Supplementary Handbook to
‘Guidelines for Safer House Construction’

Content

Introduction

This handbook has been produced as a supplementary document to the ‘Guidelines for Safer House Construction.’ The purpose of the handbook is to summarise the key elements from the ‘Guidelines for Safer House Construction’ into easy to follow diagrams and pictures.

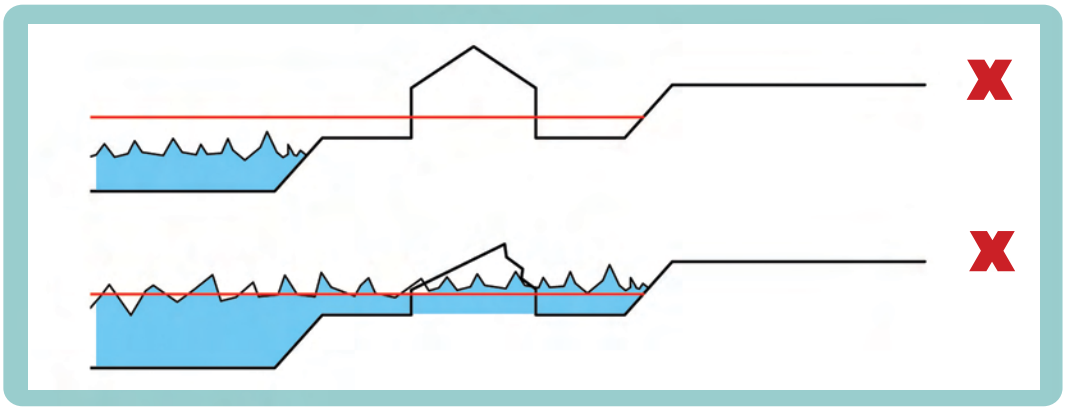
The handbook should be read alongside the ‘Guidelines for Safer House Construction.’ and serve as a quick reference guide.

The main aim is to encourage safer house construction, to mitigate damage from earthquakes, floods and other natural forces. The handbook has been divided into four main sections; Site selection, design, construction, and retrofitting. By starting at the beginning of the guide it should be possible to follow the stages from choosing a site to the final construction of a house.

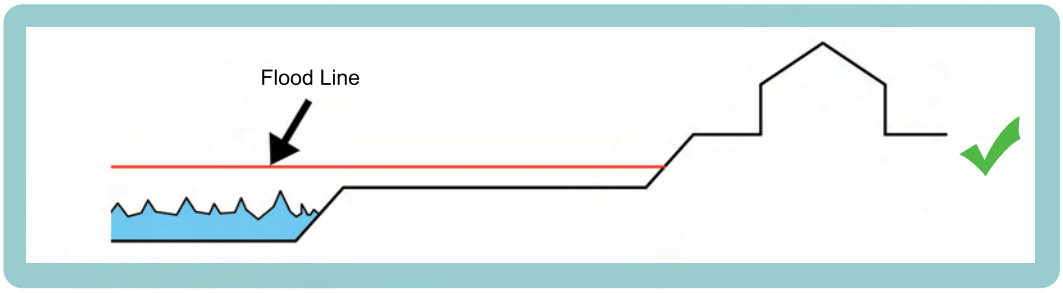
1. Site Selection

Floods and Flash Floods

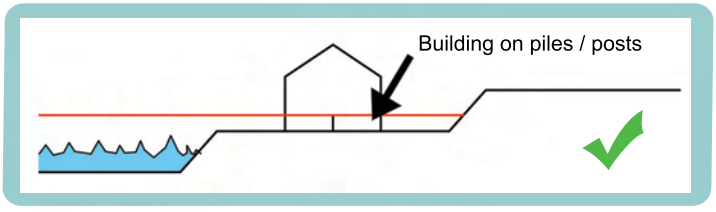
- Floods can cause damage to buildings
- Identify areas with a low flood risk.
- A selection of materials and structure may reduce damage. Materials that are more resistant to damage include burnt brick, stone and cement mortar.



- A building should be positioned away from the flood risk area.



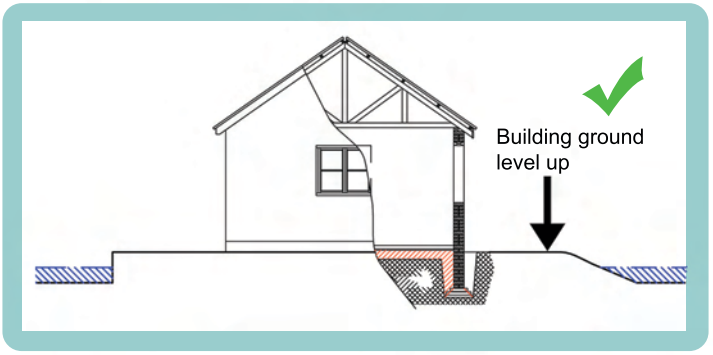
- Constructing buildings within a flood risk area requires that the floor level is raised above the flood line.



- This can be achieved by building on piles/posts

OR

- Constructing foundation walls to the height required and building the ground up around the the building.

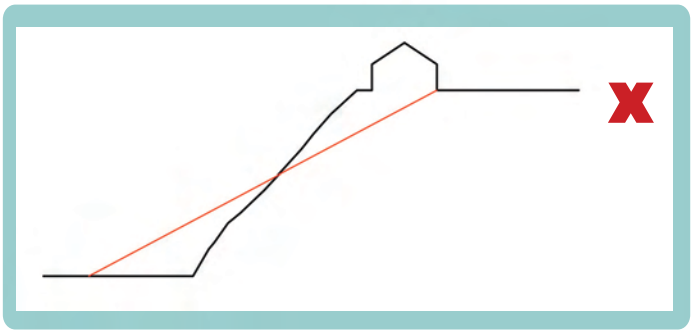


a) Local knowledge, hydrological data and historic reports will allow areas at risk to be identified.

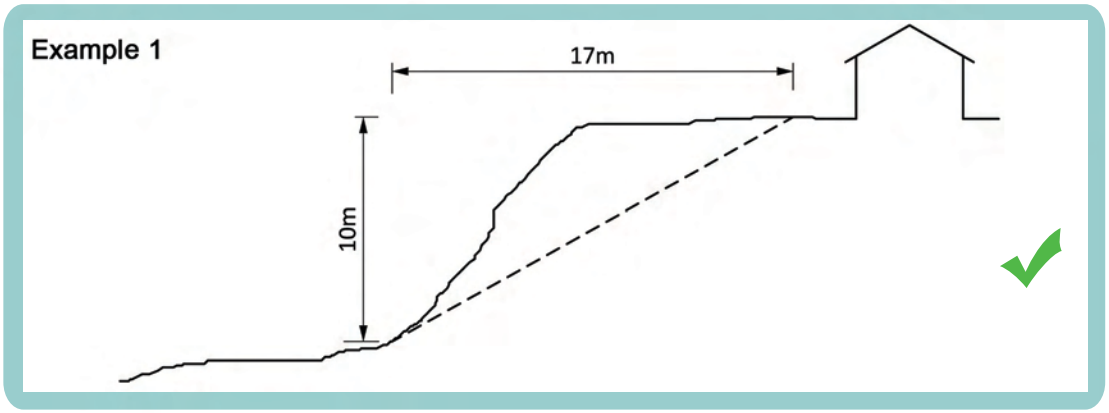
b) Damage caused by floods can be either eroding the mortar and materials, under scouring the foundations, or by water pressure and debris where there is flowing water.

Landslides

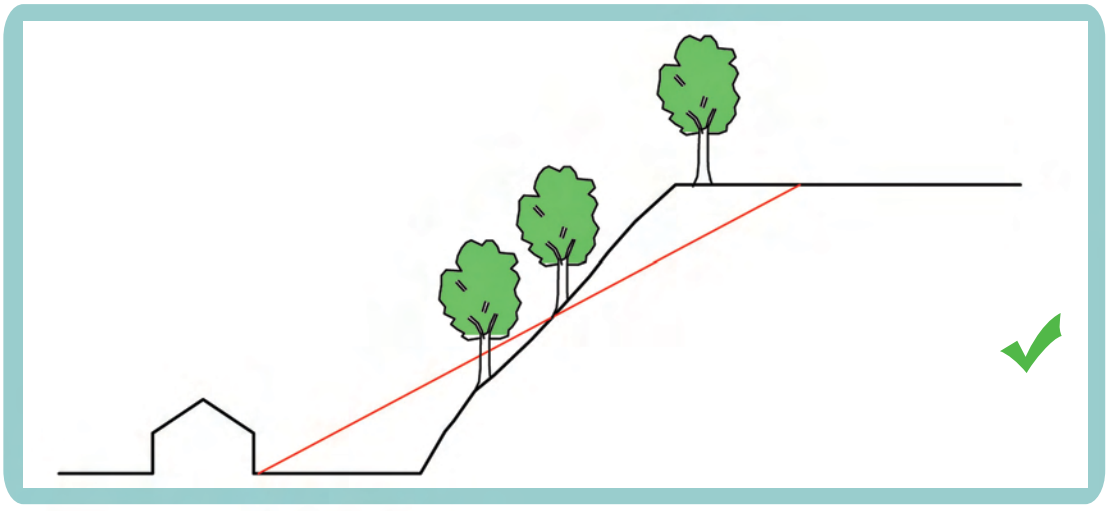
- Slopes with more than 30 degrees are at risk of landslide.
- Make sure any building is located out of the area of risk.



- As a guide allow 1.7m horizontally for every 1m vertically to identify the area of risk.



- Buildings constructed at the bottom of slopes may be more at risk than those above.
- Locate the building away from a slope to reduce risk.
- Plant trees on the slope to reduce risk.



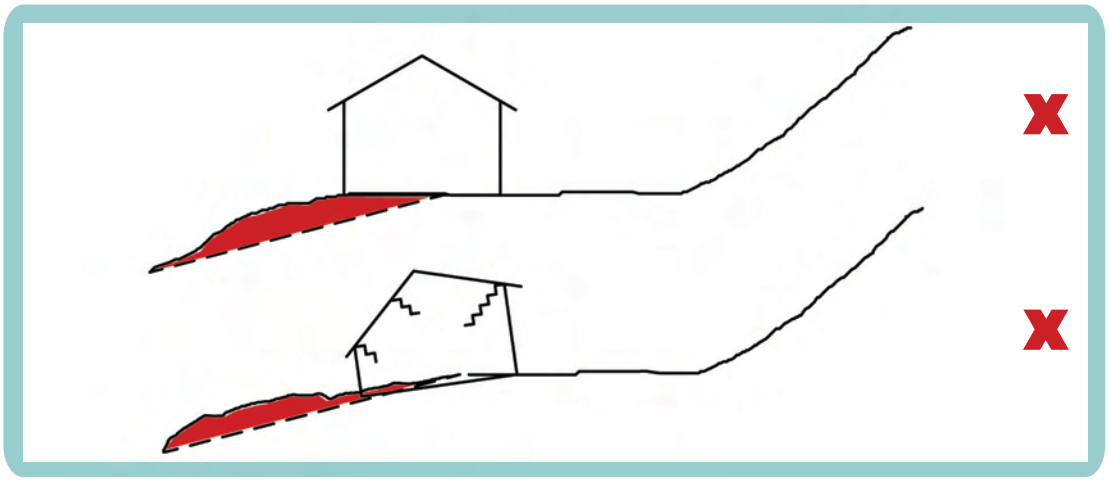
c) Factors that make areas vulnerable to landslide include: soil type and conditions, steepness of slope, lack of surface water drainage, deforested and cultivated land.

d) It is 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.

