Guidelines for Safer House Construction

Technical Manual

Department of Housing and Urban Development

Ministry of Lands, Housing, and Urban Development

Contents

FOREWORD

The series of earthquakes that occurred in Karonga and parts of Chitipa Districts in December 2009 caused a lot of damage to buildings as well as injuries and deaths arising from falling buildings. This tragedy brought to the fore the need to focus on the way we construct buildings and how we can construct safer houses so that they are able to withstand earthquakes better when they occur. As affected households, businesses and institutions begin to rebuild, it is important that they are supported with technical guidelines to enable them construct better and safer structures. It is also important to ensure that new future construction takes into account the need to minimize risk of damage or injury due to earthquakes.

It is important to note that these guidelines are not earthquake proof but they should greatly minimize risk of damage and injury due to earthquakes. Earthquakes are not the only hazard facing human settlements and communities. There are also other hazards such as floods and landslides. These guidelines have sought to address risk reduction for these hazards too. This technical manual is a living document and although it is first being applied in the current earthquake affected areas, it should form the basis for mainstreaming disaster risk reduction in construction and human settlements planning in Malawi.

The Malawi Government acknowledges with appreciation the technical and financial support of UN-HABITAT, the World Bank, DFID Malawi Red Cross Society, TEVETA, Centre for Community Organisation and Development (CCODE), and the Malawi Institution of Engineers that has made the production of this Technical Manual possible.

Honourable Professor Peter N. Mwanza
MINISTER OF LANDS, HOUSING AND URBAN DEVELOPMENT

Introduction

The following Guidelines have been produced by the Department of Housing and Urban Development within the Ministry of Lands, Housing, and Urban Development to provide technical and practical advice to those involved with the construction of houses. The impetus for this was to support reconstruction activities in the aftermath of the earthquakes in Karonga, 6th and 20th of December 2009, to reduce risk of future damage and injury due to earthquake. While producing the Guidelines it was recognised that providing information and advice on Safer House Construction applied nationally and that risk reduction should not be limited to earthquake but include other causes of risk, such as flood, fire, landslide, and high winds.

The intention is that the Guidelines provide practical information and advice that is affordable, appropriate and sustainable. In this respect the Guidelines have been developed to build upon current construction practises where local skills and materials are used. Also that the Guidelines should be disseminated in a form that is easily understood, including those with limited or no technical training or background.

The Guidelines have been produced in collaboration with other Government Departments, UNHABITAT, Malawi Red Cross Society, TEVETA, CCODE, and the Malawi Institute of Engineers, with technical and financial assistance from the World Bank and DFID. A working group was formed and through a process of discussion and consultation the Guidelines are in the process of being developed after consultation with local and district government, interested organisations and NGOs. Communities and those involved with construction were also consulted to ensure that the Guidelines were providing the information needed and in a format was readily understood.

To accompany this technical manual, the Guidelines will be produced as a series of posters and pamphlets so that individuals and communities have access to the information. It is the intention that the Guidelines build on current good practise and that should in no way contradict any future development of building standards or codes.

It should be noted that this document is in the process of being developed and will be revised over a period of time. It is expected that there will be additions and revisions that will be captured in future editions of this manual.

Understanding Risk

In understanding risk there is a need to comprehend the level of hazard as well as the possible causes and the likelihood or frequency that adverse events may occur. The ability to cope with such risk determines the level of vulnerability. These hazards can be categorised under four main headings:

Hydro-Metrological

- Landslides
- Excessive and Rapid Erosion
- Floods (including Flash Floods)
- Fire and Wildfires
- Windstorms

Geophysical

- Earthquake
- Subsidence and Heave

Biological / Chemical

- Transmittable disease
- Chemical pollution

Technological / Man Made

- Building collapse
- Industrial accidents
- Roads accidents
- Failure to infrastructure, such as power lines, drains, and other services

All of the above have the potential to be a risk to either health, property, and livelihood. Risk also has to measured against the likelihood of any event occurring and the intensity of such an event. For example earthquakes may not occur often but when they do the impact can be more significant that other types of disaster.

Avoidance and mitigation are the principle strategies for reducing or eliminating risk. In reality the choice of where to live is determined by factors other than consideration of risks to property, such as livelihood, land availability, social connections, and economic constraints.

In considering house construction, reconstruction, or repair, it is necessary to consider the following as the factors to reducing risk against the actual and potential causes of risk:

- **Site Location** – *Spatial planning and site selection*
- **Design** – *Architecture; purpose, shape and form, features*
- **Construction** – *Structure and technology*
- **Materials** – *Type and quality of materials used*
- **Methods** – *Techniques, skills, and quality assurance*

The above form the main headings for the following Guidelines and the most prevalent hazards will be considered.

Site Selection

Where a building is located may reduce risk to the property and person as well as risk to adjacent properties. Such considerations influence decisions around spatial planning, especially pertinent in the urban context but also revevant for rural communities

The following should be considered:

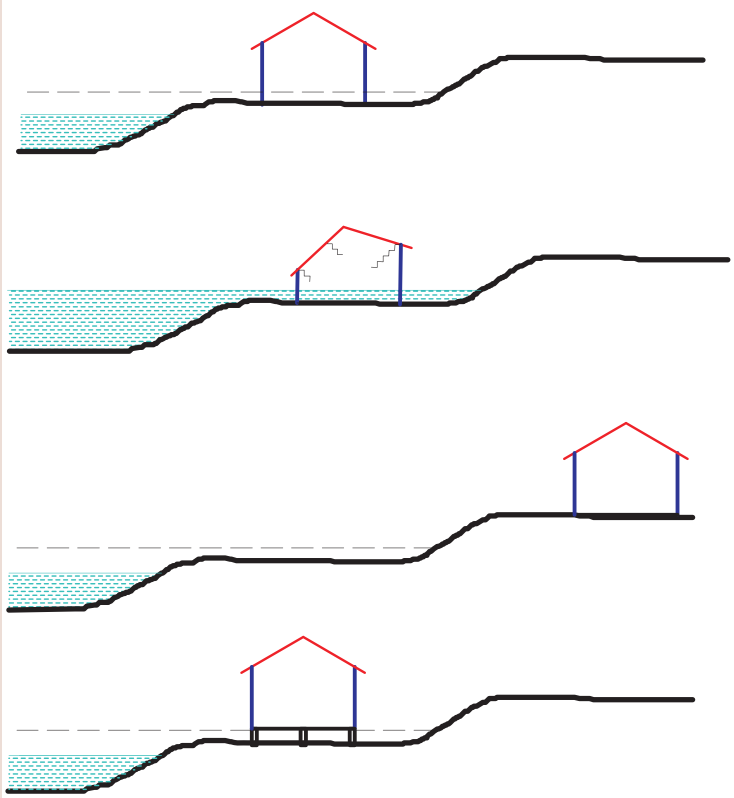
Flood and Flash Floods

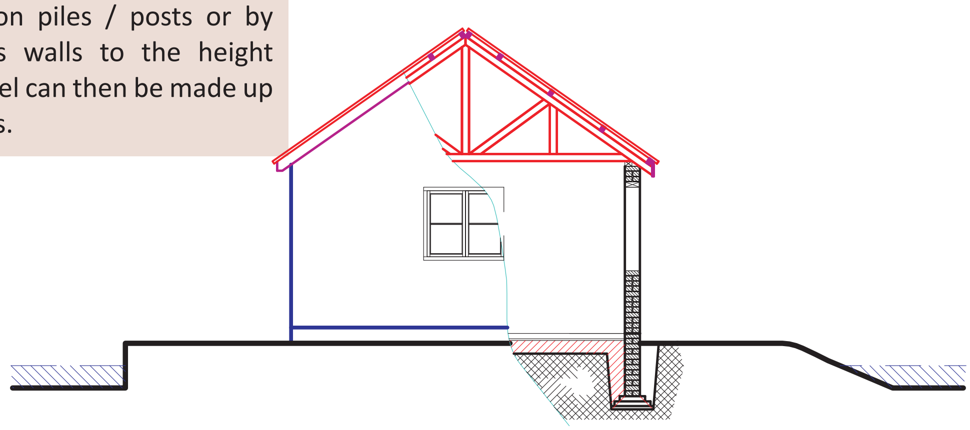
Identify the risk of flooding and areas where flash flooding may occur. Local knowledge, hydrological data and historic reports will allow areas at risk to be identified.

Floods can cause structural damage to buildings by either eroding the mortar and materials, under scouring the foundation, or by water pressure and debris where there is flowing water. Selection of materials and structure may reduce damage, such as constructing in burnt brick or stone and using a cement mortar below the flood line.

Positioning the building away from the flood risk maybe an option but for many individuals and communities this is not possible.

Constructing buildings within an area at risk of flooding requires that the floor level is raised above the flood line. This can be achieved either by raising the building on piles / posts or by constructing foundations walls to the height required. The ground level can then be made up to protect the foundations.





Landslides

Landslides can be caused by excavations, surface water and earthquake. Factors that make areas vulnerable to landslide include:

- Soil type and conditions
- Steepness of slope
- Lack of surface water drainage
- Deforested and cultivated land

Where a slopes is more than 30° this area may be particularly at risk of landslide especially where soil conditions, such as underlying clay, are present and where there is poor surface water drainage.

Stabilising soil on slopes can be expensive although maintaining deep rooting trees and plants will assist.

