional Specification	Quantity	Unit	Comments
Foundations				
Bamboo 1	10m long	24	Piece	7mm – 9mm diameter
Plywood 1	6mm thick	5	Sheet	1525mm x 1525mm sheets
Main Structure				
Plastic sheet		7	Sheets	5m x 4m sheets
Fixings				
Common nails	102mm long	1.6	kg	
Common nails	50mm long	2.5	kg	For fixing plastic sheeting
Bolts	6mm dia x 150mm	84	Piece	Include nut and 2 washers
Washers		1.0	kg	
Rope	5mm	60	m	Cotton rope
Tools				
Tools were used for many shelters and were centrally maintained by construction teams on site and in fabrication workshops. A generator and electric mitre saws were required for the cutting benches to prefabricate parts.				

Details

Cutting details for plywood roof truss bracing are illustrated below



B.2 Burkina Faso – 2009 – 'Emergency Shelter'



Summary information

Disaster: Flood, September 2009

Materials: Concrete floor slab with timber framed walls and roof and plastic sheeting wall and roof covering

Material source: Locally procured, plastic sheeting imported

Time to build: 3 days

Anticipated lifespan: 2 years (limited by plastic sheeting covering)

Construction team: 4 people

Number built: 2,840

Approximate material cost per shelter: Unknown

Shelter Description

This shelter is a rectangular timber frame with a pitched roof and a covered floor area of 2.7m x 1.8m. The frame has plastic sheeting for both roof and wall covering, and one door on each short side.

The wall frame is made from timber panels that are pre-fabricated on the ground. The timber roof structure is nailed to these panels. Both walls and roof are reinforced with wire cross bracing. There is a knee braced timber framed along the roof ridge which supports the roof panels, and provides stability during construction. Wall and roof covering is fastened to the timbers using flat-head nails.

Shelter Performance Summary

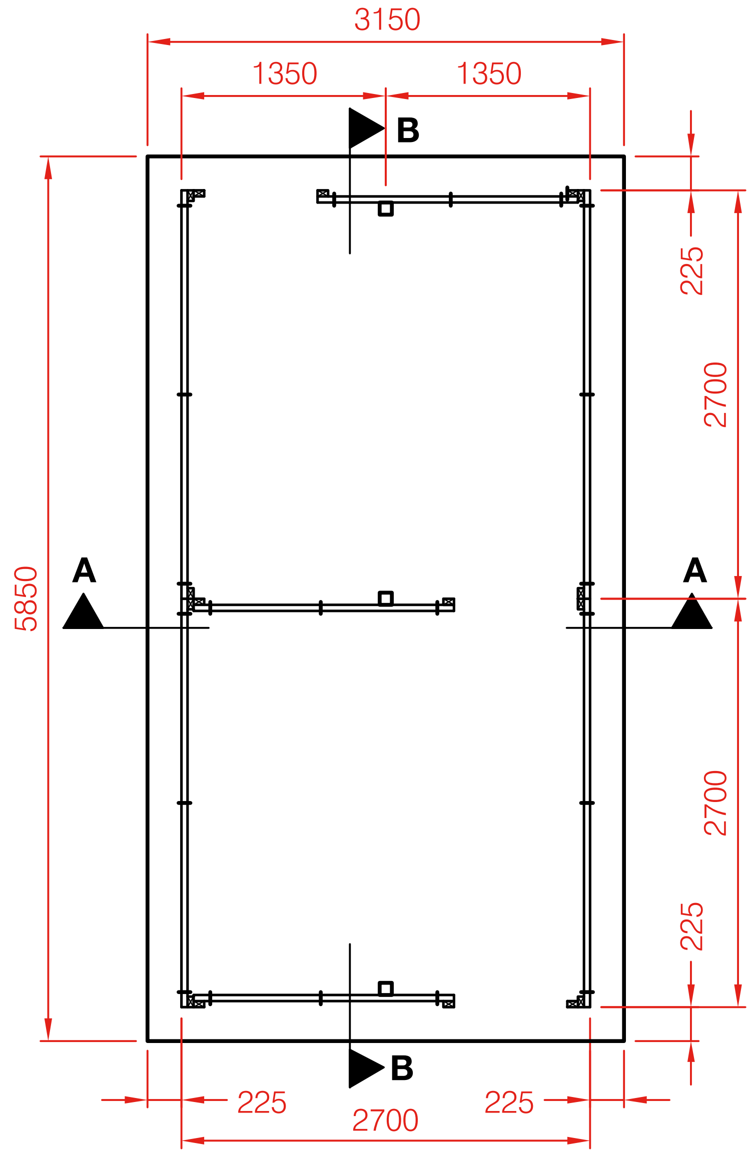
This style of construction uses locally available materials to create a lightweight shelter which can be constructed with unskilled labour. It offers a good short term solution and can be quickly deployed and constructed after a disaster. The frame is relatively simple to maintain and the sheeting can be replaced increasing the shelter's lifetime.

Due to its light weight, it is ideal for areas of high seismic activity, and the plastic sheeting walls are sufficient for the light wind loads at this location.

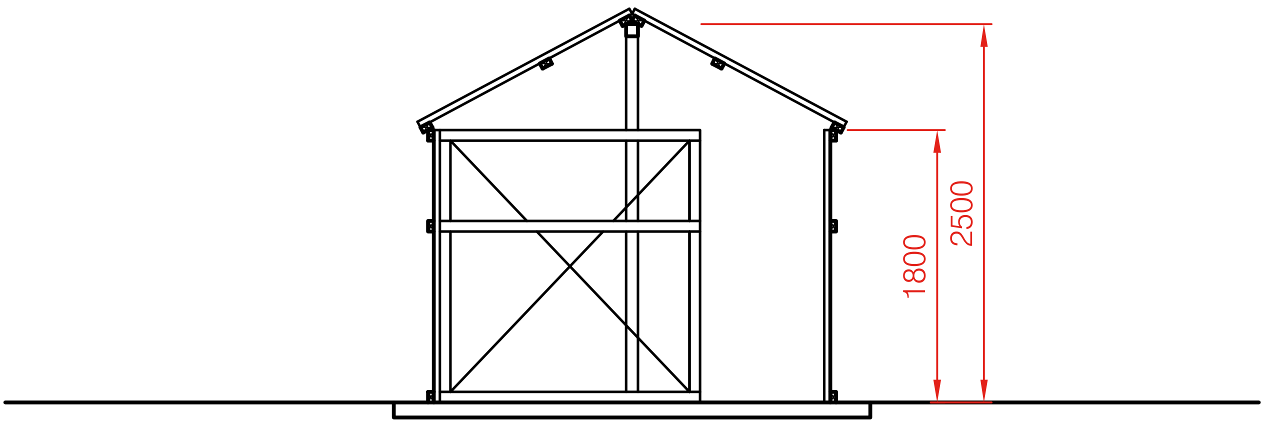
If this shelter is intended for use in areas with higher expected wind loads, the plastic sheeting covering may need to be removed or the timber members reinforced for the shelter to withstand full strength storms without being destroyed. If the wall and roof covering is upgraded to material such as plywood or boards, the panels and frames many need to be strengthened.

Since the floor is only a few millimetres above grade, it does not offer significant protection from flood waters.

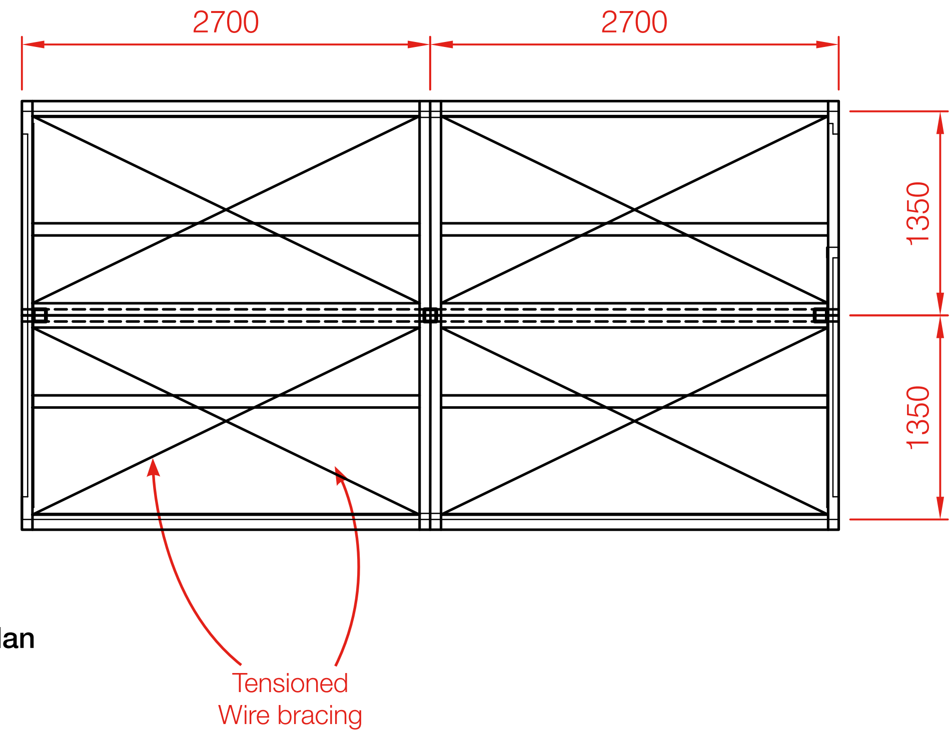
Plans



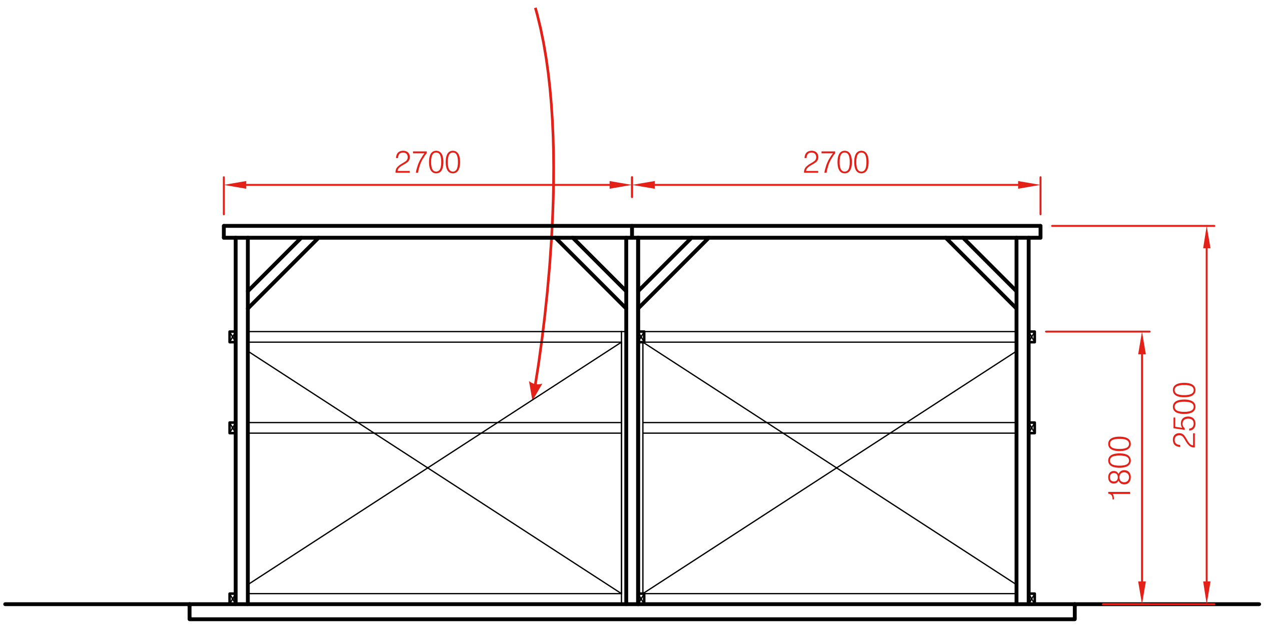
Floor plan



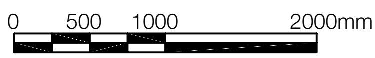
Section A-A



Roof Framing Plan



Section B-B



Durability and lifespan

Given the tropical climate in the summer and the presence of termites, it is unlikely that the framing will remain usable for extended periods of time unless the timber is treated before construction.

The plastic sheeting roof and walls are simple to install, but will not withstand many seasons before exposure to sunlight and wind causes them to deteriorate. It should be expected that high winds and/or windblown debris will rip or tear the covering. Plastic sheeting can be expected to last less than two years.

For these reasons it is not likely that these shelters will be incorporated into permanent housing, However the timbers may be re-used later if not damaged by insects.

Performance analysis

The performance of the shelter is good for seismic loads and the light wind loads in Burkina Faso. The shelter can provide shade from sun and rain for a limited period. Proper site analysis is necessary prior to construction to determine appropriate finished floor heights to provide any mitigation of flood hazards.

Hazard*	Performance
Earthquake LOW	**GREEN:** There are no expected seismic events for this location. In general structural framing is very light, all panels have wire cross bracing, and all wall panels are anchored to the concrete slab with wire ties. Therefore performance for seismic loads should be satisfactory.
Wind LOW	**GREEN:** Structural framing is sufficient for the wind loads at this location, but framing will need to be strengthened for this design to be used in areas of high wind speeds. The wall and roof covering will require replacement every few years, and wire tension requires regular checking and maintenance.
Flood HIGH	**RED:** The first floor of the shelter is only located a few millimeters above exterior grade and the wall construction will not prevent water from entering. As the shelter is currently designed The only defence against flood damage will be site selection.
Fire LOW	**AMBER:** The components of the structural system are flammable, and will not offer significant fire resistance. The plastic sheeting is not fire retardant or fire resistant. Fortunately the small floor plan and two means of egress make it easy for occupants to exit before being harmed.

* See section A.4.5 Performance analysis summaries

Notes on upgrades

Wire ties between individual wall panels and between wall panels and the concrete slab can be installed in a crossing pattern to increase the lateral resistance of the shelter.

The wire ties can be replaced by timber bracing. See the following note on fixing details for more detail.

Timber members can be preservative treated to resist rot and treated to resist termites. This will improve the durability of the construction materials.

The top timber member of the interior wall panel can be extended across the entire width of the shelter and connected to the wall panels and roof frame to help distribute lateral loads into the cross bracing.

The wood posts along the ridge can be anchored to the concrete slab with wire ties and/or nailed to the exterior wall panels to improve uplift resistance.

Upgrading the wall and roof covering to more durable materials such as planks or plywood should be approached with caution. In specific situations the plastic sheeting can be upgraded without affecting structural performance, but in general upgrading the covering will require strengthening the timber panels.

Raised floors could be built to improve performance during flooding of sites.

Burying the plastic sheeting in the ground outside the slab is a possible solution. Installing the plastic sheeting under the wall panels will cause conflicts with the wire ties that anchor the panels to the concrete slab.

Assumptions

- Timber framing is assumed as Southern Pine Grade No 2, or equivalent.
- The wooden dowels used to embed the wire ties in the concrete slab are sufficiently large and strong.
- The twisted wire joints are sufficiently strong.
- The individual timber panels are connected to each other and the roof beams are tied down to the wall panels with wire ties.
- All wire is at least 2.5mm diameter.
- Lateral foundation loads are resisted by friction between the concrete slab and the soil.
- The slab was assumed to be 75mm thick.
- Structural analysis does not include roof live load.
- Burkina Faso has no building code, so the International Building Code (IBC) 2009 was used for analysis.

Potential Issues

Site Selection

- Site selection is the best way to mitigate flood hazards. Select sites on higher ground and away from flood hazards. Provide proper drainage around shelters to prevent accumulation of rain water.

Materials

- Inspect timber to ensure that pieces are straight, not twisted or bowed, free of knots, and not cracked.
- Cement should be a fine grey powder. If there are larger pieces in the sacks, it is an indication that the cement has at least partially set and may not produce sound concrete.
- Gravel for the concrete slab should ideally consist of sand and stone only. Fine and/or dusty soils should be avoided, and stone should not exceed 25mm in size.
- Ideal proportions for concrete are 1:2:3 (Cement : sand : crushed stone) (all by volume).
- Only add enough water to place the concrete. Excess water reduces durability and will cause cracking of the finished slab. If concrete is mixed in batches, maintain consistent proportions for all batches.
- Treat the timbers against termites as this can significantly enhance the durability of the frame.

Foundation

- Verify that the soil under the concrete slab is free of organic material, and that any soft spots have been compacted. Ground surface should be flat and level prior to concrete placement.
- The wood dowels for embedded wire ties should be at least 25mm from the top of the slab surface.
- Verify that all required wire ties are in place before concrete placement.
- Do not dump all the concrete on one side of the slab and push it across to the other side, as it will result in mainly stone on one side of the slab and mainly cement on the other. Instead place concrete on the ground in batches.
- The concrete floor slab also supports the structure, so it should have a flat, level and smooth finish.
- The slab should cure for at least three days before the shelter is installed. Immersing the slab with water or placing a plastic sheet on top of the concrete will improve curing.
- Raising the slab will help reduce flood risk.

Timber Framing

- Layout the timber members of each frame so that one side of the frame is free of sharp edges, nail heads or other items which could damage the sheeting. Install this side on the exterior of the shelter.
- Ensure proper nailing is used to attach timber panels and beams, and that wire cross bracing is securely fastened to the panels and is not loose.
- Verify that wire ties between concrete slab and the wall panels and between wall panels and roofing members are installed and are secure.
- Verify that the wire cross bracing in each wall and roof panel is installed in a taught condition.
- If pressure treated wood is used, use galvanized fasteners, as most preservatives corrode mild steel.

Wall and Roof

- Plastic sheeting for wall and roof covering should be installed neat and tight to the timber framing, and should not billow in the wind, Plastic sheeting can be damaged by flapping against the framing.
- Ensure that the plastic sheeting are fastened to timber framing with battening strips or fasteners with large heads or washers to avoid the fastener head from pulling through the sheeting.

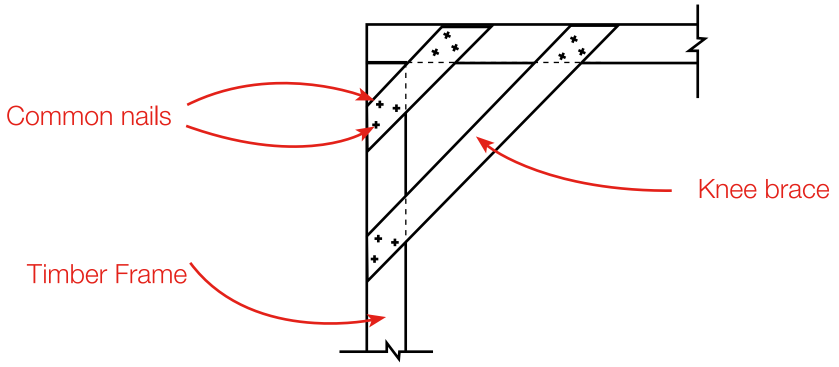
Bill of quantities

The table of quantities below is for the materials required to build the shelter. It does not take into account issues such as which lengths of timber are available and allowances for spoilage in transport and delivery.

Item See annex I.1	Additional Specification	Quantity	Unit	Comments
Foundations				
Portland Cement		2	Bags	42.5 kg/bag
Gravel		0.8	m^3	
Sand		0.6	m^3	
Water		280	Litre	
Main Structure				
Timber 2	70mm x 40mm x 2.7m long	28	Piece	Southern Pine No 2 or Equal
Timber 2	80mm x 80mm x 2.7m long	3	Piece	Southern Pine No 2 or Equal
Covering – Wall and Roof				
Plastic sheet	6m x 6m	3	Piece	note this is not IFRC standard dimensions, but is the size that was used in the field.
Fixings				
Wire 2	5m long	3	Piece	
Common nails	75mm long	1.5	Kg	
Roofing nails	32mm long	1.5	Kg	
Tools				
Spade		1	Piece	
Hoe		1	Piece	
Machete		1	Piece	
Wheelbarrow		1	Piece	
Trowel		1	Piece	
Framing hammer		1	Piece	
Hand saw		1	Piece	
Wire cutters		1	Piece	
Rope	0.9m long	1	Piece	The rope is used during construction to make measurements and to ensure the wall and roof panels are plumb
Gloves		1	Pair	

Note on fixing details

If timber were to be used instead of wire for cross bracing, attention should be given to the design of the joints and the bracing.



Possible timber knee bracing detail: by having dual braces the joint

Knee bracing is typically much less efficient that cross bracing. Cross bracing only puts axial loads in the members (i.e. along their length), which is the direction they are strongest. Knee bracing relies on bending the members, where they are weaker. Additionally, the forces developed in the knee braces are typically much larger than the forces in cross bracing, thereafter requiring stronger connections.

B.3 Haiti – 2010 – 'T-Shelter'

Summary information

Disaster: Earthquake, January 2010

Materials: Wood framed walls with plywood sheathing, metal roofing on wood trusses, concrete slab floor

Material source: Internationally procured

Time to build: 2 – 3 days

Anticipated lifespan: 3 – 5 years

Construction team: 9 people

Number built: 2,000

Approximate material cost per shelter: 1,560 CHF

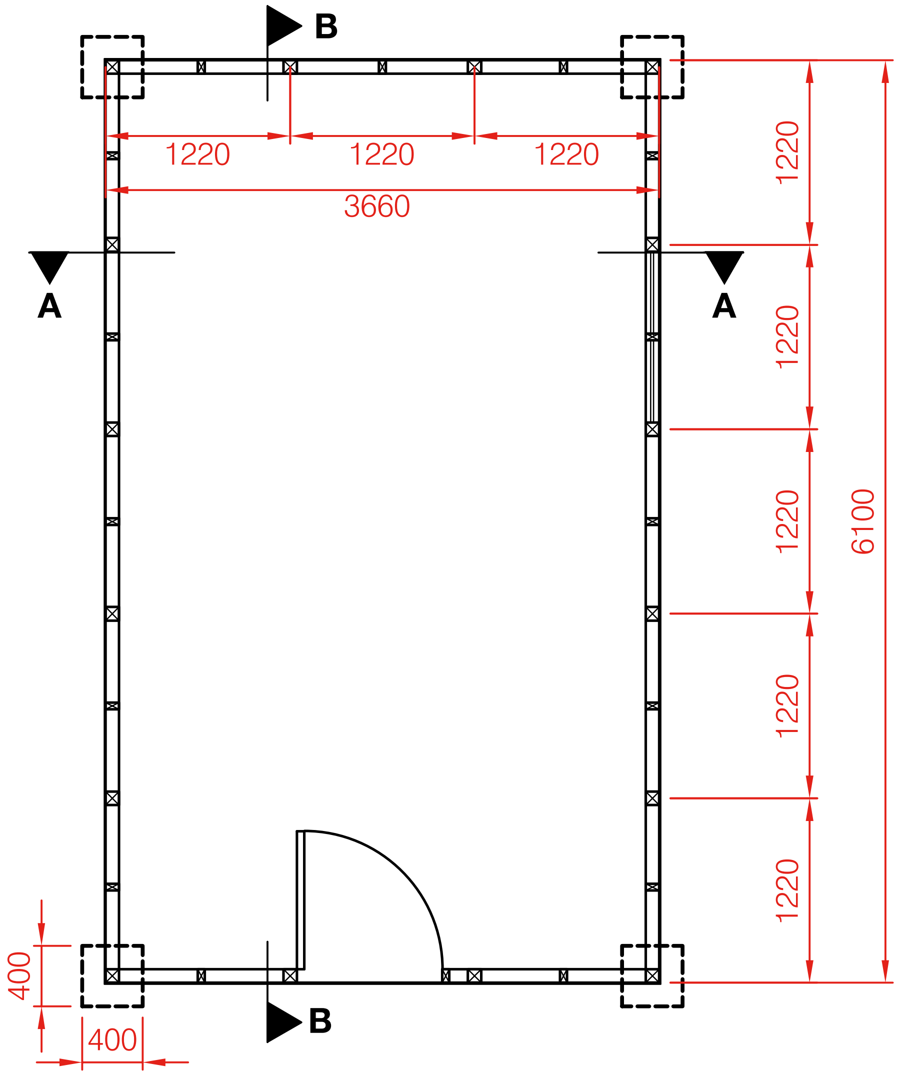
Approximate project cost per shelter: 2,300 CHF

Shelter Description

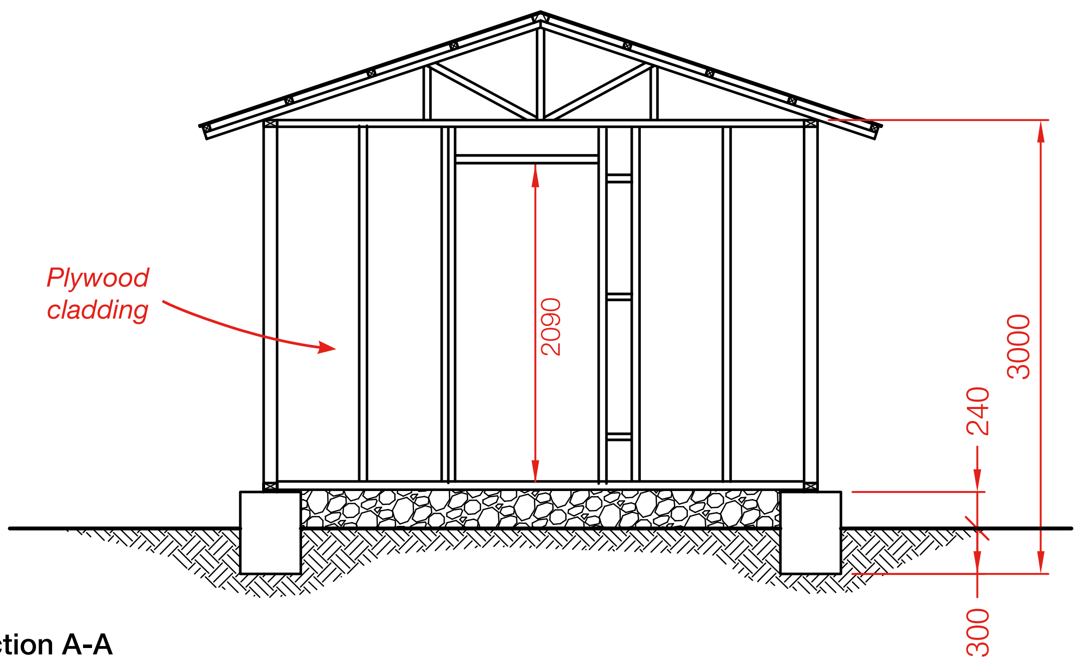
This shelter is a rectangular timber framed structure with a gable roof and a covered floor area of approximately 21 square meters. Wall consists of wood studs with plywood sheathing, and the roof consists of metal roofing on wood purlins and trusses. The trusses are supported on wood posts within in the perimeter walls. The wood trusses can be pre-manufactured and shipped to the construction site. The foundation consists of concrete piers in the four corners and a stone masonry wall in-between the piers. The floor is a cast-in-place concrete slab. As designed, the shelter has only one door and one window.

Shelter Performance Summary

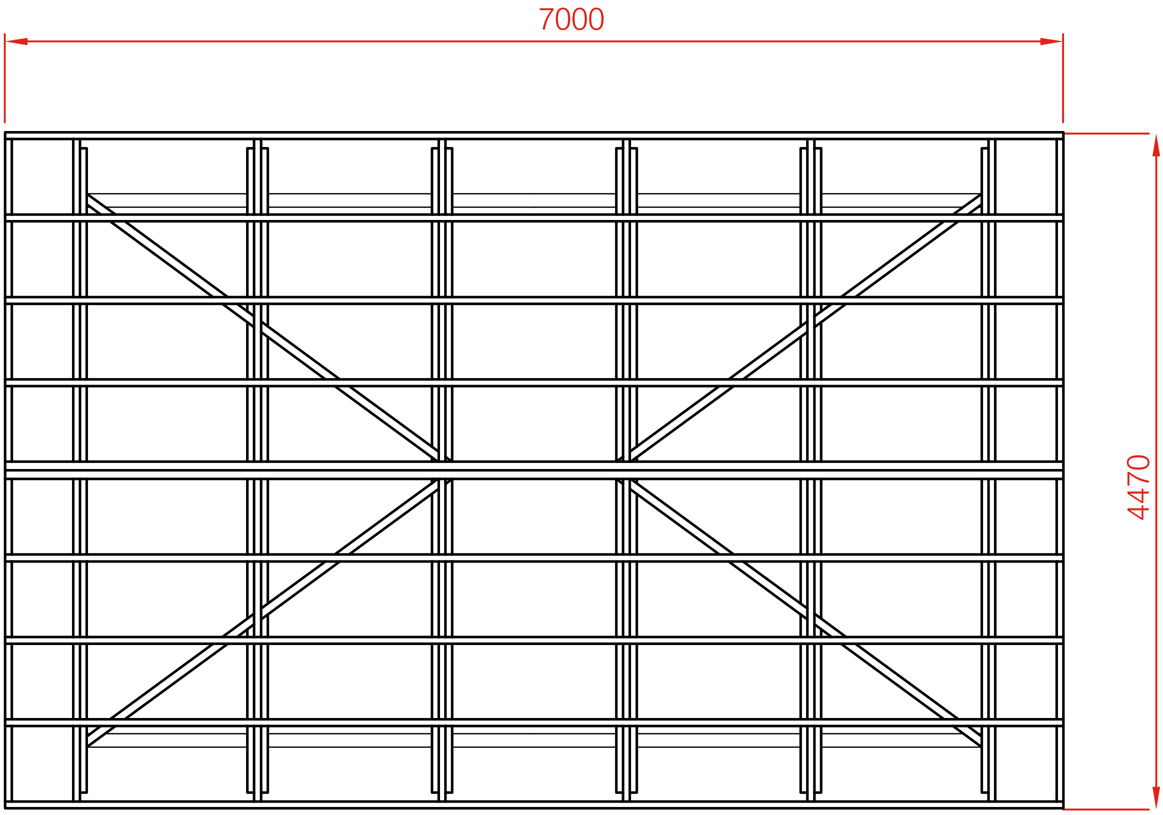
The construction techniques used for this shelter can produce a very durable structure with a design lifespan much larger than the typical transitional shelter, and can provide the basis for more permanent housing. The timber and plywood framing provides a light weight structural system, and with some modification to the anchoring details, can provide excellent performance for both high winds and seismic events. The stone masonry foundation wall raises the floor above the surrounding ground surface, providing resistance to flood damage. To increase the life of the structure, preservative treated wood and/or protective coatings should be applied to prevent rot and other deterioration of the framing.