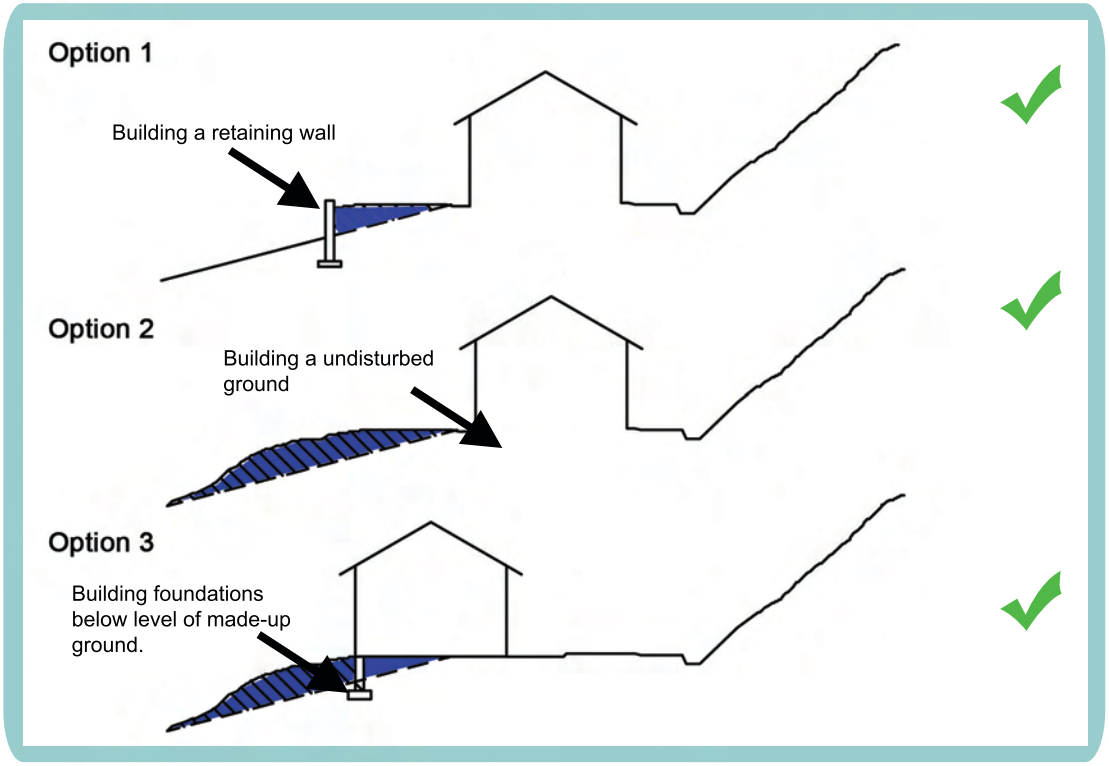
e) If it is necessary to construct within the area of risk, the construction of retaining walls and reducing slopes may be an option.

Building on slopes

- Houses constructed on slopes may be at risk of landslide.
- Many buildings on slopes are constructed on levels created by cutting into the slope and using the excavated material as fill.
- This made up ground has the potential to collapse.



- Buildings should be constructed on undisturbed ground.
- To reduce risk of subsidence and landslide of made up ground, retaining walls can be constructed.

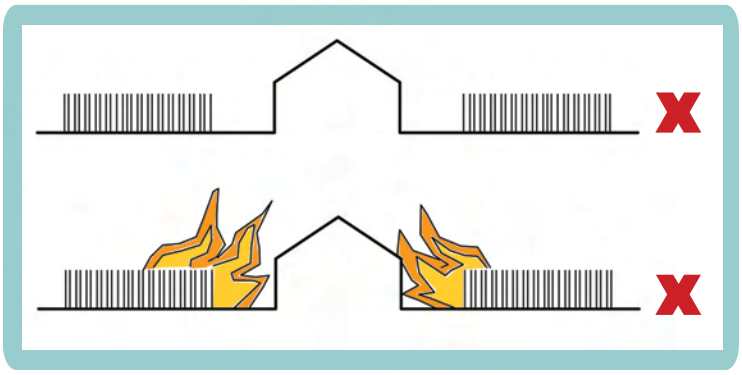


f) The made-up ground has the potential to subside or give way over a period of time as the ground settles; movement due to surface water, such as heavy rains; or because of earthquake.

h) 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 can cause a landslide.

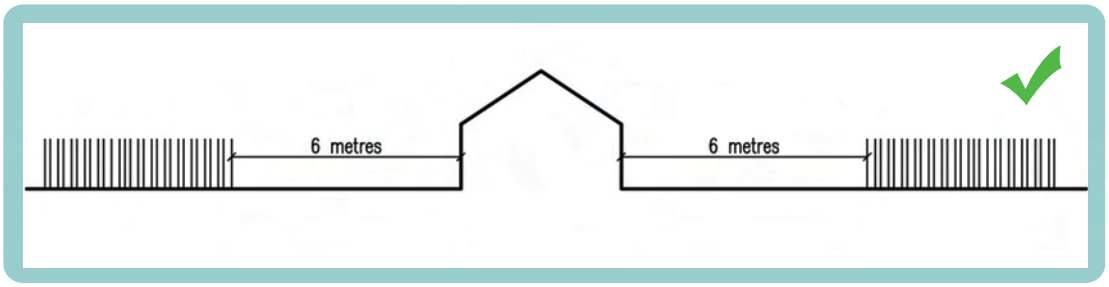
Fires and Wild Fires

- Fire is a major threat to person and property.
- If a house is positioned less than 6m away from dry grass or crops this creates a fire hazard.



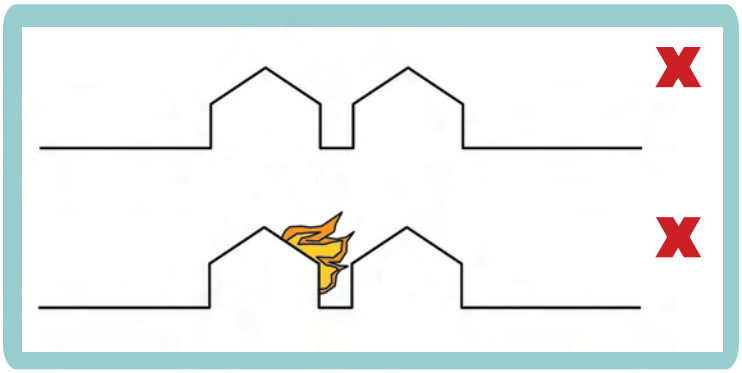
i) Dry grass and vegetation, including crops, are the obvious fuel for fires. Wild fires can spread quickly.

- Houses should be positioned 6-10 metres away from dry grass/crops.

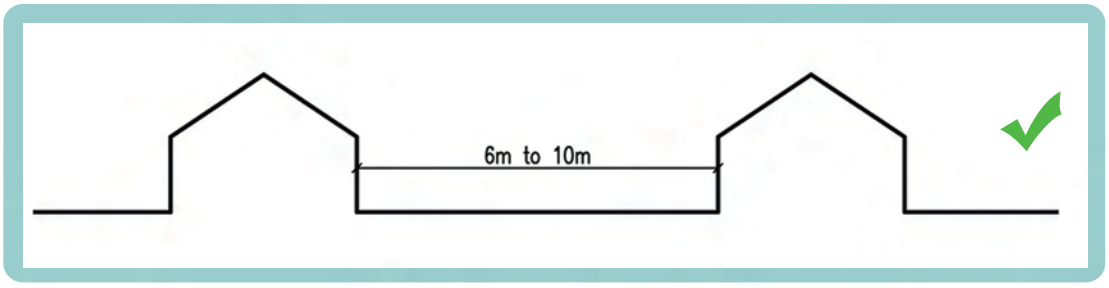


j) The guideline is that a distance of 6m in urban areas and 10m in rural areas should be maintained between any other building or boundary.

- Fire spread between houses is a major threat to person and property.
- Non-combustible materials such as sheet metal and concrete should be used on walls facing nearby houses.

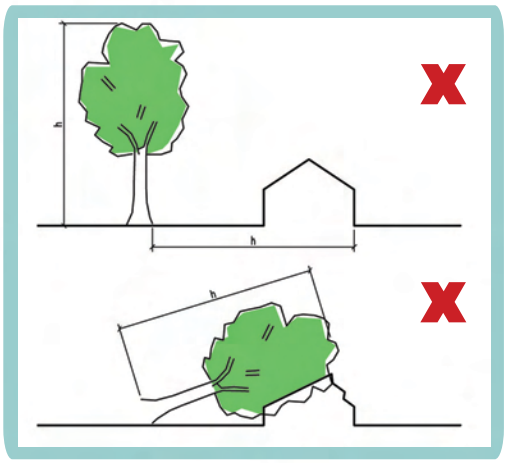


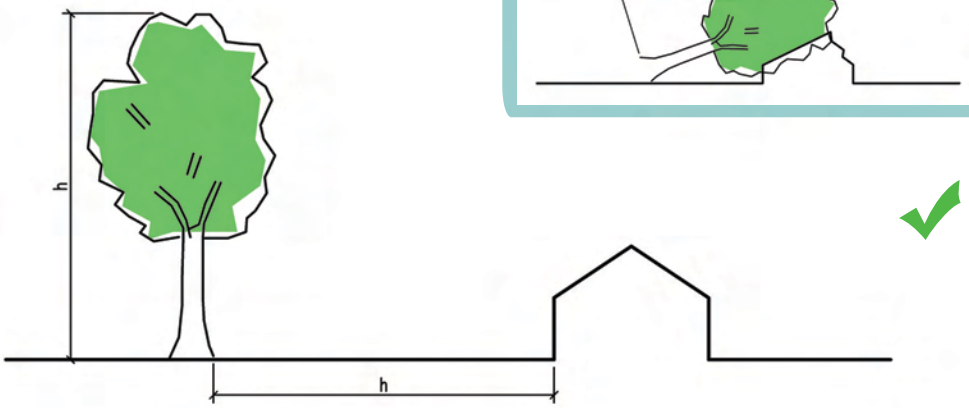
- A minimum distance of 6-10m should be maintained between houses.



Wind Storms

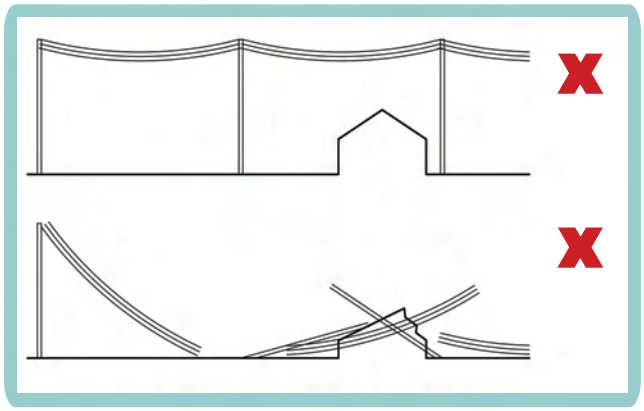
- In high winds there is a potential for trees, power lines and other structures to fall on property.
- A house should be located a distance equal to the height of a tree or object to reduce risk.

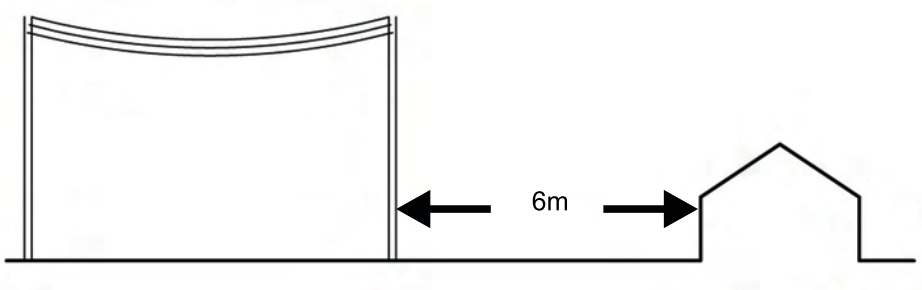




Power Lines

- Houses should not be constructed under power lines and should maintain a minimum distance.
- As a minimum any property should be at least 6m horizontally from a power line.

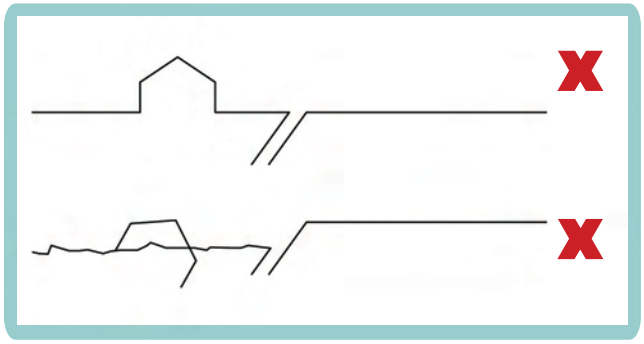




k) The electricity supply company (ESCOM) should always be consulted for confirmation of the safe distance that applies.

