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.

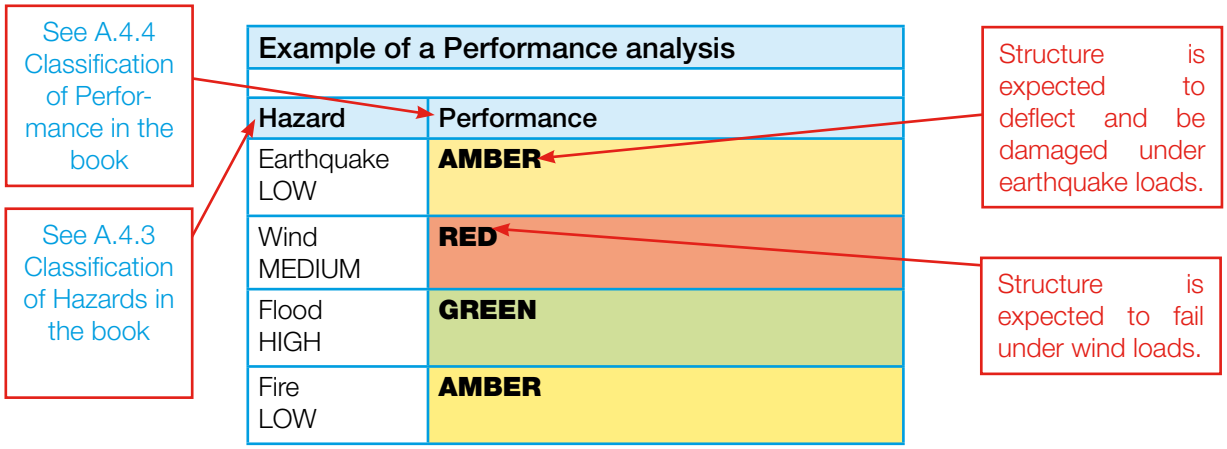
A fuller description is of the methods used is available in Section A of Post-disaster Shelters: 10 Designs, IFRC, 2012.

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.8 Bangladesh – 2007 – 'Core-Shelter'

Summary information

Disaster: Cyclone Sidr, November 2007

Materials: Reinforced concrete columns and a steel framed roof. Concrete pier foundations, brick exterior base, and bamboo matting walls with Corrugated Galvanized Iron (CGI) roofing

Materials source: Local

Time to build: 5 days

Anticipated lifespan: 2 – 5 years

Construction team: 3-4 people

Number built: 1,250

Programme cost per shelter: 1,822 CHF - an additional 60 CHF cash grant was provided to shelter owners.

Shelter Description

This shelter is has reinforced concrete columns, a steel framed hip roof with metal roofing and bamboo mat walls. The total covered area is approximately 4.5m x 3.2m, and there is one door and three windows.

The floor is raised above existing grade, and a short brick wall is provided around the perimeter to resist flood waters and windblown rain. The 8 concrete columns are embedded approximately 1.5m into the ground. The roof truss is constructed with steel angles and is anchored to the concrete columns. The foundation consists of the 8 embedded columns, and a perimeter concrete grade beam. There are wooden beams between the columns approximately 2.1m above the first floor, which allow the addition of a mezzanine level to the shelter.

The shelter is designed to be easily moved by unbolting the columns and roof frame with hand tools and the materials can be re-used as a part of permanent housing reconstruction. Additionally it is designed so that a mezzanine level can be built to provide storage space in case of floods.

