Improved Practices for the Construction of Houses in the Caribbean

July 2018 Edition

CONTENT DISCLAIMER

This document has been prepared on behalf of the Caribbean Development Bank by independent Contractors. The findings, interpretations and conclusions expressed herein are those of the author and do not necessarily reflect the views of the Caribbean Development Bank, its Board of Directors or any of its member countries.

Course Content

This course is divided into 5 sections.

O. INTRODUCTION

A. BEFORE CONSTRUCTION

B. DURING CONSTRUCTION

C. AFTER CONSTRUCTION

D. SUCCESSFUL CONTRACTING

TABLES

TABLES

O.1 Preface

- This training builds upon the *'Regional Code of Practice for the Construction of Houses'*, which was prepared by the Caribbean Regional Organisation for Standards and Quality (CROSQ).
- The Code was initially developed as a training course for construction supervisors by the Caribbean Disaster Emergency Management Agency (CDEMA) in 2005. Grenville Phillips II was the principal author.

Preface

- Over the past 8 years, Walbrent College has continually improved the course, to address the lessons learnt from the impact of natural hazards on the current methods of construction around the Caribbean.
- This training is the latest edition of that course, which includes lessons learnt up to July 2018.

O.2 Welcome

- Welcome.
- If you are an artisan, construction supervisor, or a person interested in building, this course will teach you how to supervise (and check) the construction of a strong and durable house in the Caribbean.

O.3 Why the Caribbean?

- The Caribbean is one place on this Earth where buildings should be constructed to be safe during natural hazards, and durable (less vulnerable to progressive weakening).

O.4 Natural Hazards

- The Caribbean is one of the most hazard-prone regions on Earth. Its inhabitants face the threat from a diverse set of natural hazards including: 1) earthquakes 2) hurricanes 3) floods 4) landslides 5) volcanoes 6) tsunamis 7) torrential rainfall and now the predicted negative effects of climate change.

O.5 Progressive Weakening

Once structures are built in the Caribbean, they can be progressively weakened, eg:

- steel reinforcement can corrode,
- moisture can penetrate and damage timber, masonry, and concrete elements,
- insects can damage timber frames, and
- intense heat and UV rays can damage plastics, binders, sealants, and paints.

O.6 What You Can Learn Here.

- This is a unique course. It is one of only 2 proven methods that has actually significantly reduced the damage to houses following a major natural hazard in the Caribbean.
- This course will teach you at least 2 things:

1. how to supervise the construction of a safe and durable house; and
2. how to check whether a safe and durable house is being built.

O.7 Legal Disclaimer

- No one can guarantee that a building will not sustain damage from a natural or man-made hazard. However, using the construction methods described in this course may result in a house that is stronger and more durable than houses typically built in the Caribbean.
- This course includes structural designs that assume a rectangular shaped house with a maximum floor area of 140 sq-m (1,500 sq-ft) and a floor load of 1.5 kPa. However, persons should seek the advice of a qualified structural engineer for their individual projects.
- This course is based on building standards that continue to be updated (and corrected). Therefore, neither the Author nor Walbrent College can accept any liability for any damage that results from persons following the building methods described in this course.

O.8 Copyright

Why We Must Build Properly.

Anguilla – Irma 2017

Anguilla – Irma 2017

Dominica – Maria 2017

Dominica – Maria 2017

Haiti –2010

Haiti –2010

Haiti –2010

Home

A. BEFORE CONSTRUCTION

A 1. Contract With the Client

1. Before you start working, you should have a written contract with the home owner or client, which should include:
   - 1.1 Contractor (Builder) obligations.
   - 1.2 Client (House-owner) obligations.
   - 1.3 Procedures for making changes to the contract.
   - 1.4 Procedures for resolving disputes.

A 1.1 Contractor (Builder) Obligations

The Contractor agrees to build:

1. the house that was approved by the planning authorities;
2. using specified construction standards;
3. for a specified amount of money; and
4. in a specified period of time.

A 1.2 Client (House-owner) Obligations

The Client agrees to:

1. pay a specified sum of money;
2. within a specified period of time after receiving the Contractor's invoice; and
3. according to a specified payment schedule.

A 1.3 Making Changes to the Contract

1. Clients normally request changes to their building project (or Contract).
2. The Contractor should provide the Client with:
   a. The additional cost (saving) of the change.
   b. The additional time (saving) to complete the change.
3. The Client can then decide whether to approve the Change.

A 1.4 Resolving Disputes

1. Disputes normally arise from the quality of the finishes.
2. To manage these foreseen disputes, the Contractor should prepare 1 sq-m (or 1 sq-yd) samples of floor, wall and ceiling finishes for the Client’s approval.
3. Disputes between approved samples and permanent finishes can be referred to an Adjudicator.
4. Appeals of the Adjudicator's decision can be arbitrated and/or litigated.

A 2. Planning Approval

1. Before construction starts, Development Planning approval must be obtained.

2. Obtaining Planning approval is the responsibility of the home owner.

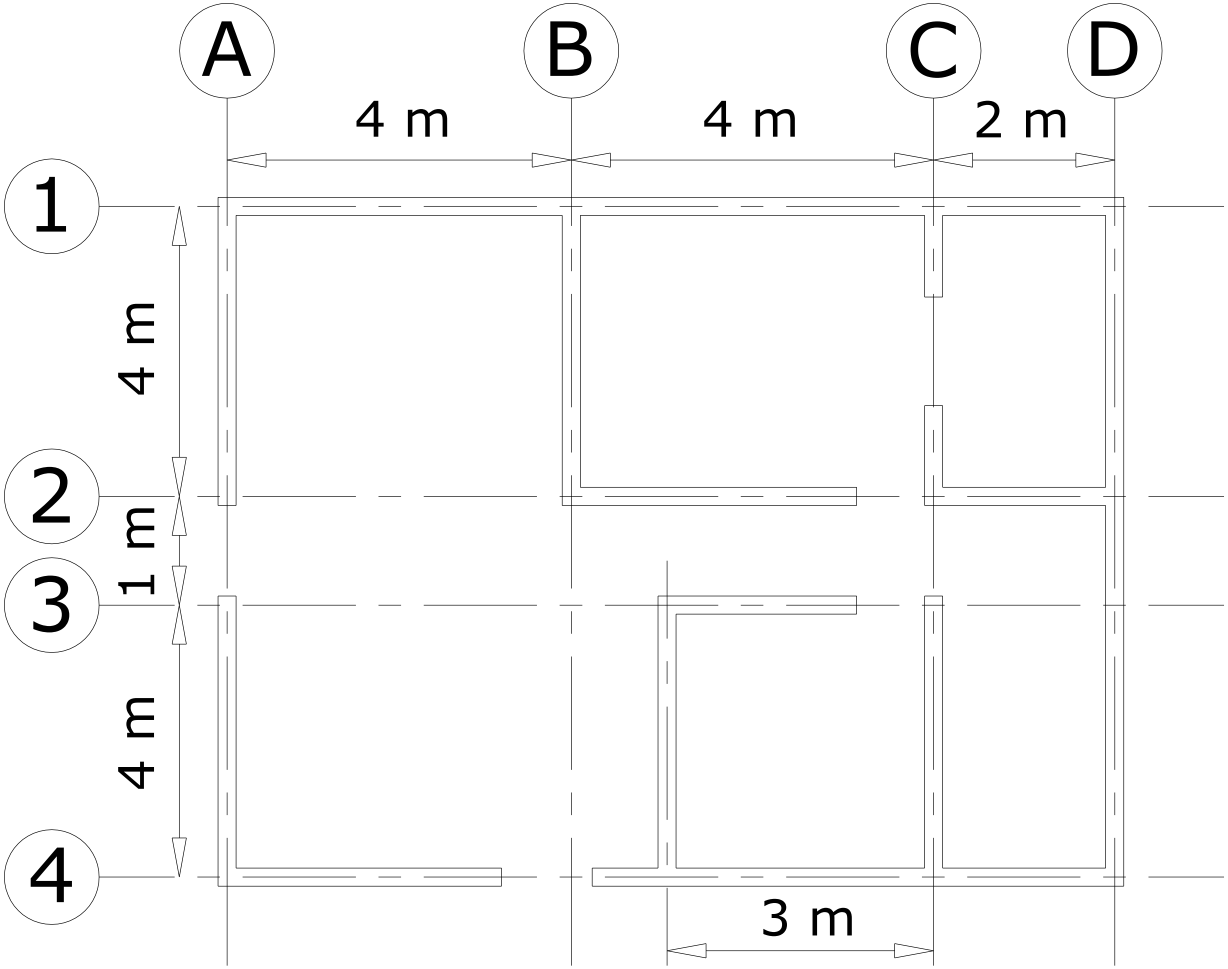
A 2. Planning Approval (Cont'd)

3. A property that has planning approval should have, among other things:
   a. accurate and identifiable boundary markers;
   b. dimensions to set-out the house; and
   c. provision for sewage disposal.

A 3. Drawing Review

1. Examine the drawings and check whether they contain enough information for the builder to:
   a. Set out the building.
   b. Locate all walls (including manholes and wells).
   c. Locate all window and door openings.
   d. Identify the heights of walls, openings, ceilings and roofs.
   e. Locate electrical fixtures, switches, and panels.
   f. Locate plumbing fixtures.
   g. Obtain all plumbing and electrical fixtures.
   h. Obtain all floor, wall, ceiling, and roof finishes - and
   i. Build all cabinets (bath & bedroom, kitchen, etc).

2. Draw and dimension a grid along the centre-line of each wall. **Ask for any missing dimensions. This grid will be set out on the site later.**



A 4. Safe Construction

Safe construction includes the following:

1. Building in areas with a low vulnerability to natural hazards (stable soil, non-flood and non-wave prone areas);

2. Using strong (will not bend excessively or break) and durable (will not deteriorate and lose its strength) building materials.

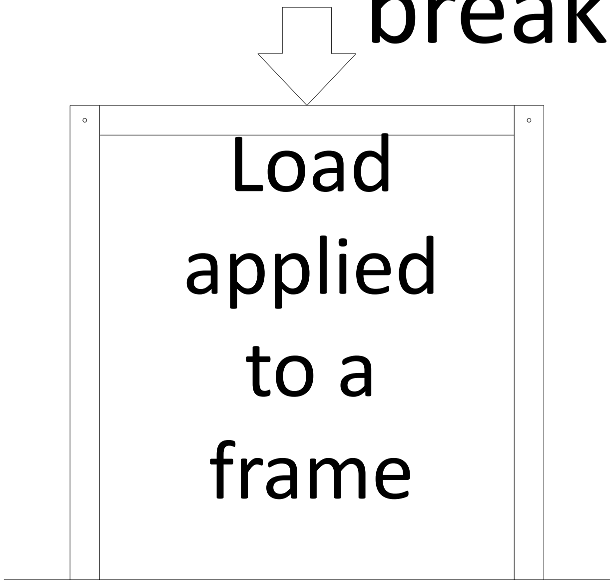
A 4. Safe Construction (Cont'd)

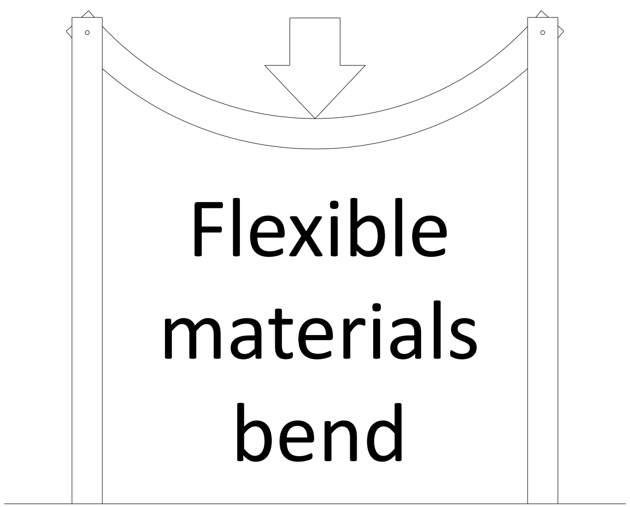
3. Assembling the materials properly to obtain good quality building elements (footings, floors, walls, roofs);

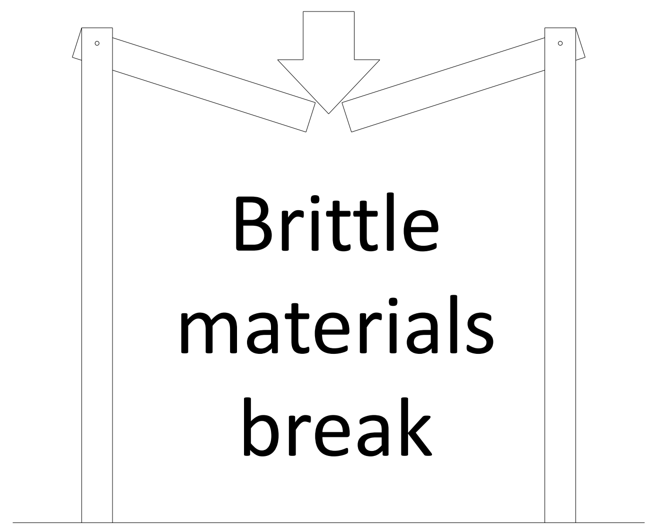
4. Connecting the building elements properly;

5. Bracing the building elements properly.

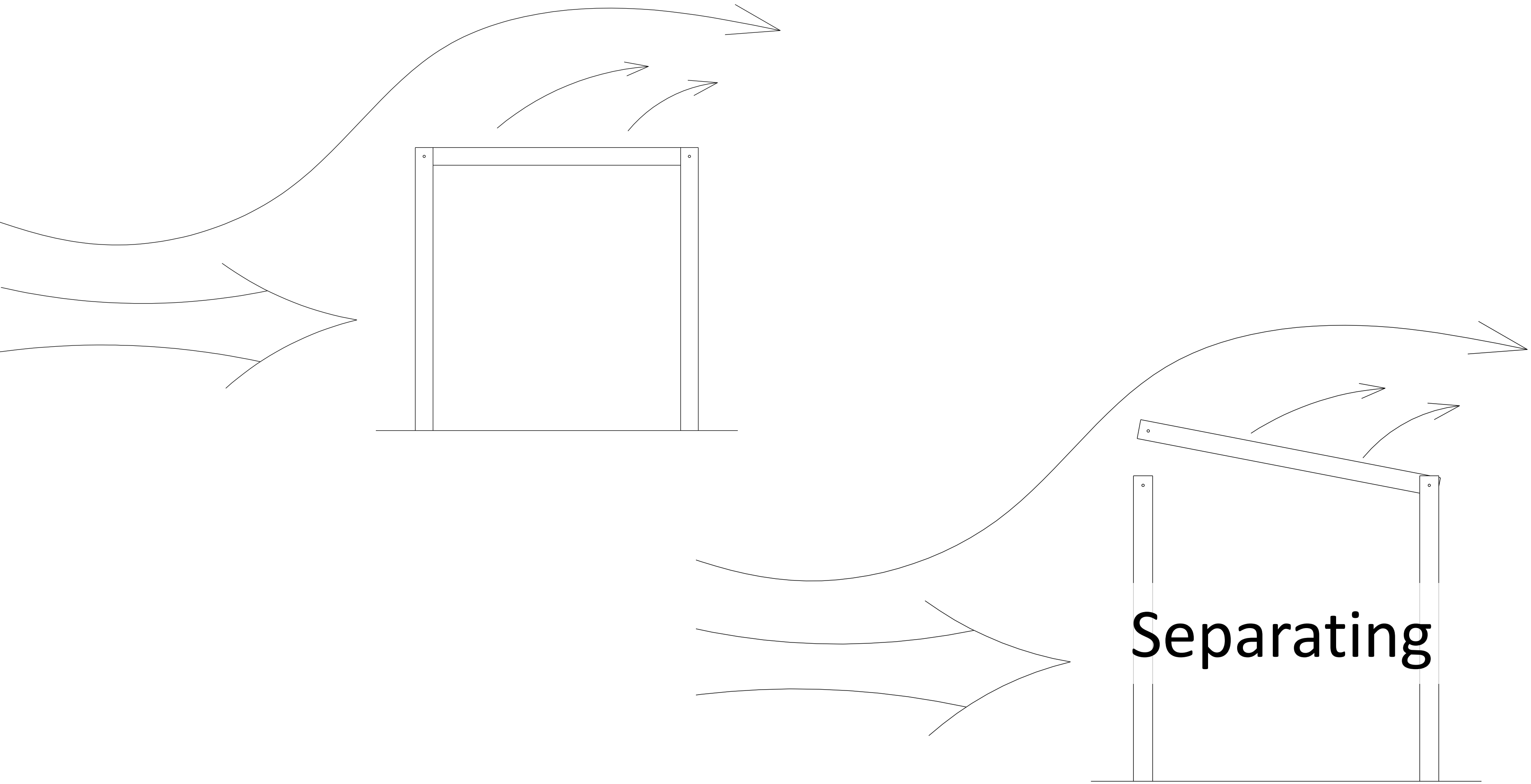
Weak materials can bend excessively or break prematurely.



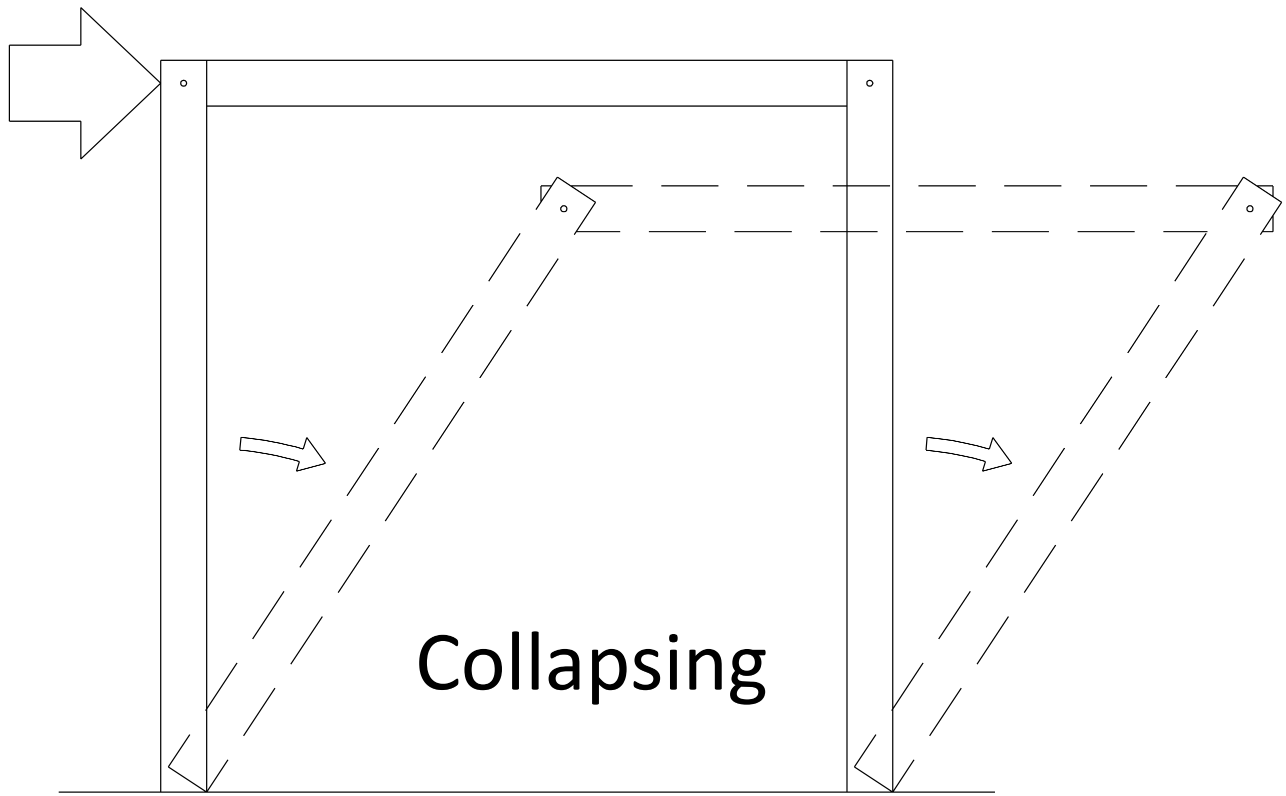




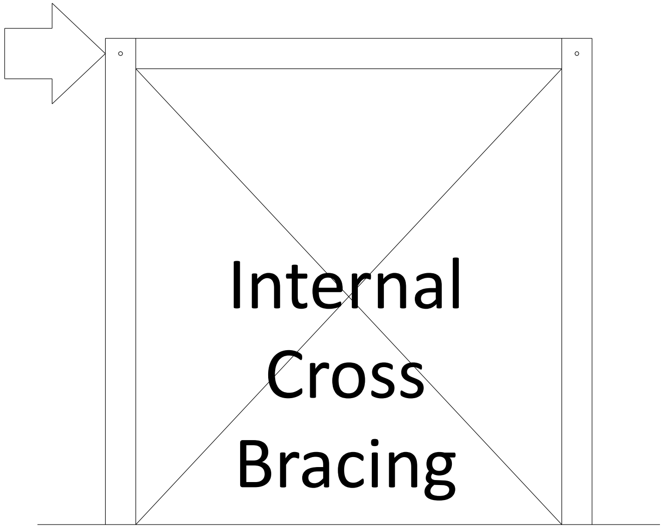
Weak connections can cause structural materials to separate during hurricanes.

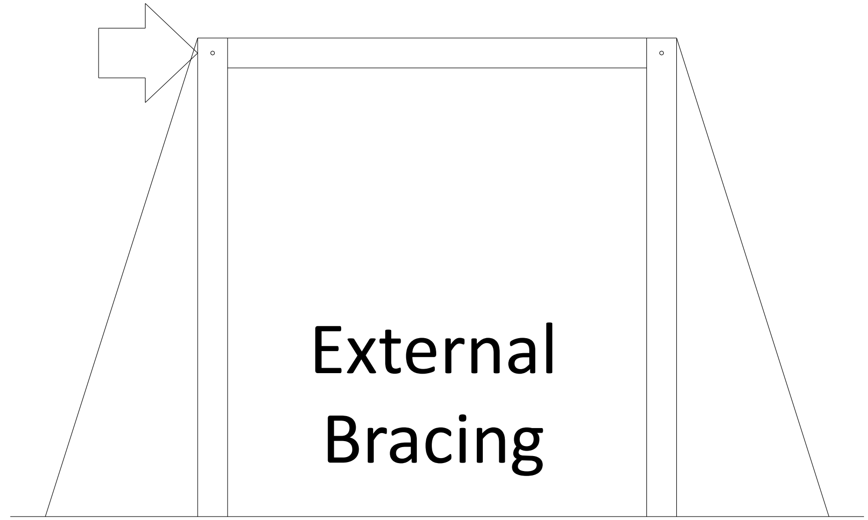


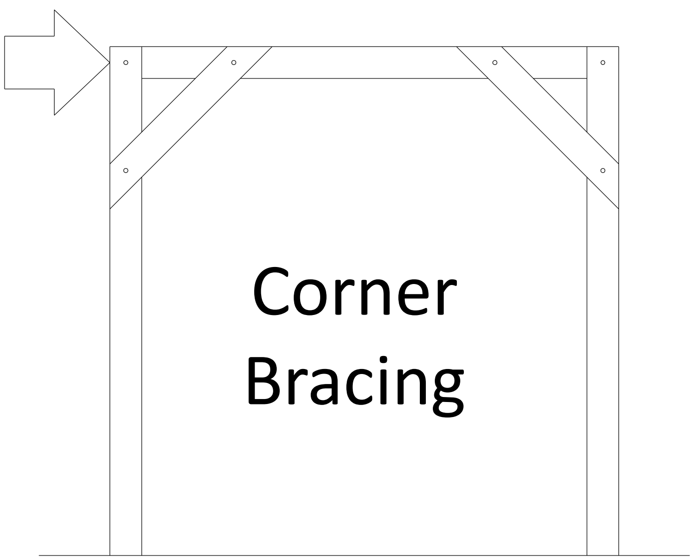
Unbraced structures can collapse under lateral loads like earthquakes and hurricanes.

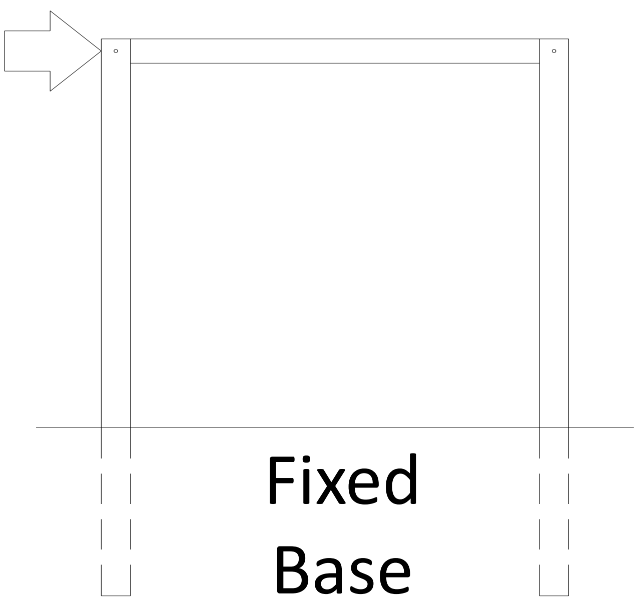


Bracing methods

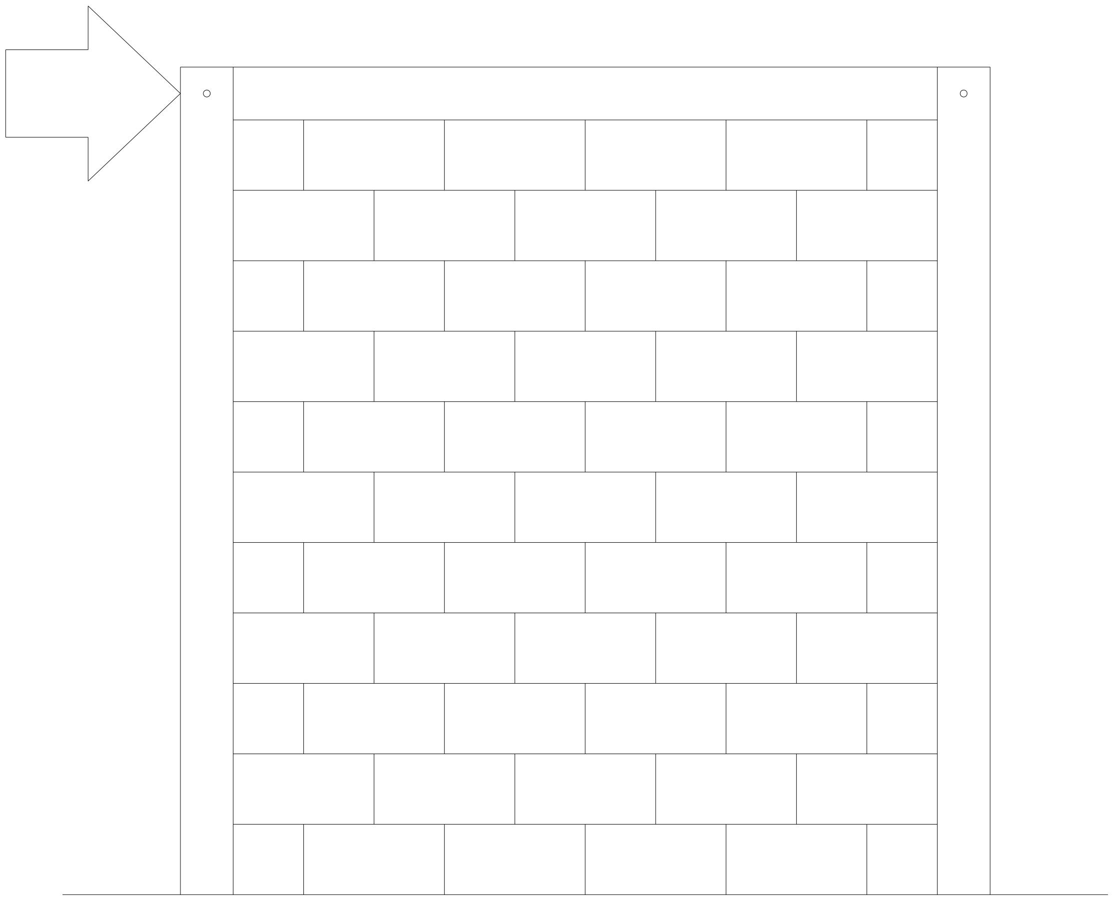








Bracing methods (Cont'd)



Shear Wall

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A 5. Site Inspection

1. Before you start constructing, you need to check whether the land is a good spot to build.
2. Is it prone to flooding or land slippage? **If so, then the owner should be told so that the owner can make the choice of whether to proceed.**
3. **If you are unsure of the buildability of the land, then consult with an Engineer.**
4. Some vulnerable locations are described below with some additional design requirements where Engineering advice should be obtained.

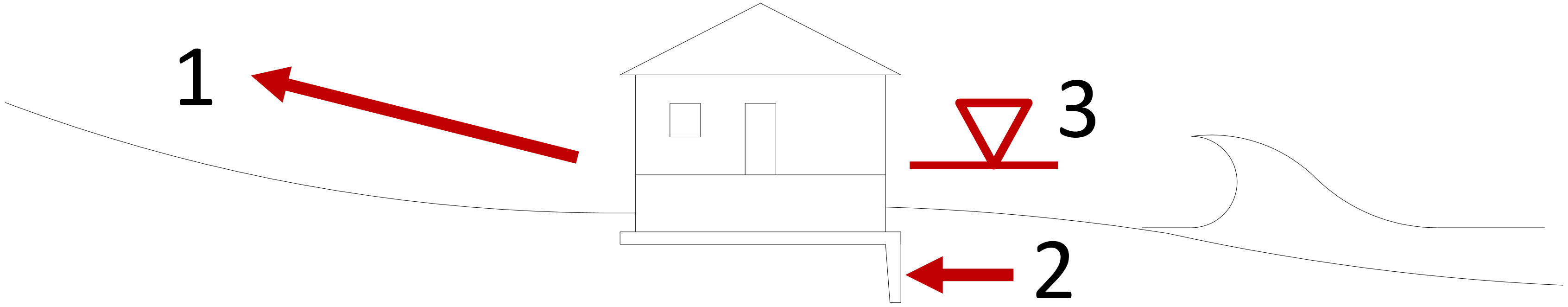
Coastal and Low Lying Areas

Natural Hazards

- Waves, floods, tsunamis.

Design Requirements

1. Set back to high ground.
2. Protect foundations from scour .
3. Build the ground floor above the flood level of a storm with a return period of 100 years.



Home

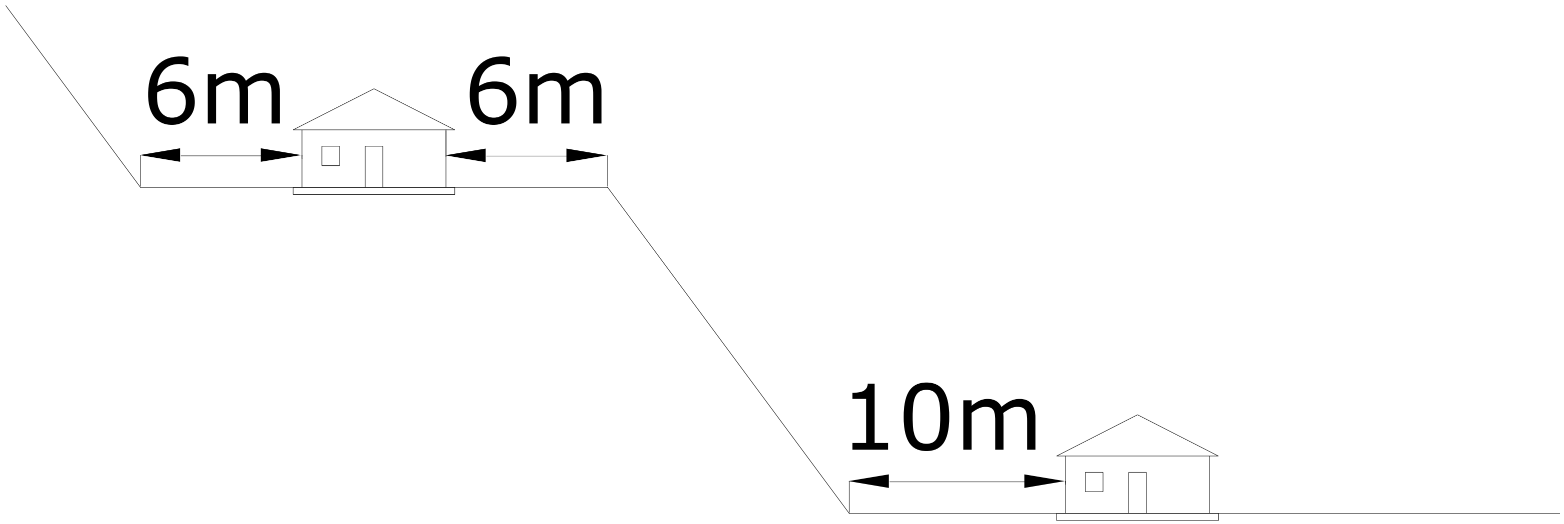
Steep Slopes

Natural Hazards

- Wind, landslides

Design Requirements

1. Set back 6m (20 ft) from the terrace's back and crest.
2. Set back 10m (30 ft) from base of the slope



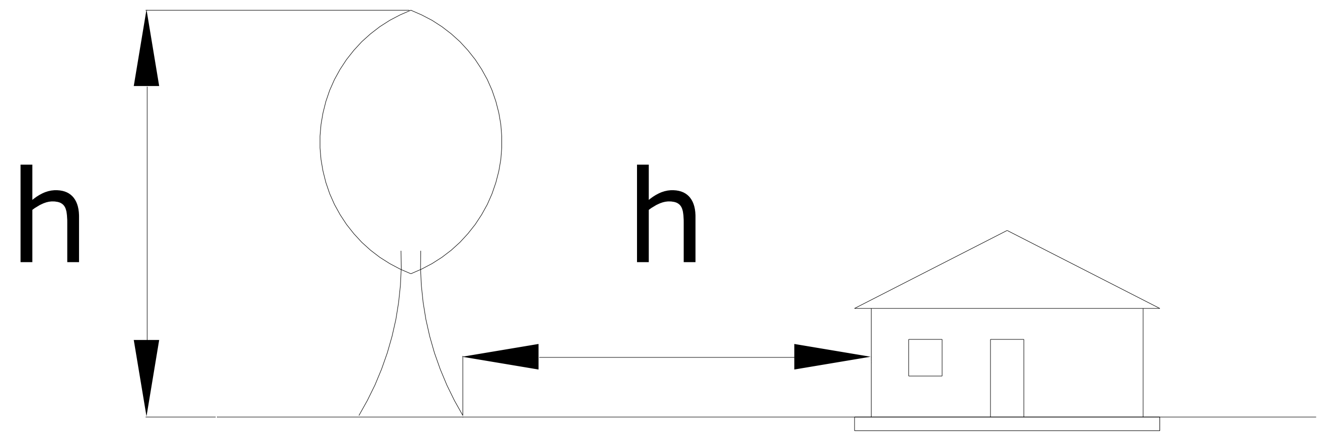
Trees

Natural Hazards

- Foundation, wall and roof damage from falling trees and aggressive roots

Design Requirements

- Set back a distance equal to the height of the mature tree.



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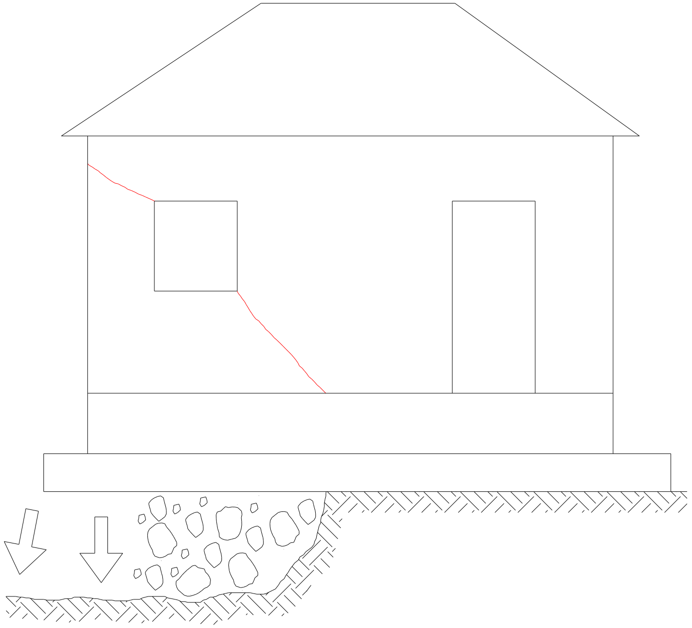
Unstable Soil

Natural Hazards

- Foundation settlement and wall damage.

Design Requirements

- Build on a firm foundation.