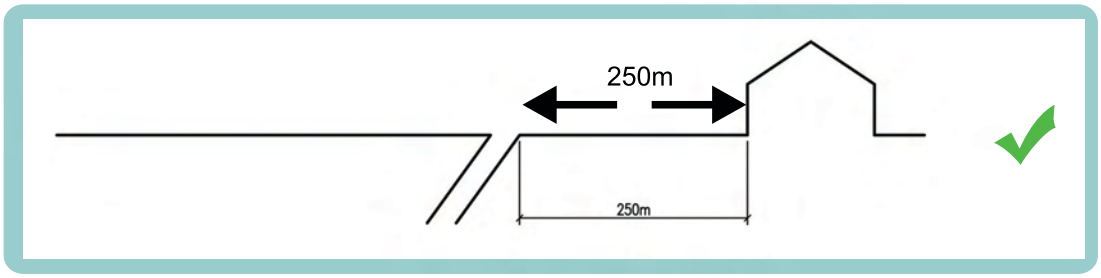
Earthquakes

- Earthquakes are unpredictable in terms of location and occurance.
- Areas of known seismic activities, where there are faults and ground ruptures should be avoided when constructing buildings.



l) Using local knowledge and geological and historic data, buildings should be constructed away from areas where there has been known ground movement.

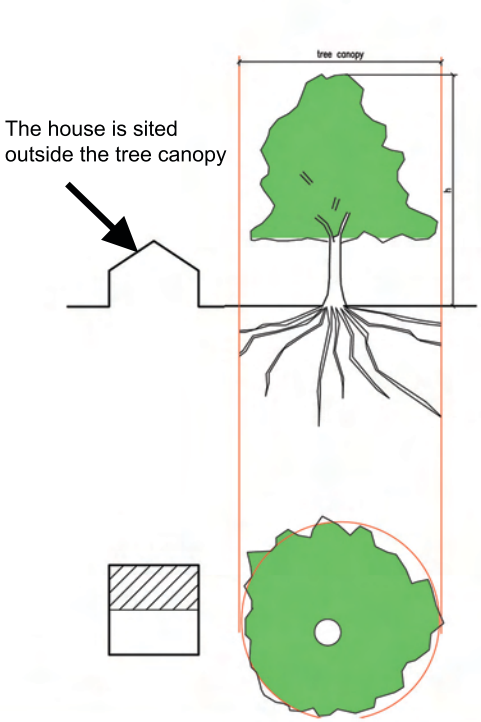
- It is recommended that any buildings are constructed a minimum distance of 250m from any known area of ground disturbance.

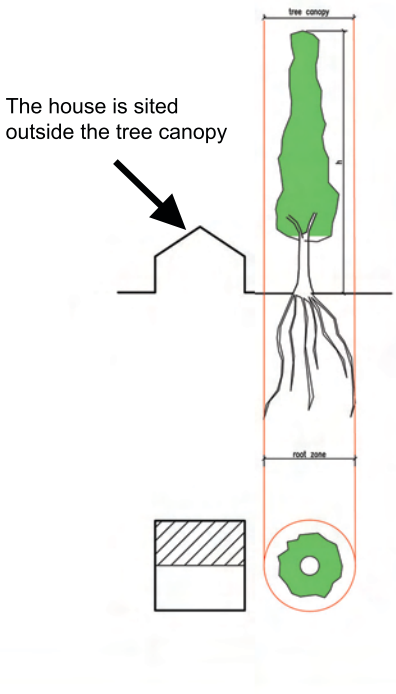


Subsidence and Heave

- Buildings should be constructed outside of the canopy of any tree.
- An estimate of the mature tree size is required if the tree is not fully grown.

m) Soil type, soil moisture and organic content are primarily the cause of subsidence and heave especially where there are high shrinkage clays.

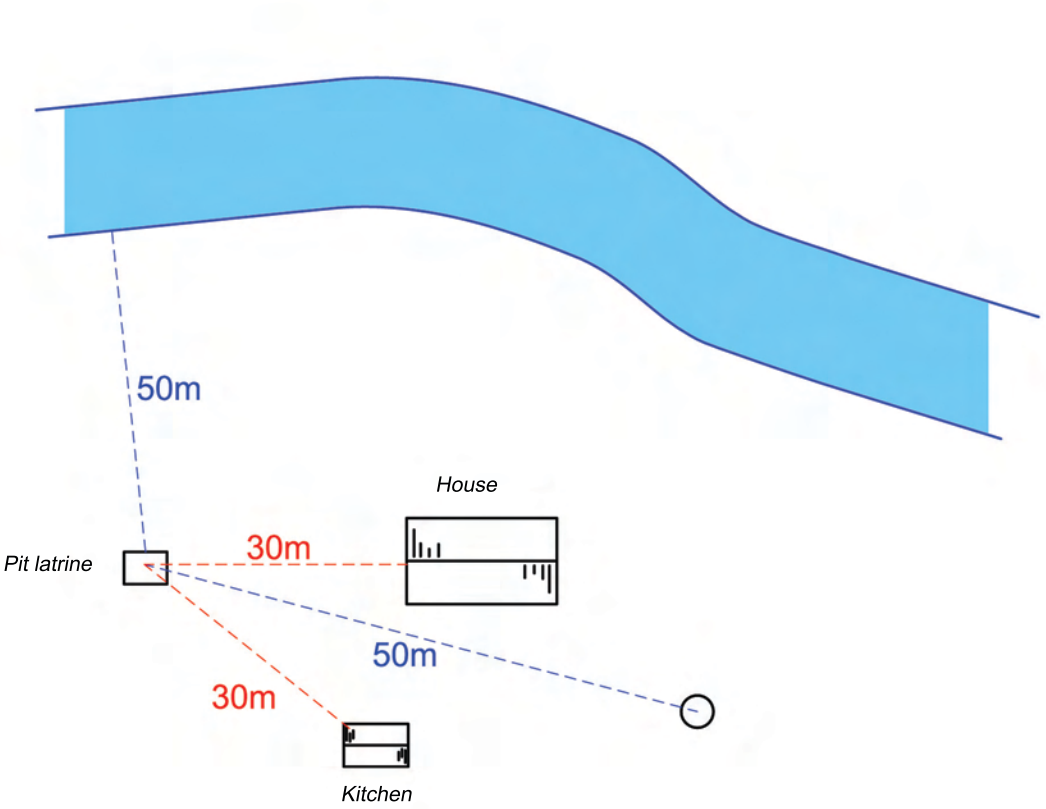




Pit Latrine Location

- Houses need to be located at a sufficient distance from latrines and refuse areas.
- Pit latrines should be a minimum of 30m from houses.
- Pit latrines should be at least 50m from any water sources such as wells, boreholes, river and water courses.

n) This is to avoid risk of vector (flies, rodents etc...) borne infection.



2. Design

Shape

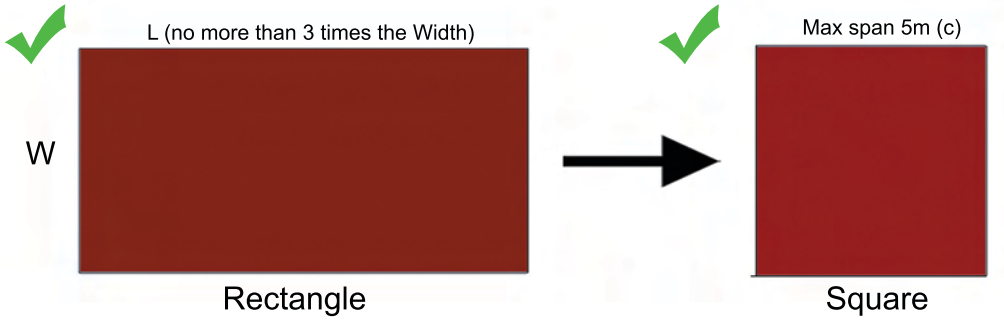
- The shape of a building is fundamental to the structural stability and ability to withstand external forces, in particular seismic activity and wind loads.

a) The taller and more slender a building is the more vulnerable it is.

- The main principle to reduce risk is to design buildings that are low and wide.

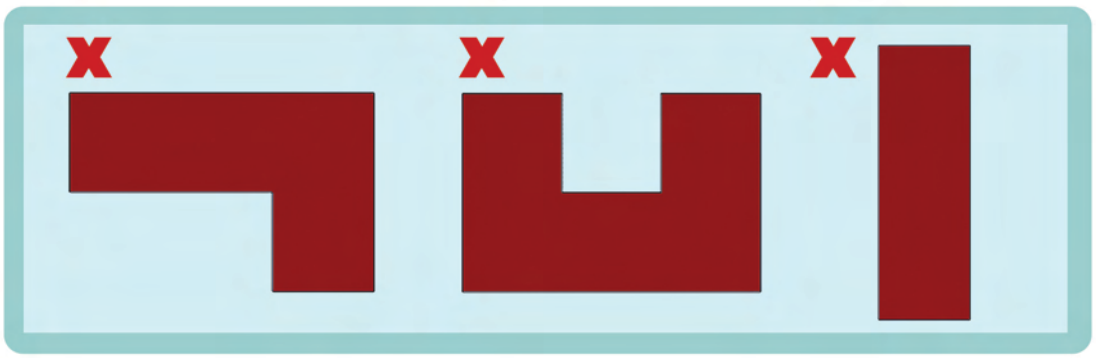
b) The best shapes for design recommended in the guidelines should not require complex engineering solutions.

- A square or rectangle is the safest design option.



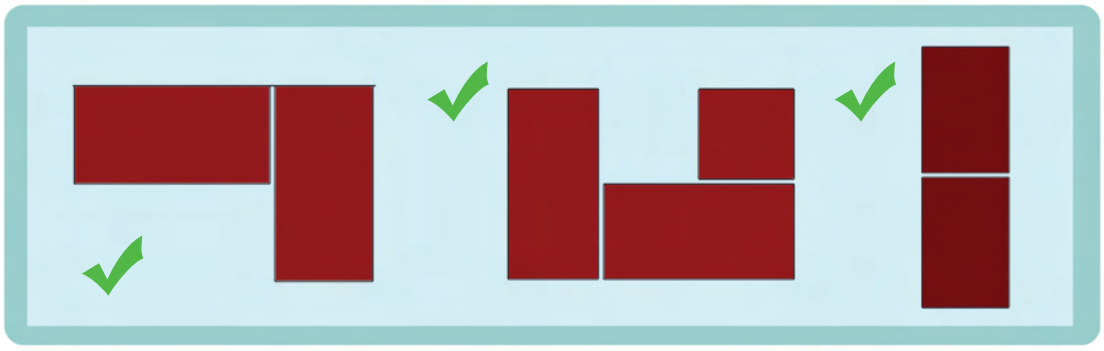
c) Any unsupported wall should be maximum 5m. Longer lengths can be achieved with support.

- Narrow rectangular shapes and complex shapes are not acceptable.



d) Narrow rectangular shapes and complex shapes have inherent weakness.

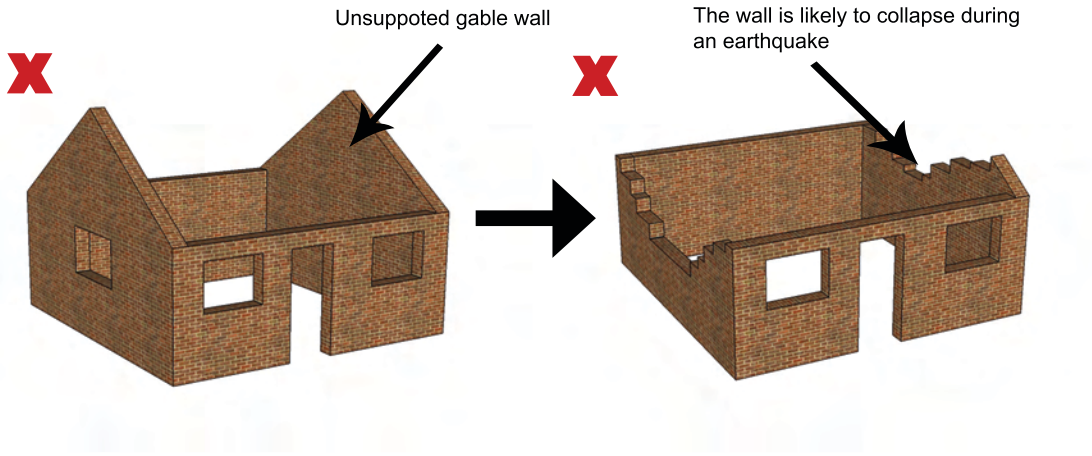
- The same building shape can be achieved using modules.
- The space between the modules can allow for movement during earthquakes.



e) The space between modules create seismic joints that allow differential movement during earthquakes.

