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.7 Indonesia, Aceh (2005) - Steel frame

Summary information

Disaster: Tsunami, 2004

Materials: Galvanised steel frame, steel sheet roofing, Radiata Pine/Douglas Fir or equivalent treated timber planks, steel foundation plates and anchors, door fixtures, nails, bolts and screws

Material source: Steel frames were manufactured regionally. The roof sheeting and timber imported internationally

Time to build: 1 day to construct the frame. 2 days minimum to clad the shelter

Anticipated lifespan: Minimum 5 years

Construction team: 4-5 people

Number built: 20,000

Approximate material cost per shelter: 4765CHF (2004)

Project cost per shelter: 5100CHF (2004)

Shelter description

The structure consists of a cold rolled, hot dip galvanised steel frame with a pitched roof of 24.3 degrees and a raised floor. The height is 2.8m to the eaves and 4.15m to the ridge. The platform area of the shelter is 25m^2 with a cantilevering balcony at opposite sides front and back and a cantilevering roof covering the balconies. There are 6 columns fixed using column base plates nailed directly into the ground. Metal roof sheets are screwed to steel purlins spanning between primary roof beams. Limited lateral stability is provided by timber plank wall cladding fixed to timber studs that are in turn screwed to the steel frame. The floor consists of timber planks spanning between steel joists.

Shelter performance summary*

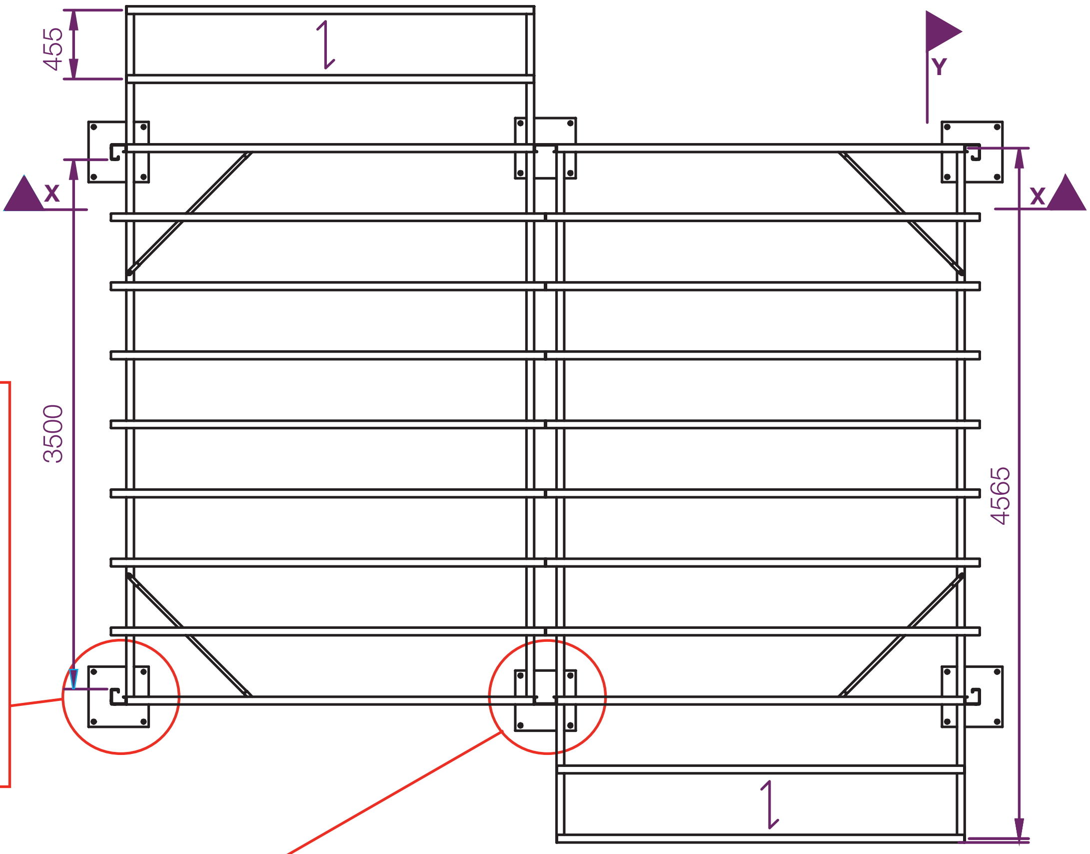
This shelter 'kit' presents a good design solution that is appropriate in areas vulnerable to high seismic loading although minor alterations are required for wind loads. Ensuring that timber planks are nailed to create a diaphragm or substituting them for plywood panels, strengthened columns and upgraded foundation details would improve its performance significantly (See Section C). It provides a transitional shelter option that is good quality, quickly scalable, and can be re-used or re-cycled. However it is comparatively expensive and there may be delays due to importation of materials. The design is similar to that of vernacular housing, with the steel replacing the traditionally used timber for the framing material.