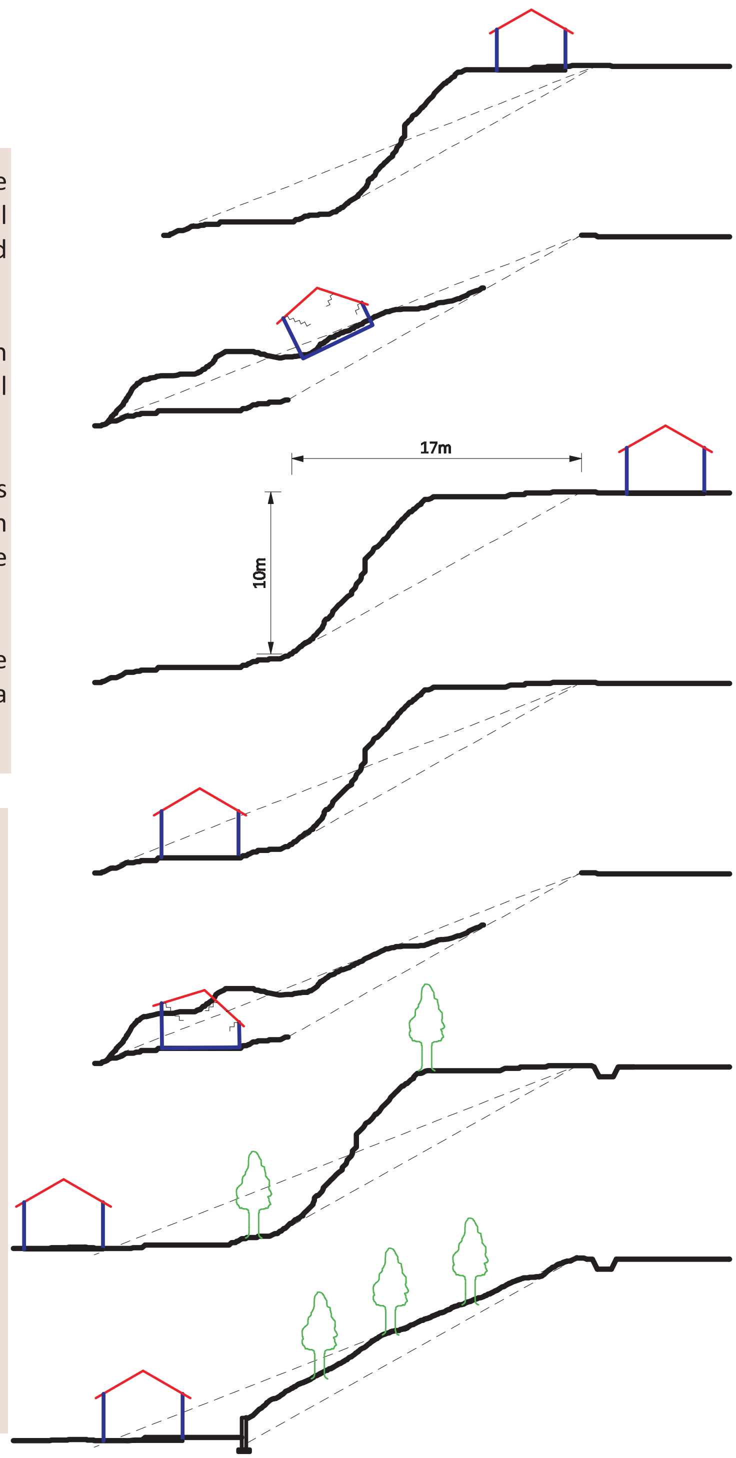
The main strategy is to ensure that any building is located out of the area at risk. As a guide allow 1.7m Horizontally for every 1m Vertically to identify the area that is at risk.

For example a slope that is 10m in height will require that the building is positioned at least 17m as a horizontal distance from the base of the slope.

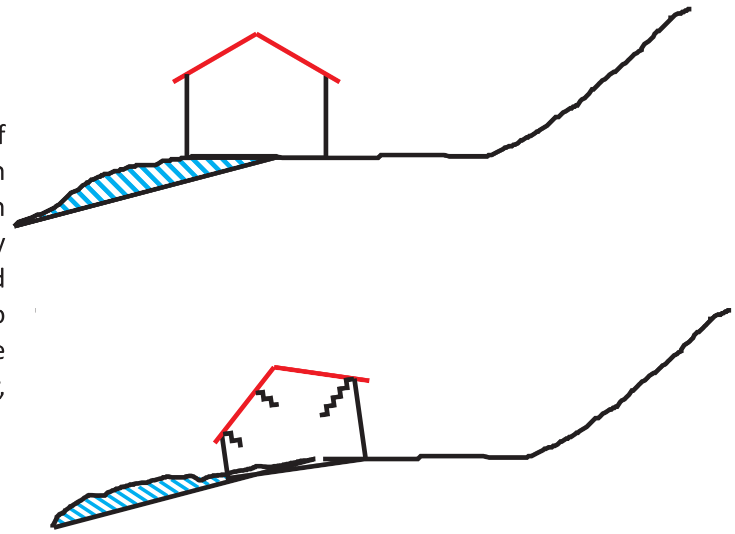
The same issues relate to buildings constructed at the bottom of slopes. It is however more difficult to predict the area that may be affected. For this reason buildings constructed at the bottom of slopes may be more at risk than those above. Where landslides are caused by surface water, the distance and speed of the landslide may be increased

Locating the building away from the slope and by planting trees will reduce the risk as well as providing adequate surface water drainage.

Where it is necessary to construct within the area at risk, the construction of retaining walls and reducing the slope may be options.



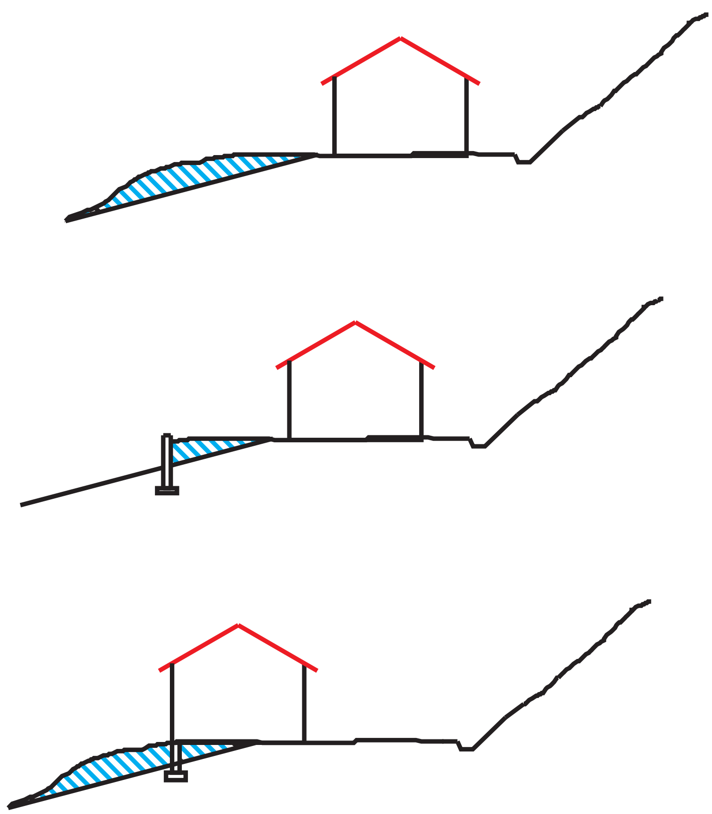
Houses constructed on slopes may be at risk of landslide and therefore the precautions given in the previous section apply. Many buildings on slopes are constructed on levels created by cutting into the slope and using the excavated material as fill. This ground has the potential to subside or give way over a period time as the ground settles; movement due to surface water, such as heavy rains; or because of earthquake.



Ideally buildings should be constructed on undisturbed ground. Where it is necessary to build on made up ground the foundations should be excavated down to the undisturbed subsoil.

To reduce the risk of subsidence and landslide of made up ground, retaining walls can be constructed.

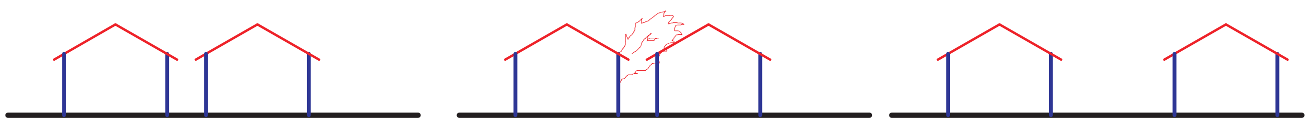
Where surface water may be an issue it is important to ensure that there is drainage to reduce erosion and saturation of the soil that



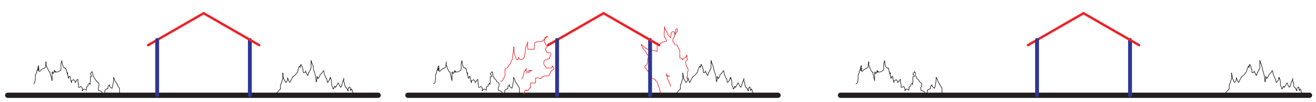
Fire and Wild Fires

Fire is a major threat to person and property. To prevent fire-spread there are three main areas to consider

- Distance between buildings and boundaries.
- Building materials
- Position and proportion of door and window openings



The Guideline is that a distance of 6m in urban areas and 10m in rural areas, depending on Bye Laws, should be maintained between any other building or boundary. Buildings constructed within these distances should avoid doors and windows facing other properties and use of materials that are not combustible, such as masonry and metal sheet cladding.



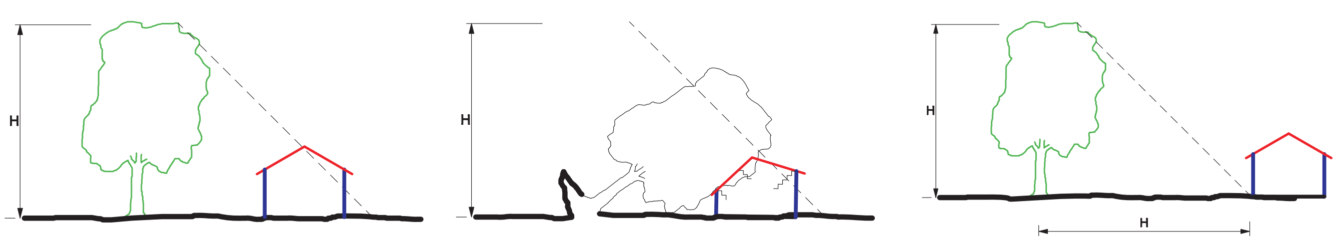
Wild Fires, as the name suggests, can be fierce and unpredictable especially where there is wind. Dry grass and vegetation, including crops, are the obvious fuel for fires. Reducing the proximity of the building to combustible materials by maintaining a preferred distance of 10m is advised as means of reducing risk.

Sources of potential fire such as kitchens need to be considered to reduce the risk of fire spread in the event of a fire. Kitchens, where possible should be situated a minimum of 6m from any other building or combustible materials.

Wind Storms

In high winds there is a potential for trees, power lines and other structures to fall on the property. Maintaining a distance equal to the height of the tree or object will reduce the risk.

Depending on the voltage of any overhead power line will determine the distance that any property should be from it. As a minimum any property should be at least 6m horizontally from a power line. The Electricity supply company (ESCOM) should always be consulted for confirmation of the safe distance that applies.

