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.

See Classification of Performance

See Classification of Hazards

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

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

Structure is expected to fail under wind loads.

B.8 Vietnam (2004) - Steel frame

Summary information

Disaster: Typhoons and floods from 1997 to the present day
Materials: Galvanised steel frame and zincalume corrugated roof sheeting
Material source: Concrete, blocks, plywood and roofing: sourced locally. Steel frame: procured nationally
Time to build: 3 days
Anticipated lifespan: 5 years
Construction team: 6 people
Number built: 215
Approximate material cost per shelter: Unkown
Approximate project cost per shelter: 1500 CHF

Shelter description

The shelter is a galvanised lightweight steel frame with plywood walls and a corrugated steel sheet roof. It has a covered area of 3.6 x 8.4m on plan including a living area of 3.6 x 7.2m. The roof has a pitch of 16.5 degrees. The height of the roof varies from 3.2m at the eaves to 4.6m at the ridge. There are two doors, one at the side and one at the front, and a cantilevered canopy projecting 1.3m beyond the door to form a porch. There are twelve columns, six of which have screw in ground anchor foundations, connected in pairs by a braced truss to form a moment frame. The stability system is formed by these three moment frames tied together by two further moment frames on each edge of the building. There is steel tie bracing underneath the roof sheeting. The shelter has a 100mm thick concrete slab base cast over the screw anchor foundations and floor tie beams. There is a low, non-structural, 0.5m, brickwork wall providing a degree of flood protection.

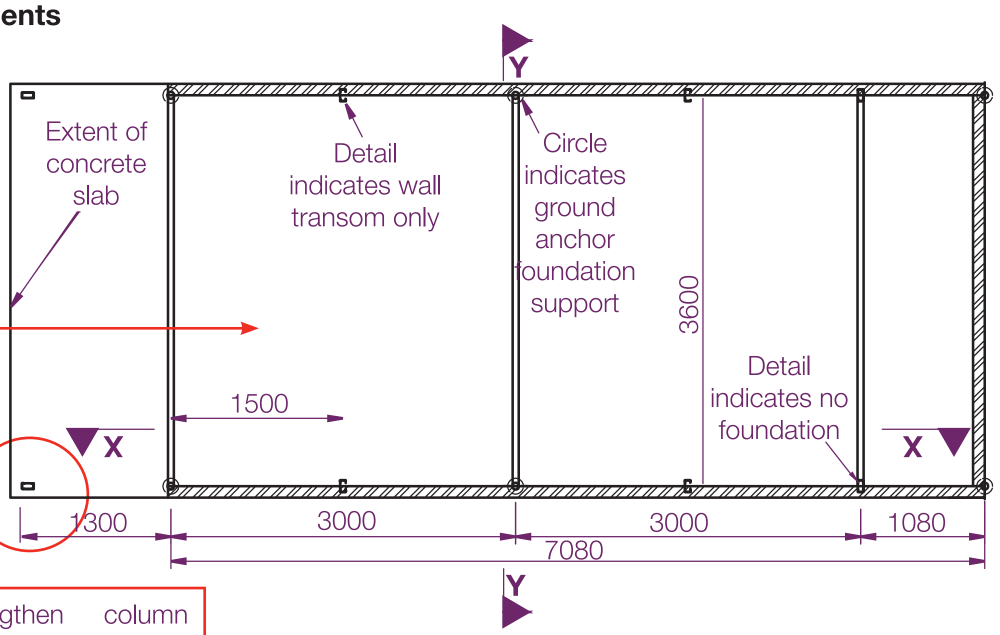
Shelter performance summary*

This shelter is an adequate design for low seismic areas but does not perform well under wind loading. The framing is relatively complex and has been adapted from previous designs. It is more than a transitional shelter and is likely to become a permanent house. It is very tall which provides the opportunity to include a mezzanine level or raised floor; although the frame would have to be strengthened structurally to support these elements. The frame is made from very thin sections not typically used in construction and the stability relies on the continuity of elements as a moment frame rather than bracing. Its performance could be greatly improved by improving the foundations, the steel members and bracing the walls and roof.

