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.

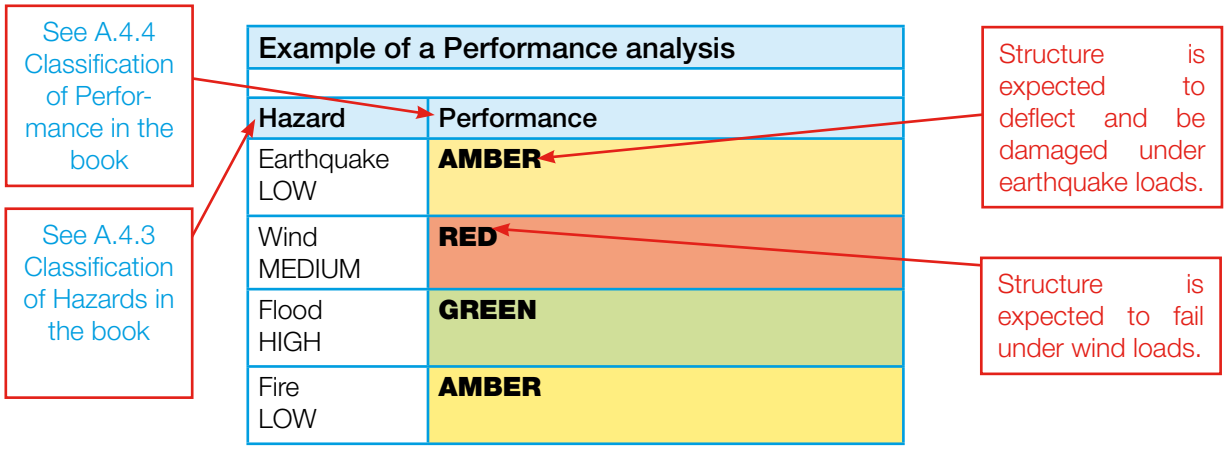
A fuller description is of the methods used is available in Section A of Post-disaster Shelters: 10 Designs, IFRC, 2012.

Classification of performance

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

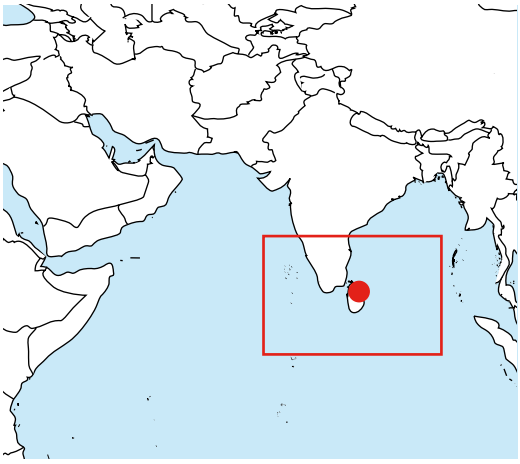
Performance analysis summaries

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.10 Sri Lanka – 2007 – 'Core Shelter'