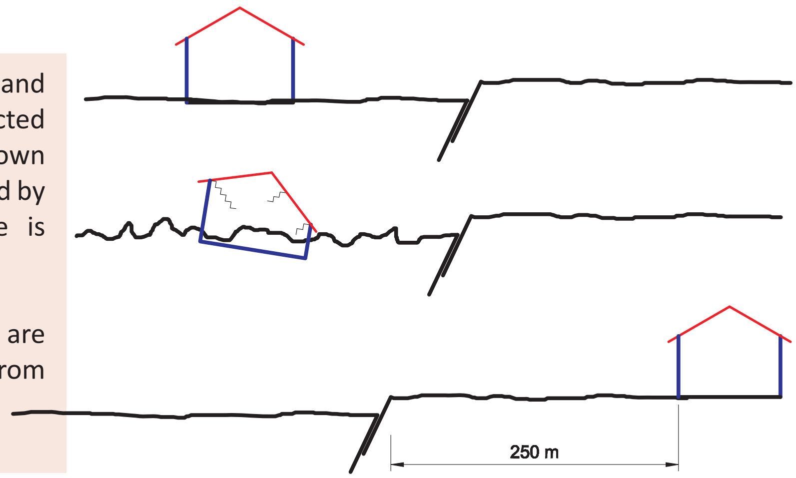


Earthquake

Earthquakes are unpredictable in terms of location and occurrence. Areas of know seismic activities where there are faults and ground rupture should be avoided when constructing buildings. Where this is not possible then buildings need to be constructed in such a way to minimise damage and injury, this will be looked at later in this manual.

Using local knowledge and geological and historical data, buildings should be constructed away from areas where there has been known ground movement. These are often marked by cracks in the ground and where there is differential movement.

It is recommended that any buildings are constructed a minimum distance of 250m from any known area of ground disturbance.



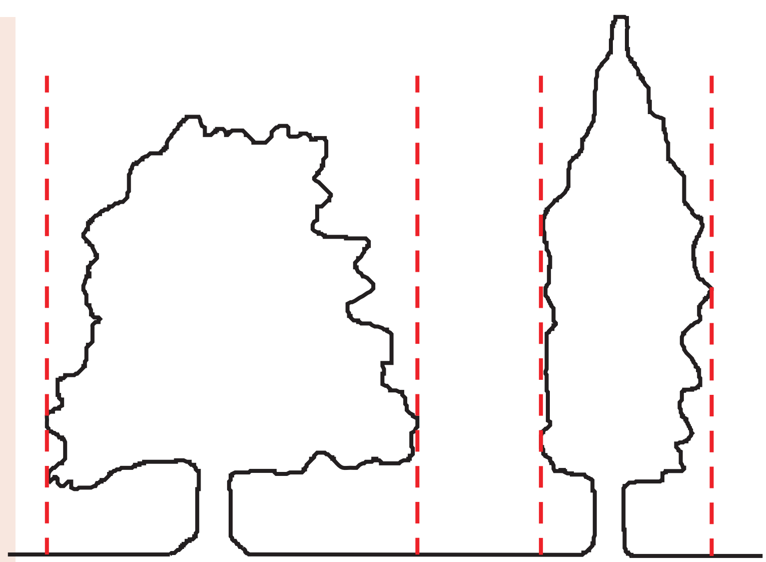
Subsidence and Heave

Soil type, soil moisture and organic content are primarily the cause of subsidence and heave especially where there are high shrinkage clays. Trees have a particular impact on the amount of water in soil and depending on the time of year and soil type may cause the ground to heave or subside.

Trees that are tall with a narrow canopy have vertically deep roots, trees with a wide canopy have wide spreading roots.

Buildings should be constructed outside of the canopy of any tree. This requires that an estimate is made of the mature tree size.

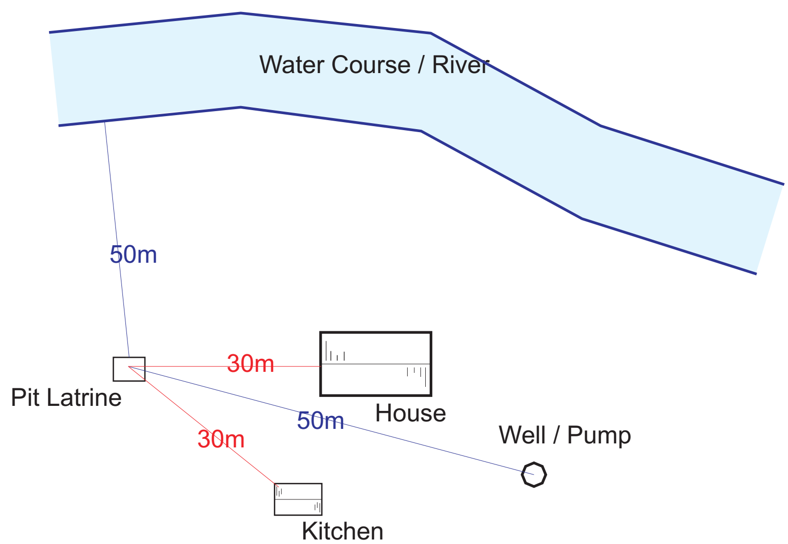
Any planting of trees should consider the impact on adjacent buildings. This is not to discourage the planting of trees, as leaf cover has other advantages such as providing shade, as well as preserving the natural environment

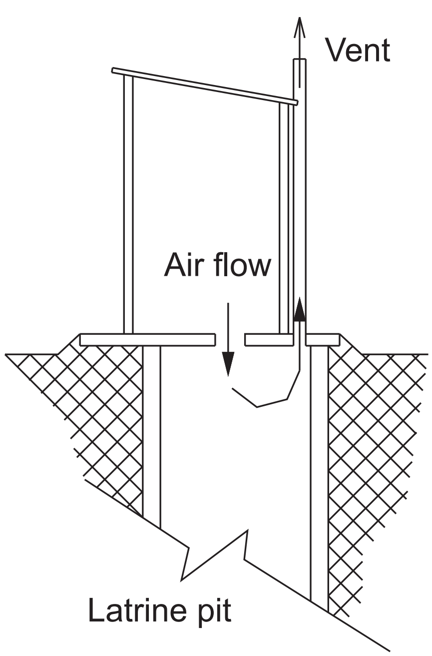


Other site location issues

Houses need to be located at a sufficient distance from latrines, and areas where there is refuse. This is to avoid risk of vector (flies, rodents, etc) borne infection. Ideally latrine pits should be a minimum of **30m** from a habitable buildings and at least **50m** from any water sources such, well, borehole, river or water course. In reality, especially in urban areas it may not possible to achieve this standard due to constraints of land ownership and space.

Effluent from the latrine can contaminate ground water and vector such as flies transmit disease. The guiding principle is to have the latrine at a maximum distance from water source, food, and the household. Where the latrine is near to the house the construction of a ventilated latrine can will control the number of flies.



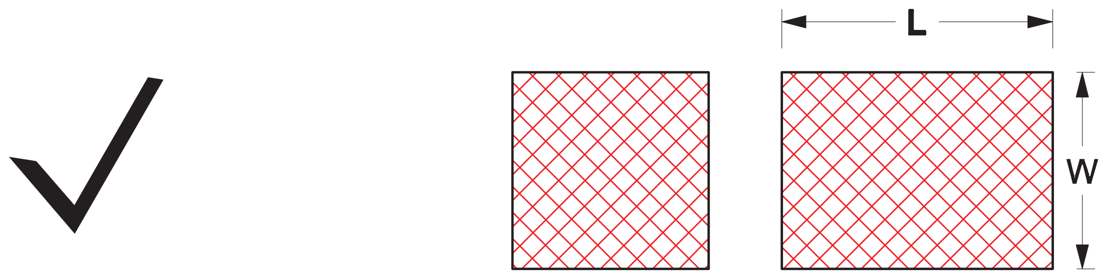


The location of the latrine should also consider the direction of the prevailing wind to reduce odour and flies. The same consideration should be extended to neighbouring property.

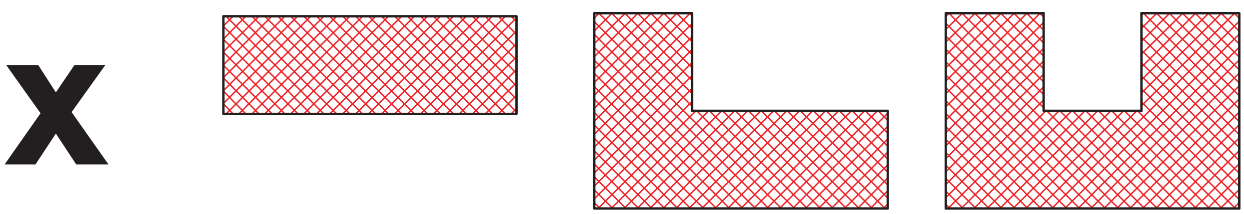
Design

The shape and proportion of a building is fundamental to the structural stability and ability to withstand external forces, in particular seismic activity and wind loads. The taller and more slender a building is the more vulnerable it is. Therefore the principle to reduce risk, without involving more complex engineering solutions, is to design buildings that are low and wide.

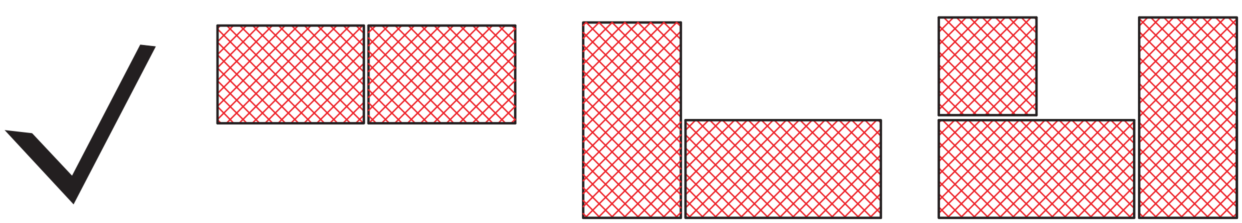
The following provides examples of shape and proportion.



Square shaped buildings offer best resistance where the maximum span of unsupported wall is no more than 5m. Rectangular shapes, where the length of the building is no greater than 3 times the width, are acceptable. Outside of theses proportions other strategies need to be employed.