* Note that on a recent project evaluation, most of these shelters were found to be still standing after seven years, and remained in good condition. They are seen by many as a permanent house.

Plans and comments

CHECK: The concrete mix for the base slab should be as per I.1.2 and a layer of mesh reinforcement used to prevent cracking and increase strength.



Ground floor plan

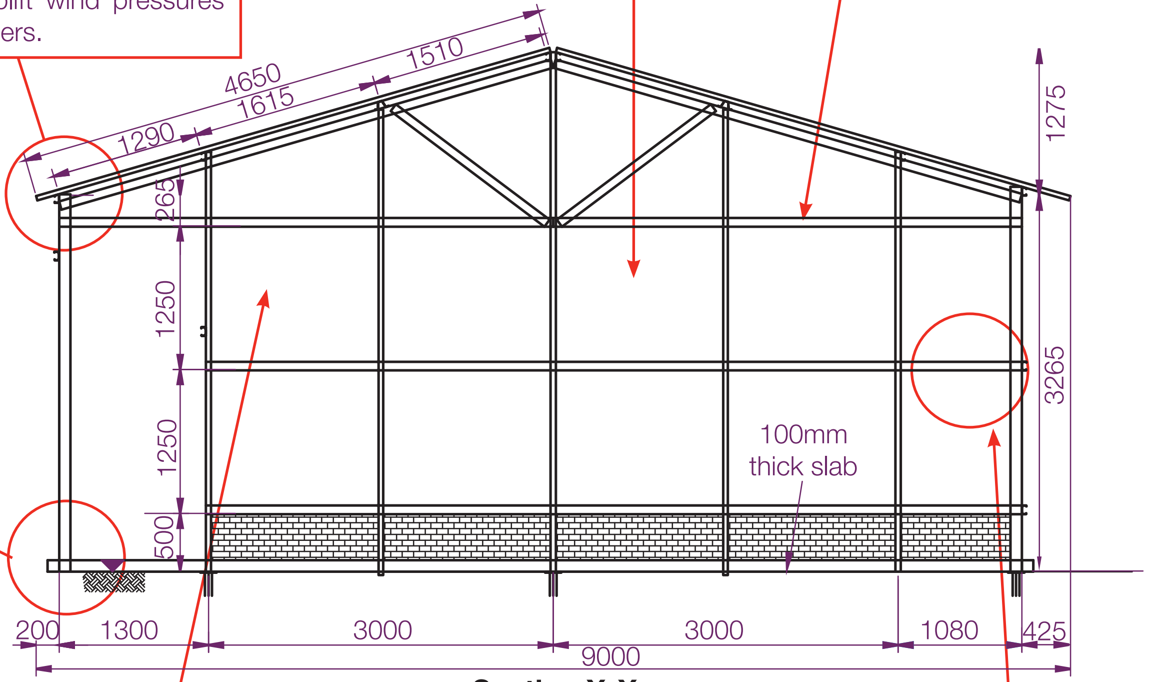
CHANGE: Strengthen column members by using a box section or by connecting thicker interlocking channel sections to improve bending capacity under seismic and wind loads.

CHECK: Plywood wall sheeting (Plywood 1, annex I.1.3) must be nailed to intermediate timber studs spaced at a maximum of 600mm with 150mm nail spacing and 8d nails.

CHANGE: Increase size of eaves beams on all sides to take seismic and wind loads.

CHANGE: Reduce height and length of porch canopy to reduce the effect of uplift wind pressures on these members.

CHANGE: Canopy columns require screw in ground anchors (see Section C.2) as used for other columns in order to prevent uplift under the high local wind pressures.