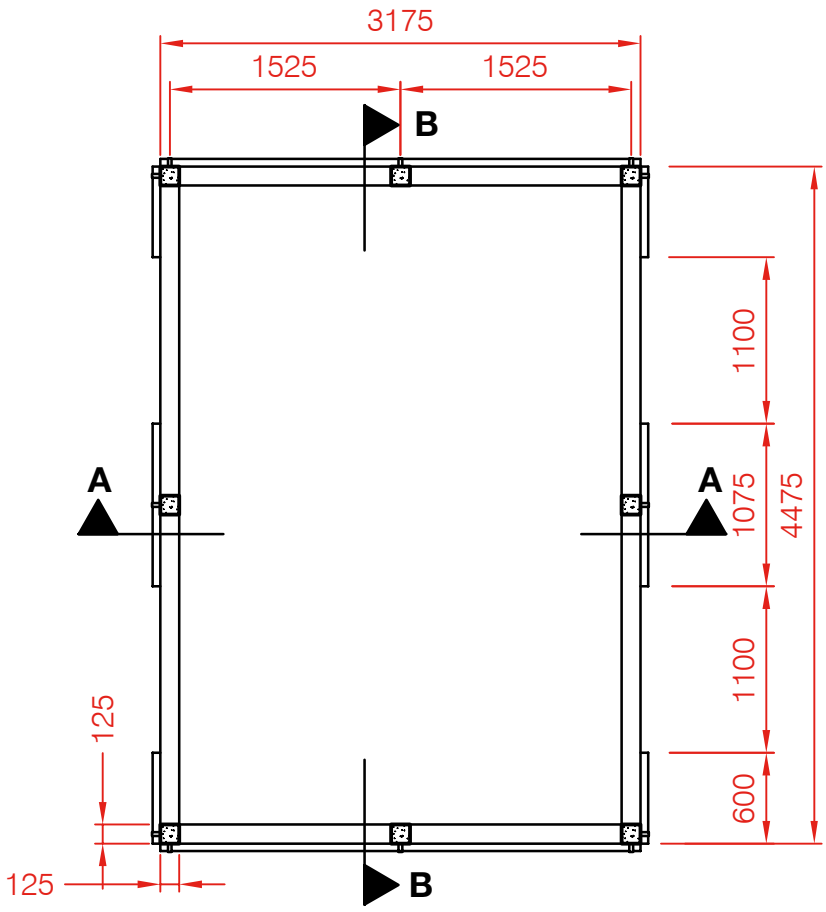
Shelter Performance Summary

This shelter is constructed with materials that are locally available and o fgood quality given the context. The roofing structure is complex and requires skilled workers to construct it. It is intended to be more than a transitional shelter and to become either a permanent residence or for the materials to be re-used in new permanent construction. The shelter is tall, which allows for a mezzanine level.

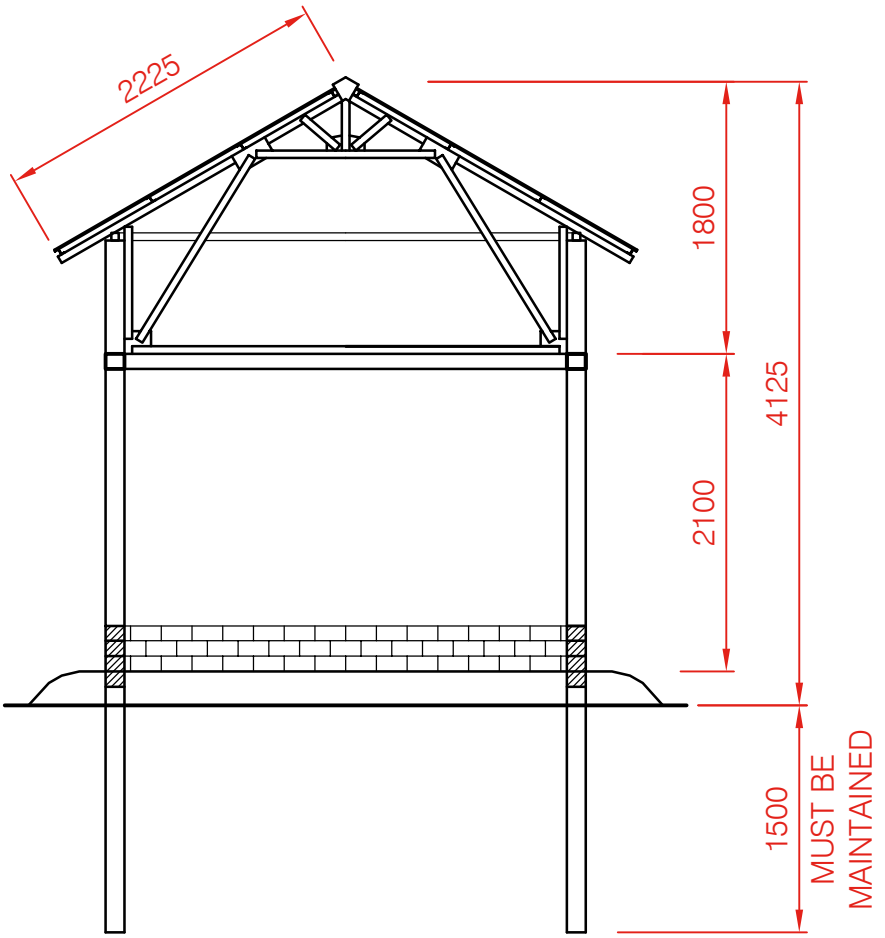
The frame performs adequately for seismic loads. The frame is not sufficient to resist the high wind loads if the walls remain in place through a strong storm, however it is anticipated that the woven wall panels will detach under such conditions. Due to the high quality materials and design, the only way to improve performance is to increase the sizes of the columns and the members of the roof truss.