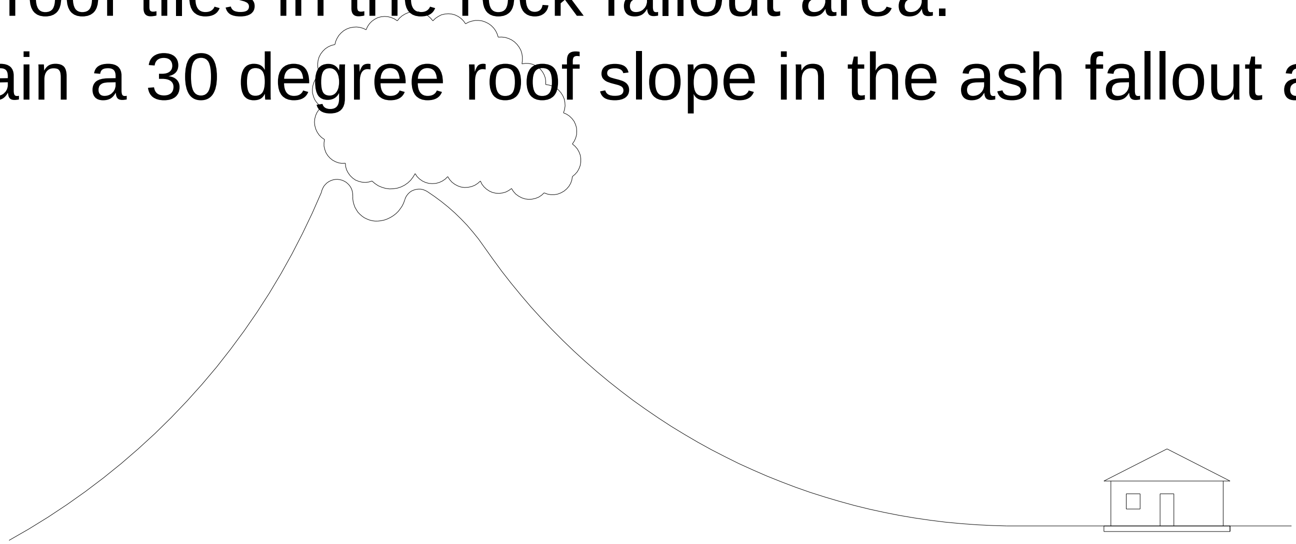
Volcanic Influence

Natural Hazards

- Lava & fire from the pyroclastic flow path.
- Broken windows and roof tiles from the rock fallout area.
- Roof damage from the ash fallout area.

Design Requirements

- Relocate out of the pyroclastic flow path.
- Install window shutters to protect glass, and do not use brittle roof tiles in the rock fallout area.
- Maintain a 30 degree roof slope in the ash fallout area.



A 6. Quality of Materials

Structural Material	Standards
Concrete blocks	Minimum 28-day compressive strength = 7 MPa (1,000 psi) over net block area. (US$10 compression test)
Cement	Portland Cement – Type 1 (Normal use) Type 5 (High Sulphate soils)
Sand	Clean natural sand from inland source, free of clay, organic material, and broken shells.
Stone	Crushed stone or gravel with a minimum size of 5mm (1/4”) and a maximum size of 20mm (3/4”) free of a coating of dust.
Water	Clean, potable water.
Formwork release agent	Vegetable, mineral or engine oil based agents can effectively release the formwork from the hardened concrete.

Structural Material	**Standards**
Concrete curing	Use a spray-on curing compound, otherwise keep sand or under a plastic (polythene) covering continuously wet for at least 3 days. (US$10 compressive test)
Damp proofing membrane (DPM)	DPM to be 500 gauge (125 microns) polythene vapour barrier with 350mm (14”) taped laps.
High Yield Reinforcement	Yield strength 460 MPa and reasonably free from rust. Rebars to be tied together using mild steel tying wire. **Reference mark T.** **Eg. T12 = High yield 12 mm (1/2”) diameter bar.**
Mild Steel Reinforcement	Yield strength 250 MPa. and reasonably free from rust. Rebars to be tied together using mild steel tying wire. **Reference mark R.** **Eg. R10 = Mild steel 10 mm (3/8”) diameter bar.**

Structural Material	**Standards**
Timber framing	Sound, straight, and well seasoned timber with a moisture content between 15% and 19%. Timber should be pressure treated against insect attack.
Anchor Bolts in Concrete connecting timber	High strength Grade 8.8 with 40mm diameter 3mm (1/8”) thick galvanised steel washers.
Nails	8d (8 penny - 2.5” long, 3.4 mm dia) galvanised common wire nails.
Roof metal sheeting	0.5mm (24 ga) thick profiled metal sheets.

A 7. Using Reinforced Concrete

Once you have chosen to use reinforced concrete, you must:

1. Mix the concrete properly.
2. Bend and lap the steel safely.
3. Smock all sides of the steel in contact with the formwork to get a protective concrete cover.
4. Compact the concrete using a vibrator.
5. Cure the concrete, preferably by spraying all exposed faces with a curing agent.

A 7.1 Mixing Concrete, Grout & Mortar

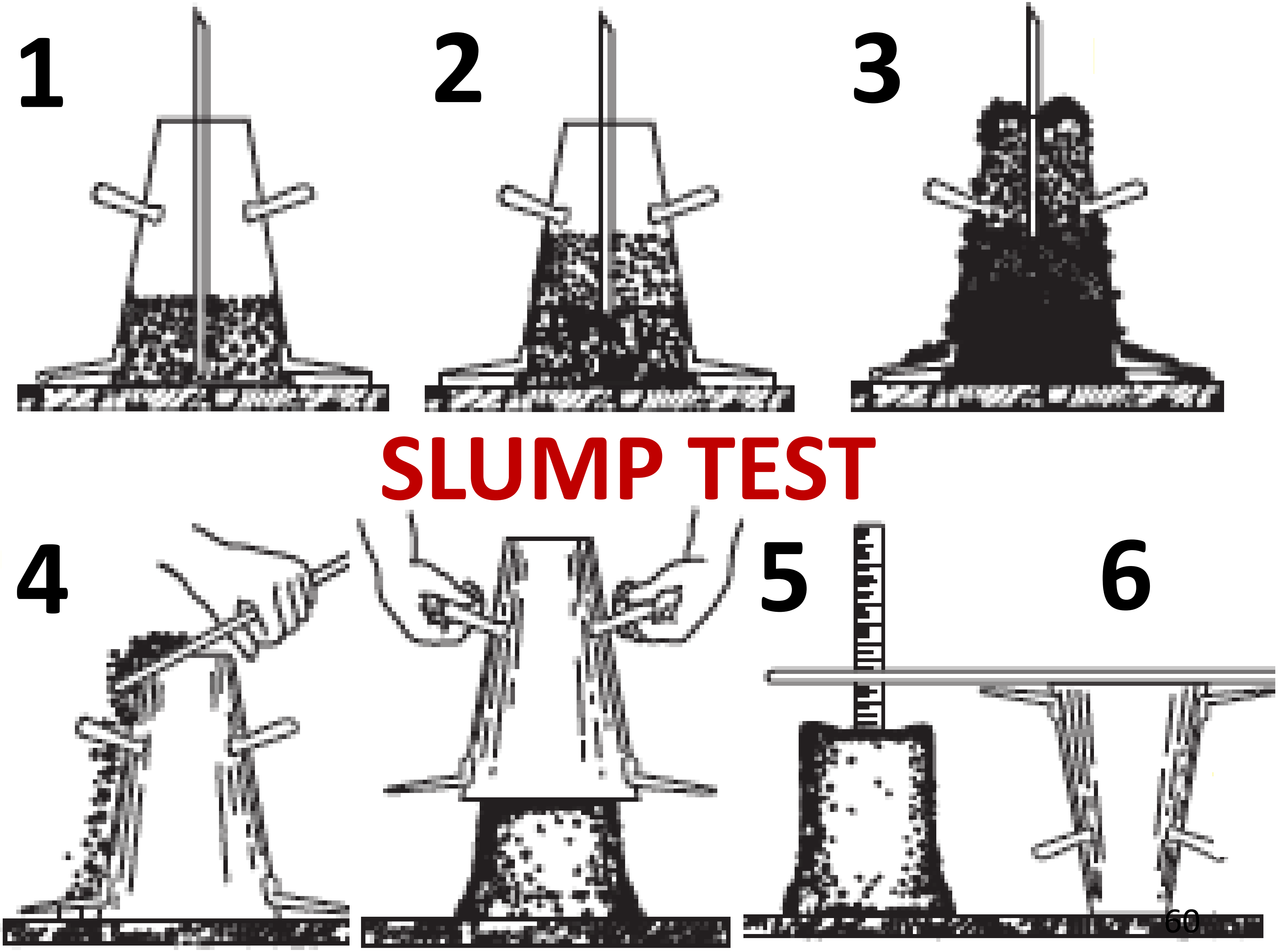
1. Concrete is used to construct:
   - Foundations
   - Walls, beams, columns and slabs
2. Grout is used to fill cores in concrete blocks
3. Mortar is used to:
   - Bond concrete blocks together
   - Plaster concrete walls and slabs

Note: Mix concrete, grout and mortar in a concrete mixer or on a hard surface (eg. concrete blinding).

Using a concrete mixer

Mixing concrete on a hard surface

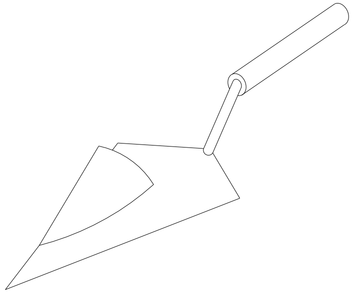
Structural Material	**Standards**
Concrete for Foundations 	Concrete mix producing a compressive cube strength of 21 MPa (3,000 psi) at 28 days = 1 bag of cement (94 lbs = 1 cu-ft = 1.5 x 5 gal bucket) + 2 cu-ft sand (3 buckets) + 4 cu-ft of stone (6 buckets) + 5 gallons of water (1 bucket) Slump = 50 – 100 mm (2”-4”) To be used within 1.25 hours after adding water. 
Concrete for beams, suspended slabs, columns and walls.	Concrete mix producing a 28-day compressive cube strength of 25 MPa (3,600 psi) = 1 bag of cement (94 lbs = 1 cu-ft = 1.5 x 5 gal bucket) + 1.5 cu-ft sand (2.25 or 2-1/4 buckets) + 3 cu-ft of stone (4.5 or 4-1/2 buckets) Slump = 50 – 100 mm (2”-4”) To be used within 1.25 hours after adding water.

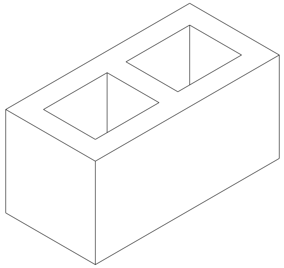

1
2
3
SLUMP TEST
4
5
6


1 cu-ft measuring box

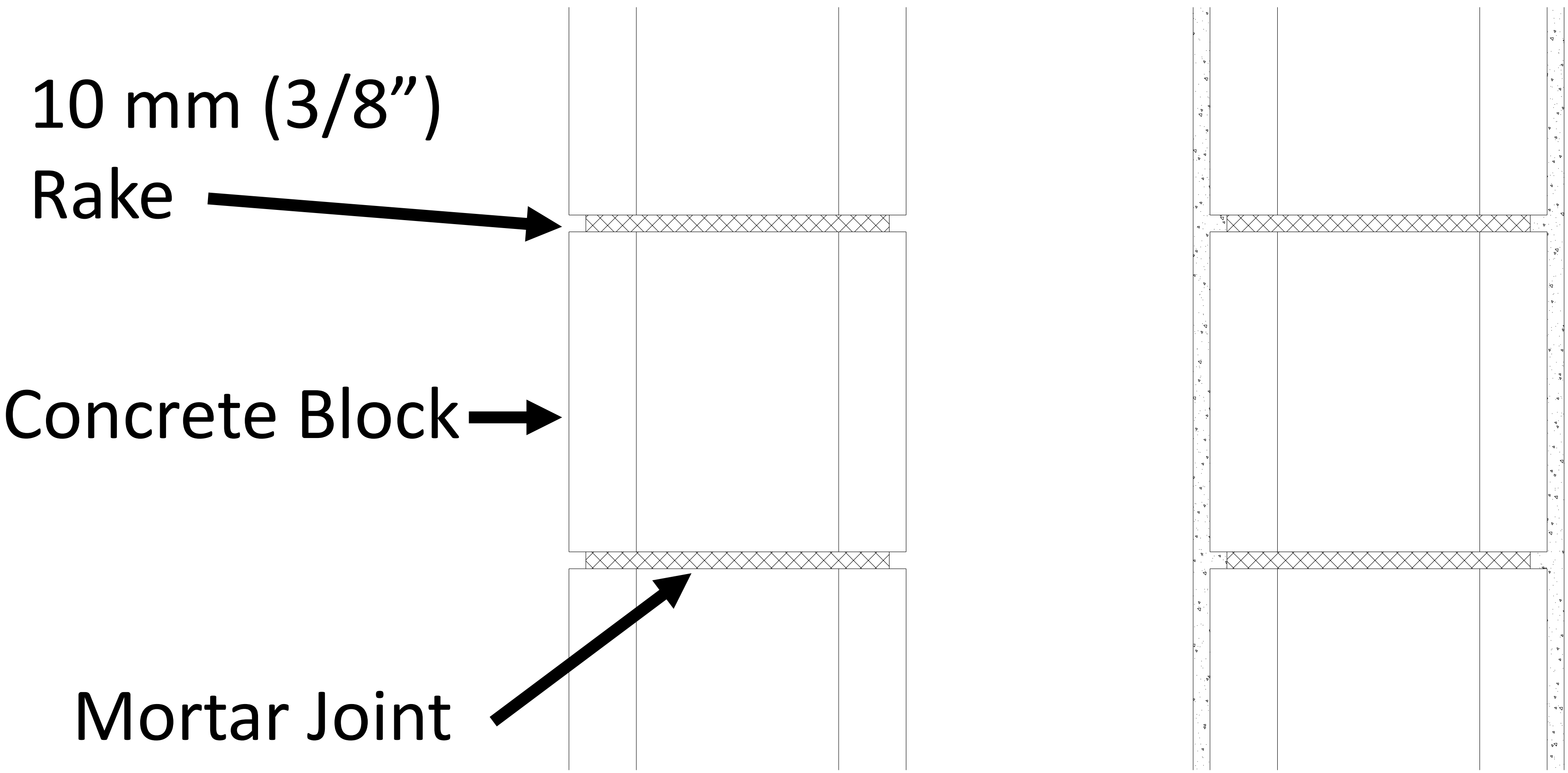

5 gallon bucket

Structural Material	**Standards**
Mortar for block joints and plastering walls above grade.	1 bag of cement (94 lbs = 1 cu-ft = 1.5 x 5 gallon bucket) + 1/2 lime (3/4 bucket) + 4 cu-ft sifted sand (6 buckets) To be used within 1 hour after mixing.
Mortar for repairs and below grade masonry work.	1 bag of cement (94 lbs = 1.5 buckets) + 1/4 lime (~1/2 bucket) + 3 cu-ft sifted sand (4.5 buckets) To be used within 1 hour after mixing.
Grout for infilling blocks	Concrete mix producing a 28-day compressive cube strength of 15 MPa (2,175 psi) = 1 bag of cement (94 lbs = 1.5 buckets) + 3 cu-ft sand (4.5 buckets) + 6 cu-ft of 12 mm (1/2”) stone (9 buckets) Slump = 115 – 230 mm (4.5” – 9”) To be used within 1.25 hours after adding water.

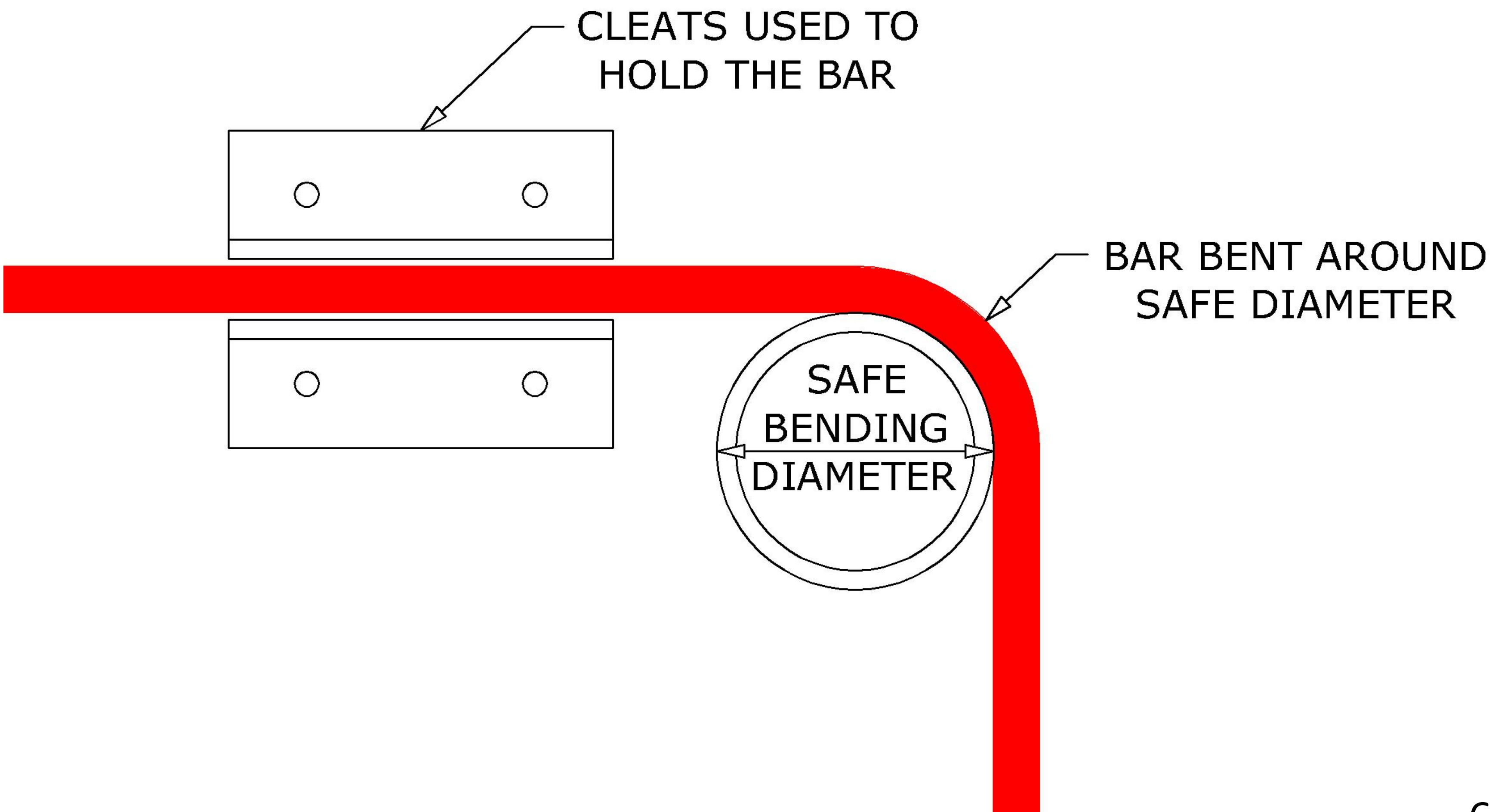




Mortar joints should be raked 10 mm (3/8”) to improve the bond with the plaster.

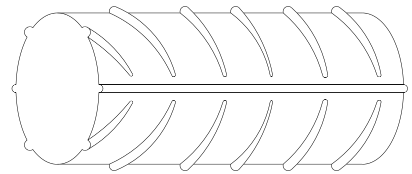


Bars should be bent around safe bending diameters.



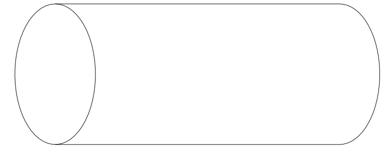
A 7.2 Safe (Minimum) Bend Diameters

High Yield (T) Bars (460 MPa)



- For bar diameters of 20 mm (3/4”) and less, the safe bending diameter = 6 x Bar Diameter
- For bar diameters of 25 mm (1”) and greater, the safe bending diameter = 8 x Bar Diameter

Mild Steel (R) Bars (250 MPa)



- For all bar sizes, the safe (minimum) bending diameter = 4 x Bar Diameter

A 7.2 Safe (Minimum) Bend Diameters

Bar Diameter	**High Yield (T)**	**Mild Steel (R)**
6 mm (1/4”)	36 mm (1.5”)	24 mm (1”)
8 mm (5/16”)	48 mm (2”)	32 mm (1.25”)
10 mm (3/8”)	60 mm (2.5”)	40 mm (1.5”)
12 mm (1/2”)	72 mm (3”)	48 mm (2”)
16 mm (3/4”)	96 mm (4”)	64 mm (2.5”)
20 mm (5/8”)	120 mm (5”)	80 mm (3.15”)
25 mm (1”)	200 mm (8”)	100 mm (4”)

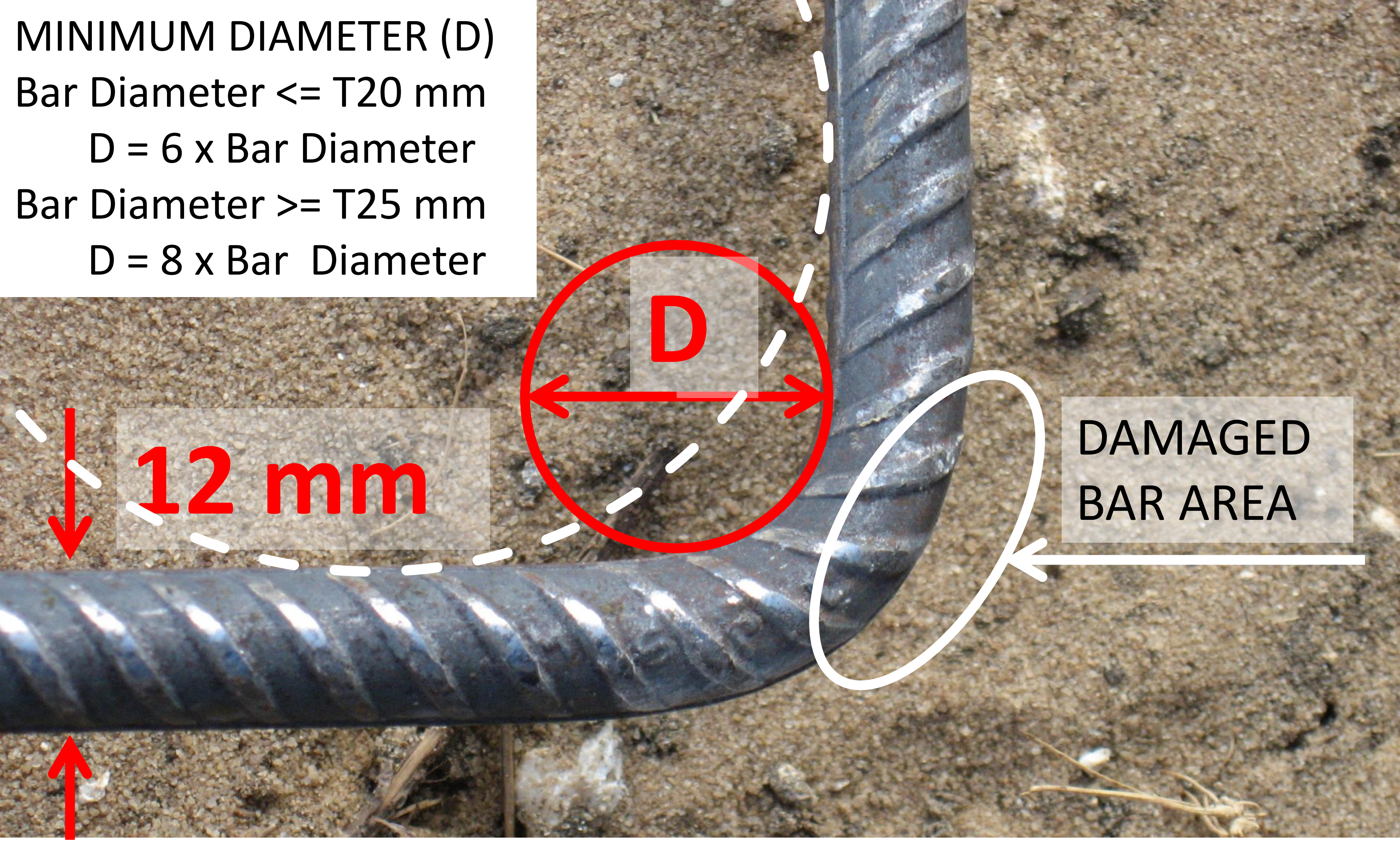
MINIMUM DIAMETER (D)

Bar Diameter <= T20 mm

D = 6 x Bar Diameter

Bar Diameter >= T25 mm

D = 8 x Bar Diameter



Bar Diameter = 12 mm

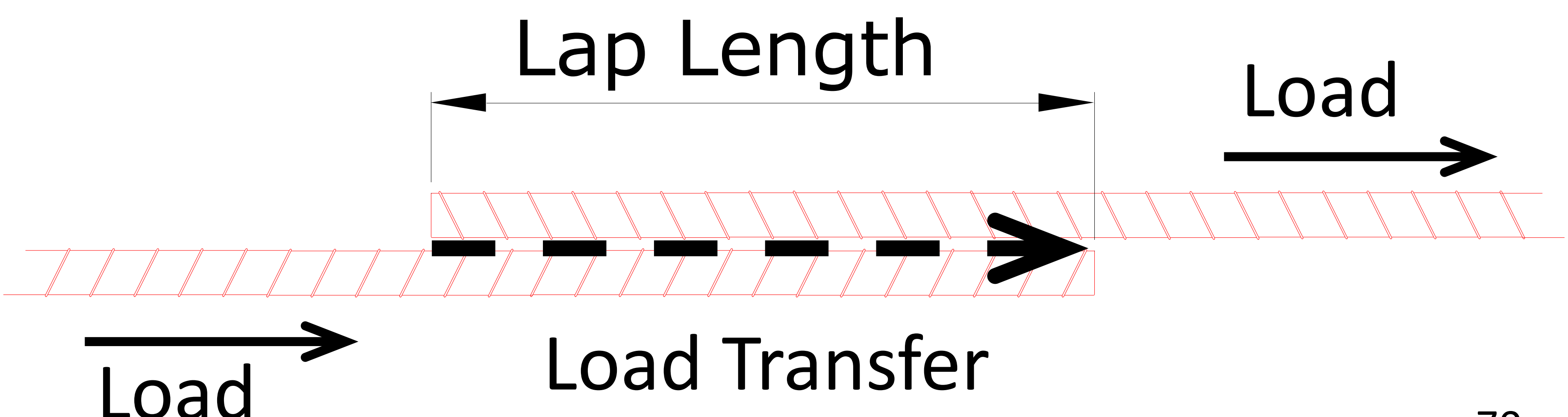
D should be 6 x 12 = 72 mm minimum (dashed white curve)

D was measured as 24 mm (continuous red circle).

A 7.3 Safe Reinforcement Lap or Splice Distances (50 x bar diameter)

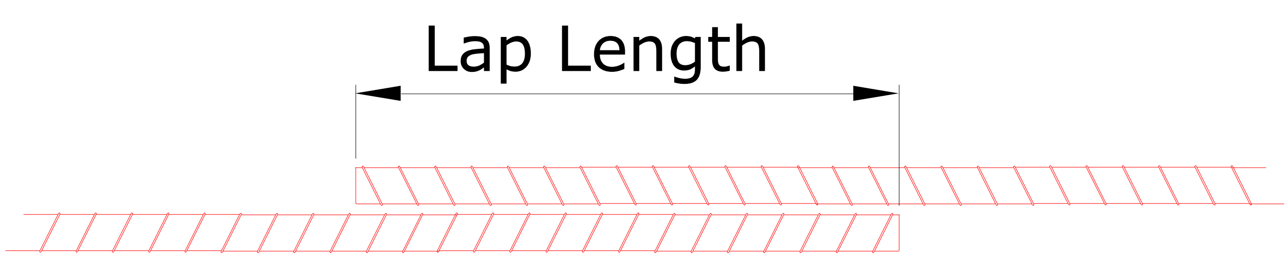
Home

- To effectively transfer the tension load from one bar to another, they need to be lapped.
- If the lap length is too short, then the load may not be effectively transferred.



A 7.3 Safe Reinforcement Lap or Splice Distances (50 x bar diameter)

Bar Diameter mm (in)	Lap Distance mm (in)
6 (1/4”)	300 (12”)
8 (5/16”)	400 (16”)
10 (3/8”)	500 (20”)
12 (1/2”)	600 (24”)
16 (5/8”)	800 (32”)
20 (3/4”)	1000 (40”)
25 (1”)	1250 (48”)



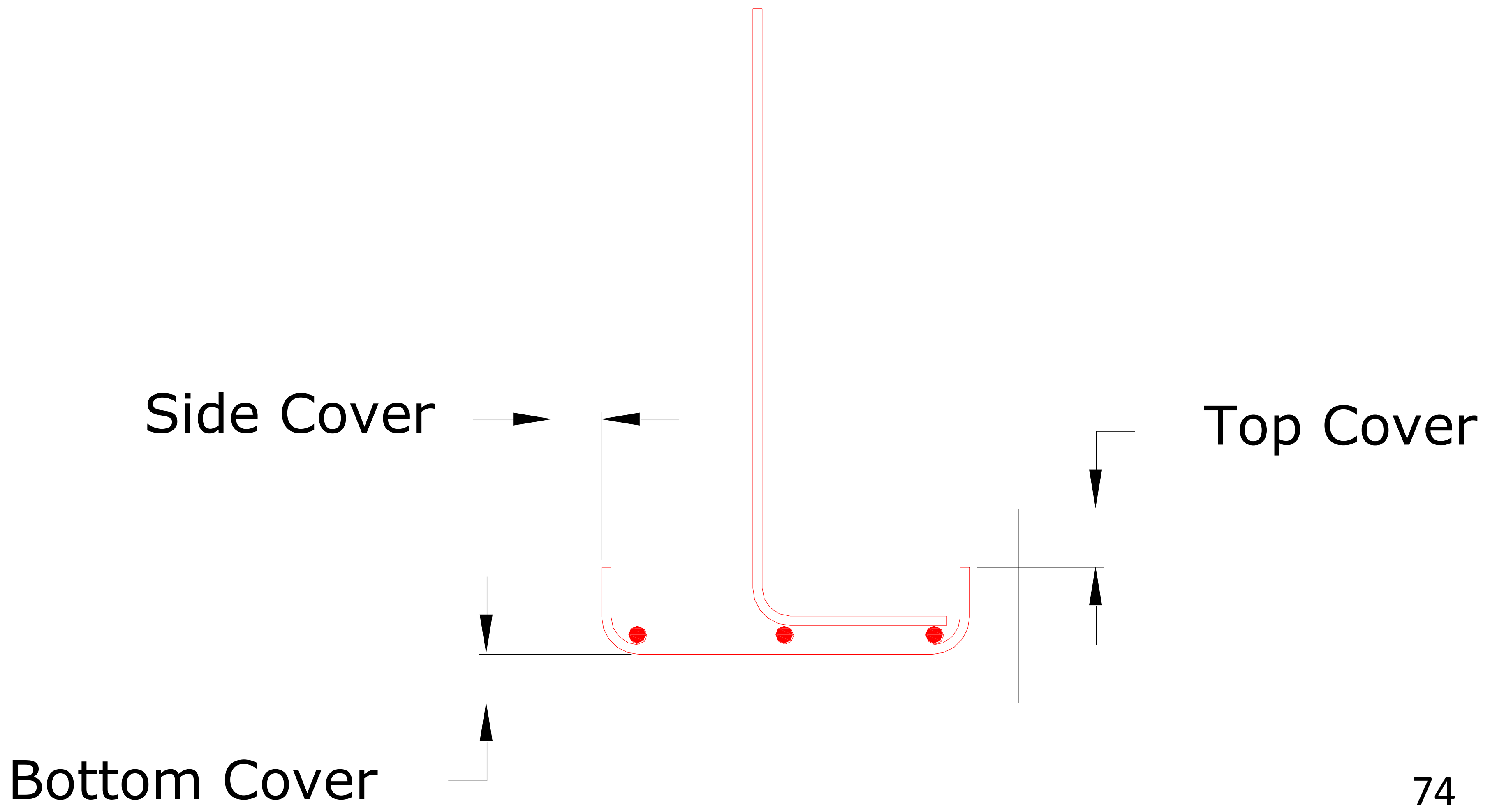
A 7.4 Corrosion and Fire Protection

1. Steel reinforcement must be protected from the natural environment and from fire.
2. Concrete cover is used to protect the reinforcement from a corrosive environment (air, moisture and salts) and from fire.
3. To provide adequate fire protection to reinforced concrete (RC), the structural members must have minimum dimensions and concrete cover as shown in the following Table.

Inadequate concrete cover means that reinforcement is vulnerable to corrosion.

Home

Cover to Strip Footings

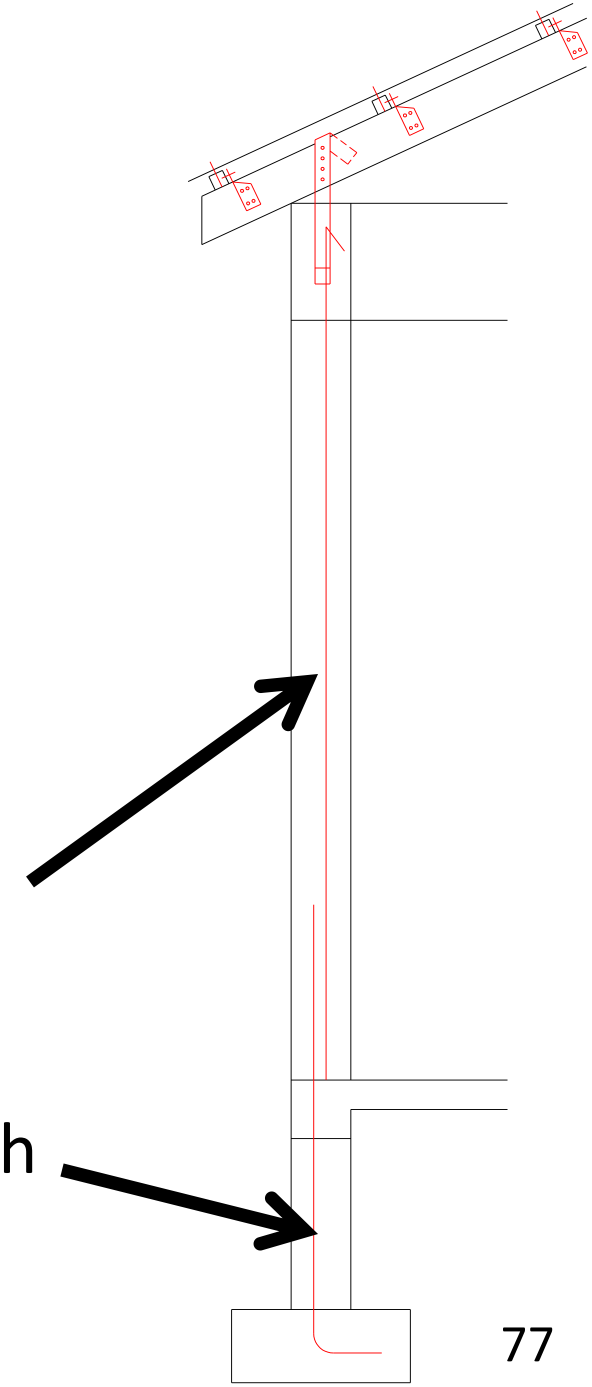


Reinforced Concrete Structural Element	Minimum Protective Concrete Cover	Fire Resistance Rating
Foundations – surfaces in contact with earth	75mm (3”)	> 4 hours
Slabs - Minimum thickness 100mm (4”)	25mm (1”)	1.5 hours
Beams - minimum width 150mm (6”)	40mm (1 5/8”)	1.5 hours
Internal Columns - minimum width 250mm (10”)	30mm (1¼”)	1.5 hours
External Columns - minimum width 200mm (8”)	30mm (1¼”)	1.5 hours

A.8 Quality of Connections

- Good quality connections can reduce the risk of the property blowing away or coming apart during natural hazards.

1. Roof sheeting (24 ga, 0.5 mm) connected to Purlins with screws.
2. Purlin connected to Rafters with hurricane connectors and screws.
3. Rafters connected to Ring Beam with Truss Anchor.
4. Ring beam connected to wall with Rebars.
5. Wall connected to Foundation with rebars.