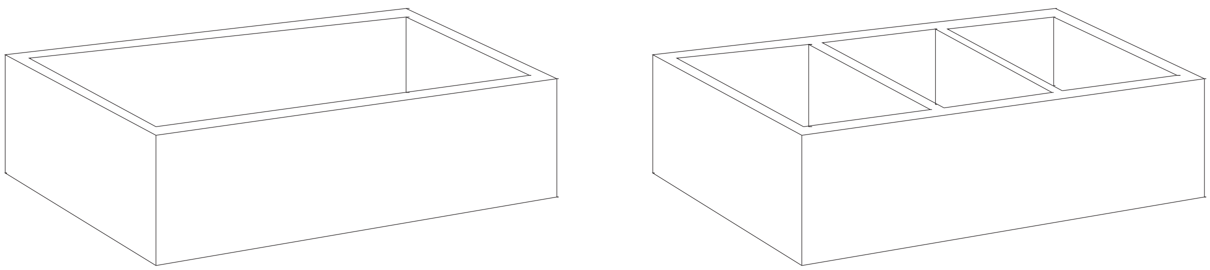


Building shapes that are not acceptable. Narrow rectangular shapes and complex shapes have inherent weakness.

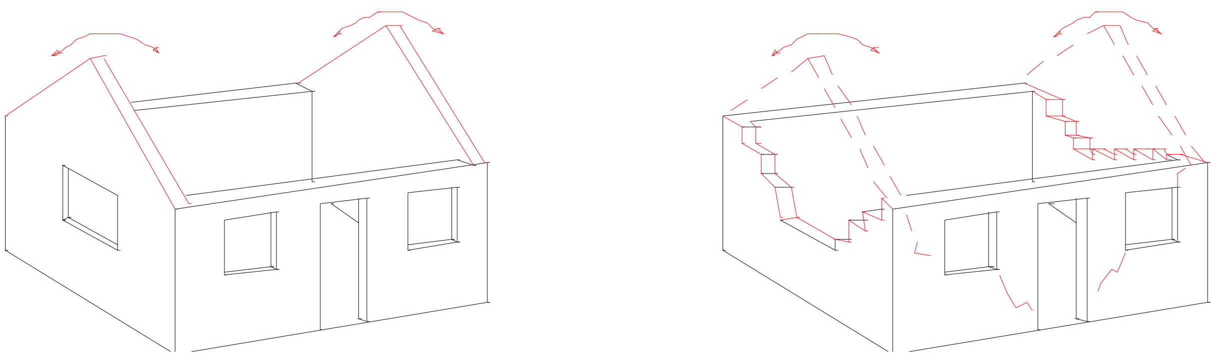


The same building shapes can be achieved using modules that are proportionally acceptable. The space between the units create seismic joints that allow differential movement during earthquakes.

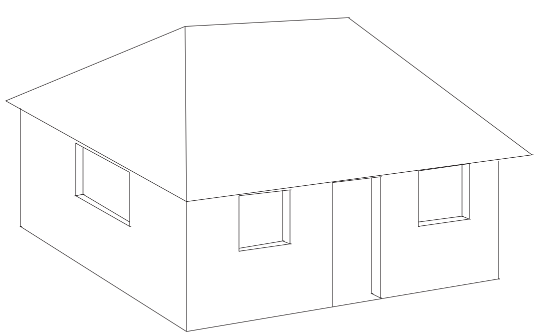
Longer rectangular buildings can be created by providing additional support using the internal wall as shown below. To prevent the outward movement of the walls in an earthquake there needs to be sufficient connection between the internal and external walls. This will be looked at in the next section.



Buildings should avoid features where there is unsupported masonry such as gable walls and pillars. Unsupported gable walls is one of the main causes of structural failure in earthquakes. In an earthquake or under wind load the gables are liable to movement and collapse. Designs should eliminate these features where possible.



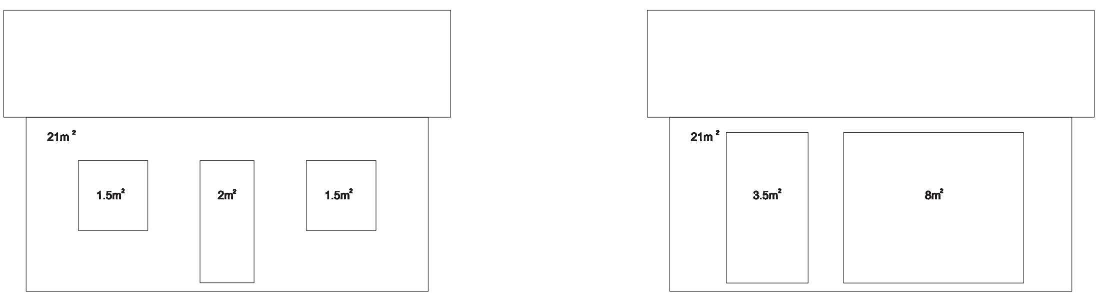
A hipped roof not only removes the requirement for gable support it also reduces the surface area for wind load.



The angle of the roof should be considered in areas that may experience high winds. Flat and low pitched roofs are susceptible to uplift. By increasing the roof pitch the uplift is reduced, ideally an angle of between 30° and 45° should be achieved. This may have the added advantage of providing better air circulation space to reduce overheating.

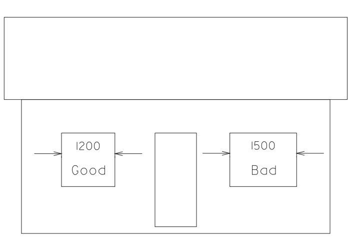
The strength of the walls will be influenced by the number, size and position of door and window openings. The following details provide advice and Guidelines for this aspect of design.

The area of openings should not exceed 50% of any wall area, as shown in the diagrams below.

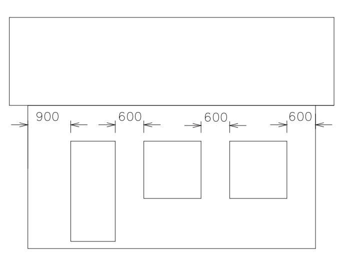


Good – Openings < 50% of wall area **Bad – Openings > 50% of wall area**

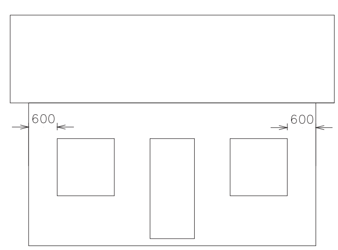
The position of the openings should allow a sufficient length of wall to provide structural stability. The general rule is that a minimum distance of 600mm should be kept between window openings and the corners of the buildings. Where there is a door opening this should be ideally situated toward the centre of the wall or be at least 900mm from the corner of a building. Additionally, it recommended that openings exceeding 1200mm in width should be avoided.



Size of window and door openings should not exceed 1200mm

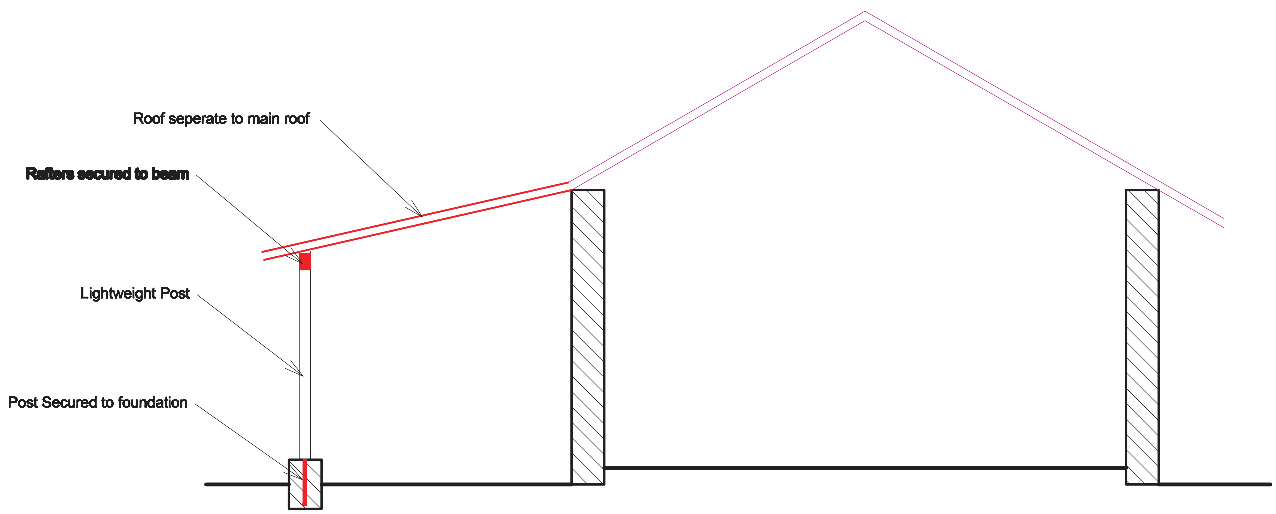


Windows should be a minimum of 600mm from corners, doors 900mm from corners, and 600mm between openings.



Doors should ideally be located near the centre of the wall.

Pillars are required to provide support for covered areas but as these elements have little support they are vulnerable to earthquake. Ideally pillars and posts should be excluded from designs but as these will be required in some designs it is best to design any covered area as a separate element so that in the event of an earthquake or high winds any movement will not affect the rest of the structure. Additionally pillar should be lightweight in construction and fixed to the foundations to prevent uplift.



Construction

This section is concerned with how buildings are constructed, concentrating on brick construction, as this is the most common construction type and the type most at risk.

