Note on the assessment:

The following is an excerpt from the Book Transitional Shelters: 8 Designs, IFRC, 2012, available from www.sheltercasestudies.org. 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 Uniform Building Code (UBC) 1997, National Building Codes and international seismic codes. Below is a summary of the approach used.

Risk to life or risk of structure being damaged

The performance of the shelter was assessed based on whether or not the shelter is safe for habitation. As a structure may deform significantly under extreme hazard loading without posing a high risk to life, the shelter was also assessed on the risk of it failing or being damaged.

For lightweight shelters, the risk that falling parts of the building would severely injure people is reduced.

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 Transitional Shelters: 8 Designs, IFRC, 2012.

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, and not the risk of people being injured.

Classification used in Section B for the performance of structures	
Classification	Meaning of classification
GREEN:	Structure performs adequately under hazard loads
AMBER:	Structure is expected to deflect and be damaged under hazard loads
RED:	Structure is expected to fail under hazard loads

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 of the shelter with respect to the hazards at the given location.

Performance analysis (example)	
Hazard	**Performance**
Earthquake LOW	AMBER:
Wind MEDIUM	RED:
Flood HIGH	GREEN:

See Classification of Performance

See Classification of Hazards

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

Structure is expected to fail under wind loads.

B.2 Indonesia, Sumatra, Padang (2009) - Timber frame

Summary information

Disaster: Earthquake, 2009

Materials: Timber frame, palm fibre roof, concrete bucket foundations and palm matting wall panels

Materials source: Local

Time to build: 2 days

Anticipated lifespan: 6-12 months (residents expected it to last more than 24 months)

Construction team: 5 people

Number built: 7000

Materials cost per shelter: Approximately 350 CHF (2009)

Project cost per shelter: Approximately 500 CHF (2009)

Shelter description

The shelter is a timber framed structure with palm roofing and walls. It measures 4.5m x 4m on plan and is 3.35m tall to the ridge beam and 2.4m to the eaves. It has a pitched roof of 23.6 degrees.

There is no bracing, but some stability is provided by three portal frames tied together by horizontal members at ground, eaves and ridge level. Each portal frame is made up of two or three columns and a roof truss with rafters and corner bracing members. The corner bracing in the frames provides lateral stiffness. Secondary non-structural members include: floor joists, roof joists spanning between rafters and transoms to support palm matting wall panels. The shelter has a suspended floor. This is assumed to be coconut wood boarding spanning between the floor joists. The columns are embedded into concrete bucket foundations that sit directly on the ground.

Shelter performance summary

The shelter is constructed from locally sourced materials that are familiar to the occupants and do not require specialist tools or equipment for assembly. It can therefore be quickly constructed after a disaster and is relatively simple to maintain and adapt over time, depending on the needs of the occupants. This shelter offers a good short term design solution that is appropriate in areas vulnerable to high seismic and wind loading. The minor addition of bracing would improve its performance significantly and reduce deflections. However, if the shelter is upgraded, for instance by replacing the matting with roof sheeting or ply, then the roof trusses, frame and foundations will need to be strengthened, and the timber should have been treated.

Plans and comments

CHECK: The design and detailing of all connections is critical to the stability of the structure. It should be checked for local load cases.