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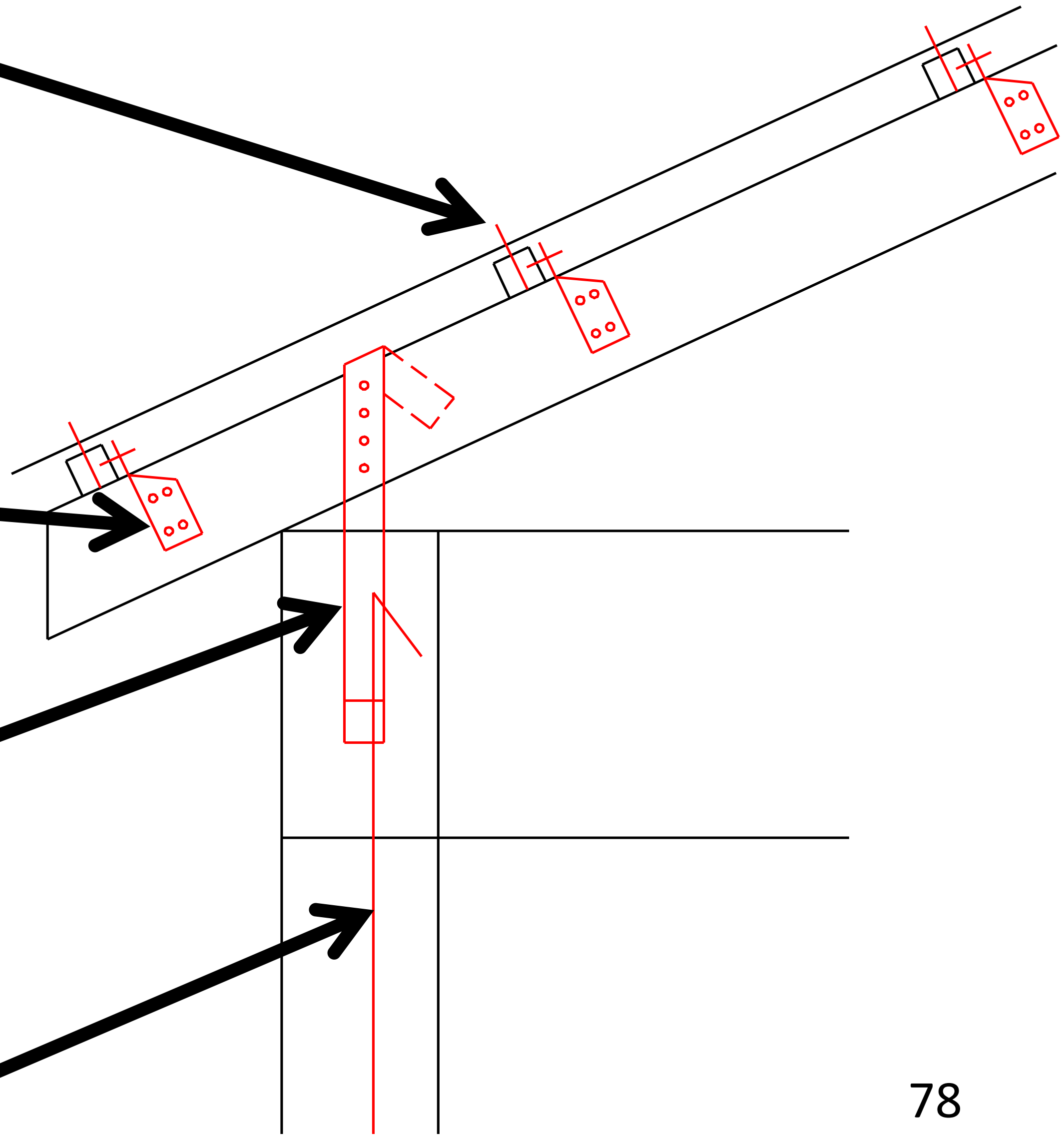
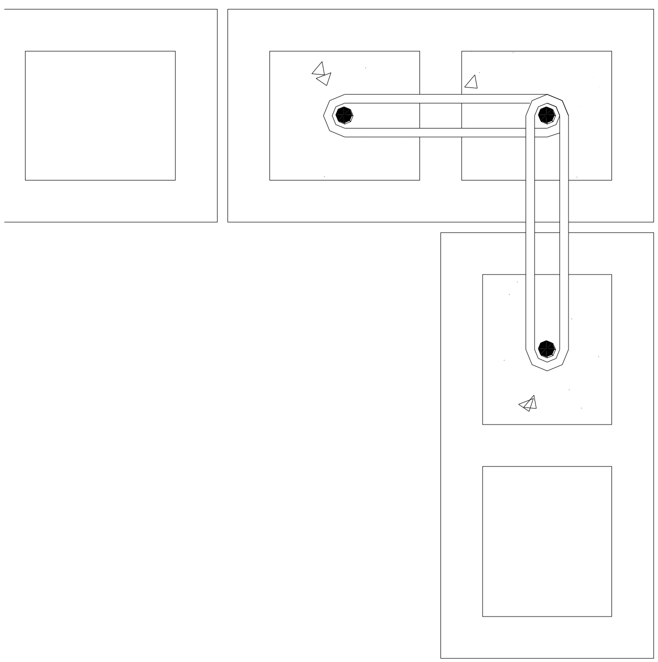
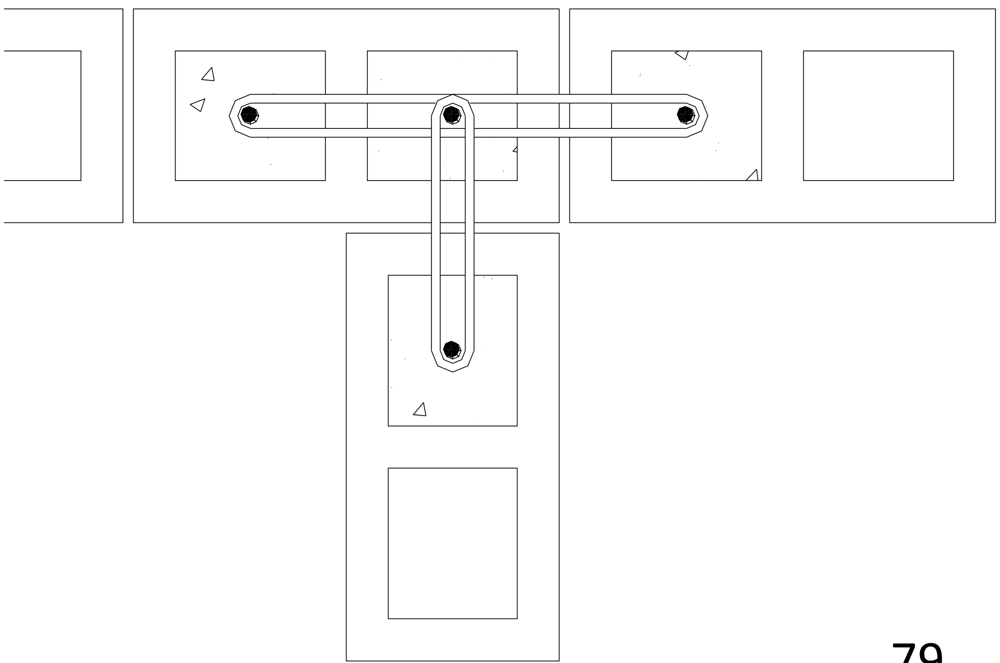
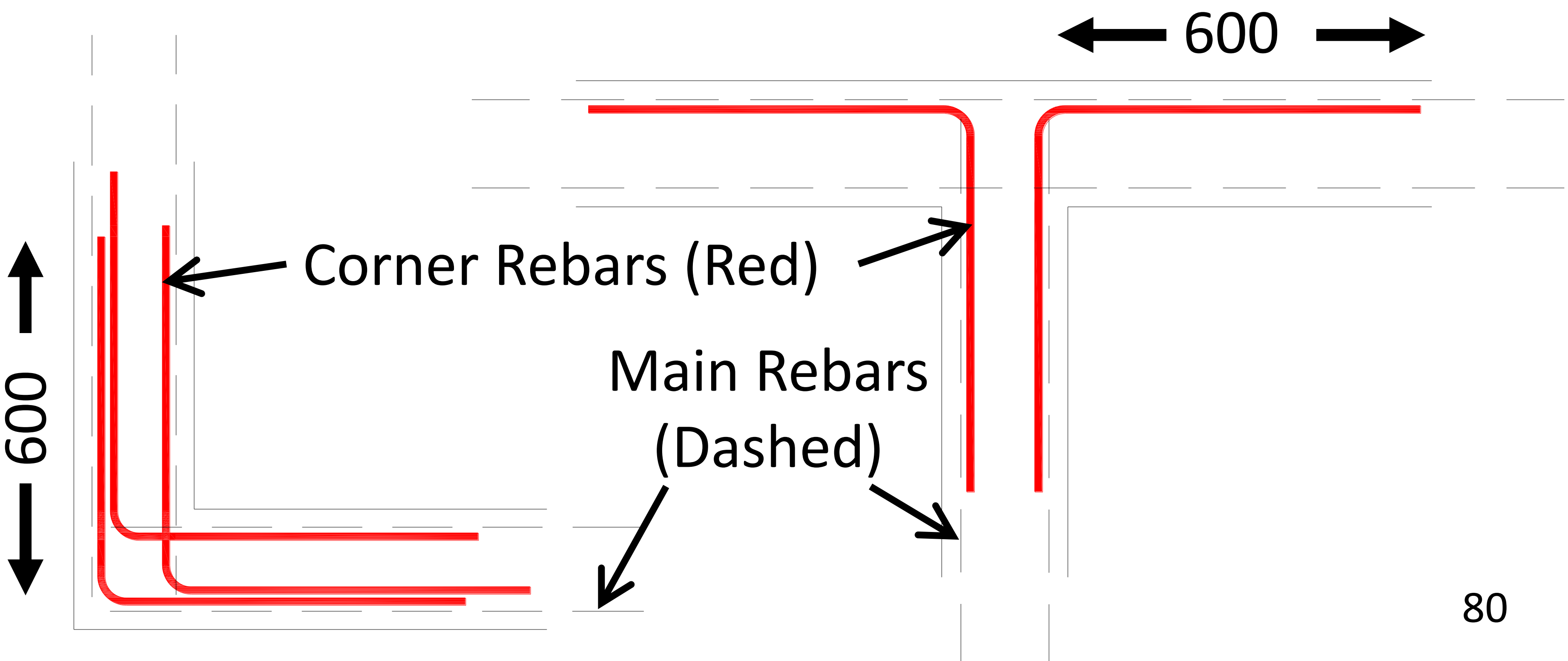


Structural Elements	**Connections**
Concrete block walls	T12mm (1/2”) diameter rebars at each junction. R6mm (1/4”) diameter ties at each wall junction every other course, and the reinforced cores filled with concrete.





Structural Elements	Connections
RC beam	T12mm diameter reinforcing bar should lap each bar 600 mm (24”) at each junction and level.

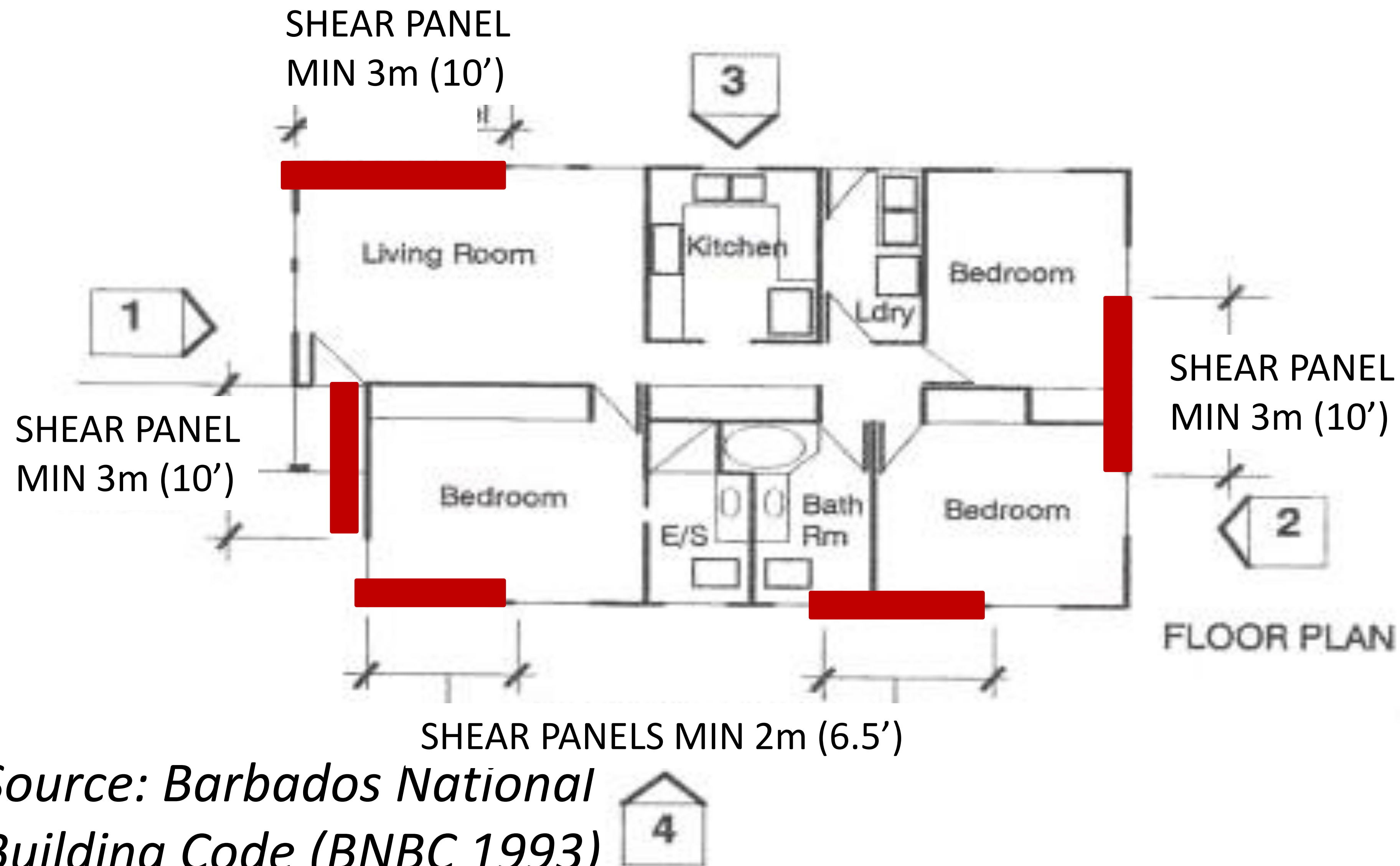


A.9 Lateral Stability

- Good quality bracing methods can keep the building stable and allow the building connections to work as they were designed to during natural hazards and other design loads.
- The most economical method of structural stability for houses is shear walls. **If they are not present, then suggest to the Client that they be included.**

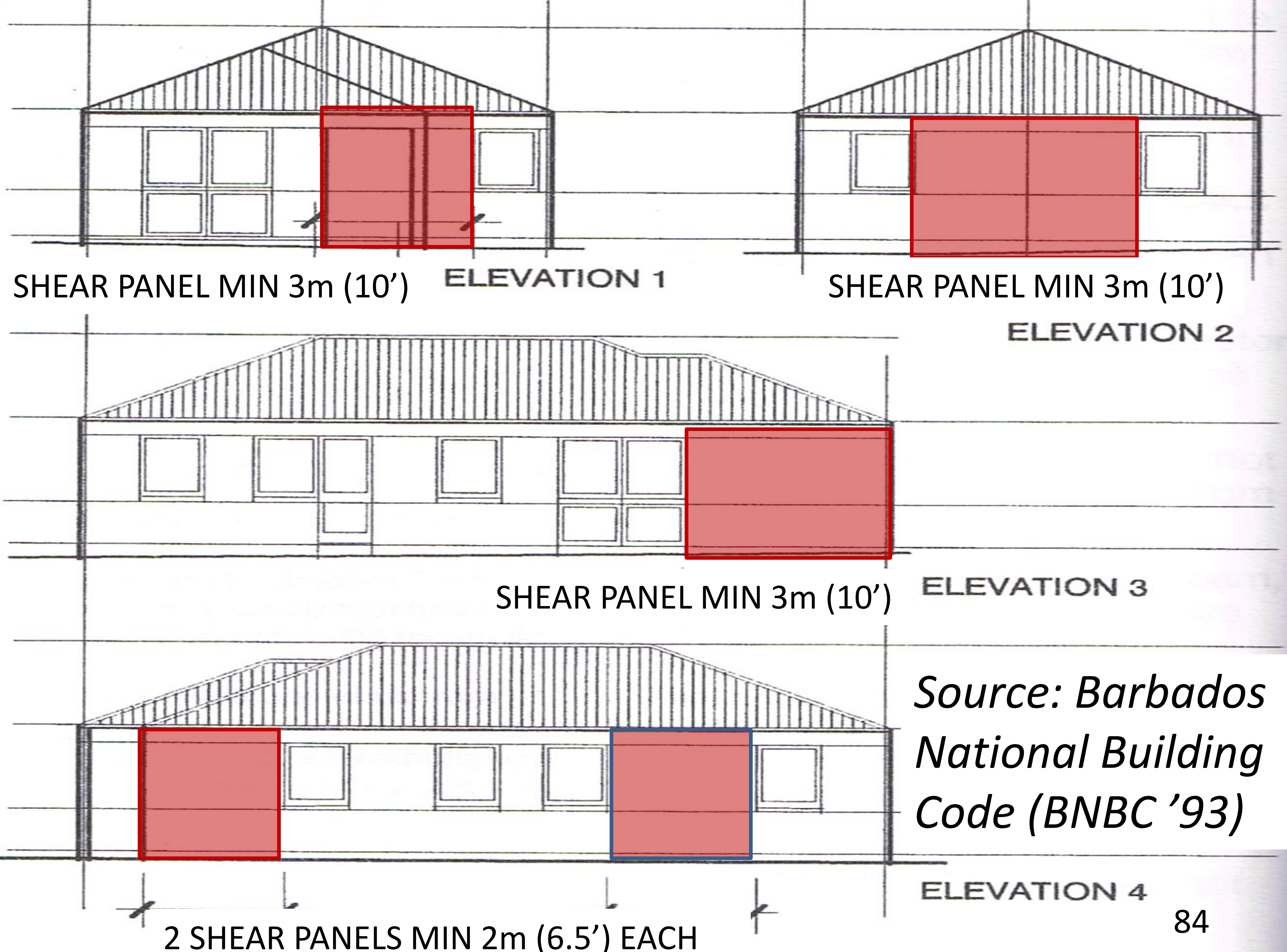
A 9.1 Concrete Block Walled House

- For concrete block houses, provide one 3m (10’) wide external shear wall at each wall elevation. If 3m (10’) is inconvenient, then use two 2m (6.5’) wide shear walls at each wall elevation.
- The shear walls must be constructed from foundation to roof with no openings (windows or doors).



Source: Barbados National Building Code (BNBC 1993)

Figure 2.405A
EXAMPLE PLAN - SINGLE STOREY DWELLING


SHEAR PANEL MIN 3m (10’)
ELEVATION 1
SHEAR PANEL MIN 3m (10’)
ELEVATION 2
SHEAR PANEL MIN 3m (10’)
ELEVATION 3
ELEVATION 4
2 SHEAR PANELS MIN 2m (6.5’) EACH
Source: Barbados National Building Code (BNBC ’93)

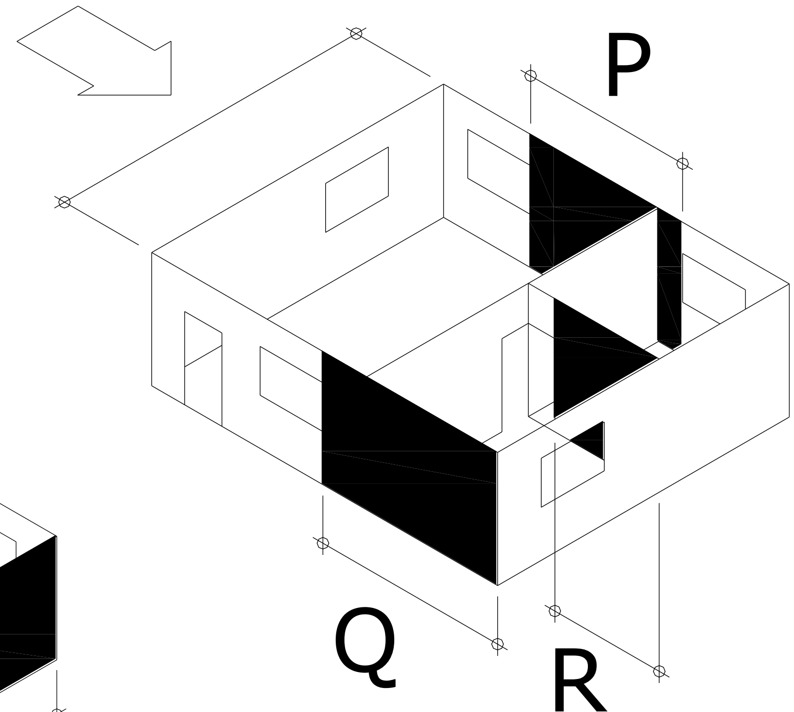
A 9.2 Timber Walled House

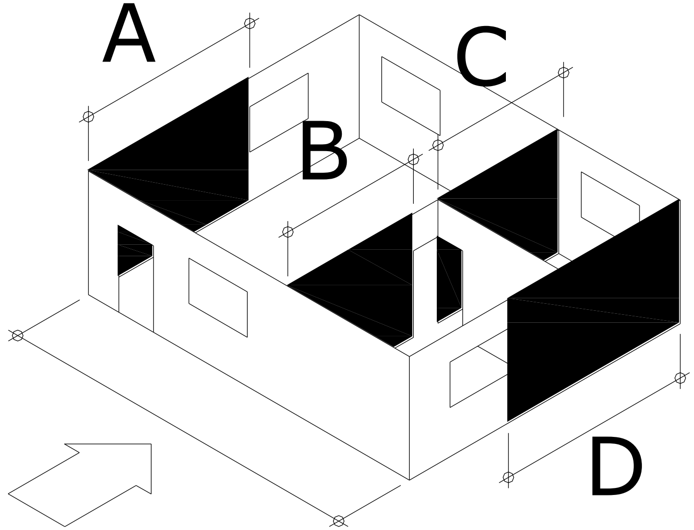
- Both the internal and external walls can be used to provide stability to a timber walled house.
- The sum of the shear walls parallel (in the same direction) to the wind should exceed twice the width of the house elevation facing the wind.
- Shear walls must be braced with diagonal members at the corners.

Timber Shear Walls

(Provided in both directions)

P+Q+R > 2xW2
WIND DIRECTION 2
(W2)

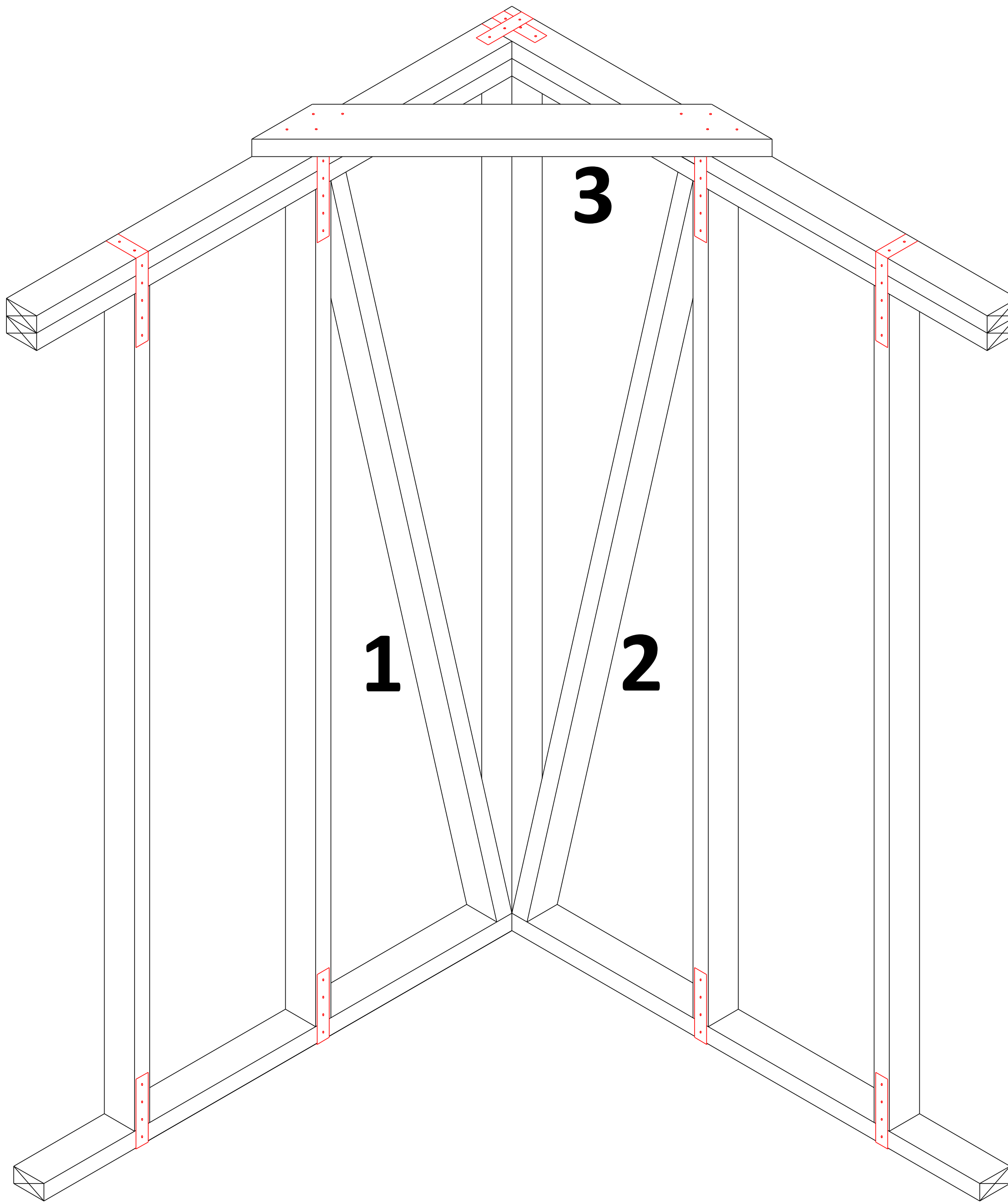




(W1)
WIND DIRECTION 1
A+B+C+D > 2xW1

Note:
Internal bracing must be evenly distributed.

Timber bracing at each corner in three planes (1, 2 & 3).



A.10 Design for Elderly and Disabled People

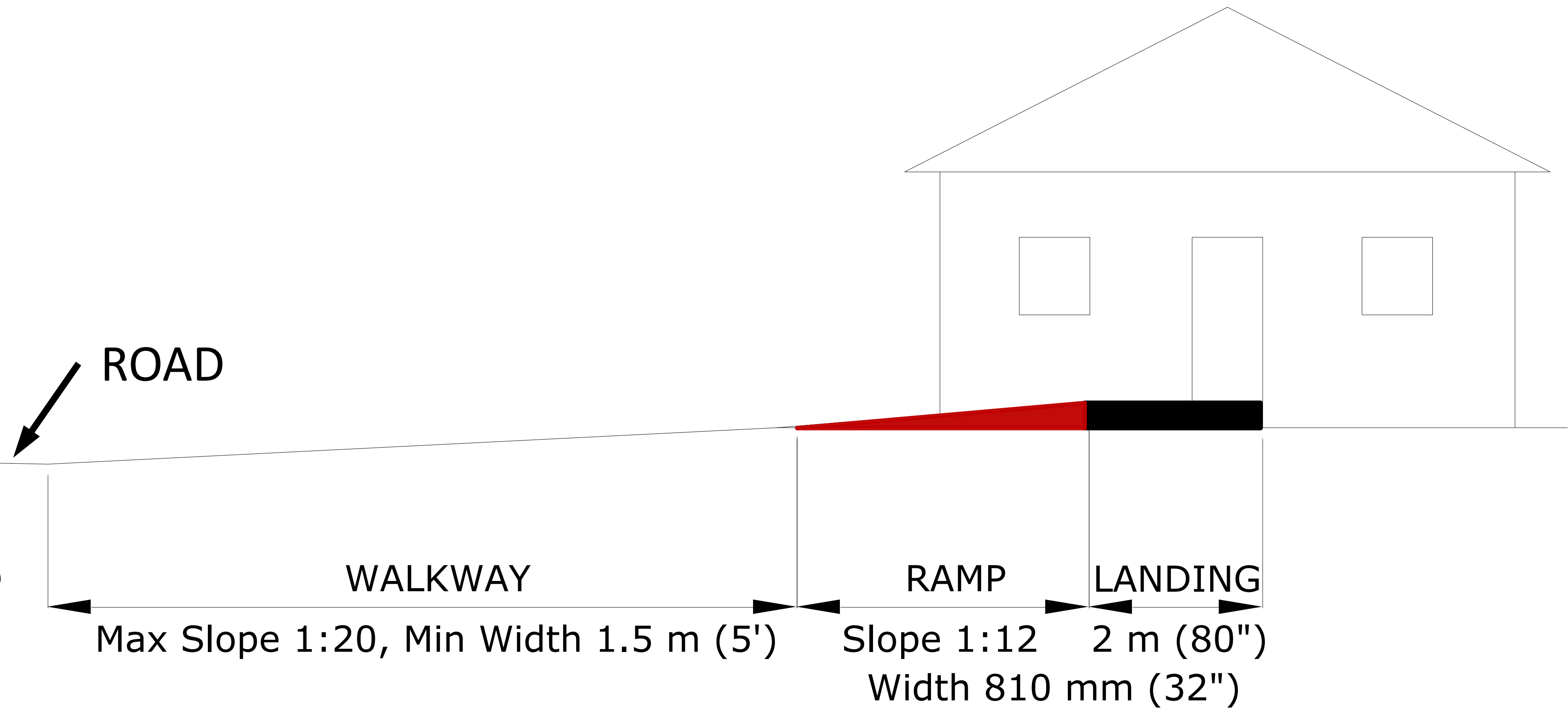
A.10.1 Maintenance

- Elderly and disabled persons normally have a challenge in maintaining their properties.
- If good quality materials are used, and assembled properly, then the house will not attract high maintenance requirements.

A.10.2 Building Access

- The walkway from the street to the house should be at least 1.5 m (5 ft) wide, with a slope of at least 1:20.
- Allowance should be made for a ramp width of 810 mm (32”) and slope of 1:12.
- At the entrance, the length of the landing should be at least 2 m (80”).

A.10.2 Building Access



A.10.3 Doors and Corridors

- All external doors and bathroom doors should open outwards.
- All door openings should be 810 mm (32”) wide.
- Door levers should be used, not door knobs.
- All corridors should be a minimum width of 1 m (40”).

A.10.4 Kitchen, Laundry and Bathrooms

- A clearance of 1,370 mm (54”) should be provided around all: cabinets, counter tops, ovens, washers, driers, tubs, and any other furniture or appliance.

A.10.5 Electrical Light Fixtures

- All electrical light bases are to accommodate screw type bulbs.

B. DURING CONSTRUCTION

B.1 Preparing the Site

B.1 Preparing the Site

Before the foundations can be constructed, the following should be done:

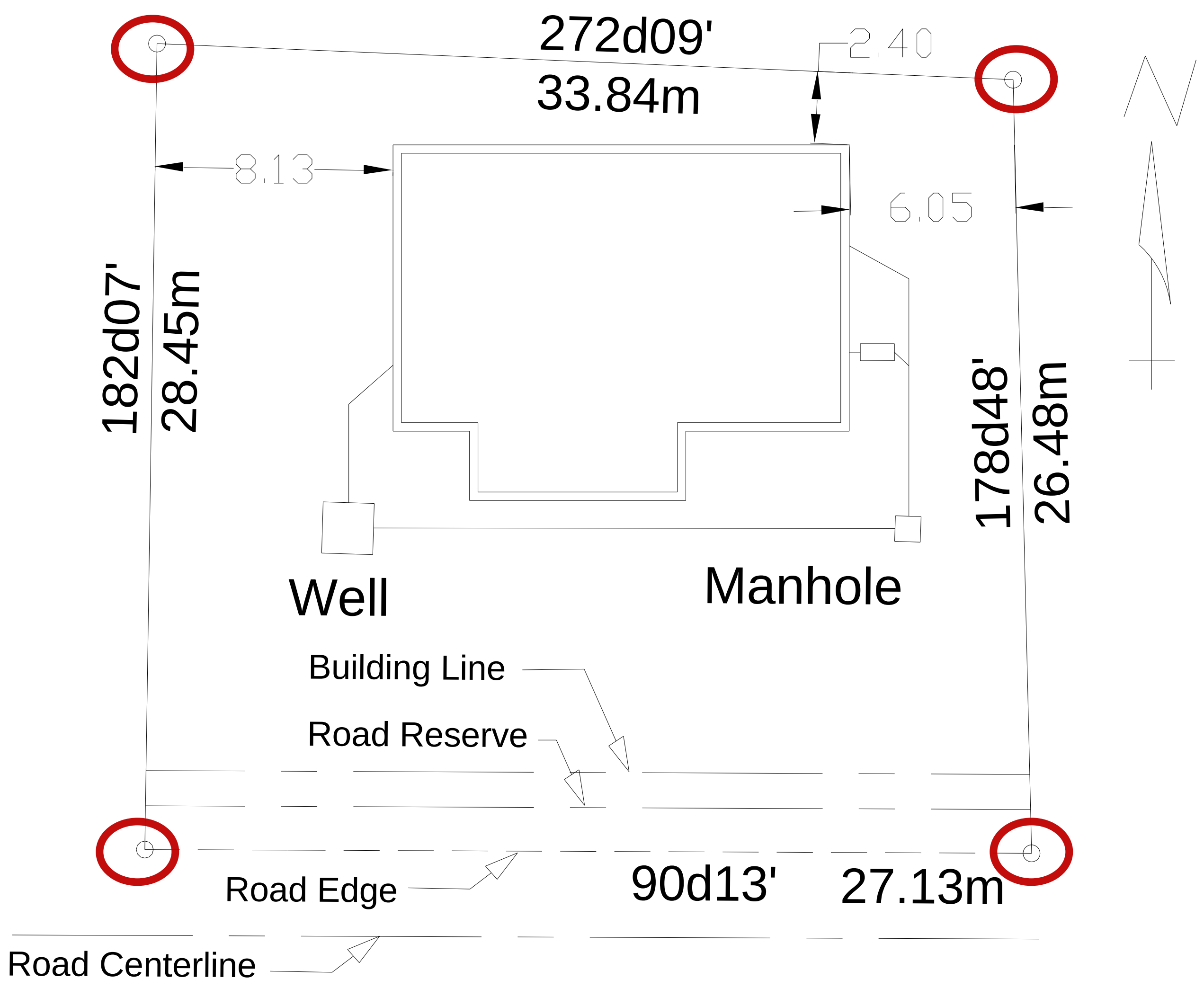
1. The site should be cleared,
2. The boundary markers should be identified and protected.
3. The building should be set out.
4. Areas should be identified for the proper storage of construction materials.
5. The access road should be constructed.
6. The well should be dug and inspected.

B 1.1 Clearing the Site

1. If the site is overgrown with bush, then it needs to be cleared.
2. A tidy and orderly site can reduce the risk of accidents occurring.
3. The area where the building is to be located should be striped of top soil, which should be stockpiled for landscaping.

B 1.2 Boundary Markers

1. Identify and protect the boundary markers.



2. Check that the distance between the boundary marks are the same as on the Surveyor's plot plan.

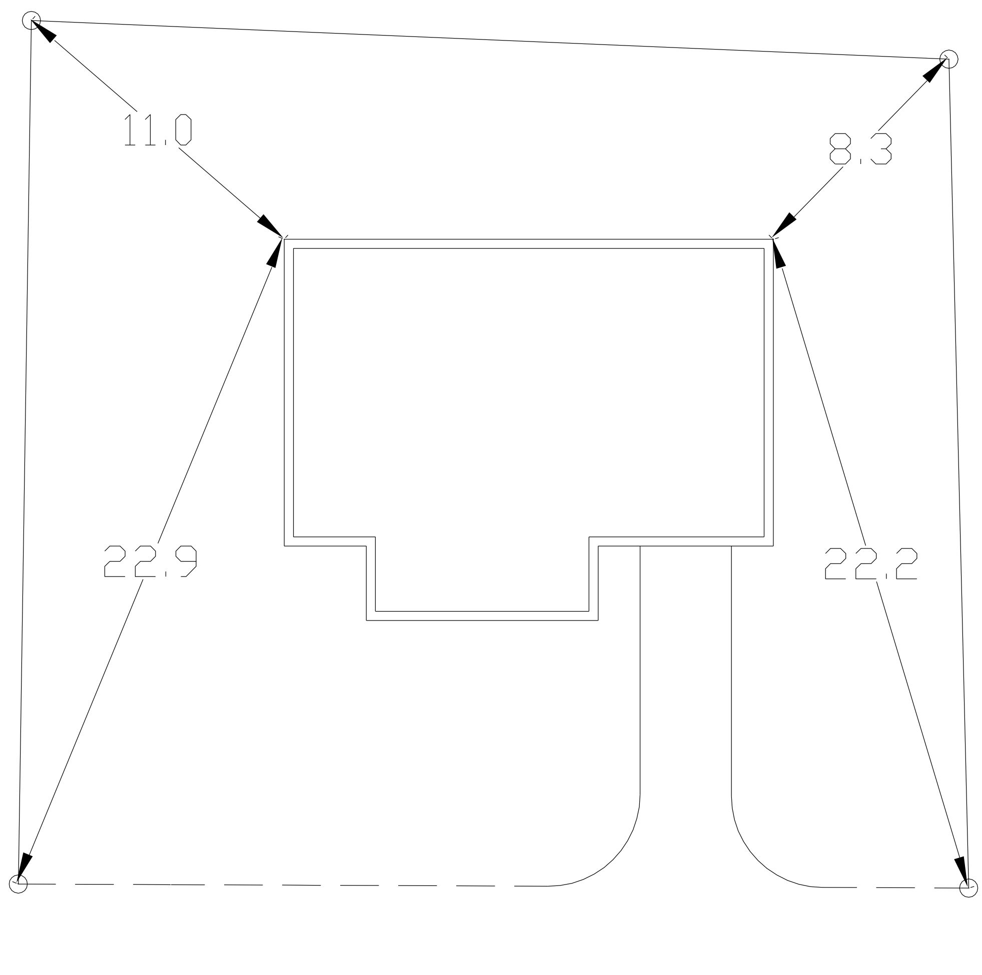
3. If there is uncertainty regarding the location of the boundary markers, then the property-owner should be requested to identify them.

4. If the wall is built on the neighbour's property, or too close to your Client's boundary – without planning permission - then your Client may be forced to demolish part of the house, and you may not get paid.