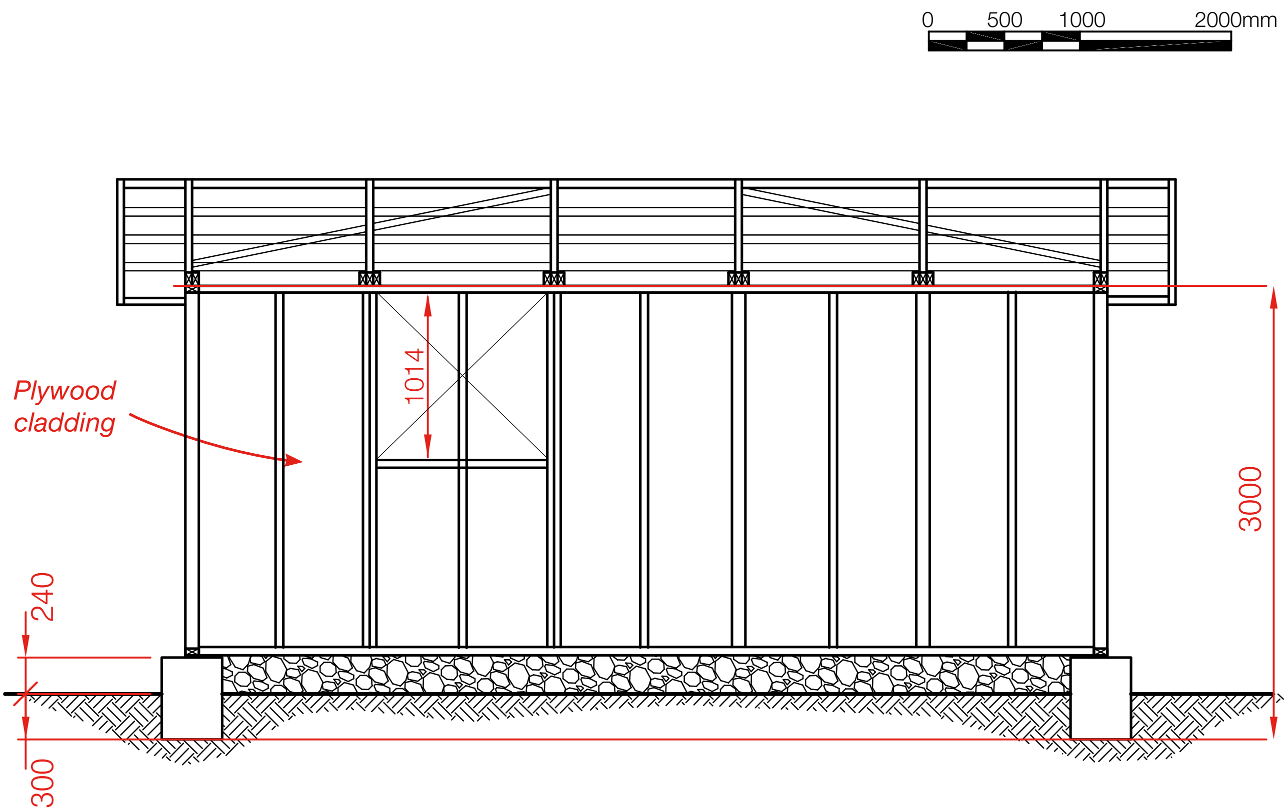
Floor plan



Section A-A



Roof Framing Plan



Section B-B

Durability and lifespan

In general the shelter framing is well designed, and can provide for a long lifespan structure. However there are a few areas of potential concern:

Given the tropical climate in the summer and the presence of termites, it is unlikely that the framing will remain serviceable for extended periods of time unless the timber is treated before construction.

Unless marine or exterior grade plywood is used in the wall and floor construction, or a high quality coating is applied, the wall sheathing may delaminate or deteriorate before the shelter reaches its full design life.

Performance analysis

The plywood shear walls and timber framing are light and provide good resistance for seismic and wind loads typical of Haiti. Proper site analysis is necessary prior to construction to determine appropriate finished floor heights to provide any mitigation of flood hazards.

Hazard*	Performance
Earthquake HIGH	**GREEN:** The plywood shearwalls are light weight and provide excellent resistance for seismic loads. The corner posts are anchored to their foundations, the base of the walls are anchored into the concrete slab, and the roof trusses are tied to the walls with hurricane straps.
Wind HIGH	**AMBER:** As with seismic loading, the plywood shearwalls provide excellent resistance but the concrete piers in the building corners to do not provide sufficient weight to fully resist overturning forces, and it is possible the shelter could tip during strong storms.
Flood HIGH	**GREEN:** The first floor of the shelter is elevated from the surrounding ground surface, and it is easy to modify the design to provide additional clearance if site specific situations required it.
Fire LOW	**AMBER:** The components of the structural system are flammable, and will not offer significant fire resistance. Consideration should be given to providing a second means of egress from the shelter in case the single door is blocked.

* See section Performance analysis summaries

Notes on upgrades

To ensure there are no issues with overturning in large storms, the depth of the concrete piers should be extended to a total of 600mm.

The plywood wall covering is the primary element supporting the roof. To improve durability and longevity of the shelter 64mm long nails should be used to fasten the plywood to the wall framing

The 51mm x 51mm roof purlins are at an AMBER performance level, to achieve GREEN performance either adjust the spacing to 457mm or increase the size of the purlin to 51mm x 76mm.

To improve overall durability and longevity of the shelter, preservative treated wood could be used. If this option is selected, all nails, fasteners, and hurricane ties should be hot dip galvanized.

During hurricanes, roof overhangs are one of the primary areas where roof failures start. The large overhang, especially the one on the gable end, could be reduced to improve wind resistance.

Provided the timber is preservative treated, relatively little maintenance is expected.

Assumptions

- Timber framing is assumed as Spruce-Pine-Fir No 2, or equivalent.
- Plywood sheathing is nailed at 150mm on center along the panel edges, and at 300mm in the middle of the panel.
- Roof truss top chords are fully braced by the purlins, and the bottom chords are fully braced at mid-span by the bottom chord bracing.
- Lateral foundation loads are resisted by lateral soil bearing on the concrete piers.
- Foundation uplift forces are resisted only by the weight of the shelter, and any frictional resistance of between the piers and soil are ignored.
- There is no building code for Haiti, so this shelter was only analysed using the International Building Code.

Potential Issues

Site Selection

- Site selection is the best way to mitigate flood hazards. Select sites on higher ground and away from flood hazards. Provide proper drainage around shelters to prevent accumulation of rain water. Locate shelters a minimum of 10 meters from ravines, or as required by local authorities.
- Avoid sites where soil liquefaction during an earthquake may be a hazard (near river beds, coastal areas with sandy soils and high water tables).

Materials

- Inspect timber to ensure that pieces are straight, not twisted or bowed, free of knots, and not cracked.
- Ideal proportions for concrete are 1:2:3, cement : sand : gravel (all by volume) (see I.2.5 Concrete).
- Stone for the masonry walls should be solid, not fractured, and free of honeycombs and voids.
- Marine plywood is typically manufactured from tropical hardwood veneer. Like exterior grade plywood, it is made with waterproof adhesive.
- The foundation hold downs used in Haiti are specified in USP HPAHD22. Standard coiled hurricane straps can be used in the roof.

Foundation

- Verify that the soil under the shelter is free of organic material, and that soft spots are compacted. The ground surface should be flat and level prior to concrete placement.
- Make sure the hold down straps for the wood posts are installed in the proper location and at the proper depth prior to concrete placement for the piers.
- Stone masonry should be set with mortar and not dry stacked. To the largest extent practical, stones should be laid in an interlocking pattern and mortar joints should ideally be between 10mm and 50mm thick. Since the wall of the shelter sits on top of the masonry wall, the top surface should be finished flat and level.
- Do not dump all the concrete on one side of the slab and push it across to the other side. This will result in most the stone on one side of the slab and the cement on the other. Instead place concrete on the ground in batches to reduce the distance it need to be moved.
- To ensure sound concrete, the slab should cure for at least three days before the shelter is built. Proper curing methods include immersing the slab with water or placing a plastic sheet on top of the concrete

Timber Framing

- Nails should not split or crack the wood framing. Verify the proper number of nails are provided and the proper size is used in each connection. Use of toe nailing should be avoided.
- Verify the truss bottom chord bracing is properly installed, as is required for the roof to resist wind uplift.
- If pressure treated wood is used, hot dip galvanized fasteners should be used, as most preservatives are corrosive to mild steel.

Wall and Roof

- Ensure that wall sheathing is properly nailed to supporting framing.
- Ensure all the nails fastening the roof panels are properly installed.

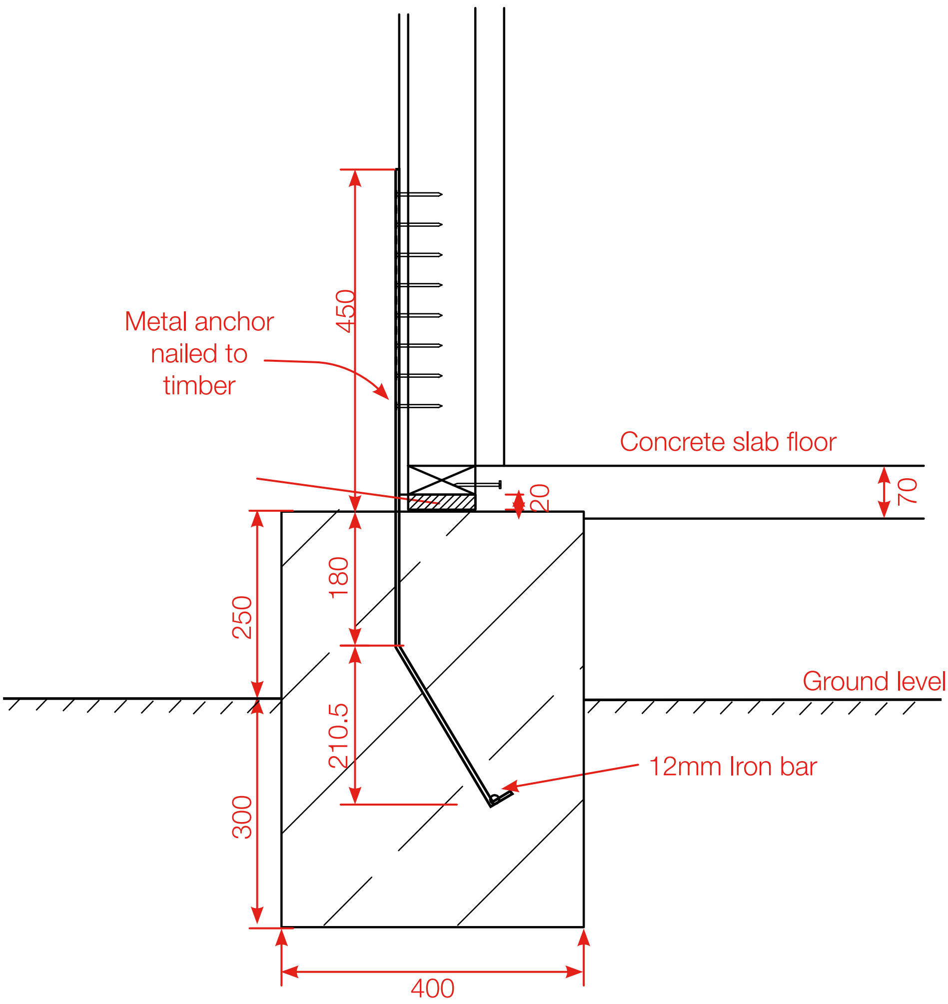
Bill of quantities

The bill of quantities in the table below is for the shelter as it was built, without the design alterations suggested here. It does not take into account issues such as which lengths of timber are available and allowances for spoilage in transport and delivery.

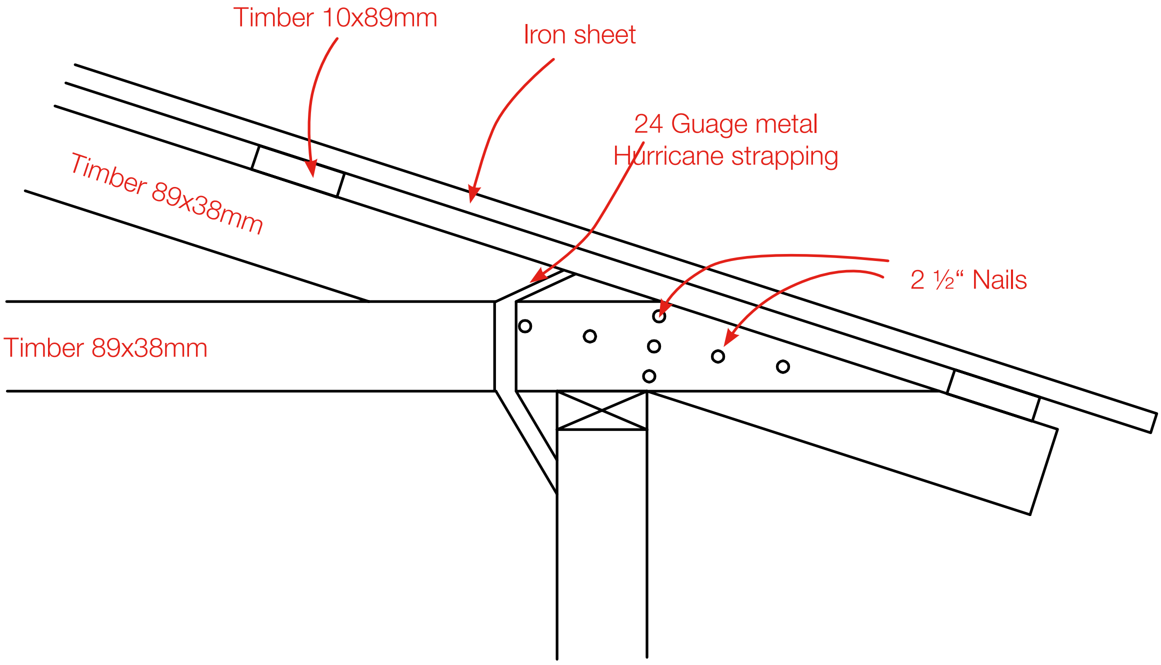
Item See annex I.1	Additional Specification	Quantity	Unit	Comments
Foundations				
Portland cement		18	Bags	42.5 kg/bag
Gravel		1.5	m^3	
Sand		1.0	m^3	
Water		250	litre	
Main Structure				
Timber 2	89mm x 89mm x 2.4m	16	Piece	
Timber 2	38mm x 89mm x 2.4m	32	Piece	
Timber 2	38mm x 89mm x 3.0m	5	Piece	
Timber 2	38mm x 89mm x 3.7m	5	Piece	
Timber 2	38mm x 89mm x 4.3m	11	Piece	
Timber 2	38mm x 89mm x 6.1m	5	Piece	
Timber 2	38mm x 38mm x 3.0m	8	Piece	
Timber 2	38mm x 38mm x 4.3m	8	Piece	
Timber 2	19mm x 89mm x 4.9m	3	Piece	
Covering – Wall and Roof				
Plywood 1		17	Sheet	1.2m x 2.4m sheets
Iron sheet 2		18	Sheet	0.8m x 1.8m sheets
Iron sheet 2		18	Sheet	0.8m x 0.9m sheets
Ridge cap	3.0m Long	2	Piece	
Ridge cap	0.9m Long	1	Piece	
Hinge		7	Piece	Brass with fasteners
Lock		3	Piece	Brass padlock
Surface bolt		3	Piece	
Safety hasp		1	Piece	
Fixings				
Ring nails	76mm long	0.3	kg	
Ring nails	51mm long	3.0	kg	
Ring nails	38mm long	0.1	kg	
Common nails	127mm long	20	Piece	
Common nails	102 mm long	5.6	kg	
Common nails	76 mm long	1.3	kg	
Roofing nails	64 mm long, 15mm head	2	kg	
Nail plates	105mm x 178mm x 1 mm	12	Piece	Galvanized
Hurricane strap	USP HPAHD22	12	Roll	91m per roll, galvanized
Post straps		4	Piece	Galvanized

Tools				
Spade		1	Piece	
Hoe		1	Piece	
Wheelbarrow		1	Piece	
Framing hammer		2	Piece	
Hand saw		2	Piece	
Wire cutters		1	Piece	
Gloves		4	Pair	

Foundation detail - with metal anchor



Roof fixing detail



B.4 Haiti – 2010 – 'T-Shelter'

Summary information

Disaster: Earthquake, January 2010

Materials: Wood framed walls, floor, and roof with plywood sheathing and metal roofing.

Material source: Internationally procured

Time to build: 3 – 5 days

Anticipated lifespan: 5 – 10 years

Construction team: 5 – 7 people

Number built: 4,471

Approximate material cost per shelter: 2580 CHF

Approximate project cost per shelter: 5430 CHF

Shelter Description

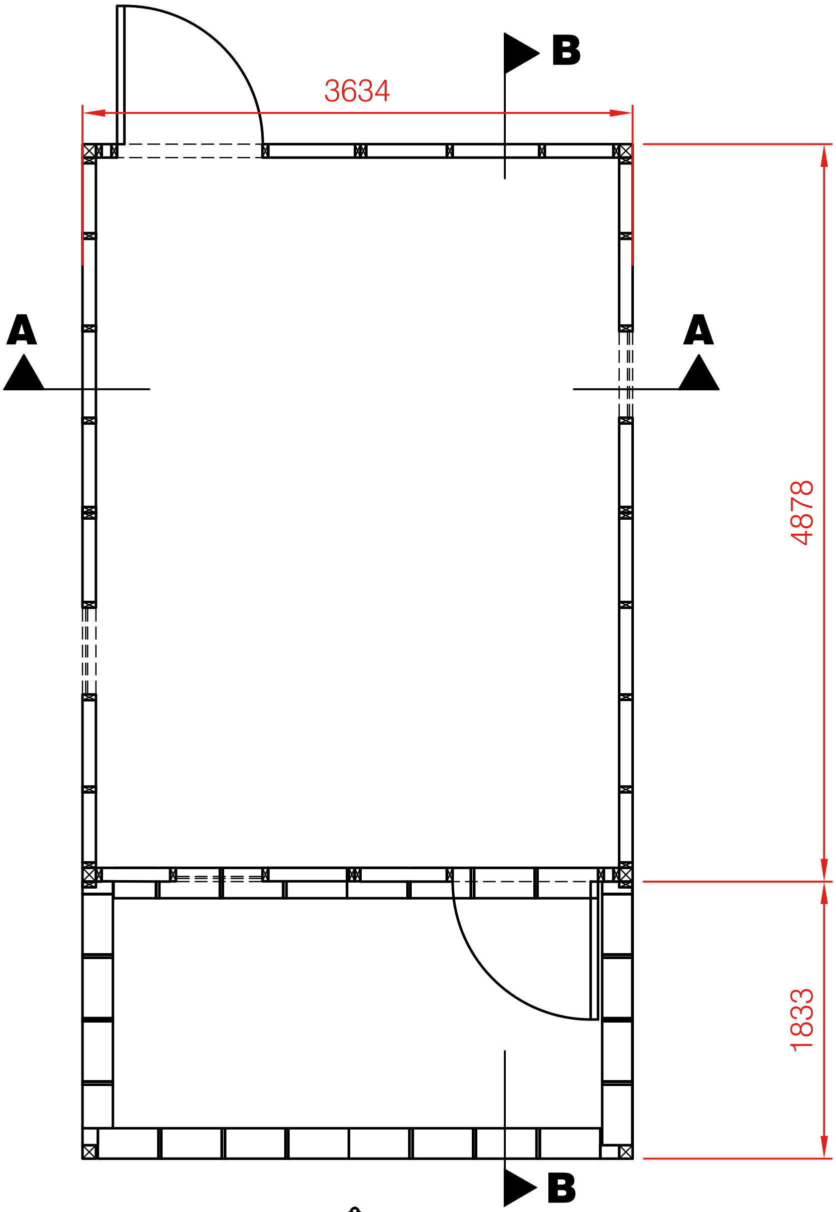
This shelter is a rectangular timber framed structure with a gable roof and a covered floor area of approximately 3.6m x 4.9m with a covered porch measuring approximately 3.6m x 1.8m in front. The floor is constructed with wood joists, and the walls are constructed with wood studs. Both are supported by built-up timber posts. The roof is framed with wood trusses that can be pre-manufactured and shipped to the site. The roof extends over the porch to provide cover. Floors and walls are covered with plywood, and the roof is covered with metal panels. The bottom of the built-up timber posts are encased in concrete and embedded in the ground. The design includes one door in the front and back walls, and louvred wall openings.

Shelter Performance Summary

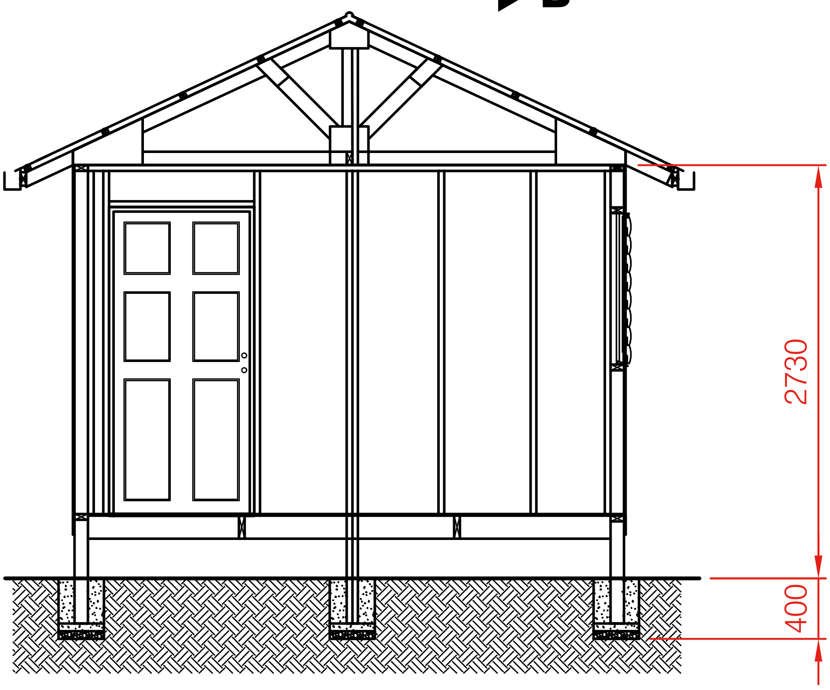
The construction techniques used for this shelter will produce a very durable structure with a design lifespan of five to ten years, and can provide the basis for more permanent housing. The modular construction facilities prefabrication of many building components for shipment to the site, which can greatly reduce the required construction time. The timber and plywood framing provides a light weight structural system with excellent performance for both high winds and seismic events. This design also provides flood resistance since the first floor is raised above the surrounding ground surface.

If a long life for the structure is desired, preservative treated wood and/or protective coatings should be applied to prevent rot and other deterioration of the framing. Ongoing maintenance will also be required.

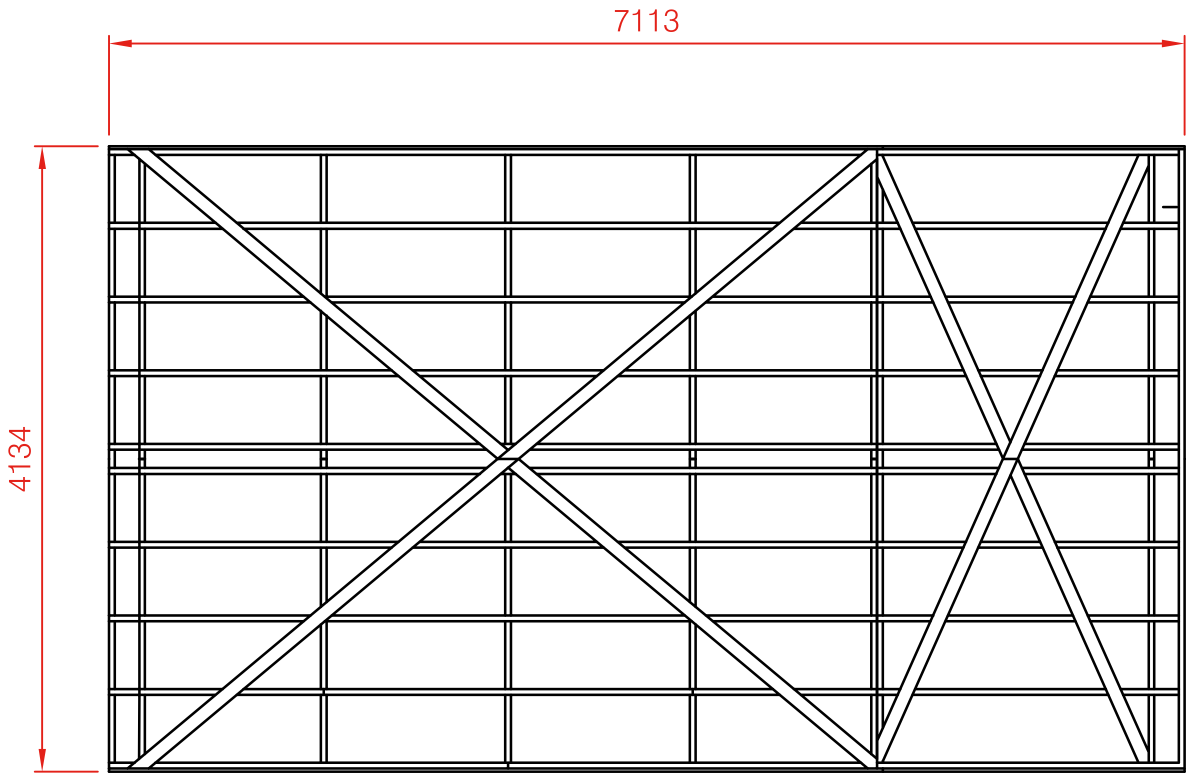
Plans



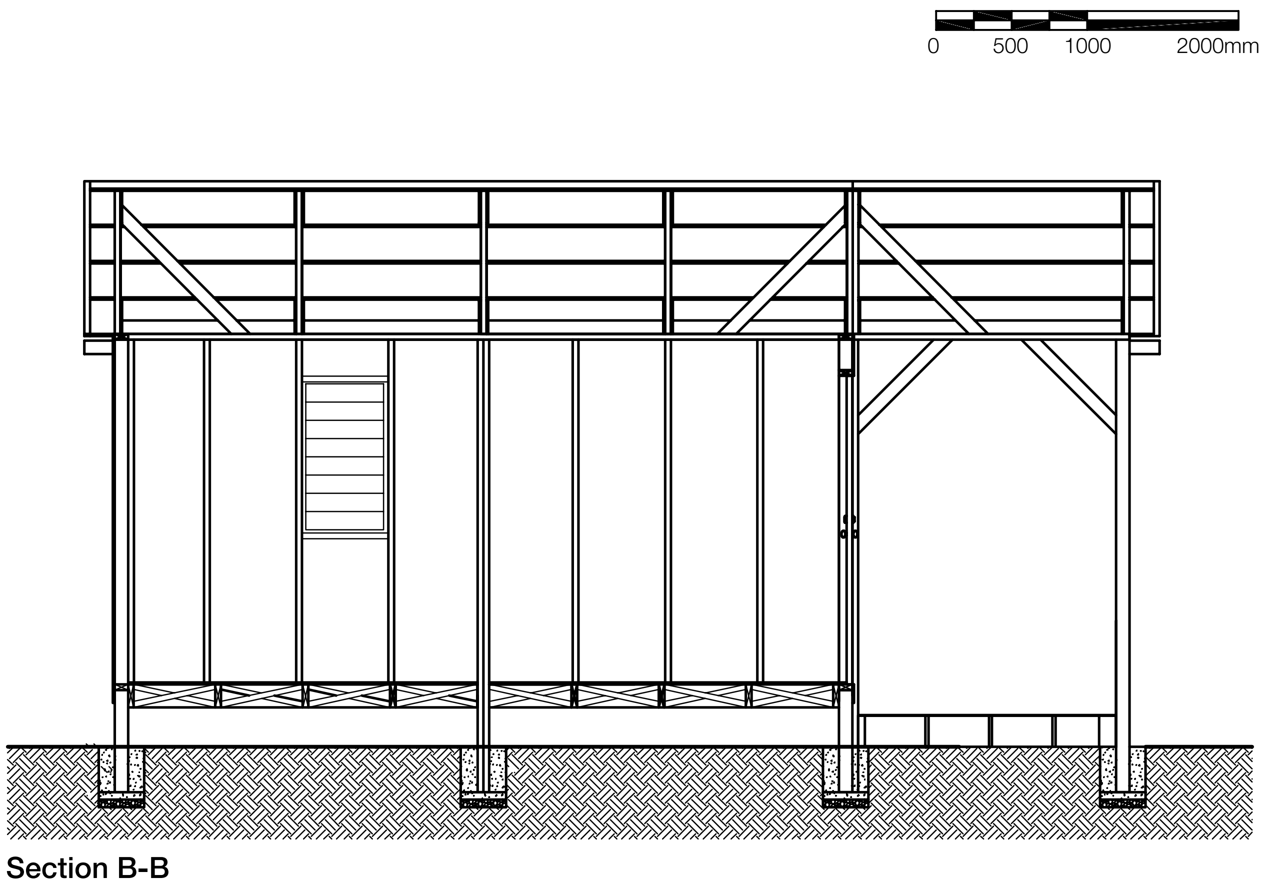
Floor plan



Section A-A



Roof Framing Plan



Section B-B

Durability and lifespan

In general the shelter framing is well designed, has excellent resistance to wind and seismic loads, and should provide for a structure with a long lifespan. However there are a few areas of potential concern:

- Given the tropical climate in the summer and the presence of termites, it is unlikely that the framing will remain serviceable for extended periods of time unless the timber is treated before construction.
- Unless marine grade plywood is used in the wall and floor construction, or a high quality coating is applied, the wall and floor covering may delaminate or deteriorate before the shelter reaches its full design life.

Performance analysis

The performance of the shelter is good for high seismic and wind loads typical of Haiti. Depending on the grade of lumber used, the girders in the floor system may require strengthening to meet the floor live loads. Proper site analysis is necessary prior to construction to determine appropriate finished floor heights to provide any mitigation of flood hazards.

Hazard*	Performance
Earthquake HIGH	**GREEN:** The plywood shear walls are light weight and provide excellent resistance for seismic loads. This structure should perform well throughout earthquakes.
Wind HIGH	**AMBER:** As with seismic loading, the plywood shear walls provide excellent strength, and the roof trusses are adequately tied and braced to resist hurricane loads. The small size of the concrete footings does not provide adequate weight to fully resist overturning forces, and it is possible the shelter could tip during strong storms.
Flood HIGH	**GREEN:** The first floor of the shelter is elevated 425mm above the surrounding ground surface, and it is easy to modify the design to provide additional clearance if site specific situations required it.
Fire LOW	**AMBER:** The components of the structural system are flammable, and will not offer significant fire resistance. Fortunately the small floor plan and two means of egress make it easy for occupants to exit before being harmed.

* See section A.4.5 Performance analysis summaries

Notes on upgrades

The strength of the floor system is controlled by the girder between the wood columns. This member can be strengthened by either increasing its depth to 200mm or providing two wood members nailed together.

To ensure there are no issues with overturning in large storms, the footings should be increased to 450mm diameter by 450mm deep.

The wood framed floor can be replaced with concrete or masonry perimeter walls and an elevated concrete slab on fill to further improve flood resistance.

To increase the durability of the wood posts, a metal cap plate or another anchor can be used to connect to the foundation instead of embedding the wood in the concrete. Embedded wood has a tendency to rot due to prolonged contact with moisture.

The plywood wall covering is the primary element supporting the roof. To improve durability and longevity of the shelter 64mm long nails should be used to fasten the sheathing to the wall framing. Additionally, although at a greater cost, higher quality marine ply could be used.

To improve overall durability and longevity of the shelter, preservative treated wood could be used. If this option is selected, it is important that all nails, fasteners, and hurricane ties be hot dip galvanized.

Assumptions

- Timber framing is assumed to be Spruce-Pine-Fir No 2, or equivalent.
- Plywood is nailed at 150mm on center along the panel edges, and at 300mm in the panel's centre.
- Roof truss top chords are fully braced by the purlins, and the bottom chords are fully braced at mid-span by the bottom chord bracing.
- The hurricane ties provided are strong enough and are adequately fastened to supporting framing to resist the design wind uplift loads.
- Lateral foundation loads are resisted by lateral soil bearing on the concrete piers.
- Foundation uplift forces are resisted only by the weight of the shelter, and any frictional resistance of between the piers and soil are ignored.
- There is no building code for Haiti, so this shelter was only analysed using the International Building Code.