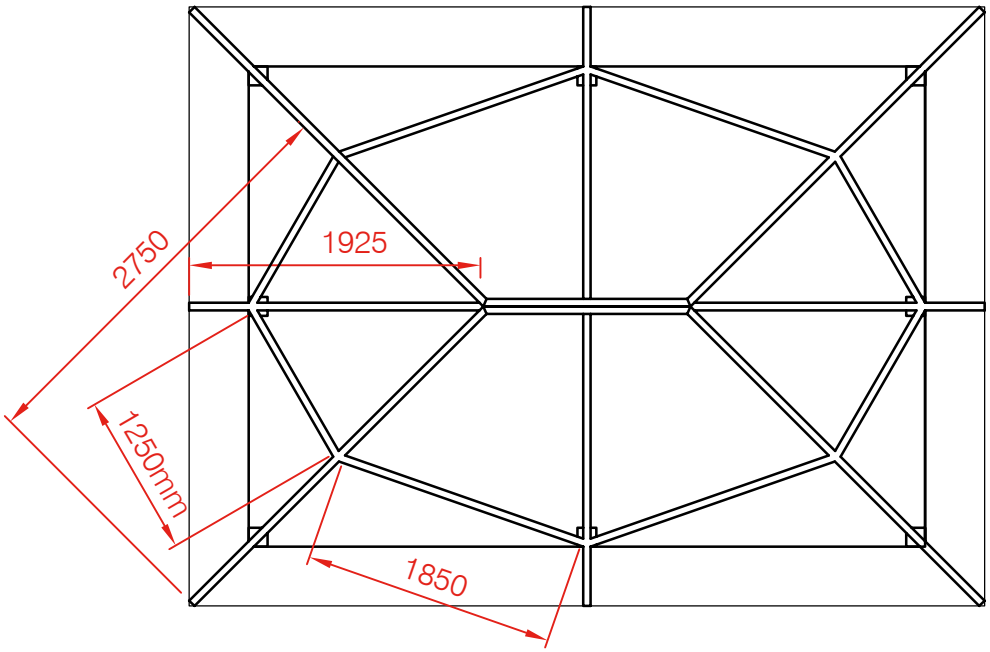
Plans

Floor plan

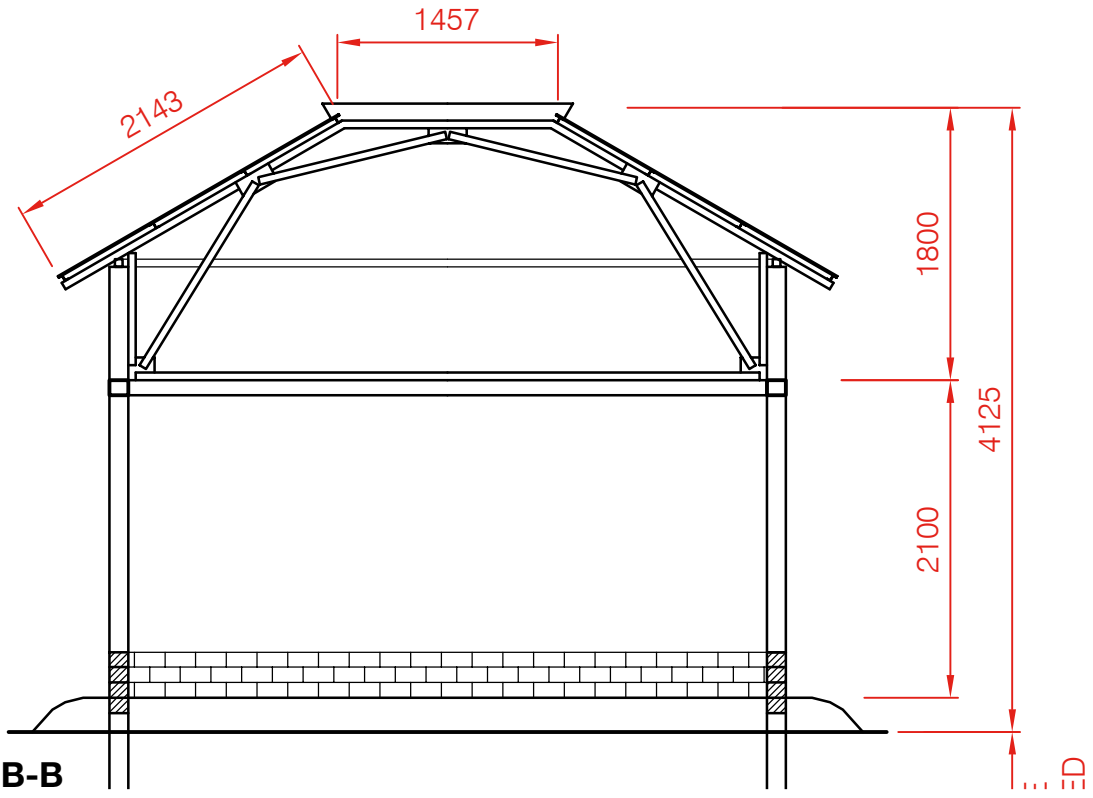


Section A-A





Roof Framing Plan



Section B-B

Durability and lifespan

The reinforced concrete columns and steel roof frame are built with durable construction materials and their deterioration should not limit the service life of the shelter.

The bamboo wall covering and garjan (local timber) framing at the mezzanine and door/window openings, while untreated, do have some natural resistance to tropical environments. Depending on how long the shelter is in use, these components will likely have to be replaced. In addition, it should be expected that the bamboo wall covering will be damaged and/or removed by winds from strong storms.

Performance analysis

The performance of the shelter for gravity loads and seismic events is good. In order to survive strong storms, the wall sheathing will have to be removed before the peak winds. Depending on the soil conditions, the embedment depth of the concrete columns may need to be increased. Also, proper site analysis is necessary prior to construction to determine appropriate finished floor heights to minimize flood damage potential.

Hazard*	Performance
Earthquake HIGH	**GREEN**: The structural framing is satisfactory under expected seismic loads, and little deflection or damage are foreseen for an event that could be expected within the design life. The low level masonry walls perform poorly under seismic loads, but their short height creates minimal risk to life.
