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.

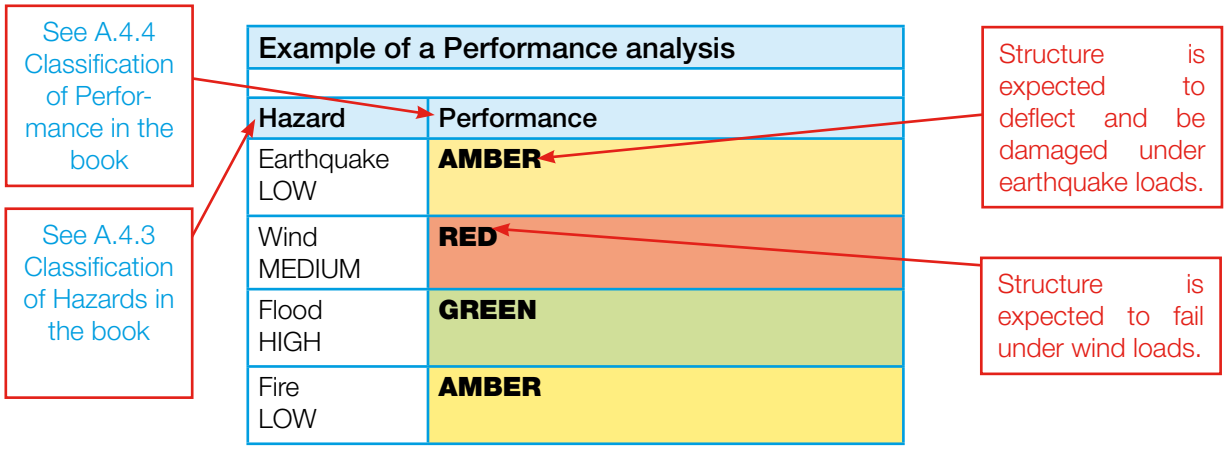
A fuller description is of the methods used is available in Section A of Post-disaster Shelters: 10 Designs, IFRC, 2012.

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.



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

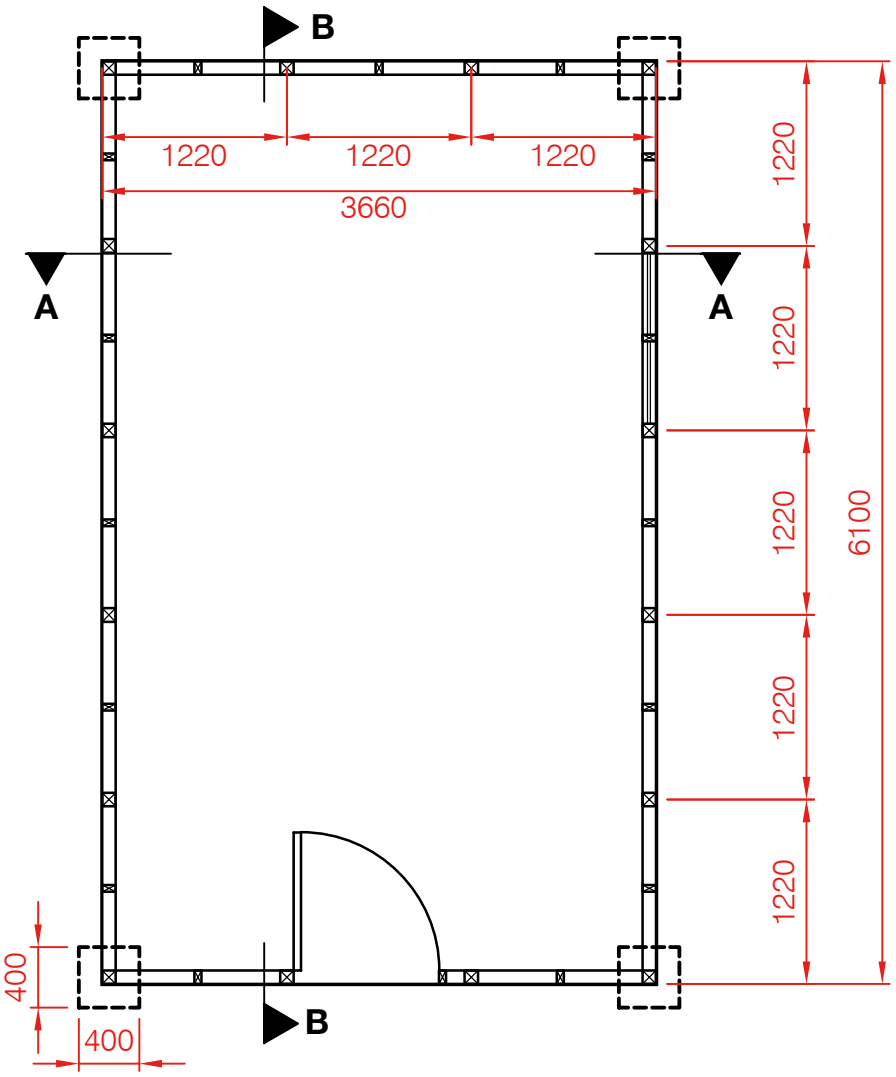
Approximate project cost per shelter: 2,300 CHF