Photo: Jake Zarins



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

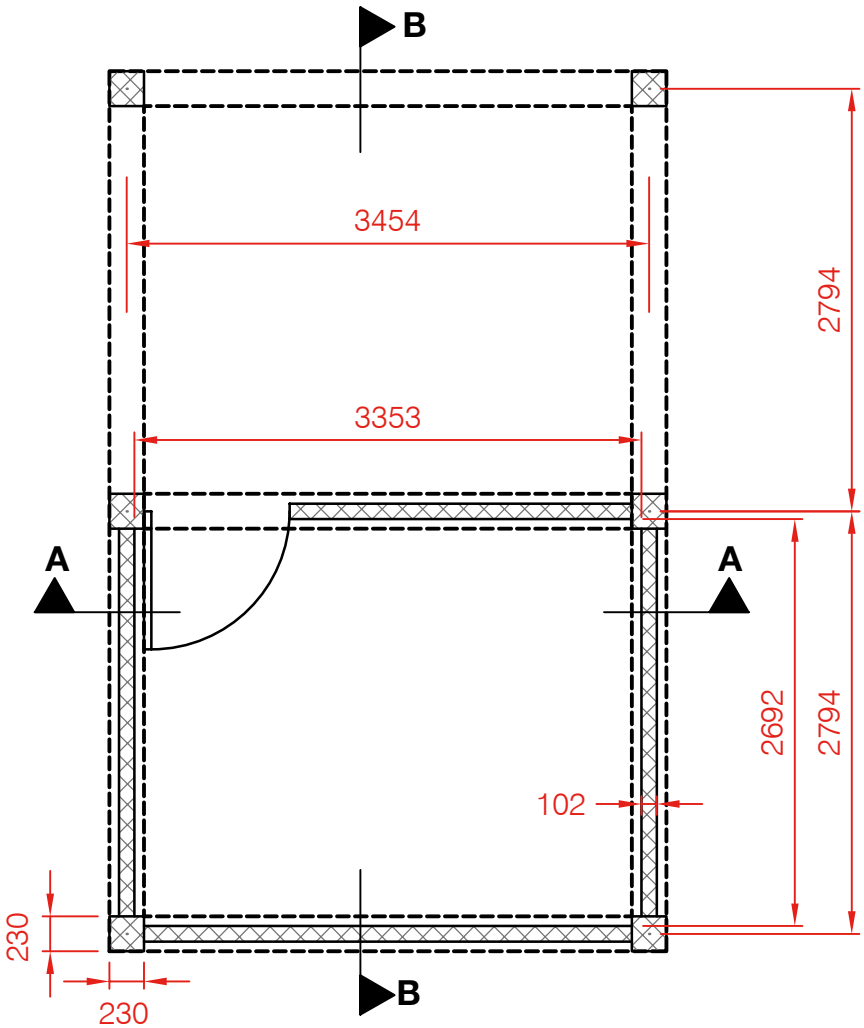
Shelter Description

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.

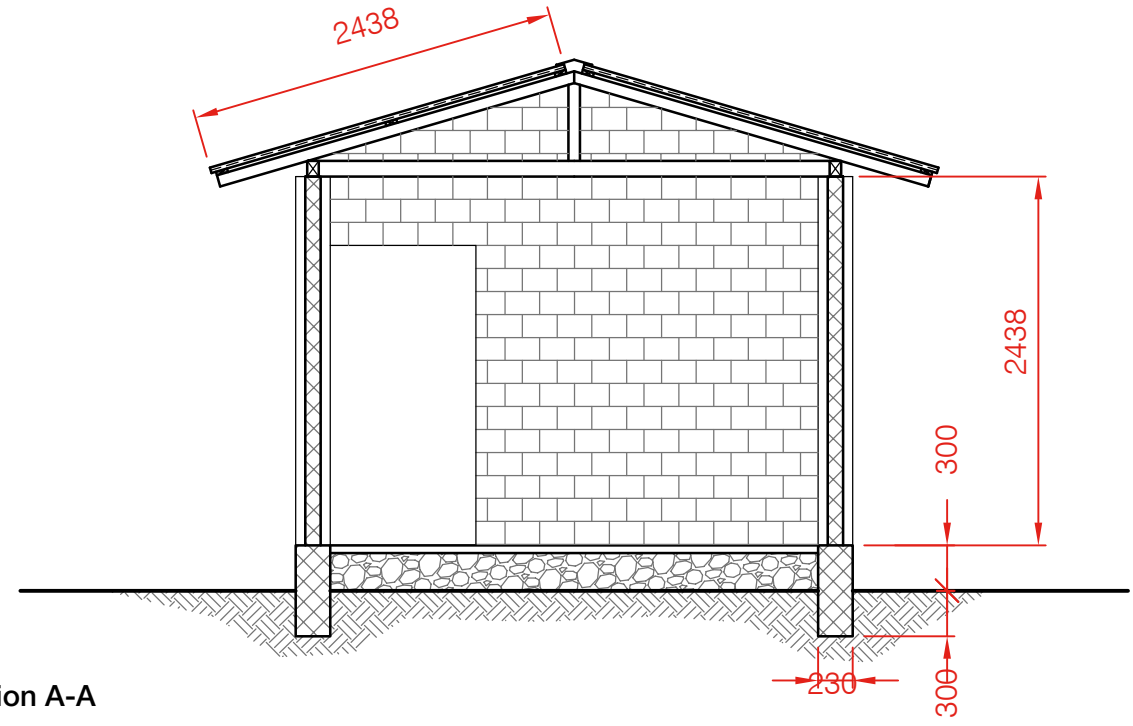
Shelter Performance Summary

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.