Wind HIGH	**RED**: Structural framing is not adequate if the bamboo walls remain in place for wind loads up to the design storm of 260 kph. This affects the concrete columns, the steel roof truss, and the foundations. If walls are removed prior to significant storms (wind speeds in excess of 180 kph), the performance of the structure will be **AMBER**. Adding cross-bracing can potentially improve the above ground structure, but will most likely have an adverse impact on the foundation performance. Selection of a site with the proper soil type is required to ensure adequate performance of the foundation.
Flood HIGH	**GREEN**: This structure is designed to be elevated a minimum of 225mm above existing ground. It is also designed to have a 300mm brick wall around the structure which will minimize damage due to wind-blown rain coming under the bamboo matting. The mezzanine level also provides an elevated location where people can find shelter in an extreme flood event
Fire LOW	**AMBER**: The basic structural system is comprised of relatively fire retardant materials. The foundations and columns are reinforced concrete, and the roof structure if metal. These materials could survive a brief fire that was quickly extinguished. However, the wood frames around the doors and windows and the bamboo matting walls could create a fire event which burned hot enough and long enough to permanently weaken the roof structural members.

* See section Performance analysis summaries

Notes on upgrades

Cross bracing (using steel angles or cables) from the ground level to the roof can improve resistance to wind loads. For full effectiveness, bracing must be added to all four exterior faces.