Shelter Description

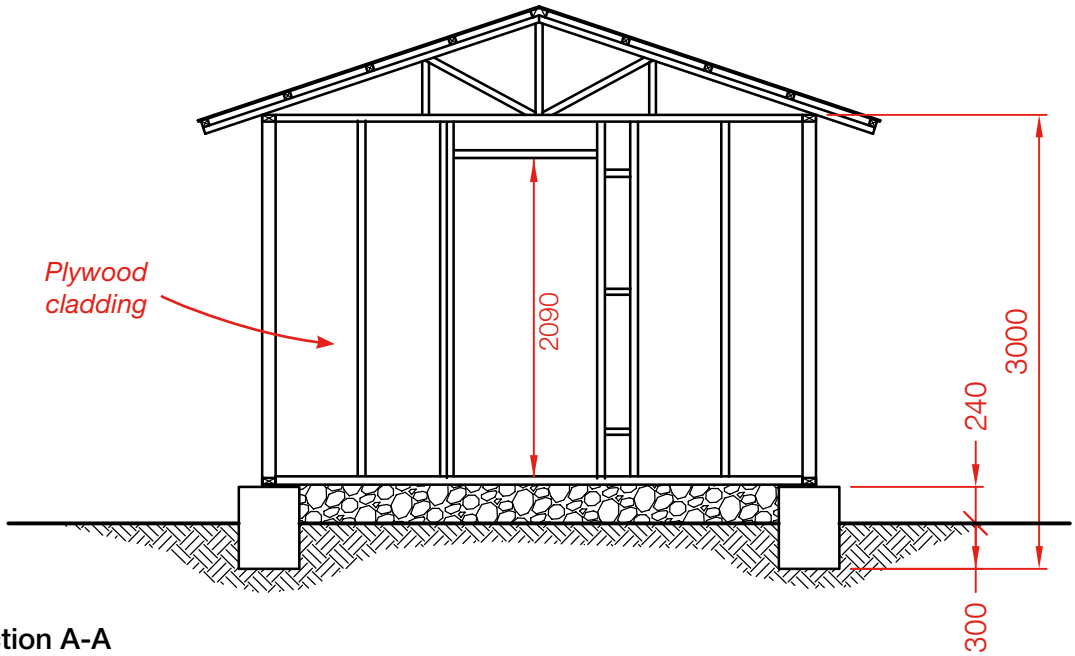
This shelter is a rectangular timber framed structure with a gable roof and a covered floor area of approximately 21 square meters. Wall consists of wood studs with plywood sheathing, and the roof consists of metal roofing on wood purlins and trusses. The trusses are supported on wood posts within in 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