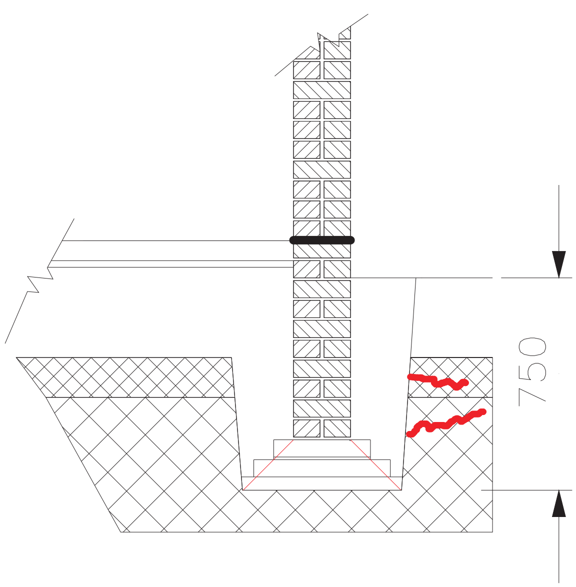
The section will look at the following:

- **Foundations –** Depth of foundations, foundation construction, infill, damp proof membrane, and ground floor construction
- **Walls –** External and internal walls, damp proof course, bonds and connections, lintels and ring beams.
- **Roof –** Roof structure, wall plate connection, roof covering

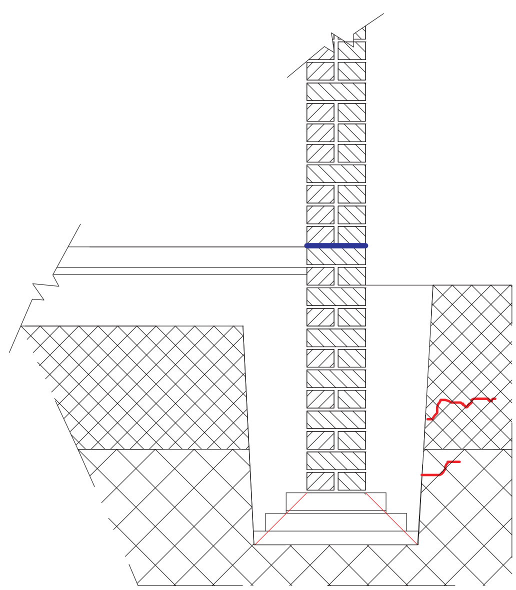
Foundations

The function of foundations is to transfer the building loads to a ground bearing strata. The foundations need also to be at a depth that protects them from erosion, surface water, subsidence and heave, and tree roots.

Foundations need to be a minimum of 750mm depth, but preferably 900mm. Foundations may need to be excavated to a greater depth depending on soil and site conditions.



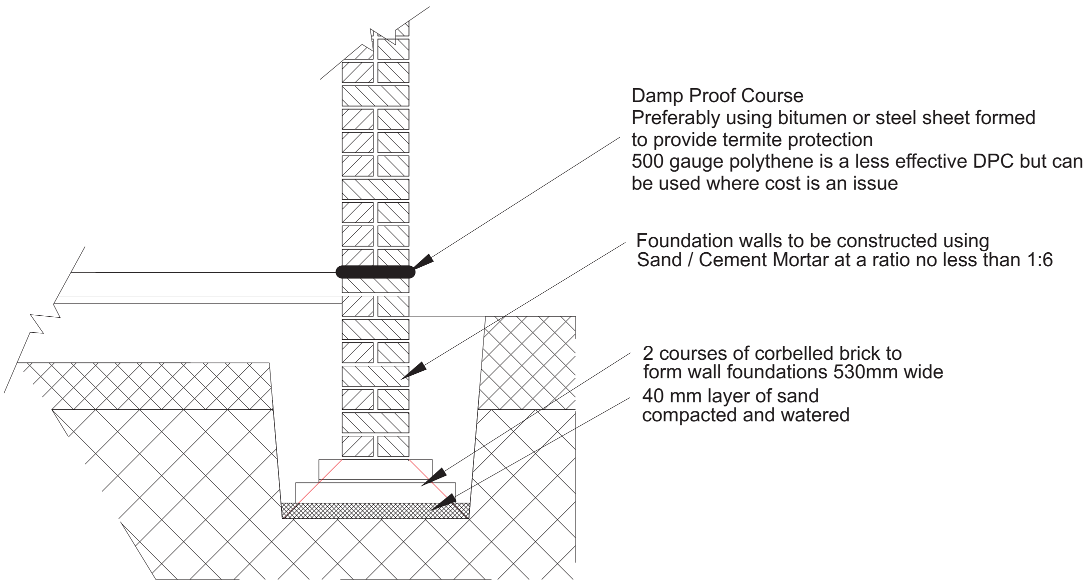
Minimum foundation depth where there is firm sub-strata. To test the ground use the heel of a boot or an iron rod. If the ground is soft then the foundations will have to be dug deeper. Foundations should never be constructed on made up ground even if it appears firm.



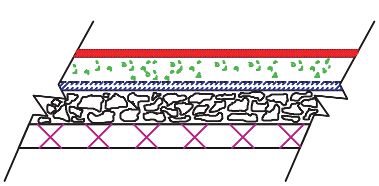
Foundations excavated to a ground bearing depth. In selecting the site, to minimise foundation depth, trial holes should be dug. Foundations for load bearing internal walls should be excavated applying the same rules.

Foundation walls should be constructed on a 40mm compacted layer of sand. Burnt brick or lump stone should be used for foundations where the bottom courses are corbelled out to provide a wide footing. The bottom of the footing is established by taking a line of 45 degrees from the foundation wall to the bottom of the footing. Where the wall is 230mm wide and there are two course of brick, then the footing will be a total of 530mm wide.

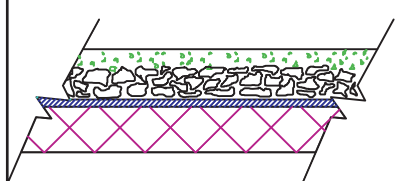
Where it is afforded, anti termite insecticide should be applied to the soil around the foundations. The effectiveness of the treatment will depend on the brand and supplier.



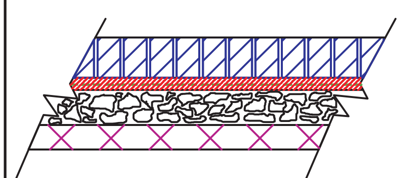
The construction of the ground floor can be constructed in a number of different ways depending upon the available funds and materials. A Damp Proof Membrane using 500 gauge polythene (plastic paper) should be installed to prevent damp rising through the floor. Some examples are given below:



- 20mm Sand /cement screed
- 75mm Concrete
- DPM
- Sand blinding
- Crushed brick / stone
- Compacted subsoil



- 50mm floated concrete
- Crushed brick / stone
- Sand blinding
- DPM
- Compacted subsoil

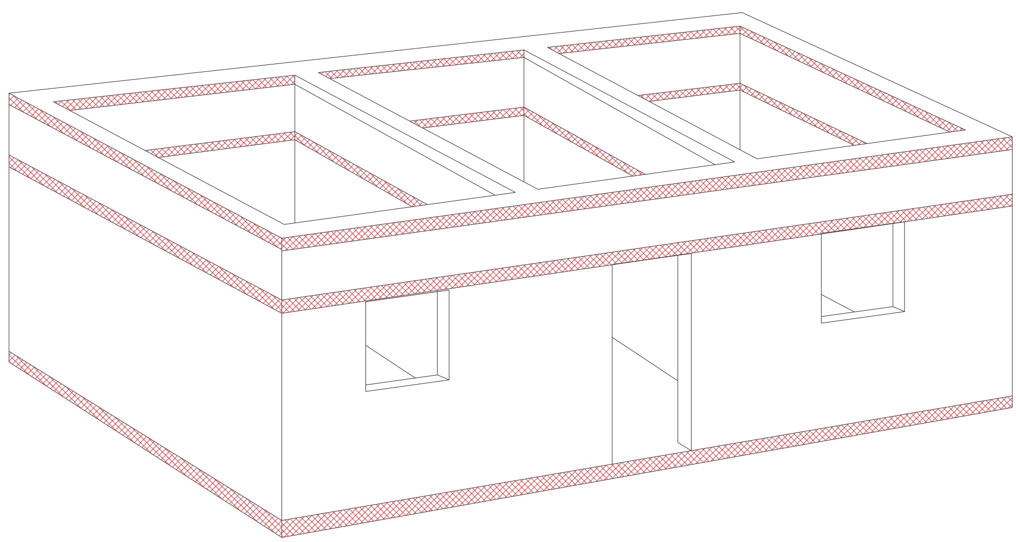


- Brick paving
- Sand bedding
- DPM
- Sand blinding
- Crushed brick / stone
- Compacted subsoil

Walls

A slenderness ratio applies to walls both horizontally and vertically. The thickness of a wall is determined both by its height and length. The length of a wall can be reduced by the introduction of piers or by being braced and supported by internal walls. Wall lengths should be no longer than 5m without having additional bracing.

The wall can be supported along its length with introduction of ring beams. Ring beam require formwork, reinforcement, and a design mix of concrete. Ring beams give additional strength and support to walls and are essential in seismic design but it is recognised that the cost implication of this may not be an option for financial reasons.

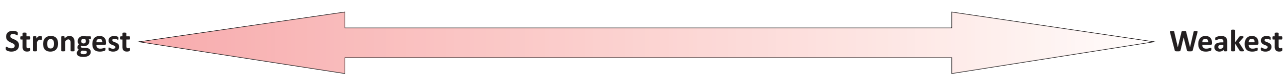


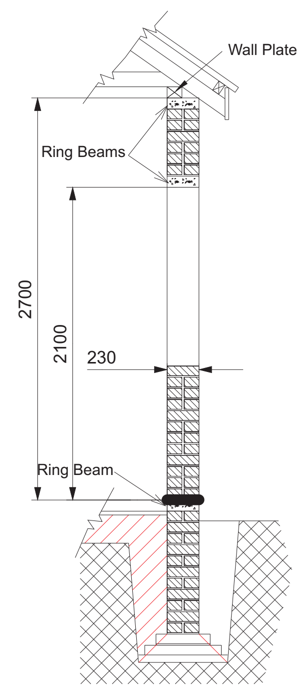
Ring beams and internal walls provide longitudinal support for walls. Ring beams should be positioned at plinth level, lintel level, and at wall plate level to tie the building together.

Where reinforced concrete cannot be used for reasons of cost, then reinforcement should be built into the walls. 2 x 6mm reinforced bar at every 8th course when using soil stabilised brick or Brick Force Wire in every 4th course when building using conventional brick.

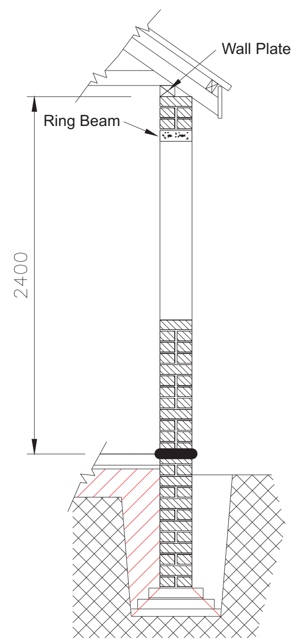
It is stressed that ring beams and horizontal reinforcement are essential for seismic resistant design.