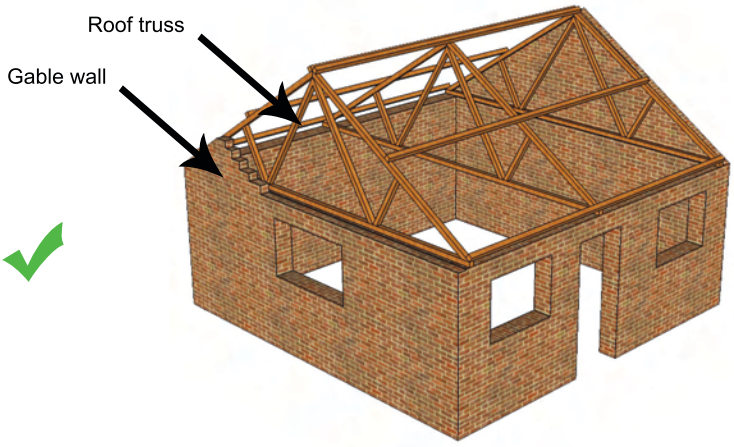
Gable Walls

- Buildings should avoid features where there is unsupported masonry such as gable walls.
- Unsupported gable walls is one of the main causes of structural failure in earthquakes.

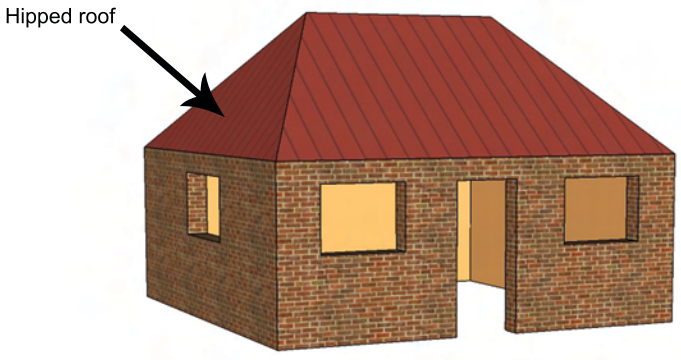


f) In an earthquake or under wind loads the gables are liable to movement and collapse. Design should eliminate these features where possible.

- A safe design is to use roof trusses. This provides structural support to the gable wall.



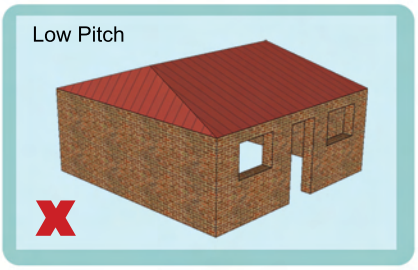
- A safer design is to build a hipped roof. This removes the need for a gable wall.



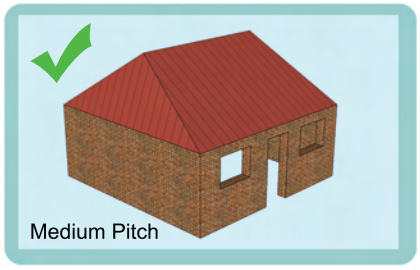
g) A hipped roof not only removes the requirement for gable support, it also reduces the surface area for wind load.

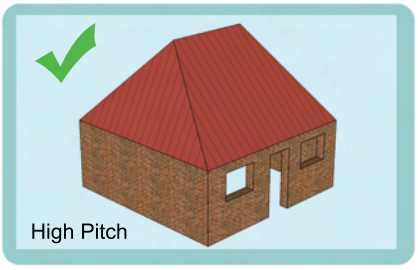
Roof Pitch

- 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 degrees and 40 degrees should be achieved.



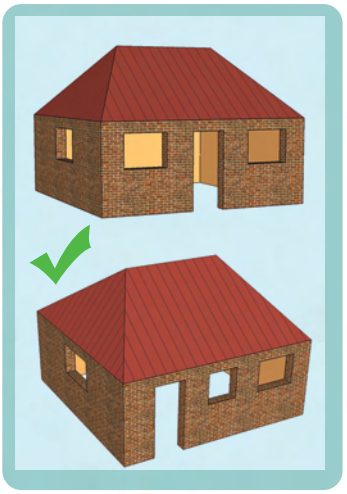
h) A high pitch roof may have the added advantage of providing better air circulation space to reduce over heating.

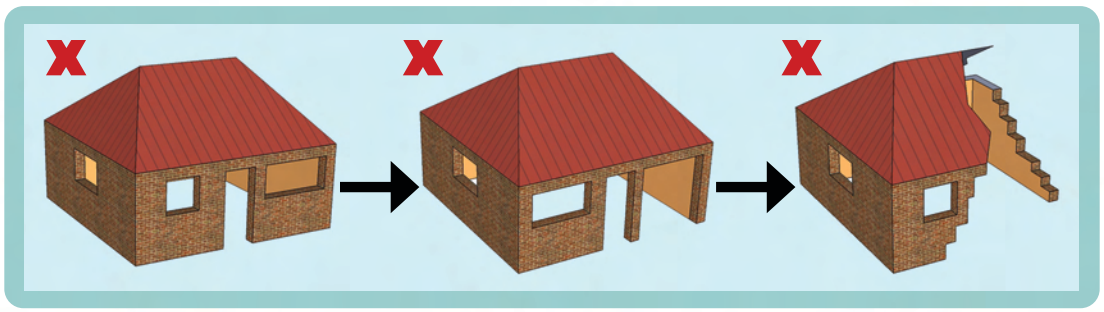




Openings

- The strength of walls is influenced by the number, size and position of door and window openings.
- The area of openings should not exceed 50% of the wall.
- A general rule is a minimum distance of 600mm from window openings to corners of buildings.
- A door should be ideally situated toward the centre of the wall or a minimum 900mm from the corner of a building.
- Openings should be maximum 1200mm in width.





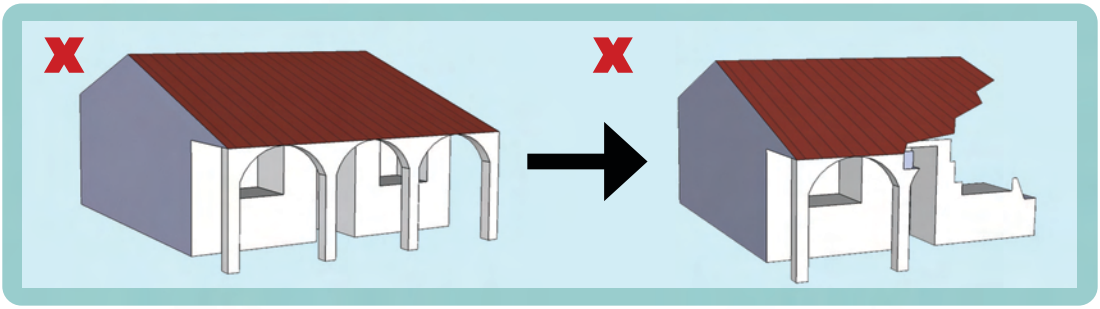
Pillars and Posts

- Pillars are required to provide support for covered areas.

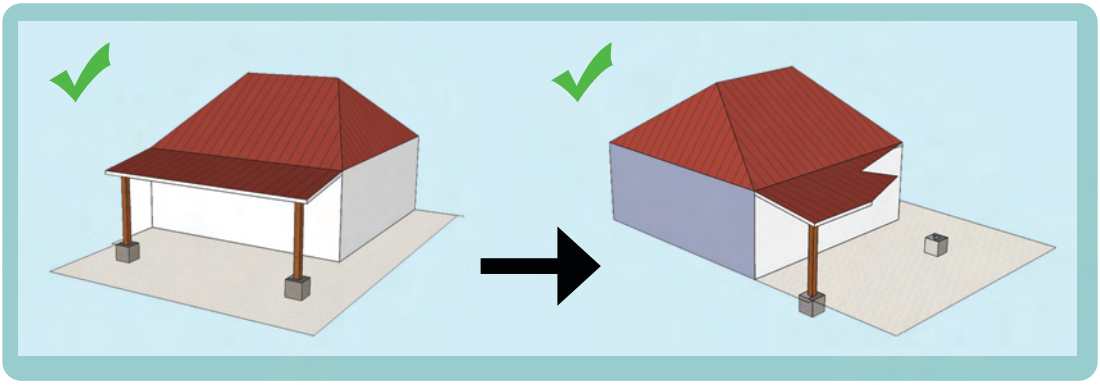
- Should pillars and posts be required in design it is best to design the covered area as a seperate element.

- The pillar should be lightweight in construction.

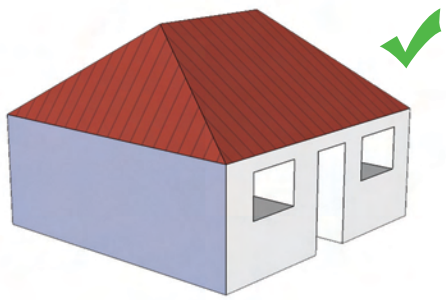
- The pillar should be fixed to the foundations to prevent uplift.



- During an earthquake the pillar is likely to collapse. If it is seperate from the main structure the damage will be minimal.



- The safest design is to have NO pillars or posts.



i) Pillars have little support and so are vulnerable during earthquakes.

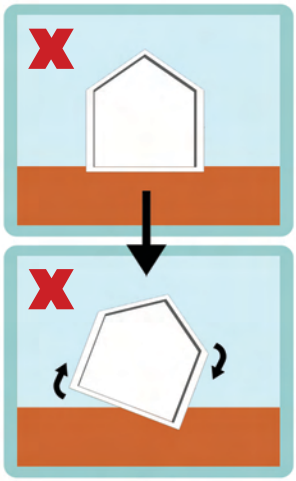
j) Ideally the safest design should exclude pillars and posts.

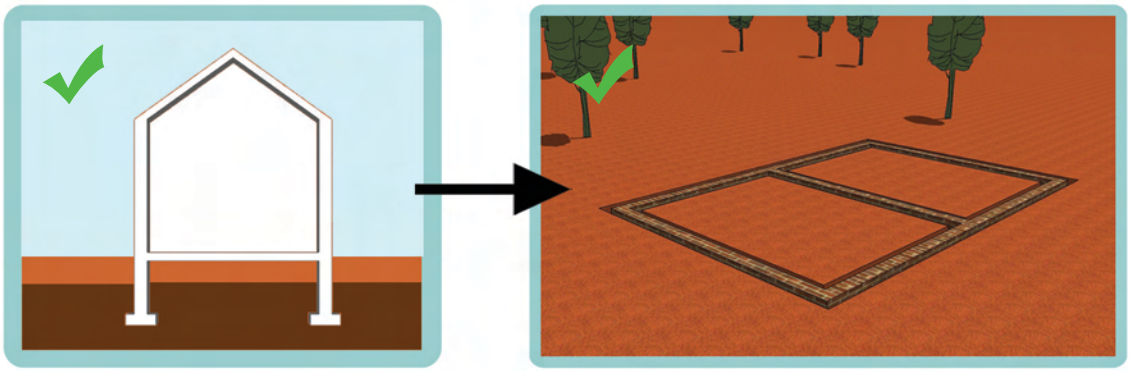
k) It is best to design the covered area as a seperate element so that in the event of an earthquake or highwinds any movement will not affect the rest of the structure.

3. Construction

Foundations

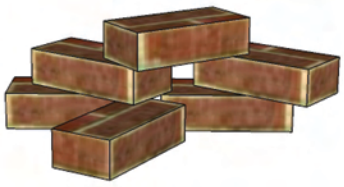
- Foundations are commonly brick walls built into the ground to a safe depth.
- The foundations anchor the structure of a building to the ground.
- Foundations transmit the loads of the building directly to the earth.
- Foundations have to be deep enough to protect them from erosion, surface water, tree roots, and subsidence and heave.





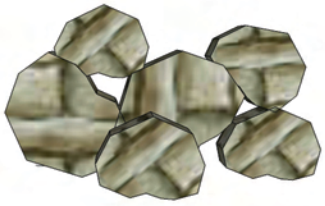
a) The guidelines focus on brick construction, as this is the most common construction type and the type most at risk.