Home

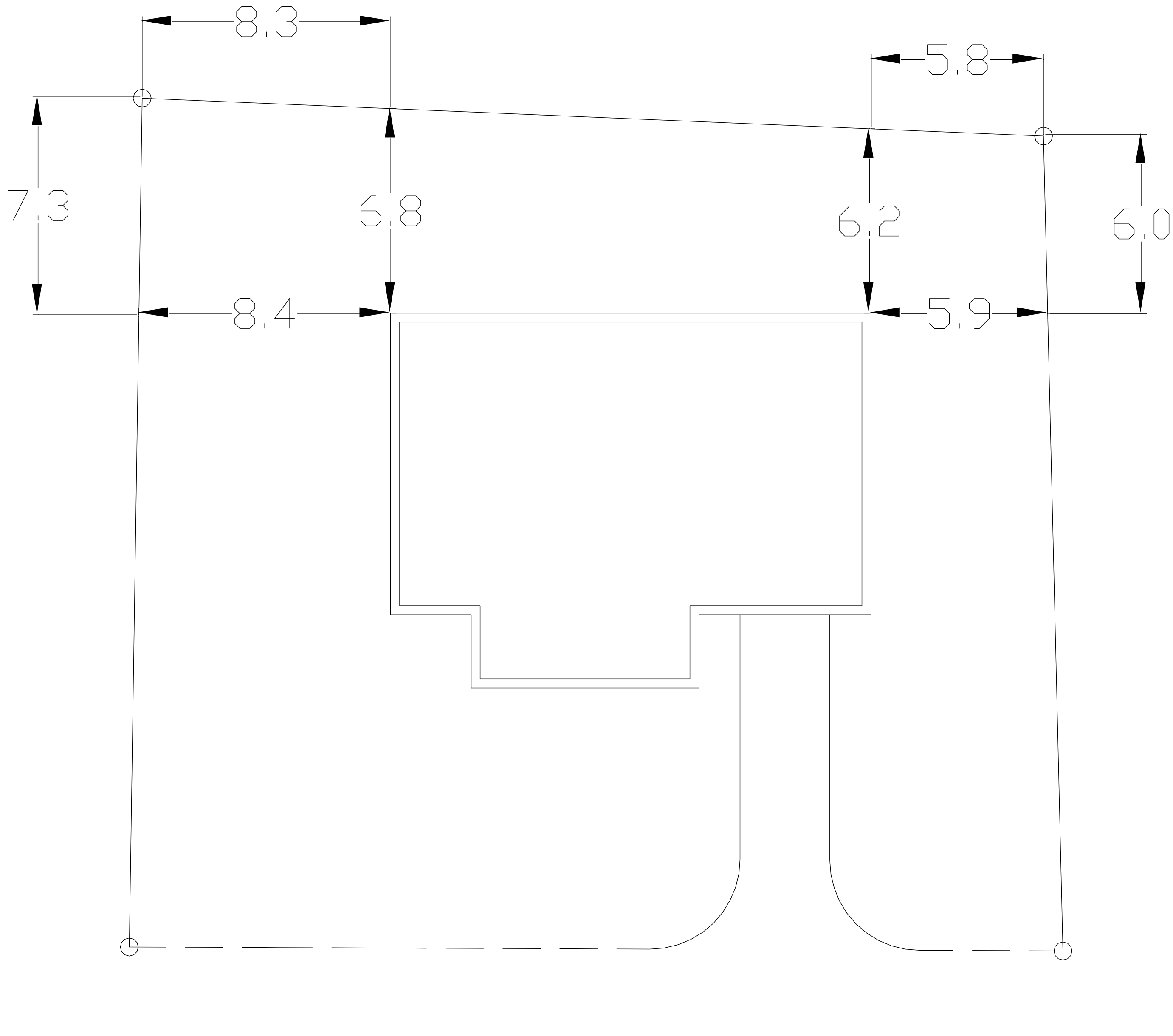
5. Obtain enough dimensions from the boundary to accurately set out one wall of the building.

Triangulation Method (requires 2 measurements at each corner)

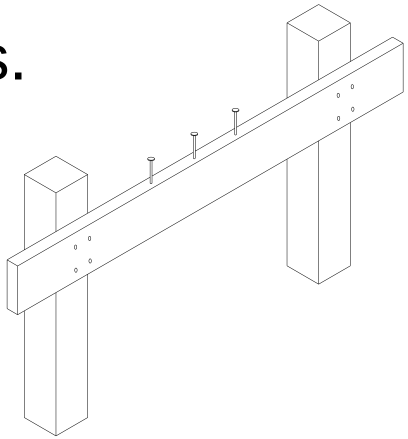


Offset Method (requires 4 measurements at each corner)

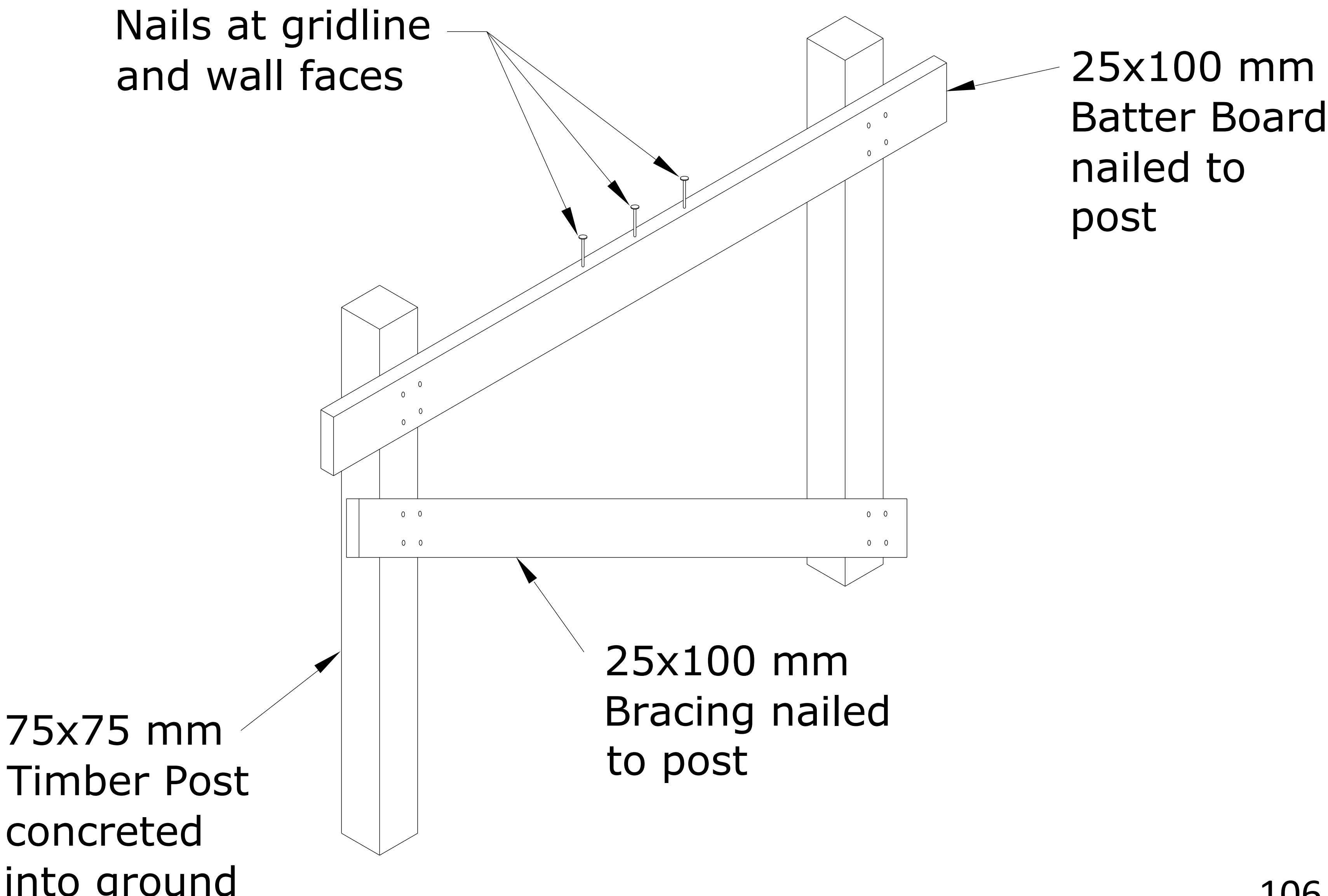
Home



No.	Setting out Construction Method	Comment
1	Clear the building area from all vegetation.	To provide a clean surface to make setting out measurements.
2	Lay out the corners of the building using measurements from the boundary irons. **Ask for any missing dimensions.**	To position the building as designed.
3	Set out temporary pegs defining the area to be excavated. Paint or sprinkle sand between the pegs as a guide.	To avoid over or under excavating.
4	Excavate to rock or sound formation using a mechanical excavator, and cut into the rock if it is found.	To reduce settlement.

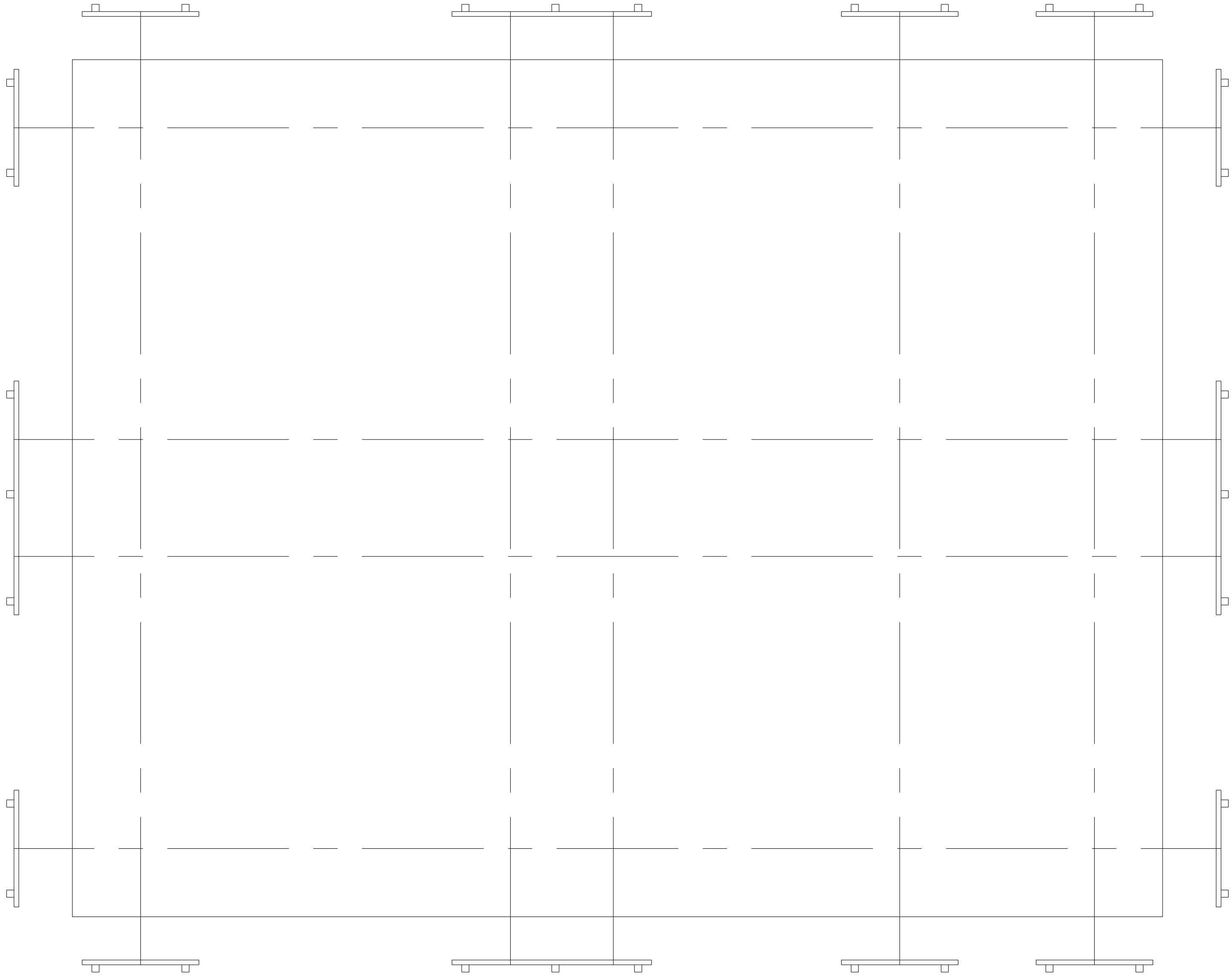
No.	Construction Methods	Comment
5	Erect batter boards at the corners and at the ends of internal walls. The boards should be located at least 1m away from the edges of the trenches or excavated area.	To provide clearance for formwork and access. 
6	Brace high (over 300 mm (1')) batter boards with a diagonal brace (1"x4").	To reduce the risk of subsequent movement.
7	Install 3 nails at the top of the batter board – one at the centre line of the wall and one at each face.	To reduce the risk of misinterpretation by different trades.

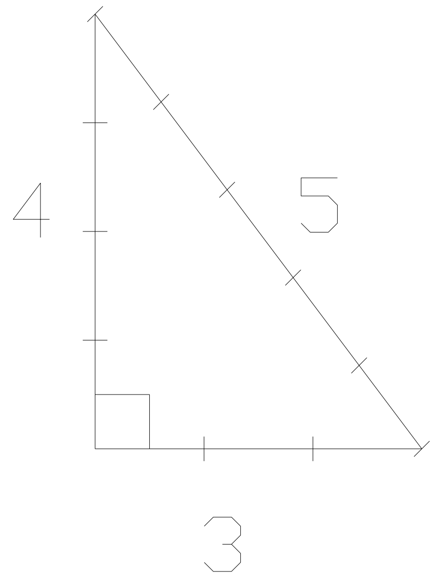
Batter Board



One nail can easily be misinterpreted

Grid Layout on Site Using Batter Boards

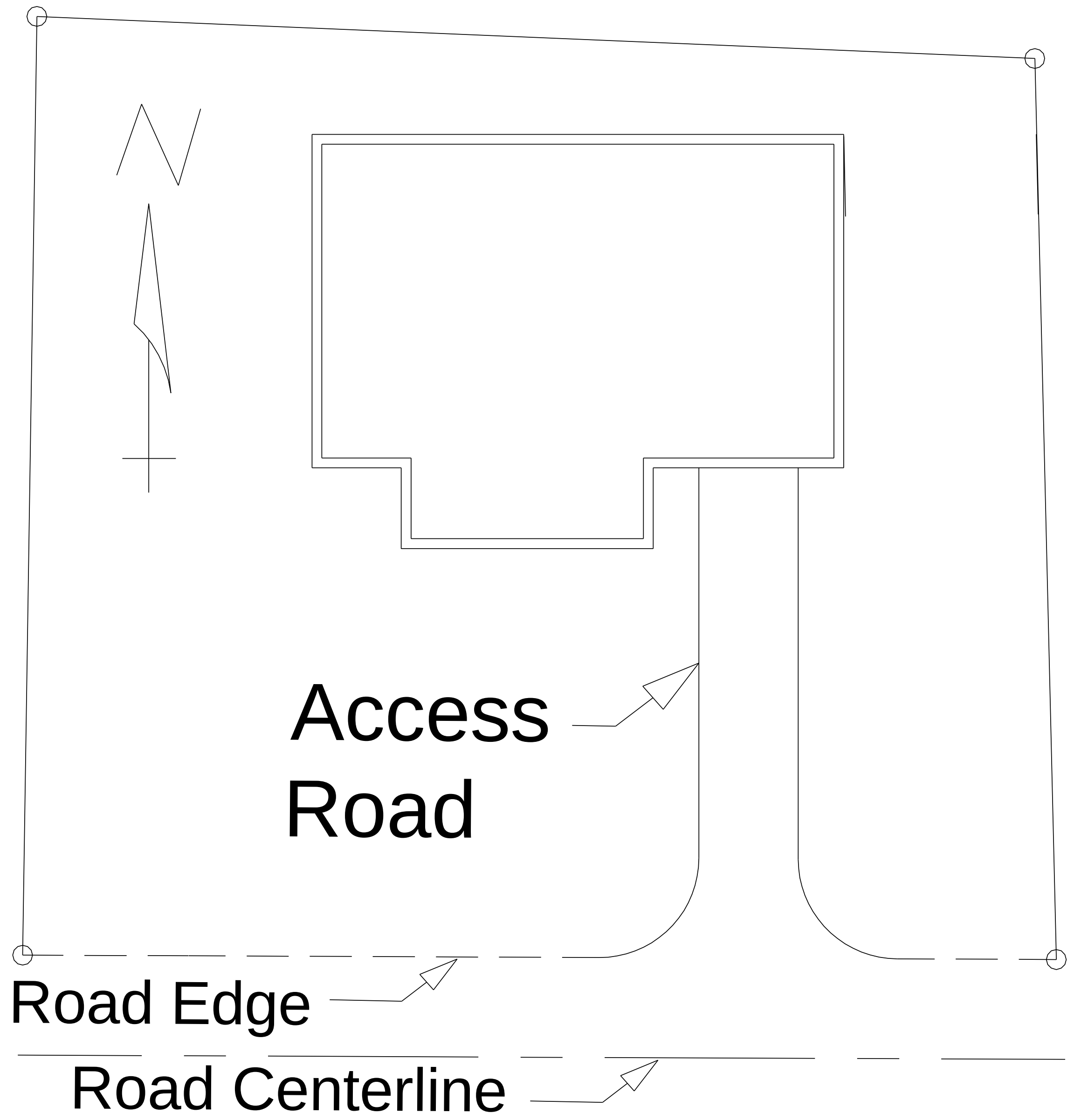


No.	Construction Methods	Comment
8	Check perpendicular angles using the 3-4-5 method and identify (and mark) the vertical distance to the finished ground floor level. 	To facilitate building straight walls, and floors at the correct level.
9	Check periodically to ensure that the boards have not moved during construction.	To maintain the design geometry of the building.

B 1.3 Access Roads

1. If the site is difficult to access, especially while the soil is wet, then a temporary access road may need to be constructed to facilitate deliveries to the site.

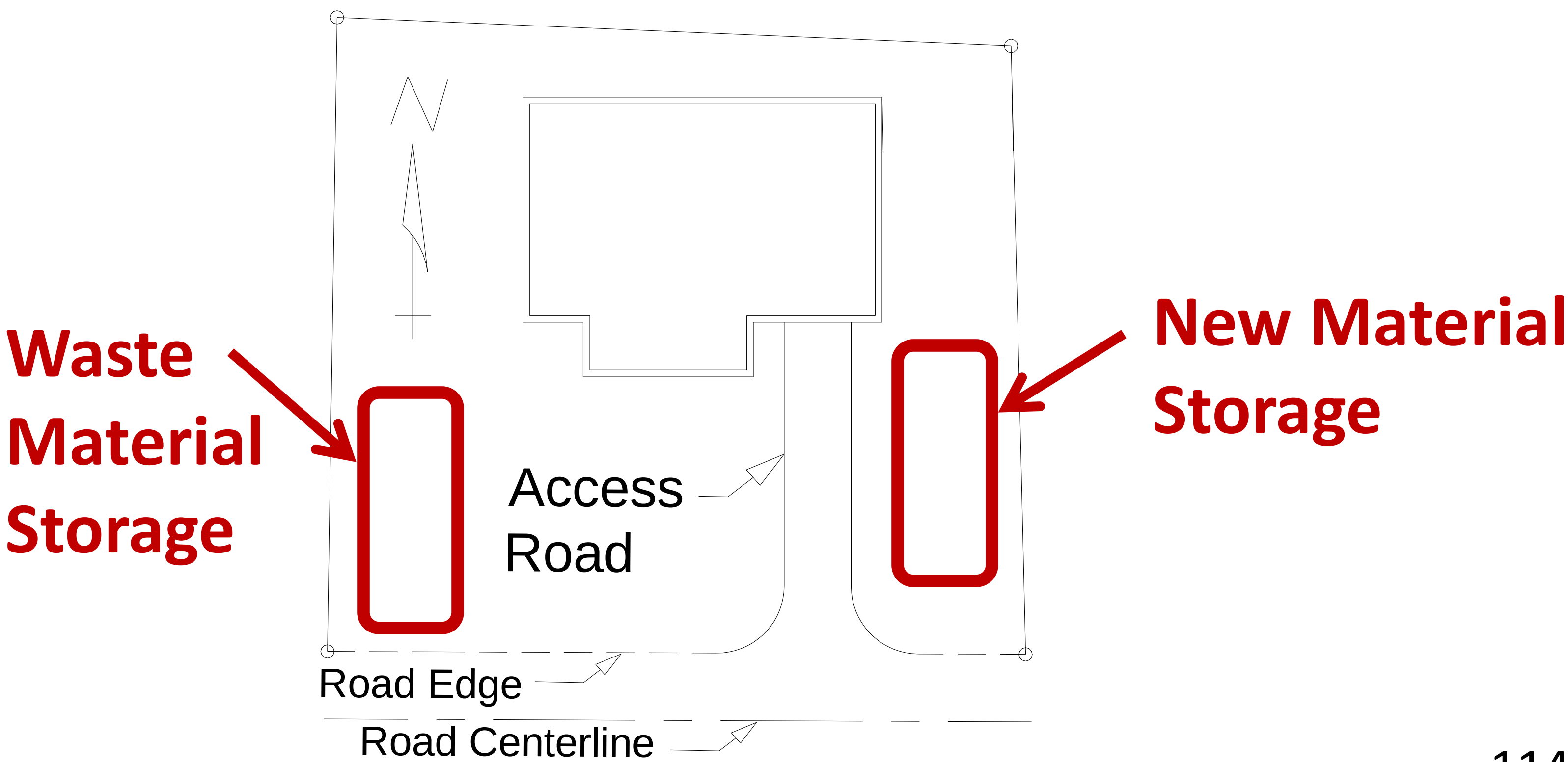
2. If a permanent access road or driveway is required, then the road will have to be accurately set out and properly constructed.


N
Access Road
Road Edge
Road Centerline

No.	Access Road Construction Method	Comment
1	Clear the road area of all vegetation.	To provide a clean surface to make setting out measurements.
2	Lay out the centre line of the access road using measurements from the boundary markers.	To set out the road as designed.
3	Offset the centre line by 1.5m.	To provide a minimum road with of 3.0 m.
4	Remove topsoil and any soft soil to a hard bearing layer (e.g. rock) or to a minimum depth of 600 mm (2 ft).	To reduce settlement.
5	Backfill slab area using well graded granular fill well compacted in placed layers not exceeding 200 mm (8”) thick.	To reduce settlement.

B 1.4 Storing Construction Materials

- Areas need to be identified for storing new and waste construction materials.



Construction Material	Storage	Comment
Cement bags	100 mm off of the floor and covered	To prevent the cement from getting wet (hard and unusable).
Sand and stone	Covered	To prevent it from being blown or washed away.
Timber	100mm off of the ground and covered.	To reduce wet rot and deformation
Reinforcing bars	100 mm off of the ground and covered	To reduce corrosion

B 1.5 Well

1. The well should be dug before the foundations are built in order to check:

a) the depth to rock, or to hard formation on which the building will be founded.

b) whether there are any voids (caves), cracks (joints or fissures), or compressible material (peat, other organic material, refuse, or fill) that can cause the building to move. **Notify the Client if found.**

Protect the well opening to prevent persons from falling in.

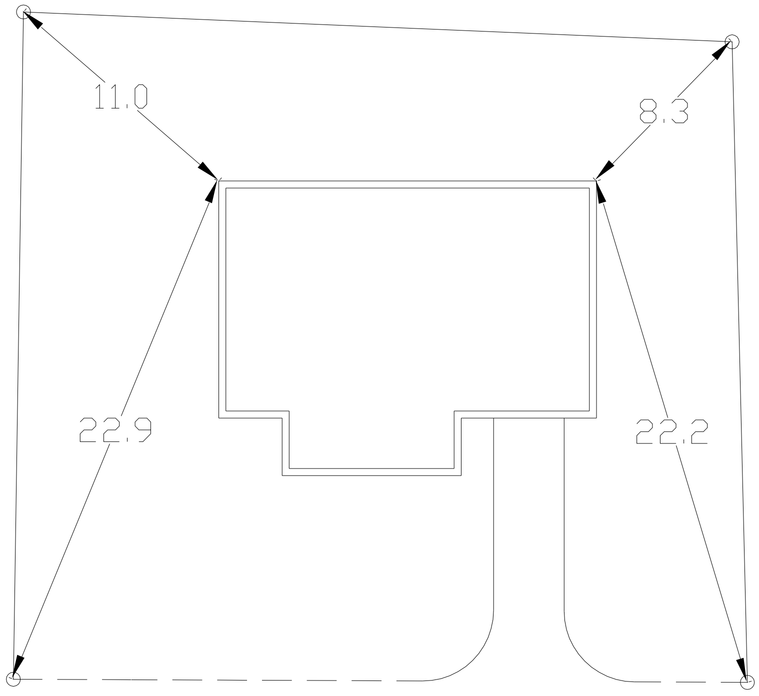
B.2 FOUNDATIONS

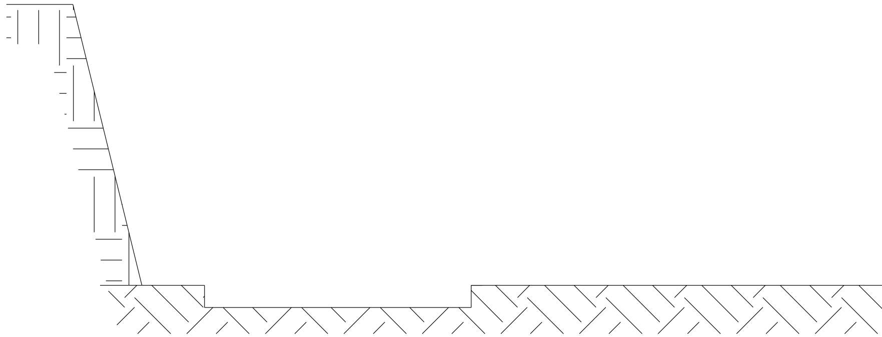
B 2.1 Foundation Types

1) Foundations are designed to support the building by the underlying material, and to prevent the building from moving during natural hazards.
2) There are four types of foundations that are described in this course:
   a) concrete strip
   b) concrete pad
   c) concrete slab-on-ground
   d) timber post

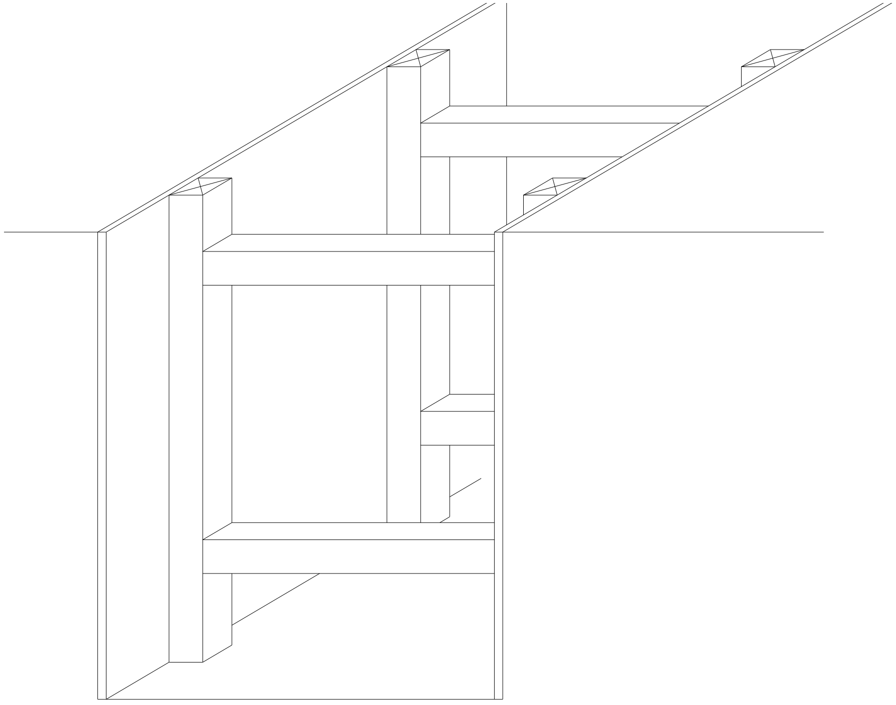
B 2.2 Excavations

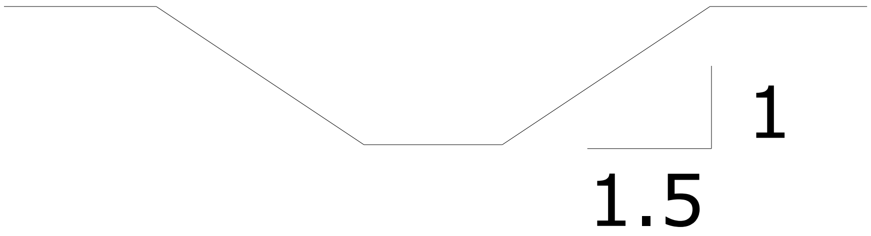
No.	Construction Methods	Comment
1	Setting out (see section B 1.2)	To correctly position the house on the lot.
2	Excavate a minimum of 900mm (3 ft) to a good foundation layer (dense sand, stiff clay) or to rock.	To reduce settlement.

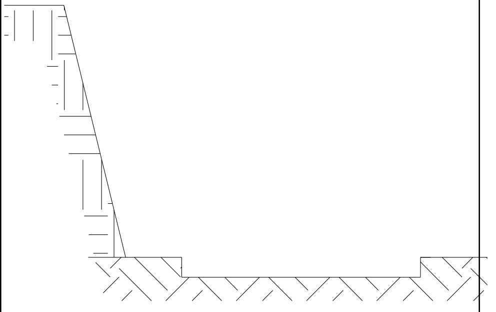




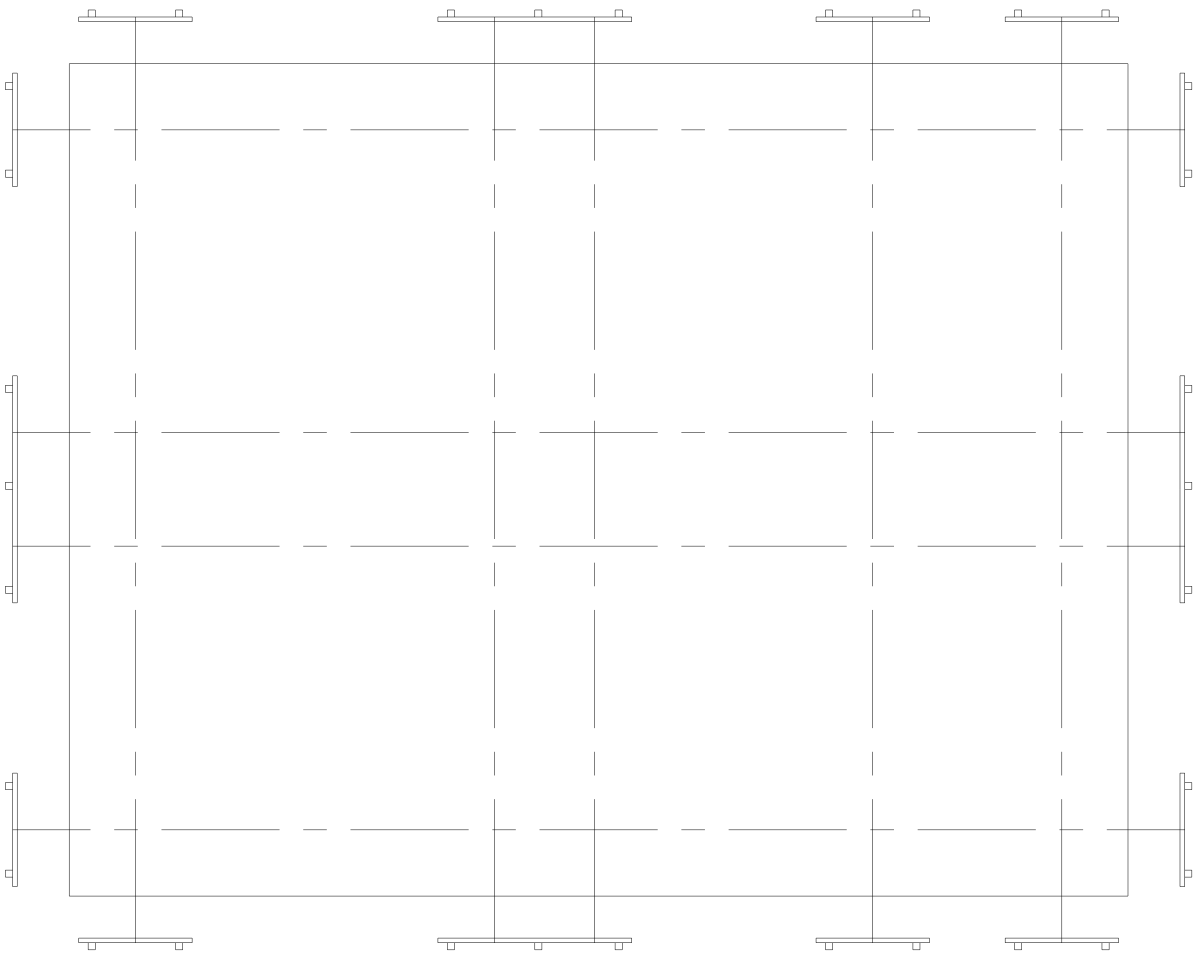
No.	Construction Methods	Comment
3	If the depth of excavation is greater than 1.2m (4 ft), then: a) support the sides of the trench by providing planks and horizontal struts, or b) cut back the sides to a slope of 1.5 horizontal:1 vertical.	To reduce the risk of the sides collapsing.

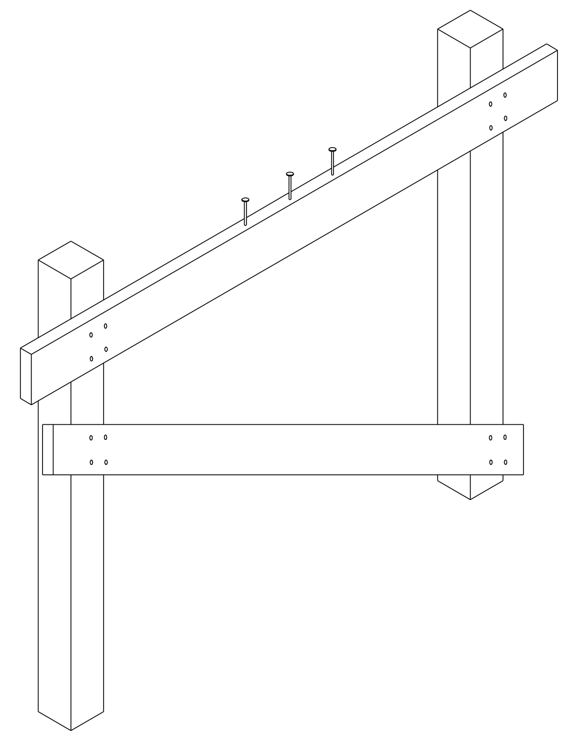




No.	Construction Methods	Comment
4	Inspect the bottom of the excavation. a) If the foundation is rock, then provide a key for the foundations by excavating at least 50mm (2”) into the rock. b) If the bottom of the excavation is loose, then the foundation bottom can be compacted by ramming. c) If there are pockets of unsuitable material (clay), then they need to be removed. Deep areas and over excavated areas can be backfilled with compacted granular material or with 1:3:6 concrete. d) If clay is found or if there is uncertainty, then Engineering advice should be sought.	To reduce foundation settlement. 

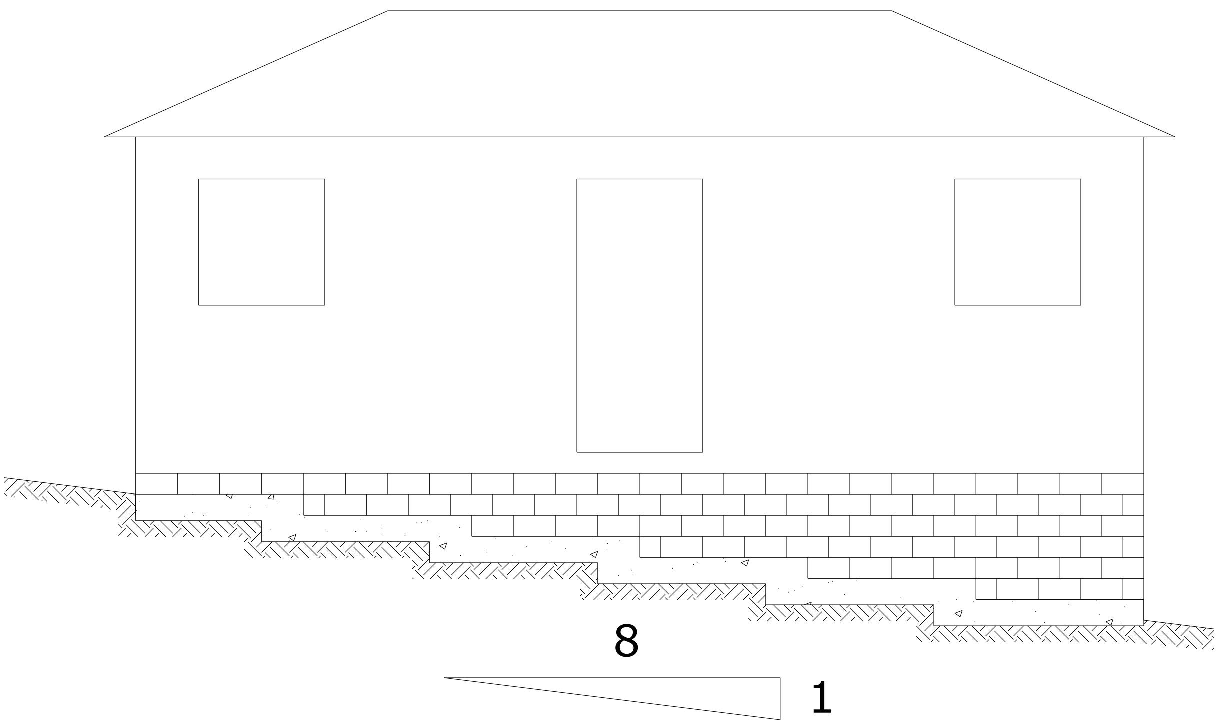
No.	Construction Methods	Comment
5	Install the batter boards on the grids.	To facilitate the accurate layout of the walls.