Generally in seismically active areas a slenderness ratio of 1:8 is recommended for unreinforced masonry walls. This means that a wall of 2.4m will need to be a minimum of 300mm wide. This falls outside of standard brick sizes, where walls are 230mm wide but with additional bracing at wall plate height, structural stability can be improved. The introduction of a ring beam at head of door and windows height reduces the effective wall height to 2.1m and therefore falls approximately within the 1:8 ratio standard. The examples below show walls constructed with and without ring beams.

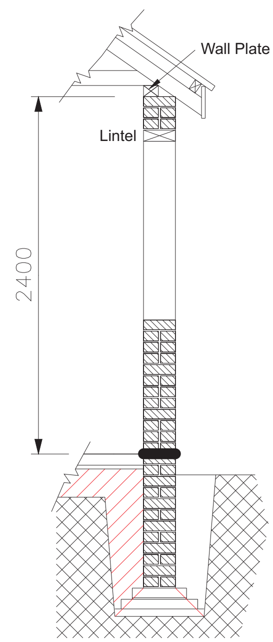




230mm wall constructed with two ring beams

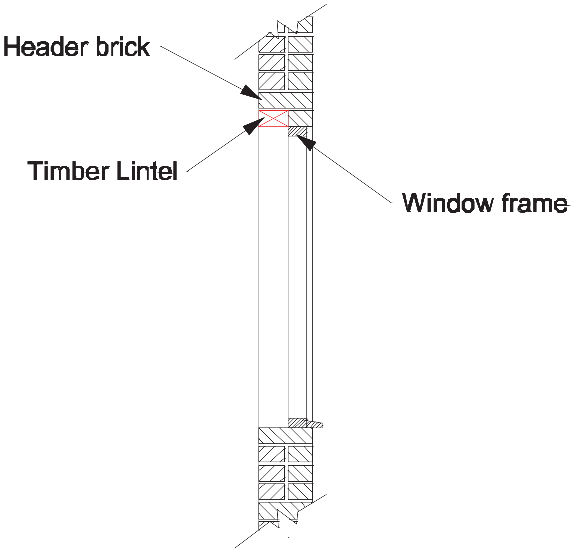


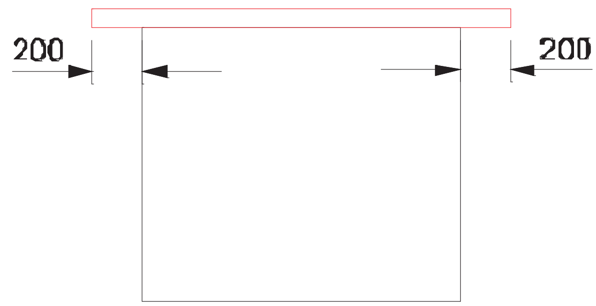
230mm wall constructed with one ring beam at lintel height



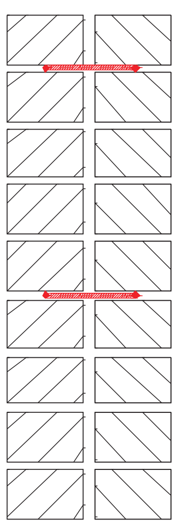
No ring beams with lintels fitted over doors and windows

Lintels should be fitted over doors and window openings and extending a minimum of 200mm beyond the opening. Concrete lintels are best used but cost can be prohibitive. An affordable solution, though not as strong, and so that the lintels are not visible on the face brickwork, the following detail can be used:

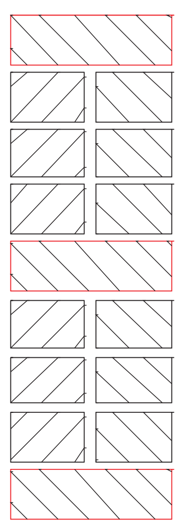




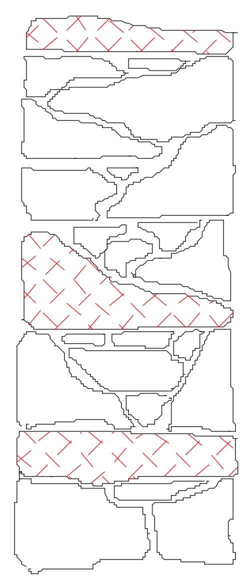
Masonry walls constructed of brick, earth, and stone need to have sufficient bonding. Unless cement mortars are used, brick force wire (BFW), will have little benefit, as it is the formation of the cement mortar reinforced layer that provides the bond between brick leafs. The most cost effective and strongest bond is to use the walling material as demonstrated below.



Brick Force Wire installed every 4th course. Must have cement mortar to be effective.

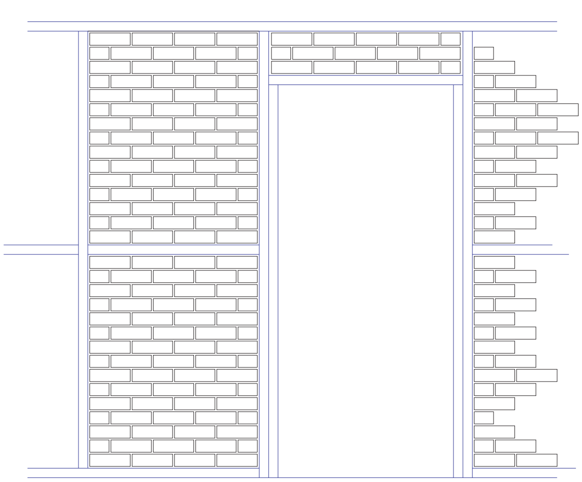


Brick header bond at every 4th course. Provides connection regardless of mortar used

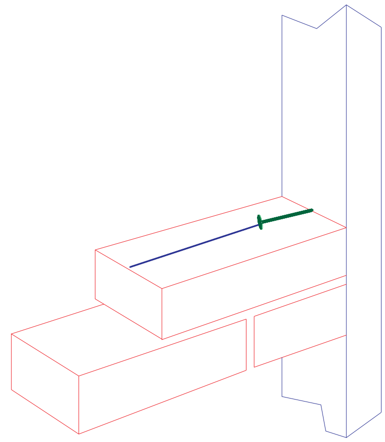


Tie stones built into the wall at spacing of maximum 600mm vertically and horizontally.

Internal walls, even those that are not load bearing require stability. In the recent earthquake many injuries were sustained due to the collapse of internal walls. The recommendation is that 115mm walls without additional support should not be used and should be 230mm wide. An affordable way of creating a 115mm wall is to construct a timber frame and brick between the studs and noggins. Use nails at every 4th course with a joining wire to provide connection between the brick and timber.



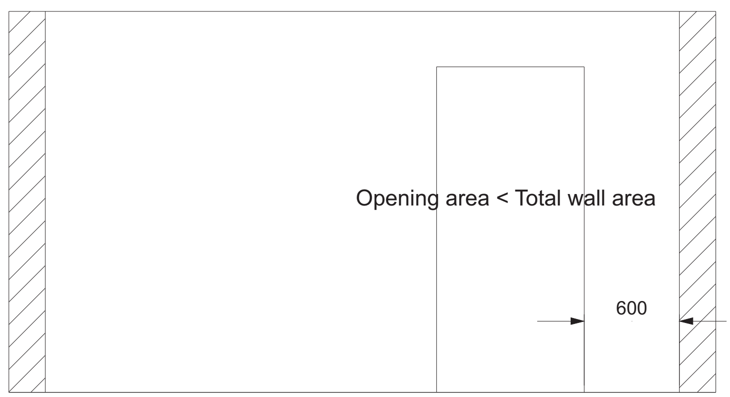
Timber stud wall with brick infill



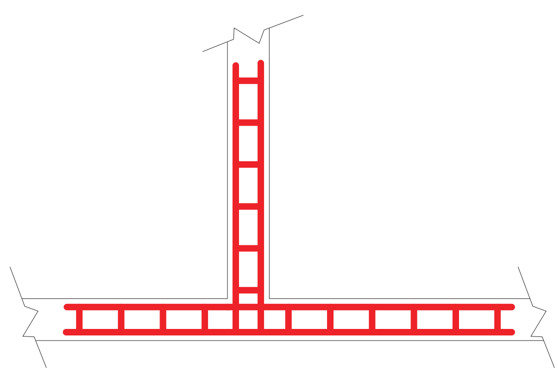
Nails fixed at every 4^{th} course

Where internal walls are load bearings and providing longitudinal bracing and support to the external walls, these need to be constructed in the same way as external walls and must be constructed on foundations.

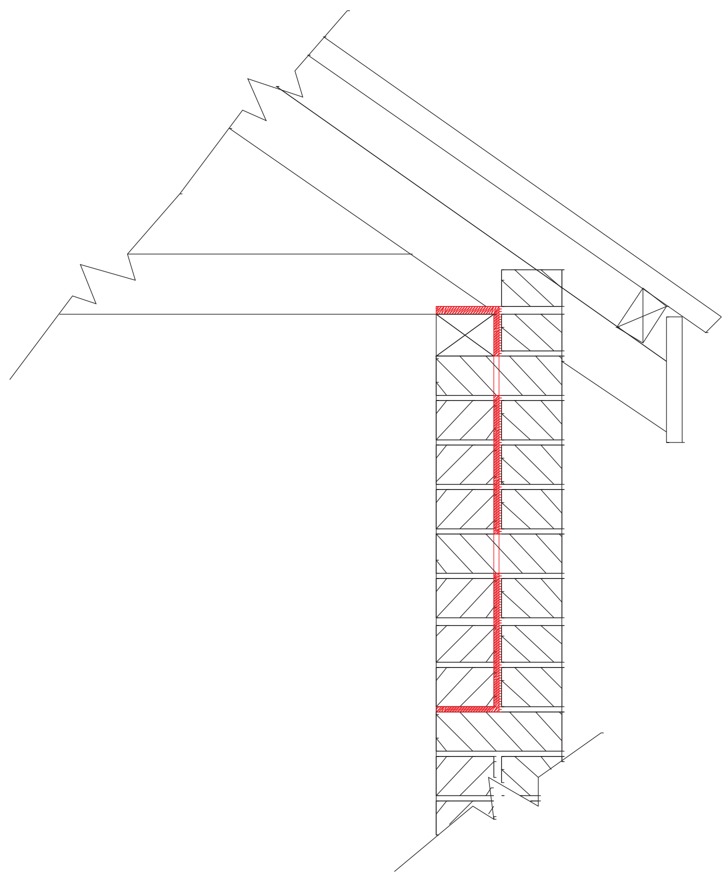
The position of internal openings effects the performance of the wall. As a general rule doorways and openings should be 600mm from the junction with the external walls.