* This shelter assessment is based on the assumption that the timber cladding was non-structural. In fact the timber planing was double nailed to form a structual system as in C.3.2 Walling option 2: shear panels.

Plans and comments

CHECK: In areas known to have high local wind pressures adequate foundations and member sizes must be provided.

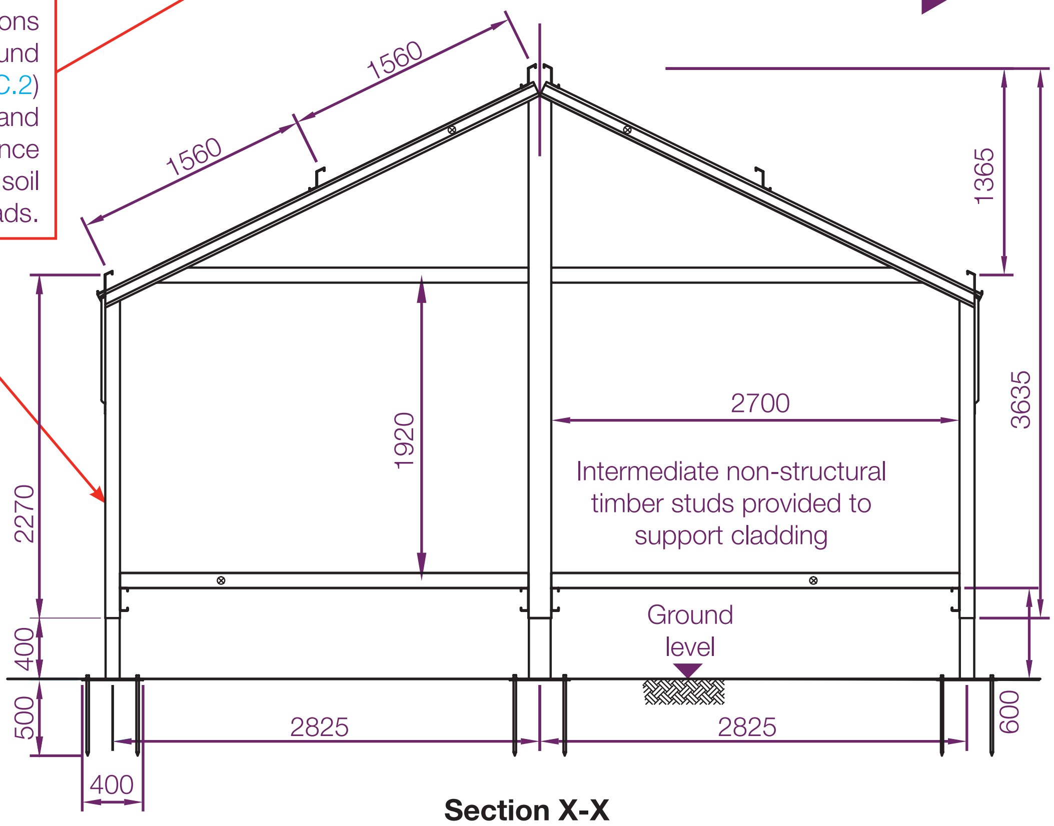
CHANGE: Modify the foundations from base plate nailed to the soil to concrete pad foundation (Section C.2) depending on soil type to prevent settlement of shelter.