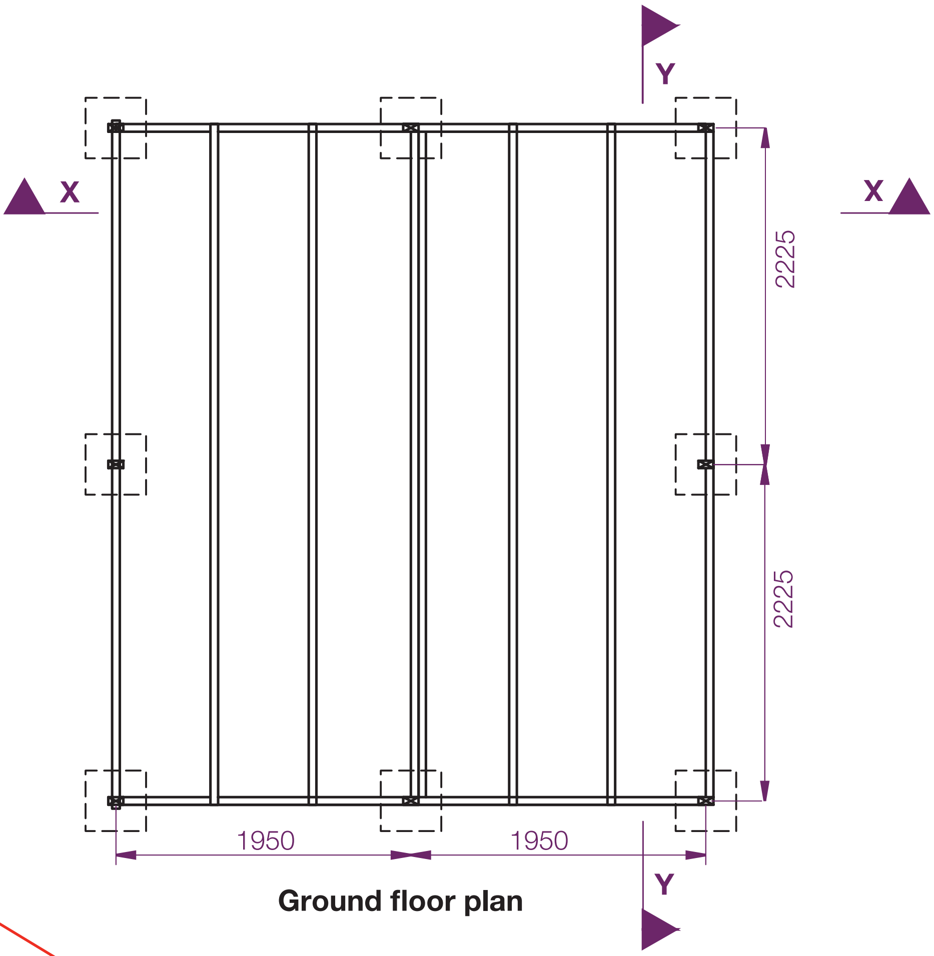
CHECK: The palm matting and thatch has been assumed to be sacrificial or permeable under wind loading. Where walls and roof are upgraded care should be taken to modify the structure to resist the additional wind or seismic loads.

CHECK: If roof or walls are upgraded the roof needs to be strengthened by adding an extra truss and increasing the size of purlins, rafters and the eaves beams.

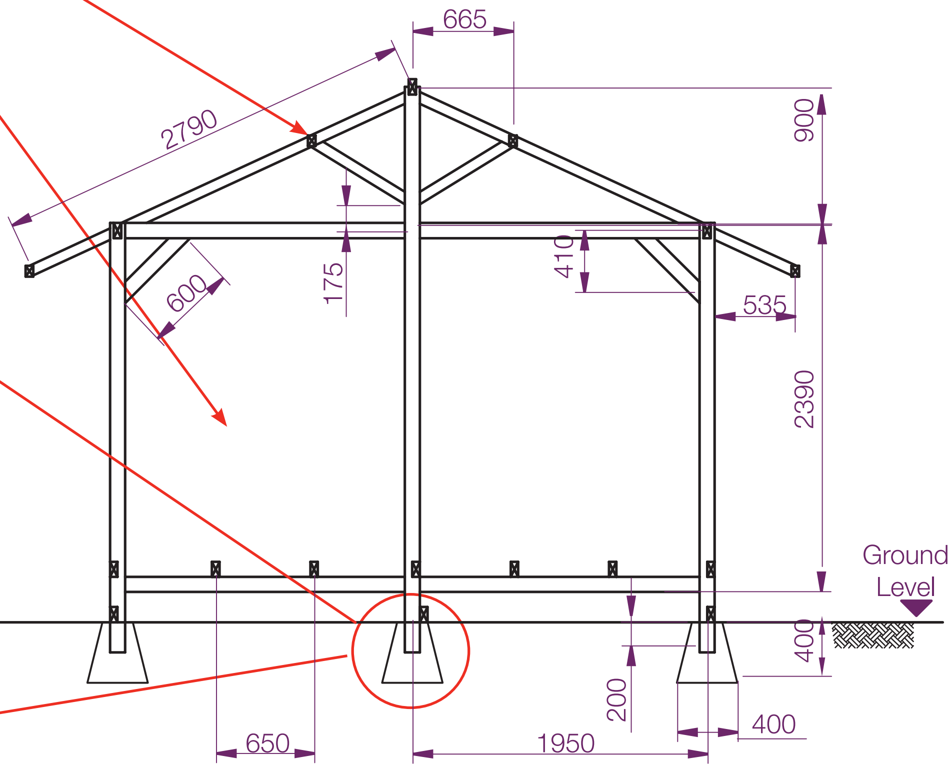
CHANGE: Add diagonal in-plane bracing to walls to improve lateral stability.