For optimal foundation performance, concrete columns should be embedded in gravelly or sandy soils. If installed in silty or clayey soils, the columns should be buried 2m in the ground.

Permanent upgrades (e.g masonry) to the exterior walls should be avoided, as they will adversely impact the structure in high wind events. Also, increasing the height of the brick walls should be avoided as they can cause injury to occupants during seismic events.

Increasing the cross-sectional dimensions of the columns (to 200mm x 200mm) will increase strength and ensure adequate consolidation of concrete around the reinforcement.

The Mezzanine floor was not included with the shelter. It was expected that occupants would add it at a later time. A design load of 1kPa was included for the Mezzanine.

Assumptions

- The low brick wall is free standing, is not connected to the structural frame, and does not transfer loads to the columns but is used to resists foundation uplift.
- The optional wood mezzanine floor is in place, and supports floor live load.
- Lateral foundation loads are resisted by lateral soil bearing of the embedded concrete columns. Any frictional resistance is ignored
- The perimeter concrete grade beam is used to distribute vertical foundation loads to the supporting soil.
- Foundation uplift is resisted by the weight of the shelter alone, and any frictional resistance is ignored.
- In addition to the International Building Code (IBC) 2012, the shelter was also analysed against the 2006 Bangladesh National Building Code. This code was originally written in 1993, and is in the process of being updated by the Ministry of Housing and Public Works. Once this new code has been released, the shelter should be re-analysed to verify its adequacy.

Potential Issues

Site Selection

- Site selection is the 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
- For sites where soil liquefaction may occur during an earthquake (near river beds, coastal areas with sandy soils and high water tables) the shelter could be seriously damaged in an earthquake. The weight of these shelter components could cause injury to occupants.
- Ideally foundations should be made in sandy or gravely soils. If the site consists of clay or silts, foundations may need to be embedded 2m.

Construction Materials

- If possible, inspect fabrication of concrete columns to verity reinforcement is provided as indicated on the drawings prior to placement of concrete (the reinforcing steel should be a minimum of 25mm into the column). Adequate reinforcement and its position are important to structural capacity.
- Before columns are placed in the ground, inspect to ensure there is no damage such as cracking, chipping, or exposed reinforcement before they are placed in the ground. Also verify the embedded anchor bolts are present.
- Verify the steel angles are straight and are not damaged prior to building the roof.

Foundation

- Verify concrete columns are embedded in the soil to a minimum of 1500mm as in the plan.
- Make sure the columns are in their proper location, plumb, and the tops are level before soil is compacted around them. Otherwise construction of the steel roof truss will be difficult.
- The concrete grade beam is important for foundation performance, and it must be tied to the columns. Verify the steel reinforcing through the columns is installed prior to concrete placement.

Roof

- Make sure there are no empty bolt holes and that all bolts are tightened. The roof will only support itself if the pieces are properly fastened to each other.
- Verify the steel angles are not bent or twisted, and that at connections the angles sit flat against each other or the connection plates. If not, this could indicate that the columns are not properly installed.
- Ensure all the J-bolts fastening the roof panels are properly installed. Wind blown metal roofing can cause serious injury.

Exterior Walls

- Since bamboo mats will need to be removed during storms, make sure the connections can easily be undone. Permanent wall coverings should be avoided.
- Make sure that the low brick wall is installed, as it is needed to resist foundation uplift forces, but do not increase the height of the brick wall. It could cause injury to occupants during an earthquake.

Bill of quantities

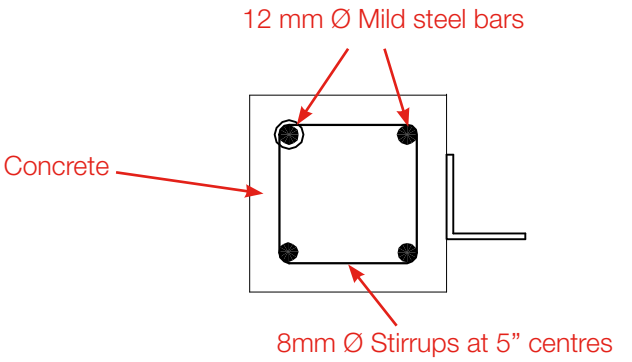
The table of quantities below is for the materials required to build the shelter. It does not take into account issues such as which lengths of timber are available and allowances for spoilage in transport and delivery.