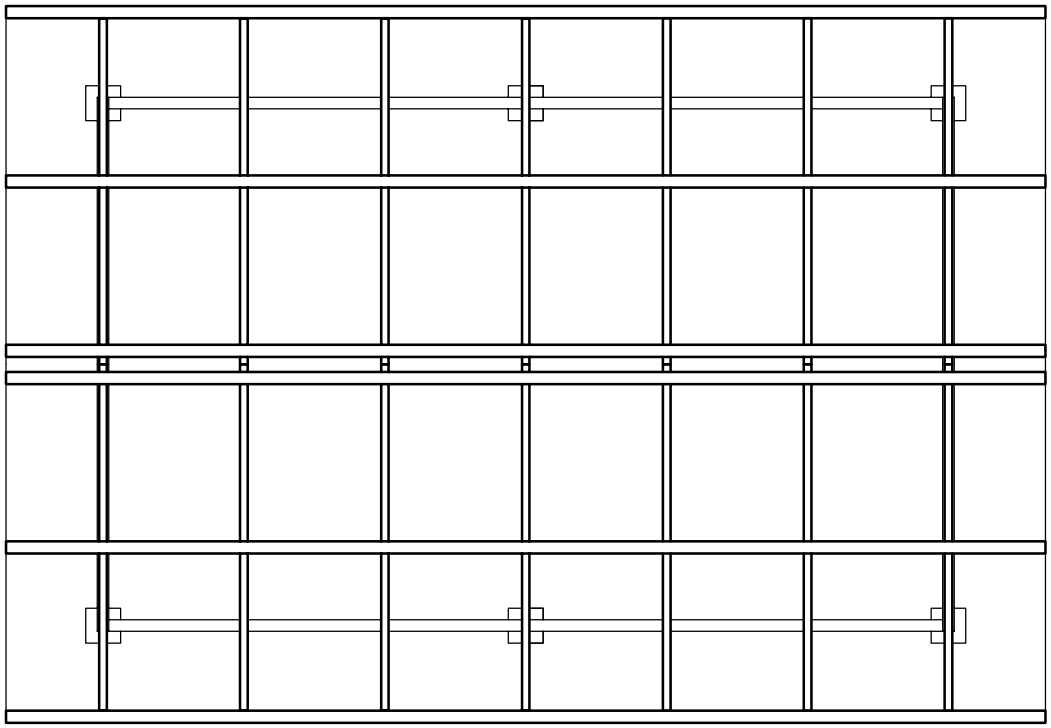
Plans



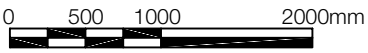
Floor plan

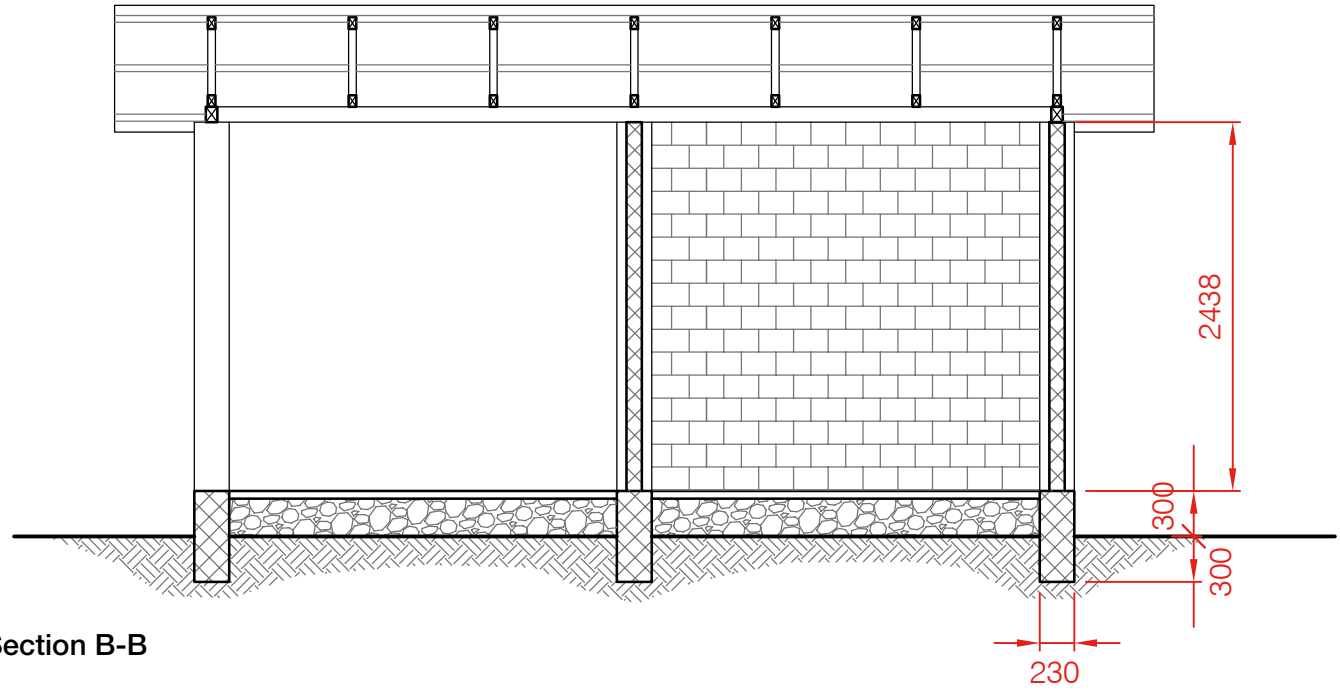


Section A-A



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				