Potential Issues

Site Selection

- Site selection is the best way to mitigate flood hazards. Select sites on higher ground and away from flood hazards. Provide proper drainage around shelters to prevent accumulation of rain water. Locate shelters a minimum of 10 meters from ravines, or as required by local authorities.
- Avoid building shelters close to ravines as they have a no-building zone defined by local authorities.
- For sites where soil liquefaction during an earthquake may be a hazard (near river beds, coastal areas with sandy soils and high water tables) the shelter could be seriously damaged in an earthquake.

Materials

- Inspect timber to ensure that pieces are straight, not twisted or bowed, free of knots, and not cracked.
- Cement should be a fine grey powder. If there are larger pieces in the sacks, it is an indication that the cement has at least partially set and may not produce sound concrete.
- Ideal proportions for concrete are 1:2:3, cement : sand : gravel (all by volume). Only add enough water to allow the concrete to be placed. Excess water reduces durability and will cause more cracking of the finished slab. See I.3.1 Concrete.

Foundation

- Verify that the soil under the piers are free of organic material, and that any soft spots have been compacted. The ground surface should be flat and level prior to concrete placement.
- Provide nails, bolts, spikes, or other protrusions on the end of the wood post encased in the concrete pier to ensure post is adequately anchored. In certain cases additional anchoring may be required.
- Make sure wood posts are in their proper location, vertical, the tops are level and are at the correct elevation. Otherwise construction of the wood framing will be difficult.

Timber Framing

- All framing should be adequately nailed together, and nails should not split or crack the wood framing. Verify the proper number and size are used in each connection. Use of skew nailing should be avoided.
- Verify the truss bottom chord bracing is properly installed, as is required for the roof to resist wind uplift pressures.
- Verify all the hurricane straps are properly installed, as they are required for the roof to resist wind uplift.
- If pressure treated wood is actually used, hot dip galvanized fasteners should be used, as most preservatives are corrosive to mild steel.

Wall and Roof

- Ensure that wall and floor coverings are properly nailed to the supporting frame with the proper size and spacing of nails.
- Ensure all the nails fastening the roof panels are properly installed.

Door location

- Although the door location does not significantly affect the performance of this structure, in general it is bad practice to put the door in the corner of a shelter in an area with earthquake risks.

Bill of quantities

The table of quantities below is for the materials required to build the shelter. It does not take into account issues such as which lengths of timber are available and allowances for spoilage in transport and delivery.

Item See annex I.1	Additional Specification	Quantity	Unit	Comments
Foundations				
Portland Cement		5	Bags	42.5 kg/bag
Gravel		0.8	m^3	
Sand		1.5	m^3	
Water		0.2	m^3	
Concrete blocks	Concrete Masonry Unit (CMU)	30	Piece	(for flooring the outside area)
Main Structure				
Timber 2	38mm x 38mm x 3.7m	34	Piece	
Timber 2	38mm x 102mm x 2.4m	40	Piece	
Timber 2	38mm x 102mm x 3.1m	28	Piece	
Timber 2	38mm x 102mm x 3.7m	10	Piece	
Timber 2	38mm x 102mm x 4.3m	5	Piece	
Timber 2	38mm x 152mm x 3.7m	16	Piece	
Timber 2	102mm x 102mm x 3.1m	6	Piece	
Covering – Wall and Roof				
Plywood	13mm thick	28	Sheet	1.2m x 2.4m sheets
Sheet 2		18	Sheet	0.8m x 2.4m sheets
Ridge cap	1.8m long	6	Piece	
Door	962mm x 2040mm	2	Piece	
Window Louver	572mm x 100mm	3	Piece	
Lock Set		2	Piece	
Latch Set		2	Piece	
Hinges		5	Pair	
Fixings				
Common nails	50mm long	4.5	kg	
Common nails	76mm long	3.2	kg	
Common nails	102mm long	7.7	kg	
Common nails	Roofing	5.5	kg	
Wire 1		1	kg	
Hurricane Straps		3	Roll	
Tools: Depends on the composition of the construction team and used many times.				
Pickaxe		1	Piece	
Rope		1	Roll	
Pegs		6	Piece	
Ladder		1	Piece	
Spade		1	Piece	
Hoe		1	Piece	
Wheelbarrow		1	Piece	
Framing Hammer		2	Piece	
Hand Saw		2	Piece	
Wire Cutters		1	Piece	
Gloves		4	Pair	

B.5 Haiti – 2010 – 'T-Shelter'

Summary information

Disaster: Earthquake, January 2010

Materials: Wood framed walls with clissage infill, corrugated bitumen on timber trusses, concrete slab floor.

Material source: Internationally procured

Time to build: 66 man days, but could be built in less than 2 weeks onsite

Anticipated lifespan: 3 – 5 years

Construction team: 10 people plus fabrication team in warehouse

Number built: 1,050

Approximate material cost per shelter: 1,650 CHF materials, 850 CHF (for staffing, supervision and labour)

Shelter Description

This shelter is a rectangular timber framed structure with a gable roof and a covered floor area of approximately 5.4m x 3.7m with a covered porch measuring approximately 1.8m x 3.7m. The roof has wood and corrugated bituminous roofing supported on timber purlins and trusses. The exterior walls are wood framed, and the wall infill is constructed using a traditional technique called clissage, which consists of thin slats of wood woven between the wall framing. The foundation consists of wood posts embedded in concrete piers, and the floor is an elevated concrete slab supported by a short masonry wall between the wood posts. As designed, the shelter has one door and two windows. The shelters were designed to be accessible by persons with reduced mobility and individual modifications were made according to personal needs.

Shelter Performance Summary

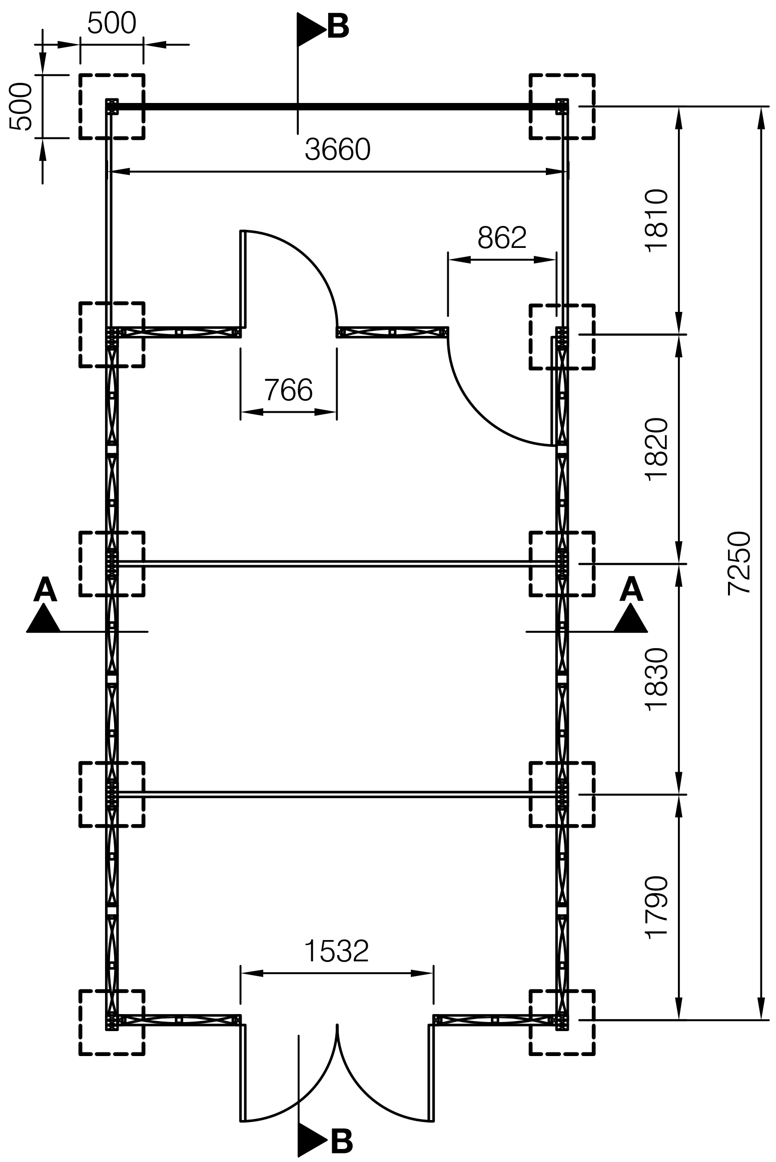
The construction of this shelter is based on traditional techniques typical to Haiti, which has a successful historical track record. The clissage walls allow excellent ventilation if they are left uncovered, and they can also be reinforced with mud or mortar to provide a solid wall. This technique allows for the use of local labour, and reduces the size and volume of material required, allowing construction in remote areas.

Unfortunately there is only anecdotal evidence for the performance of the framing system, and there is little, if any, engineering data or analysis techniques for this construction type. Therefore, the adequacy of the lateral load resisting system cannot be verified. Filling in the walls will increase the lateral load capacity, but the weight and brittle properties of the wall most likely will not perform well in a severe earthquake or under high winds. Laboratory tests of the wall panels are required to determine their lateral load capacity for future analysis.

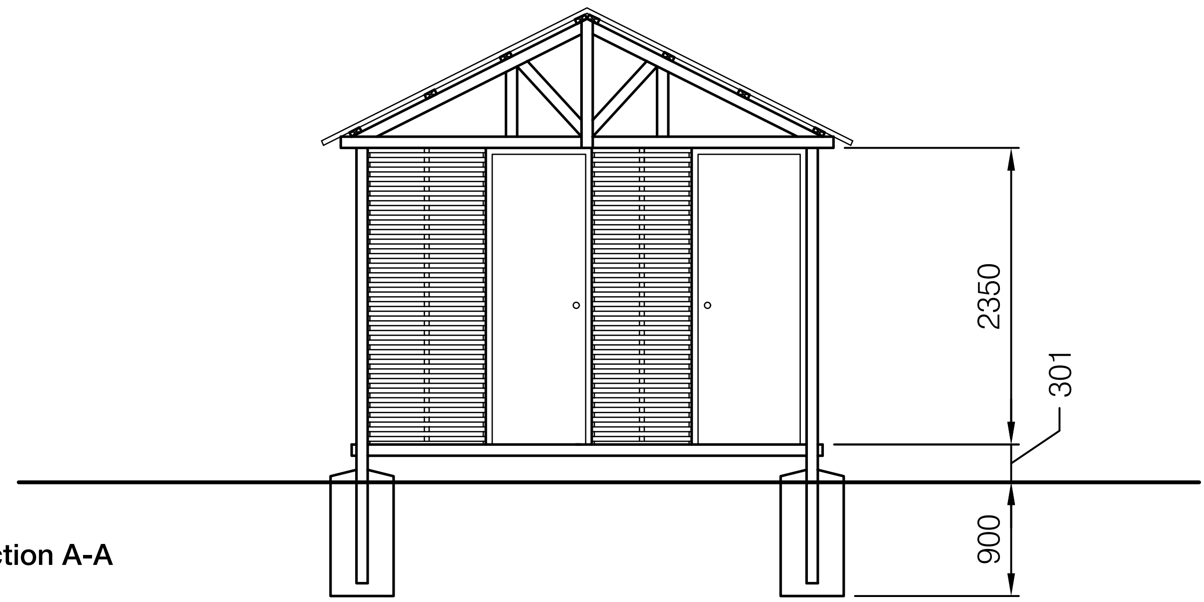
The masonry foundation wall raises the floor, providing resistance to flood damage. Using preservative treated wood and/or protective coatings would help prevent deterioration of the frame, increasing the shelter lifetime.

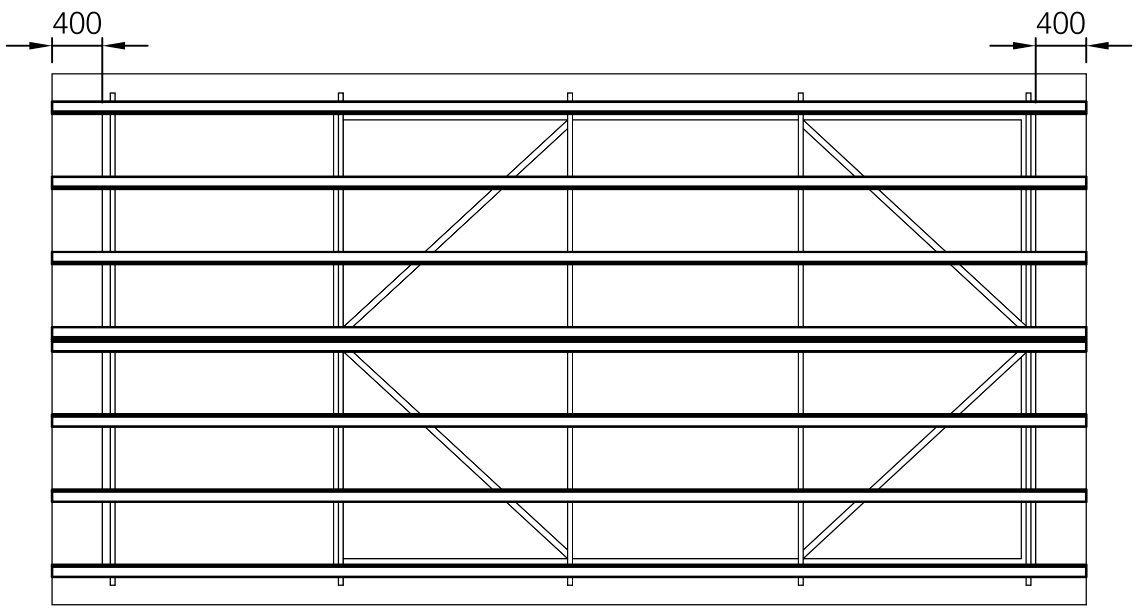
Plans

Floor plan

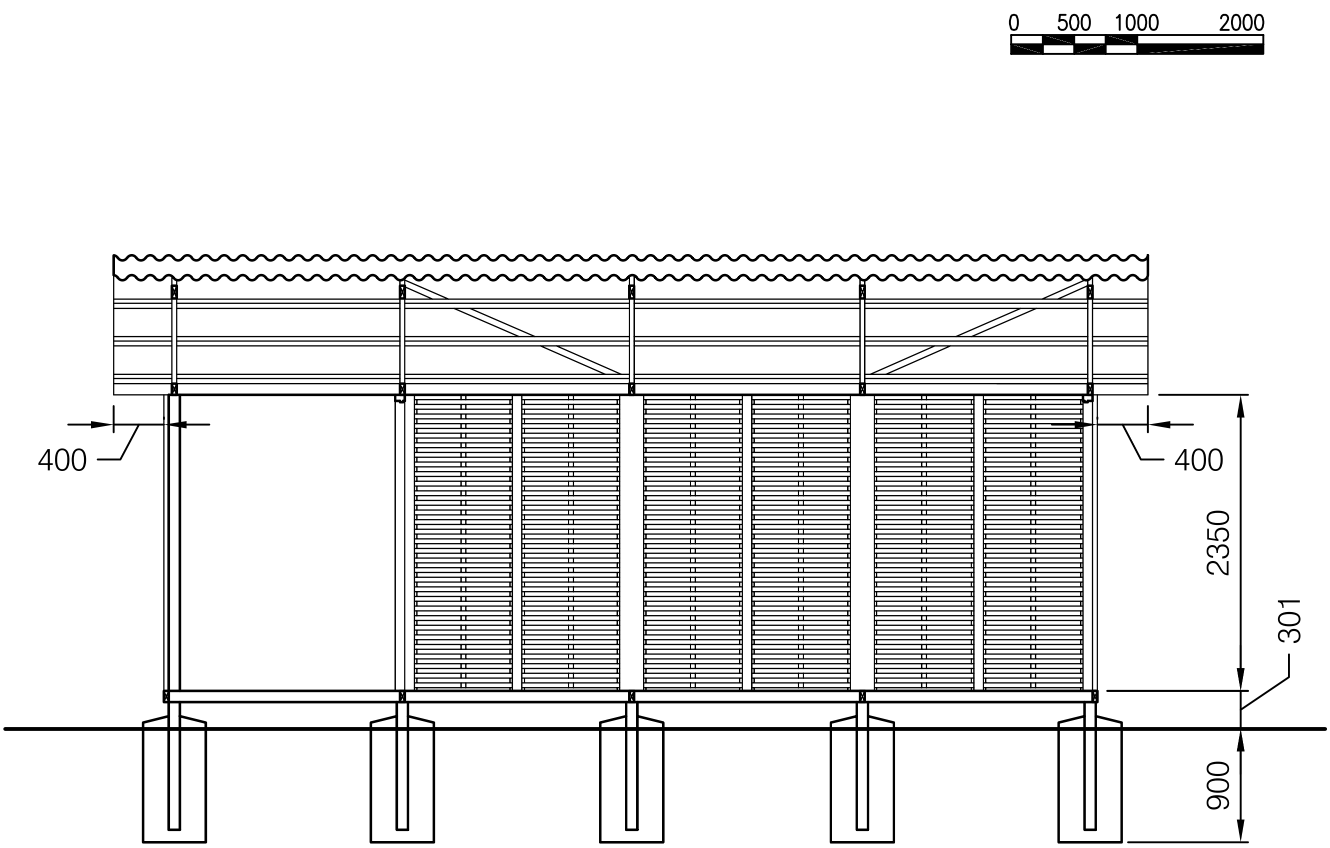


Section A-A





Roof Framing Plan



Section B-B

Durability and lifespan

Because There is limited engineering data available for the clissage technique, It is not certain how well the shelter will perform in large storms or earthquakes.

Given the tropical climate in the summer and the presence of termites, the timber was pressure treated before construction. All nails, fasteners, and hurricane ties were hot dip galvanized.

Performance analysis

There is a lack of data on the performance characteristics of the clissage walls under lateral loading, it is not possible to determine the performance of the shelter under wind and earthquake with any accuracy. Proper site analysis is necessary prior to construction to determine appropriate finished floor heights to provide any mitigation of flood hazards

To fully assess the clissage construction technique to enable full engineering calculations, a sample shelter would need to be constructed and load tests applied.

Hazard*	Performance
Earthquake HIGH	**UNKNOWN:** Given the lack of engineering data surrounding the clissage technique, the bare walls do not provide a complete lateral load path. Filling the walls with mud will add some lateral capacity, but the increase in weight along with the brittle nature of the finish will most likely not perform well under the cyclical loading typical of an earthquake.
Wind HIGH	**UNKNOWN:** Given the lack of engineering data surrounding the technique, and as with seismic loading, the bare clissage walls do not provide a complete lateral load path. Filling the walls will add lateral capacity, and may provide resistance to wind pressures but could be vulnerable to damage from wind blown debris.
Flood HIGH	**GREEN:** The first floor of the shelter is elevated the surrounding ground surface, and it is easy to modify the design to provide additional clearance if site specific situations required it.
Fire LOW	**AMBER:** The components of the structural system are flammable, and will not offer significant fire resistance. Filling the wall panels would improve the performance of the wall, but offer no protection to the roof. However, the shelter does have two doors.

* See section A.4.5 Performance analysis summaries

Notes on upgrades

Installation of wire or cable bracing to each wall will insure that there is a system to resist lateral loads, and can dramatically improve the performance of the shelter.

To improve overall durability and longevity of the shelter, preservative treated wood could be used. If this option is selected, it is important that all nails, fasteners, and hurricane ties be hot dip galvanized.

Assumptions

- Timber framing is assumed as Spruce-Pine-Fir No 2, or equivalent
- Roof truss top chords are fully braced by the purlins, and the bottom chords are fully braced at mid-span by the bottom chord bracing.
- Lateral foundation loads are resisted by lateral soil bearing on the concrete piers.
- Foundation uplift forces are resisted only by the weight of the shelter, and any frictional resistance of between the piers and soil are ignored.
- There is no building code for Haiti, so this shelter was only analysed using the International Building Code

Potential Issues

Site Selection

- Site selection is the best way to mitigate flood hazards. Select sites on higher ground and away from flood hazards. Provide proper drainage around shelters to prevent accumulation of rain water. Locate shelters a minimum of 10 meters from ravines, or as required by local authorities.
- For sites where soil liquefaction during an earthquake may be a hazard (near river beds, coastal areas with sandy soils and high water tables) the shelter could be seriously damaged in an earthquake.

Materials

- Inspect timber to ensure that pieces are straight, not twisted or bowed, free of knots, and not cracked.
- Cement should be a fine grey powder. If there are larger pieces in the sacks, it is an indication that the cement has at least partially set and may not produce sound concrete.
- Ideal proportions for concrete are 1:2:3, cement:sand:gravel (all by volume). Only add enough water to allow the concrete to be placed. Excess water reduces durability and will cause more cracking of the finished slab. If concrete is mixed in batches, maintain consistent proportions for all batches. See I.3.1 Concrete

Foundation

- Verify that the soil under the piers, concrete slab and masonry walls are free of organic material, and that any soft spots have been compacted. Ground surface should be flat and level prior to concrete placement.
- Provide nails, bolts, spikes, or other protrusions on the end of the wood post encased in the concrete pier to ensure post is adequately anchored .
- Do not dump all the concrete on one side of the slab and push it across to the other side. This will result in most the stone on one side of the slab and the cement on the other. Instead place concrete on the ground in batches to reduce the distance it needs to be moved.
- To ensure sound concrete, slab should be allowed to cure for at least three days before the shelter is installed. Proper curing methods include immersing the slab with water or placing a plastic sheet on top of the concrete.

Timber Framing

- All framing should be adequately screwed together, and screws should not split or crack the wood framing. Verify the proper number of screws are provided and the proper size is used in each connection.
- Verify the truss bottom chord bracing is properly installed, as is required for the roof to resist wind uplift pressures.
- If pressure treated wood is actually used, hot dip galvanized fasteners should be used, as most preservatives are corrosive to mild steel.

Wall and Roof

- Ensure that the corrugated bituminous roofing is properly fixed with suitable screws.

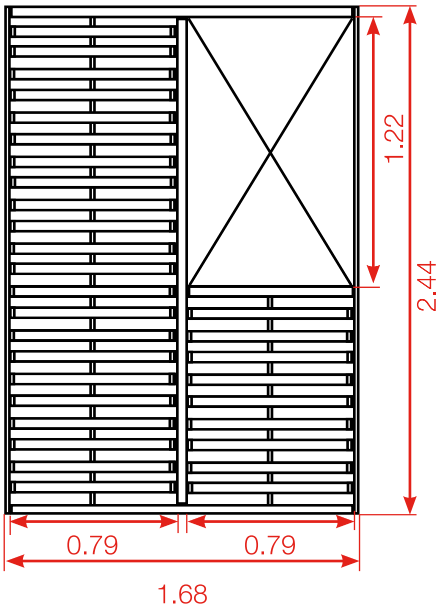
Bill of quantities

The bill of quantities in the table below is for the shelter as it was built, without the design alterations suggested here. It does not take into account issues such as which lengths of timber are available and allowances for spoilage in transport and delivery.

Item	Material Specification See annex I.1	Quantity	Unit	Comments
Foundations				
Portland cement		18	Bags	42.5 kg/bag
Gravel		4	m3	
Sand		6	m3	
CMU blocks	203mm x 203mm x 406mm	90	Piece	
Main Structure				
Timber 2	38mm x 89mm x 4.3m	105	Piece	
Timber 2	38mm x 38mm x 4.3m	5	Piece	
Timber 2	19mm x 152mm x 4.3m	2	Piece	
Timber 2	19mm x 89mm x 4.3m	29	Piece	
Plywood	13mm thick	3	Sheet	1.2m x 2.4m sheets
Covering – Wall and Roof				
Plastic netting	1.2m wide x 30.5m long	0.2	Roll	
Corrugated bituminous roofing (Onduline)		24	Sheet	950mm x 5m
Bituminous ridge Cap (onduline)		8	m	
Door Hinges		1	Pair	
Window Hinges		3	Pair	
Door Lock		1	Piece	
Window Lock		3	Piece	
Hinge Door Lock		1	Piece	
Fixings				
Wood glue		0.4	liter	
Fasteners	25mm x 127mm	30	Piece	
Threaded rod	9.5mm dia x 2m long	5	Piece	
Hex nut & washers	9.5mm dia	100	Piece	
Wood screws	89mm long	40	Piece	
Common nails	127mm long	1.8	kg	
Common nails	102mm long	8.3	kg	
Common nails	76mm long	5.2	kg	
Common nails	64mm long	1.4	kg	
Common nails	51mm long	2.6	kg	
Common nails	38mm long	1.8	kg	
Common nails	25mm long	0.5	kg	
Roofing nails	64mm long	6.4	kg	
Hurricane strap		18	m	coiled

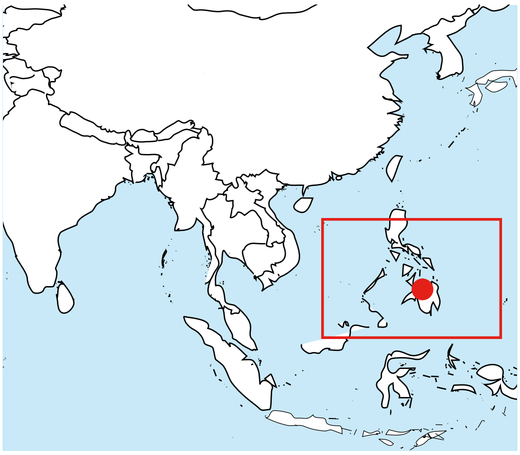
Tools				
Spade		1	Piece	
Hoe		1	Piece	
Wheelbarrow		1	Piece	
Framing Hammer		2	Piece	
Hand Saw		2	Piece	
Socket Set		2	Sets	
Wire Cutters		1	Piece	
Gloves		4	Pair	

Details of a clissage panel



Left drawing of a pre-manufactured clissage window panel and right photograph to show how the wooden slats were woven together. Panels were pre-fabricated and then nailed together on site.

B.6 Philippines – 2011 – 'Transitional-Shelter'



Summary information

Disaster: Typhoon, December 2011

Materials: Concrete footings, coconut wood frame, plywood floor, amaken walls and corrugated iron roof

Material source: Locally procured

Time to build: 5 days

Anticipated lifespan: 5 years

Construction team: 5 people

Number built: 1,823

Approximate material cost per shelter: 500 CHF

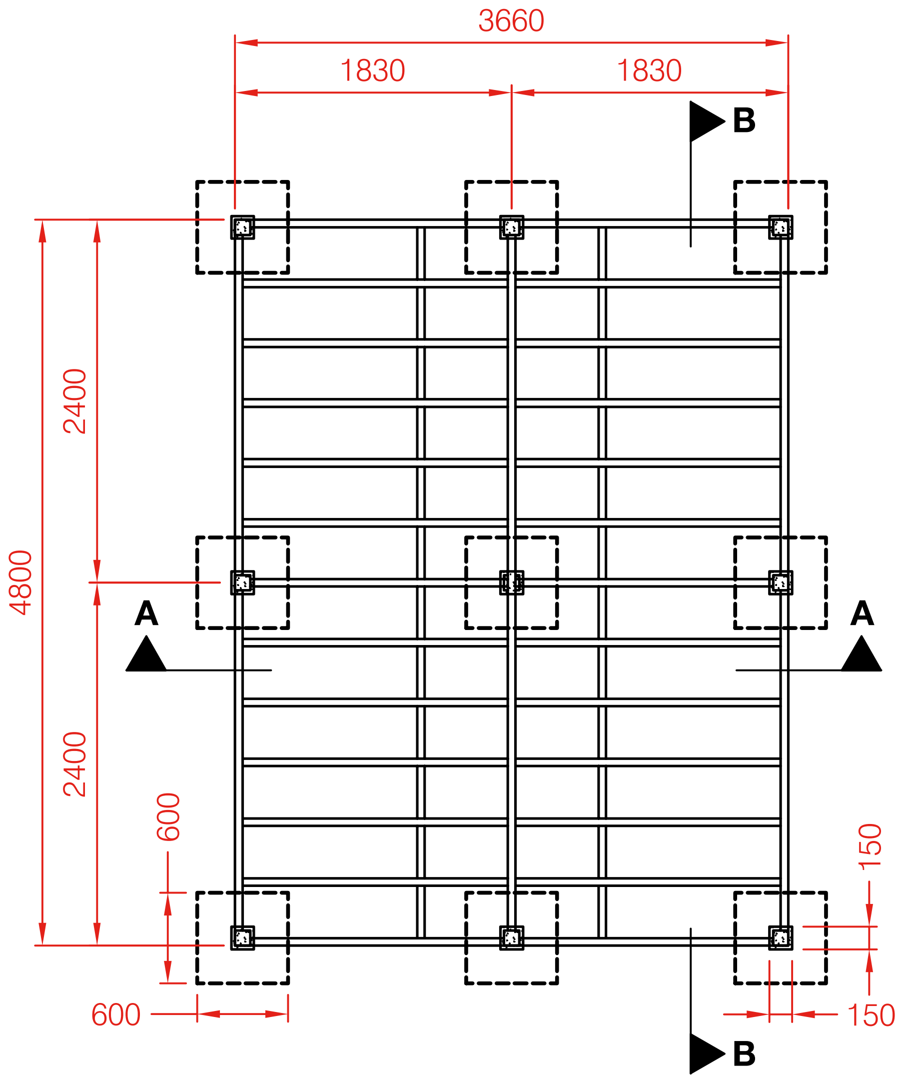
Shelter Description

This shelter is a rectangular structure with a single pitch roof and a covered floor area of approximately 4.8m x 3.7m. The shelter is supported on concrete piers and footings such that the first floor is raised approximately 750mm above grade. The floor and roof are framed with coconut wood beams and joists. The floor is plywood and the roof is corrugated metal roofing. The exterior walls consist of amakan (woven panels of bamboo or palm leaves) fastened to the coconut wood frame. The light weight wood frame can be lifted off the concrete piers and moved to a different location by a small number of people. As designed, the shelter has one door and two windows.

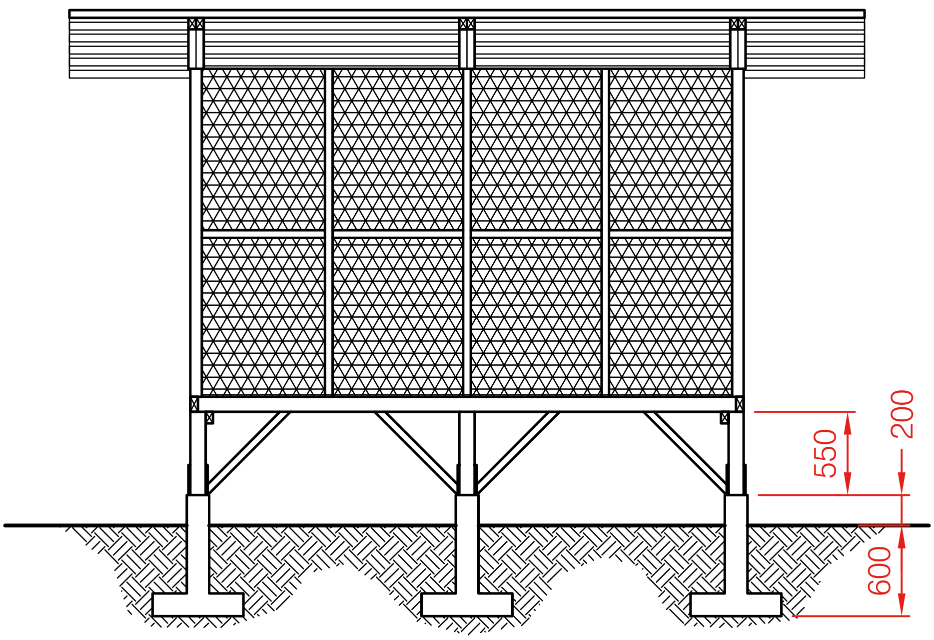
Shelter Performance Summary

The timber framing should be relatively durable, provided it is properly treated prior to construction. The timber framing and amakan wall panels can be built with locally sourced materials, and the simple construction reduces the need for skilled labor. Provided the wood posts and roof rafters are adequately anchored to their supports the shelter should perform satisfactorily, but damage should be expected during strong storms. The adequacy of the floor and roof framing is dependent on the use of high quality wood. To ensure good performance of the floor and roof framing, all the beams supporting floor joist and roof rafters should be doubled up.

