Note on the assessment:

The following is an excerpt from the book Post-disaster shelter: 10 Designs, IFRC, 2013. Inclusion of this design is for information purposes and does not necessarily imply best practice. Designs are site specific.

Assessments were conducted against hazard data for each location by structural engineers using the International Building Code (IBC) 2012, and National Building Codes as applicable.

Risk to life or risk of structure being damaged

The performance of the shelter was assessed on whether or not the shelter was safe for habitation. As a structures 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.

Classification of hazards

For the purposes of this assessment, 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 in various codes and standards as applicable to lightweight, low rise buildings, and statistical assumptions about the likelihood of hazard occurring.

A fuller description is of the methods used is available in Section A of Post-disaster Shelters: 10 Designs, IFRC, 2012.

Classification of performance

The performance of each shelter has been categorised using a **RED**, **AMBER** or **GREEN** scheme.

Performance analysis summaries

The shelter review is summarised in a table titled ‘performance analysis’. This table provides an overall summary of the robustness of the shelter. The table assesses the performance of the shelter with respect to the hazards at the given location.

See A.4.4 Classification of Performance in the book

See A.4.3 Classification of Hazards in the book

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.

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

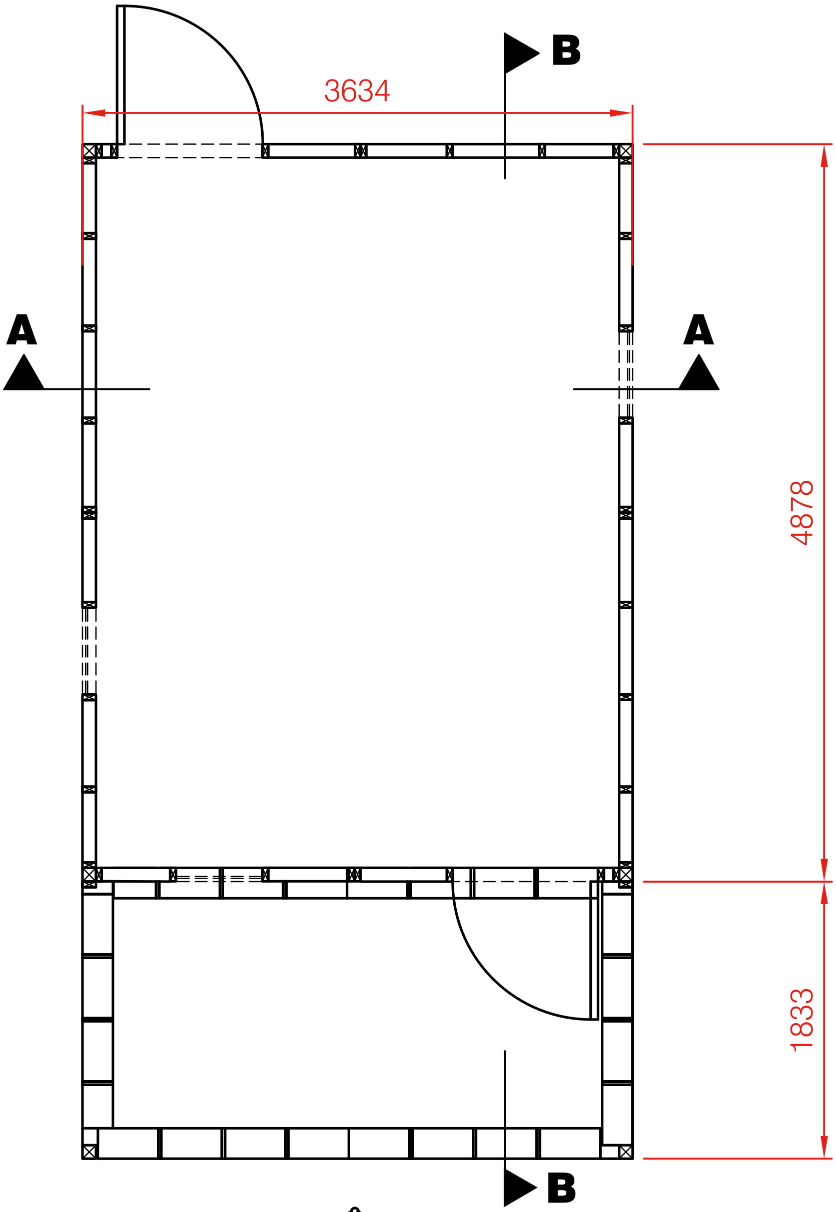
This shelter is a rectangular timber framed structure with a gable roof and a covered floor area of approximately 3.6m x 4.9m with a covered porch measuring approximately 3.6m x 1.8m in front. The floor is constructed with wood joists, and the walls are constructed with wood studs. Both are supported 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