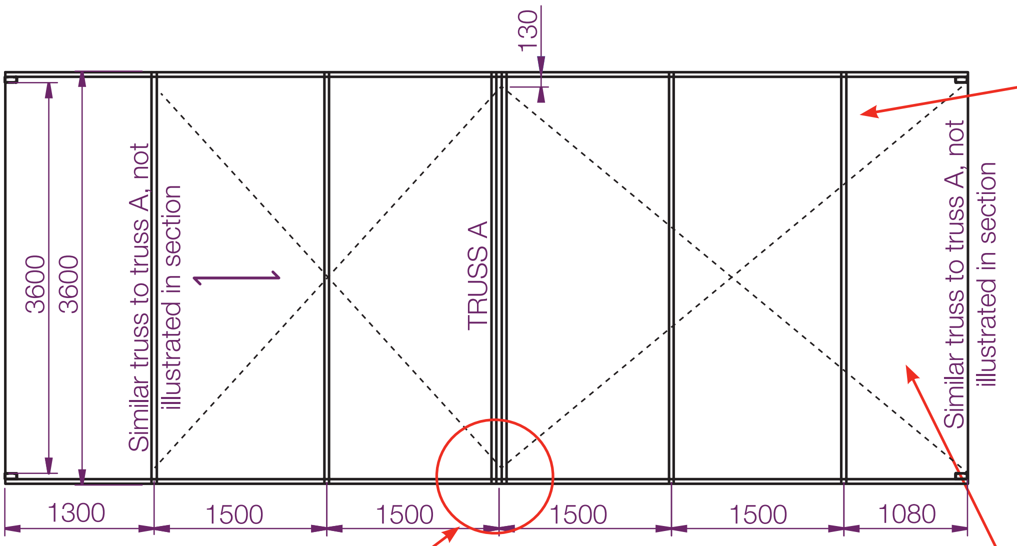


Section X-X

CHANGE: In-plane wall cross bracing or plywood shear walls required to improve the lateral stiffness of the shelter (see Section C.3).

CHECK: Brick wall will not withstand seismic loads and may collapse in an earthquake event.

CHANGE: Decrease spacing of wall transoms and change orientation so that bending under wind loads occurs around the stiff axis.



Roof Level Plan

CHANGE: Decrease spacing of roof purlins according to design for critical uplift wind pressures.

CHECK: Roof sheeting should be 0.5mm thick and should span 3m with an intermediate purlin at the centre. Sheeting should be fixed using nails with washers at each crest at the eaves and ridge, and at every other corrugation crest on purlins in between.

CHANGE: Do not offset roof bracing from columns. Bracing diameter should be increased to take forces from lateral wind loading.

CHANGE: Column heights can be reduced since no attic or mezzanine level is provided in the shelter. This would reduce the wall areas and therefore the wind loads on the shelter.

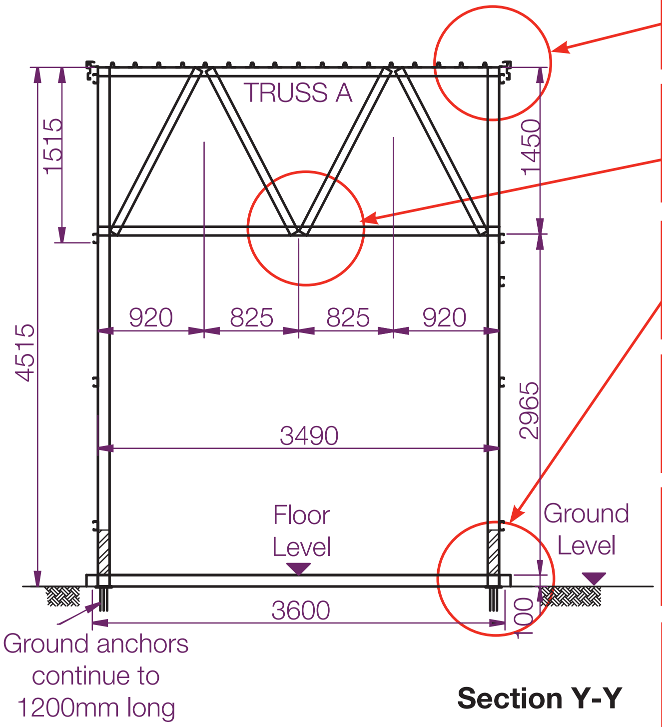
CHANGE: Strengthen rafters, bracing and truss chords to take lateral wind loads, for example by using thicker sections.