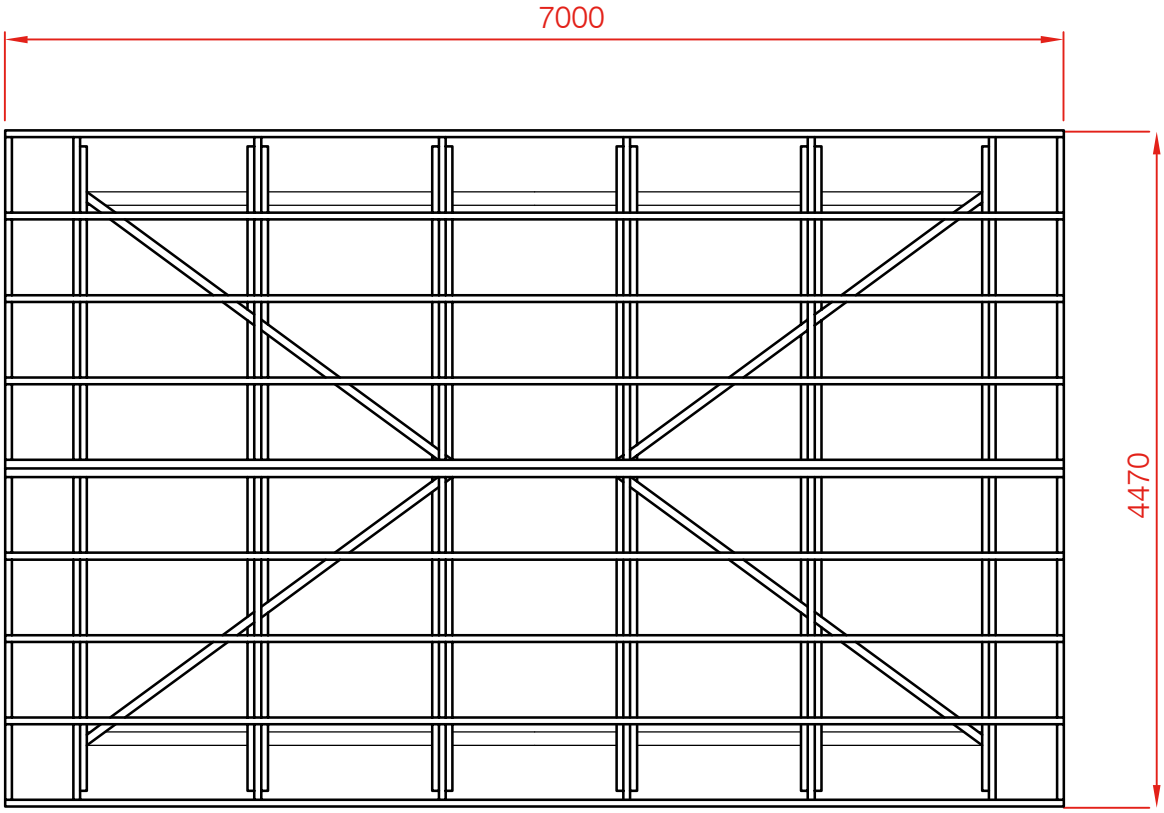
The construction techniques used for this shelter can produce a very durable structure with a design lifespan much larger than the typical transitional shelter, and can provide the basis for more permanent housing. The timber and plywood framing provides a light weight structural system, and with some 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.