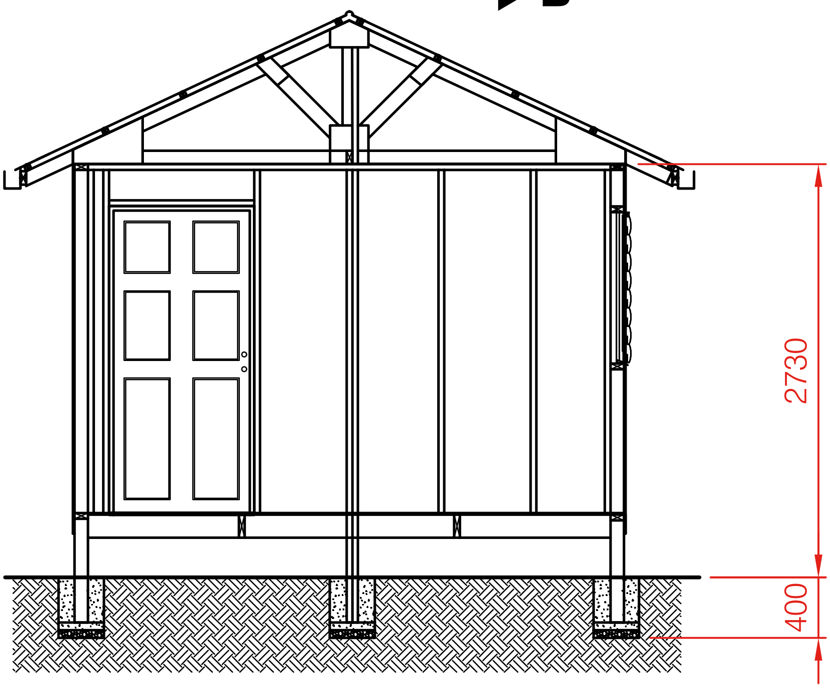
The construction techniques used for this shelter will produce a very durable structure with a design lifespan of five to ten years, and can provide the basis for more permanent housing. The modular construction facilities prefabrication of many building components for shipment to the site, which can 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.