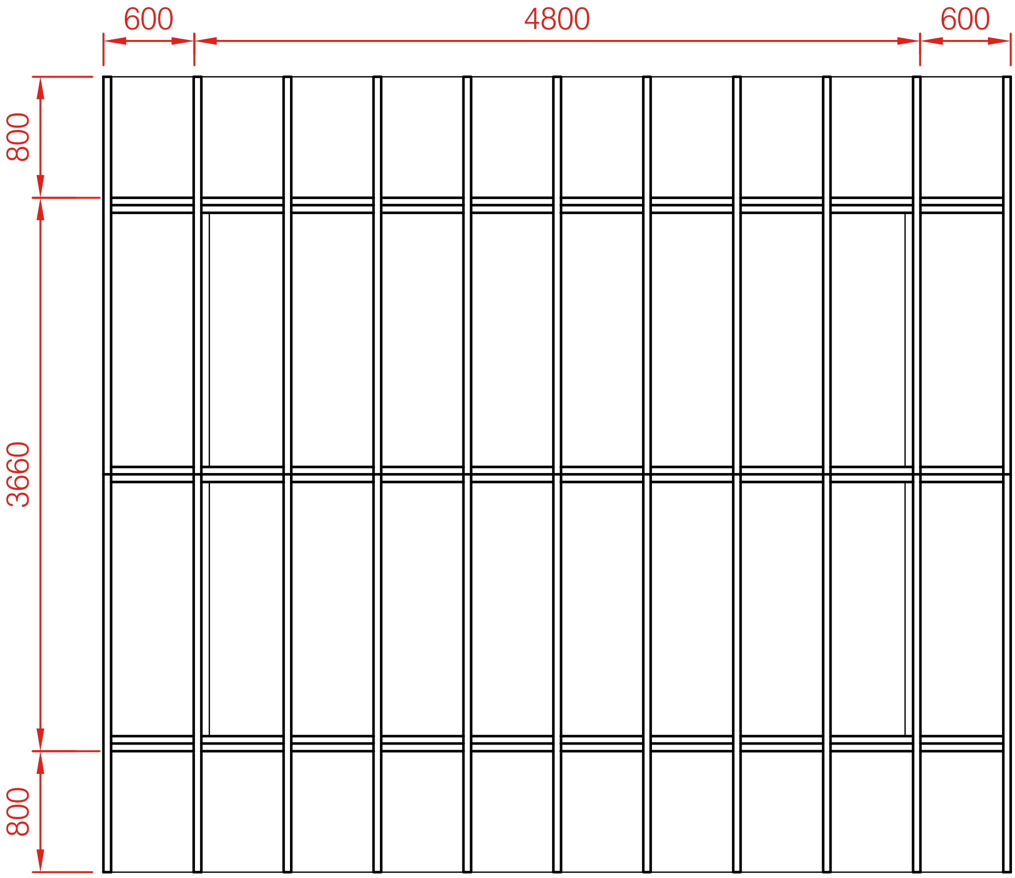
Plans



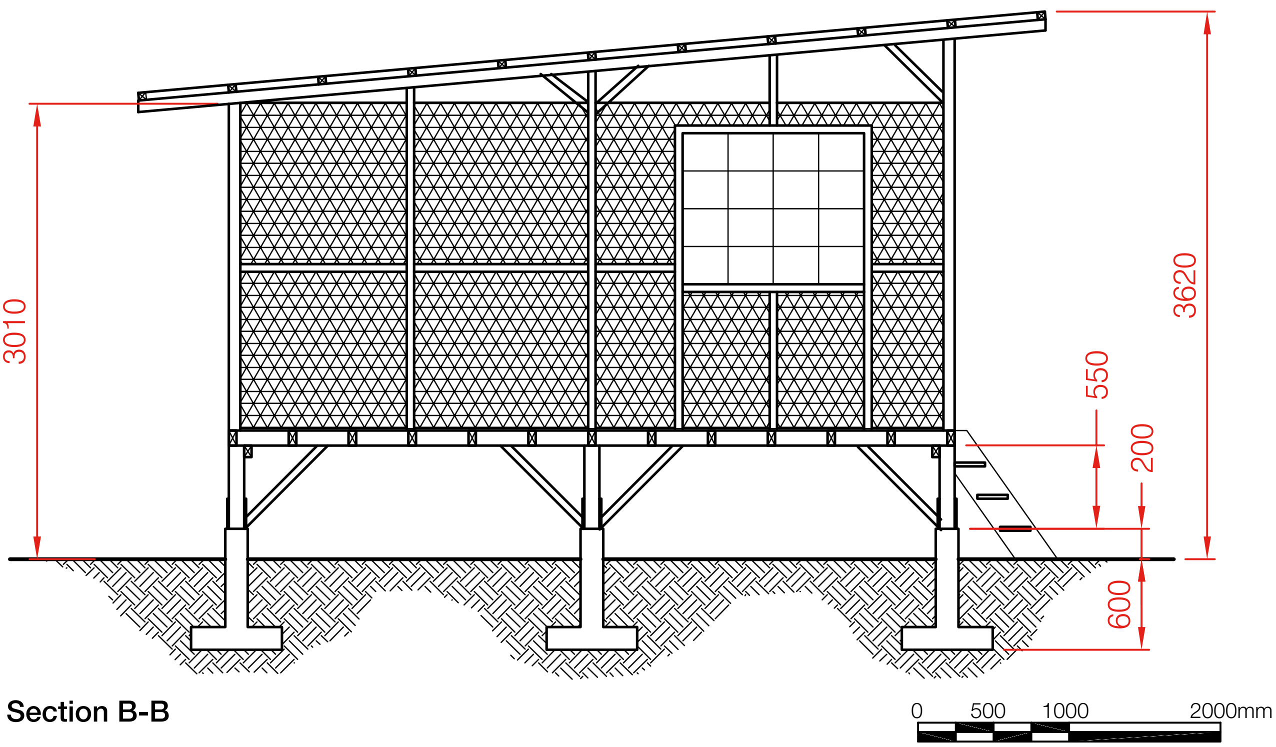
Floor plan



Section A-A



Roof Framing Plan



Section B-B

Durability and lifespan

The concrete piers are very durable, however coconut wood and plywood are not naturally rot resistant and should be treated to resist fungal and insect attack. Otherwise the timber portions of the building may need to be replaced before the concrete components reach the end of their life.

Based on the construction of the wall panels, it is likely they will be blow off the building during strong storm events.

Performance analysis

Adequate performance of this shelter is dependent on proper connections between all of the components. Without the connections between the timber framing and the concrete piers, the shelter will not be able to withstand the potential wind and earthquakes for this area. In addition, adequate performance of the shelter is dependent on selection of high quality timber. Proper site analysis is necessary prior to construction to determine appropriate finished floor heights to provide any mitigation of flood hazards.

Hazard*	Performance
Earthquake HIGH	**GREEN:** Given the light weight of the shelter, expected seismic loads are less than the expected wind loads, and provided all components are properly connected, the shelter should withstand seismic events with little to no damage.
Wind HIGH	**AMBER:** The expected wind loads are much larger than the seismic loads. Localised damage of some framing members should be expected during large storms, but collapse of the shelter is not expected. If the walls are removed prior to a storm, expected damage should be minimized and possibly eliminated.
Flood LOW	**GREEN:** The floor is raised significantly above adjacent grade, and provided the shelter is properly anchored to the concrete piers, should offer excellent protection from flood waters
Fire LOW	**AMBER:** The components of the structural system are flammable, and will not offer significant fire resistance. Fortunately the small floor plan along with the door and windows should provide adequate egress making it easy for occupants to exit before being harmed. The design is individual units thus to plan each house with good separation will reduce the risk of fire spread.

* See section A.4.5 Performance analysis summaries

Notes on upgrades

All timber beams that support floor joists and roof rafters can be increased in width or depth to provide additional strength for floor and roof loads.

The knee braces at the roof could be modified to provide bracing throughout the entire bay to increase the lateral resistance, and limit the amount of damage the framing during storms.

It is possible to upgrade the walls with plywood to provide more permanent construction and improve the lateral resistance.

The best way to improve performance of the shelter design to wind loads is to increase the size of the timber framing.

Assumptions

- Design wood values were assumed equivalent strength to Spruce-Pine-Fir South, No 1.
- Lateral foundation loads are resisted by lateral soil bearing on the piers and friction on the bottom of the footings.
- Foundation uplift forces are resisted only by the weight of the shelter and soil on top of the footing. Any frictional resistance of between the foundation and soil are ignored.
- In addition to the International Building Code, the shelter was also analyzed against the National Building Code of the Philippines.

Potential Issues

Site Selection

- Site selection is the best way to mitigate flood hazards. Select sites on higher ground and away from flood hazards. Provide proper drainage around shelters to prevent accumulation of rain water. Locate shelters a minimum of 10 meters from ravines, or as required by local authorities.
- For sites where soil liquefaction during an earthquake may be a hazard (near river beds, coastal areas with sandy soils and high water tables) the shelter could be seriously damaged in an earthquake. The heavy weight of the building components could seriously injure any occupants of the shelter.
- Locate shelters safe distance away from trees which may fall in a storm.

Materials

- Inspect timber to ensure that pieces are straight, not twisted or bowed, free of knots, and not cracked.
- Cement should be a fine grey powder. If there are larger pieces in the sacks, it is an indication that the cement has at least partially set and may not produce sound concrete.
- Ideal proportions for concrete are 1:2:3, cement:sand:gravel (all by volume). Only add enough water to allow the concrete to be placed. Excess water reduces durability and will cause more cracking of the finished slab. If concrete is mixed in batches, maintain consistent proportions for all batches. See I.3.1 Concrete

Foundation

- Verify that the soil under the footing is free of organic materials, and that any soft spots have been compacted. Ground surface should be flat and level prior to placing the concrete.
- Ensure that all reinforcement is located as detailed on the drawings prior to placement of concrete.
- Make sure the tops of the piers are in their proper location and that the tops are level, otherwise construction of the shelter framing may be difficult.

Wall and Roof

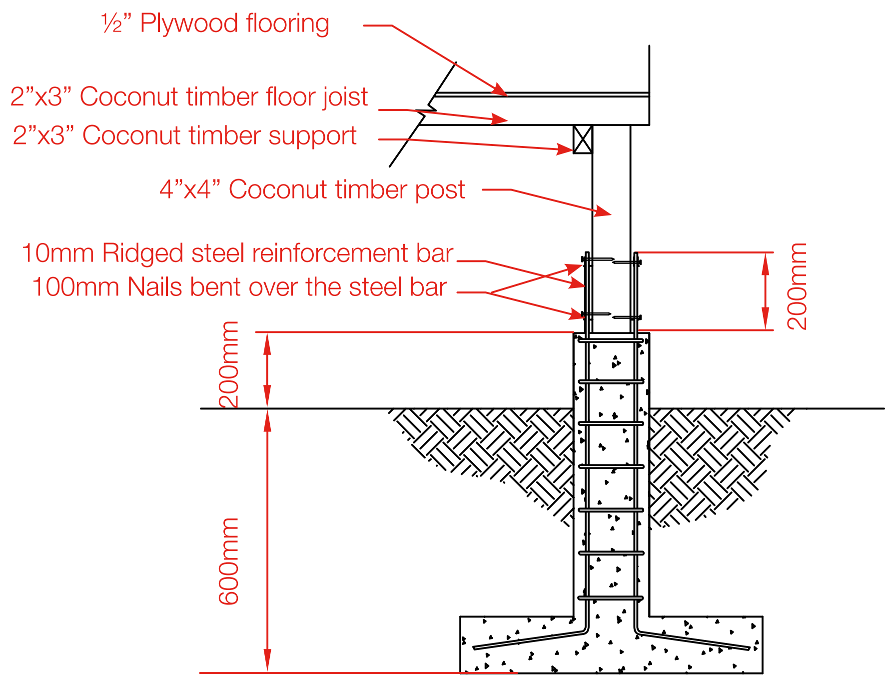
- All framing should be adequately nailed together, and nails should not split or crack the wood framing. Verify the proper number of nails are provided and the proper size is used in each connection. Use of toe nailing should be avoided.
- All wood framing in direct contact with concrete should have tarpaper or other barrier between the two materials to help prevent rot.
- Verify all the hurricane straps or other anchoring systems are properly installed, as they are required for the roof to resist wind uplift pressures. Also insure that the posts are properly anchored to the concrete piers.
- If pressure treated wood is used, hot dip galvanized fasteners should be used, as most preservatives are corrosive to mild steel.
- It is important to make sure all the anchors fastening the roof panels are properly installed. Wind blow metal roofing can cause serious injury.
- The roofs do not have additional bracing, but this should not prove to be an issue. Monosloped roofs with sheathing typically do not require additional bracing, unlike gable roofs.

Bill of quantities

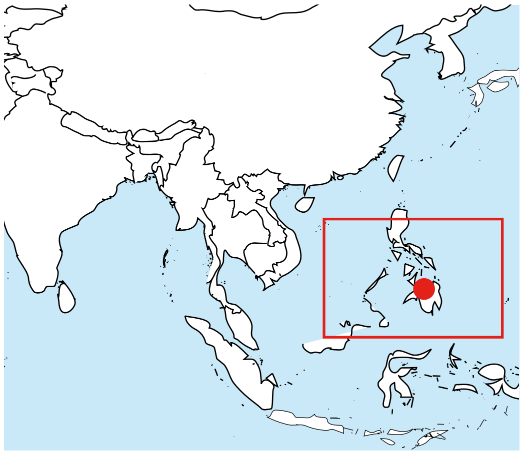
The bill of quantities in the table below is for the shelter as it was built, without the design alterations suggested here. It does not take into account issues such as which lengths of timber are available and allowances for spoilage in transport and delivery.

Item See annex I.1	Additional Specification	Quantity	Unit	Comments
Foundations				
Portland Cement		5	Bags	42.5 kg/bag
Gravel		0.1	m^3	
Sand		0.1	m^3	
Steel reinforcement	10mm dia x 6m long	12	Bar	
Steel reinforcement	8mm dia x 6m long	3	Bar	
Main Structure				
Timber 2	89mm x 89mm x 3.7m	4	Piece	
Timber 2	38mm x 64mm x 3.7m	23	Piece	
Timber 2	38mm x 89mm x 2.4m	6	Piece	
Timber 2	38mm x 38mm x 3.7m	32	Piece	
Timber 2	38mm x 38mm x 2.4m	28	Piece	
Covering – Wall and Roof				
Bamboo slats		3	Bundle	
Amakan	1.2m x 2.4m	13	Sheet	
Plywood 2	1.2m x 2.4m	6	Sheet	
Plywood	1.2m x 2.4m	2	Sheet	
Sheet 2	3.1m long	14	Sheet	
Fixings				
Umbrella nails	51mm long	1	kg	
Common nails	102mm long	6	kg	
Common nails	64mm long	4	kg	
Common nails	38mm long	1	kg	
Wire 1		2	kg	
Vulcaseal		0.5	Litre	
Hinges		1	Pair	
Tools				
Spade		2	Piece	
Hoe		2	Piece	
Wheelbarrow		1	Piece	
Framing hammer		2	Piece	
Hand saw		2	Piece	
Gloves		4	Pair	

Footing details



B.7 Philippines – 2011 – 'Transitional-Shelter'



Summary information

Disaster: Typhoon, December 2011

Materials: Reinforced concrete columns, masonry and timber walls, timber roof framing with metal siding

Material source: Locally and internationally procured

Time to build: 12 days

Anticipated lifespan: 5 years

Number built: 250

Approximate material cost per shelter: 1,550 CHF

Approximate project cost per shelter: 2,000 CHF

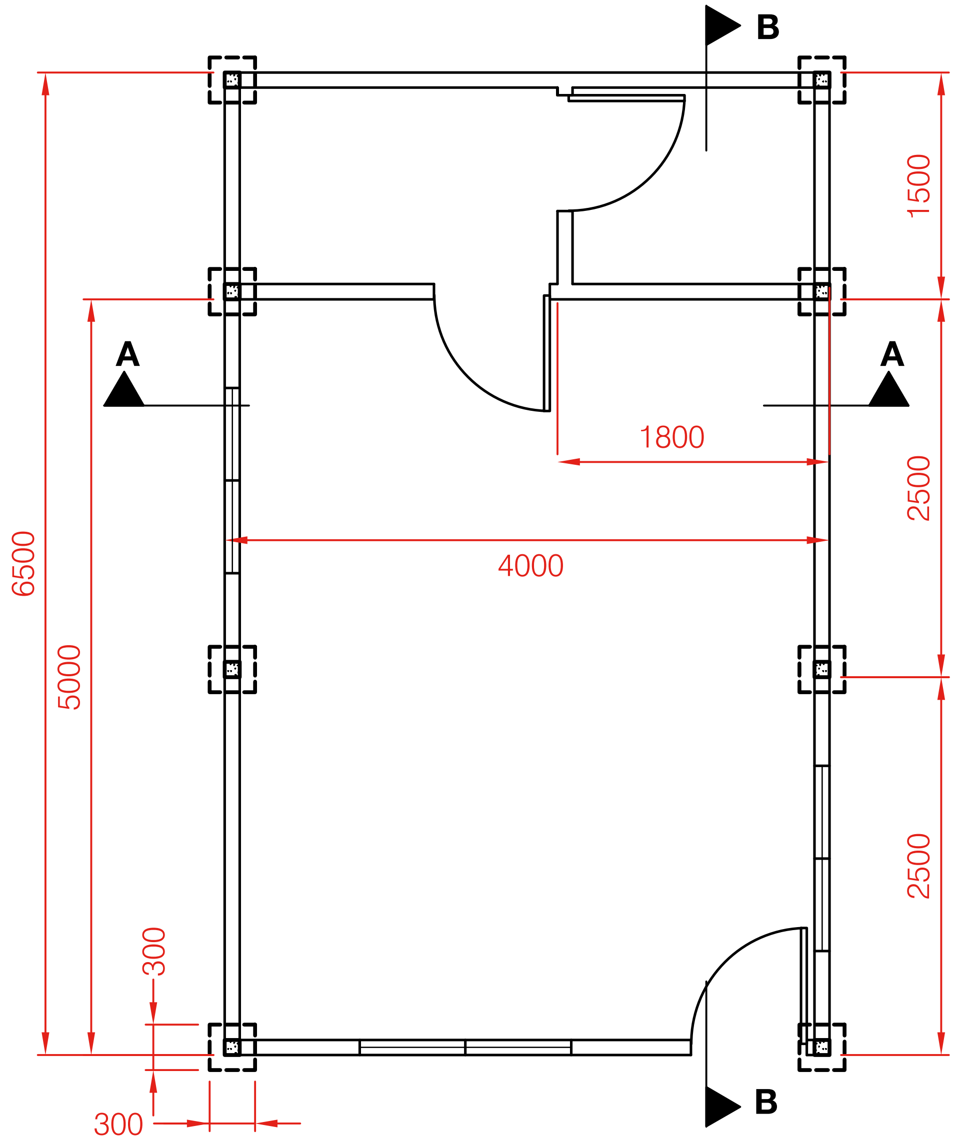
Shelter Description

This shelter is a rectangular structure with a gable roof and a covered floor area of approximately 4.0m x 5.0m with a covered bathroom and vestibule of approximately 4.0m x 1.5m. The exterior walls have a half height concrete masonry wall with wood framing on top up to the eaves. The roof consists of timber trusses and purlins supporting corrugated metal roofing. The roof framing is supported by eight precast concrete columns located within the exterior walls. The concrete columns and masonry walls are embedded in the ground, and the plans do not specifically call for footings. The floor is a cast in place concrete slab, and the bathroom has a below grade septic tank. The modular construction for the shelter allows for expansion in both horizontal directions with only minor modifications to the core shelter. It is also possible to deconstruct the shelter for relocation and/or to be included in permanent construction. As designed, the shelter has two doors and two windows.

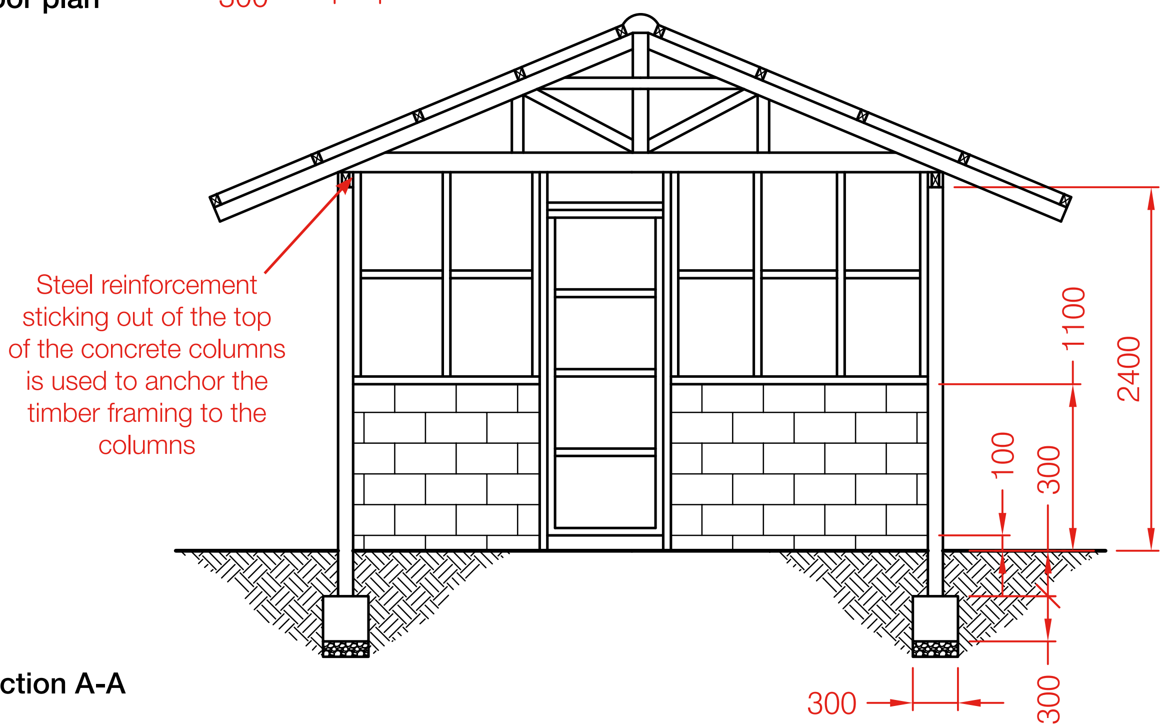
Shelter Performance Summary

The concrete and masonry components of the shelter are very durable materials, and provided the timber components are treated, the shelter should be durable with a decent design life. The use of precast concrete columns allows for quick construction of the roof to provide covered shelter while the exterior walls are constructed, and allow for possible re-use in more permanent construction. Provided the timber framed portion of the walls are properly anchored to the lower masonry walls and to the roof framing, the performance of the shelter for lateral wind and seismic loads should be adequate. However, there is not enough shelter weight to resist uplift loads for full wind speeds. Provided the roof trusses are adequately braced at each panel point the wood framing is adequate with the exception of the truss overhangs. The large overhangs of the top chords are not sufficiently strong to resist the anticipated uplift loads from a full storm.

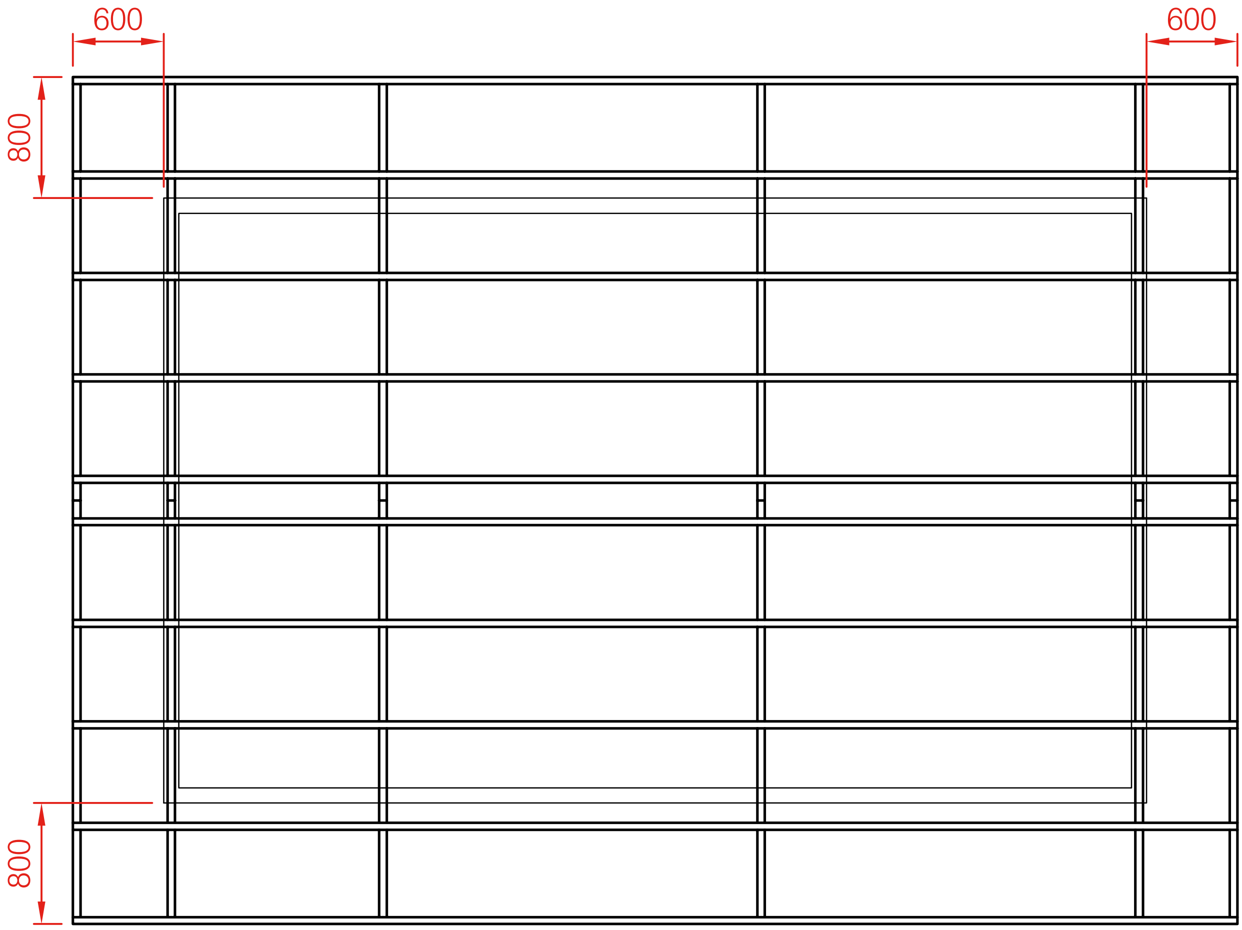
Plans



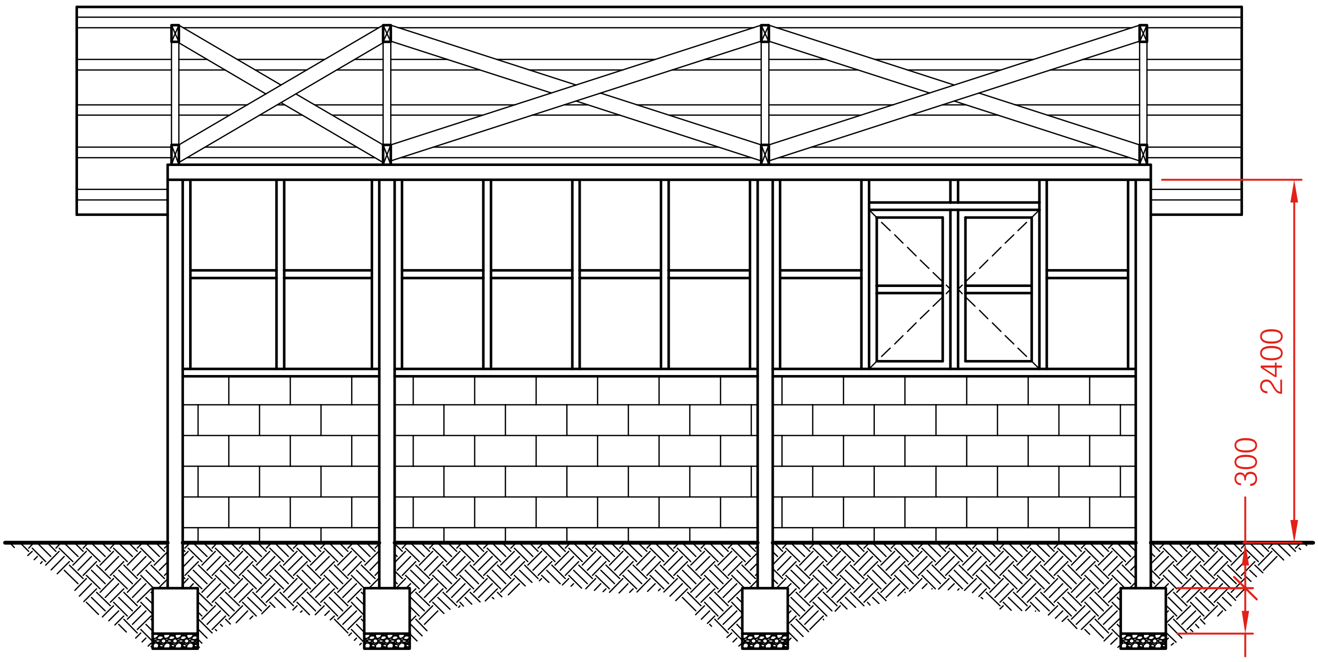
Floor plan



Section A-A



Roof Framing Plan



Durability and lifespan

The masonry and concrete portions of the shelter are very durable. However, coconut wood and plywood are not naturally rot resistant and should be treated to resist fungal and insect attack. Otherwise the timber portions of the building may need to be replaced before the concrete and masonry components reach the end of their life.

Performance analysis

Adequate performance of this shelter is dependent on proper connections between all of the components. Without the connections between the roof framing, the concrete columns and the timber/masonry exterior walls, the shelter will not be able to withstand the potential wind and earthquakes for this area. In addition, the shelter does not weigh enough to resist wind uplift loads, nor are the truss top chords large enough to resist the uplift pressures on the eaves. Proper site analysis is necessary prior to construction to determine appropriate finished floor heights to provide any mitigation of flood hazards.