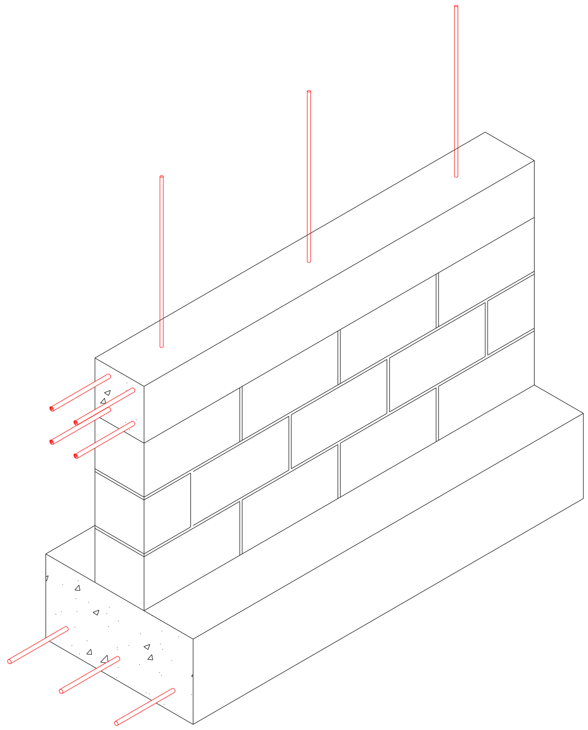


B 2.3 Strip Footings

- On relatively flat ground, RC strip footings may be more economical.

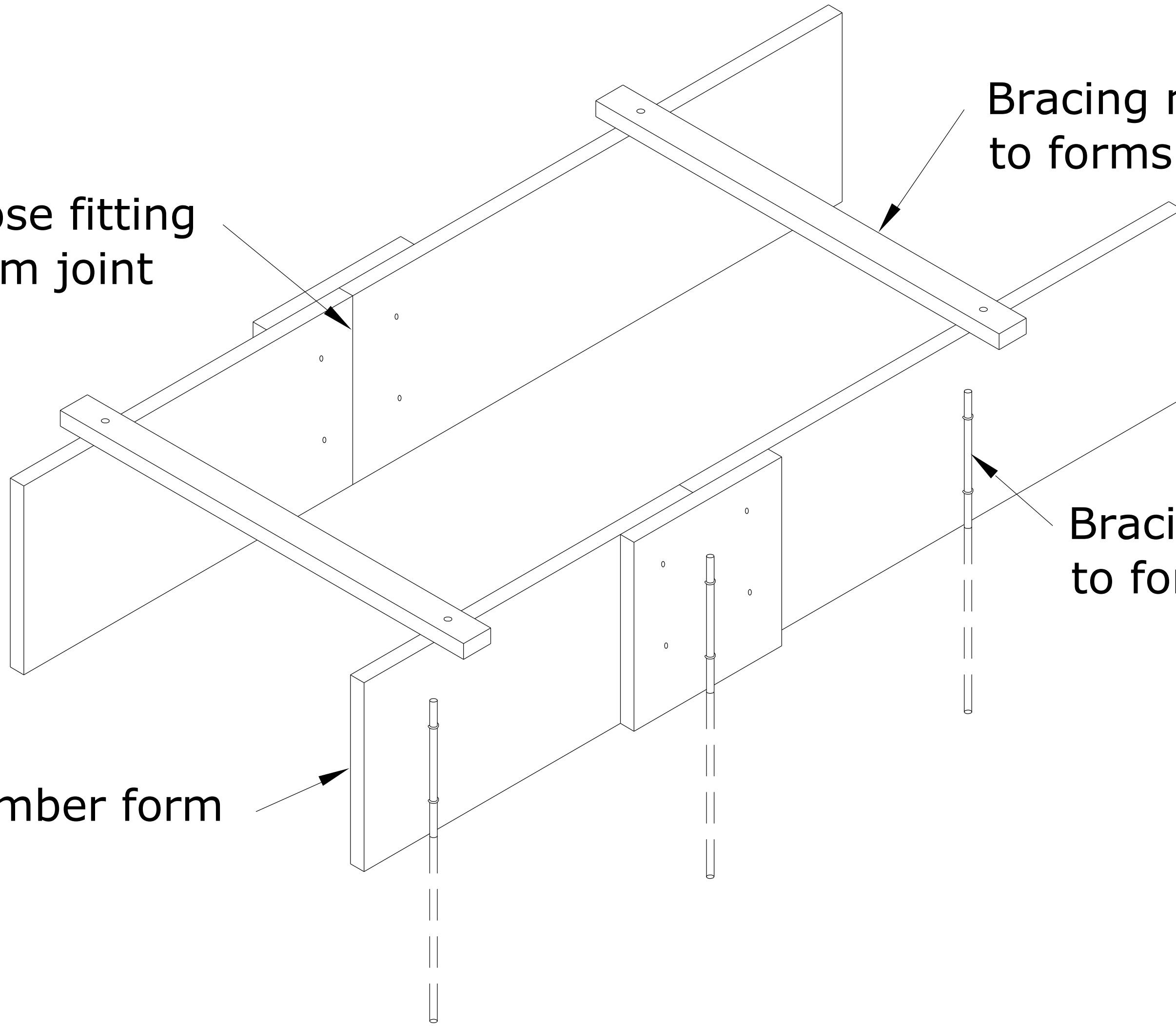


Slope less than 1 (Vertical) : 8 (Horizontal)



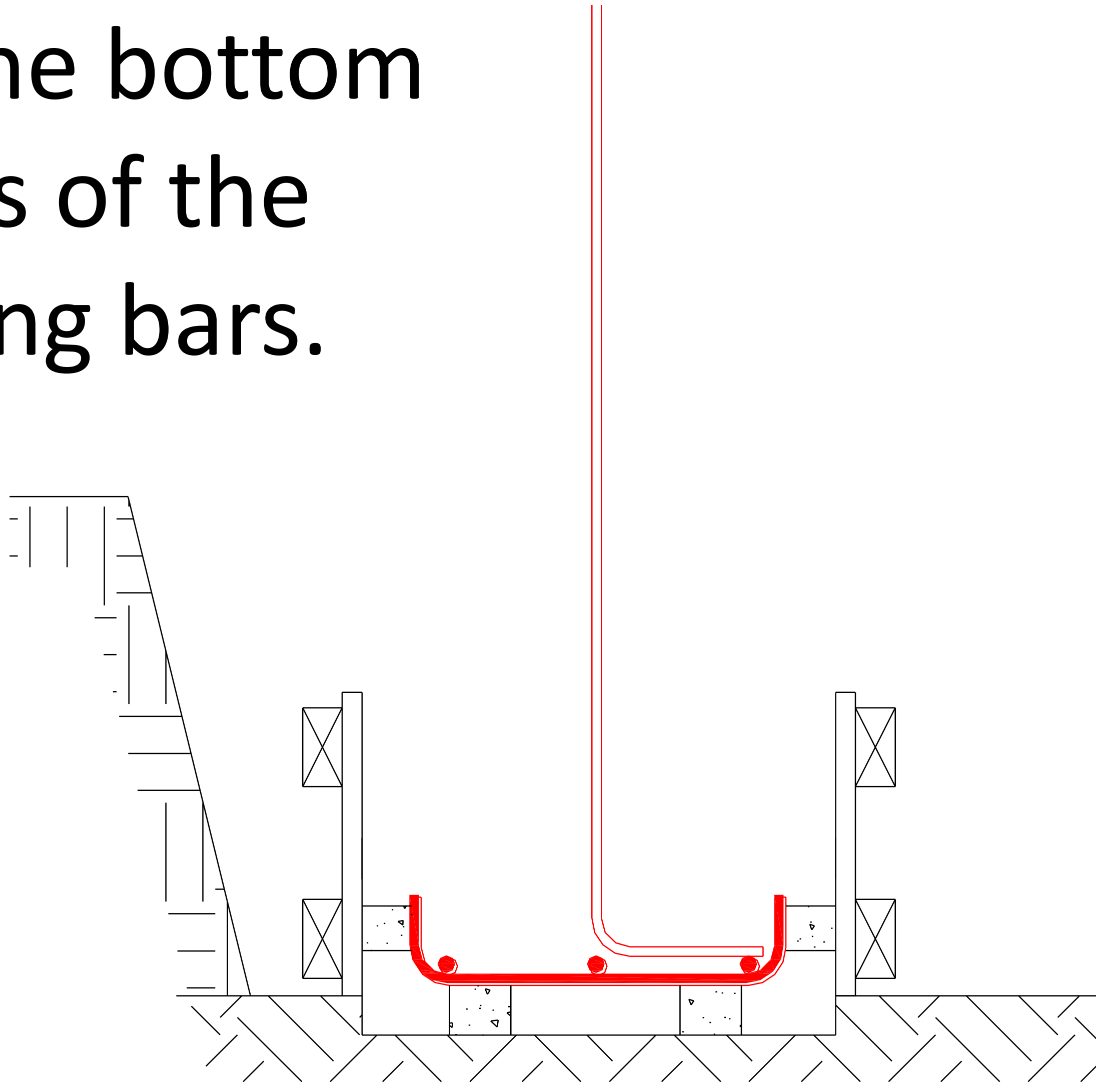
No.	Construction Methods	Comment
1	Excavate to a good bearing layer.	To reduce settlement.
2	Apply termite treatment to ground under footings. Use a pesticide with a minimum 5-year warrantee.	To protect the timber from termites.
3	Place thin mass concrete (1:3:6) blinding layer if the surface is uneven.	To provide a flat surface to accommodate the placement of reinforcement.
4	Erect formwork to fit the strip footing. Use braced timber with close fitting joints.	To prevent deformation and leakage of fine aggregate, cement or water.

Strip Footing Formwork

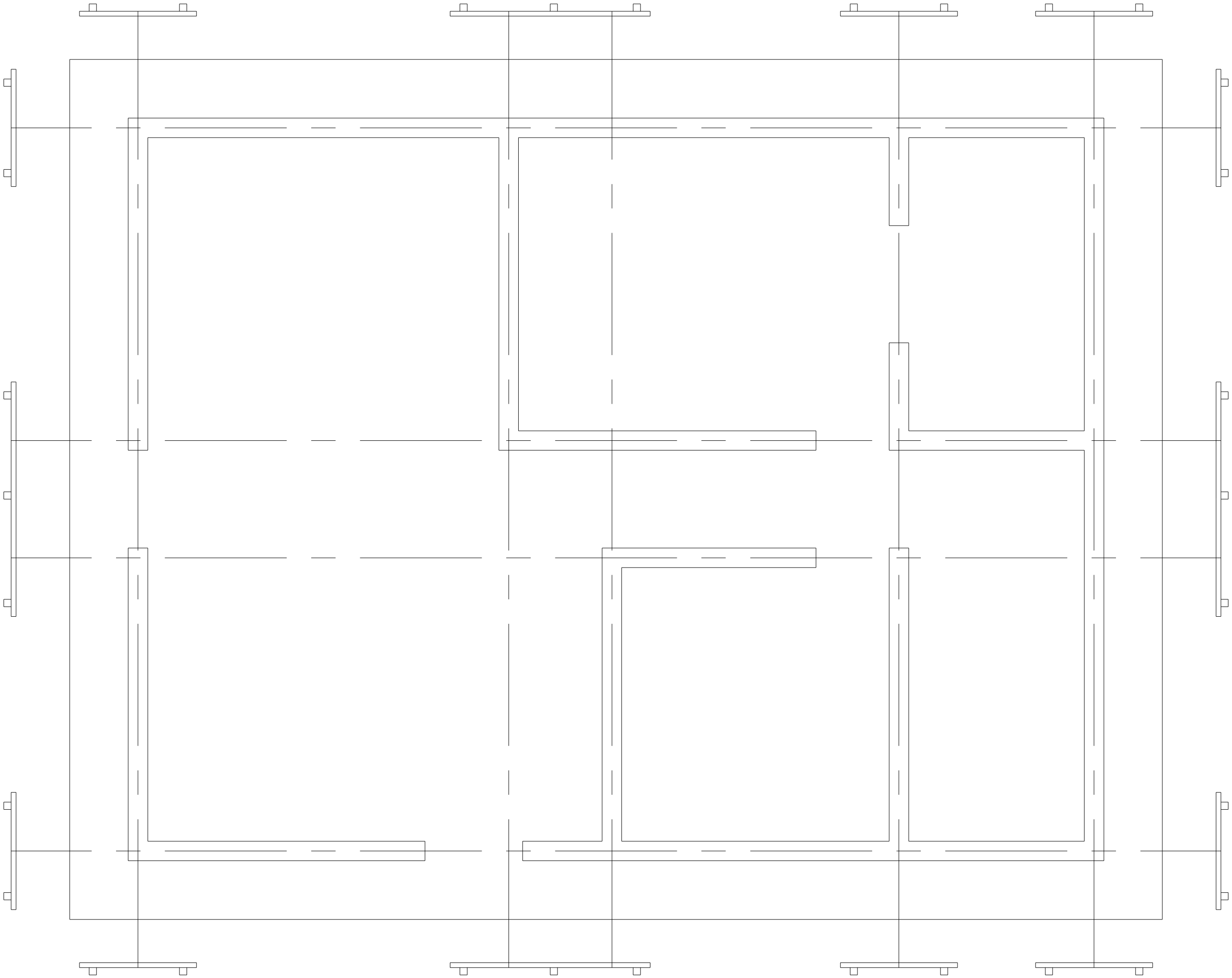


No.	Construction Methods	Comment
5	Place strip footing rebars in the formwork and tie the bars together or place the already fabricated reinforcing cage in the formwork. Strip footing rebar laps to be 600mm (24”).	For durability and structural safety and to prevent the reinforcing bars from moving out of position during the concreting.
6	Raise the reinforcement to the correct level to maintain the concrete cover using concrete spacer blocks or plastic chairs. Cover to surfaces in contact with earth = 75mm (3”).	To protect the reinforcing bars from corrosion.
7	Install the concrete block wall starter bars at the wall corners, junctions, openings, and ends, using the grid-line intersections.	To strengthen the walls.
8	Install the remaining concrete block wall starter bars. (Exterior wall = T12mm (1/2”) diameter at 600mm (24”) centres. Interior walls = T12mm diameter at 800mm (32”) centres)	To strengthen the walls.

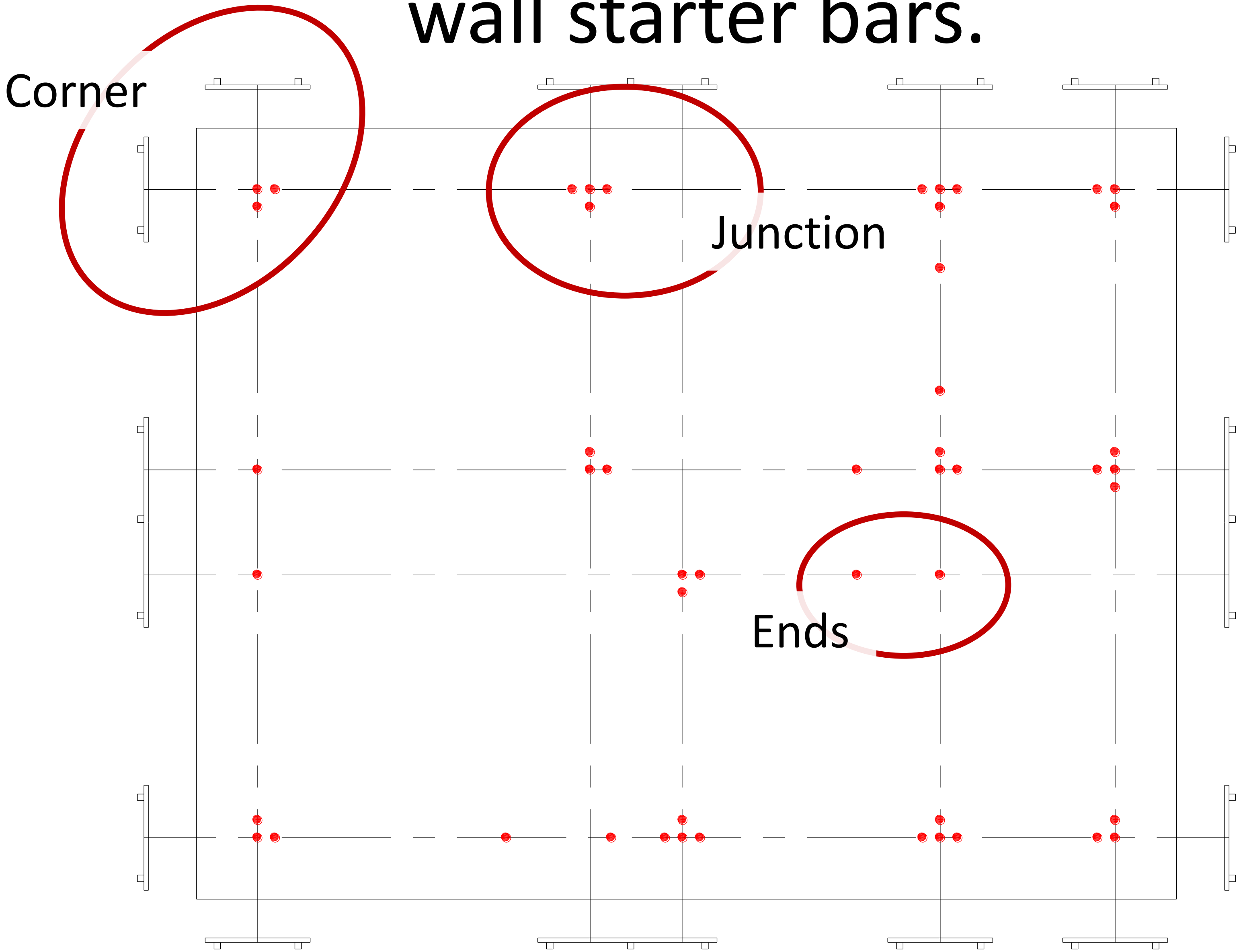
Smock the bottom and sides of the reinforcing bars.

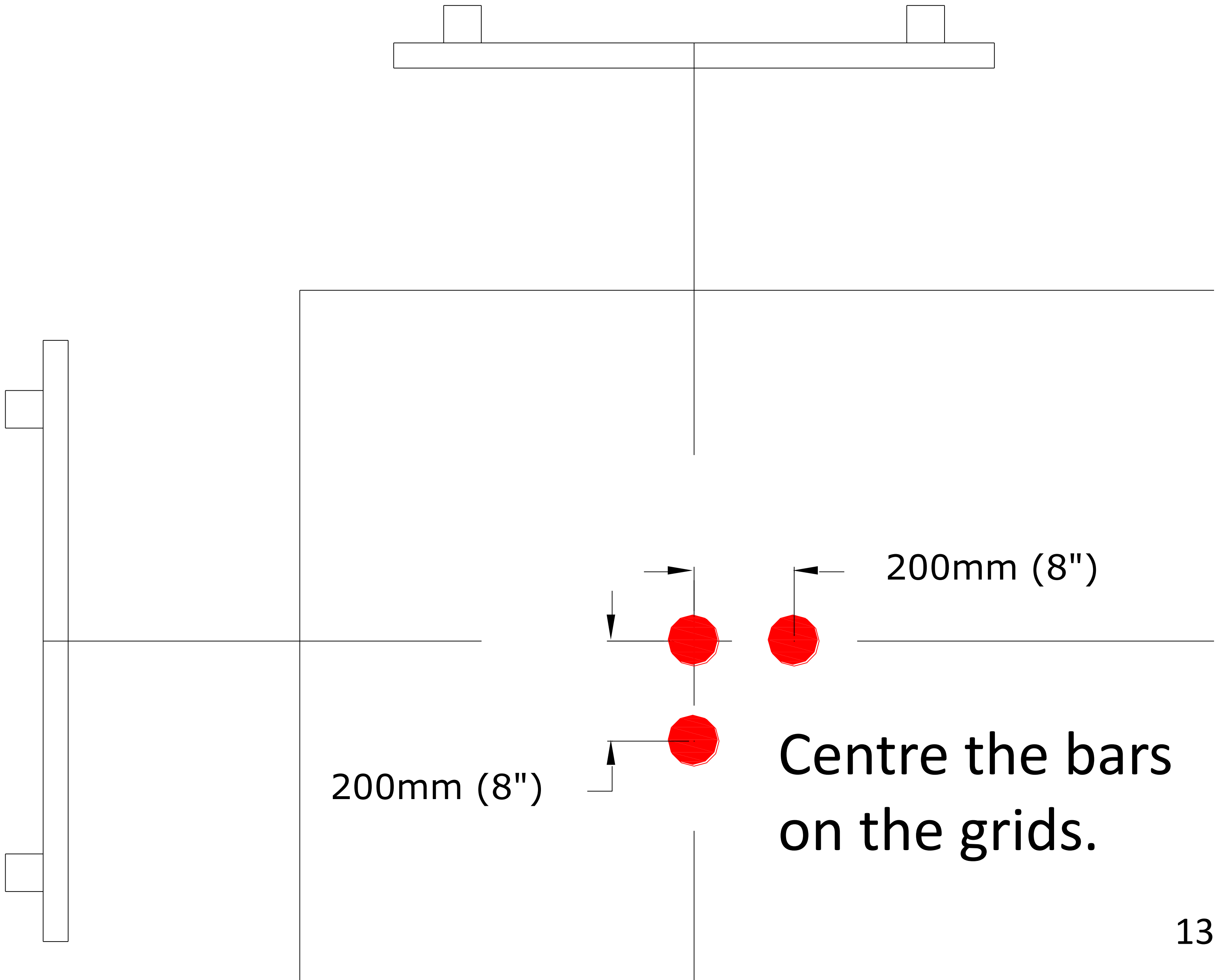


0. The intended wall layout.



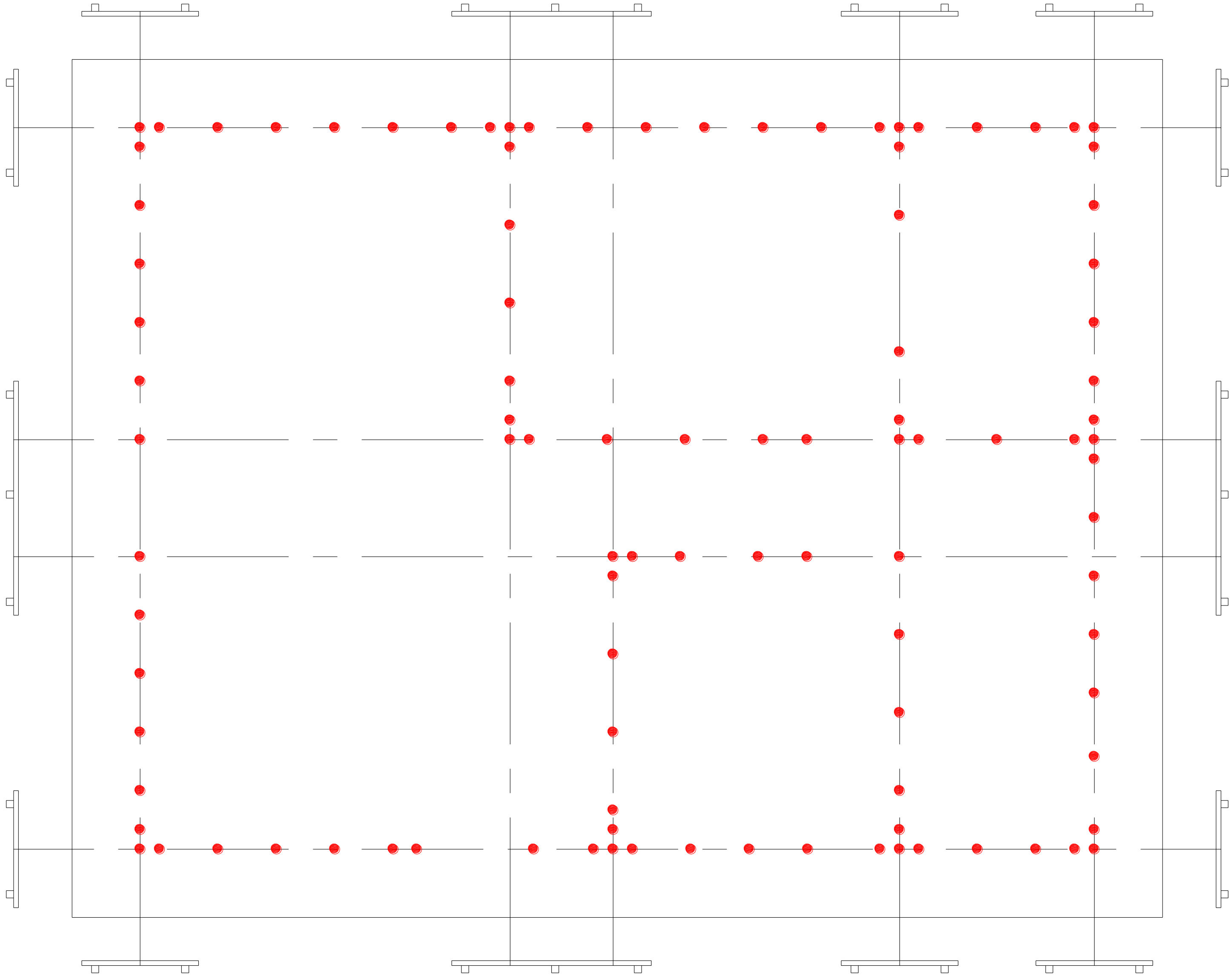
1. Install corner, junction, and end wall starter bars.





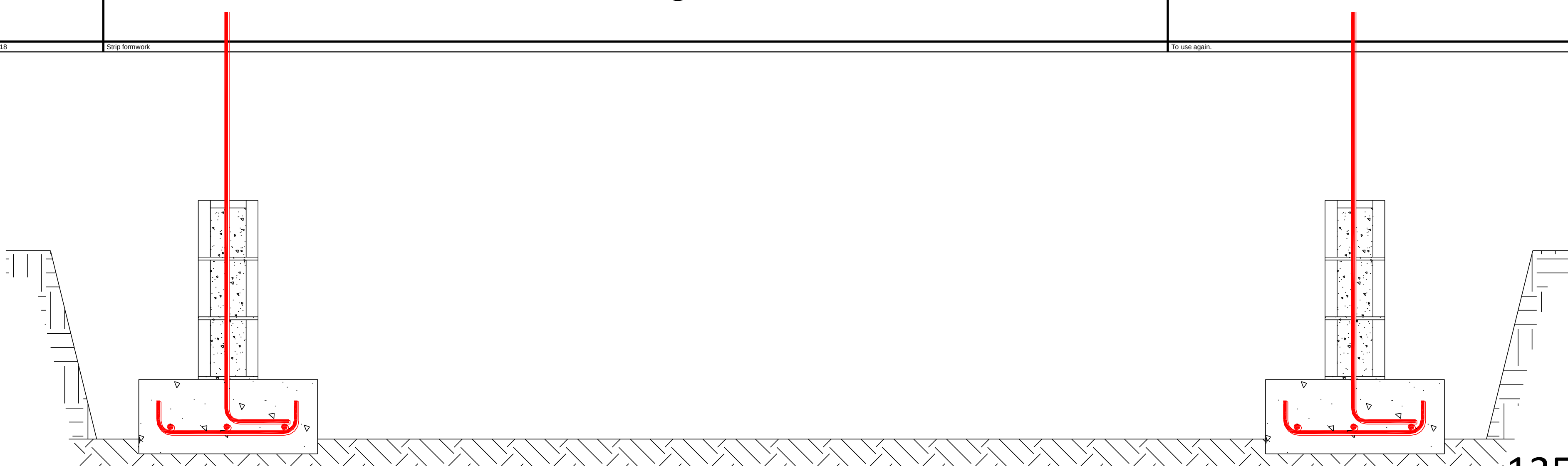
Centre the bars on the grids.

2. Install the remaining starter bars

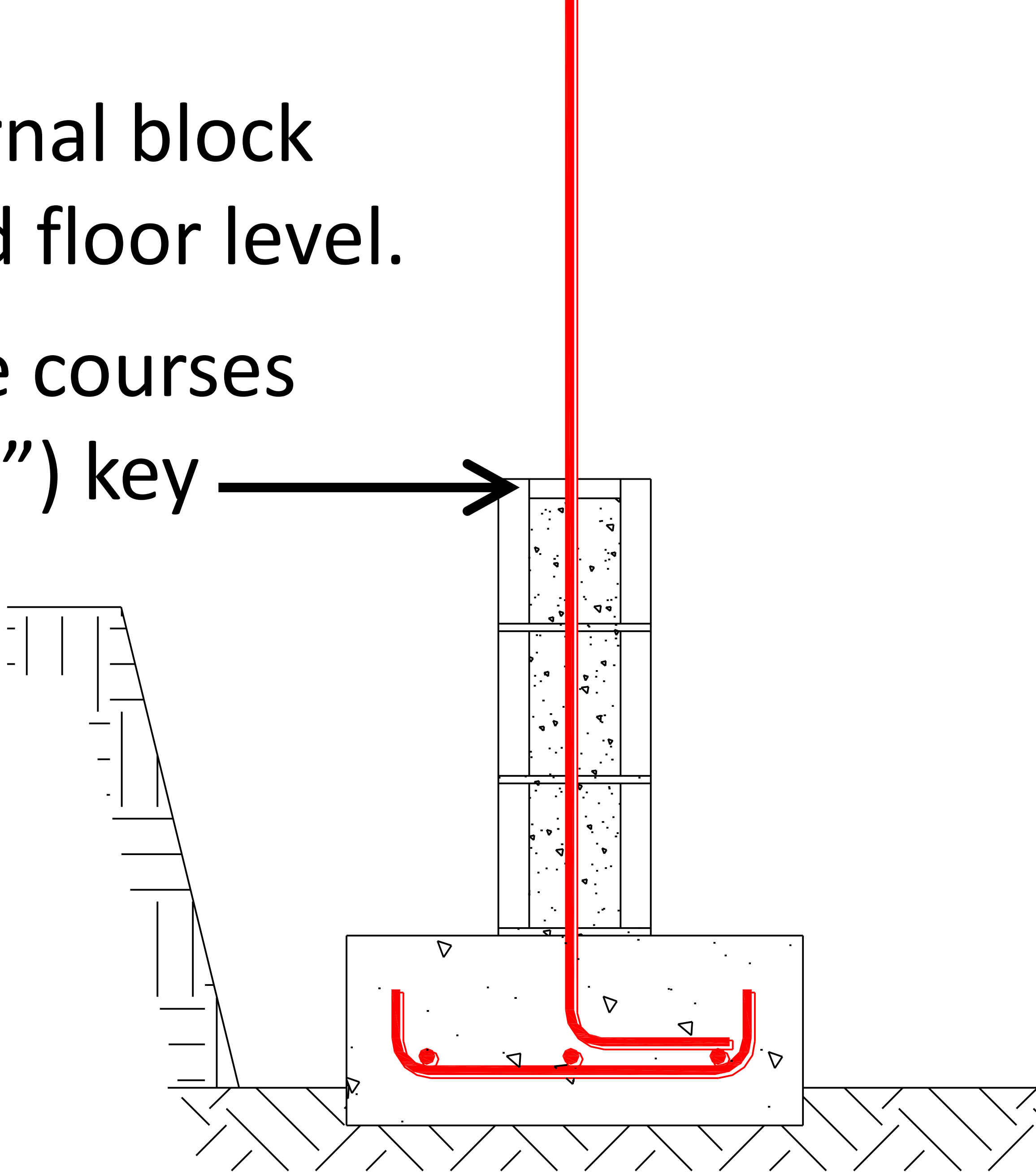


No.	Construction Methods	Comment
9	Remove any debris from within the forms. Blowing debris with compressed air or flushing with pressurised water are effective methods.	To avoid contaminating the concrete.
10	Apply a release agent to the formwork surface to be in contact with concrete. (See A 6)	To facilitate stripping the formwork.
11	Pour concrete with a design strength of 21 MPa (3,000 psi) at 28 days. (See A 6)	For durability and structural safety.
12	Compact the concrete using a vibrator.	For strength and durability of the concrete.
13	Trowel finish.	To provide a flat bearing surface for the walls.

No.	Construction Methods	Comment
14	Cure by keeping continuously wet for at least 3 days. (See A 6)	To allow the concrete to achieve the design strength.
15	Construct 200mm thick block wall to 200mm below ground floor level. Use T12mm (1/2”) diameter rebar at 600mm centres and all cores filled solid with 1:3:6 concrete with 115 – 230 mm (4 ½” to 9”) slump. For concrete block walls, extend the rebars a minimum 600mm above the ground floor level.	To help transfer the loads.
18	Strip formwork	To use again.

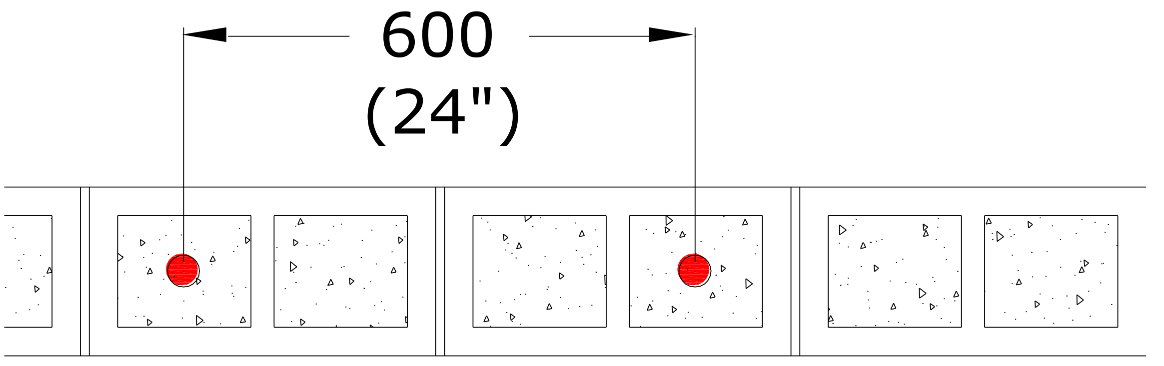


- Grout every external block core below ground floor level.
- Grout every three courses leaving a 25mm (1”) key

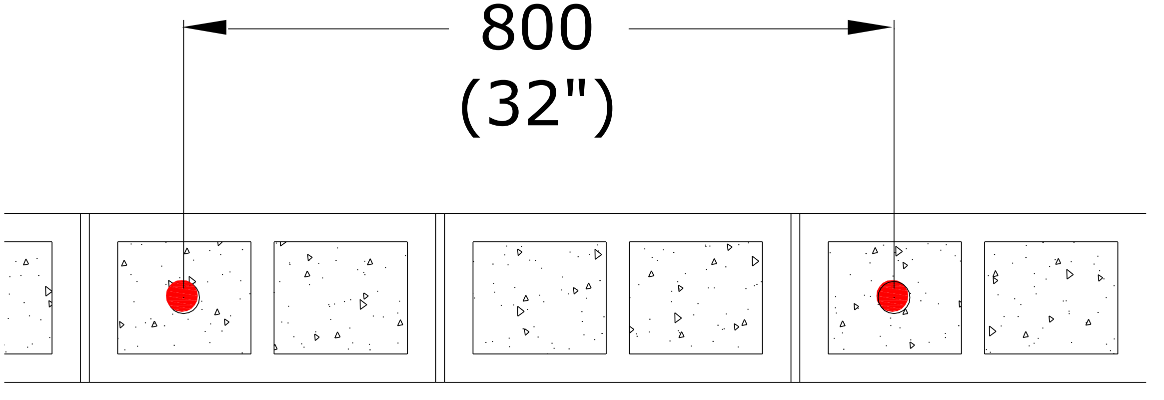


Walls Below Ground Floor

External Walls

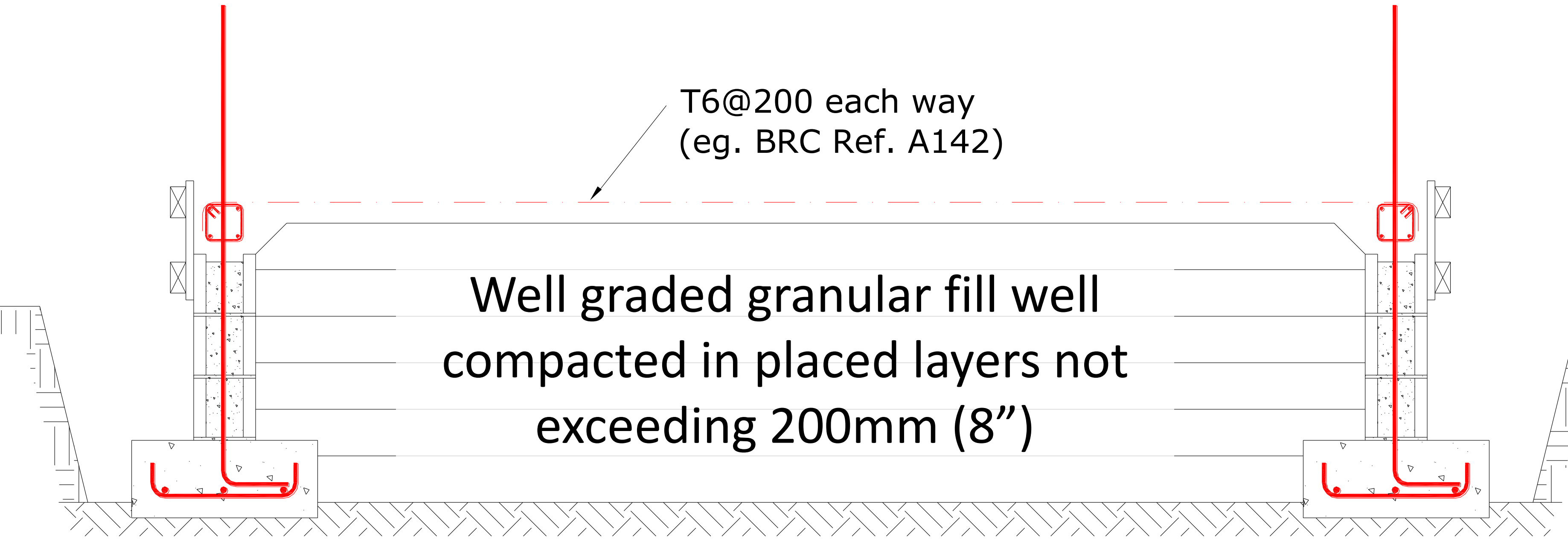


Internal Walls

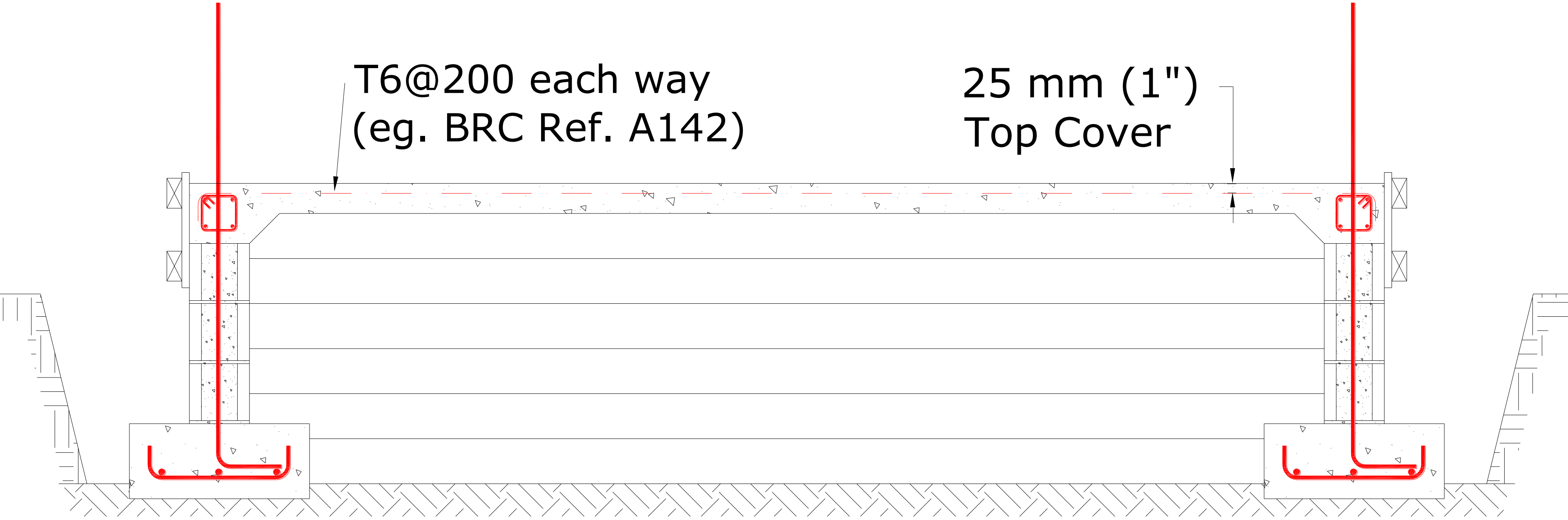


Fill all cores with 1:3:6 grout every 3 courses.