CHANGE: Use a screw in Ground Anchor foundation (See Section C.2) as indicated but with stabiliser plates to increase the shear capacity.

CHANGE: Increase thickness of all steel members to standard section sizes in order to increase the durability of the structure.

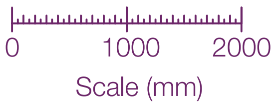
CHECK: The design and detailing of all connections is critical to the stability of the structure and should be checked for individual cases.

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



Section Y-Y

CHECK: A stiff soil type has been assumed in analysis of the structure. Rock or softer soils may not be suitable for screw in ground anchors so an alternative foundation solutions may be required.



Durability and lifespan

In many cases the shelters have been upgraded and extended using salvaged and recycled materials. The shelters were designed to be demountable and reusable in other locations.

As the cold formed steel sections are extremely thin, they are susceptible to corrosion, especially in salty environments, and the durability of the shelter is therefore poor.

Performance analysis*

Performance under gravity loads is satisfactory. Bracing or plywood shear walls must be provided in order to increase the lateral stiffness of the structure.

Hazard	Performance
Earthquake LOW	AMBER: The performance of the shelter under seismic loads is satisfactory. Damage is expected as the structure is flexible and has a low stiffness under lateral loads. Some steel members require strengthening to ensure the frame will not fail in the event of an earthquake. However, it is lightweight and attracts very low seismic loads so will pose a low risk to life.
Wind MEDIUM	RED: The shelter attracts high wind loads because of its height. The frame is un-braced and relies on the continuity between the steel members and the cladding for stability. As a result, it is unlikely to perform well under wind loads. The foundations require strengthening to improve the shear capacity, and the spacing of the purlins and wall transoms should be decreased and the size and thickness of all members increased.
Flood HIGH	GREEN: Specific checks against standing water have not been made, however the provision of the 0.5m high brick wall helps to prevent flood damage.

* See section A.4.5 Performance analysis summaries

Notes on upgrades:

Upgrading the roof or walls with materials of a similar weight would not change the structural performance of the shelter providing all cladding materials are adequately fixed to prevent damage under wind loads.

Upgrading the roof or walls with heavier materials, would mean that member sizes would need to be increased and the connections and foundation capacities checked under the increased gravity and seismic loads.

Upgrading the shelter with masonry or other very heavy materials above the current wall level 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 life.

Assumptions:

- The bottoms of the columns that are not connected to the screw anchors are provided with limited restraint since they are cast in to the 100mm thick concrete floor slab. This slab is assumed to be reinforced with mesh only.
- The low brickwork wall is not connected to the structural steel frame so does not place any loads on it.
- All connections between members have been assumed to be pinned and fixed with two screws. Throughout it has been assumed that all connections are of sufficient strength to transmit forces between members.
- The columns are bolted to base plates and the screw in ground anchors have a stiffened 140mm diameter plate welded to the top of them. These plates are bolted together using four 30mm long, M12 bolts in slotted holes. The column bases, screw foundation connections and floor ties have then been cast into a 100mm thick slab that forms the floor of the shelter and from which the 0.5m high wall is supported. The column bases have been assumed to be pinned and the slab is assumed to be resting on the ground.
- The screw in ground anchor foundations are similar to those illustrated in Section C.2 (1200mm long, 60mm diameter, 3mm thick steel tube with a 400mm diameter, 3mm thick, 150 pitch helical screw plate at the base).
- The shelter walls are made from plywood sheets nailed to timber studs. These studs are screwed to the frame or an equivalent system that transmits wind loads back to the frame without being damaged.