Item	Material Specification See annex I.1	Quantity	Unit	Comments
Foundations				
Earth fill		4.5	m^3	
Portland cement (columns)		3	Bags	42.5 kg/bag
Sand (columns)		0.16	m^3	
Brick chips (columns)		0.32	m^3	
Steel reinforcement	12mm dia x 6m	32	Bars	
Steel reinforcement	8mm dia x 6m	28	Bars	
Portland cement (Grade Beam)		3	Bags	42.5 kg/bag
Sand (grade beam)		0.13	m^3	
Brick chips (grade beam)		0.26	m^3	
Steel reinforcement	10mm dia x 6m	21	Bars	
Steel reinforcement	8mm dia x 6m	17	Bars	
Main Structure				
Steel 1	38mm x 38mm x 3mm	12	Piece	L = 6m
Steel 1	200mm x 200mm x 5mm	39	Piece	
Steel 1	38mm x 38mm x 3mm	11	Piece	L = 6m
Secondary structure				
Brick	125mm thick	4.6	m^2	1st Class Brick
Timber 5	100mm x 63mm x 2m	8	Piece	Knot free Garjan
Timber 5	100mm x 63mm x 2m	8	Piece	Knot free Garjan
Timber 5	100mm x 63mm x 2m	6	Piece	Knot free Gargan
Covering – Wall and Roof				
sheet 2	1m x 2.25m sheets	20	Piece	
Ridge / hip cap	225mm x 225mm	12.5	m	
Bamboo mesh		44.5	m^2	Woven, 8mm thick
Bamboo mesh supports		62	m	100mm dia Bamboo
Window		3	Piece	Bamboo mesh shutter
Door		1	Piece	Bamboo mesh shutter
Fixings				
Threaded rod	12mm dia x 450mm	8	Piece	Include nut and washer
Threaded rod	10mm dia x 150mm	8	Piece	Include nut and washer
Threaded rod	7mm dia x 150mm	32	Piece	Include nut and washer
Bolts	7mm dia x 20mm	255	Piece	Include nut and washer
Roof sheeting J-bolt	5mm dia	150	Piece	Include nut ,washer, & gasket

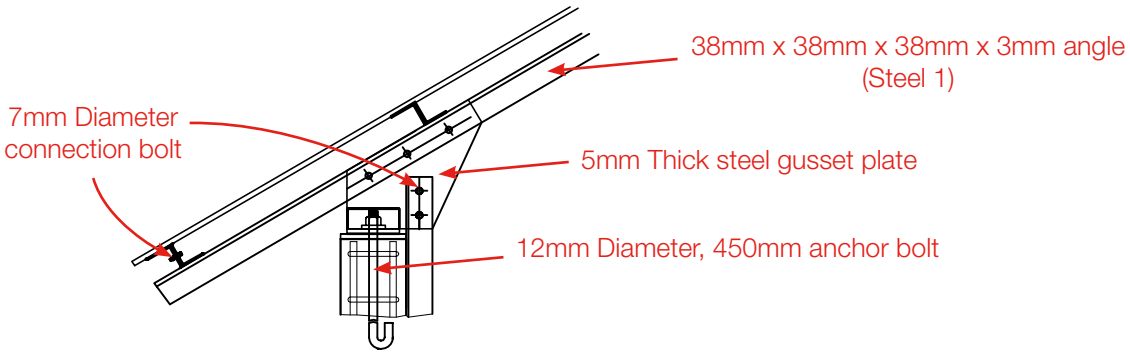
Item	Material Specification See annex I.1	Quantity	Unit	Comments
Tools				
Shovel		1	Piece	
Pick axe		1	Piece	
Drill		1	Piece	
Hammer		2	Piece	
Screw driver		2	Piece	
Tape measure		1	Piece	
Level		1	Piece	
Plumb bob		1	Piece	
Hand saw		1	Piece	
Sockets	(5, 7, 10, and 12mm)	4	Piece	
Spanners	(5, 7, 10, and 12mm)	4	Piece	
Gloves		2	Piece	
Ladders		2	Piece	

Design details

Section of a column showing placing of reinforcement



Detail of connection of roof to column



Detail of truss connections