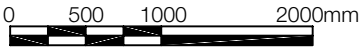
Floor plan

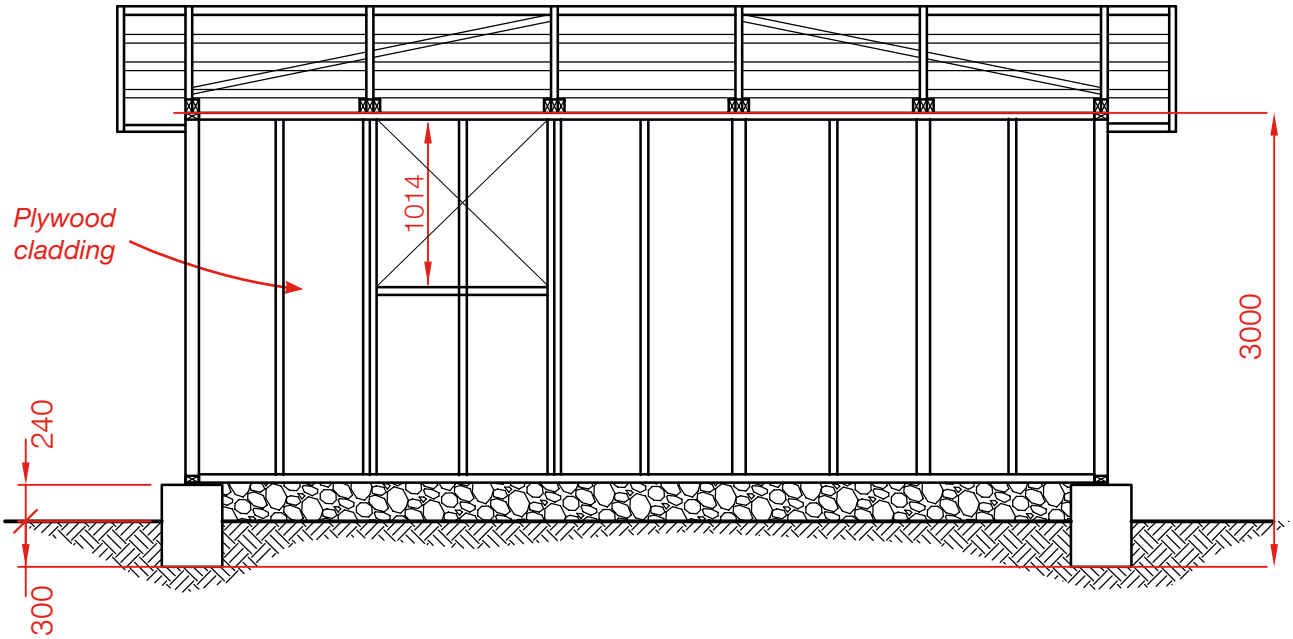


Section A-A



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.

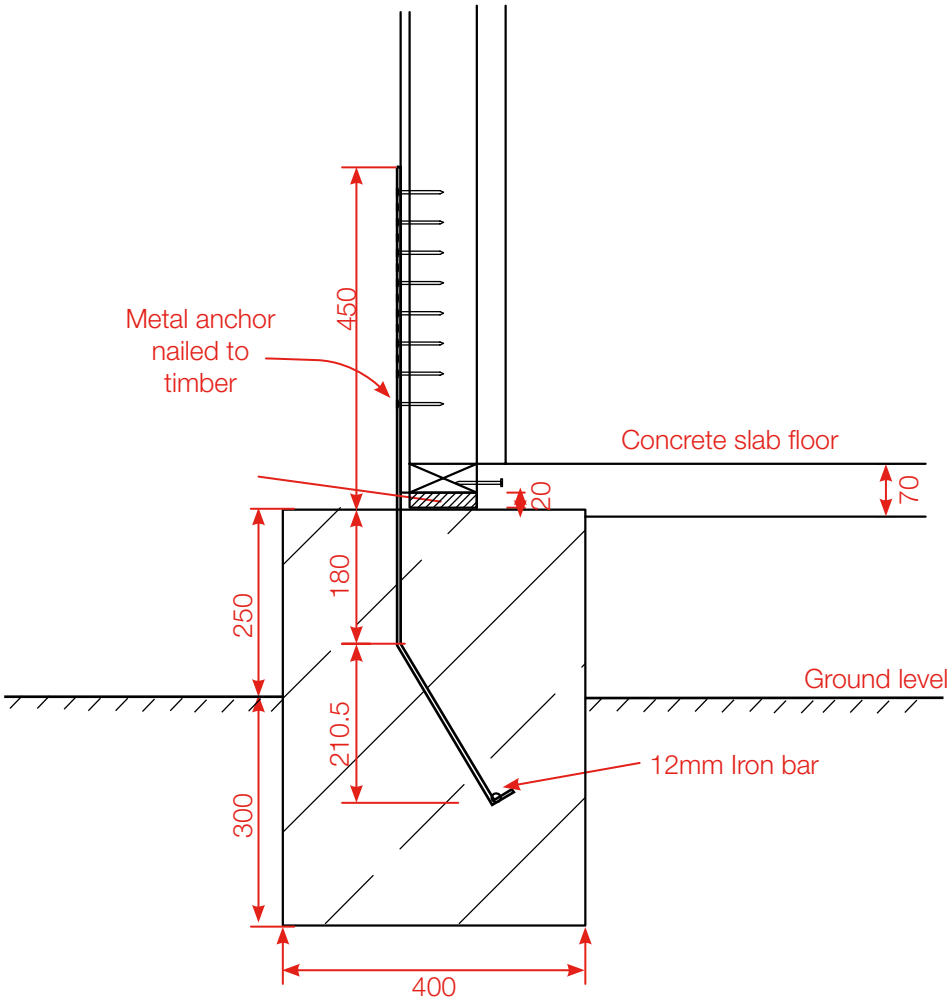
Bill of quantities

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