- Burnt brick



OR

Lump Stone



- Anti-termite Spray

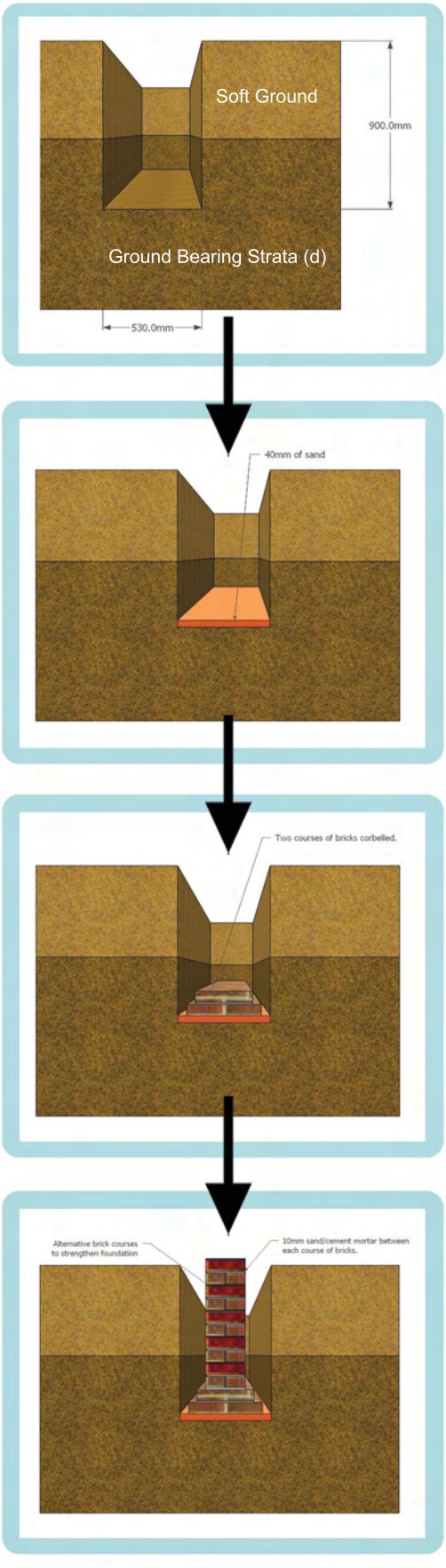
The effectiveness of anti-termite spray will be determined by brand and supplier.

b) Where it is afforded, anti termite insecticide should be applied to the soil around the foundations.

- Sand / Cement mortar for bonding brick or stone.
  The mix ratio = 1:6

c) 1: 6 mix means 6 part sand and 1 part cement.
For example: one bucket of cement and six buckets of sand. Mixed with water.

Foundation Construction



- The minimum depth of a foundation is 750mm. The best depth is 900mm.
- The width of the foundation should be 530mm, based on a 230mm brick wall.
- If the ground is soft the foundation has to be dug deeper.
- Foundations should never be constructed on made-up ground, even if it appears firm.

d) 'Ground bearing strata' can be defined as soil that has been undisturbed and is compact.
A rod can be used to detect the depth to ground bearing strata.

- Once the foundations have been dug a 40mm layer of sand can be laid on the bottom of the foundations.
- The sand should be compacted and watered.

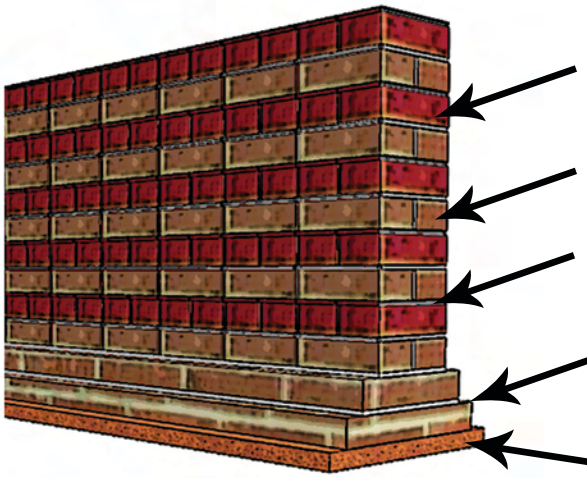
- Two courses of brick should be laid on top of the sand using sand/cement mortar.
- The bricks should be corbelled at an angle of 45 degrees.

e) Corbelled brick courses should be stepped by 50mm.

- The brick size should be minimum 230mm wide x 65mm x 110mm.
- The brick courses should have 10mm sand/cement mortar inbetween.
- The brick courses should alternate from stretcher to header bond.

f) Please refer to the following page that describes the brick bond.

Foundation Wall



Header Course .
Brick size = 230mm x 65mm x 110mm

Stretcher Course
Brick size = 230mm x 65mm x 110mm

10mm Sand/cement mortar.
1:6 mix ratio.

Corbelled (stepped) brick by 50mm for two courses

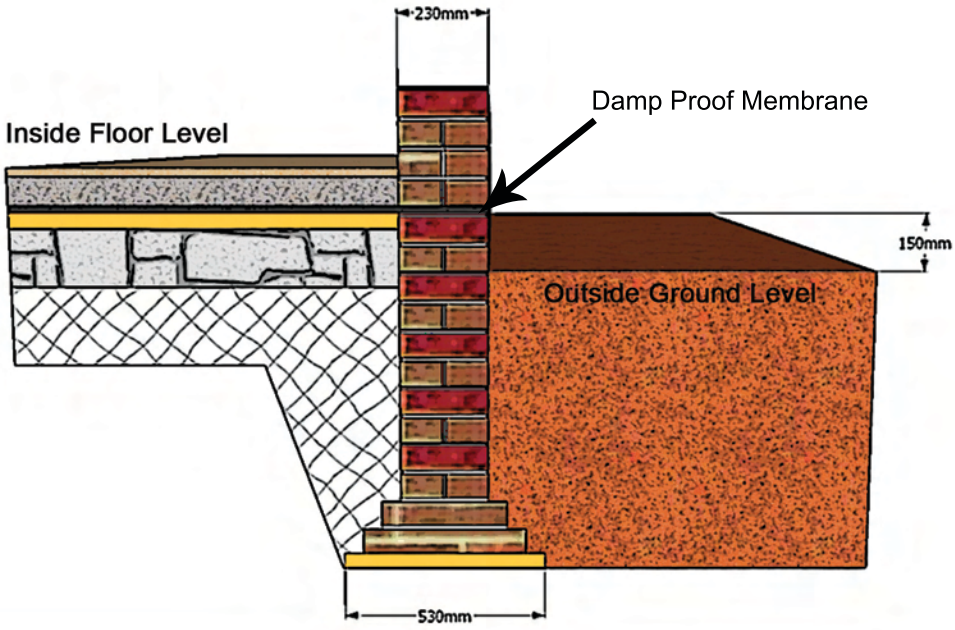
40mm Sand blinding. Compacted and watered - 530mm wide.

g) It is important to alternate the courses for stronger foundations

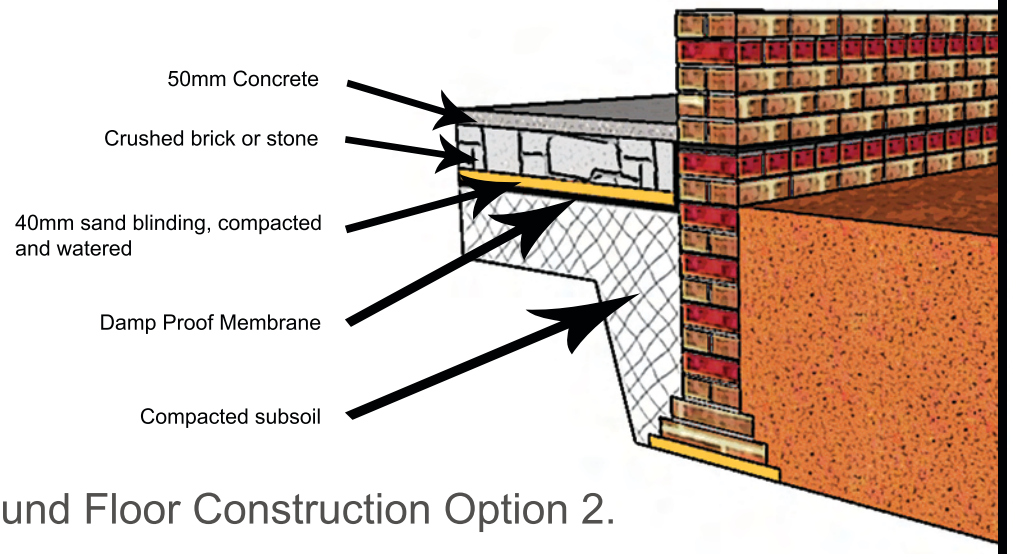
Ground Floor Construction

- The ground floor should be constructed in a number of different ways, depending on funds and materials.
- A Damp Proof Membrane should be installed to prevent damp rising from the floor.
- The Damp Proof Membrane should be installed a minimum 150mm from the outside ground level.

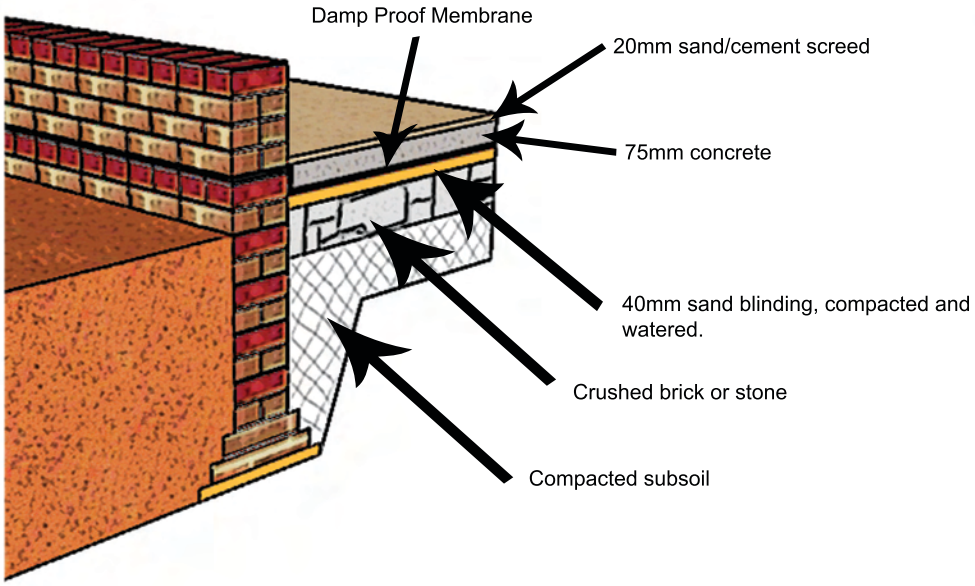
h) The damp proof membrane should be 500 gauge polythene (plastic bag).



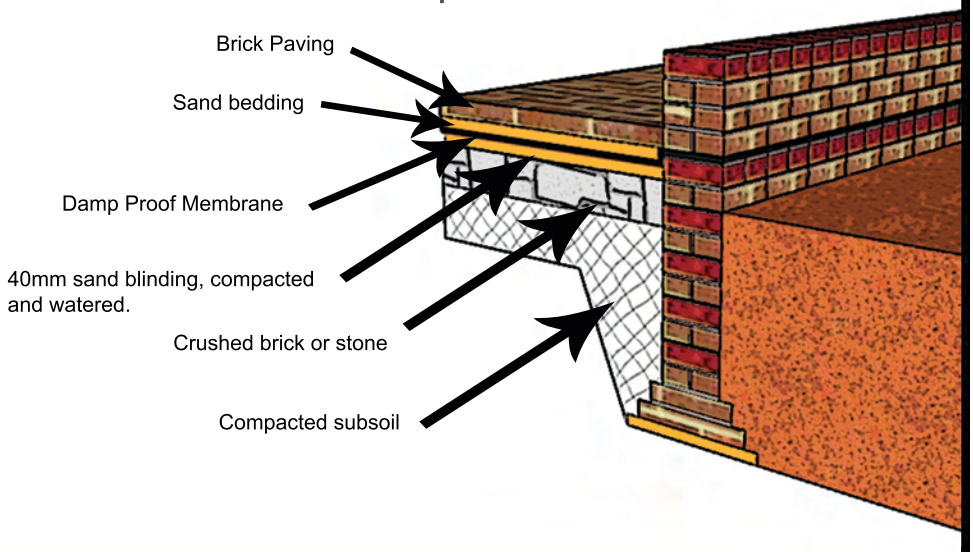
(a) Ground Floor Construction Option 1.