CHANGE: Columns should be properly tied to the foundations to prevent uplift of the structure. If the shelter is upgraded, use embedded base plate foundations or screw in ground anchors (Section C.1) to resist seismic loads and wind loads.

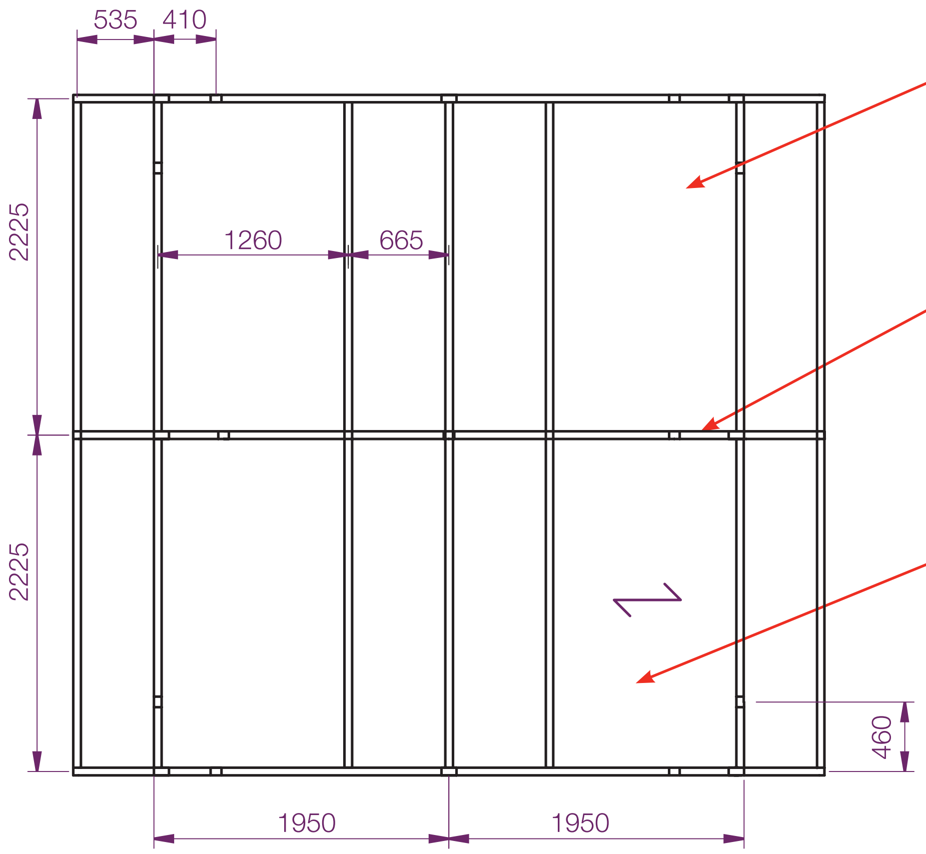
CHECK: In areas known to have high local wind pressures care must be taken to provide adequate foundations and member sizes to account for this.



Ground floor plan



Section X-X



Roof Level Plan

CHANGE: Add bracing in the plane of the roof. Alternatively, use properly nailed roof sheets (see Section C.3) so that the roof acts as a diaphragm.