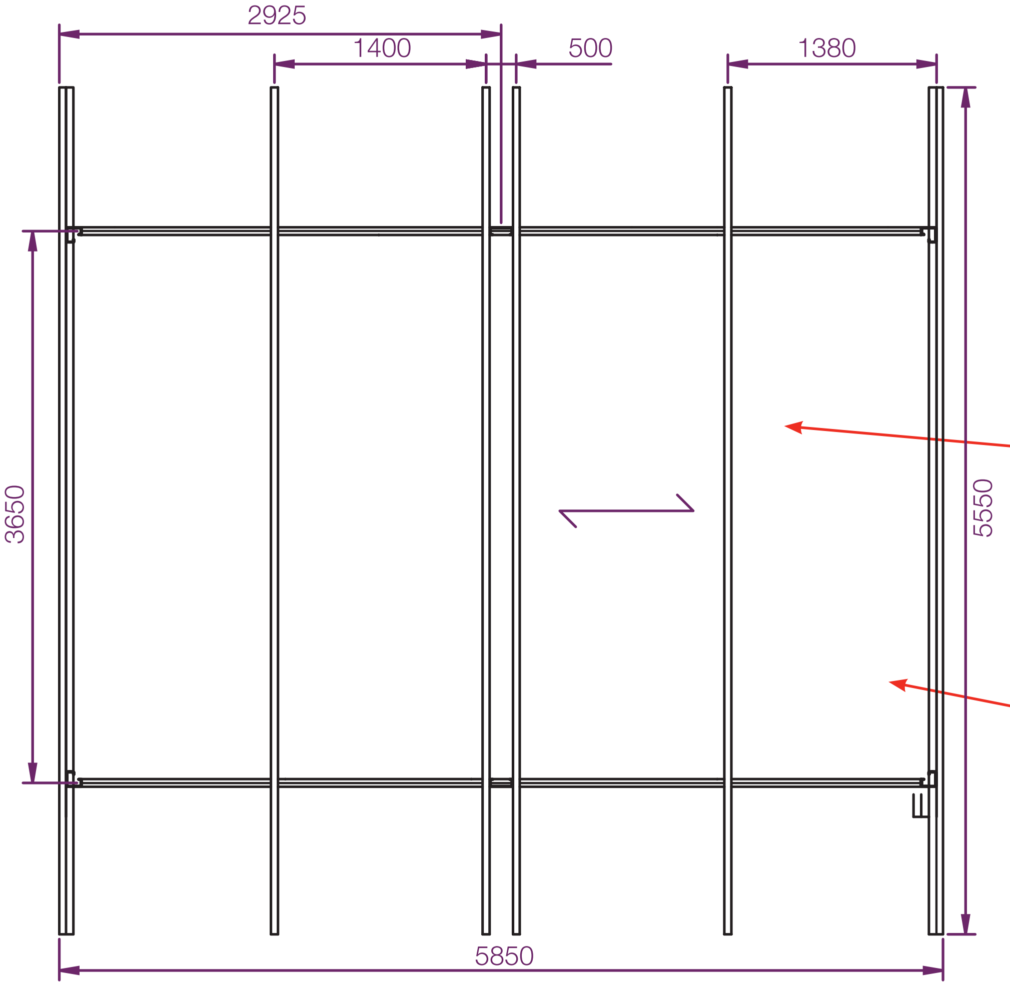
Ground floor plan

CHANGE: Use base plate or foundations or screw in ground anchor (Section C.2) to increase uplift and sliding resistance depending on soil type and wind loads.

CHANGE: All column sizes should be increased in accordance with design to local wind pressures.