Hazard*	Performance
Earthquake HIGH	**AMBER:** Given the light weight of the shelter, expected seismic loads are less than the expected wind loads. Provided the exterior walls are properly connected, they are adequate to resist the lateral loads as shear walls.
Wind HIGH	**RED:** As for earthquake loads, the exterior walls should be sufficient to resist the lateral wind loads provided the walls are adequately attached. However, there is not sufficient weight to resist uplift, and the columns should either be extended further into the ground or the footing on bottom increased. In addition, the roof overhang should be shortened, or the size the top chord increased to prevent failure of the roof trusses.
Flood LOW	**AMBER:** The floor is not significantly elevated relative to the surrounding grade. However the structural components of the shelter at grade are concrete and masonry, which are relatively flood resistant materials.
Fire LOW	**AMBER:** The concrete and masonry components of the framing are very fire resistant, but the wooden framing in the roof is not. The roof may be able to survive a brief fire that was quickly extinguished.

* See section Performance analysis summaries

Notes on upgrades

The masonry walls can be extended full height to provide a more durable wall system, but attention must be given to how the masonry is connected to the concrete columns and roof framing to ensure the walls will not collapse on the occupants.

The design of the shelter could be modified such that the concrete columns are the primary lateral system by fabricating them longer and embedding them further into the ground. The advantage being that the infill walls could be modified and/or removed without affecting the performance of the shelter.

In areas where flooding is a significant risk, the design can be easily modified to add more fill inside the shelter to raise the elevation of the concrete floor slab above the surrounding grade. Care should be taken though to ensure the ceiling height is sufficient for the occupants.

Analysis should be performed before any additional openings are put into the exterior walls, as they will reduce the lateral load capacity of the shelter.

Reducing roof overhang will reduce shading, but will improve performance in strong winds by reducing uplift.

Assumptions

- Analysis is based on a compressive capacity of masonry of 2,100 kPa, a tensile capacity of masonry of 138 kPa, and a concrete compressive strength of 20 MPa.
- Design wood values were assumed equivalent strength to Spruce-Pine-Fir South, No 1.
- Roof truss top chords are fully braced by the purlins, and the bottom chord of the roof trusses are braced at each panel point.
- Plywood is nailed at 150mm on centre along the panel edges, and at 300mm in the middle of the panel.
- Lateral foundation loads are resisted by lateral soil bearing on the foundation walls.
- Foundation uplift forces are resisted only by the weight of the shelter, and any frictional resistance of between the foundation and soil are ignored. The exterior masonry walls extend down to the top of the concrete column footing, and sit on the footing to help resist wind uplift forces.
- The shelter was analysed against the National Building Code of the Philippines and the International Building Code (IBC) 2009.

Potential Issues

Site Selection

- Site selection is the best way to mitigate flood hazards. Select sites on higher ground and away from flood hazards. Provide proper drainage around shelters to prevent accumulation of rain water. Locate shelters a minimum of 10 meters from ravines, or as required by local authorities.
- The concrete and masonry building construction requires a stiff supporting soil to avoid settlement and possible cracking of the exterior walls.
- For sites where soil liquefaction during an earthquake may be a hazard (near river beds, coastal areas with sandy soils and high water tables) the shelter could be seriously damaged in an earthquake. The heavy weight of the building components could seriously injure any occupants of the shelter.

Materials

- Inspect the fabrication of concrete columns to ensure correct placement of reinforcement before concrete is poured. Adequate reinforcement and its position are important to structural capacity.
- Before columns are placed in the ground, inspect to ensure there is no damage such as cracking, chipping, or exposed reinforcement. Also verify the embedded anchor bolts are present.
- Inspect timber to ensure that pieces are straight, not twisted or bowed, free of knots, and not cracked.
- Blocks for the masonry walls should be solid, not fractured, and free of honeycombs and voids.
- Mortar should be freshly mixed in small batches so it is used before it sets.

Foundation

- Verify that the soil under the foundations and the floor slab are free of organic materials, and that any soft spots have been compacted. The ground surface should be level prior to constructing the shelter.
- Verify concrete columns are sufficiently embedded in the soil.
- Make sure the columns are in their proper location, plumb, and the tops are level before soil is compacted around them. Otherwise construction of the steel roof truss will be difficult.
- Ensure steel reinforcing for the piers is installed, especially if the veranda is left open.

Wall and Roof

- Masonry Blocks should be laid level, and joints should overlap between courses (running bond).
- All joints between blocks should have mortar between them. Ideally mortar joints should be between 6mm and 13mm thick. All exposed mortar joints should be recessed slightly from the face of brick.
- All framing should be adequately nailed together, and nails should not split or crack the wood framing. Verify the proper number of nails are provided and the proper size is used in each connection.
- All wood framing in direct contact with masonry should have tar paper or another barrier between the two materials to help prevent rot.
- Verify all the hurricane straps are properly installed, as they are required to resist wind uplift pressures.
- If pressure treated wood is used, hot dip galvanized fasteners should be used, as most preservatives are corrosive to mild steel.
- Ensure that all the anchors fastening the roof panels are properly installed.

Bill of quantities

The bill of quantities in the table below is for the shelter as it was built, without the design alterations suggested here. It does not take into account issues such as which lengths of timber are available and allowances for spoilage in transport and delivery.

Item See annex I.1	Additional Specification	Quantity	Unit	Comments
Foundations				
Portland cement		41	Bags	42.5 kg/bag
Gravel		3.5	m^3	
Sand		4	m^3	
Steel reinforcement	10mm dia x 6m long	30	Bar	
Concrete column	102mm x 102mm x 3.1m	8	Piece	
Main Structure				
Timber 1	38mm x 114mm x 4.3m	4	Piece	
Timber 1	38mm x 89mm x 3.1m	16	Piece	
Timber 1	38mm x 64mm x 3.7m	53	Piece	
Timber 1	38mm x 38mm x 3.1m	50	Piece	
Covering – Wall and Roof				
Concrete masonry	102mm Standard	400	Piece	
Plywood 1	4.7mm thick	17	Sheet	1.2m x 2.4m sheets
Plywood 1	6.4mm thick	0.5	Sheet	1.2m x 2.4m sheets
Sheet 2	0.4mm x 3.1m	18	Sheet	
Ridge cap	0.4mm x 0.9m x 2.4m	2	Piece	
Plumbing				
Water closet		1	Piece	Buhos type
Floor drain	102mm x 102mm	1	Piece	Plastic
PVC wye	102mm x 51mm	1	Piece	
PVC 90 deg elbow	102mm	1	Piece	
PVC tee	102mm	1	Piece	
PVC P-trap	51mm	1	Piece	
PVC pipe	102mm dia x 3 m	1	Piece	
PVC pipe	51mm dia x 3m	0.5	Piece	
Fixings				
Roofing nails	64mm long	3.5	kg	Twisted shank
Common nails	102mm long	4.5	kg	
Common nails	76mm long	7	kg	
Common nails	64mm long	2	kg	
Common nails	51mm long	5.5	kg	
PVC solvent cement		1	Can	100 cm^3 can
Wire 1		1	kg	
Vulcaseal		3	Pack	220g per packs
Hinges	51mm x 102mm	12	Piece	Brass
Door		2	Piece	Include frame and hardware
Window		2	Piece	Include frame and hardware

B.8 Bangladesh – 2007 – 'Core-Shelter'

Summary information

Disaster: Cyclone Sidr, November 2007

Materials: Reinforced concrete columns and a steel framed roof. Concrete pier foundations, brick exterior base, and bamboo matting walls with Corrugated Galvanized Iron (CGI) roofing

Materials source: Local

Time to build: 5 days

Anticipated lifespan: 2 – 5 years

Construction team: 3-4 people

Number built: 1,250

Programme cost per shelter: 1,822 CHF - an additional 60 CHF cash grant was provided to shelter owners.

Shelter Description

This shelter is has reinforced concrete columns, a steel framed hip roof with metal roofing and bamboo mat walls. The total covered area is approximately 4.5m x 3.2m, and there is one door and three windows.

The floor is raised above existing grade, and a short brick wall is provided around the perimeter to resist flood waters and windblown rain. The 8 concrete columns are embedded approximately 1.5m into the ground. The roof truss is constructed with steel angles and is anchored to the concrete columns. The foundation consists of the 8 embedded columns, and a perimeter concrete grade beam. There are wooden beams between the columns approximately 2.1m above the first floor, which allow the addition of a mezzanine level to the shelter.

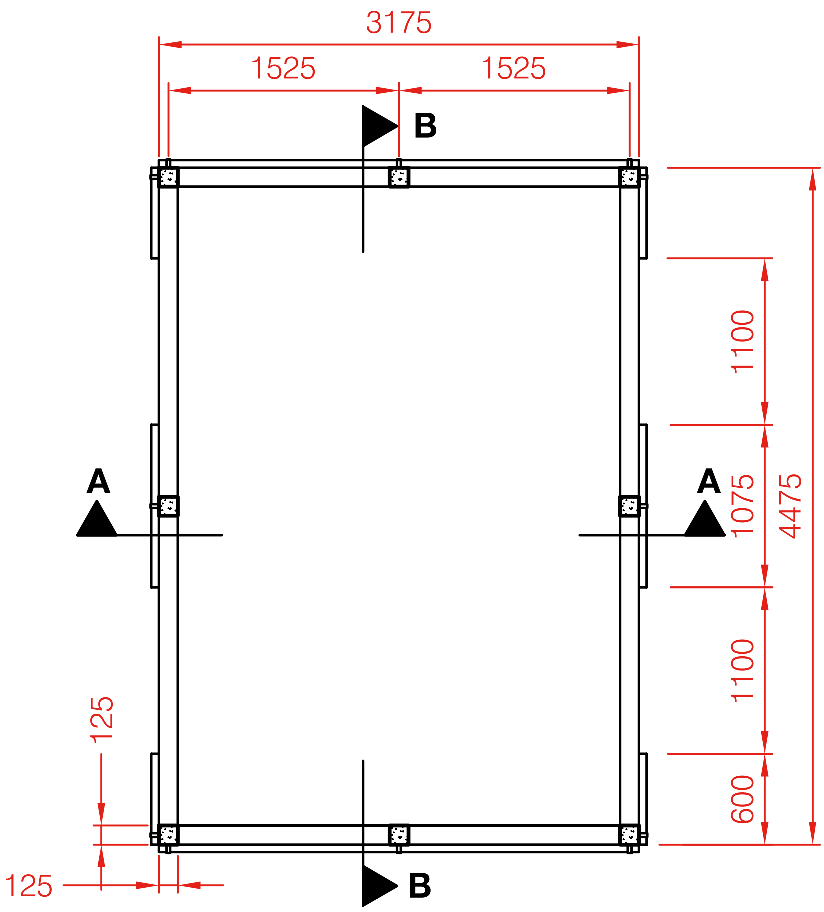
The shelter is designed to be easily moved by unbolting the columns and roof frame with hand tools and the materials can be re-used as a part of permanent housing reconstruction. Additionally it is designed so that a mezzanine level can be built to provide storage space in case of floods.

Shelter Performance Summary

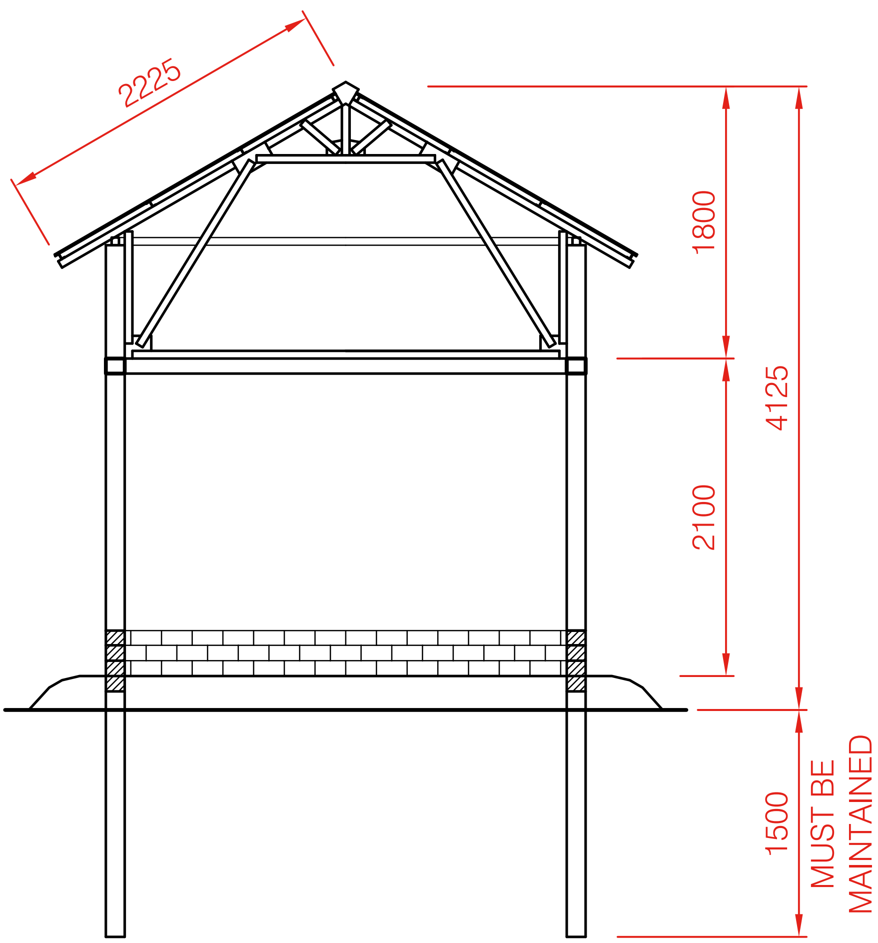
This shelter is constructed with materials that are locally available and o fgood quality given the context. The roofing structure is complex and requires skilled workers to construct it. It is intended to be more than a transitional shelter and to become either a permanent residence or for the materials to be re-used in new permanent construction. The shelter is tall, which allows for a mezzanine level.

The frame performs adequately for seismic loads. The frame is not sufficient to resist the high wind loads if the walls remain in place through a strong storm, however it is anticipated that the woven wall panels will detach under such conditions. Due to the high quality materials and design, the only way to improve performance is to increase the sizes of the columns and the members of the roof truss.

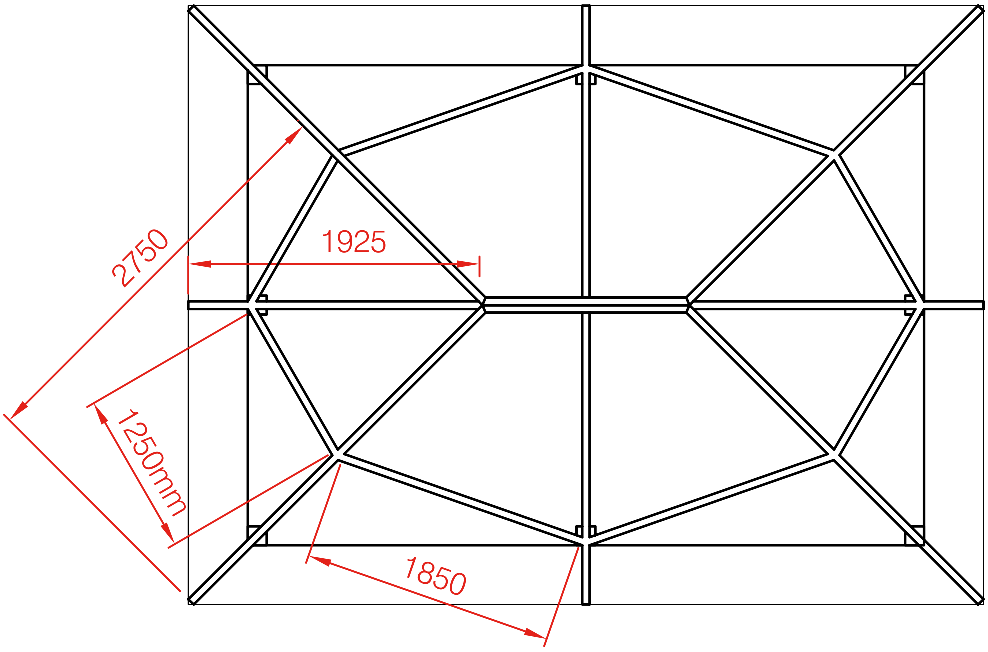
Plans



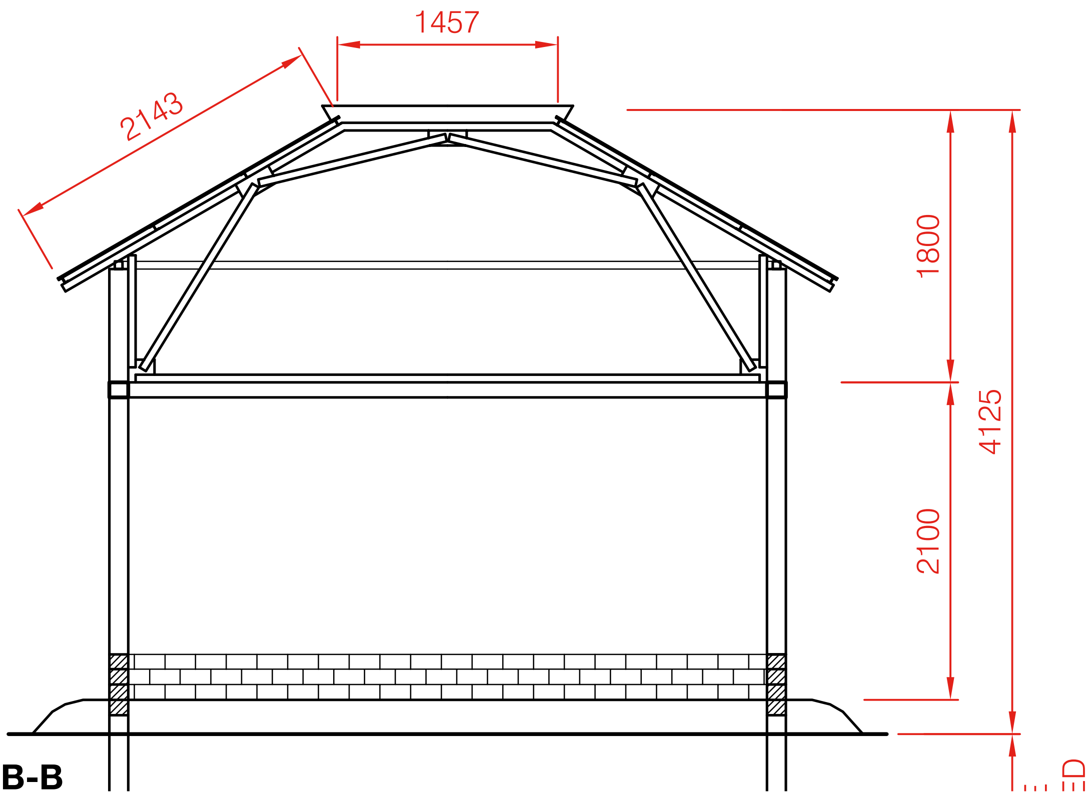
Floor plan



Section A-A



Roof Framing Plan



Section B-B

Durability and lifespan

The reinforced concrete columns and steel roof frame are built with durable construction materials and their deterioration should not limit the service life of the shelter.

The bamboo wall covering and garjan (local timber) framing at the mezzanine and door/window openings, while untreated, do have some natural resistance to tropical environments. Depending on how long the shelter is in use, these components will likely have to be replaced. In addition, it should be expected that the bamboo wall covering will be damaged and/or removed by winds from strong storms.

Performance analysis

The performance of the shelter for gravity loads and seismic events is good. In order to survive strong storms, the wall sheathing will have to be removed before the peak winds. Depending on the soil conditions, the embedment depth of the concrete columns may need to be increased. Also, proper site analysis is necessary prior to construction to determine appropriate finished floor heights to minimize flood damage potential.

Hazard*	Performance
Earthquake HIGH	**GREEN**: The structural framing is satisfactory under expected seismic loads, and little deflection or damage are foreseen for an event that could be expected within the design life. The low level masonry walls perform poorly under seismic loads, but their short height creates minimal risk to life.
Wind HIGH	**RED**: Structural framing is not adequate if the bamboo walls remain in place for wind loads up to the design storm of 260 kph. This affects the concrete columns, the steel roof truss, and the foundations. If walls are removed prior to significant storms (wind speeds in excess of 180 kph), the performance of the structure will be **AMBER**. Adding cross-bracing can potentially improve the above ground structure, but will most likely have an adverse impact on the foundation performance. Selection of a site with the proper soil type is required to ensure adequate performance of the foundation.
Flood HIGH	**GREEN**: This structure is designed to be elevated a minimum of 225mm above existing ground. It is also designed to have a 300mm brick wall around the structure which will minimize damage due to wind-blown rain coming under the bamboo matting. The mezzanine level also provides an elevated location where people can find shelter in an extreme flood event
Fire LOW	**AMBER**: The basic structural system is comprised of relatively fire retardant materials. The foundations and columns are reinforced concrete, and the roof structure if metal. These materials could survive a brief fire that was quickly extinguished. However, the wood frames around the doors and windows and the bamboo matting walls could create a fire event which burned hot enough and long enough to permanently weaken the roof structural members.

* See section Performance analysis summaries

Notes on upgrades

Cross bracing (using steel angles or cables) from the ground level to the roof can improve resistance to wind loads. For full effectiveness, bracing must be added to all four exterior faces.

For optimal foundation performance, concrete columns should be embedded in gravelly or sandy soils. If installed in silty or clayey soils, the columns should be buried 2m in the ground.

Permanent upgrades (e.g masonry) to the exterior walls should be avoided, as they will adversely impact the structure in high wind events. Also, increasing the height of the brick walls should be avoided as they can cause injury to occupants during seismic events.

Increasing the cross-sectional dimensions of the columns (to 200mm x 200mm) will increase strength and ensure adequate consolidation of concrete around the reinforcement.

The Mezzanine floor was not included with the shelter. It was expected that occupants would add it at a later time. A design load of 1kPa was included for the Mezzanine.

Assumptions

- The low brick wall is free standing, is not connected to the structural frame, and does not transfer loads to the columns but is used to resists foundation uplift.
- The optional wood mezzanine floor is in place, and supports floor live load.
- Lateral foundation loads are resisted by lateral soil bearing of the embedded concrete columns. Any frictional resistance is ignored
- The perimeter concrete grade beam is used to distribute vertical foundation loads to the supporting soil.
- Foundation uplift is resisted by the weight of the shelter alone, and any frictional resistance is ignored.
- In addition to the International Building Code (IBC) 2009, the shelter was also analysed against the 2006 Bangladesh National Building Code. This code was originally written in 1993, and is in the process of being updated by the Ministry of Housing and Public Works. Once this new code has been released, the shelter should be re-analysed to verify its adequacy.

Potential Issues

Site Selection

- Site selection is the the best way to mitigate flood hazards. Select sites on higher ground and away from flood hazards. Provide proper drainage around shelters to prevent accumulation of rain water
- For sites where soil liquefaction may occur during an earthquake (near river beds, coastal areas with sandy soils and high water tables) the shelter could be seriously damaged in an earthquake. The weight of these shelter components could cause injury to occupants.
- Ideally foundations should be made in sandy or gravely soils. If the site consists of clay or silts, foundations may need to be embedded 2m.

Construction Materials

- If possible, inspect fabrication of concrete columns to verity reinforcement is provided as indicated on the drawings prior to placement of concrete (the reinforcing steel should be a minimum of 25mm into the column). Adequate reinforcement and its position are important to structural capacity.
- Before columns are placed in the ground, inspect to ensure there is no damage such as cracking, chipping, or exposed reinforcement before they are placed in the ground. Also verify the embedded anchor bolts are present.
- Verify the steel angles are straight and are not damaged prior to building the roof.

Foundation

- Verify concrete columns are embedded in the soil to a minimum of 1500mm as in the plan.
- Make sure the columns are in their proper location, plumb, and the tops are level before soil is compacted around them. Otherwise construction of the steel roof truss will be difficult.
- The concrete grade beam is important for foundation performance, and it must be tied to the columns. Verify the steel reinforcing through the columns is installed prior to concrete placement.

Roof

- Make sure there are no empty bolt holes and that all bolts are tightened. The roof will only support itself if the pieces are properly fastened to each other.
- Verify the steel angles are not bent or twisted, and that at connections the angles sit flat against each other or the connection plates. If not, this could indicate that the columns are not properly installed.
- Ensure all the J-bolts fastening the roof panels are properly installed. Wind blown metal roofing can cause serious injury.

Exterior Walls

- Since bamboo mats will need to be removed during storms, make sure the connections can easily be undone. Permanent wall coverings should be avoided.
- Make sure that the low brick wall is installed, as it is needed to resist foundation uplift forces, but do not increase the height of the brick wall. It could cause injury to occupants during an earthquake.

Bill of quantities

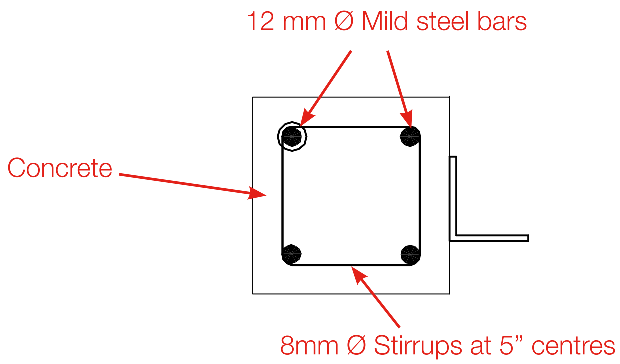
The table of quantities below is for the materials required to build the shelter. It does not take into account issues such as which lengths of timber are available and allowances for spoilage in transport and delivery.

Item	Material Specification See annex I.1	Quantity	Unit	Comments
Foundations				
Earth fill		4.5	m^3	
Portland cement (columns)		3	Bags	42.5 kg/bag
Sand (columns)		0.16	m^3	
Brick chips (columns)		0.32	m^3	
Steel reinforcement	12mm dia x 6m	32	Bars	
Steel reinforcement	8mm dia x 6m	28	Bars	
Portland cement (Grade Beam)		3	Bags	42.5 kg/bag
Sand (grade beam)		0.13	m^3	
Brick chips (grade beam)		0.26	m^3	
Steel reinforcement	10mm dia x 6m	21	Bars	
Steel reinforcement	8mm dia x 6m	17	Bars	
Main Structure				
Steel 1	38mm x 38mm x 3mm	12	Piece	L = 6m
Steel 1	200mm x 200mm x 5mm	39	Piece	
Steel 1	38mm x 38mm x 3mm	11	Piece	L = 6m
Secondary structure				
Brick	125mm thick	4.6	m^2	1st Class Brick
Timber 5	100mm x 63mm x 2m	8	Piece	Knot free Garjan
Timber 5	100mm x 63mm x 2m	8	Piece	Knot free Garjan
Timber 5	100mm x 63mm x 2m	6	Piece	Knot free Gargan
Covering – Wall and Roof				
sheet 2	1m x 2.25m sheets	20	Piece	
Ridge / hip cap	225mm x 225mm	12.5	m	
Bamboo mesh		44.5	m^2	Woven, 8mm thick
Bamboo mesh supports		62	m	100mm dia Bamboo
Window		3	Piece	Bamboo mesh shutter
Door		1	Piece	Bamboo mesh shutter
Fixings				
Threaded rod	12mm dia x 450mm	8	Piece	Include nut and washer
Threaded rod	10mm dia x 150mm	8	Piece	Include nut and washer
Threaded rod	7mm dia x 150mm	32	Piece	Include nut and washer
Bolts	7mm dia x 20mm	255	Piece	Include nut and washer
Roof sheeting J-bolt	5mm dia	150	Piece	Include nut ,washer, & gasket

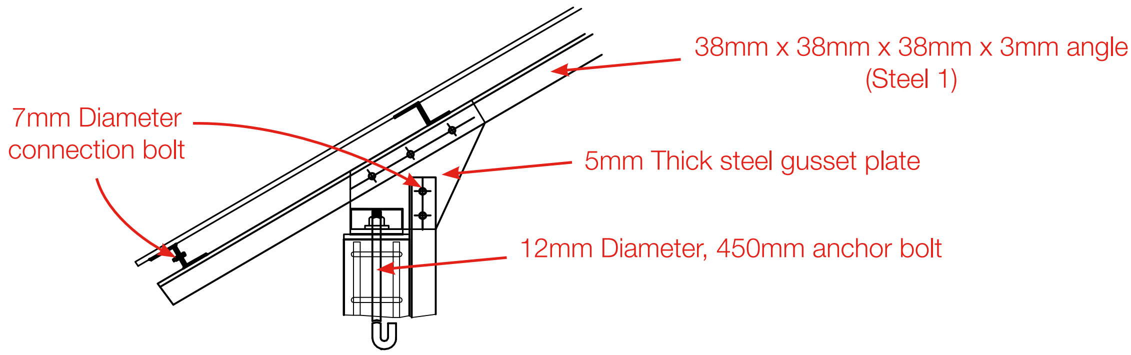
Item	Material Specification See annex I.1	Quantity	Unit	Comments
Tools				
Shovel		1	Piece	
Pick axe		1	Piece	
Drill		1	Piece	
Hammer		2	Piece	
Screw driver		2	Piece	
Tape measure		1	Piece	
Level		1	Piece	
Plumb bob		1	Piece	
Hand saw		1	Piece	
Sockets	(5, 7, 10, and 12mm)	4	Piece	
Spanners	(5, 7, 10, and 12mm)	4	Piece	
Gloves		2	Piece	
Ladders		2	Piece	

Design details

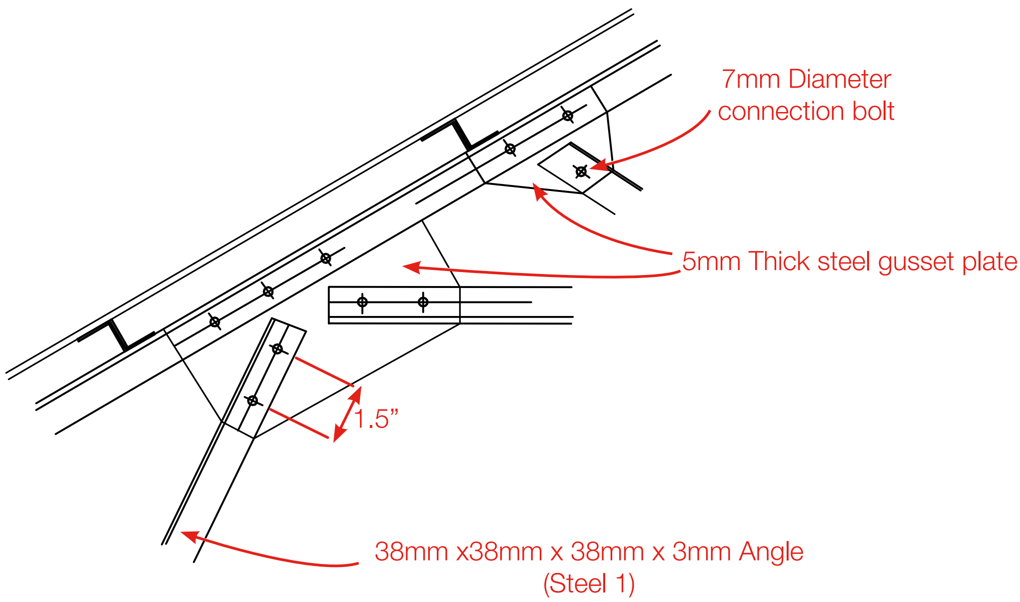
Section of a column showing placing of reinforcement



Detail of connection of roof to column



Detail of truss connections



B.9 Pakistan – 2010 – 'One Room Shelter'

Summary information

Disaster: Flood, July 2010

Materials: Unreinforced brick exterior walls, tile roof supported on steel framing.