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					
Screw Ground Anchors	See Section C.2	6	6	Pieces	See assumptions
Portland Cement	Concrete	15kg	15	Bags	42.5kg/bag, estimate only for 3.5m^3 concrete
Sand	Concrete		1.3	m^3	Estimate
Gravel	Concrete		2.55	m^3	Estimate
Wire Mesh Reinforcement			32.5	m^2	
Primary Structure					
Columns 2No. 100x50x0.75 Channels Interlocking to form box (L=3.3m)	Steel 4	4x2	26.4	m	
Columns 2No. 100x50x0.75 Channels Interlocking to form box (L=4.5m)	Steel 4	2x2	18.1	m	
Columns 2No. 100x50x0.75 Channels Interlocking to form box (L=3.7m)	Steel 4	4x2	29.2	m	
Rafters 75x40x0.75 Channel (L=4.5m)	Steel 4	4	18	m	
Transverse Beams 75x40x0.75 Channel (L=3.5m)	Steel 4	4	14	m	
Longitudinal Beams 75x40x0.75 Channel (L=4.3m)	Steel 4	2	8.6	m	
Longitudinal Beams 75x40x0.75 Channel (L=4.1m)	Steel 4	2	8.2	m	
Truss Bracing 75x40x0.75 Channel (L=1.65m)	Steel 4	8	13.2	m	
Truss Bracing 75x40x0.75 Channel (L=1.93m)	Steel 4	3	5.8	m	
Wall Bracing 75x40x0.75 Channel (L=1.7m)	Steel 4	4	6.8	m	
Secondary Structure					
Floor Ties 100x50x0.75 Channel (L=3.5m)	Steel 4	3	10.5	m	
Cable Bracing – 4mm dia. (L=5.3m or 4.5m) + Turn Buckle	Steel 4	4	19.6	m	
Wall columns 75x40x0.75 Channel (L=3.65m)	Steel 4	2	7.3	m	
Wall Transoms 75x40x0.75 Channel (L=3.0m)	Steel 4	6	18.2	m	
Wall Transoms 75x40x0.75 Channel (L=4.1m)	Steel 4	2	8.2	m	

Door Framing 75x40x0.75 Channel (L=2.3m)	Steel 4	2	4.6	m	
Purlins 75x35x0.75 Channel, 12mm lip (L=3.6m)	Steel 4	6	21.6	m	
Purlins 103x61x1.0 thk. (L=3.6m)	Steel 4	2	7.2	m	
Covering – Wall and Roof					
Plywood – 12.5mm thick	Plywood 1		90	m^2	
Roof Sheeting – 0.5mm thick (4.65x2m)	Sheet 2	4	34	m^2	
Ridge Capping 578x0.45mm thk. (L=3.8m)	Sheet 2	1	3.8	m	
Flashing 289 x 0.4mm thk (L=4.9m)	Sheet 2	4	19.6	m	
Timber studs	Timber 2				As required for walls
Fixings					
Bolts – M12x30	Bolts	35	35	Pieces	
Self tapping screws 10-24x22	Screws	200	200	Pieces	Roofing
Self tapping screws 15-15x20	Screws	80	80	Pieces	Flashing
Self tapping screws 12-14x20	Screws	500	500	Pieces	Frame
Cleat 100x50x1.9mm thick	Steel 1	4	4	Pieces	
Foundation Cleat 150x80x4mm thk	Steel 1	6	6	Pieces	
Nails – 8d	Nails				As required for walls
Fixing Strap	Steel 1		76	Pieces	For roof
Tools Required					
Drill		1	1	Pieces	
Hammer		2	2	Pieces	
Big Hammer		1	1	Pieces	
Screw Driver		3	3	Pieces	
Tape Measure, 5m		1	1	Pieces	
Spirit Level		1	1	Pieces	
Plumb bob + line		1	1	Pieces	
Spade		1	1	Pieces	
Hand saw		1	1	Pieces	
Ladders		2	2	Pieces	