Internal walls need to be connected to the external walls by bonding the brickwork with the external walls and where the walls are load bearing these should be further reinforced with BFW and cement mortar used at these junctions if possible.



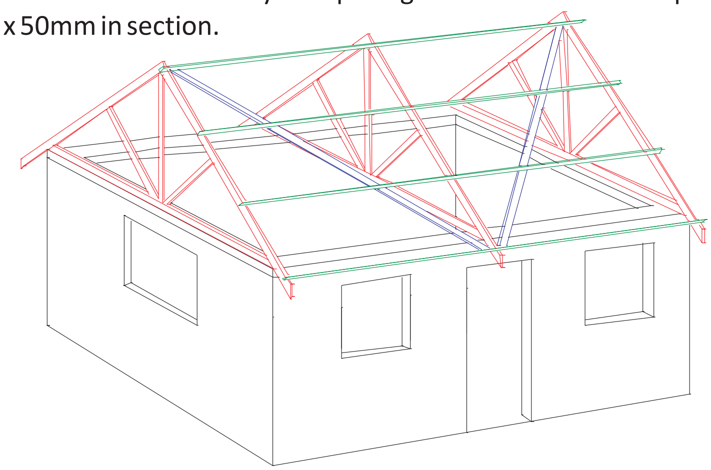
The wall plate is the junction between the roof structure and the wall. So that the roof structure provides bracing to the walls and that the roof is tied down, there needs to be suitable connection. By building wire ties into the masonry at 600mm centres, the wall plate can be secured.



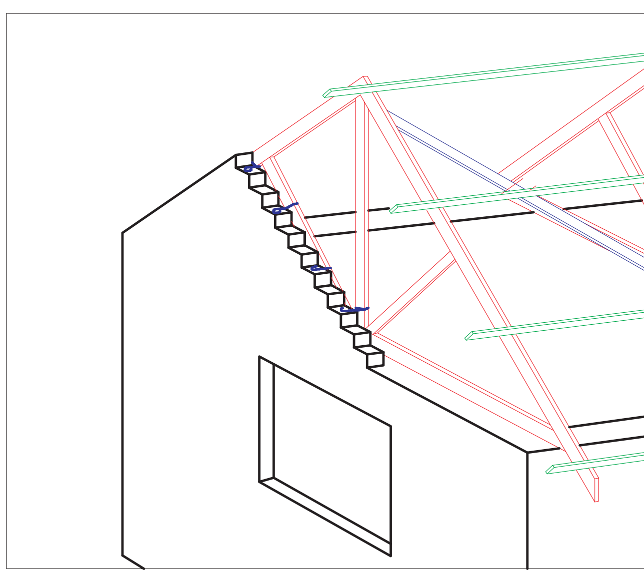
Roof

To eliminate high unsupported masonry walls it will be necessary to construct the roof using trusses. For reasons of cost these would normally be constructed using timber. The roof trusses support purlins which in turn support the roof covering. The roof must then be braced with 100 x 50mm timber to prevent movement from wind loads and earthquakes. The bracing must be fixed with two nails to the truss, wall plate and each intersecting purlin.

The spacing of the trusses is determined by the spacing and dimension of the purlins. Generally purlins should not be less than 100 x 50mm in section.



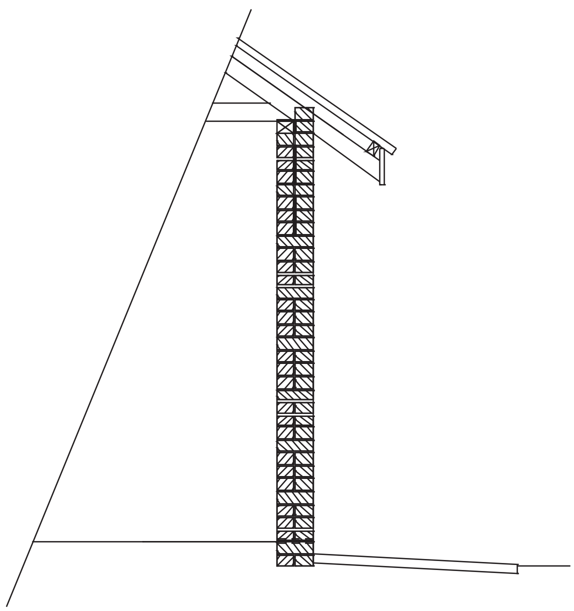
Where masonry gable walls are constructed these should not be load bearing and fixed to the truss to provide support and stability against wind load. The timber truss should be fitted in place and then a single thickness (115mm) wall constructed using the truss as the form. Using wire ties, the brickwork is attached to the truss. In the event of an earthquake the brickwork gable may collapse but the roof structure will remain. It is vital that bracing is fitted to the roof for this detail to work.



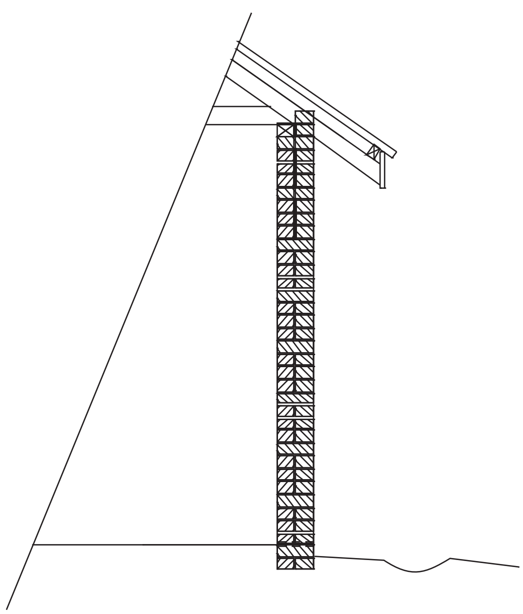
Trusses can also be constructed using steel and has the advantage of providing protection from termites. Where timber is used wood preservative should be used to protect against termite.

Surface Water Drainage

Rain and surface water can damage the fabric of the building and undermine the structure. It is therefore important to ensure that the external walls are protected and that surface water is directed away from the building.



Extending the eaves (over hang) of the roof will help protect the walls and also can provide shading. Where possible a concrete path or apron with a 1:10 fall should be constructed around the building to direct surface water away from the wall. This will protect the base of the wall and the foundations.



Where a concrete path cannot be afforded, a drainage channel should be constructed to take surface water away from the building.

Materials

This section is a simple guide to materials, their properties, issues of quality assurance, and cost.

Brick

Burnt and mud brick (adobe) should be made to standard brick sizes by taking care of the mould sizes and by minimising the amount of water used to reduce shrinkage. Bricks of even standard size should be selected when purchasing.

Burnt Bricks should be fired using fuel that is sustainable such as coppiced wood, wood waste, and rice husks.

Compressed earth bricks are formed using a hand or machine press. The compaction can produce a stronger brick than adobe bricks but will weather when exposed to rain. If the bricks take in moisture they will lose strength. Walls built from mud bricks must be protected from the weather.

Stabilised Soil Bricks (SSB) are compressed earth bricks that have a stabiliser such as cement or lime added to them. This creates a stronger more durable brick but is still liable to weathering and should not be used below Damp Course. The benefit over Burnt Brisk is the speed of production and the reduced impact to the environment.

Mortar

It is recognised that the cost of cement and lime based mortar may be prohibitive to be used throughout the construction.

Mud mortar needs to be kept dry to maximise its strength. Therefore ensuring a damp proof course is fitted and that the walls are protected where possible from driving rain is important. Pointing the brick with cement based mortar will also help to protect the mud mortar beds. Adding even small amounts of lime or cement will strengthen the mix. The soil should be passed through a screen to reduce the particle size to ensure that mortar beds of no greater than 10mm can be achieved.

Sand Cement mortar is to be mixed according to the manufacturers instruction but generally for masonry walls a mix of 1:1:9 (Cement : Lime : Sand / Mud) and 1:6 (Cement : Sand) on courses where there is reinforcement.

Concrete and screeds

Concrete is mixed to different mixes depending on the use. The table below provides measures by volume for each.

Application	Cement	Sand	Grave / Stone
Foundations	1	3	6
General Use	1	2.5	5
Reinforced	1	2	4

Aggregates

The quality of sand is fundamental to the eventual quality of the mortar and concrete. Sand from rivers may have high levels of clay and may required the level of cement to be increased. Sand should be also be selected so that there is no organic matter. Prior to using for mortar, the sand should be passed through a screen to remove larger particles.

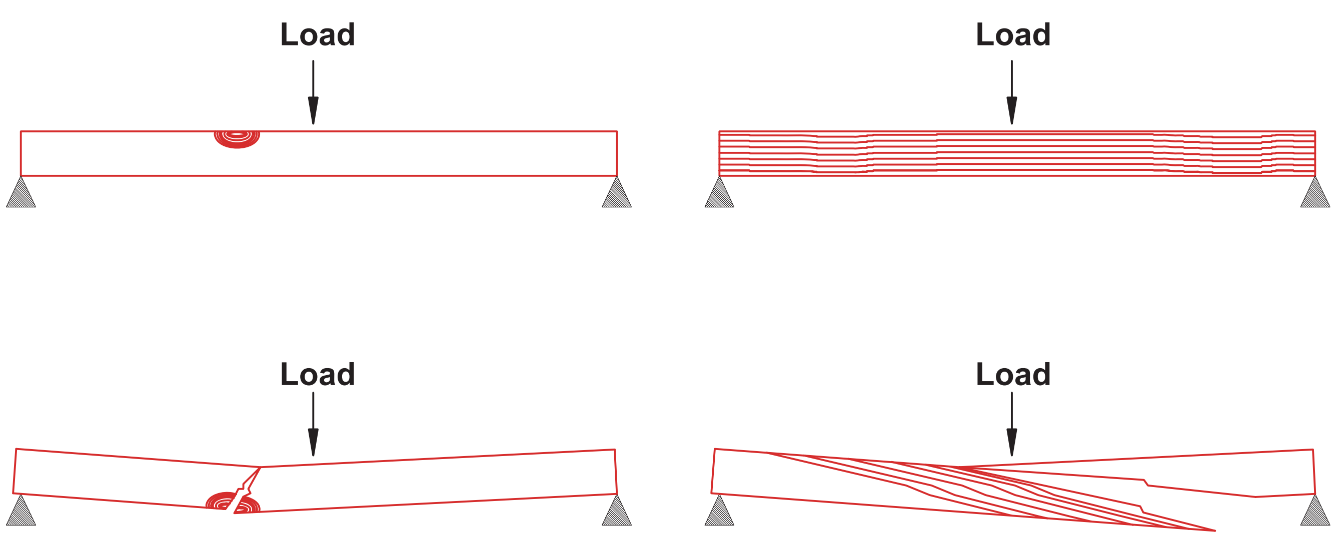
Stone and gravel used for concrete should ideally be crushed so that the particles have sharp edges to allow better cohesion. The strength of the stone will affected the mix and should be a granite or similar.