Material source: Locally procured

Anticipated lifespan: 10 years

Number built: 875

Approximate project cost per shelter: 1,300CHF

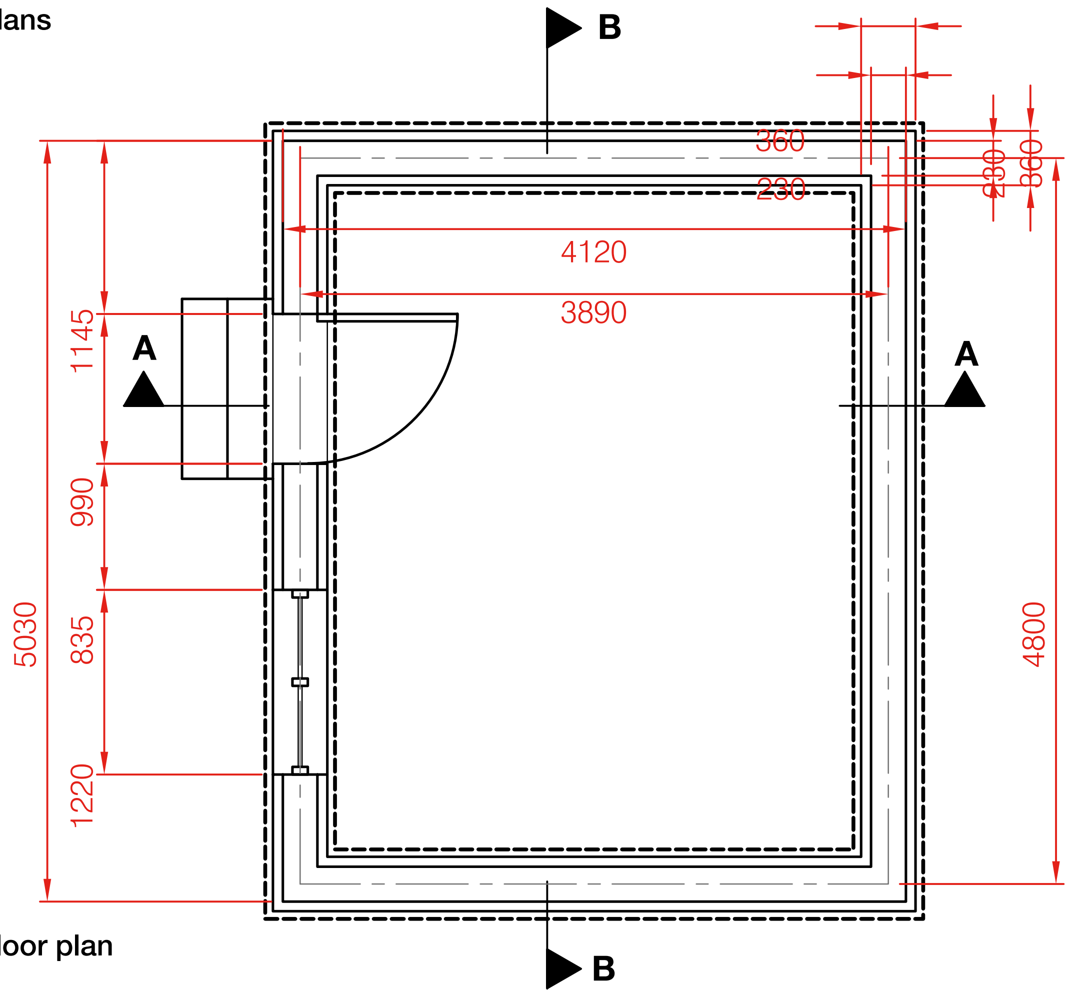
Shelter Description

This shelter is a rectangular structure with a flat roof with approximate dimensions of 4.8m x 3.9m. Walls are built with 230mm thick unreinforced fire burned brick walls supporting the roof. The roof is constructed with ceramic tiles supported on steel beams, and a cement plaster coating is placed on top of the tiles. The foundation consists of unreinforced brick footings and foundation walls. The mud plastered floor is raised a minimum of 610mm above the surrounding ground surface. As designed, the shelter has one door and one window, along with air vents near the top of the walls.

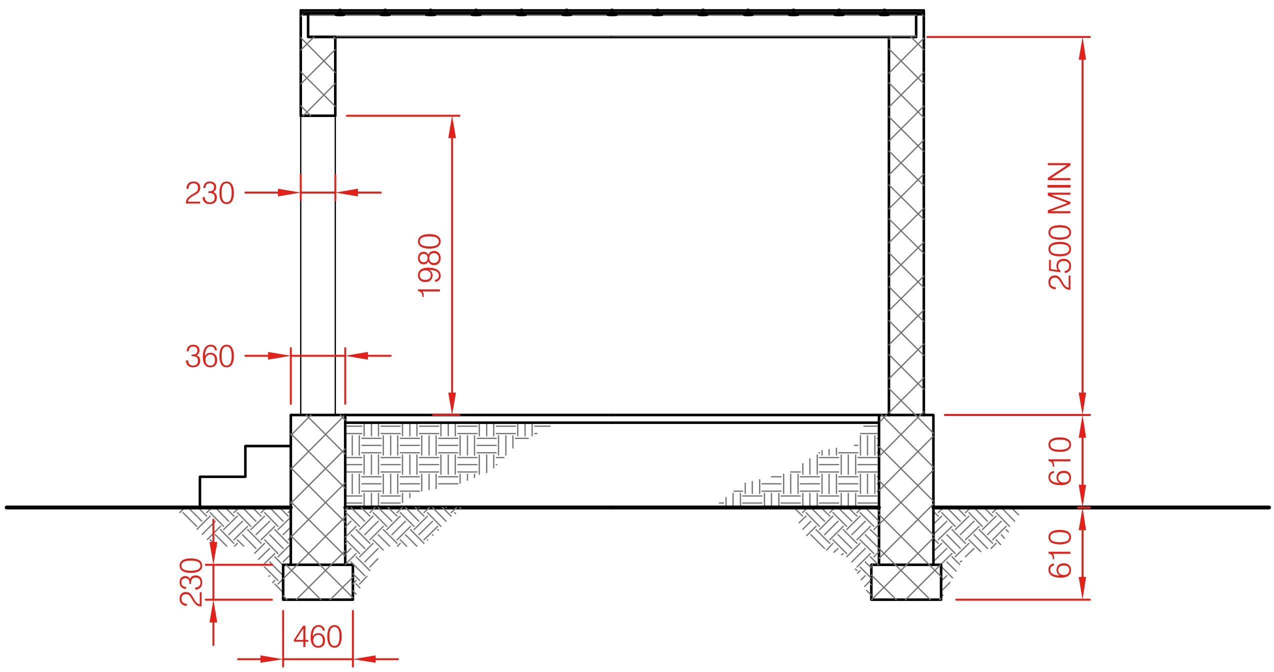
Shelter Performance Summary

The construction materials used for this shelter are high quality and very durable, and can produce a shelter with a long design life. In addition, the use of local materials simplifies the deployment for shelter construction, and should allow for a quick response to disaster situations. The brick walls and tile roof offer good resistance to wind loads, but given the weight of the building components, the performance under earthquake loads is not quite as good. The number of air vents at the top of the walls should balance the benefits of additional ventilation versus reductions of the vertical and lateral capacities of the walls.

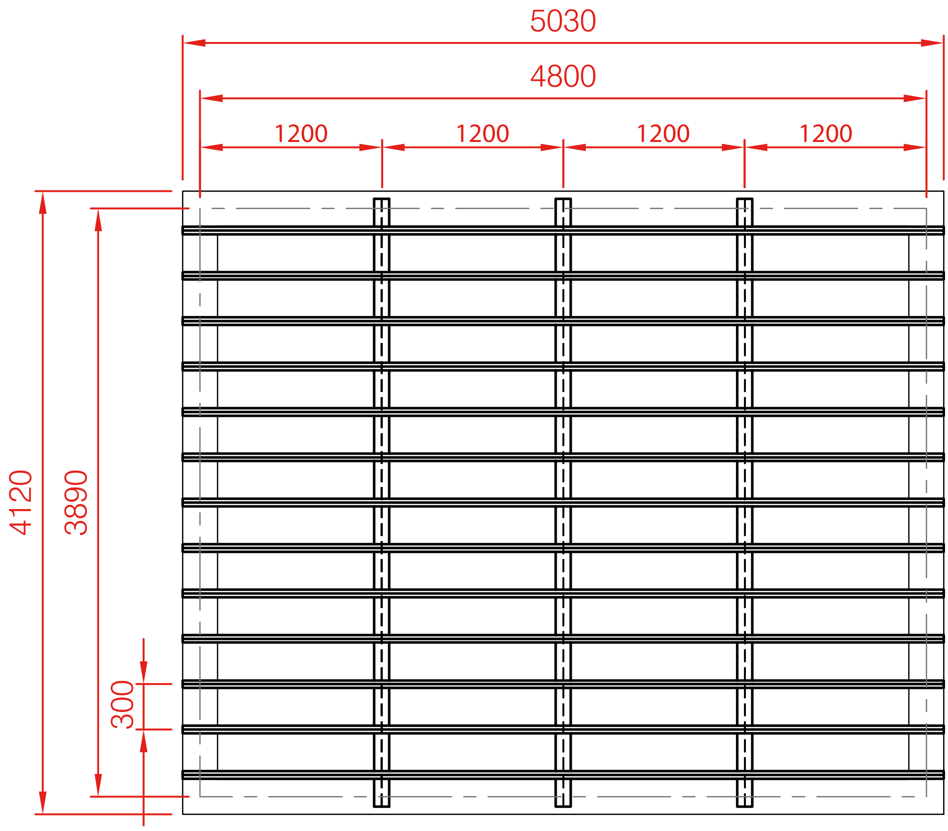
Plans



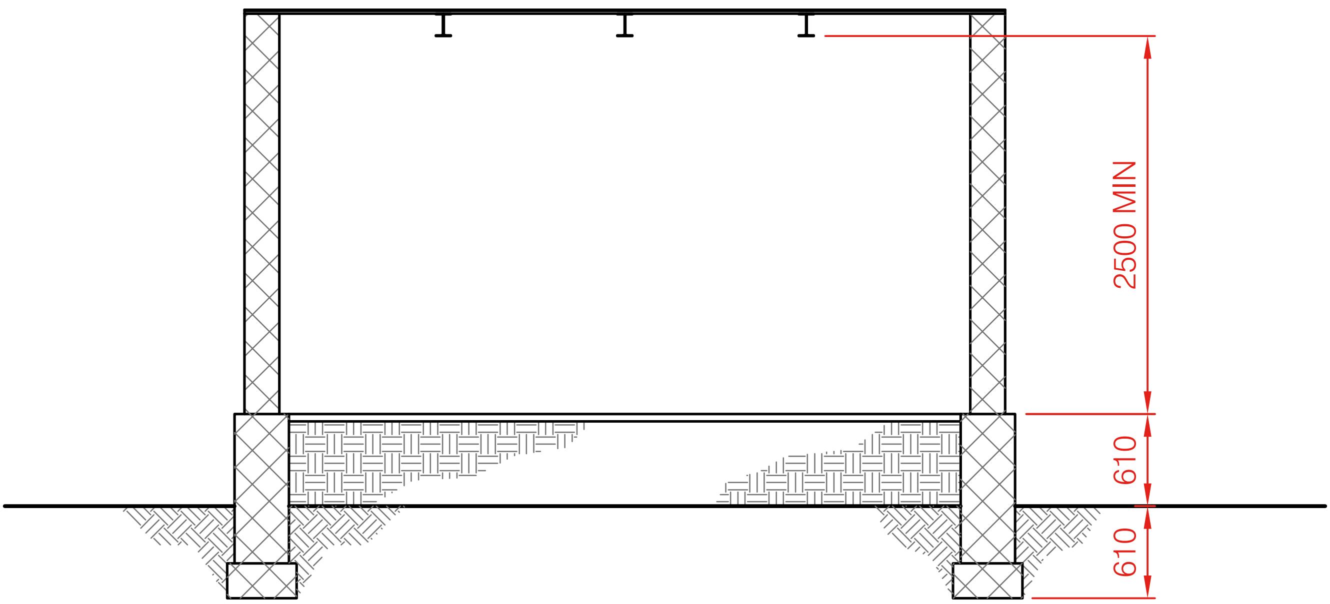
Floor plan



Section A-A



Roof Framing Plan



Section B-B

Durability and lifespan

In general this shelter is well designed and is constructed of high quality and durable materials, and should have a long expected lifespan provided it is properly maintained. If the fire burnt brick is replace with mud block the cost of the shelter with decrease, but so will the longevity.

Performance analysis

While the brick walls are not reinforced, they offer excellent resistance for wind loads. The heavy weight of the walls and roof increase seismic loads, and reduces the performance of the shelter. Proper site analysis is necessary prior to construction to determine appropriate finished floor heights to provide any mitigation of flood hazards.

Hazard*	Performance
Earthquake MEDIUM**	**GREEN:** With fired bricks and portland cement mortar, the 229mm thick brick walls have sufficient strength to resist the expected wind loads, and the weight of the structure is sufficient to prevent any overturning or sliding of the shelter during storms.
Wind MEDIUM	**AMBER:** The weight of the building components increases the seismic forces, but the wall have adequate resistance to meet the International Building Code. However, they do not meet the requirements of the Building Code of Pakistan, which has much more conservative provisions for the design of walls.
Flood HIGH	**GREEN:** The first floor of the shelter is elevated at least 610mm from the surrounding ground surface, and it is easy to modify the design to provide additional clearance if site specific situations required it.
Fire LOW	**GREEN:** With the exception of the steel framing, the components of the structural system are not flammable and should reduce the risk of significant fires. In addition, the small amount of flammable material expected in the shelter should not allow fires that are hot and long enough to significantly damage the steel framing. Consideration should be given to providing a second means of egress from the shelter in case the single door is blocked.

* See section A.4.5 Performance analysis summaries

** Although Pakistan has areas of high seizmic risk, this shelter was built in the Sindh Province, with a medium risk

Notes on upgrades

It is possible to increase the height of the roof, but analysis should be performed to verify that the extra height will not increase the wind or earthquake loads enough to cause performance issues.

Analysis should be performed before any additional openings are put into the shelter walls, as they will reduce the lateral load capacity of the shelter.

Assumptions

- Analysis is based on a compressive capacity of masonry of 2,100 kPa, and a tensile capacity of masonry of 138 kPa, and a steel strength of 248 MPa.
- The ceramic tiles in the roof provide lateral bracing for the steel framing.
- Lateral foundation loads are resisted by lateral soil bearing on the foundation walls.
- Foundation uplift forces are resisted only by the weight of the shelter, and any frictional resistance of between the foundation and soil are ignored.
- The performance of the shelter was compared against the requirements of both the International Building Code and the Building Code of Pakistan.

Potential Issues

Site Selection

- Site selection is the best way to mitigate flood hazards. Select sites on higher ground and away from flood hazards. Provide proper drainage around shelters to prevent accumulation of rain water. Locate shelters a minimum of 10 meters from ravines, or as required by local authorities.
- The weight of the building construction requires a stiff supporting soil to avoid settlement and possible cracking of the exterior walls.
- For sites where soil liquefaction during an earthquake may be a hazard (near river beds, coastal areas with sandy soils and high water tables) the shelter could be seriously damaged in an earthquake. The heavy weight of the building components could seriously injure any occupants of the shelter.

Materials

- Bricks for the masonry walls should be solid, not fractured, and free of honeycombs and voids.
- Mortar should be freshly mixed in small batches so it is used before it sets.
- Ensure steel framing is straight, and brush off any surface rust before installation.

Foundation

- Verify that the soil under the brick foundations and the floor slab are free of organic materials, and that any soft spots have been compacted. Ground surface should be flat and level prior to constructing the shelter.
- Bricks should be laid flat and level, and joints should overlap between courses (running bond).
- All joints between bricks should have mortar between them. Ideally mortar joints should be between 6mm and 13mm thick. All mortar exposed mortar joints should be tooled such that the mortar is re-cessed slightly from the face of brick. Mortar joints below grade do not need to be tooled.

Roof

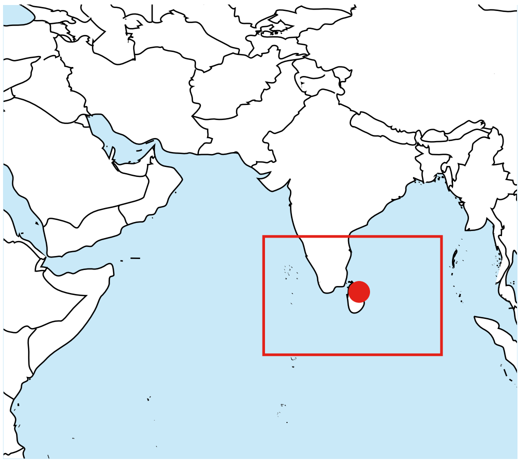
- Steel beams should bear a minimum of 100mm into the brick walls.
- Ensure steel framing is set flat and level before installing ceramic tile.
- Pack cement plaster between ceramic tiles and steel framing to provide lateral support for the steel beams.

Bill of quantities

The bill of quantities in the table below is for the shelter as it was built, without the design alterations suggested here. It does not take into account issues such as which lengths of timber are available and allowances for spoilage in transport and delivery.

Item See annex I.1	Additional Specification	Quantity	Unit	Comments
Main Structure				
Portland cement		26	Bags	42.5 kg/bag
Gravel		1	m^3	
Sand		4	m^3	
Water		940	liter	
Bricks		93,000	Piece	
Steel 1	5.8m long Tee	12	Piece	
Steel 1	152mm x 76mm x 4.3m beam	3	Piece	
Covering – Wall and Roof				
Ceramic tiles	304mm x 152mm	515	Piece	
Fixings				
Timber door	1m x 2 m	1	Piece	With frame, hinges, and locks
Timber window	0.9m x 1.2m	1	Piece	With frame, hinges, and locks
Tools				
Spade		1	Piece	
Hoe		1	Piece	
Wheelbarrow		1	Piece	
Framing hammer		2	Piece	
Hand saw		2	Piece	
Gloves		4	Pair	

B.10 Sri Lanka – 2007 – 'Core Shelter'



Summary information

Disaster: Civil conflict in Sri Lanka

Materials: Unreinforced masonry exterior walls, metal roofing on timber trusses

Material source: Locally procured

Time to build: 5 days after fabricating blocks

Anticipated lifespan: 10+ years

Construction team: 2 - 3 people (Owner driven process with dependence upon skills in immediate famiily)

Number built: 1,000+

Approximate cost per shelter (including labour and transport): 650 CHF

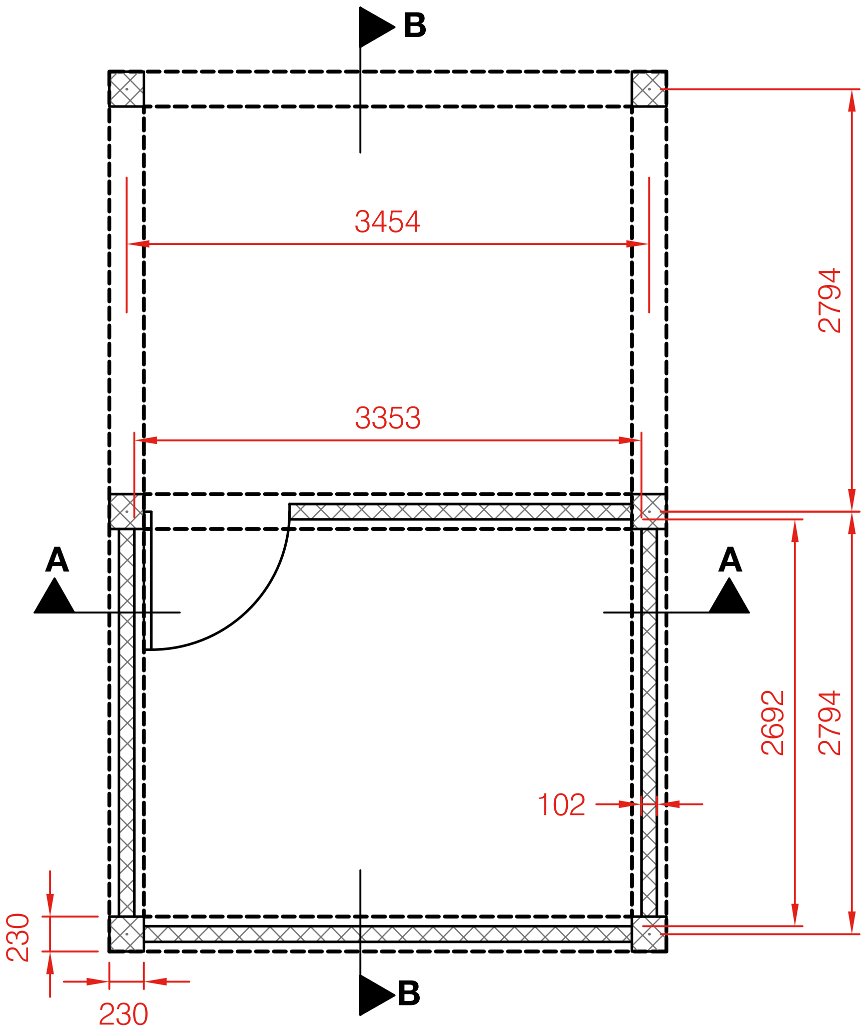
Shelter Description

This shelter is a rectangular structure with a gable roof and an enclosed floor area of approximately 3.5m x 2.8m with an additional covered veranda of approximately 3.5m x 2.8m. The exterior walls are built with unreinforced bricks with six reinforced masonry piers. All masonry blocks are fabricated by the shelter occupants prior to construction. The roof consists of coconut wood rafters and purlins supporting corrugated iron sheet roofing. The compacted earth and concrete floor is raised above the surrounding ground surface. The perimeter walls extend into the ground, and are supported on brick footings. The modular construction for the shelter allows for expansion in both horizontal directions with only minor modifications to the core shelter. As designed, the shelter has one door and one window.

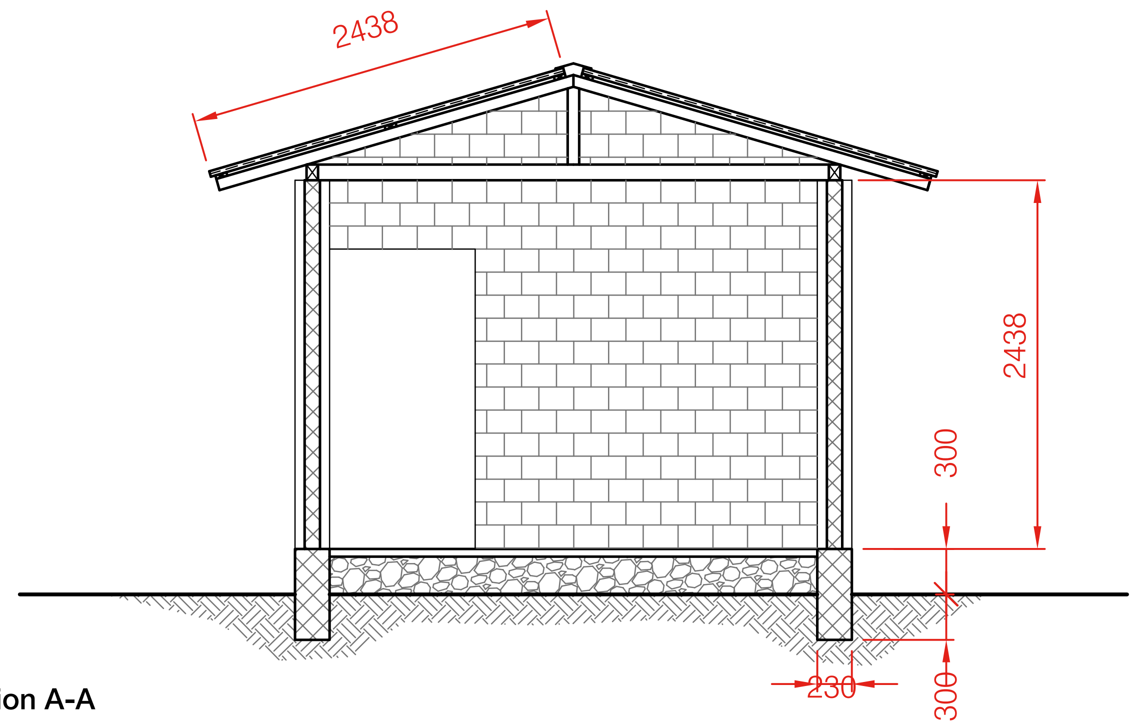
Shelter Performance Summary

The construction materials used for this shelter are of high quality and very durable, and can provide a shelter with a long design life. While the materials themselves are durable, the wall thickness and wood member dimensions are not sufficient to resist the wind pressures from a full storm, but performance of the structural system under the anticipated seismic loads is acceptable. The simplest solutions for the performance under wind load are to either evacuate the shelter during a storm, or to increase the size of the walls and roof framing.

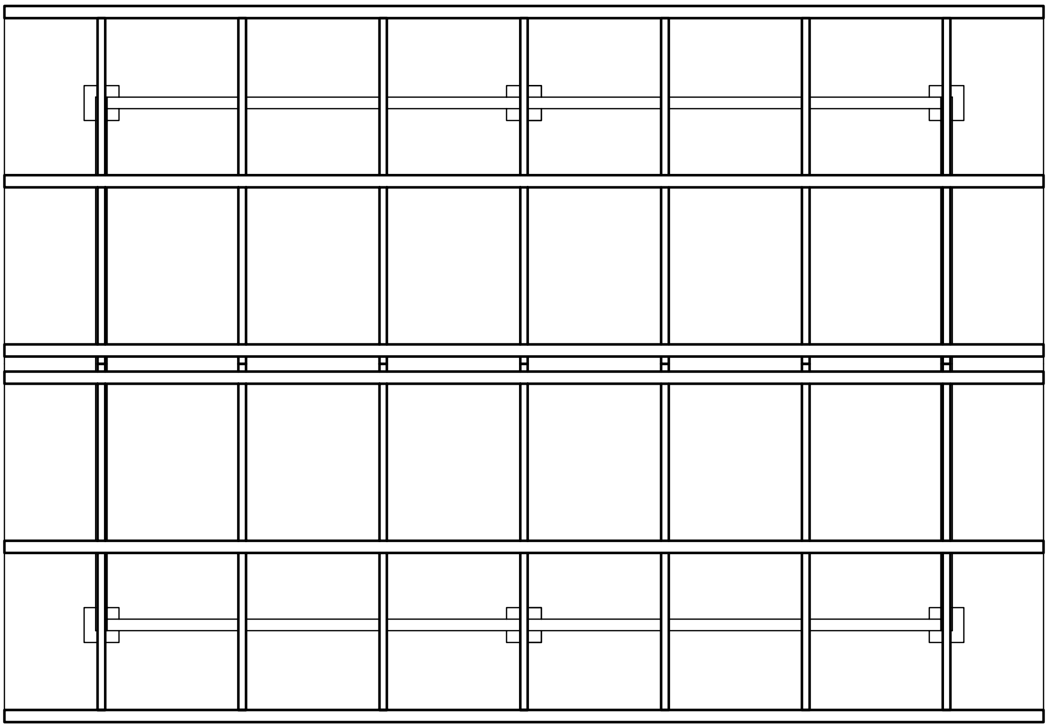
Plans



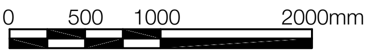
Floor plan

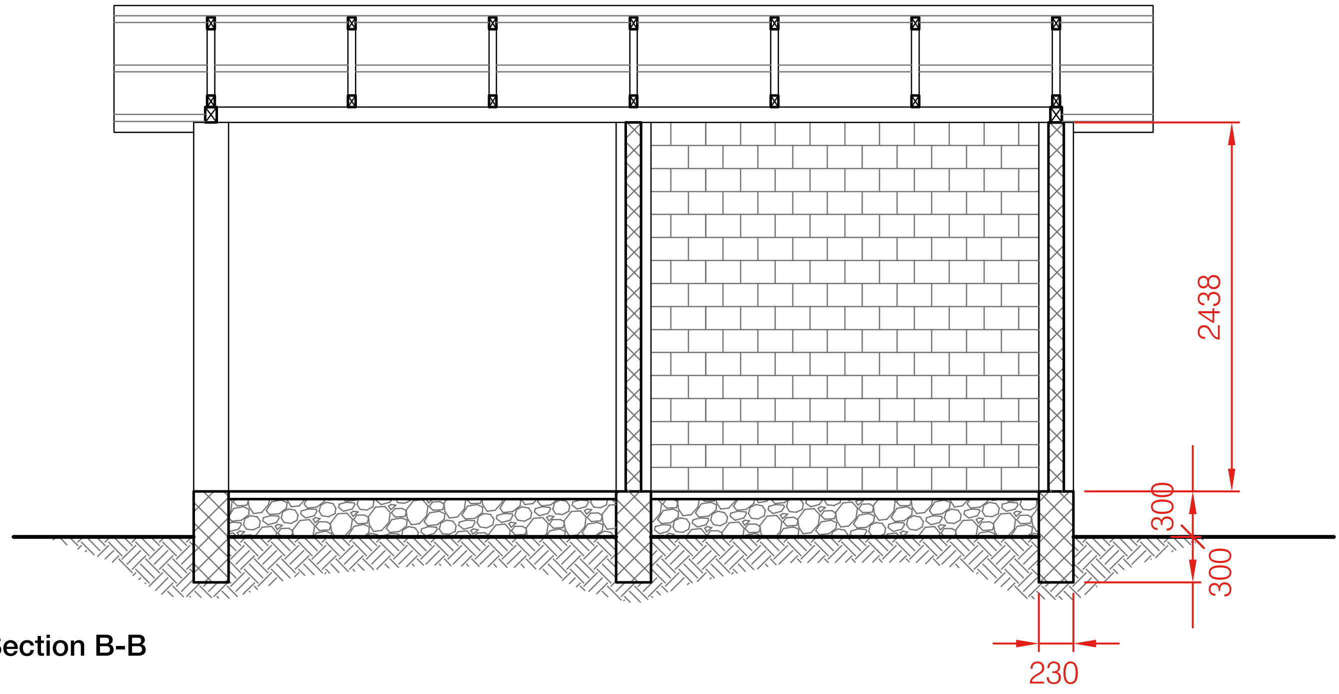


Section A-A



Roof Framing Plan





Section B-B

Durability and lifespan

The masonry and concrete portions of this shelter are very durable. However, coconut wood is not naturally rot resistant and should be treated to resist fungal and insect attack. Given the expected lifespan of the masonry components, If the lumber is not treated, it should be expected that the roof framing well require replacement during the life of the shelter.

Performance analysis

The single width unreinforced brick walls are capable of resisting the expected seismic loads, but are not sufficient for the expected effects of a typhoon. If the walls fail, the falling brick could injure any occupants. In addition, depending on the grade and quality of the coconut wood, the wood framing may not be capable of resisting the expected uplift pressures from the storm winds. Proper site analysis is necessary prior to construction to determine appropriate finished floor heights to provide any mitigation of flood hazards.