(b) Ground Floor Construction Option 2.

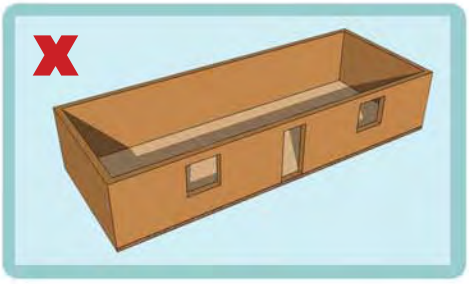


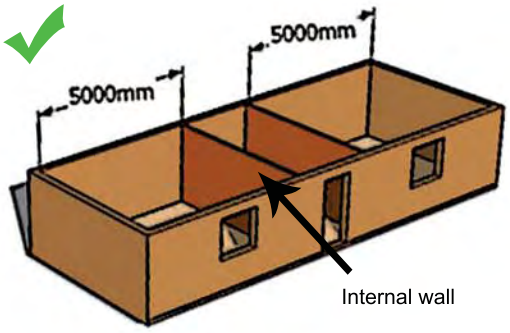
(c) Ground Floor Construction Option 3.

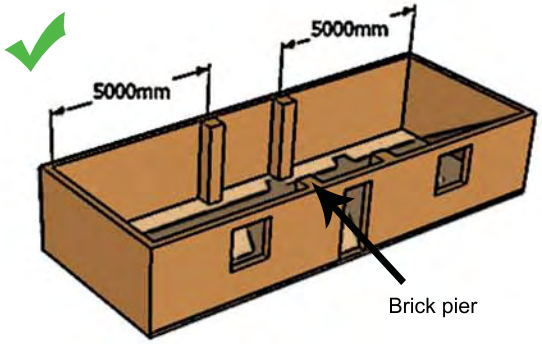


Wall Construction

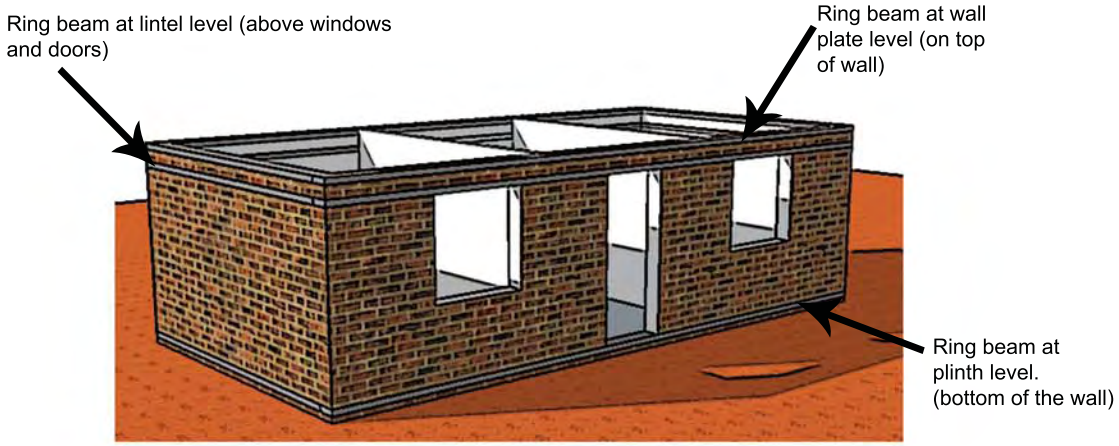
- A wall length should be no longer than 5m (5000mmm).
- If a wall is longer than 5m it needs to have additional bracing.
- Additional bracing can be an internal wall or pier







- A wall can be supported along its length with the introduction of ring beams.
- Ring beams require formwork, reinforcement, and a design mix of concrete.
- Ring beams are important in seismic design.
- Ring beams should be positioned at plinth level, lintel level, and at wall plate level to tie the building together.

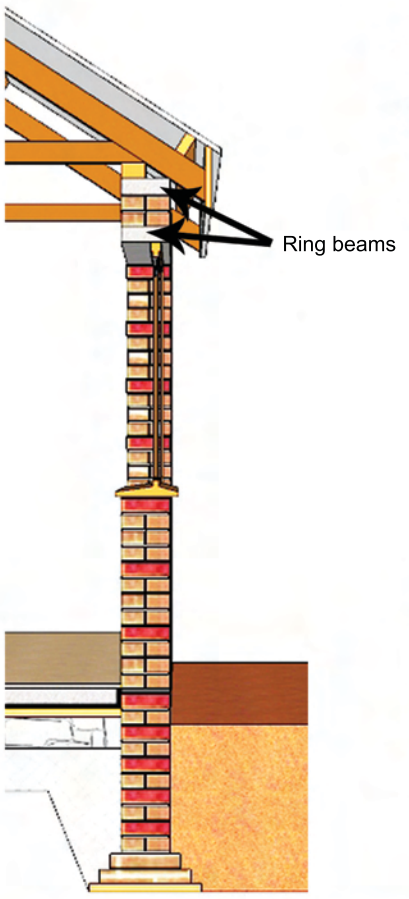


a) A slenderness ratio applies to walls both horizontally and vertically. The thickness of a wall is determined both by its height and

b) It is recognised that the cost implication of ringbeams may not be an option for financial reasons.

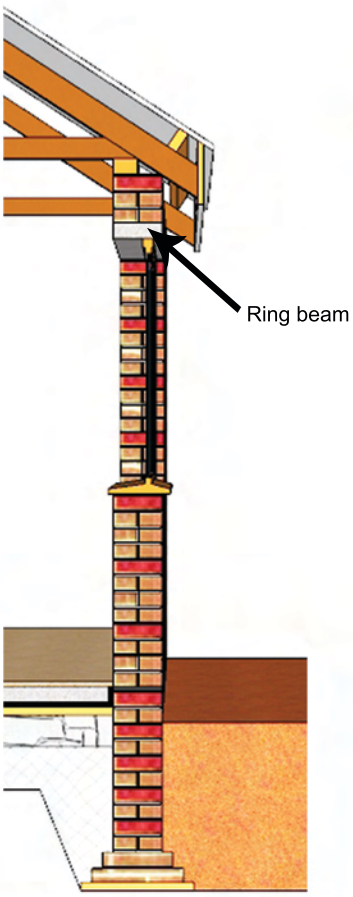
c) Ring beams and internal walls provide longitudinal support for walls.

Strengthening Walls



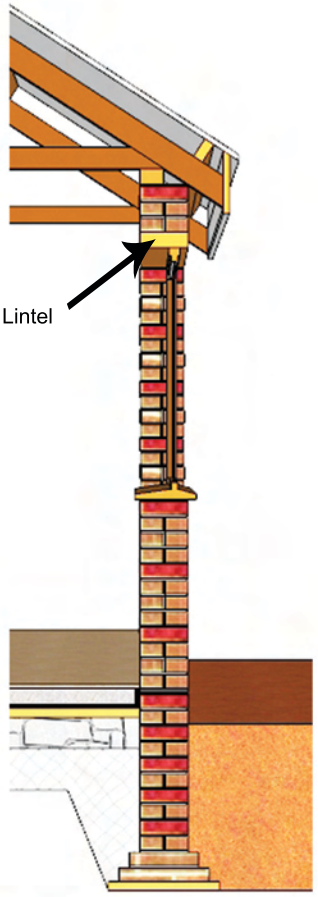
Option 1 - Two ring beams

- 230mm brick wall
- One ring beam at wall plate level
- One ring beam at lintel level



Option 2 - One ring beam

- 230mm brick wall
- One ring beam at lintel level.



Option 3 - No ring beams

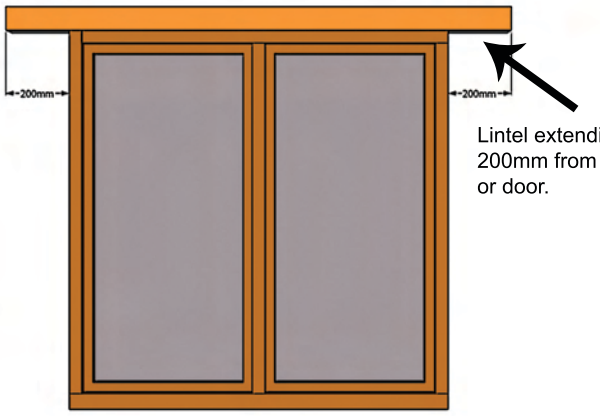
- 230mm brick wall
- No ring beam
- Lintels used over doors and windows.

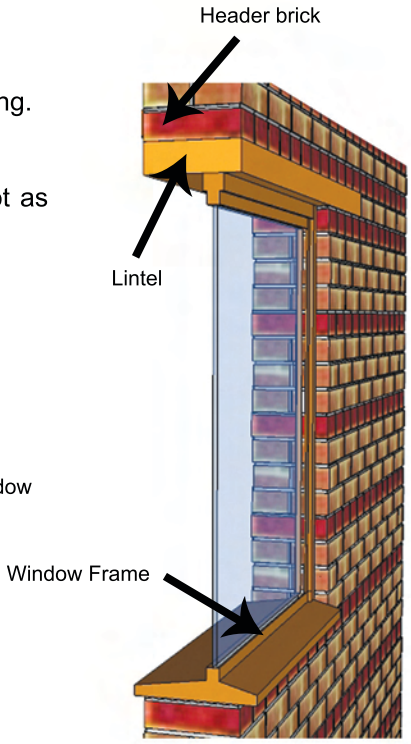
Strongest

Weakest

Lintels

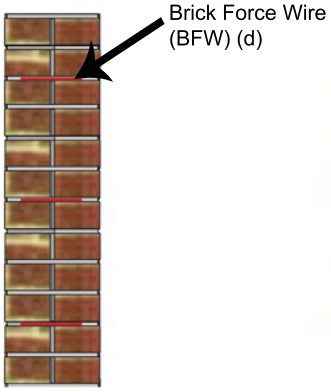
- Lintels should be fitted over doors and windows.
- Lintels should extend 200mm minimum beyond the opening.
- Timber lintels are an affordable solution, but they are not as strong as concrete lintels.





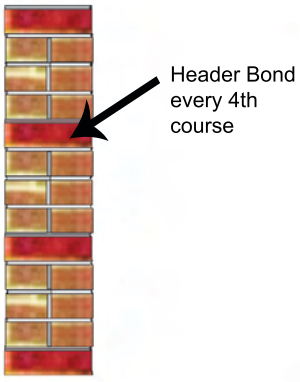
Wall Bonding

- Masonry walls constructed of brick, earth and stone need to have sufficient bonding.
- The most cost effective and strongest bond is to use the walling material shown below.



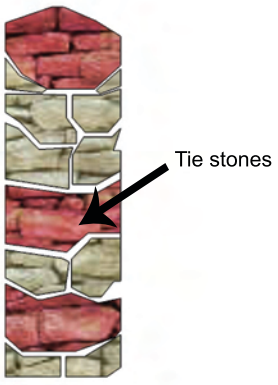
Option 1

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



Option 2

Brick header bonds at every 4th course. Provides connection regardless of mortar use.