Section X-X



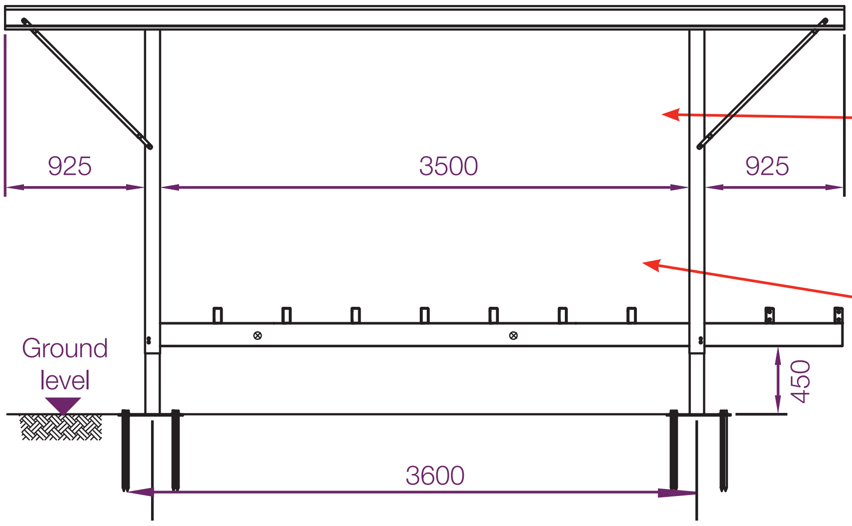
CHECK: The design and detailing of all connections is critical to the stability of the structure and should be checked for individual cases.

CHECK: Fasten roof sheet to purlins using screws spaced at appropriate intervals (Section C.4).

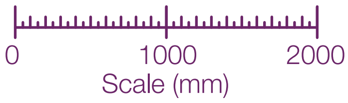
CHANGE: Provide in-plane bracing in the roof to increase lateral stability.

Roof Level Plan

CHANGE: Improve lateral stability by nailing planks to eash other (Section C.3.2) upgrading the walls using ½" thick plywood (plywood 1 annex I.1.3) with vertical framing spaced at 600mm and the plywood with maximum 150mm on centre nail spacing (Section C.3). In this case header and primary floor beams would also require strengthening. Alternatively, walls could be braced in-plane with diagonal steel bracing.



CHECK: Do not upgrade walls using masonry or cement blocks due to risk to life and increase in seismic force attracted to the structure.



Section Y-Y

Durability and lifetime

The shelter frame, tools, timber planks and studs were delivered as a 'kit'. The timber planks and studs were delivered to site pre-cut and treated. The plywood wassupplied separately. Windows and gable materials were not provided in the kit to encourage local markets. The shelter 'kit' was designed to be demountable and easy to relocate.

The durability of the shelter is good since the steel members are galvanised and the timber is treated.

Performance analysis*

The performance of the frame under gravity loads alone is adequate. The foundations must be upgraded to prevent the settlement of the column bases into the soil. Bracing is required in the walls and roof to improve the lateral stability and make the structure safe.

Hazard	Performance
Earthquake HIGH	AMBER: Medium risk of failure: Damage to the shelter is to be expected due to the low resistance to lateral loads provided by the timber cladding. Bracing or suitably nailed plywood should be used to improve the lateral stability and prevent failure in the event of an earthquake. The foundations should also be changed to prevent settlement. The structure is lightweight and relatively flexible so will pose a low risk to life if damaged.
Wind LOW	RED: High risk of failure: The shelter does not perform well under wind loads. In addition to bracing the walls and roof, an alternative foundation is required to prevent settlement, uplift and sliding under wind loads. The column size should also be increased.
Flood HIGH	GREEN: Low risk of failure: The shelter has a raised floor to prevent damage but no specific checks against standing water have been made.