Hazard*	Performance
Earthquake MEDIUM	**GREEN:** Even though the walls are only a single block thick, they are strong enough to resist earthquake loading, primarily due to the light weight of the roof. Any modifications to the roof which increase its weight should be carefully considered.
Wind MEDIUM	**RED**:** If a shelter is in a location exposed to storms, the brick walls will not be capable of resisting the winds from a design level storm. Even if they are strong enough, there does not appear to be sufficient connection between the top of the wall and the roof framing to transfer lateral loads into the roof. The adequacy of the roof framing is dependent on the grade of the coconut wood used in the construction. Only high quality and high density wood from the outer sections of the coconut truck should be used for structural applications.
Flood HIGH	**GREEN:** The first floor of the shelter is elevated above the surrounding ground surface, and it is easy to modify the design to provide additional clearance if site specific situations require.
Fire LOW	**AMBER:** The concrete and masonry components of the framing are very fire resistant, but the wooden framing in the roof is not. The roof may be able to survive a brief fire that was quickly extinguished. Consideration should be given to providing a second means of egress from the shelter in case the single door is blocked.

* See section A.4.5 Performance analysis summaries.

** Although the shelter failed the structural analysis for predicted wind loads based on available windspeed data, the team that built the shelters felt that the sites were less exposed to typhoon risk than the available wind data indicated. For this reason we have not coloured the cells in red.

Notes on upgrades

To improve the resistance to wind loads, the exterior walls can be increased to two widths thick. In addition, the wall sections between piers should be positively attached to the wall top plate to prevent the top of the wall from deflecting.

The veranda can be converted into enclosed space by bricking in between the piers. In this situation, it is important that the interior wall down the middle remain in place to support the ridge beam in the roof.

If the shelter is expanded out either side, analysis should be conducted to determine how much of the brick infill walls can be removed without impacting the lateral load resistance.

Analysis should be performed before any additional openings are put into the shelter walls, as they will reduce the lateral load capacity of the shelter.

Assumptions

- Analysis is based on a compressive capacity of masonry of 2,100kPa, and a tensile capacity of masonry of 138kPa.
- The wood roof framing is not laterally braced when loaded in uplift.
- Lateral foundation loads are resisted by lateral soil bearing on the foundation walls.
- Foundation uplift forces are resisted only by the weight of the shelter, and any frictional resistance of between the foundation and soil are ignored.
- There is no building code for Sri Lanka, so this shelter was only analyzed using the International Building Code.

Potential Issues

Site Selection

- Site selection is the best way to mitigate flood hazards. Select sites on higher ground and away from flood hazards. Provide proper drainage around shelters to prevent accumulation of rain water. Locate shelters a minimum of 10 meters from ravines, or as required by local authorities.
- The weight of the building construction requires a stiff supporting soil to avoid settlement and possible cracking of the exterior walls.
- For sites where soil liquefaction during an earthquake may be a hazard (near river beds, coastal areas with sandy soils and high water tables) the shelter could be seriously damaged in an earthquake. The heavy weight of the building components could seriously injure any occupants of the shelter

Materials

- Inspect timber to ensure that pieces are straight, not twisted or bowed, free of knots, and not cracked.
- Bricks for the masonry walls should be solid, not fractured, and free of honeycombs and voids.
- Mortar should be freshly mixed in small batches so it is used before it sets.

Foundation

- Verify that the soil under the brick foundations and the floor slab are free of organic materials, and that any soft spots have been compacted. Ground surface should be flat and level prior to constructing the shelter.
- Bricks should be laid flat and level, and joints should overlap between courses (running bond).
- All joints between bricks should have mortar between them. Ideally mortar joints should be between 6mm and 13mm thick. All mortar exposed mortar joints should be tooled such that the mortar is recessed slightly from the face of brick. Mortar joints below grade do not need to be tooled.
- Ensure steel reinforcing for the piers is installed, especially if the veranda is left open.

Roof

- All framing should be adequately nailed together, and nails should not split or crack the wood framing. Verify the proper number of nails are provided and the proper size is used in each connection. Use of toe nailing should be avoided.
- All wood framing in direct contact with masonry should have tarpaper or other barrier between the two materials to help prevent rot.
- Verify all the hurricane straps are properly installed, as they are required for the roof to resist wind uplift pressures.
- If pressure treated wood is actually used, hot dip galvanized fasteners should be used, as most preservatives are corrosive to mild steel.
- Ensure that all the J-Hooks and L-Hooks fastening the roof panels are properly installed.

Bill of quantities

The bill of quantities in the table below is for the shelter as it was built, without the design alterations suggested here. It does not take into account issues such as which lengths of timber are available and allowances for spoilage in transport and delivery.

Item	Material Specification See annex I.1	Quantity	Unit	Comments
Main Structure				
Portland cement		26	Bags	42.5 kg/bag
Aggregate		0.1	m^3	
Sand		3.1	m^3	
Gravel		1.3	m^3	
Steel reinforcement	10mm dia x 3.1m long	6	Piece	
Steel reinforcement	6mm dia	3.7	m	
Tie Wire		0.2	kg	
Timber 1	64mm x 114m x 3.7m	1	Piece	
Timber 1	64mm x 114m x 1m	1	Piece	
Timber 1	38mm x 89mm x 3.7m	6	Piece	
Timber 1	38mm x 89mm x 2.5m	18	Piece	
Timber 1	19mm x 38mm x 3.7m	16	Piece	
Tar Sheet	1m wide	3.4	m	
Covering – Wall and Roof				
Sheet 2	0.5mm x 2.4m long	20	Sheet	
Ridge Tiles		20	Piece	
Fixings				
L-Hook		6	kg	Include nut and washer
Bolt	10mm dia x 152mm long	2	Piece	Include nut and washer
Bolt	10mm dia x 127mm long	6	Piece	Include nut and washer
Common nails	127mm long	2	kg	
Common nails	51mm long	2	kg	
Bitumen based wood preservative		10	Litre	
Door	0.9m x 1.8m	1	Piece	Include frame and hardware
Window	0.9m x 1.1m	1	Piece	Include frame and hardware
Timber Door	1m x 2 m	1	Piece	With frame, hinges and locks
Timber Window	0.9m x 1.2m	1	Piece	With frame, hinges and locks
Tools (shared within community) many households already had basic tools including hammers and saws				
Block cast mould				
Mason trowel				
Shovel	Steel handle			
Mason float				
Sprit level				
Wheel barrow				
Plumb bob				
Straight edge 6’0” long				
Pliers				
Spanner				

Annexes

These Annexes contain materials specifications, a template for a design brief that can be used to start discussions in future disasters, basic metric to imperial conversion tables, a glossary of terms used and documents for further reading complete with annotations.

Contents

I.1 Hazards and design details

A shelter's ability to resist a hazard is a combination of where it has been located and its design. For lightweight shelters, some risks, such as tidal surges, landslides and volcanos cannot be reduced by design, and choosing safe locations is the only way to reduce the risks. For shelters with longer expected lifetimes, such as core shelters, additional consideration will be required for risks.

The table below, summarises how various hazards can be mitigated through choice of location and through improved design.

Hazards	Mitigating actions		
	Site Selection and Planning	Shelter Design	Construction
Windstorm and Hurricane	↘ Locate away from areas exposed to strong winds.	↘ Use appropriate building shapes, materials and detailing (e.g. building orientation and roof pitch to minimise wind load).	↘ Ensure good quality of construction and workmanship. ↘ Strong foundation, bracing and good connections, including hurricane straps
Flood	↘ Locate away from flood plains and locations with high water tables. ↘ Provide adequate drainage systems.	↘ Raise houses above ground level. ↘ Reinforce ceiling for storage in mezzanine level.	↘ water proof foundation
Earthquake	↘ Locate away from fault lines. ↘ Locate away from areas where liquefaction occurs: e.g. river beds, coastal areas with sandy soils and high water tables. ↘ Ensure adequate spacings between shelters	↘ Use appropriate building shapes, materials and detailing (e.g. strengthen ring beams at corners).	↘ Ensure good quality of construction and workmanship.
Tidal surge and Tsunami	↘ Locate away from areas vulnerable to tsunamis or storm surges. ↘ Provide clear evacuation routes, and establish clear warning systems and evacuation plans.	↘ Simple, low cost structures cannot be designed to withstand tidal surges or tsunamis.	
Landslide	↘ Locate away from areas vulnerable to landslides (e.g. on or at the bottom of steep slopes). ↘ Provide slope stabilising systems (e.g. retaining walls, vegetation, adequate drainage).	↘ Simple, low cost structures cannot be designed to withstand landslides.	
Volcano	↘ Locate away from areas vulnerable to volcanoes (e.g. away from lava flows, smoke, ash and explosions).	↘ Simple, low cost structures cannot be designed to withstand volcanic eruptions.	
Fire	↘ Plan settlements with fire breaks. ↘ Leave gaps between shelters to provide fire breaks.	↘ Use appropriate building materials and detailing (e.g. use fire retardant materials). ↘ Suitable kitchen location ↘ Clear escape routes	↘ Safe cooking stove and lighting

I.2 Materials specifications

I.2.1 Introduction

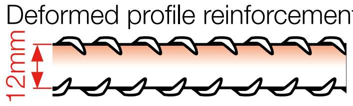
The materials specifications below contain the values as used in the calculations in section B. In most cases they are not of sufficient detail to launch large scale procurements.

Please refer to UNOCHA / IFRC / CARE International, Timber for fuller guidance on specification on timber, plywood, cement, corrugated galvanised iron and plastic sheeting. The emergency relief items catalogue also contains detailed specifications for tools, nails and wire in the shelter tool kit (catalogue number KRELSHEK01).

Humanitarian Bamboo Project is a good starting place for further information on bamboo.

I.2.2 Structural materials

Material	Material Type	Specification	Required Properties
Timber 1*	Coconut wood	High to medium density coconut wood from outside of tree or wood of similar properties.	Density 400kg/m^3, elastic modulus 7584N/mm^2, bending strength 15N/mm^2
Timber 2*	Southern Yellow Pine, Douglas Fir-South, or equivalent	No. 2 Structural grade treated timber**.	Density 530 kg/m^3, Young's Modulus 8274N/mm^2, bending strength 5.86N/mm^2
Timber 3*	Aspen or acacia/white poplar with same properties	No. 2 Structural grade treated timber**.	Density 420 kg/m^3, Young's Modulus 6895N/mm^2, bending strength 4.14N/mm^2
Timber 4*	'White Bolaina' or Douglas Fir	No. 2 Structural grade treated timber or equivalent**.	Density > 410 kg/m^3, Young's Modulus 8274N/mm^2, bending strength 5.86N/mm^2
Timber 5*	Knot free Garjan		Density 650kg/m^3 Young's modulus 12.6kN/mm^2 Bending strength 16N/mm^2
Steel 1	Minimum grade structural steel.	Hot rolled, hot dip galvanized steel.	Yield strength 275N/mm^2, Young's Modulus 210kN/mm^2
Steel 2	Cold formed galvanised steel.	Cold rolled, hot dip galvanised steel, JIS G3302, ASTM A653 M-95*, minimum thickness 1.6, 2mm.	Yield strength 275N/mm^2, Young's Modulus 210kN/mm^2
Steel 3	Cold formed galvanised steel.	Cold rolled galvanised steel, JIS G3302, ASTM A653 M-95*, minimum thickness 2mm.	Yield strength 275N/mm^2, Young's Modulus 210kN/mm^2
Steel 4	Cold formed galvanised steel.	Cold rolled galvanised steel, JIS G3302, ASTM A653 M-95*, minimum thickness 0.75mm prior to galvanising.	Yield strength 550N/mm^2, Young's Modulus 210kN/mm^2
Bamboo 1****	Giant Bamboo, also known locally as Bambu Petung (Dendrocalamus Asper.)	Average properties along length: 150mm diameter, 13.5mm wall thickness, 700kg/m^3 density, 300mm node spacing.	Young's Modulus 17KN/mm^2 Allowable stresses for design (excluding load duration): compression 9.1N/mm^2, bending 14N/mm^2, shear 2.1N/mm^2.

Bamboo 2***	Tropical Black Bamboo, also known locally as Bambu Apus (Gigantochola Apus).	Average properties along length: 80mm diameter, 7.2mm wall thickness, 700kg/m^3 density, 330mm node spacing.	Young's Modulus 17KN/mm^2 Allowable stresses for design (excluding load duration): compression 9.1N/mm^2, bending 14N/mm^2, shear 2.1N/mm^2.
Concrete	Concrete	Portland cement, sand and 20mm aggregate in mix ratio 1:3:6 by volume.	Concrete assumed to be of the best available quality but with a minimum compressive cube strength, fcu, of 15-20MPa at 28 days.
Steel reinforcing bar	Steel reinforcing bar	Deformed profile reinforcement 	Mild steel properties assumed: minimum yield strength 250N/mm^2. Minimum cover to reinforcement 25mm.
Wire mesh	A142 Mesh	200mm x200mm wire spacings. 6mm diameter wire.	

* See also UNOCHA / IFRC / CARE International, Timber.

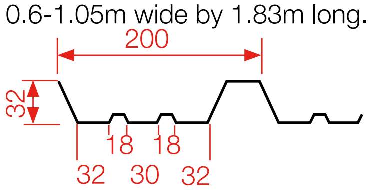
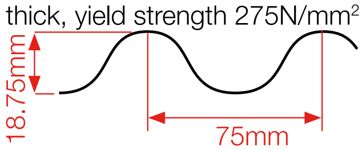
** This book uses the grading systems in NDS - see National Building Codes & Standards.

*** See International Standards for Materials, Products, Systems and Services.

**** See also Humanitarian Bamboo Project.

I.2.3 Cladding materials

Please also refer to IFRC/ICRC Emergency Items Catalogue for further guidance on the specifcation on corrugated iron.

Material	Material Type	Specification	Required Fixings
Plywood 1	Plywood for walls	½" thick marine or exterior grade, 24/16 span rated, 4 ply, density 550kg/m³	Framing must be spaced at 600mm and a maximum nail spacing of 150mm used assuming 8d nails.
Plywood 2	Plywood for floors	Plywood for floor to be 7/8" thick marine or exterior grade, 54/32 span rated, density 550kg/m³.	Plywood to be fixed using 8d nails spaced at 150mm centres.
Sheet 1	Galvanised aluminium/ zinc coated corrugated steel sheeting.	0.45mm thick, 75mm spacing between corrugations 18.75mm trough height. Standard sizes range from 0.6-1.05m wide by 1.83m long.  Sheet Profile. dimensions in mm	Sheeting should be fixed using twisted galvanised 8d roofing nails (56.25mm long) with a typical spacing of 300mm on centre. Along eaves and roof ridge it is recommended to nail every other corrugation – nails should be through crown.
Sheet 2	Galvanised aluminium/ zinc coated steel sheets.	Lightweight steel sheet, 0.5mm thick, yield strength 275N/mm²  Profile of the sheeting	Nail using 8d nails – one or two per corrugation (through crown) depending on purlin spacing and wind pressures.
Sheet 3	Fibre cement corrugated roof sheeting.	High strength fibre cement sheet with polypropylene reinforcement strips, 6.7mm thick, 1086x3050mm sheets with 70mm overlap, 0.17kN/m² installed weight.  Profile of the sheeting	Two fixings per sheet in 2mm oversize holes with 8d nails & washers. 1300mm maximum purlin spacing. Seal required between sheets for total weatherproofing.
Plastic	Plastic sheeting (4m x 6m).	IFRC standard Polyethylene sheet with braided core (HDPE/ LDPE).	Assume that sheeting is stapled or nailed at appropriate intervals in accordance with framing and wind pressures.
Tiles	Clay interlocking tiles.	Large clay interlocking pantiles: 403 x 325mm, 9.9tiles/m², minimum head lap 47mm, installed weight 0.4kN/m².	Recommended fixings use short 8d roofing nails and clips from battens laid on top of rafters.

I.2.4 Fixings

The specifications here are those used for the calculations in this book. Please refer to IFRC/ICRC Emergency Items Catalogue for further guidance on the specifcation of nails and wire.

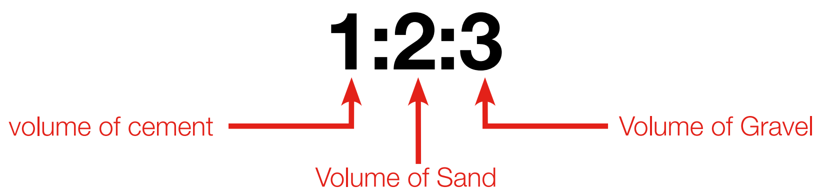
Material	Material Type	Specification	Required Properties
Hurricane strap	Galvanized steel strap	Galvanized steel, 0.91mm thick (20 gauge) 32mm wide.	Holes every 50mm step, 380N/mm² tensile strength
Common nails	Round steel wire nails	10d (~3.7mm dia. 75mm long) 6d (~2.8mm dia. 50mm long) 8d (~3.3mm dia. 62.5mm long) 4d (~2.5mm dia. 37.5mm long)	Minimum yield strength 275N/mm².
Roofing nails	Galavanised iron with rubber washer	Spiral rolled or twisted shank, 75x3.6mm. Umbrella-type head diameter 20mm minimum Rubber washer diameter 26mm x thickness 2mm	hot-dip galvanized at 300g/m2 ±10% minimum tensile strength: 650N/mm²
Staples	Steel staples	22/25 staples assumed (~0.64mm thick)	Minimum yield strength 275N/mm²
Threaded rod	Mild steel rod	JIS G3101, ASTM A307	Minimum ultimate strength 400N/ mm2, threaded at each end
Wire 1	Steel wire	American Wire Gauge 16 - 1.3mm diameter	Minimum yield strength 275N/mm²
Wire 2	Steel wire	American Wire Gauge 10 - 2.5mm diameter	Minimum yield strength 275N/mm²
Bolts	Steel bolts	Diameter as specified per shelter (M6, M10, M12, M14, M20 etc.)	Minimum yield strength 275N/mm²
Steel screws	Steel screws	Diameter and length as specified per shelter	Minimum yield strength 275N/mm²

I.3 Concrete and hurricane straps

I.3.1 Concrete

Mixes

At a minimum, concrete is a mixture of water, portland cement, sand, and gravel. The proportions of these four ingredients determine the properties of the concrete, including workability of the mix, compressive strength, and durability.



One common method of specifying the mix proportions is by volume of cement, sand, and gravel. This mix would have 2 buckets of sand and 3 buckets of gravel for each bucket of portland cement.

Given the shorter design life of many post-disaster shelters, compressive strength is generally the property for concrete of most concern. One major exception is climates where freezing temperatures are expected. If water inside the concrete freezes, its expansion can cause the concrete to rapidly deteriorate. In these situations air can be purposefully mixed into the concrete using chemical admixtures, referred to as air entrainment, to improve durability.

The table below provides information for some typical concrete mixes. All quantities are for a cubic meter of concrete, and assumes air entrainment is not required:

	Mix Proportions		
	Structural Purposes (e.g columns beams and walls)		Non-Structural (e.g floor slabs)
	1:2:2	**1:2:3**	**1:3:6**
Water (liter)	202*	202*	202*
Cement (bag**)	10	8	5
Sand (m^3)	0.56	0.47	0.41
Gravel (m^3)	0.56	0.70	0.83
Water:Cement (kg:kg)	0.44	0.57	0.97
Compressive Strength (MPa)	26.5	21.8	***

* Approximate amount of water required to produce a workable mix.
** Each bag has 42.5 kg of portland cement.
*** Water-cement ratio is beyond empirical data to estimate strength.

1:2:2 and 1:2:3 mixes are typical mixes used for structural concrete, and are used for items such as columns, beams, and walls. The third mix (1:3:6) can be used for “non-structural” for which strength is not important, or for elements (such as floor slabs on the ground, and below-ground footings) that will not risk occupant safety in the event of failure. This mix should be avoided for columns and beams, as it does not have sufficient strength.

impact of the mix on the properties of concrete	
Wrkability of the mix	Primarily determined by the total amount of water in the mix.
Strength	Primarily determined by the ratio of water to cement (by mass), the lower the ratio the stronger the concrete.
Drying shrinkage and cracking	increases as the amount of water and cement are increased.
Durability	increases as the water cement ratio is decreased.

Quality of water

Salt water should never be used for where reinforcement or where steel wires/ties are embedded into the concrete. However in other cases, sea water can be used for un-reinforced concrete, but with the following considerations:

- Sodium salts can reduce overall strength of the concrete, but this is not likely to be an issue for simple shelters as un-reinforced concrete should not be used for parts of the structure where strength is critical (i.e. floor slabs and footings)
- Eflorescence (white salt stains) can form on concrete made with sea water. This will not impact on strength, but can have an aesthetic impact.
- Some types of rock can react with the potassium salts (and the alkalis in the cement) and expand over time. This is not lilkely to be an issue within the design life of most shelters.

if water is good to drink it's acceptable for use in concrete...

Quality of sands and aggregates

- Silts and clays should not be mixed into concrete. Sand and gravel should be clean (i.e. if water is run through the sand and gravel it should not get muddy).
- If the aggregates mixed into the concrete are dry, more mixing water will be required as they will absorb some of the water.

Quality of workmanship

There are often issues in quality of cement due to poor workmanship. common issues include:

- Concrete being mixed directly on the ground and not on a mixing plate. As a result it gets contamitated wit soil.
- The concrete is inadequately mixed.
- Concrete is not kept damp as it cures. Cover floor slabs with plastic dampened fabric and moisten regularly.

I.3.2 Hurricane Straps

Proper connections between the components of a shelter are crucial to its performance during hurricanes and earthquakes. One of the most important connections is between the roof and the supporting walls or columns. Without strong connections, the roof could blow away resulting complete failure of the shelter.

"Hurricane strap" or coiled strap is a simple and cost effective product to connect the roof of a wood framed shelter. A hurricane strap is a galvanized steel strap which can be cut to length with tin snips, and has regularly spaced holes to nail or screw into wood framing. Its effectiveness as a hold-down is dependent on exactly how the strap is used to make the connection.

Factors that are important to the effectiveness of a hold-down include:

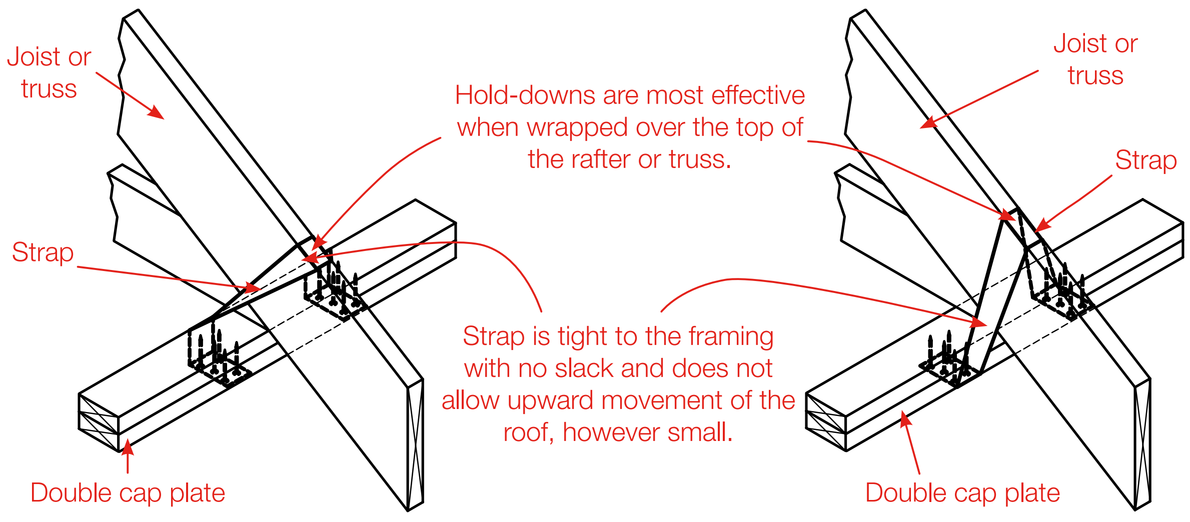
- NEVER rely on nails or screws loaded in withdrawal (where the loads of a structure are effectively pulling them out of the wood). Instead rely on fasteners loaded in shear (where the loads go across them).
- Strap should be tight to the framing with no slack, and should not allow upward movement of the roof, however small.
- Hold-downs are most effective when wrapped over the top of the rafter or truss.
- Providing a strap on only one side framing should be avoided when possible, instead provide strap on either side.
- Only bend strap once at any location. Repeated working weakens the steel.
- When creating a hold-down detail, remember the hold-down is intended to resist upward loads.

As an alternative, there are many pre-fabricated hold-downs available from various manufacturers. These products have the advantage of being relatively easy to install for unskilled labour, and to inspect for proper installation. Some disadvantages are that these products are intended for standard dressed dimension lumber, which may not be available, and that they need to supply many different types according to the connection conditions.

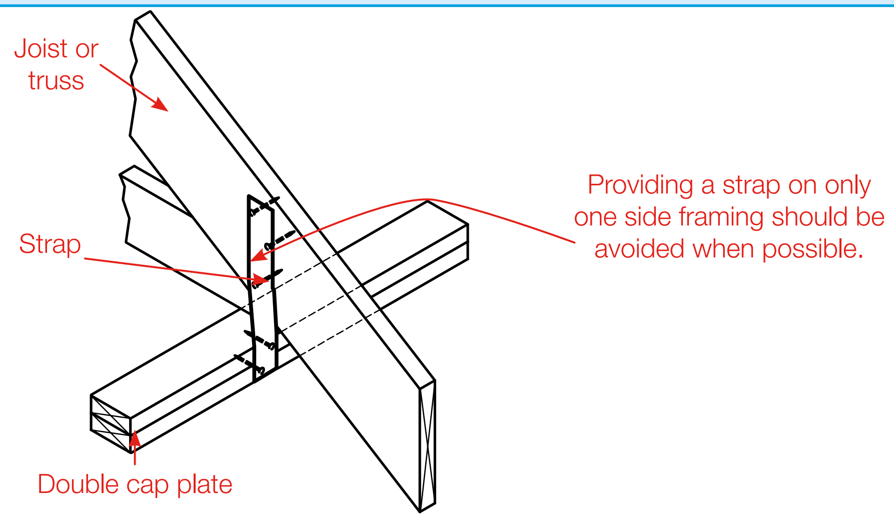
For full specifciations see: See IFRC/ICRC Emergency Items Catalogue

(EHDWSTRAHS16: Hurricane strap, galvanaised, Perforated, 32mm)

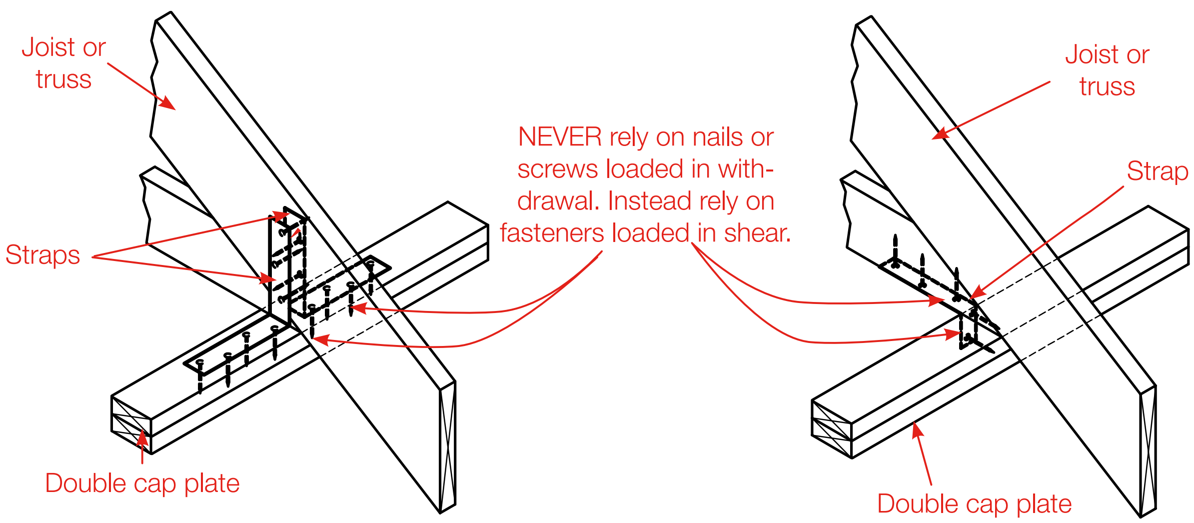
Good



Marginal



Bad



I.4 Template design brief

This annex contains a sample template for a design brief for shelters. It is based on the agreed standards for shelters that were agreed by the Shelter Clusters in Haiti, following the 2010 earthquake, and the 2009 earthquake in Padang, Sumatra, Indonesia. Where marked in blue text, indicators, standards or remarks may need to be deleted if they are not relevant to the context. Where marked with XXX, values need to be collectively agreed, specific to the context.

Organisations may wish to add programmatic issues to this technical brief such as targeting, support for the most vulnerable recipients, and messaging. This design brief should not contradict relevant building codes.

Performance standards and indicators for post disaster shelters		
Indicators	Standard	Remarks
Key data		
Life span (see A.2.6)	↘ Materials and shelter construction to allow for more than XXX months use. ↘ Materials should allow for easy maintenance and upgrade.	↘ Suggested life span XXX: ↘Temporary: min. 1 year ↘Transitional: min. 3-5 years ↘Progressive: min. 3-5 years though materials should last longer ↘Core: min. 5-10 years
Cost (see A.2.12)	↘ XXX USD including transport and labour, excluding taxes and project management costs. For one storey shelter, assuming additional input of material and labour from home owners.	↘ Consider supplying only some of the materials when existing materials remain. ↘ Cost may be adjusted upwards by XX% due to; market fluctuations, extra shipping costs, etc.
Covered living space (see A.2.7)	↘ Provide a target of XXXm² floor space with XXXm² as a maximum. ↘ In exceptional cases, a minimum of XXX m² may be considered for instances where no other space is available, and with a clear justification.	↘ Assuming average of XXX persons per family "Life span" ↘ See sphere
Head height (see A.2.7)	↘ A minimum of XXXm from the floor to the eaves.	
Hazard resistant construction (see A.2.4)		
Rains and Floods	↘ The roof should protect the interior and walling materials from rain. ↘ Foundations have sufficient strength and height to withstand flooding of site.	↘ Ensure that any roof overhang is not so large as to increase the hazard from strong winds
Wind and storms	↘ Foundations must secure the shelter to the ground in strong winds. ↘ The roof must be fixed securely to be resistant to storms and must be designed with adequate strength for proposed roofing material. ↘ Design structures so that structural members and joints take the loads rather than the fixings. ↘ Where appropriate: Metal strapping is strongly advised to protect against hurricane and earthquake.	↘ A pitch of 30⁰-45⁰ for 2-pitched roofs is optimum to resist strong winds. ↘ A design wind speed of XXX km/h is suggested. ↘ Wide roof spans are to be avoided as they weaken the structure.
Earthquake	↘ Seismic resistance techniques must be incorporated into shelter form.	↘ Special attention to locations of doors and windows, foundations, bracing and ring beam connections.