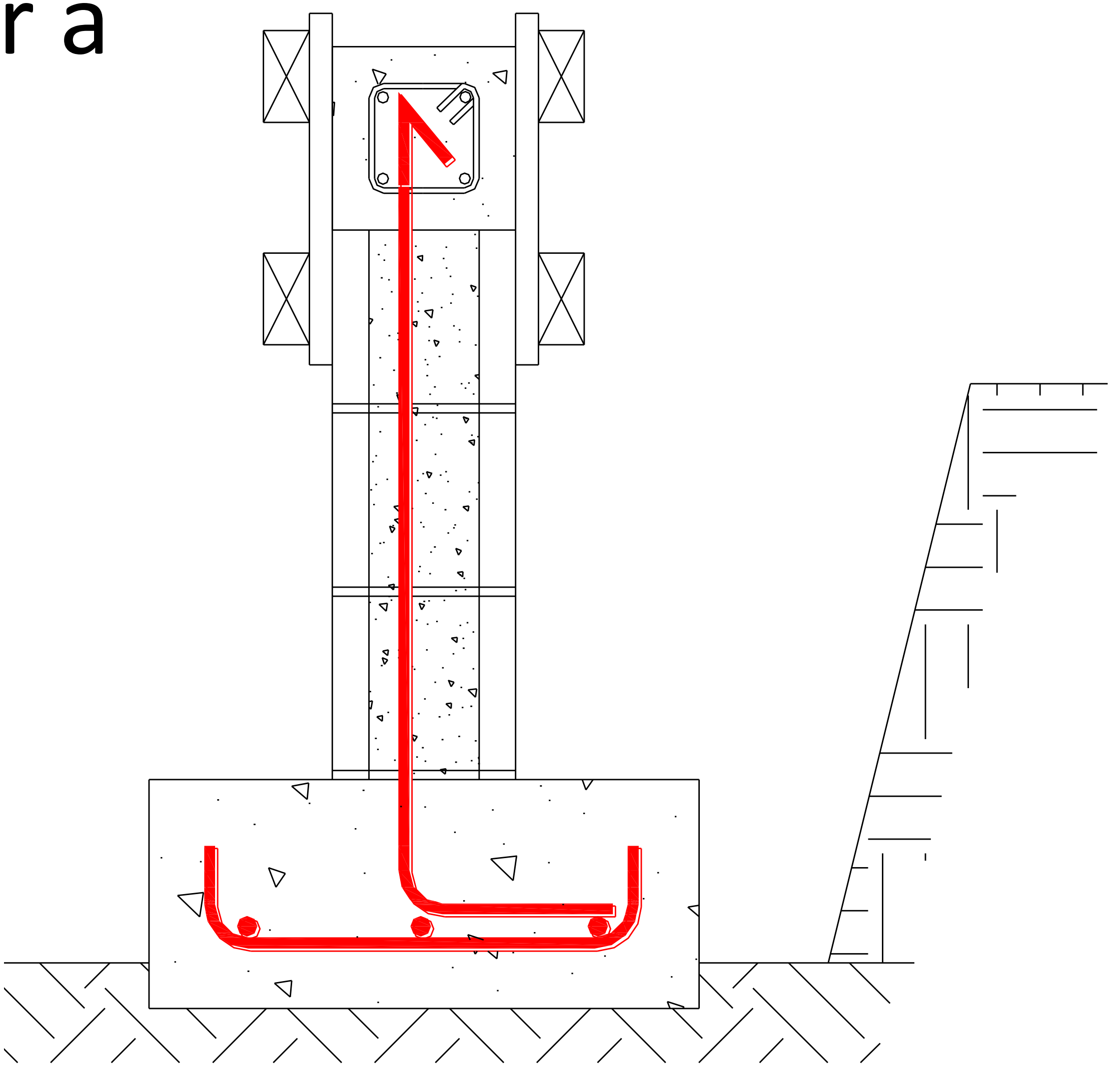
No.	Construction Methods	Comment
16	Install and compact well graded granular fill in placed layers not exceeding 200mm (8”)	To prevent floor settlement.
17	Erect formwork to fit the 200mm x 200mm (8”x8”) RC ring beam. Install utility pipes and DPM.	To prevent deformation and leakage.
18	Install and smock reinforcement (4xT12mm (1/2”) diameter bars + T6mm (1/4”) diameter links at 200mm (8”) centres.)	To tie the wall together.



No.	Construction Methods	Comment
19	For timber wall, insert 12mm diameter anchor bolts at 800mm (32”) centres.	To connect the wall to the foundation.
20	Pour, compact, trowel finish, and cure concrete (3,600 psi at 28 days)	For durability and structural safety.
21	Strip formwork	To use again.

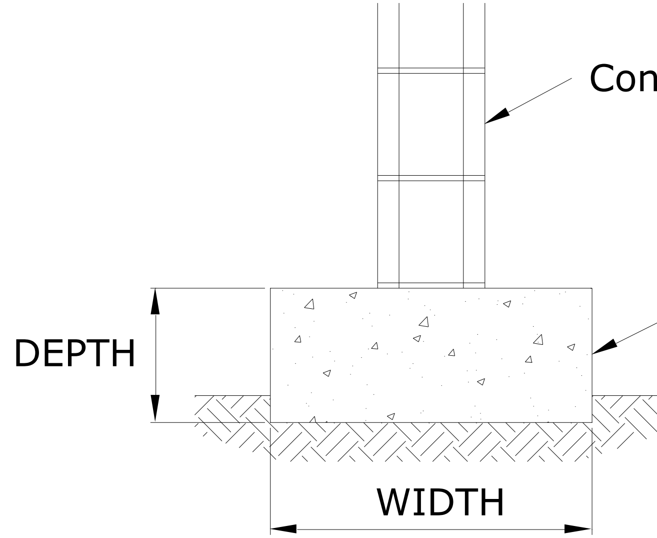


Strip footing for a timber floor.



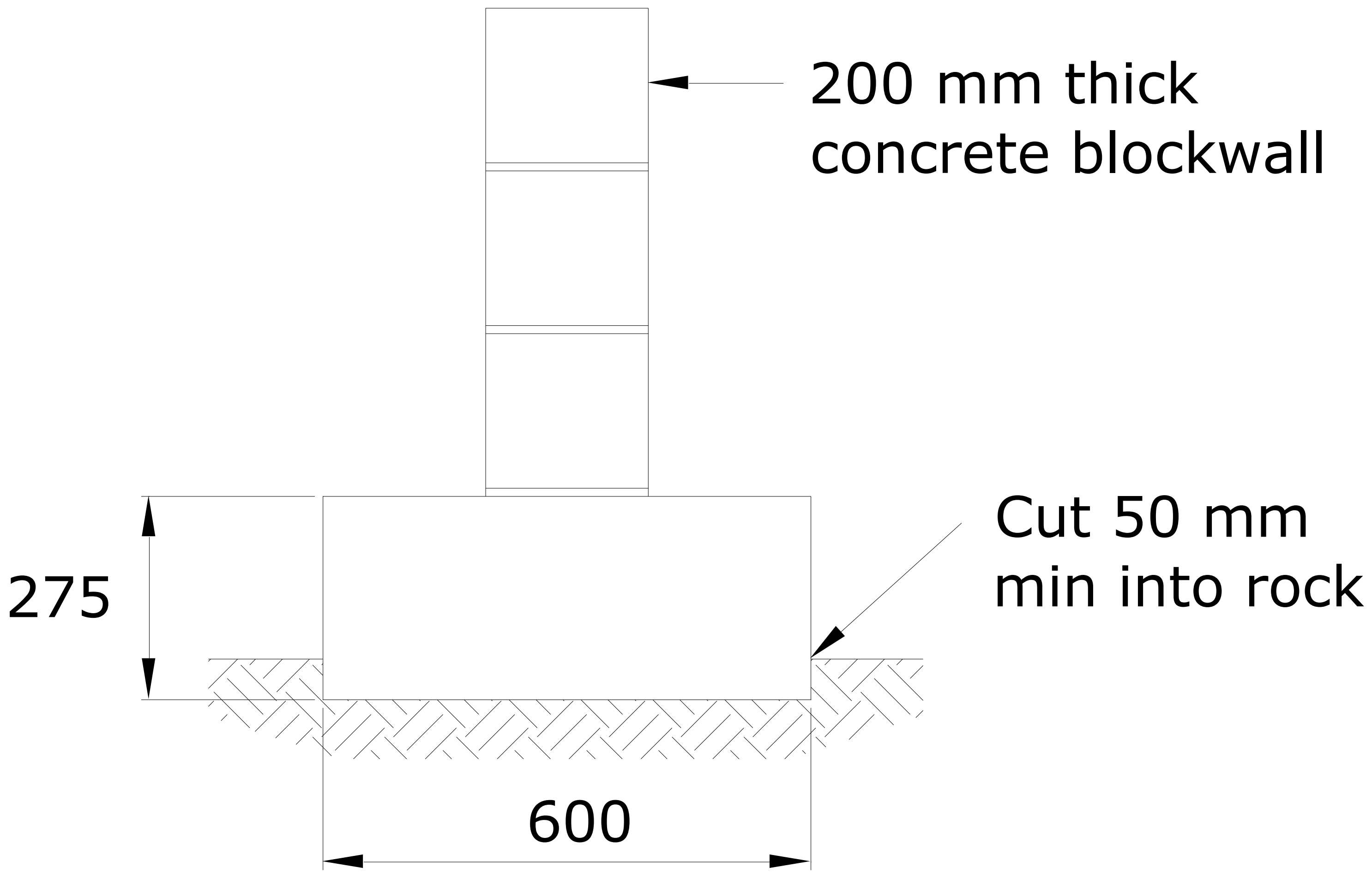
Home

Strip Footing Sizes and Reinforcement

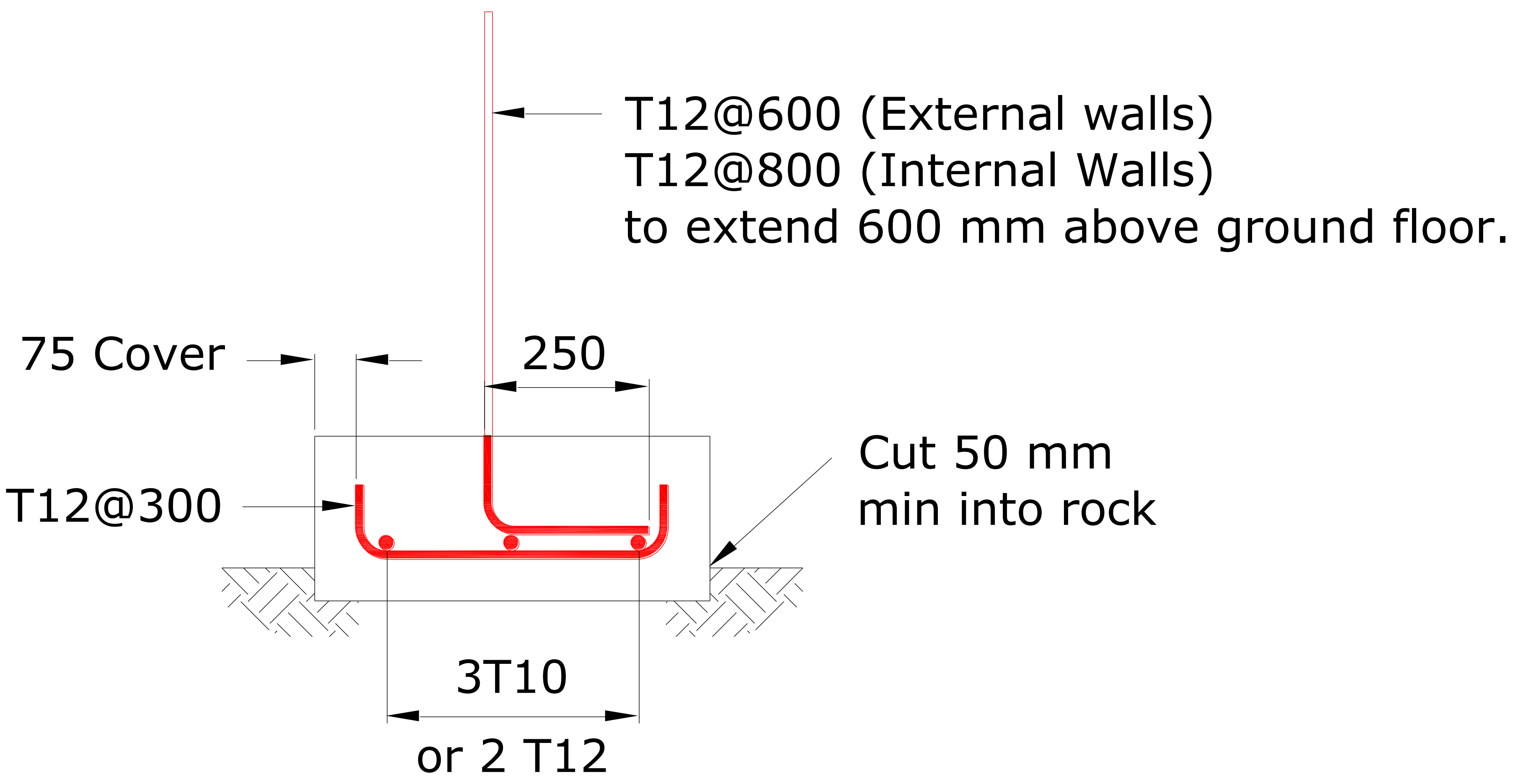


Structural Element	Minimum Size (width x depth)	Minimum Reinforcement
Strip footing on clay	760x300mm (30"x12")	2xT12mm (1/2") dia bars longitudinally + T12mm bars spaced at 300mm (12") centres transversely.
Strip footing on rock or compacted granular soil.	600x275mm (24"x11")	2xT12mm (1/2") bars longitudinally + T12mm bars spaced at 300mm (12") centres transversely.
Ring beam.	200x200mm (8"x8")	4xT12mm (1/2") bars with T6mm links at 150mm (6") spacing.

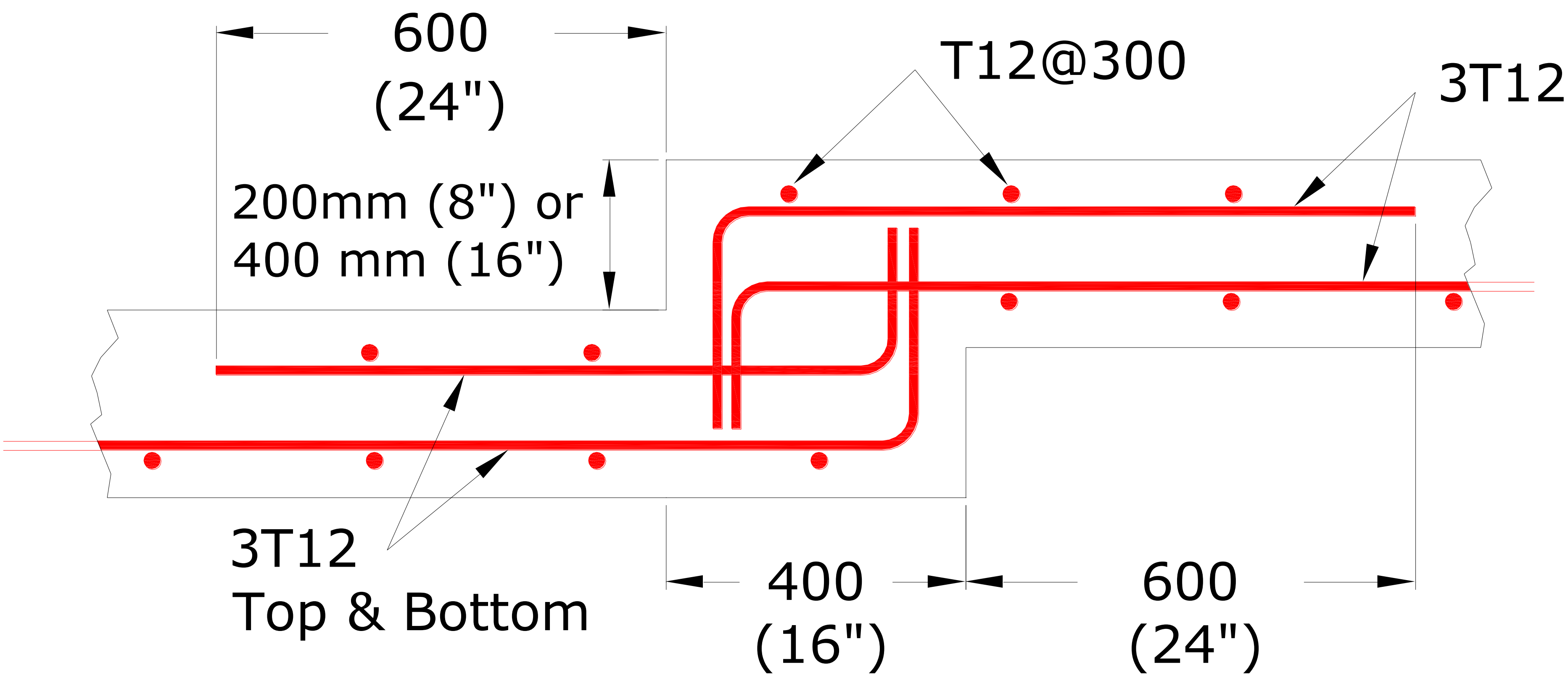
Strip Footing Layout (on rock)



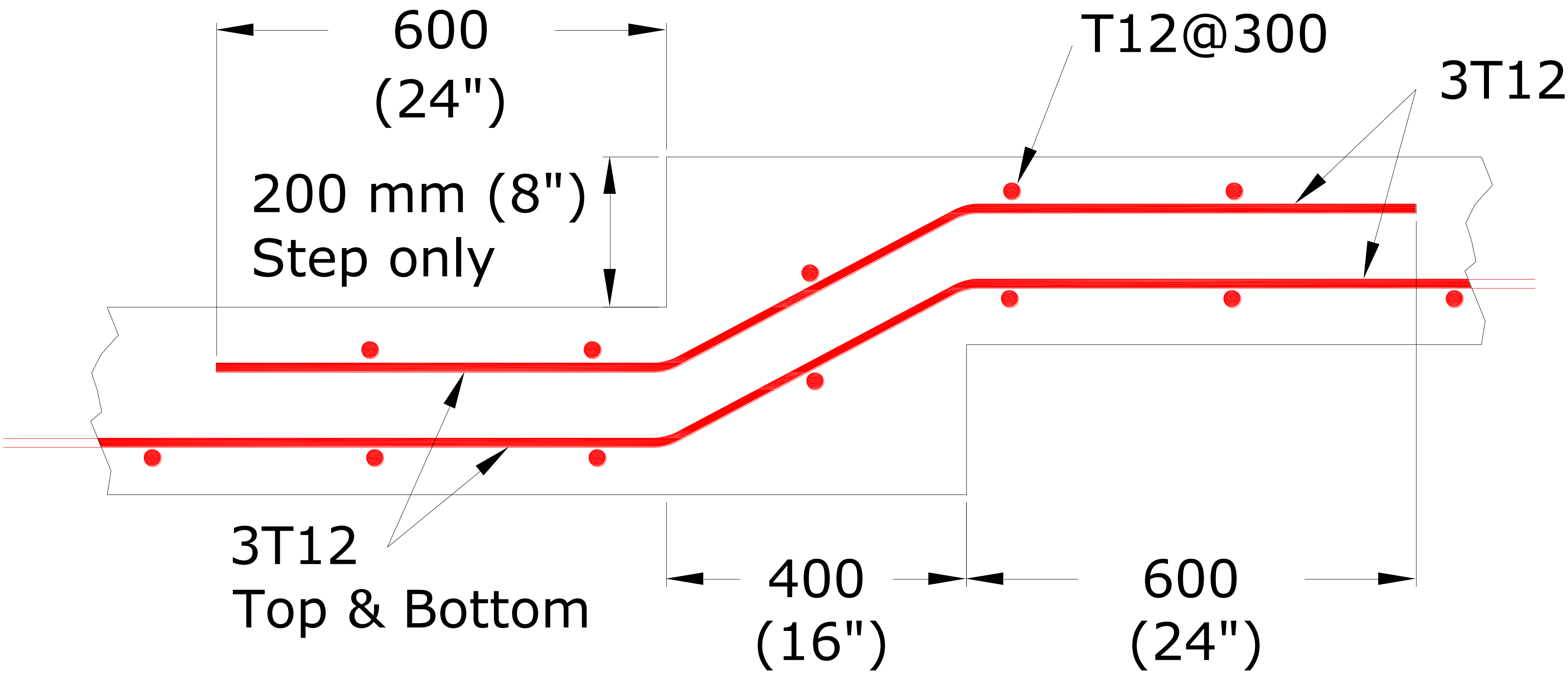
Strip Footing Rebars



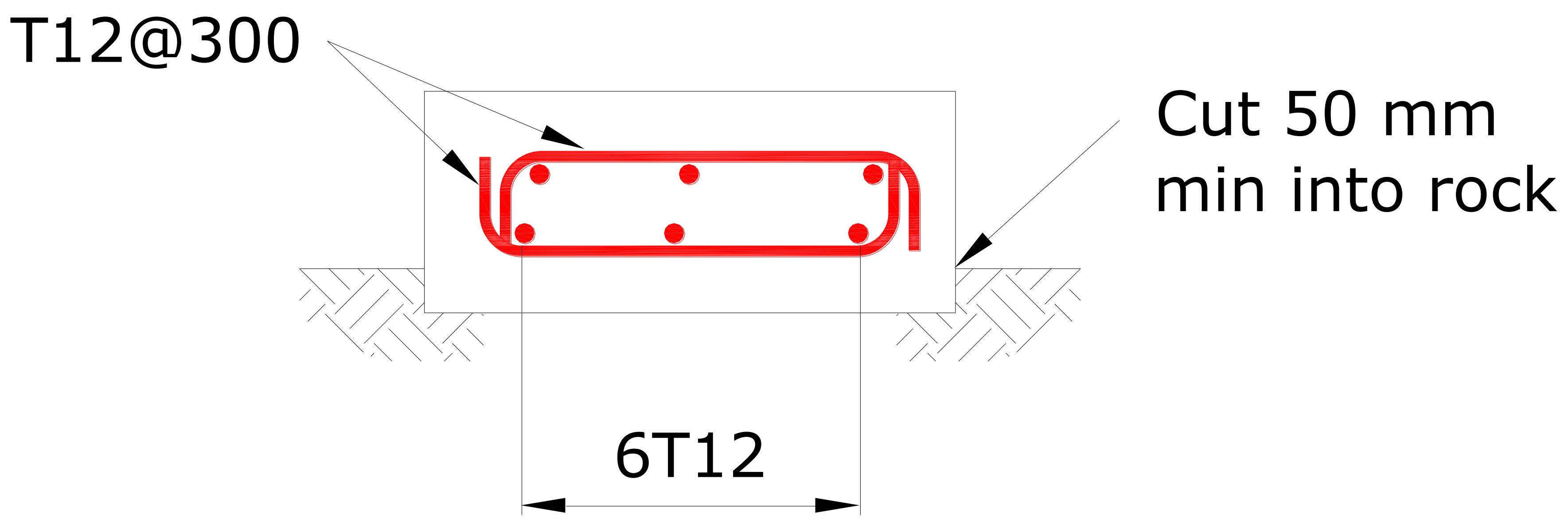
Step Footing Rebars



Step Footing Rebars – 200mm (8”) step

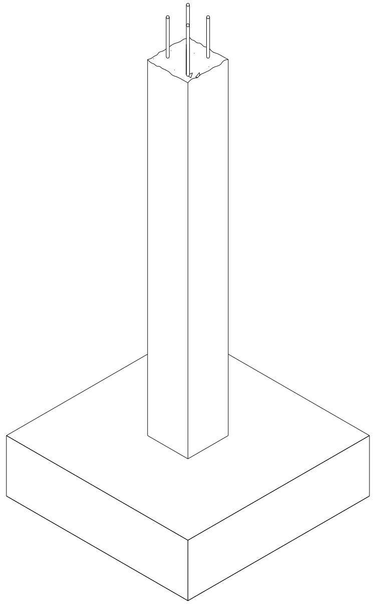


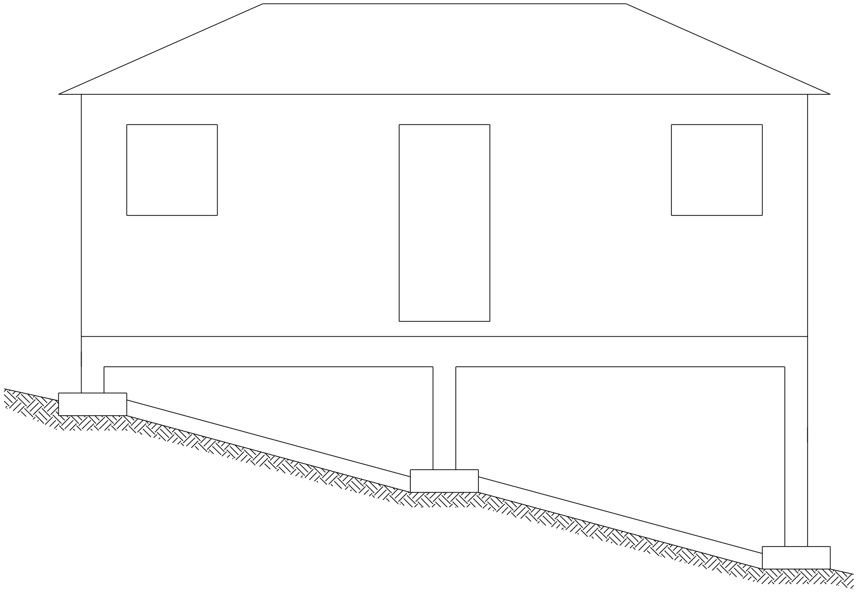
Shear Wall Footing Rebars

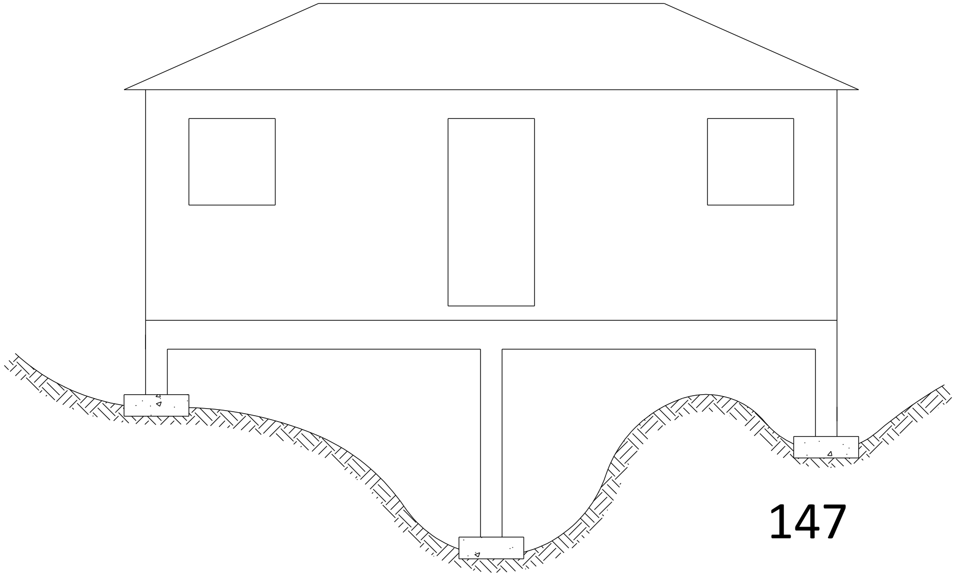


B 2.4 Pad Footings & Columns

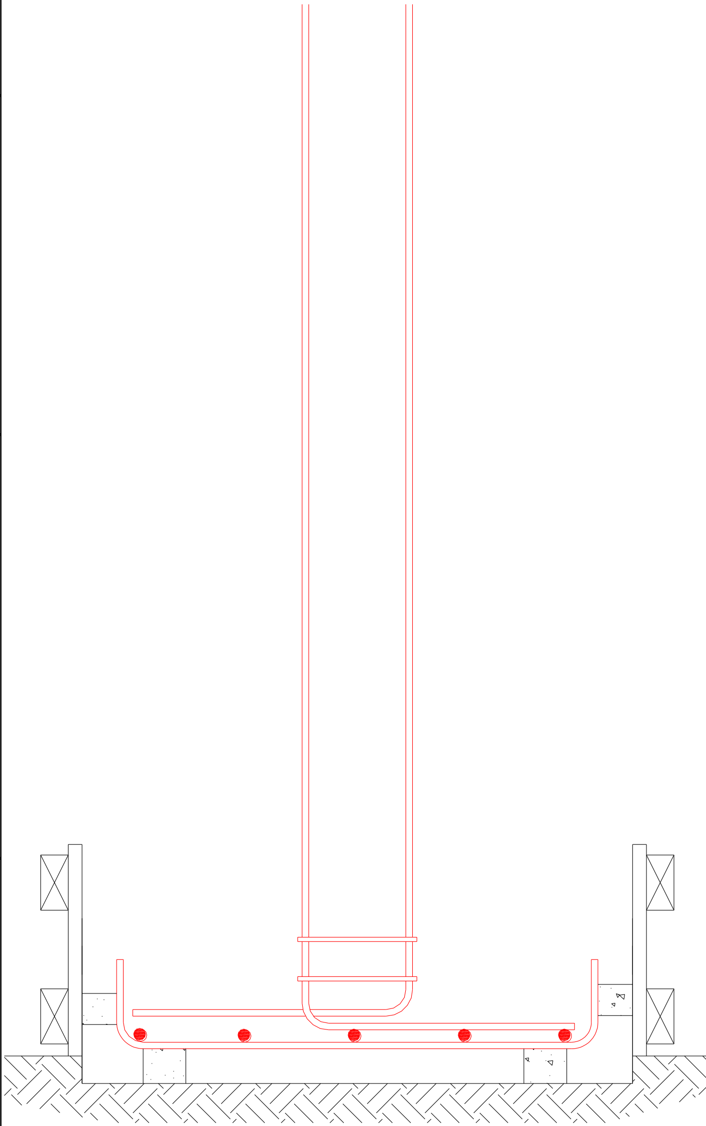
- If the land is sloping steeply, or undulating severely, then reinforced concrete (RC) pad footings supporting RC columns and beams may be an economical solution.



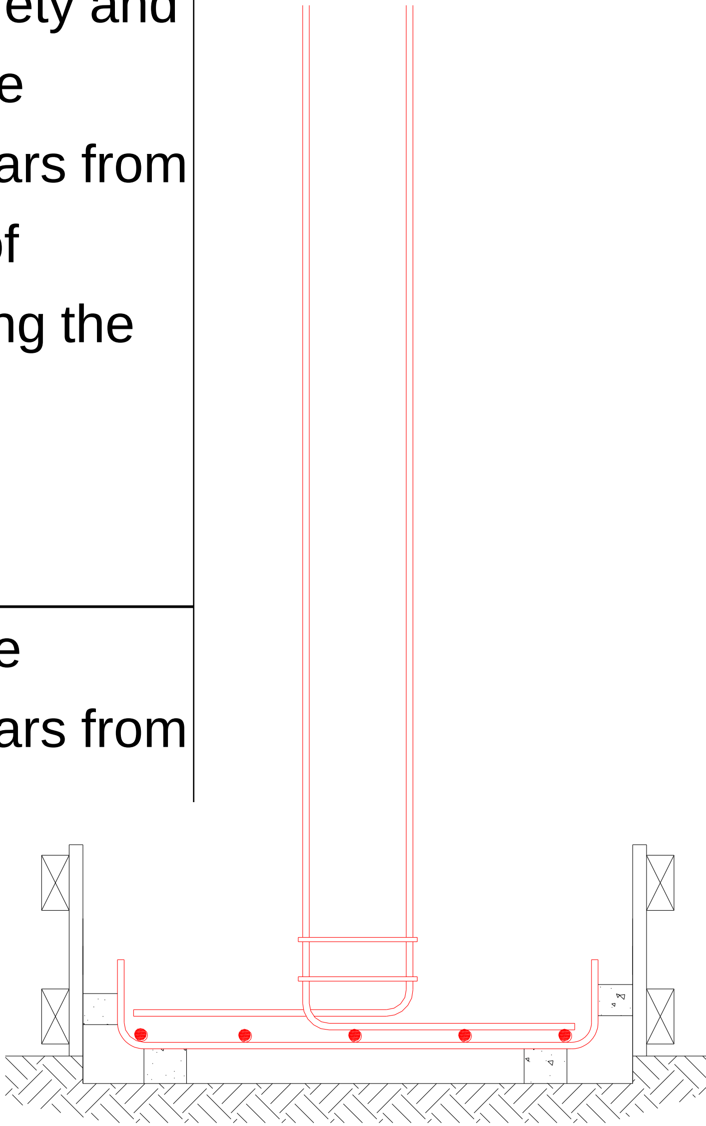




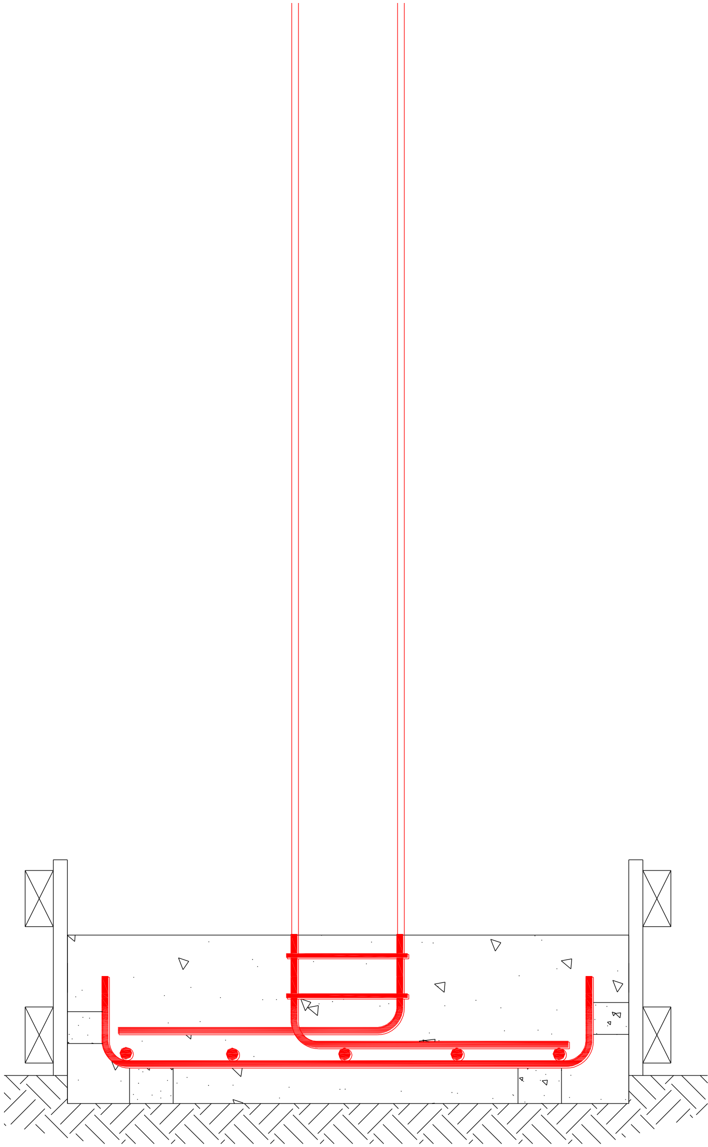
No.	Construction Methods	Comment
1	Excavate to good bearing layer.	To reduce settlement.
2	Apply termite treatment to ground under footings. Use a pesticide with a minimum 5-year warrantee.	To protect the timber from termites.
3	Place mass concrete (1:3:6) blinding layer if the surface is uneven.	To provide a flat surface to accommodate the placement of reinforcement.
4	Erect formwork to fit the pad footing. Use braced timber with close fitting joints.	To prevent deformation and leakage of fine aggregate, cement or water.