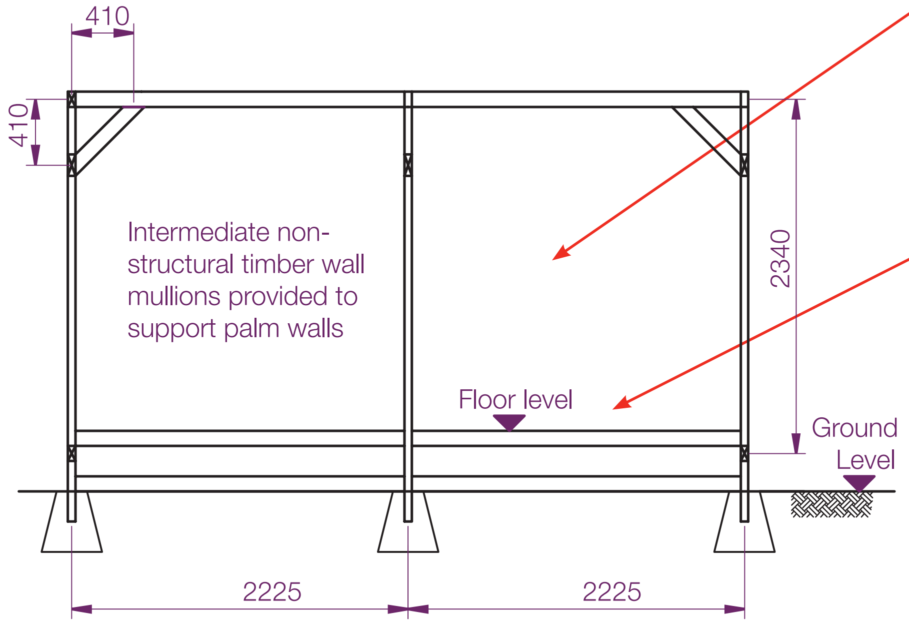
CHECK: If the weight of the roofing material is increased, the roof member sizes must be re-considered.

CHECK: The roof can be upgraded using corrugated iron sheeting: with a maximum span of 1.5m (Sheet 1, Annex I.1). If the roof is upgraded, then cross bracing will be required in the roof.

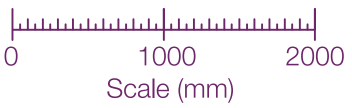
CHECK: Walls can be upgraded using ½" thick structural grade plywood (plywood 1 annex I.1.3). We have assumed that vertical framing is spaced at 600mm, and that the plywood is nailed with maximum 150mm spacing. If the wall is upgraded, then vertical framing members must be spaced closer together (24 members total rather than 16).

CHECK: Do not upgrade walls using masonry or cement blocks since heavy materials will perform poorly in an earthquake.

CHECK: Check that the soil type for the shelter location is stiff, otherwise design foundations accordingly.



Section Y-Y



Durability and lifespan

The timber is untreated but is raised from the ground and so will resist termite attack.

The palm roof and walls will require replacement if damaged by the wind or if the expected life of the structure is exceeded. The shelter is intended to be demountable but the short lifespan of the untreated materials (with possible exception of the doors) mean that it is unlikely that they will be reused.

Performance analysis*

Performance under gravity loads is satisfactory. However the walls require bracing to provide lateral stability and columns must be tied to foundations.

Hazard	Performance
Earthquake HIGH	AMBER: Damage is expected as the structure has little resistance to lateral loads. However, it is very lightweight, relatively flexible and attracts low seismic loads. Overall it will pose a low risk to the lives of the occupants.
Wind LOW	GREEN: Assuming that the walls and roof are permeable to strong winds, the frame will not be damaged. If less permeable materials are added to the walls or roof, the frame should be braced, tied down to the foundations and strengthened.
Flood HIGH	GREEN: Specific checks against standing water have not been made in this analysis. However the raised floor helps to prevent flood damage.

*See section A.4.5 Performance analysis summaries

Notes on upgrades:

If the palm matting or thatch is replaced with less permeable materials (for example roof sheets) the shelter will experience greater wind loads. Maintenance and replacement of the matting walls is required to extend the life beyond six months.