* See section A.4.5 Performance analysis summaries

Notes on upgrades:

In many cases, the shelter has been upgraded by adding porches, partitions and extensions. However the main shelter structure has largely remained unaltered. In instances where the occupants were provided with permanent housing, the shelter was used as an extension, a second home, or a shop.

The performance of this shelter would be significantly improved for a relatively small cost by providing intermediate studs, nailed plywood shear walls and roof bracing.

If the shelter is adequately braced, the foundations modified and the column sizes increased, the roof or walls of the shelter can be upgraded with materials of a similar weight to those already in use. Upgrading the shelter with heavier materials will require appropriate foundation upgrades. Upgrading the shelter with masonry or other very heavy materials is not recommended as they will 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 maximum allowable floor live load is 0.9kN/m^2, which is appropriate for lightweight shelter design, and it has been assumed that the roof of the structure will not be subjected to loading from volcanic ash, sand or snow.
- A stiff soil type (see Site Class D, 📖[4] International Building Code (IBC) 2009) has been assumed in analysis of the structure. 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 if in an earthquake but such damage is unlikely to risk the lives of the occupants.
- All fixings and connections are of sufficient strength to transmit forces between members.

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 spoilage in transport and delivery.

Item (Dimensions in mm)	Material Specification See annex I.1	No.	Total	Unit	Comments
Structure – Foundations					
Guide post foundation 1 (400x400x8mm tichk plate)	Steel 1	2	2	pieces	
Guide post foundation 2 (400x400x8mm thick plate)	Steel 1	4	4	pieces	
Anchor nails (19 dia. x 600)	Steel 1	24	24	pieces	
Main Structure					
Centre columns (150x50x1.6, L=3.79m)	Steel 2	2	7.58	m	
Corner columns (100x100x1.6, L=2.425m)	Steel 2	4	9.70	m	
Primary floor beams (150x50x1.6, L=4.613m)	Steel 2	4	18.45	m	
Roof truss beam (100x50x1.6, L=3.205m)	Steel 2	4	12.82	m	
Primary roof beams (100x50x1.6, L=2.79m)	Steel 2	4	11.16	m	
Bracing (25 dia. x 1.6thk, L=1.2m)	Steel 2	16	19.20	m	
Secondary Structure					
Floor edge joists (100x50x1.6, L=2.79m)	Steel 2	8	22.32	m	
Main floor joists (100x50x1.6, L=2.873m)	Steel 2	14	40.22	m	
Roof purlins (246x2, L=5.68m)	Steel 2	6	34.08	m	
Covering – Wall, Roof and Floor					
Roof panels (740x3440)	Sheet 2	16	40.73	m^2	
Timber wall planks (160x20, L varies)	Timber 3		44.60	m^2	Lengths by supplier
Timber studs (3.79 or 2.42m)	Timber 3	6	17.28	m	
Timber floor planks (160x20, L varies)	Timber 3		26.10	m^2	
Fixings					
Guttering (457x0.5thk, L=4.675m)		1	4.68	m	
Roof flashing (458x0.5thk, L=2.028m)		3	6.08	m	
Bolt + nut + 2 washer (M12x25)	Bolts	172	172	pieces	
Bolt + nut + 2 washer (M14x30)	Bolts	28	28	pieces	
Hex Screw (M5x19)		90	90	pieces	
Nails (8d)	Nails				Quantity as per fixings
Tools Required					
Taper Punching Tool, 3-14mm diameter		2	2	pieces	Makes holes in roof panel
Big Hammer		1	1	piece	
Carpenter Hammer		2	2	pieces	
Screw Driver		2	2	pieces	
Tape Measure, 5m		1	1	piece	
Plumb Bob + 50m gut		1	1	piece	
Water Level ~30cm		1	1	piece	

Sockets, No. 17 and 22		2	2	pieces	
Spanner, No. 17 and 22		4	4	pieces	
Knitted Gloves		2	2	pieces	
Bag		1	1	piece	
Multipurpose heavy duty spade		1	1	piece	
Hand saw, 18" length		1	1	piece	
Ladders		2	2	pieces	