Design principles		
Suitable for relocation	Transitional shelter and some temporary shelters: ↘can be relocated by the occupants. All shelters: ↘Where possible, materials should be re-usable.	↘ The shelters may later be used as kitchens, verandas, or shops.
Capacity to extend	↘ The shelter should be built so that occupants can easily extend it with their own resources.	↘ Core shelter can be expanded. ↘ Progressive shelter can be upgraded to permanent. ↘ Transtional shelter materials can be re-used.
Hazard resistant Learning	↘ Shelters should provide practical learning examples of principles of good construction (e.g. openings such as doors should be away from the corners of the structure).	↘ To promote good earthquake, hurricane and flood resistance practice. (see A.2.4)
Ventilation and thermal comfort (see A.2.9)	Hot climates only: ↘Where possible, promote openings on XXX sides of the shelter to allow for cross ventilation ↘Allow for adequate ventilation and design to minimise internal temperatures. Cold climates: ↘Minimise cold air infiltration ↘Ensure that there is ventilation to prevent health hazards due to fumes from cooking fuel.	↘ Openings shouldn't affect structural integrity of the shelter. ↘ Take in consideration possible future extension or re-use of the unit/shelter.
Privacy (see A.2.8)	↘ The design should allow the addition of at least one internal division for privacy. ↘ The shelter should provide a flexible space.	↘ Hot climates: Internal divisions should not go as high as the roof as this will reduce ventilation.
Culturally appropriate (see A.2.8)	↘ Shelter layouts, materials and construction techniques are familiar or easy to understand by the beneficiaries.	
Access	↘ Shelters should take into account access by persons with reduce mobility, wherever possible.	
Site and services (see A.2.11)		
Tenure	↘ Legal aspects of the site or plot should be resolved. ↘ A minimum time frame for any agreement is XXX. It is preferred to have an agreement of XXX years or longer (linked to life span).	↘ Take into account different forms of tenure security, including ownership, tenancy and other arrangements.
Location	↘ In principle, the location of the shelter should support the choice made by the shelter owners themselves. Wherever possible, shelter should be constructed at, or near to the existing homestead, without inhibiting permanent housing reconstruction. ↘ Shelters should not be built next to dangerous buildings or structures, on land liable to flood, or in locations that expose the occupants to other hazards. ↘ Shelters should be built in locations that help occupants to maintain access to livelihoods, basic social services/community infrastructure (health, education, commercial…) as well as electricity and telephone.	↘ Except when an existing damaged house is deemed unsafe.
Plot preparation	↘ Sites need to be cleared of any physical dangers.	↘ Refer to any agreements on rubble removal that may exist.
Water and Sanitation	↘ Adequate water supply and sanitation facilities. ↘ Construction must be coordinated with WASH. ↘ Adequate site drainage is provided to minimise the risk of flooding. Individual Shelters must be connected to site drainage solution.	

I.5 Conversion tables

The data on this page is all rounded to 4 significant figures. Penny sizes are rounded to the nearet mm.

I.5.1 Length

Imperial	1 inch (in.)	1 feet (ft.) = 12 in.	1 yard (yd.) = 3 ft. = 36 in.	1 mile = 1760 yd.
	↓	↓	↓	↓
Metric	25.4 mm = 2.54 cm	304.8 mm	0.9144 m	1.609 km

For equivalence tables in timber sizing see UNOCHA / IFRC / CARE International, Timber

I.5.2 Area

Imperial	1 square feet (sq. ft.)	1 square yard (yd^2) = 9 sq. ft.	1 acre
	↓	↓	↓
Metric	0.0929 m^2	0.8361 m^2	4046.9 m^2

1 perch = 30.25 square yards 1 acre = 4,840 square yards 1 hectare = 10 000m^2

I.5.3 Volume

Imperial	1 cubic feet (ft^3)	1 cubic yard (yd^3)
	↓	↓
Metric	28.32 litres = 0.02832 m^3	0.7646 m^3

1 US liquid gallon = 3.785 litres 1 US dry gallon = 4.405 litres 1 imperial (UK) gallon = 4.546 litres

I.5.4 Weight

Imperial	1pound (lb)	Ton (UK, long ton)	Ton (US, net ton, short ton)
	↓	↓	↓
Metric	0.4536 Kg	1.1016 MT = 1016 Kg	0.9072 MT = 907.2 Kg

Note that there are several different imperial systems of weights. We quote the British imperial ton as in the Weights and Measures Act of 1824, and the United States customary system. Additional useful conversions are:

1 lb = 16 Ounces (Oz.)

1 hundredweight (cwt.) - UK = 112 lb.

1 stone = 14 pounds (lb.)

1 hundredweight (cwt.) - US = 100 lb.

I.5.5 Nails - "penny sizes"

Imperial	Penny size	2d	3d	4d	6d	8d	10d	16d	20d	40d	50d	60d	100d
		↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
	Inches	1	1 ¼	1 ½	2	2 ½	3	3 ½	4	5	5 ½	6	10
		↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
Metric	Nearest length (mm)	25	32	38	51	64	76	89	102	127	140	152	254

I.6 Glossary

I.6.1 Full glossary

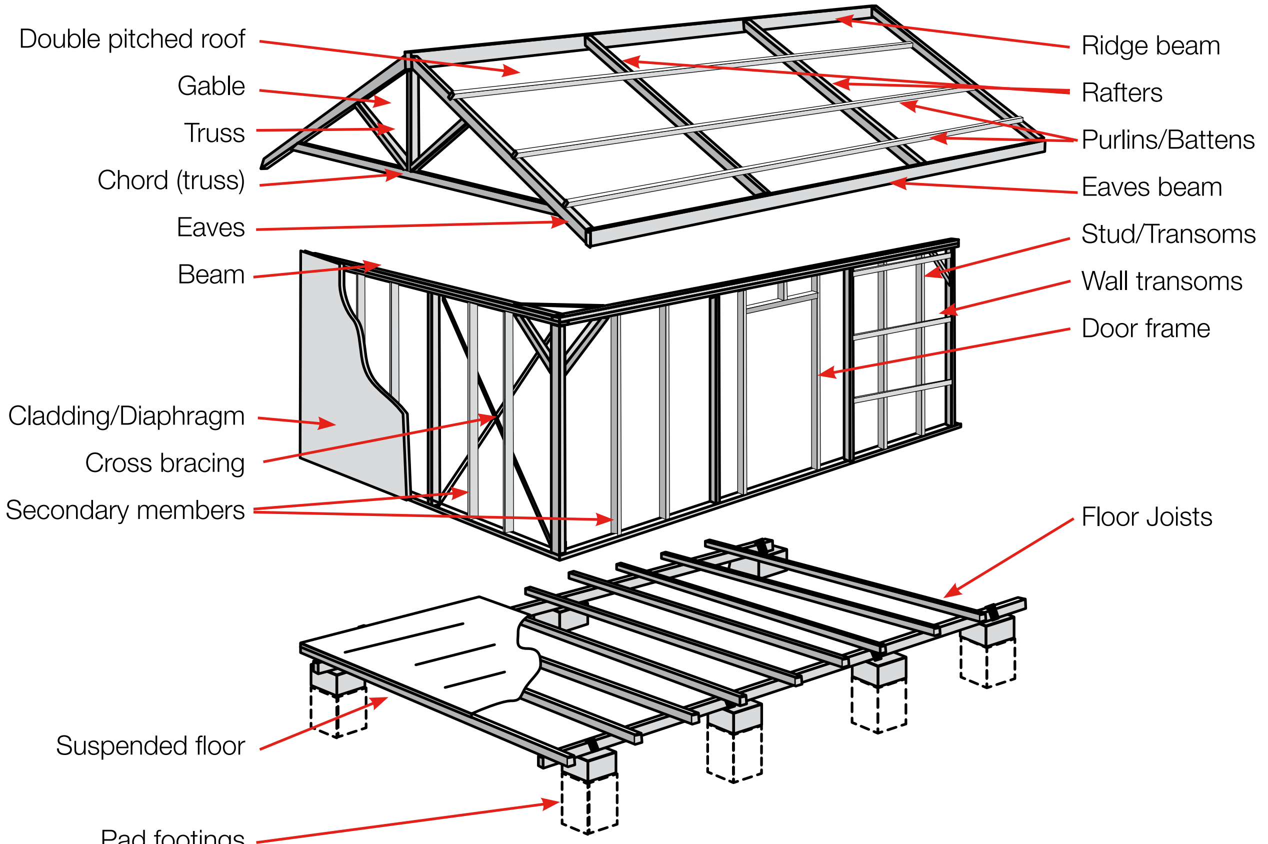
The definitions in this glossary relate to how they are used in this book. They are intended to make the technical language used in this book more understandable by the reader. Please note that we also provide a pictorial glossary in section I.6.2 Pictorial glossary

Term	Definition for the purposes of this book.
Anchor foundations	A foundation that uses a buried object to provide resistance to being pulled out.
Bill of Quantities (BOQ)	A bill of quantities (BOQ), lists the materials, and quantities required to build a structure. The BOQs in this book are the minimum required.
Bracing and braced frames	Bracing is a structural member that stiffens a frame. Bracing a frame is often achieved by adding diagonal members.
Bucket foundations	A foundation consisting of concrete cast in a "bucket" to anchor the columns to the ground.
Beam	A horizontal structural element, supported at either end, typically supporting a floor or a roof. It carries vertical or horizontal loads.
Cantilever	A structure such as a beam that is supported at one end only.
Chord (truss)	The top and bottom part (normally horizontal) of a truss that resists compression or tension.
Cladding	A covering material placed over the outside of a structure on the roof or the walls.
Cold formed steel	Steel that is rolled or bent into shape without heating.
Column	A vertical structural element which typically supports floor or roof framing
Cross bracing	Two diagonal braces that form a cross shape. They usually take only tensile forces.
Diaphragm	A structural system used to transfer loads to the frame. Usually used to resist lateral loads such as earthquakes and winds. Commonly achieved by nailing flat sheets of plywood or timber to a frame.
Dead load	The loads upon a structure due to the weight of the materials from which the structure is built.
Double pitched roof	A roof with two sloping surfaces and a central ridge.
Eaves	An overhang at the lower edge of a roof that extends past the wall.
Eaves beam	A beam to support the lower edge of a roof.
Factor of safety	Ratio of the actual capacity of a structural component and the required capacity determined by structural analysis.
fcu	A measure of the cube strength of concrete with units N/mm^2.
Flash flood	Fast moving flood water that can cause damage to structures and foundations.
Foundation	The part of a building that transfers its weight to the supporting soil.
Footing	A part of foundation that spreads loads out to transfer weight to the supporting solid
Gable	The end wall between the edges of a double pitched sloping roof. It is usually triangular.
Girder	A beam who's primary purpose is to support other beams.
Ground Anchor	See anchor foundations.
Gravity loads	Forces which are applied to a structure resulting from its own weight and the weight of the occupants under gravity.
Gusset	A plate used to connect members of a framing system, such as a truss
Header	A horizontal structural member placed between two beams, studs or joists that supports their weight.

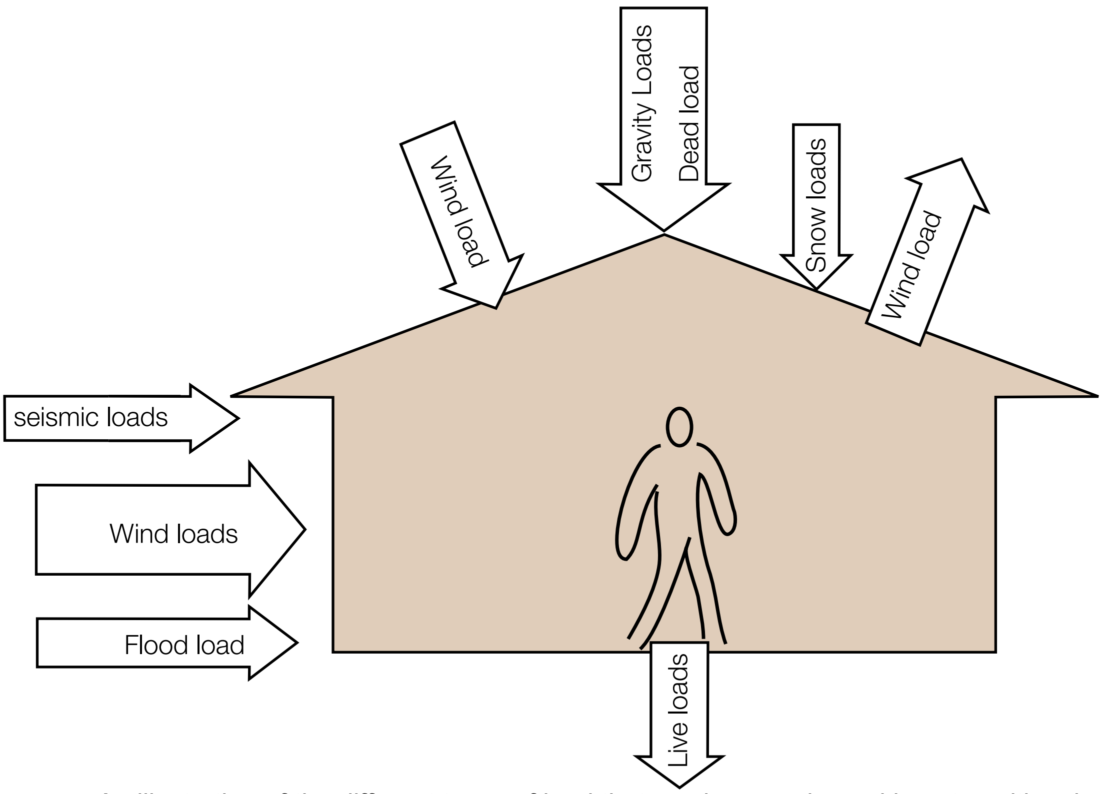
Hot dip galvanised	Steel that has been treated by dipping in a tank of molten zinc. This coats the sheet with a thin layer of zinc carbonate which protects the steel from corrosion.
Hurricane Straps	Steel strapping to tie timbers together, providing additional resistance under wind loads.
In-plane bracing	Bracing (see definition above) in the same geometric plane as the other structural elements.
Joists	A horizontal member that supports a floor, a roof or a ceiling.
Liquefaction	When soil starts to behave like a liquid in an earthquake. This is most common near river beds, in coastal areas with sandy soils and in locations with high water tables.
Knee Brace	A short diagonal brace between a column and a beam
Lateral loads	Horizontal loads upon a structure - such as those due to wind on a side wall.
Laths	Thin strips of wood that support tiles or other cladding. They are usually nailed in rows to framing.
Live load	The loads upon a structure due to occupants and their belongings.
Loads (structural)	Forces which are applied to a structure.
Member	A part of a structure such as a beam or a column.
Mezzanine	A partial floor between main floors of a building.
Mono pitch roof	A roof with one sloping surface.
Moment frame	A frame in which bending of the beams and columns (as opposed to bracing members) provides the resistance to lateral forces.
Pad footings	A foundation that spreads the load out from a column to the ground.
Pilaster	A thickening of a foundation wall to spread the load
Pinned connection	Joint between structural members that allows rotation.
Plumb bob	A weight that is suspended from a string. It is used to ensure that structures are vertical whilst they are being built.
Helical screw plate	Screw plates at the end of a tubular ground anchor. The pitch is the distance between blades of the screw thread measured along the length of the screw.
PGA	Peak ground acceleration. An engineering term that is used to indicate the maximum acceleration experienced by the ground shaking during an earthquake.
Pier	See “Column”
Porch	A covered entrance typically at the front of the building.
Portal frame	See “Moment frame”.
Portland cement	A very common form of cement. When mixed with sand, gravel and water it makes concrete.
Purlin	Roofing member to which the roof covering is attached. Purlins are supported by the rafters.
Rafters	Main structural roofing beam. On a sloped roof they run from the ridge to the eaves.
Return period	The period of time (in years) in which it is likely for a particular magnitude event to be exceeded, on a long term average.
Sacrificial cladding	Cladding that can be removed (or blown away) from a shelter without damaging the structure. Removing the cladding will reduce the wind loads on the structure and ensure its survival.
Screw foundation	See “Ground anchor”.
Secondary members	Members that do not contribute to the stability of the structure.
Seismic loads	Loads on a building caused by an earthquake.
Sheathing	A material used to cover walls, floors, and roofs. Typically plywood or metal sheets.
Slab	A rectangular concrete base to the building.

Spread Footing	See "Footing".
Standing water	Water that remains in place following a flood. This can damage structures in ways such as causing mud bricks to dissolve or timbers to swell.
(Timber) Studs	A wall framework containing upright posts to support cladding materials.
Suspended floor	Floor that does not touch the ground. It is supported by the frame.
Tie beam	A beam that connects two other structural elements preventing them from separating.
Toe nailing	Driving nails at a slant or skew to the surface of a member.
Truss	A rigid structure consisting of elements that lie in the same plane, commonly used in roofing. The truss is often in the form of a combination of triangles.
Uplift	Upward forces on a structure.
Wind loads	Loads due to wind.
Wall transoms	Horizontal members similar to studs that support cladding.
Zincalume	An alloy of zinc and aluminium used to galvanise iron sheet. Such sheets can last longer than those with pure zinc coatings.

I.6.2 Pictorial glossary



An example structure with terms used in this book marked



An illustration of the different types of load that can be experienced by a transitional shelter.

I.7 Building codes and post disaster structures

In order to determine the adequacy of any building, a set of standards must be adopted to compare the structural performance to. The analyses in this report are based on the provisions of the 2012 edition of the International Building Code (IBC). The IBC is a model code which forms the basis for the majority of legally adopted building codes within the United States of America. While the IBC is mostly focused on the USA, it was selected because the flexible framework provided by the code can be easily applied to any location. Many organizations have prepared guidance documents and/or reports providing the information necessary (wind speeds for example) to use the IBC in international settings.

For structural analysis and design, the IBC references many other standards for specific requirements. The table below provides the main supplementary standards used.

Organization	Standard
American Society of Civil Engineers (ASCE)	ASCE 7-10, Minimum Design Loads for Buildings and Other Structures
American Concrete Institute (ACI)	ACI 318-11, Building Code Requirements for Structural Concrete
American Concrete Institute (ACI)	ACI 530-11, Building Code Requirements for Masonry Structures
American Institute of Steel Construction (AISC)	AISC 360-10, Specification for Structural Steel Buildings
American Forest & Paper Association	NDS-2012, National Design Specification (NDS) for Wood Construction

In addition to the IBC, the following national codes and standards were additionally used:

- Bangladesh National Building Code (2008)
- Building Code of Pakistan (2007)
- National Building Code of the Philippines (2005)

The analysis in "IFRC, Transitional shelter: 8 designs, 2011" was based on the Uniform Building Code (UBC), which is another model building code from the USA that was used in western parts of the country. The UBC is an acceptable building code, but it has not been updated since 1997 and there are no plans for further updates. Instead, parts of the UBC were incorporated into the IBC, which is currently updated every three years. For this book, the newer codes were chosen as they are more accurate and flexible for structural analysis.

In addition to international standards, the shelters were evaluated against local building codes when they existed. The loading provisions of these codes were be compared against those of the IBC, and the most conservative was used for structural analysis. The capacities of the structural framing were analyzed using the requirements of the IBC only.

Design Loading

The design loadings contained within the IBC are intended for structures with a design life of approximately 50 years. Therefore they are not directly applicable to the design of post disaster structures, which typically have a design life that does not exceed 5 years. The following sections describe how the various building loads are modified to apply to the proper design lifespan.

Floor Live Load

Standard floor live load of 1.9 kPa from the IBC is intended for housing is based around a permanent dwelling for someone with the possessions and furnishing typical of the developed world. Since the post disaster structures in this book are all for low income contexts, 1.9 kPa is most likely excessive. For these reasons, a floor loading of 1.0 kPa was used for the analysis of any elevated floors. This is consistent with the floor loading for an attic from the IBC.

Roof Live Load:

The roof live loads included in the IBC are intended to account for maintenance activates. Maintenance workers will not be walking directly on roofing constructed of materials like tarps, plastic sheeting, or thatch. As such, shelters with these types of roofing will not have roof live load applied. Shelters with more substantial roofing systems such as plywood, corrugated metal, which are more likely to have people on the roof will have a live load of 1.0 kPa applied in accordance with the IBC.

Environmental Loading:

The IBC is intended for buildings with an approximately 50 year design life, and the environmental loads (snow, wind, seismic, etc) in the code are based on time span. For a shelter with only a 5 year design life, the statistical likelihood that the shelter will experience the full design load for a permanent structure is low, and therefore the design loads can be reduced. The IBC itself does not provide provisions for reducing design loads based on expected service life. The American Society of Civil Engineers (ASCE) has published a guide, Design Loads on Structures During Construction (ASCE 37-02), which provides reduction factors for loads from the building code based on the expected construction timeframe. While intended for structures during construction, these reduction factors are still applicable to temporary buildings like post-disaster structures.

The IBC only contains design parameters for the USA and its territories, therefore other sources will be required to design for environmental loads. Design parameters such as ground snow load, design wind speed, and seismic ground accelerations were obtained from the following documents:

- International Building Code
- Unified Facilities Criteria 03-301-01 Structural Engineering, which contains design parameters for use with the IBC for various international locations.
- Local Buildings Codes, if they exist
- Other internationally recognised design standards, building codes, or design manuals
- A continuous 30 years of historic climate date.

Snow Load

For structures with a design life of 5 years or less, ASCE 37-02 recommends that ground snow loads be reduced by 20 percent. Otherwise the full ground snow should be used. Wind Load:

ASCE 37-02 recommends reducing wind speeds in accordance with the values in the table below.

Design Life	Percent Reduction in Wind Speed
< 6 Weeks	25%
6 weeks to 1 year	20%
1 to 2 years	15%
2 to 5 years	10%
> 5 years	0%

Seismic Load

The classification of earthquake risk used in this book is based on the seismic design categories defined in ASCE/SEI 7-10. Design for earthquake loads is derived from the Peak Ground Acceleration (PGA - See Annex 1.4.1 Full Glossary) for a return period which is in keeping with the design life of the structure. The PGA is then modified to reflect the soil and building type.

For structures with a reduced design life, ASCE 37-02 does not give direct recommendations on how to reduce seismic loads. Fortunately, there is a large amount of historical global seismic data and statistical analysis of that data can be used to determine reduction factors. The design provisions of the IBC are based on a seismic event with at 2 percent probability of exceedence in any 50 year period, in keeping with a 50 year design life. Using similar logic, post-disaster structures will be designed for a seismic event with a 2 percent probability of exceedence over the design life of the structure. This analysis will be performed for each site based on available data.

Wind

The classification of wind risk used in this book is based on the International Building Code (IBC). This is expressed as wind speeds which is a parameter that can be used directly in design.

Flood

The classification of flood risk is based on knowledge of historical flood data and local weather effects, and is highly dependent on the local site conditions. Flood damage can be caused by both flash floods and standing water. Each type of flooding has a different impact on structures.

Performance Levels

Given the temporary nature of most post disaster structures, the analysis techniques used for permanent structures are not completely applicable. Building codes specify significant factors of safety to account for the larger likelihood of overload and deterioration of the building structure over its lifespan. Smaller factors of safety can be acceptable for the shorter lifespan of many post disaster structures. In addition, the typically lighter construction used for these types of shelters poses a smaller risk of injury in the event of failure. The table in section A.4.4 describes the different performance levels used to indicate how the shelters will perform under various loading conditions. For these analyses, failure is considered as either having individual members break into more than one piece, connections between members coming undone, or complete collapse of the structure.

Soil type

For all calculations, a stiff soil type (Soil Class 5 as defined in Table 1806.2 of the IBC or Soil Profile Type/Site Class D as defined in ASCE/SEI 7-10 – Minimum Design Loads for Buildings and Other Structures', Table 20.3-1) has been assumed. However, in earthquake prone locations where liquefaction of the soil can occur, specific measures may be required.

I.8 Further reading

ASCE/SEI 7-10

(See also International building Code 2009)
Minimum Design Loads for Buildings and Other Structures,
Table 20.3-1 - soil profiles
Table 11.6-1 - assuming Risk Category I (Table 1.5-1 representing a low risk to human life in the event of failure) and based on the modified PGA.

CRS, Managing Post-disaster (Re)-Construction Projects, 2013

Step-by-step guide on management of owner-driven and contractor-built construction.
www.crsprogramquality.org

Humanitarian Bamboo Project

Website containing guidance and information on the sourcing and use of bamboo for use in humanitarian responses.
http://www.humanitarianbamboo.org

IASC, Shelter Centre, Selecting NFIs for Shelter

2008.

Provides information, case studies and guidance on how to choose the best items to distribute to those affected by natural disaster or conflict
www.shelterlibrary.org

International Building Code (IBC) 2012

ICC (International Codes Council), 2012
The IBC superseded the UBC in 2000 and is updated every three years. It is primarily used in the United States although it is also a relevant guide in other geographies. It provides requirements for structural safety, fire-safety, and life-safety provisions that cover a range of aspects including roofs, seismic engineering, innovative construction technology, and occupancy classifications. It contains a large number of references to published standards that need to be consulted for its application. These include:
-2010 ASCE/SEI 7-10 – Minimum Design Loads for Buildings and Other Structures, American Society of Civil Engineers
-2005 National Design Specification for Wood Construction, American Wood Council

International Standards for Materials, Products, Systems and Services

International standards are maintained by standards organisations and are commonly used in the specification on materials. Often they will specify testing regimes that the materials need to pass in order to meet the standard. The standards and standards organisations referred to in this book and in IFRC, Transitional shelter: 8 designs, 2011 are:

- *ASTM A653: Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process. ASTM standards are maintained by ASTM International ASTM International, formerly known as the American Society for Testing and Materials (http://www.astm.org/).*
- *JIS G3302: JIS G3302 relates to the quality of zinc coated steel sheet. Japanese Industrial Standards are maintained by the Japanese Industrial Association. (http://www.jsa.or.jp)*
- *ISO standards: Maintained by the International Organisation for Standardisation (http://www.iso.org)*
- *BS standards: Maintained by the British Standards Organisation (http://www.bsigroup.com/)*

IFRC/ICRC Emergency Items Catalogue

Detailed specifications of all items commonly used by IFRC and ICRC
http://procurement.ifrc.org/catalogue/

IFRC, Guidelines for Assessment in Emergencies

2008.

Practical information and guidance on how to conduct assessments in emergencies
From: http://www.ifrc.org

ICRC/IFRC Guidelines for Cash Transfer Programming

2007

Provides information on when and how to distribute cash in disaster response

From http://www.ifrc.org

IFRC Logistics Standards Online

IFRC logistics procedures, forms and manuals

https://fednet.ifrc.org/logisticsstandards/home.asp

IFRC Owner Driven Housing Reconstruction Guidelines (ODHR)

2010

Guidance on the planning and implementation of assisted self help reconstruction projects.

IFRC, Oxfam GB, Plastic Sheeting,

A guide to the use and specification of plastic sheeting in humanitarian relief, 2007 An illustrated booklet on when and how to use plastic sheeting most effectively in emergencies

www.plastic-sheeting.org

IFRC, Shelter safety handbook, 2011

Some information on how to build simple structures safer.

IFRC, The IFRC Shelter Kit, 2010

A guide on the IFRC shelter kit and how to use it.

IFRC, Transitional shelter: 8 designs, 2011

The first edition of shelter designs, a companion edition to this document. the focus is on transitional shelters, and the document contains 8 transitional shelter designs with similar analyses. the designs in this book and in the shelter. See http://www.sheltercasestudies.org/designs/

National Building Codes & Standards

Building codes establish a set of rules that specify the minimum acceptable level of safety for constructed objects such as buildings and other structures (bridges, roads etc). The development and enforcement of building codes varies between countries. A number of national country codes and standards have been referred to for the review of these shelters, these include:

- *NDS: National Design Specification for Wood Construction. This includes the timber grading system that is referred to in this book. http://www.awc.org/standards/nds.html*
- *Pakistan: Building Code of Pakistan – Seismic Provisions 2007 (BCP SP-2007), Government of Islamic Republic of Pakistan Ministry of Housing and Works, Islamabad, 2007)*

Sheltercentre, UN, DfID, Shelter after Disaster

Strategies for transitional settlement and reconstruction, 2010

A book containing information and guidance on how to agree strategies for reconstruction after natural disasters. Contains description of the types of shelter programmes that organisations can implement.

www.shelterlibrary.org

Sheltercentre, Transitional shelter guidelines, 2011

This publication intends to: explain the 10 principles of transitional shelter, indicate when a transitional shelter approach may be inappropriate and provide guidance on how to design and implement a transitional shelter programme.

Sphere Project, Sphere

Humanitarian charter and minimum standards in humanitarian response, 2011

Contains consensus standards agreed among major humanitarian organisations for key sectors including shelter and settlement. It also contains as actions, indicators and guidance notes as to whether standards have been achieved.

www.sphereproject.org

UNHABITAT, IFRC, UNHCR, ShelterCaseStudies.org

Shelter Projects 2011-2012, Shelter Projects 2010, Shelter Projects 2009, Shelter Projects 2008

Over 100 case studies of shelter projects in humanitarian responses. Includes many different approaches to shelter provision.
http://www.ShelterCaseStudies.org

UNHABITAT, Land and Natural Disasters

Guidance for Practitioners, 2010

A book containing guidance on land issues following natural disasters.

http://www.disasterassessment.org/documents/Land_and_Natural_Disasters_Guidance4Practitioners.pdf

UNOCHA, Tents

A Guide to the Use and Logistics of Tents in Humanitarian Relief, 2004

A booklet describing when and how to use tents as well how to support those living in them to best adapt them to meet their needs
www.shelterlibrary.org

UNOCHA / IFRC / CARE International, Timber

Timber as a Construction Material in Humanitarian Operations, 2009,

An illustrated booklet on how to source and use timber for the construction of basic structures.
www.humanitariantimber.org

Note: All staff and volunteers within the Red Cross and Red Crescent Movement can access additional documents from the IFRC shelter department website on fednet:

https://fednet.ifrc.org/en/resources-and-services/disasters/shelter/

The Fundamental Principles of the International Red Cross and Red Crescent Movement

Humanity The International Red Cross and Red Crescent Movement, born of a desire to bring assistance without discrimination to the wounded on the battlefield, endeavours, in its international and national capacity, to prevent and alleviate human suffering wherever it may be found. Its purpose is to protect life and health and to ensure respect for the human being. It promotes mutual understanding, friendship, cooperation and lasting peace amongst all peoples.

Impartiality It makes no discrimination as to nationality, race, religious beliefs, class or political opinions. It endeavours to relieve the suffering of individuals, being guided solely by their needs, and to give priority to the most urgent cases of distress.

Neutrality In order to enjoy the confidence of all, the Movement may not take sides in hostilities or engage at any time in controversies of a political, racial, religious or ideological nature.

Independence The Movement is independent. The National Societies, while auxiliaries in the humanitarian services of their governments and subject to the laws of their respective countries, must always maintain their autonomy so that they may be able at all times to act in accordance with the principles of the Movement.

Voluntary service It is a voluntary relief movement not prompted in any manner by desire for gain.

Unity There can be only one Red Cross or Red Crescent Society in any one country. It must be open to all. It must carry on its humanitarian work throughout its territory.

Universality The International Red Cross and Red Crescent Movement, in which all societies have equal status and share equal responsibilities and duties in helping each other, is worldwide.

For more information on this IFRC publication, please contact:

International Federation of Red Cross and Red Crescent Societies

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This book contains reviews by structural engineers of transitional shelter designs that have been built in significant numbers. Although the designs should not be used without being adapted to the context, it is intended that the information in this book will support the early stages of shelter programmes and inform transitional shelter decision making.

This book is targeted at people within the Red Cross and Red Crescent movement working in the emergency and early recovery phases after a natural disaster. The primary audience is shelter delegates. It is also intended to inform those planning and managing shelter programmes.

It is assumed that readers have a strong understanding of the need for participation and in ensuring the close involvement of disaster affected people.

This book is a second volume of shelter designs, following on from Transitional Shelter: 8 designs (2012).

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Saving lives, changing minds.

International Federation
of Red Cross and Red Crescent Societies