Upgrading the roof with corrugated iron sheeting would result in higher uplift wind loads. As a result, roof members would need to be strengthened and the spacing between them would need to be decreased. Foundations would also need to be upgraded to prevent uplift and sliding of the shelter, and the structure would need to be tied to the foundations.

Upgrading the walls with plywood would the mean that the structure is no longer permeable to wind. Additional wall members would be required, the size of the header beam would need to be increased, and further bracing would be required in the roof and the walls to resist the increased wind loads. The foundations would also need to be upgraded to prevent sliding and to prevent uplift.

Upgrading the walls with masonry or other very heavy materials is not recommended. It would attract high seismic loads causing the structure to perform poorly in an earthquake. Collapse of a heavy roof or unreinforced masonry walls poses a serious risk to the lives of the occupants.

Assumptions:

- The structure has been checked for a roofing material weight of 0.2kN/m^2. The maximum allowable floor live load is 0.9kN/m^2 which is appropriate for lightweight shelter design.
- The palm matting and thatch has been assumed to be sacrificial or permeable under wind loading. If the walls and roof are upgraded, care is required to modify the structure to resist wind or seismic loads.
- A stiff soil type (see Site Class D, [4] International Building Code (IBC) 2009) has been assumed in analysis of the structure. Softer soil, or soil of variable quality may adversely affect the performance of the shallow foundations. For sites where liquefaction may be a hazard (near river beds, coastal areas with sandy soils and high water tables), the shelters could be seriously damaged in an earthquake. However, such damage is unlikely to pose a risk to the lives of the occupants due to the lightweight nature of the structure.
- The design and detailing of all connections is critical to the stability of the structure and should be checked for local load cases. It has been assumed that all connections can transmit member forces.

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	Total	Unit	Comments
Structure -Foundations					
Portland Cement	Concrete	0.053	0.053	m^3	2 x 42.5kg bags
Sand/Gravel	Concrete	0.267	0.267	m^3	
Main Structure					
Floor Beams 5 x 10cm (L=4.00m)	Timber 1	2	8	m	
Truss Beams 5 x 10cm (L=4.00m)	Timber 1	3	12	m	
Floor Ties 5 x 10cm (L=4.50m)	Timber 1	3	13.5	m	
Ridge Beam 5 x 10cm (L=4.50m)	Timber 1	1	4.5	m	
Eaves Beams 5 x 10cm (L=4.50m)	Timber 1	2	9	m	
Floor Joists 5 x 10cm (L=4.50m)	Timber 1	7	31.5	m	
Columns 5 x 10cm (L=2.75m)	Timber 1	6	16.5	m	
Columns 5 x 10cm (L=3.65m)	Timber 1	2	7.3	m	
Wall Mullions 5 x 7cm (L=2.20m)	Timber 1	16	35.2	m	
Portal Brace 5 x 10cm (L=0.65m)	Timber 1	10	6.5	m	
Truss Brace 5 x 7cm (L=0.80m)	Timber 1	6	4.8	m	
Truss Brace 5 x 7cm (L=0.95m)	Timber 1	1	0.95	m	
Rafter 5 x 7cm (L=2.80m)	Timber 1	6	16.8	m	
Roof Joist 5 x 7cm (L=2.25m)	Timber 1	8	18	m	
Covering -Wall					
Palm mat walling 1 x 2m			40	m^2	
Covering -Roof					
Coconut leaf roofing			25.1	m^2	
Plastic Sheet 4 x 6m	Plastic	1	24	m^2	
Covering -Floor					
Floor Boards – 2.5cm thick	Timber 1		18	m^2	
Fixings					
Nails – 8d	Nails		3	kg	
Bolts – 10 -12mm	Bolts	18	18	pieces	
Hinges		8	8	pieces	
Tools required					
Concrete formwork bucket		8	8	pieces	
Hammer		1	1	piece	
Saw		1	1	piece	
Shovel		1	1	piece	
Pick axe		1	1	piece	
Spanner		1	1	piece	