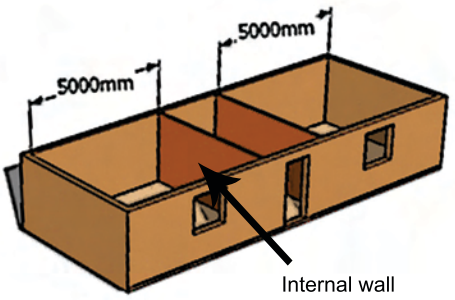
Option 3

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

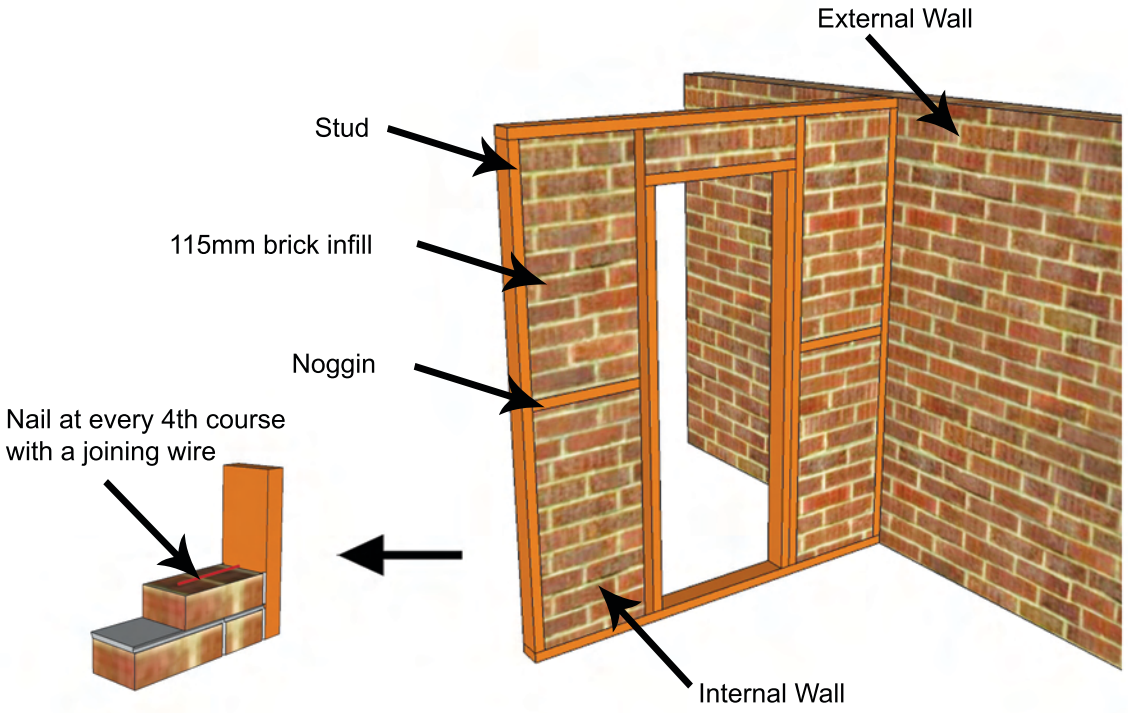
d) Unless cement mortars are used, brick force wire (BFW), will have little benefit, as it is the formation of the cement mortar reinforced layer that provides the bond between brick leafs.

Internal Walls

- It is recommended that internal walls without additional support should be 230mm wide.
- An affordable way of creating a 115mm wall is to construct a timber frame and lay brick between stud and noggin.
- Use nails at every 4th course with a joining wire to provide connection between brick and timber.

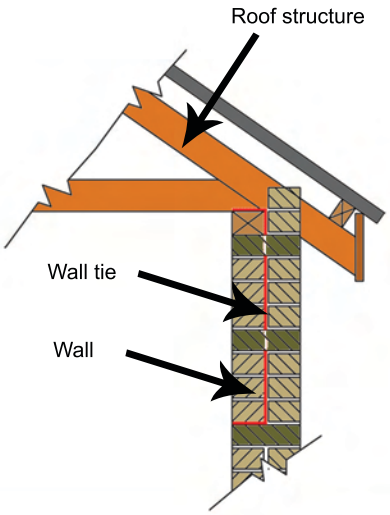


e) Internal walls, even those that are not load bearing require stability. In recent earthquakes many injuries were sustained due to the collapse of internal walls.



Wall Plate

- The wall plate is the junction between the roof structure and the wall.
- Wall ties should connect the roof and wall plate to the wall.
- The wall ties need to be placed at 600mm centres.

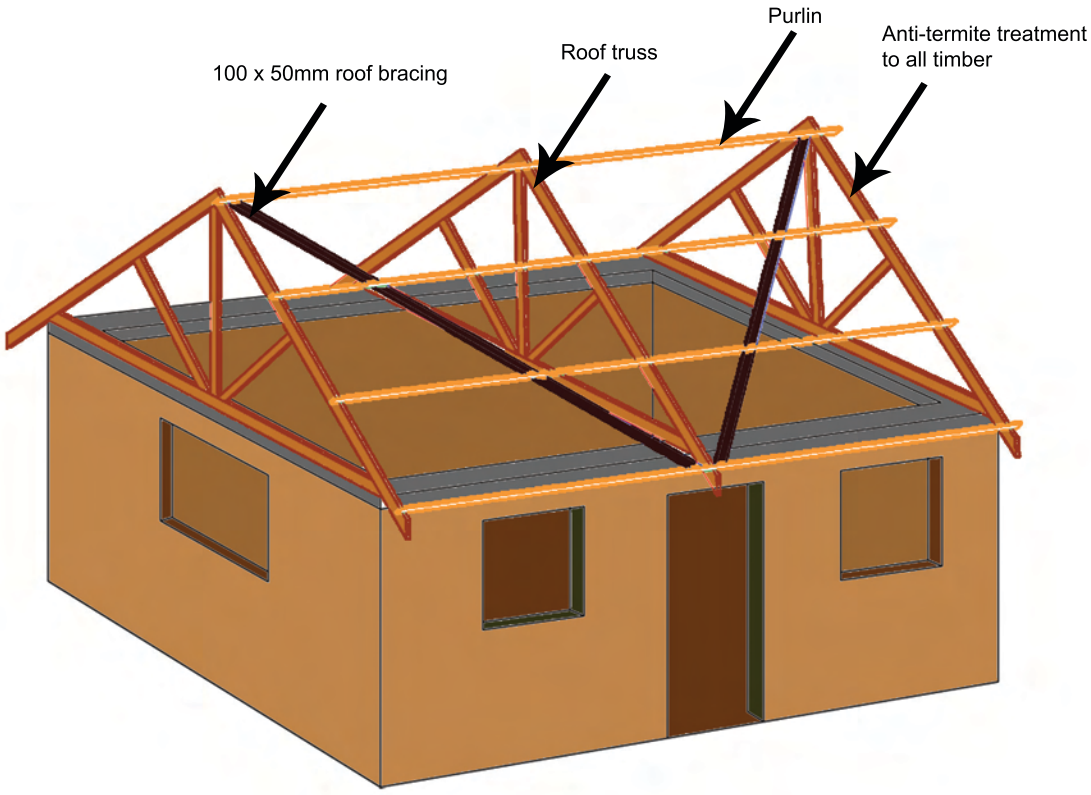


Roof Construction

- To eliminate high unsupported walls it is necessary to construct the roof using trusses.
- Roof trusses should be constructed from timber.
- The roof trusses support purlins, which provide a fixing for the roof covering.
- The roof must be braced with 100 x 50mm timber.

a) For cost reasons the guidelines recommend the use of timber trusses.

b) The roof needs to be braced to prevent movement from wind loads and earthquakes.



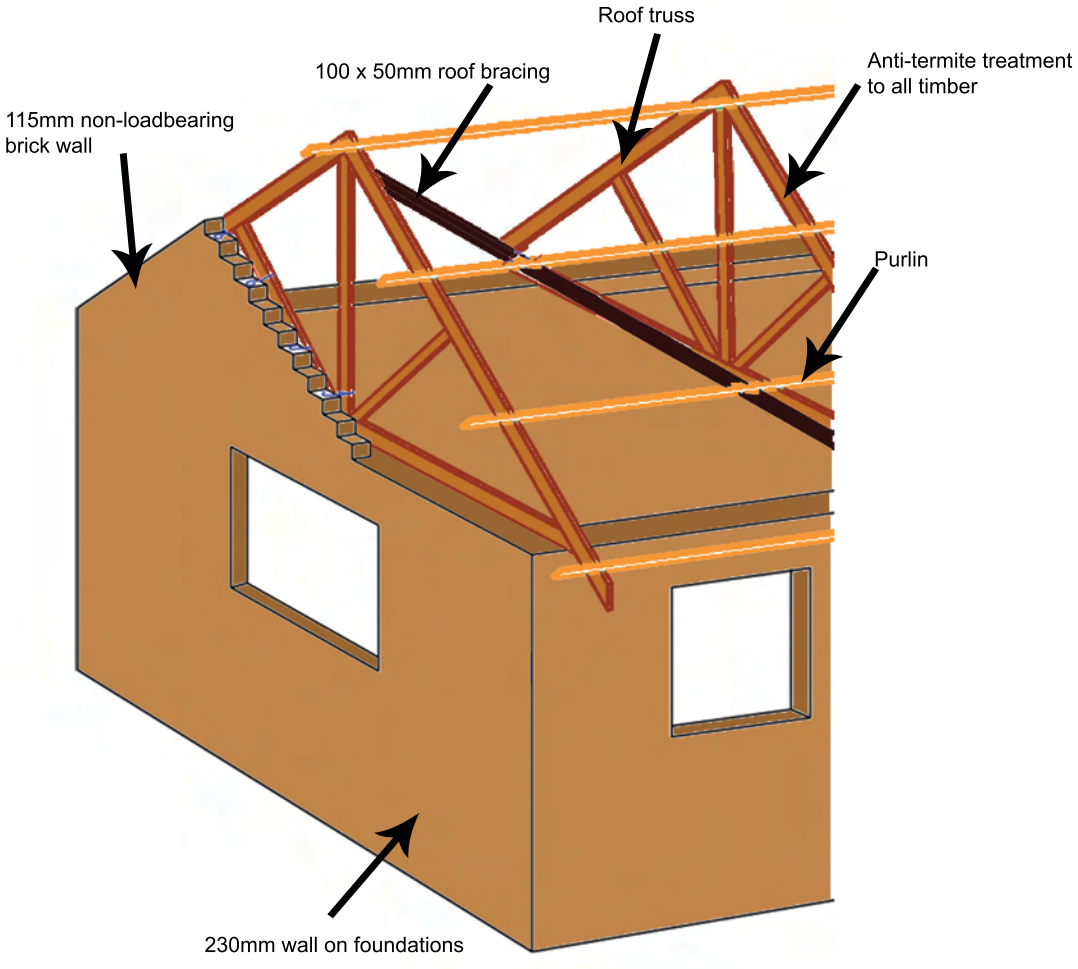
- Trusses can also be constructed using steel.
- Steel trusses have the advantage of providing protection against termites.

Gable Wall Construction

- Masonry walls should not be load bearing.
- Masonry walls should be fixed to the truss.
- The timber truss should be fitted in place and then a single thickness (115mm) wall constructed.
- The brick work should be attached to the truss using wire ties.
- In the event of an earthquake the brickwork may collapse but the roof structure will remail. It is vital that bracing is fitted to the roof for this detail to work.

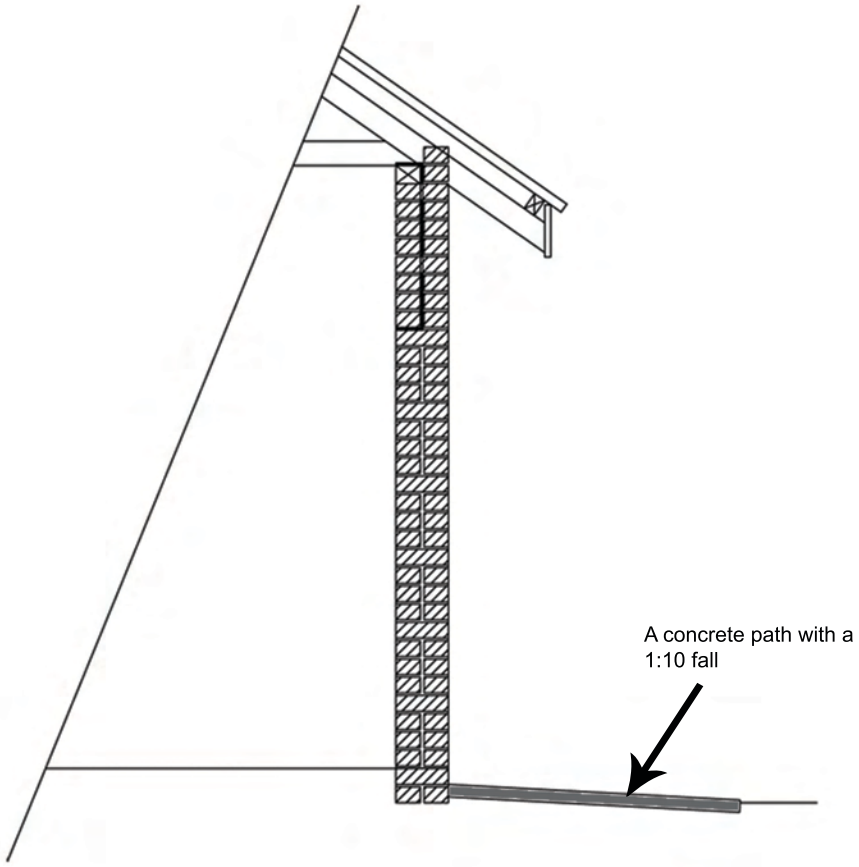
c) By fixing the masonry wall to the truss to provides support and stability against wind load.