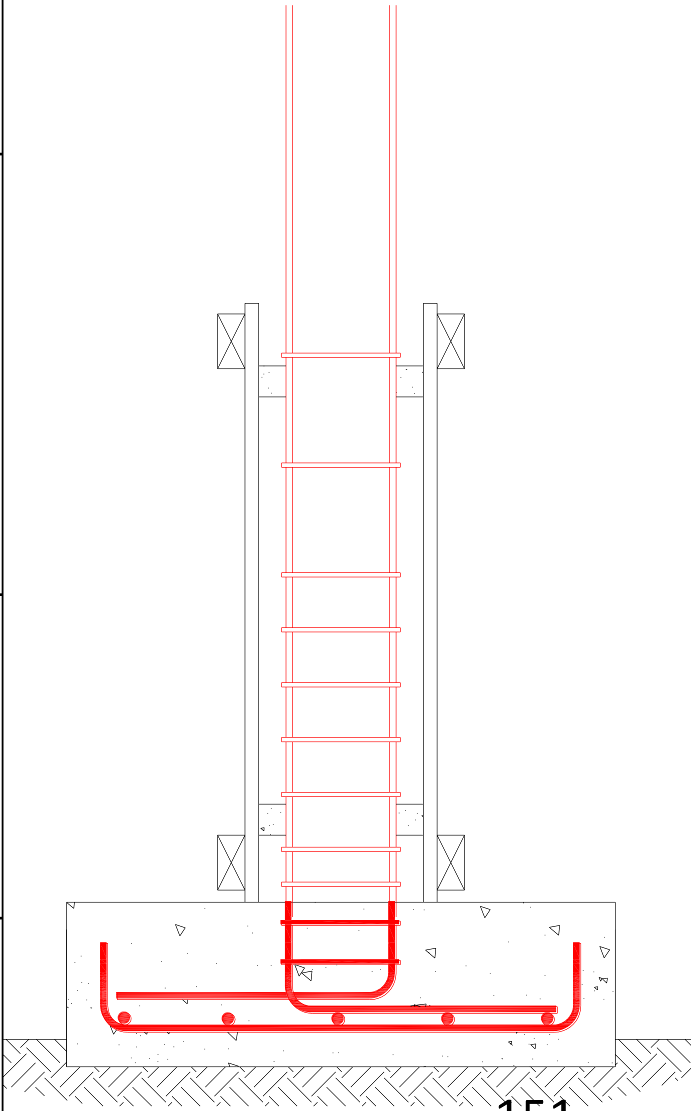
No.	Construction Methods	Comment
5	Place reinforcement including column starter bars in the formwork and tie the bars together or place the reinforcing cage in the formwork. Install tie-beam reinforcement to connect pad footings.	For durability and structural safety and to prevent the reinforcing bars from moving out of position during the concreting.
6	Raise the reinforcement to the correct level to maintain the concrete cover using concrete spacer blocks or plastic chairs. Smock all sides. Cover to surfaces in contact with earth should be 75mm (3”).	To protect the reinforcing bars from corrosion.



No.	Construction Methods	Comment
7	Remove any debris from within forms. Blowing debris with compressed air or flushing with pressurised water are effective methods.	To avoid contaminating the concrete.
8	Apply a release agent to the formwork surface to be in contact with concrete. (See A 6)	To facilitate stripping the formwork.
9	Pour concrete. Design compressive strength of 3,000 psi at 28 days (See A 6)	For durability and structural safety.
10	Compact the concrete using a vibrator.	For strength and durability of the concrete.

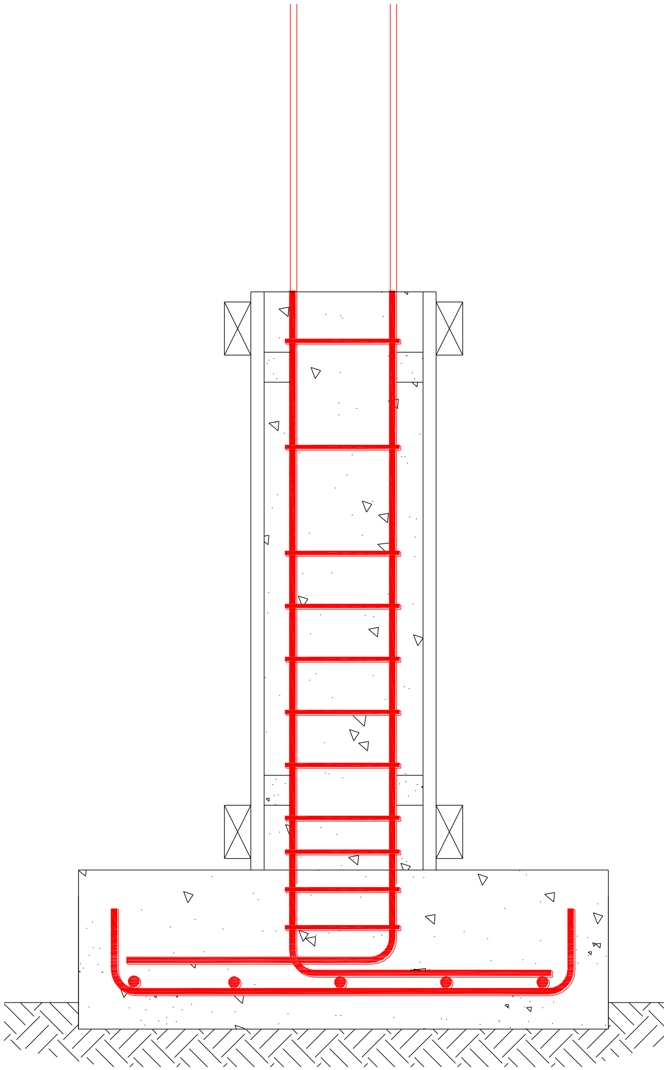


No.	Construction Methods	Comment
11	Trowel finish.	To provide a flat bearing surface for any walls.
12	Cure by keeping continuously wet for at least 3 days. (See A 6)	To allow concrete to achieve the design strength.
13	Lap column bars to starter bars and install tie-beam reinforcing bars.	To help transfer the loads.
14	Erect formwork to fit the columns and tie-beams and smock all sides.	To prevent deformation and leakage.

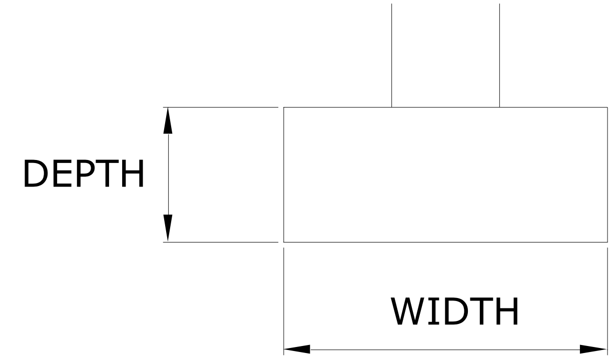


No.	Construction Methods	Comment
15	Pour RC column and tie beams, compact, trowel finish, and cure concrete (3,600 psi at 28 days)	For durability and structural safety.
16	Strip formwork	To use again.

Any column laps to be at mid height



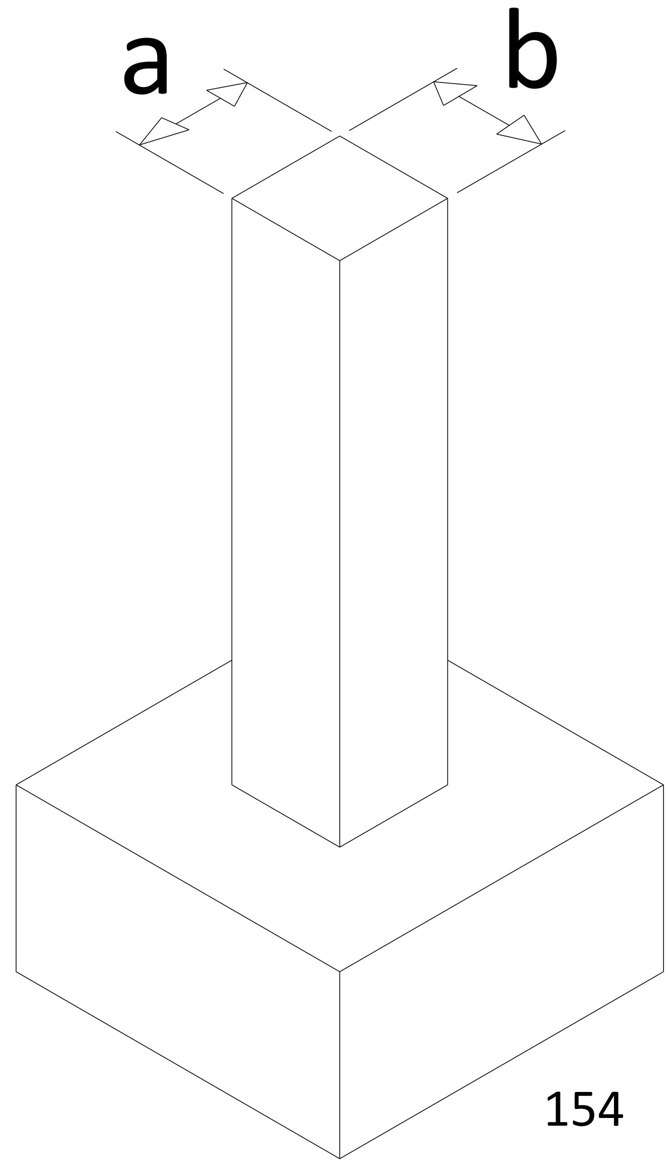
Pad Footing Sizes and Reinforcement



Pad Footing	**Minimum Size (width x depth)**	**Minimum Reinforcement**
Pad footing on clay	760x760x300mm thick (30”x30”x12”)	T12mm bars at 150mm (6”) spacing each way.
Pad footing on rock or compacted granular soil.	600x600x300mm (24”x24”x12”)	T12mm bars at 150mm (6”) spacing each way.

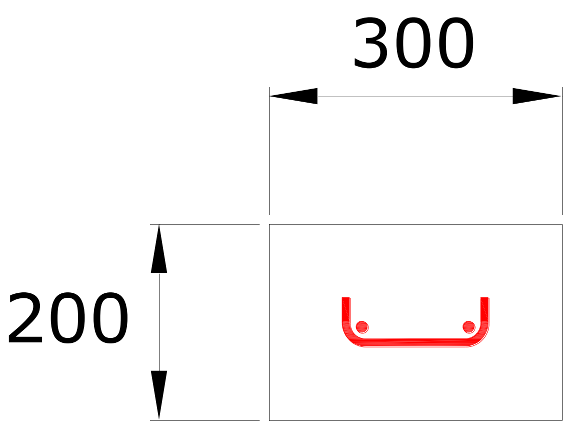
Column Sizes and Reinforcement

Column Height	Minimum Size (a x b)	Minimum Reinforcement
Less than 3.0m (10 ft) high.	200x200mm (8”x8”)	4xT12mm bars. Links: T6mm at 150mm spacing.
3.0m (10 ft) to 3.65m (12 ft) high.	250x250mm (10”x10”)	4xT16mm bars. Links: T8mm at 200mm spacing.
3.65m (12 ft) to 4.3m (14 ft) high.	300x300mm (12”x12”)	4xT20mm bars. Links: T8mm at 250mm spacing.



Tie Beams

Tie beams are used to connect columns together in at least 2 directions

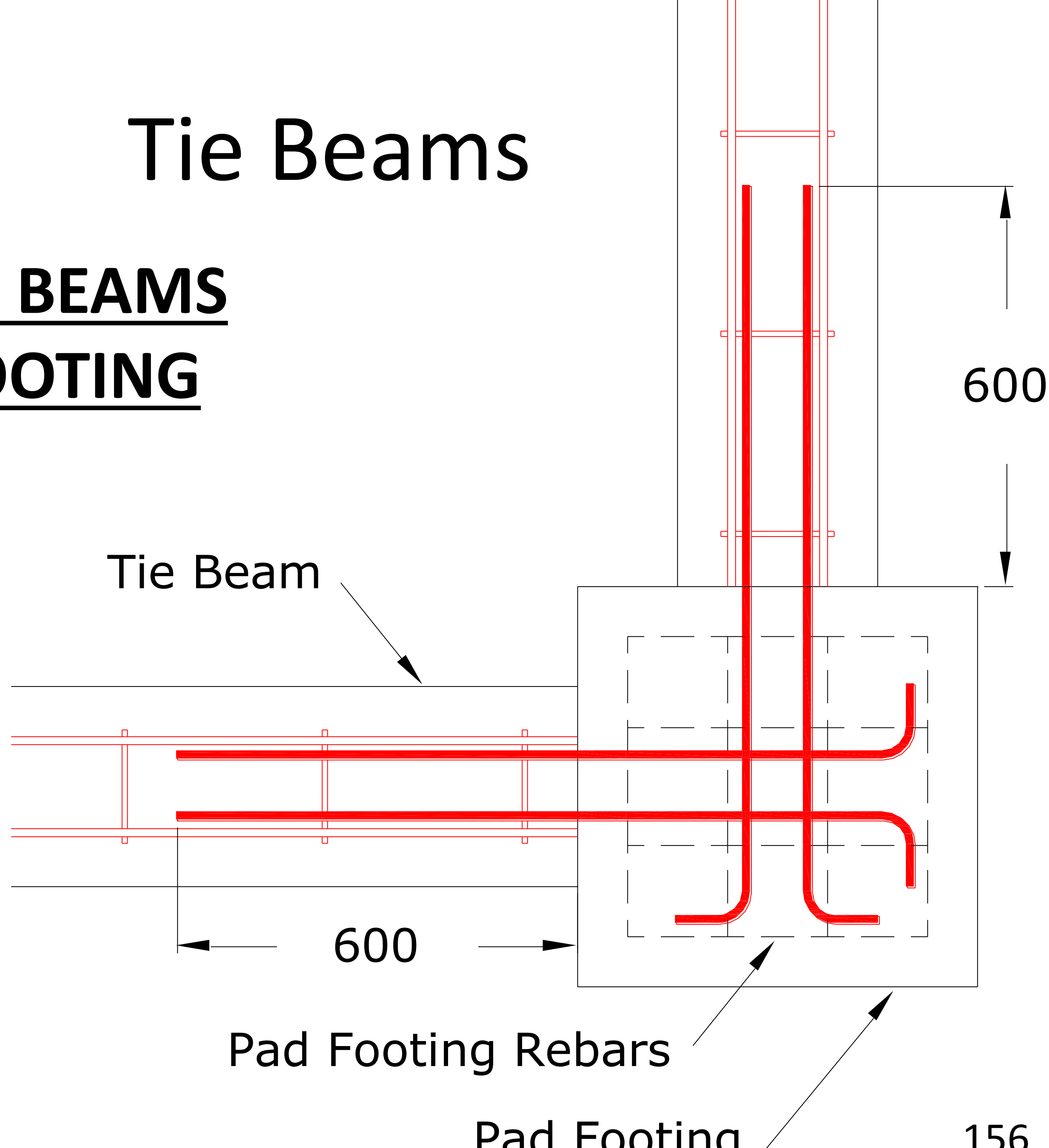


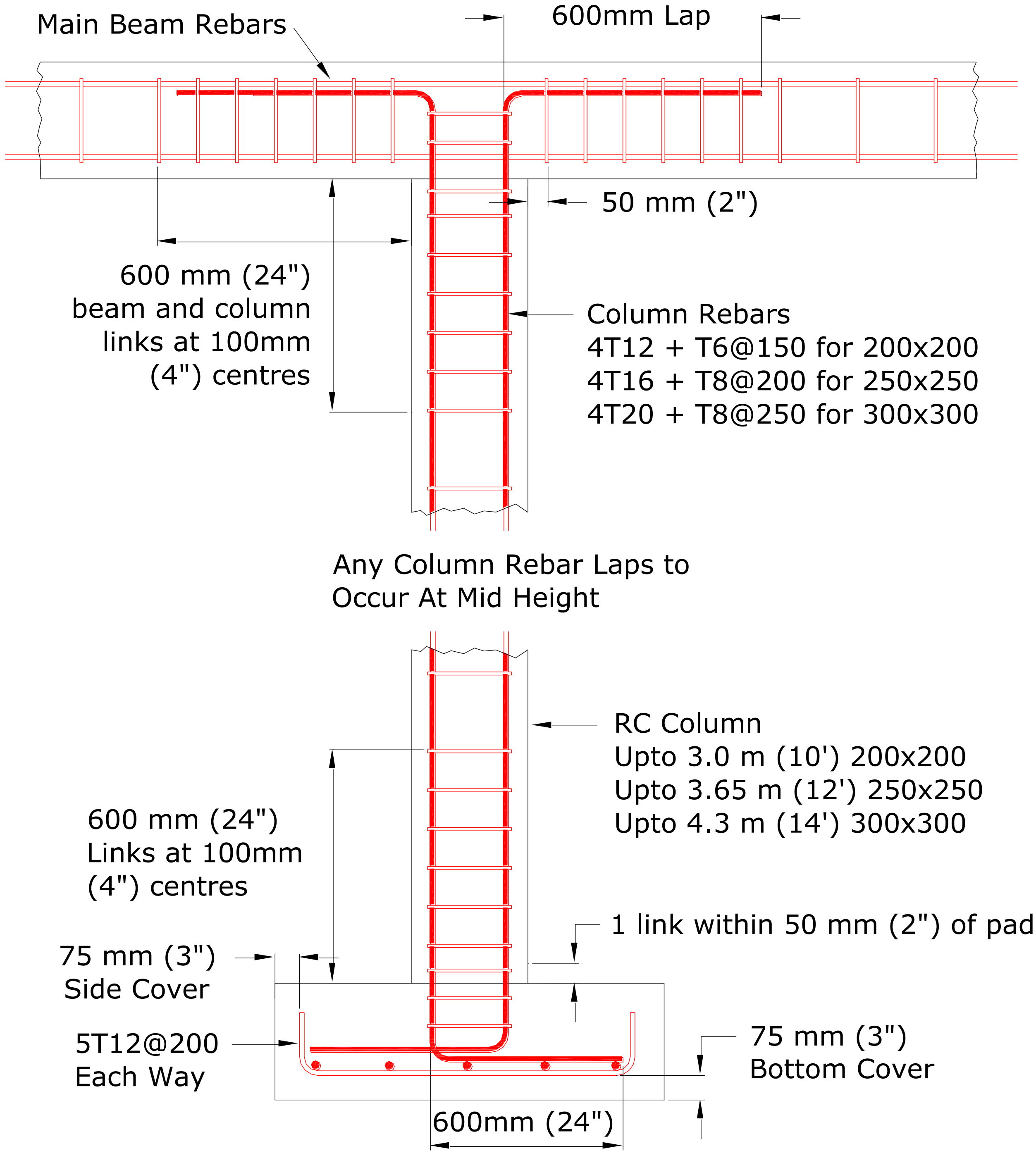
2T12 Longitudinal
T12@300 Transverse
75 mm Cover

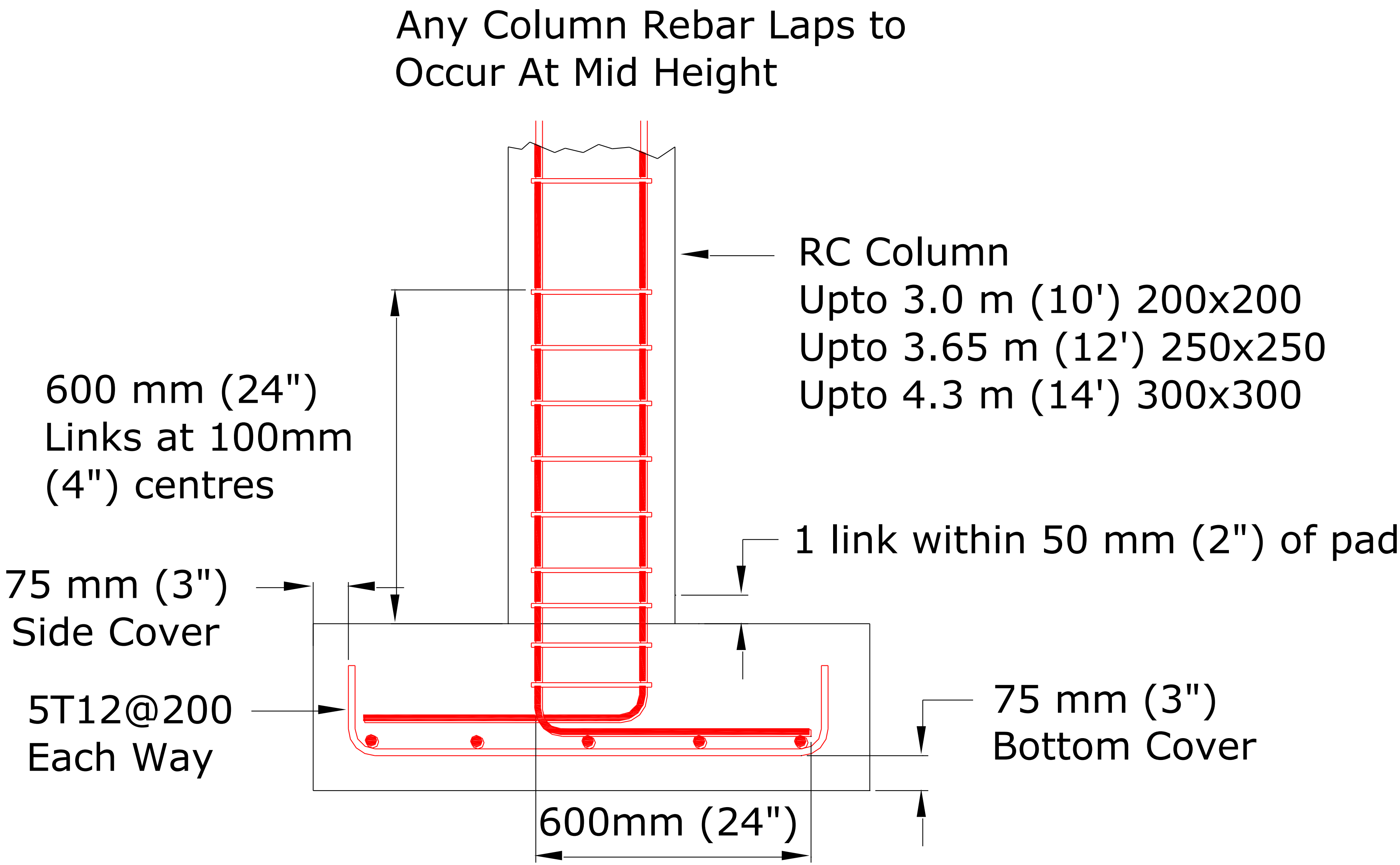
<u>SECTION THRU' TIE BEAM</u>

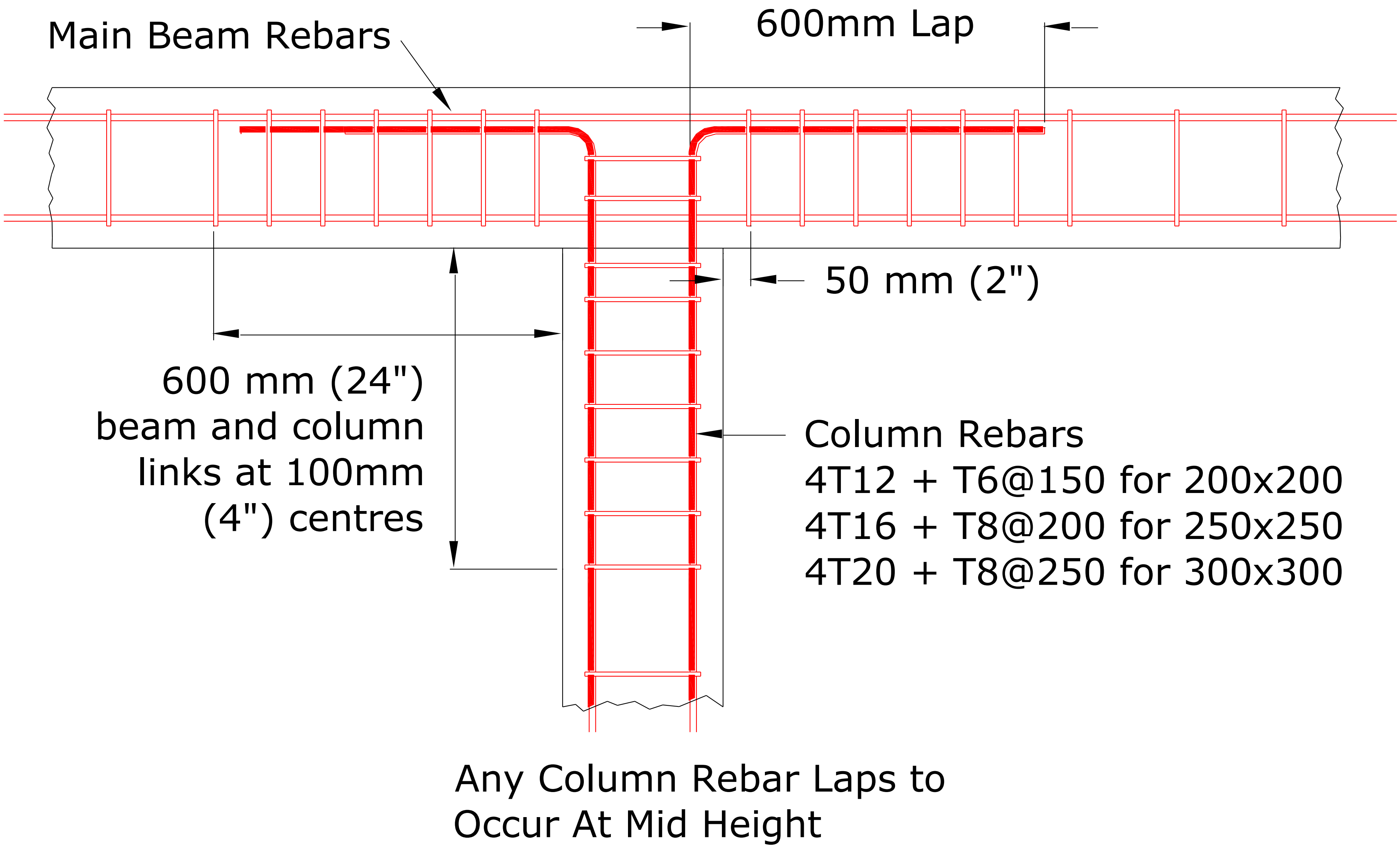
Tie Beams

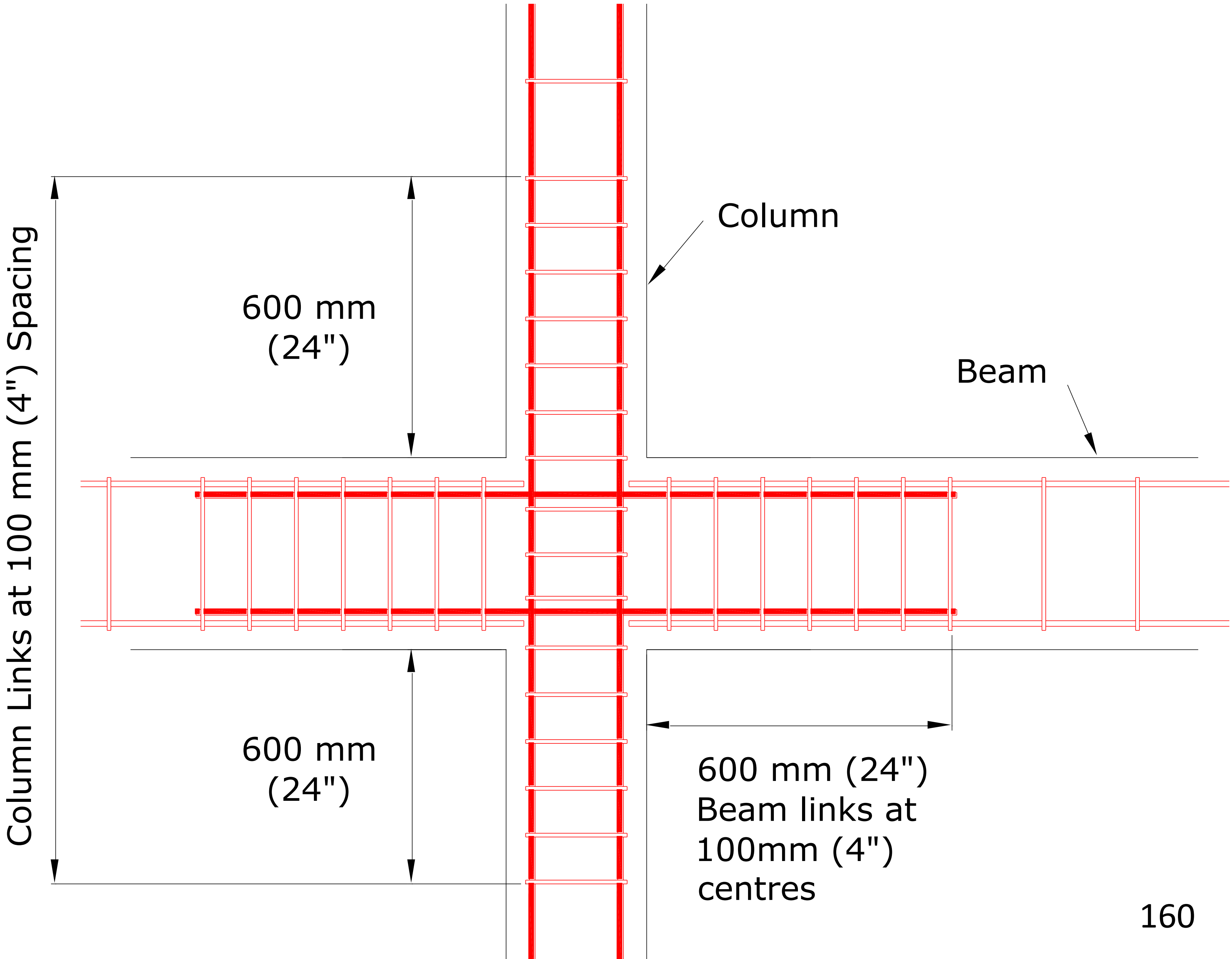
PLAN OF TIE BEAMS AND PAD FOOTING




Main Beam Rebars
600mm Lap
50 mm (2")
600 mm (24")
beam and column
links at 100mm
(4") centres
Column Rebars
4T12 + T6@150 for 200x200
4T16 + T8@200 for 250x250
4T20 + T8@250 for 300x300
Any Column Rebar Laps to
Occur At Mid Height
RC Column
Upto 3.0 m (10') 200x200
Upto 3.65 m (12') 250x250
Upto 4.3 m (14') 300x300
600 mm (24")
Links at 100mm
(4") centres
1 link within 50 mm (2") of pad
75 mm (3")
Side Cover
5T12@200
Each Way
75 mm (3")
Bottom Cover
600mm (24")


Any Column Rebar Laps to
Occur At Mid Height
RC Column
Upto 3.0 m (10') 200x200
Upto 3.65 m (12') 250x250
Upto 4.3 m (14') 300x300
600 mm (24")
Links at 100mm
(4") centres
1 link within 50 mm (2") of pad
75 mm (3")
Side Cover
5T12@200
Each Way
75 mm (3")
Bottom Cover
600mm (24")

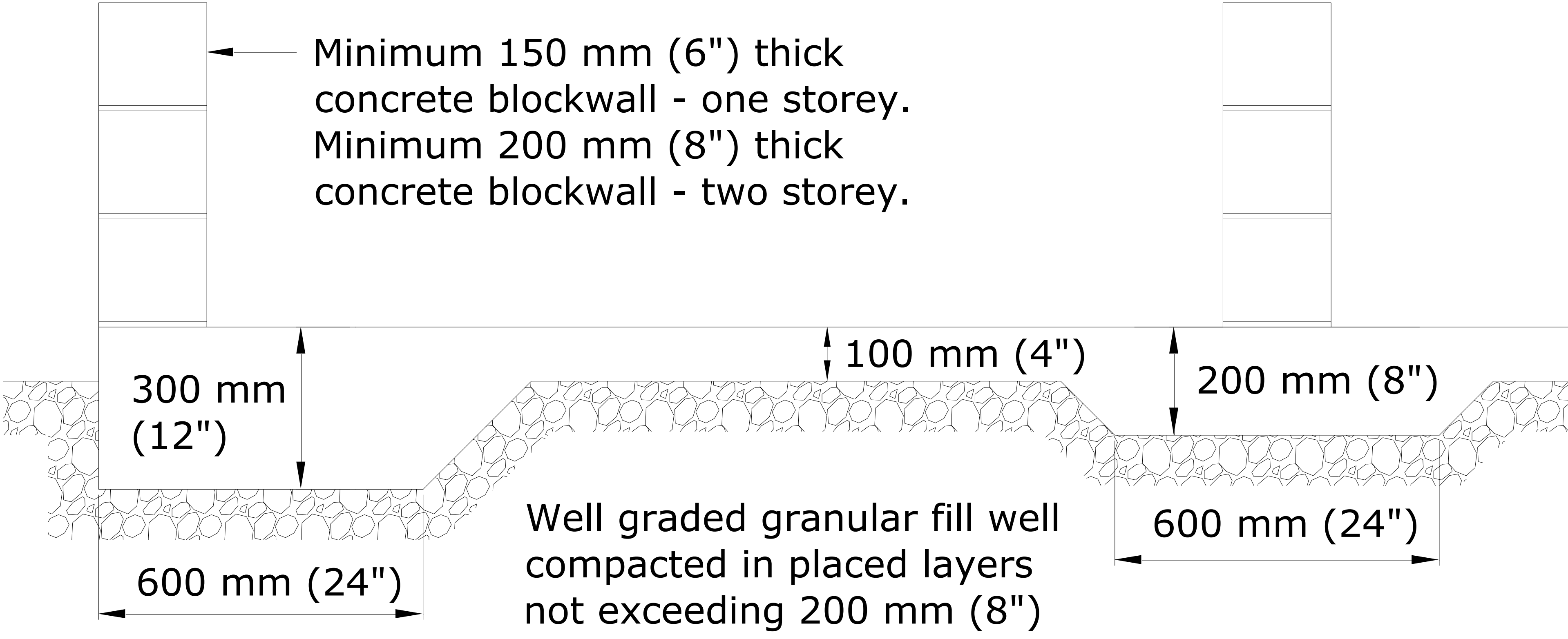

Main Beam Rebars
600mm Lap
50 mm (2")
600 mm (24")
beam and column
links at 100mm
(4") centres
Column Rebars
4T12 + T6@150 for 200x200
4T16 + T8@200 for 250x250
4T20 + T8@250 for 300x300
Any Column Rebar Laps to
Occur At Mid Height


Column Links at 100 mm (4") Spacing
600 mm (24")
Column
Beam
600 mm (24")
600 mm (24") Beam links at 100mm (4") centres

B 2.5 Concrete Slab-on-Ground Foundation

- When good bearing soil is deep, then a slab-on-ground foundation, which integrates the foundation into the ground floor slab, can be supported on well compacted granular fill material.
- A slab-on-ground foundation can also be used on relatively flat land, where hard rock is close enough to the surface to allow the footing to be cast on the rock.