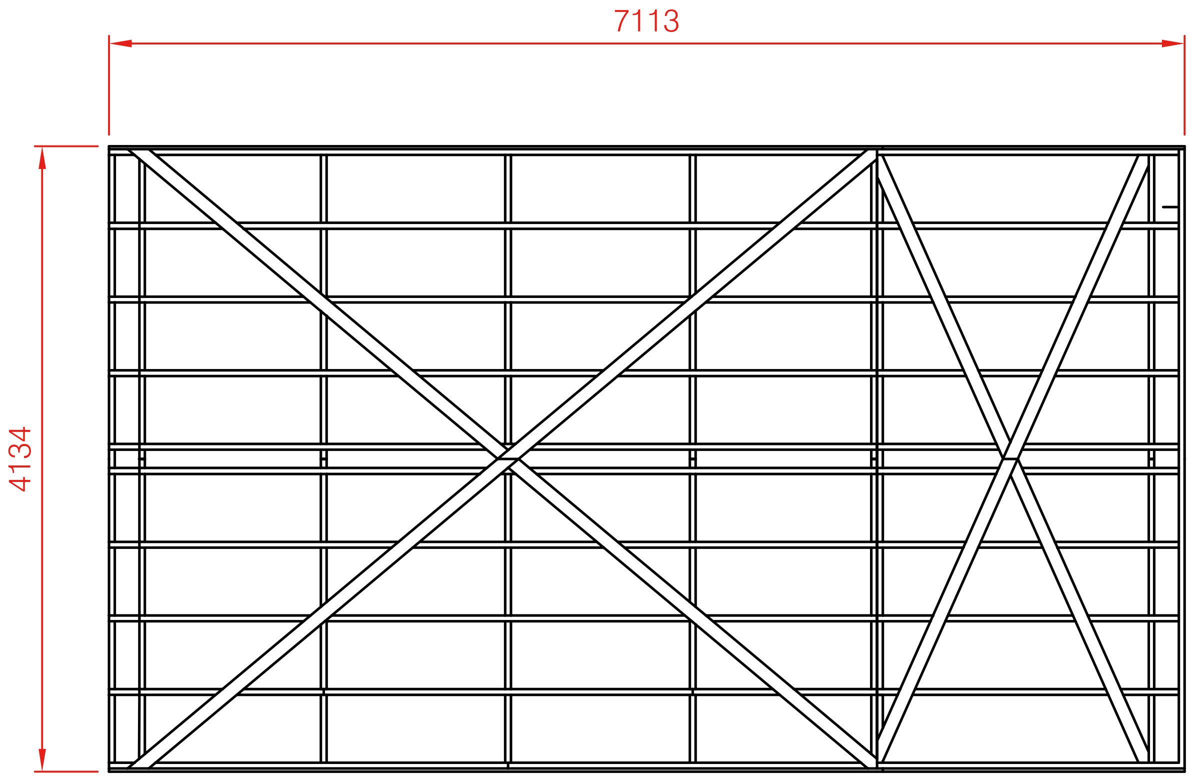
Plans



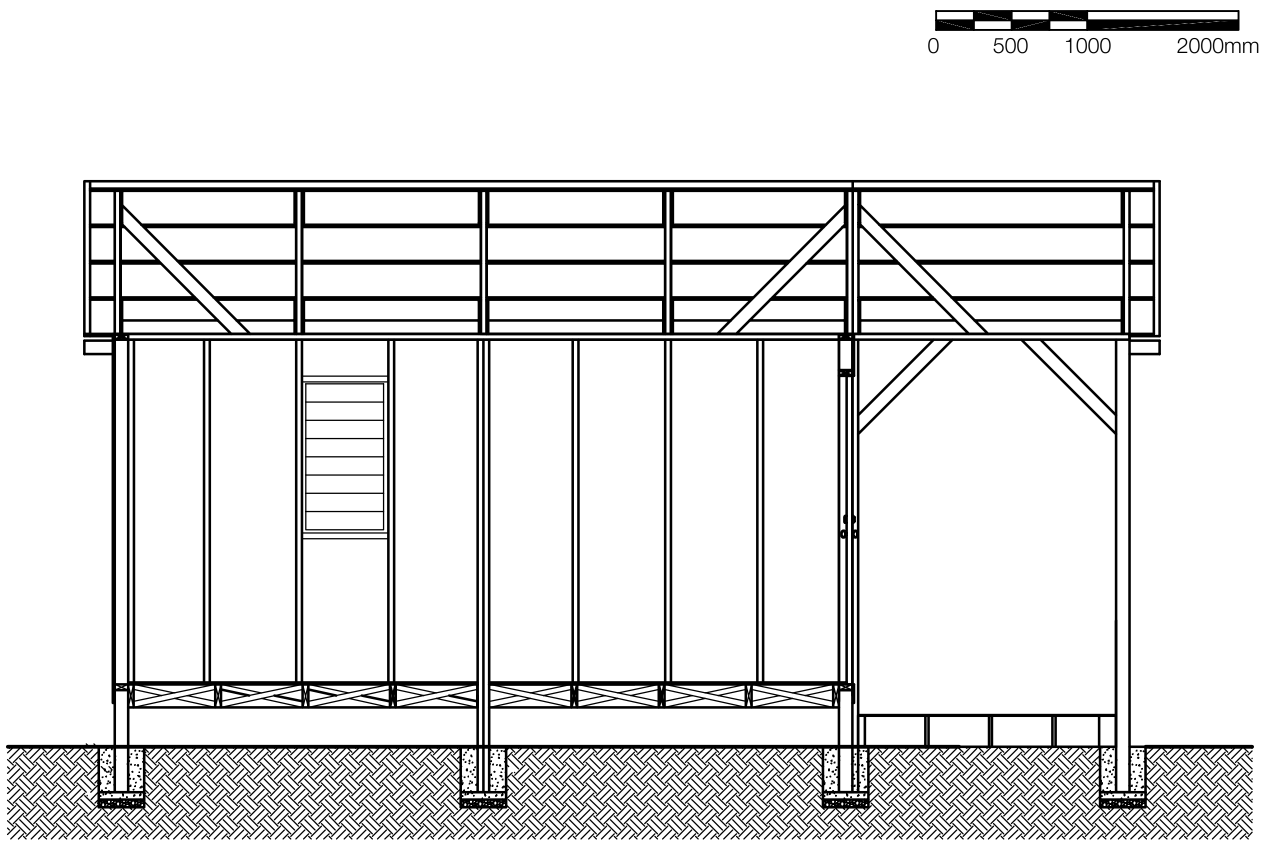
Floor plan



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	