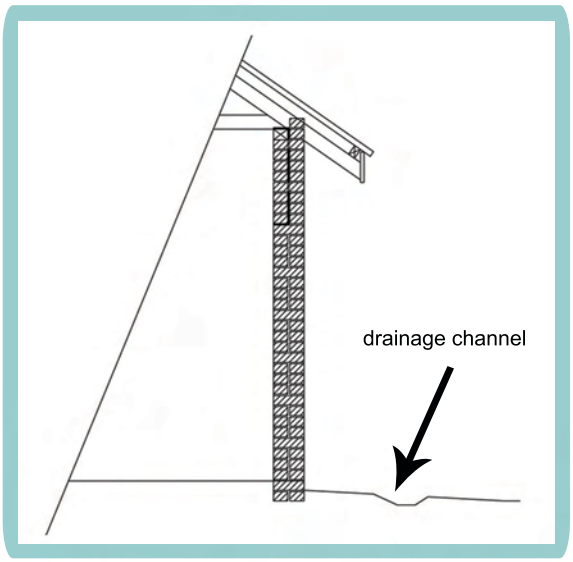
d) When constructing the masonry gable wall the timber truss should be used as a form.



Surface Water Drainage

- Rain and surface water can damage the walls and foundations of a building.
- By extending the eaves (overhang) of the roof it can help to protect the walls.
- A concrete path constructed with a 1:10 fall around the perimeter of the building will protect the base of the wall and foundations.





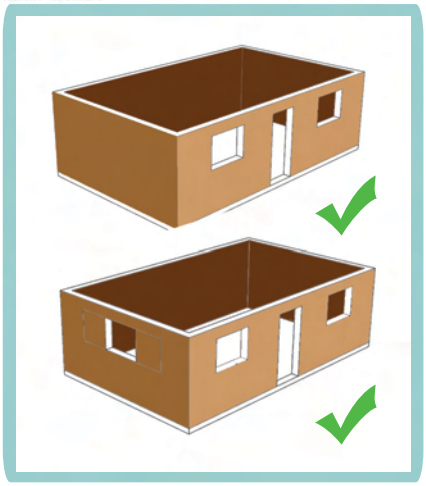
- Where a concrete path cannot be afforded, a drainage channel should be constructed to take surface water away from the building.

4. Retrofitting and Repair

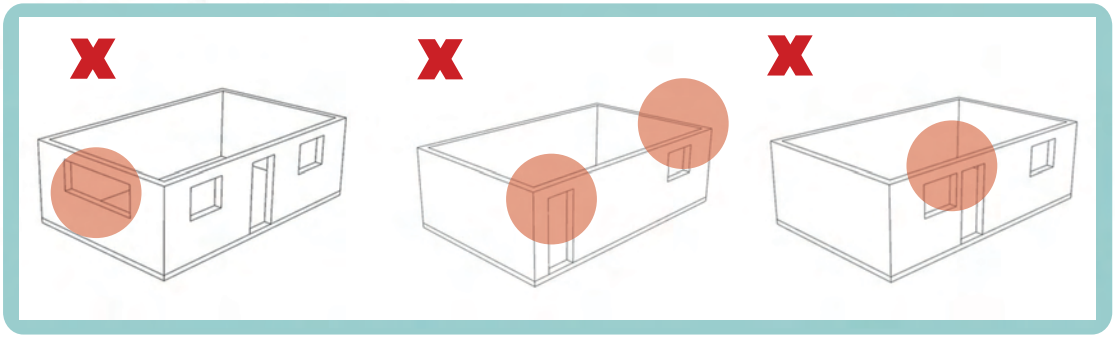
Re-positioning windows and doors

- Re-position windows and door to follow guidelines. Page
- Windows to be positioned 600mm minimum from corners of buildings.
- Windows and doors to be spaced with 600mm between.
- Doors to be positioned 900mm minimum from corners of buildings.

Example 2 - Good positioning of windows and doors

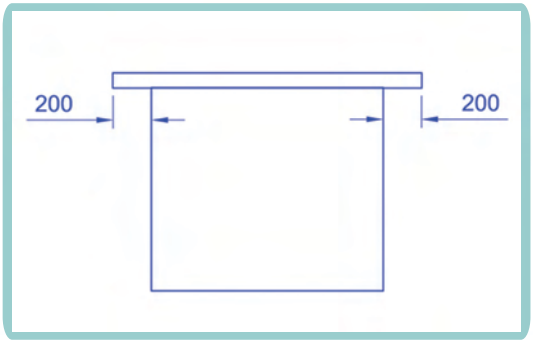


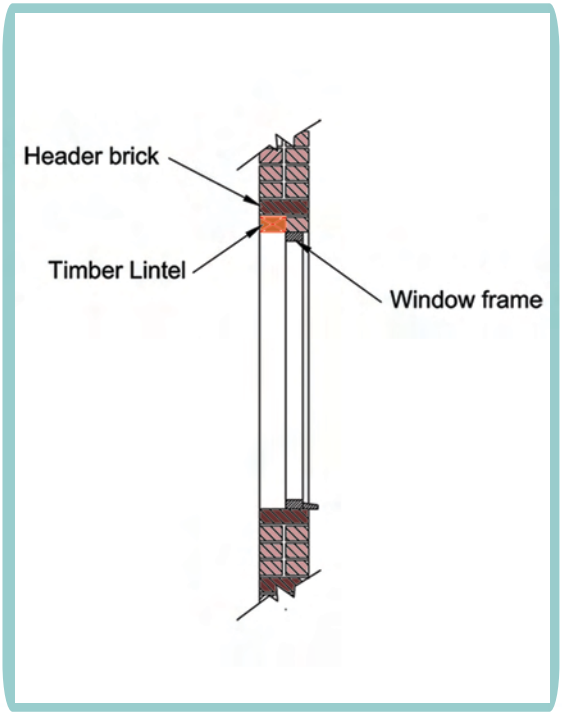
Example 2 - Poor positioning of windows and doors



Fitting lintels above windows

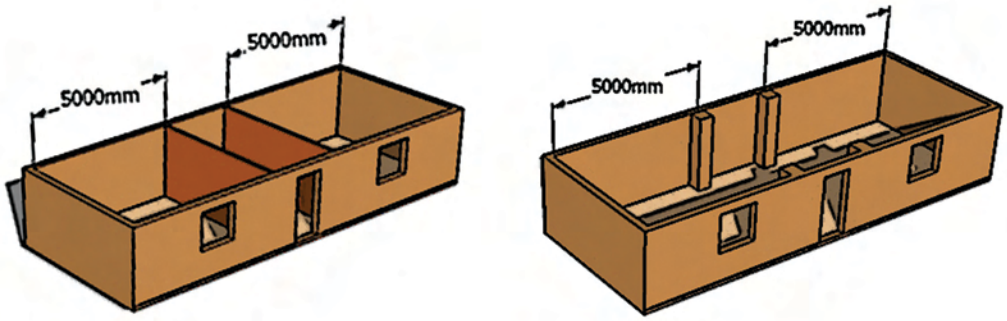
- Lintels should be fitted over doors and windows.
- Lintels should extend 200mm beyond the opening.
- Please refer to page





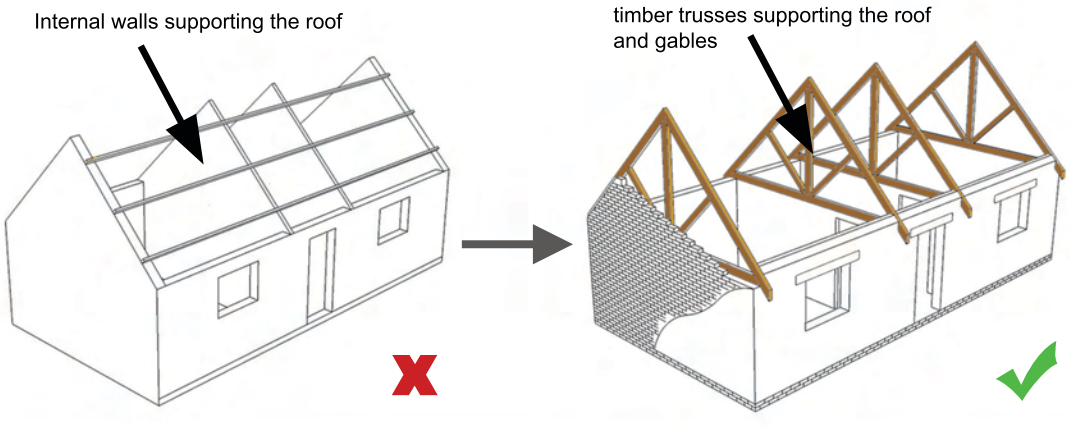
Adding piers and partitions to walls

- If a wall is longer than 5m it needs to have internal or external bracing.
- An external pier or internal pier can be added, and it should have foundations.
- Or, a new partition wall can be built. This should have foundations.



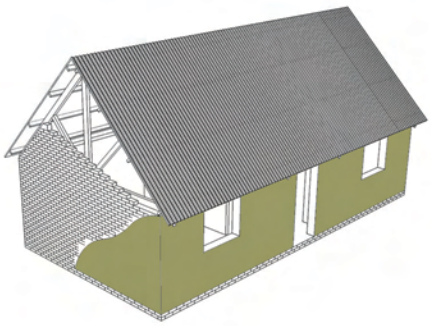
Removing gable walls to construct roof trusses

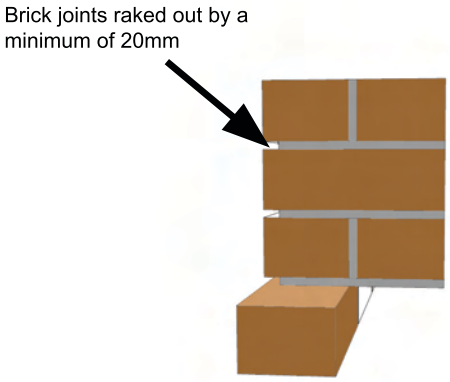
- Internal walls supporting the roof are likely to collapse during earthquakes and high winds.
- Internal walls supporting the roof should be replaced with timber trusses.
- Gables should be removed and rebuilt with 115mm brick wall tied with wire to the truss.
- Please refer to page



Applying cement render to walls.

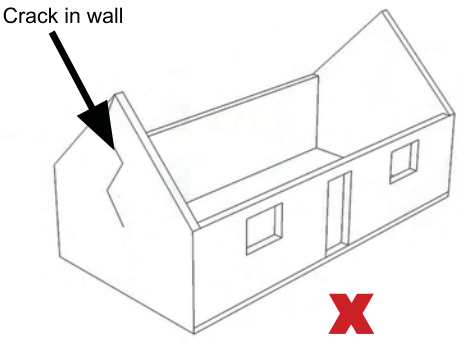
- Walls can be strengthened by applying a cement render.
- The brick joints must first be raked out by a minimum of 20mm to provide sufficient key.

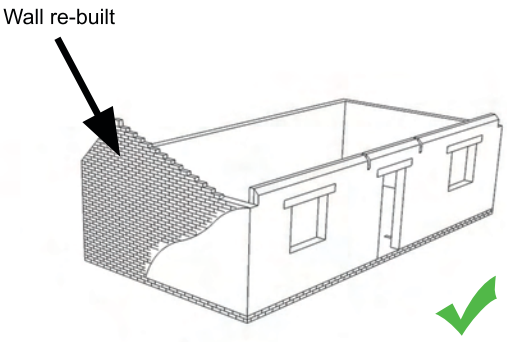




Repairing cracks in walls.

- Cracks in brickwork cannot simply be repaired by applying mortar.
- To repair a crack the brickwork in the affected area must be removed and re-built.





Rebuilding leaning walls.

- Walls that are leaning need to be repaired so as to strengthen the wall.
- The area of leaning wall needs to be removed to a point where the wall is level.
- The wall can then be re-built from this level.