Timber

Timber is selected for its strength and durability depending on the application. When selecting timber for beams the following should be observed:

- Accuracy of section dimensions
- Straightness and twist
- There are no shakes and splits
- That preferably there no large knots on the outer edges of the timber. If there are, then ensure the knot is on the side of the load.
- That the grain runs along the length of the timber and does not run to the side.

See below:



Roof Covering

Corrugated Iron Roof sheeting is the most common roofing material and is therefore used as the baseline to compare other roofing options

Corrugated Iron Sheet

Advantages

- Availability
- Quality assurance
- Speed of fitting
- Minimum roof structure required (no battening needed)
- Durability (depending on the gauge)
- Provides rigidity to the roof
- Is lightweight and therefore beneficial in earthquakes
- Light to transport

Disadvantages

- Lightweight therefore vulnerable to wind if not properly secured
- Gets very hot in sunlight causing overheating in the buildings

Cement based roof tiles and sheets

Advantages

- Cement based roofing sheets and tiles are a heavier construction and therefore provide better insulation from the sun than corrugated iron
- The large sheets will provide additional bracing (tiles provide no bracing)
- Tiles may be available from local manufacturers

Disadvantages

- Roof tiles and require roof battens to be fixed
- The roof structure will need more timber than a corrugated iron roof due to weight
- The quality of locally made tile varies depending on the manufacturer
- Heavy to transport and subject to breakages

Thatch

Advantages

- May be locally available
- Provide excellent insulation from the sun
- Has limited / no environmental impact
- Can last for many years if the right material is used and that it is fitted properly

Disadvantages

- Suitable material is not widely available and depends on the time of year
- Requires thatching skills that may be hard to find and costly
- Roof requires additional battening
- Presents a fire risk
- Can become infested with insects and rodents

Methods

Mixing Mortar

- Ensure that the sand has been graded and the cement has been stored in a dry environment.
- Prepare a clean hard surface
- Measure the cement and sand using a bucket to ensure a regular and exact mix. Mix in batches that can be used within 1 hour.
- Mix the dry ingredients so that the sand an cement are evenly distributed
- Add sufficient water so that the mix is workable. The water must be clean.

Bricklaying

- Set out the first course of bricks to prior to laying to ensure that the correct bond pattern can be created.
- Take a piece of wood and mark the brick courses and the door and window levels. Use this to measure the brickwork.
- Construct the corners to a height of approximately 900mm. String line between the corners to fill in the brickwork.
- Brickwork should be checked for vertical alignment using a plumb line or spirit level.
- Where the bricks are high suction, wet the brick by dipping in a bucket of water. This will assist in maintaining mortar beds of 10mm and assist the curing process.
- As each portion of wall is completed, cover with damp material so that the mortar does not dry before it cures.
- During construction, protect walls from rain by covering the top of the wall with a strip of plastic.
- The walls should be left for 5 days before construction on the roof starts to allow sufficient time for curing.

Concrete

- Materials should be mixed in the same way as mortar, ensuring even distribution of cement and measured quantities
- Should be mixed with the minimum amount of water so that it is workable but not liquid. Too much water will cause the concrete to crack as the water evaporates
- Before laying concrete, ensure that the surfaces are damp to prevent the mix drying before it cures
- Concrete needs to cure for several days and must be kept moist. Clean water must be used and the concrete shaded from direct sunlight to prevent rapid drying

Building Repairs

Foundations

If the foundations of the building have evidence of subsidence or heave then the foundations need to be dug deeper in the affected area. This is achieved by underpinning by going but requires specialist skills to do this.

Generally, if there is serious structural failure due to ground movement it will require that the house is rebuilt on more stable ground. Buildings often have cracks due to settlement or minor ground disturbance that are of little concern.

Walls

Cracks in the brickwork cannot be repaired by simply filling with mortar. The brickwork in the affected area has to be removed and rebuilt.

Walls that are leaning are repaired by removing the bricks to a point where the wall is level and then rebuilding.

Retrofitting

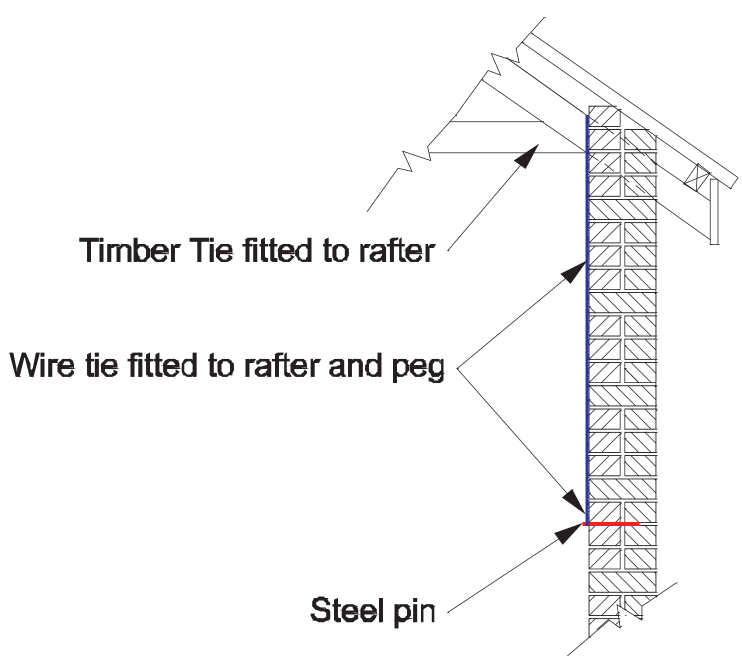
Retrofitting is the process of making an existing structure stronger. The following are suggestions how this can be done.

Walls

- Follow the design guidelines to reposition and resize door and window openings
- Lintels fitted to the door and window openings.
- Where walls are longer than 5m construct an internal or external pier. These must be constructed with foundations.
- Gables should be either be removed and a hip roof constructed or a braced truss fitted to the gable ends, the wall removed and rebuilt as 115mm wall tied with wire to the truss
- Walls can be strengthened by applying a cement render. The brick joints must first be raked out by a minimum of 20mm so that the render has sufficient key.
- Internal walls supporting the roof should be replaced by timber trusses

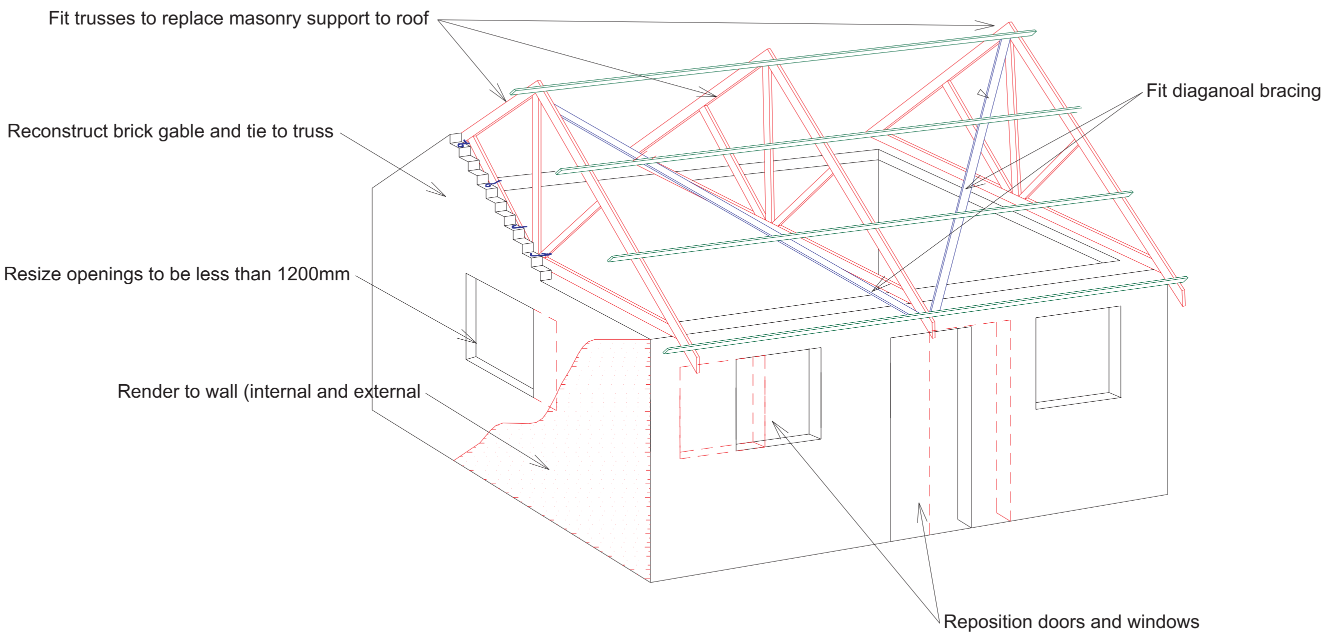
Roof

- The roof should be fitted with diagonal bracing fitted to the underside of the purlins
- Cross members / timber ties fitted to the rafters to prevent the outward movement of the rafters.
- Provide additional fixings to the roof covering at eaves and ridge to prevent being blown off in high winds and to provide additional bracing
- Fit wire ties from wall plate (if fitted) and rafter / truss ends to metal bars hammered into the brickwork at least 1200mm from the top of the wall



Retrofitting can be carried out over a period of time depending on time, available materials, and finance. The improvements should be prioritised in the following order:

- Strengthening and bracing of the roof structure
- Providing ties to hold down rafters and wall plates
- Fitting lintels to door and window openings
- Alterations to door and window openings
- Apply render to walls



The Guidelines have been produced in collaboration with other Government Departments, UNHABITAT, Malawi Red Cross Society, TEVETA, CCODE, and the Malawi Institute of Engineers, with technical and financial assistance from the World Bank and DFID