Slab-on–Ground Layout



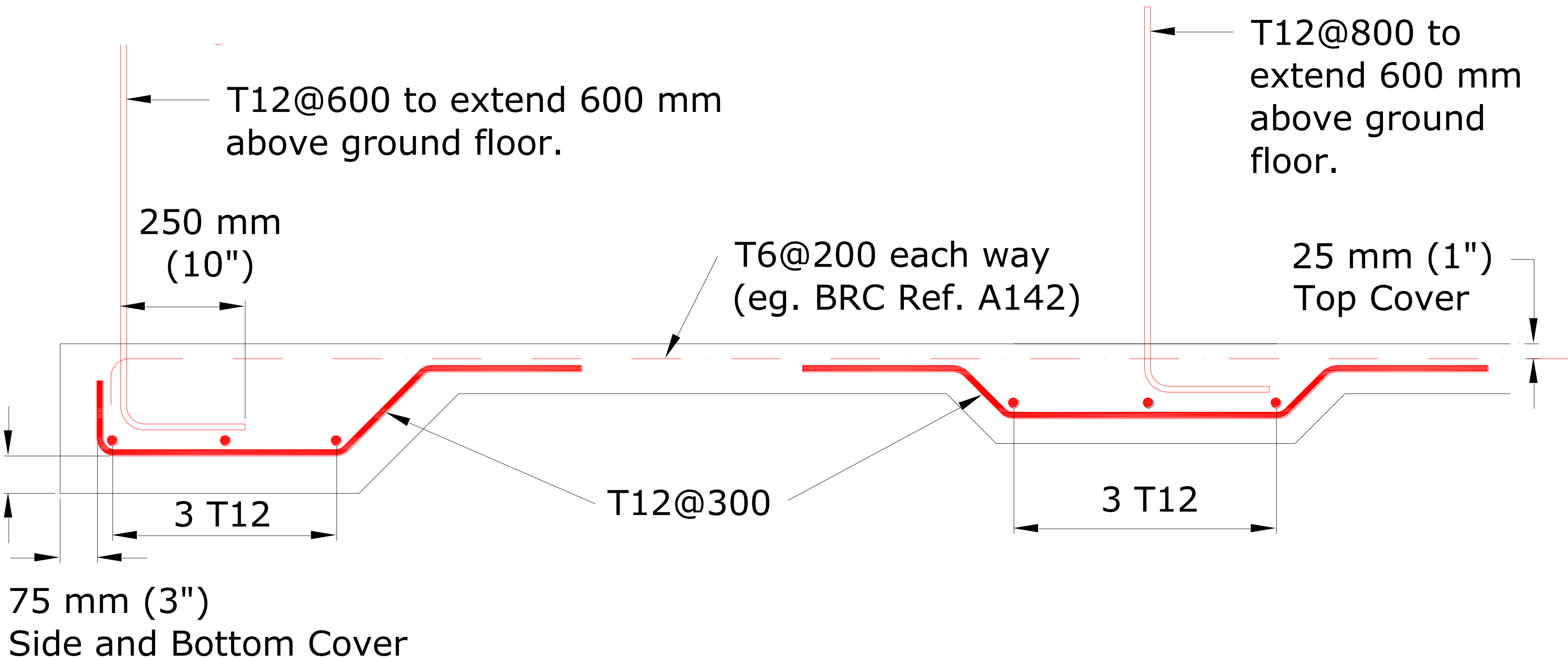
Concrete Slab-on-Ground Construction Method

No.	Construction Methods	Comment
1	Excavate slab area to good bearing layer.	To reduce settlement.
2	Backfill slab area to 150mm (6”) less slab level using well graded granular fill, well compacted in layers not exceeding 200mm (8”) before compaction.	To reduce settlement.
3	Excavate the slab thickening foundation areas in the compacted fill.	To support the walls.
4	Install water, waste, electricity, telephone, and other piped services under the slab. Test and cap pipes.	To prevent re-work.

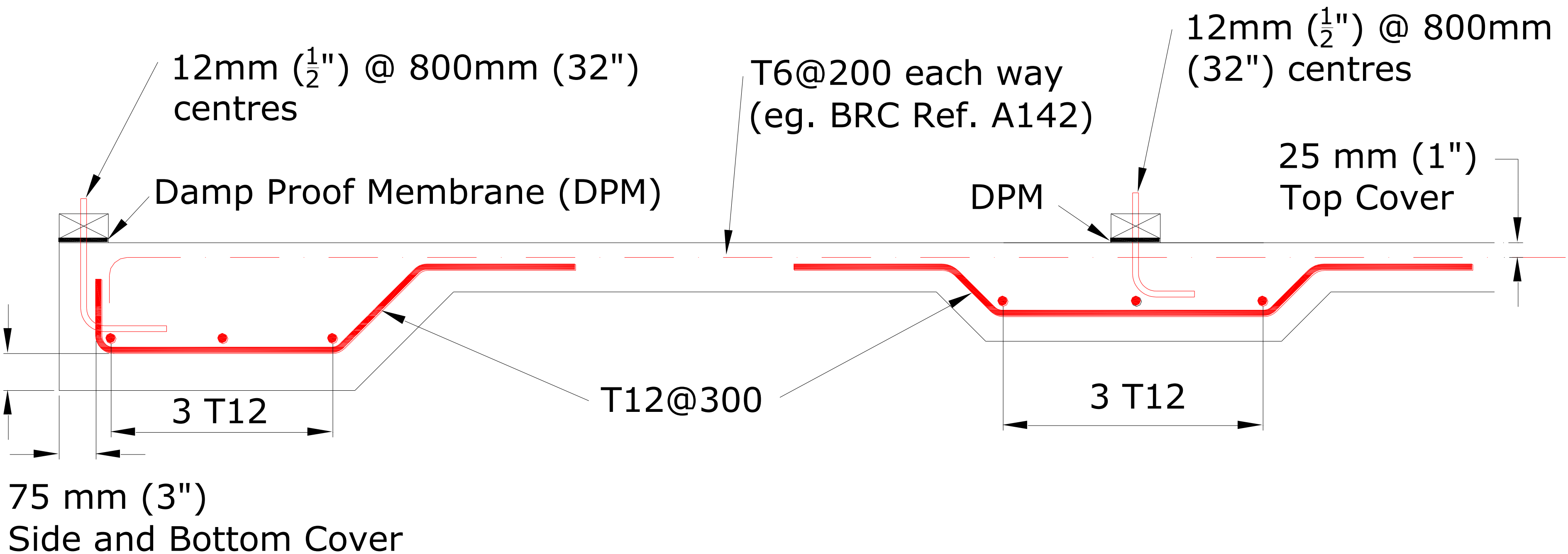
No.	Construction Methods	Comment
5	Apply termite treatment to ground under footings. Use a pesticide with a minimum 5-year warrantee.	To protect the timber from termites.
6	Place mass concrete (1:3:6) blinding layer if the surface is uneven.	To provide a flat surface to accommodate the placement of reinforcement.
7	Place damp proofing membrane (DPM). (See A 6) Tape around pipes.	To reduce the upward migration of moisture.
8	Erect formwork to fit the slab thickenings. Use braced timber with close fitting joints.	To prevent deformation and leakage of fine aggregate, cement or water.

No.	Construction Methods	Comment
9	Place reinforcement in the formwork and tie the bars together. a) For block walls, place wall starter bars (Exterior wall = T12mm (1/2”) diameter at 600mm (24”) centres. Interior walls = T12mm diameter at 800mm (32”) centres) b) For timber walls, install wall anchor bolts or straps (Exterior and Interior walls = T12mm (1/2”) diameter at 800mm (32”) centres)	For durability and to prevent the reinforcing bars from moving out of position during the concreting.
10	Raise the reinforcement at the correct level to maintain the concrete cover using concrete spacer blocks or plastic chairs. Cover to surfaces in contact with earth = 75mm (3”).	To protect the reinforcing bars from corrosion.

Slab-on-Ground Rebars - Masonry (Concrete Block) Walls



Slab-on-Ground Rebars - Timber Walls



Note: DPM to be placed under all sole plates and directly under RC slab.

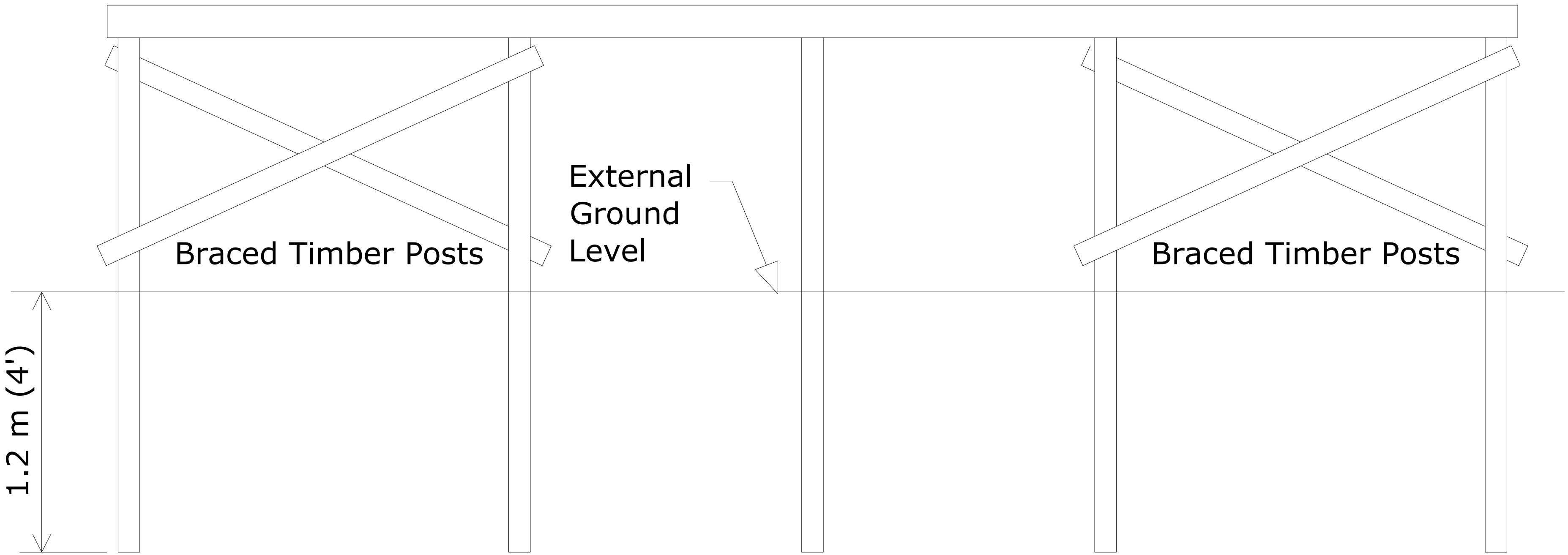
No.	Construction Methods	Comment
11	Remove any debris from within forms. Blowing debris with compressed air or flushing with pressurised water are effective methods.	To avoid contaminating the concrete.
12	Apply a release agent to the formwork surface to be in contact with concrete. (See A 6)	To facilitate stripping the formwork.
13	Pour concrete. Design compressive strength of 3,600 psi at 28 days. (See A 6)	For durability and structural safety.
14	Compact the concrete using a vibrator.	For strength and durability of the concrete.

No.	Construction Methods	Comment
15	Level and float finish.	To provide a flat bearing surface for the walls and floor covering.
16	Wash away the cement from on top of the aggregate in the wall locations.	To provide a bond.
17	Cure by keeping continuously wet for at least 3 days. (See A 6)	To allow the concrete to achieve the design strength.
18	Strip formwork	To use again.

B 2.7 Timber Post Foundations

- A relatively inexpensive foundation for a **timber building** is to drive 100mm x 100mm (4”x4”) minimum Greenheart or termite treated braced timber posts at least 1.2 m (4 ft) into the ground, or place it in a hole and concrete around it.

- To reduce the vulnerability to insect attack, precast concrete piles can be used. After excavation, the ground should be treated against termites, and the treatment should be repeated periodically.



Posts to be braced at all corners in each elevation.

B 3 FLOORS

The floor is used to support the floor loads and to transmit them to the foundations. There are 3 types described in this course.

3.1 Reinforced Concrete Slab on Fill

3.2 Suspended Reinforced Concrete Slab

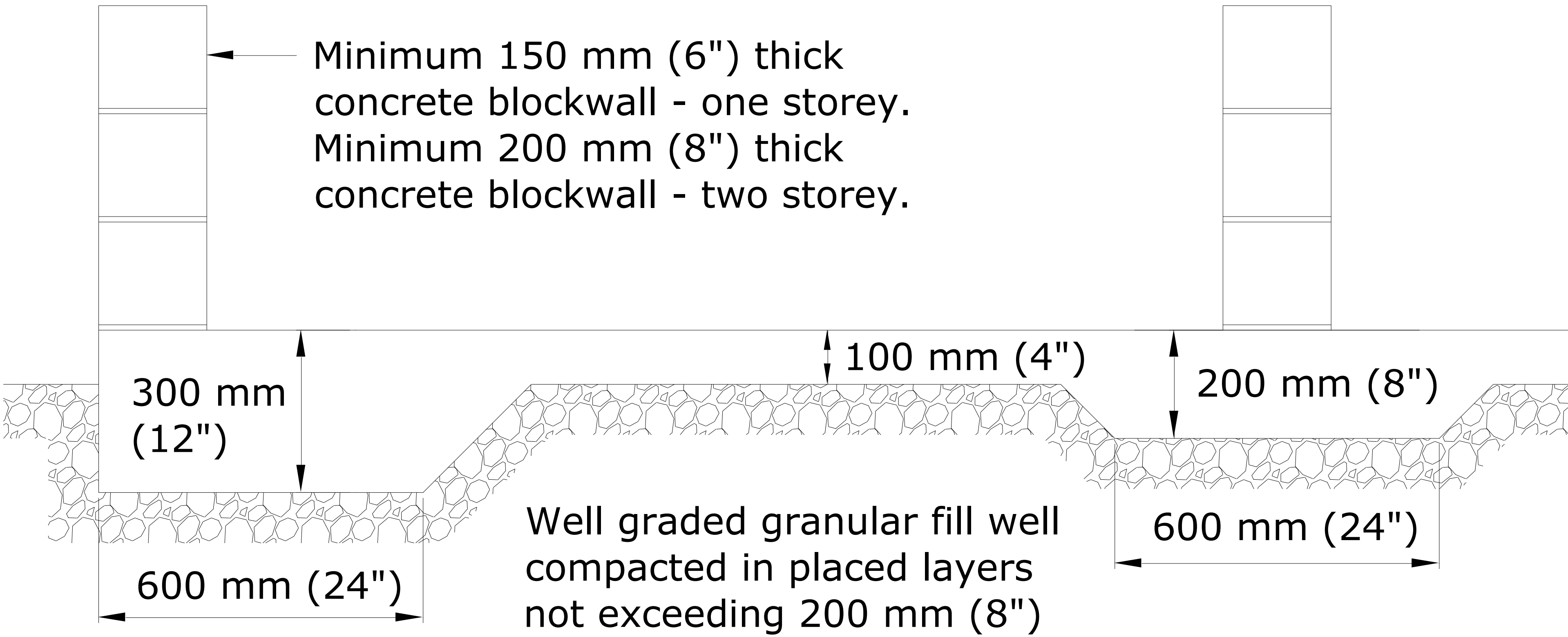
3.3 Suspended timber floor.

B 3.1 Reinforced Concrete Slab on Fill

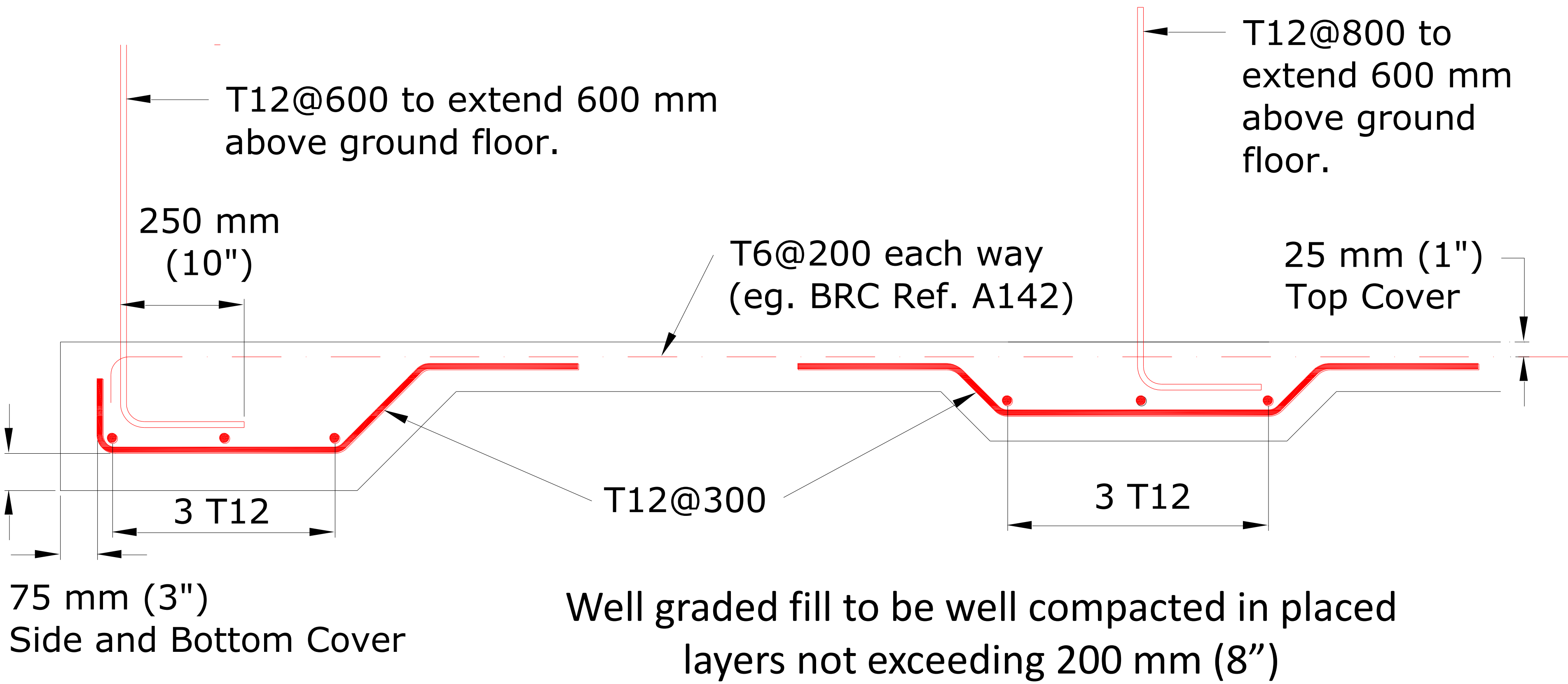
There are three types of concrete slabs on fill.

1. The slab-on-ground foundation covered in Section B 2.6.
2. The slab on strip footings covered in B 2.3.
3. Slabs that are within strip footings but not tied to walls.

B 3.1.1 Slab-on–Ground Layout

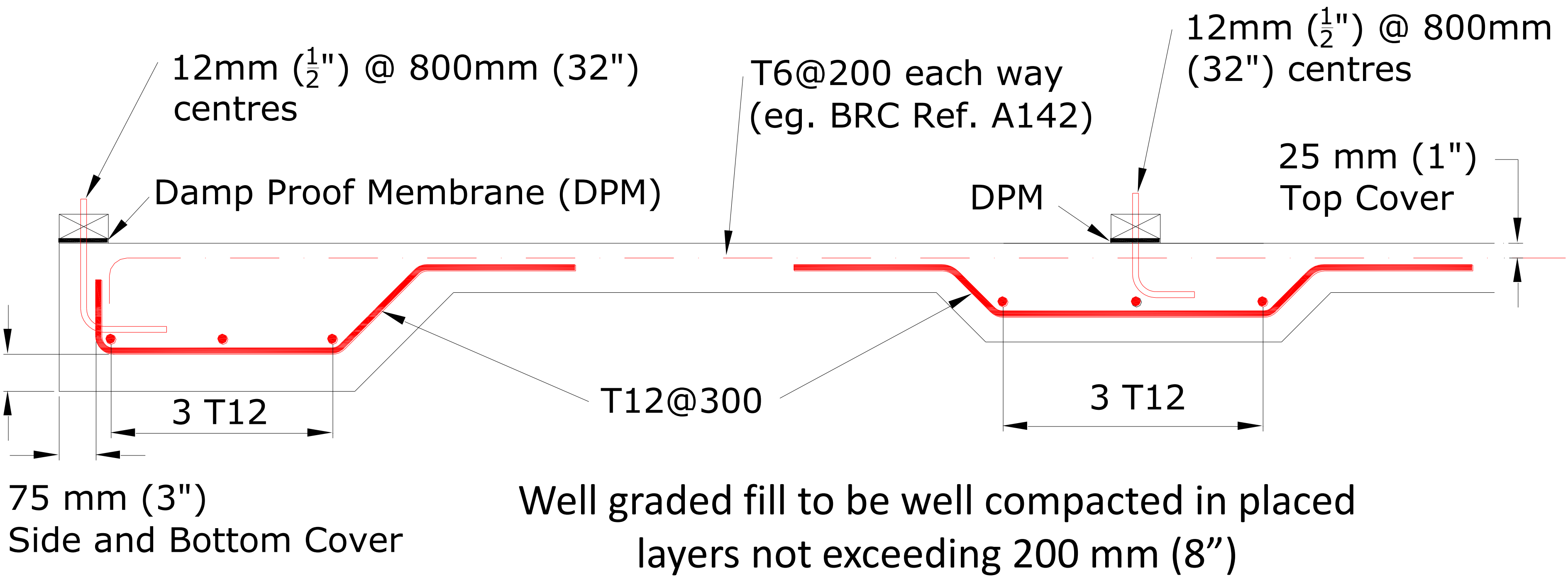


B 3.1.1 Slab-on-Ground Rebars - Masonry (Concrete Block) Walls



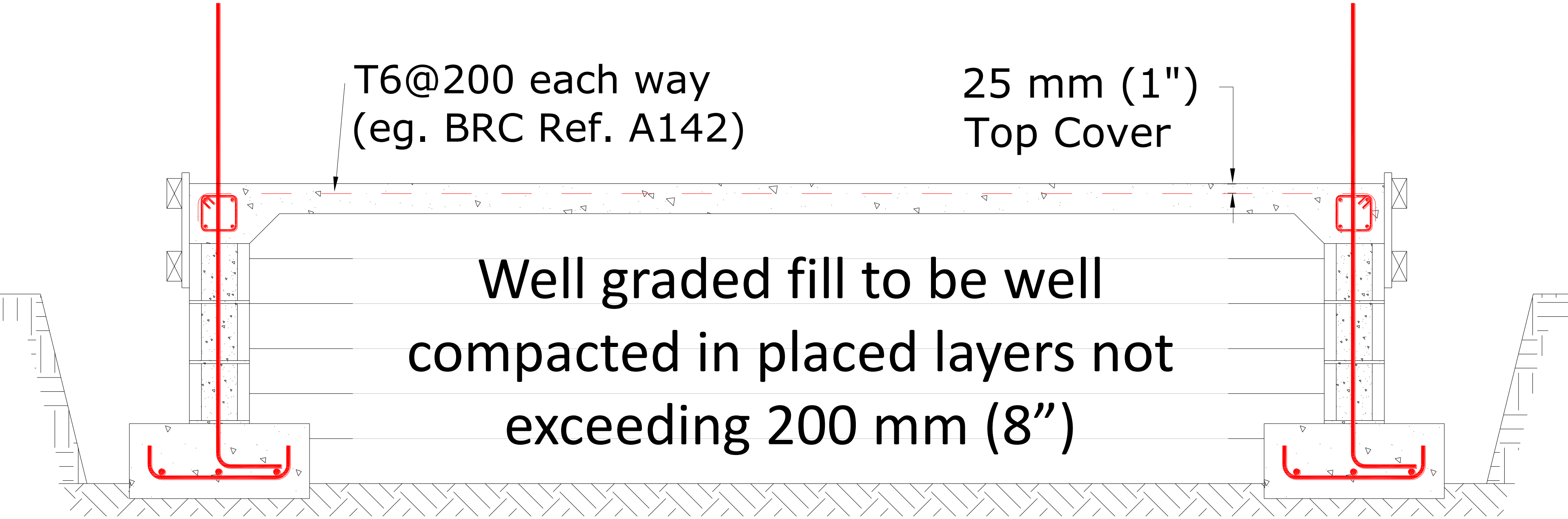
Note: DPM to be placed directly under RC slab.

B 3.1.1 Slab-on-Ground Rebars - Timber Walls



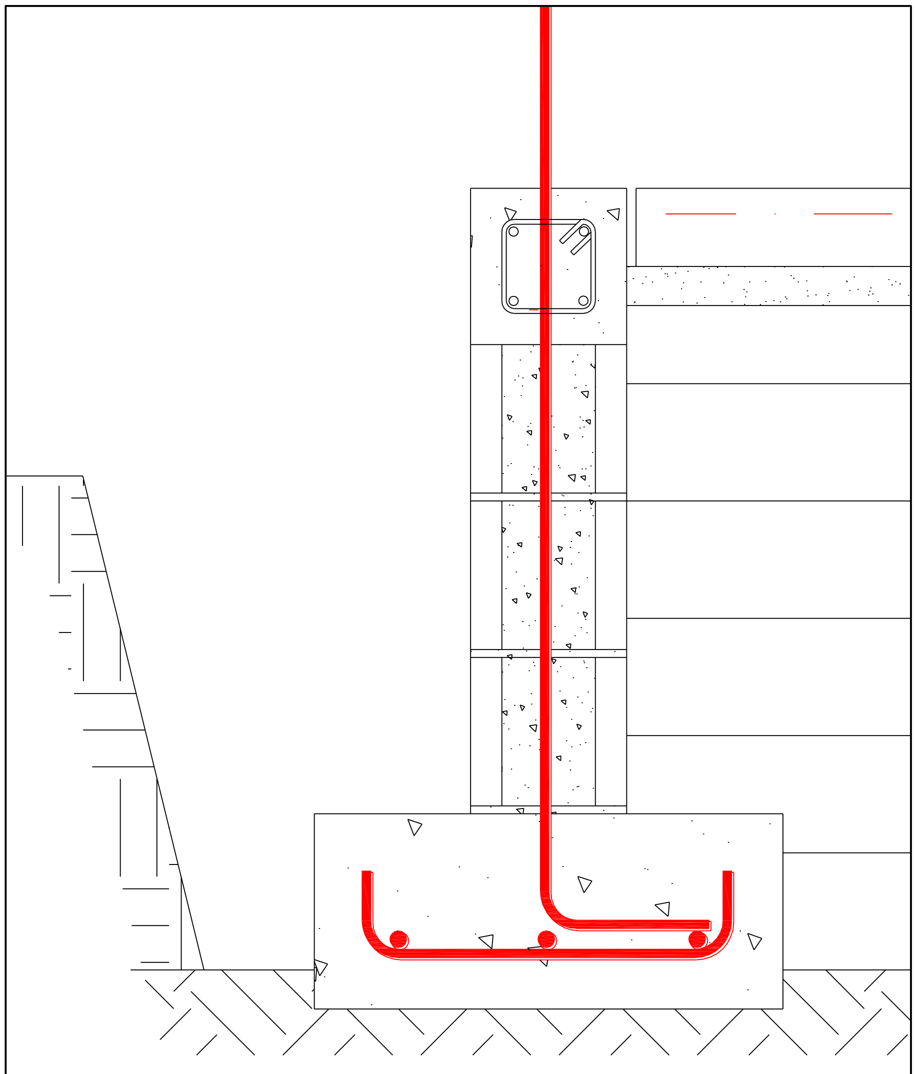
Note: DPM to be placed under all sole plates and directly under RC slab.

B 3.1.2 Slab-on-Strip Footings



Note: DPM to be placed directly under RC slab.

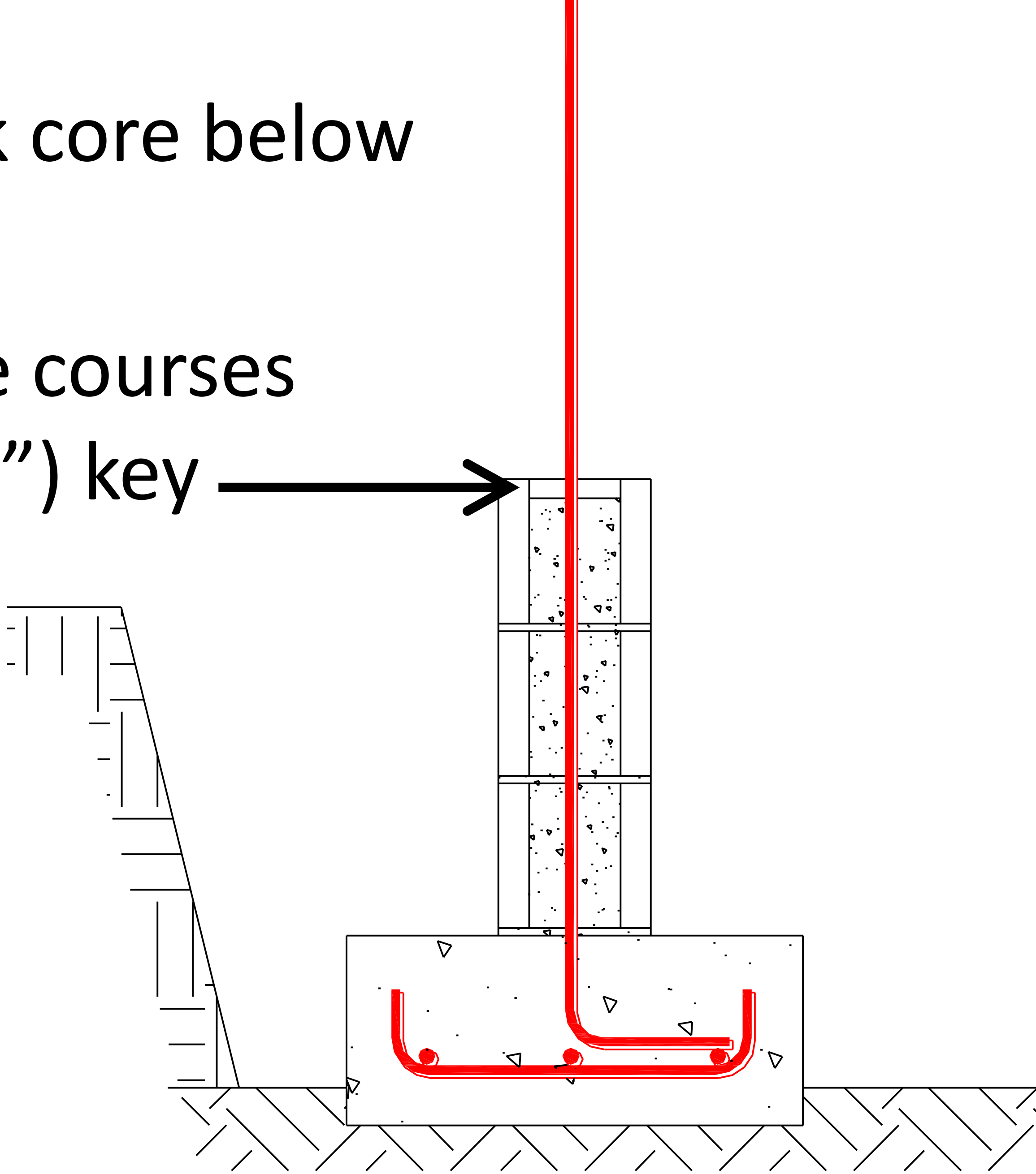
B 3.1.3 RC Ground Floor Slab Not Tied to Strip Footings



No.	Construction Methods	Comment
1	Construct strip footing (B 2 items 1 to 15)	To retain the fill and support the walls.
18	Strip formwork	To use again.

•Grout every block core below ground floor level.

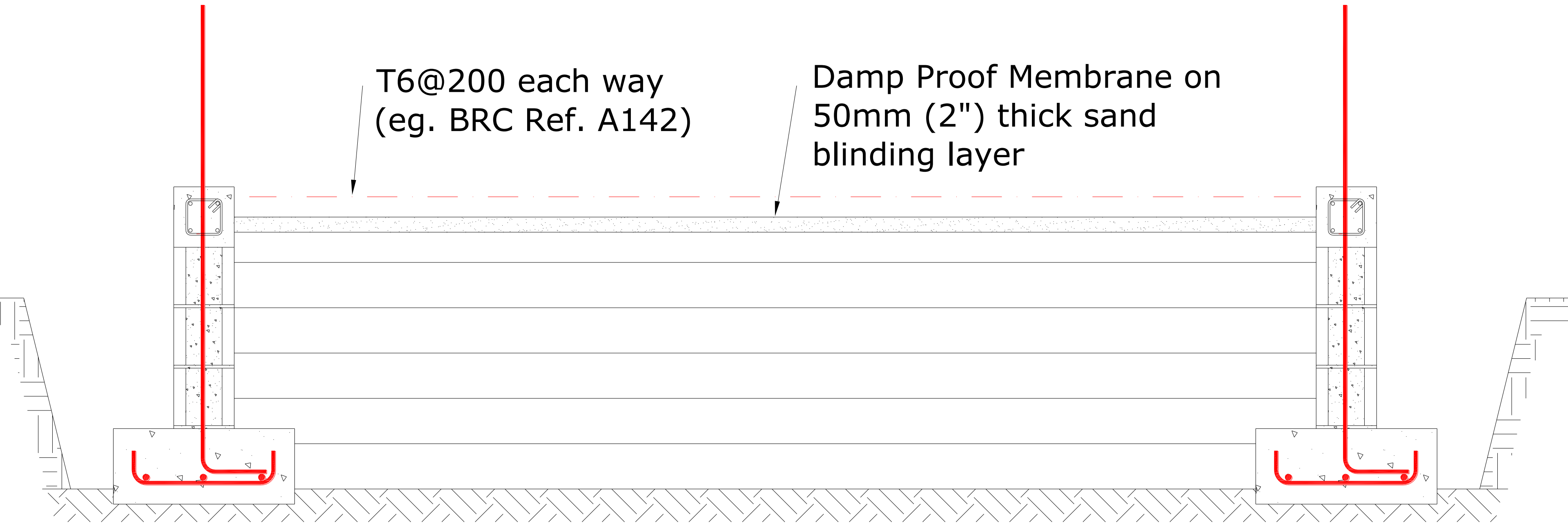
•Grout every three courses leaving a 25mm (1") key



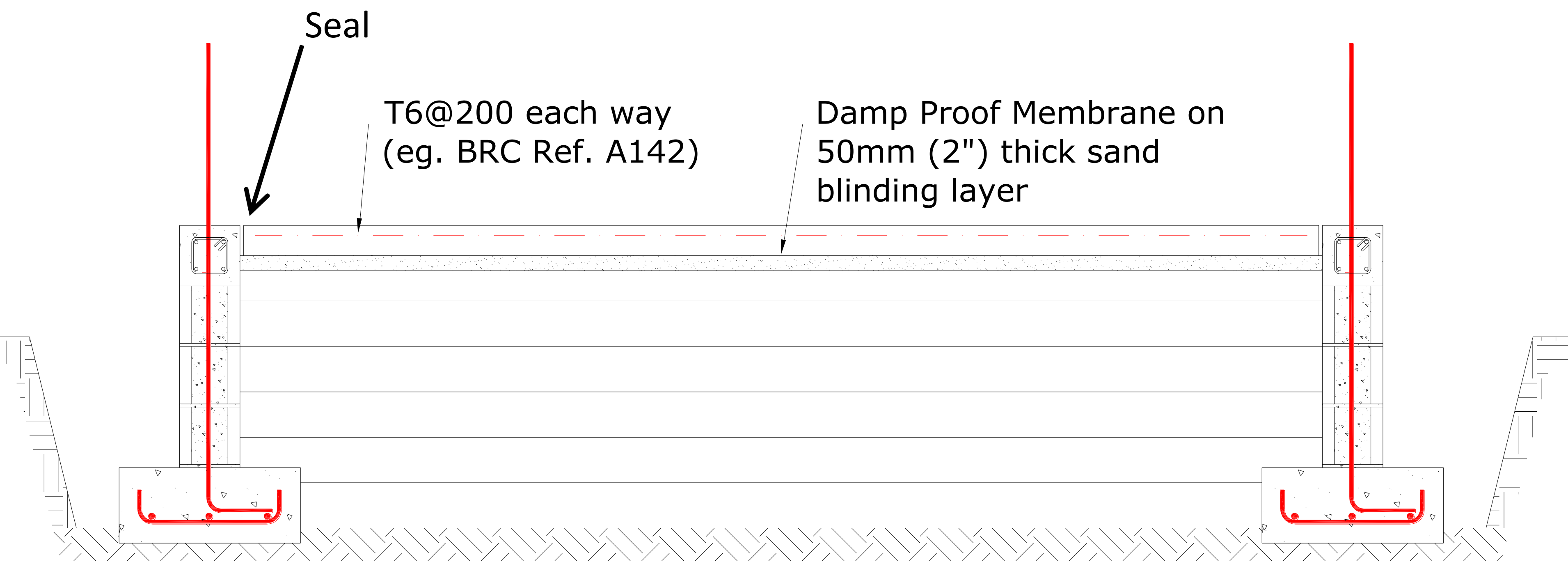
Walls must be strong enough to retain compacted fill.

No.	Construction Methods	Comment
2	Erect formwork to fit the 200mm x 200mm (8”x8”) RC ring beam.	To prevent deformation and leakage.
3	Install and smock reinforcement (4xT12mm (1/2”) diameter bars + T6mm (1/4”) diameter links at 200mm (8”) centres).	To tie the wall together.
4	Clean and oil forms and pour concrete. Design strength of 3,600 psi at 28 days. (See A 6)	For durability and structural safety.

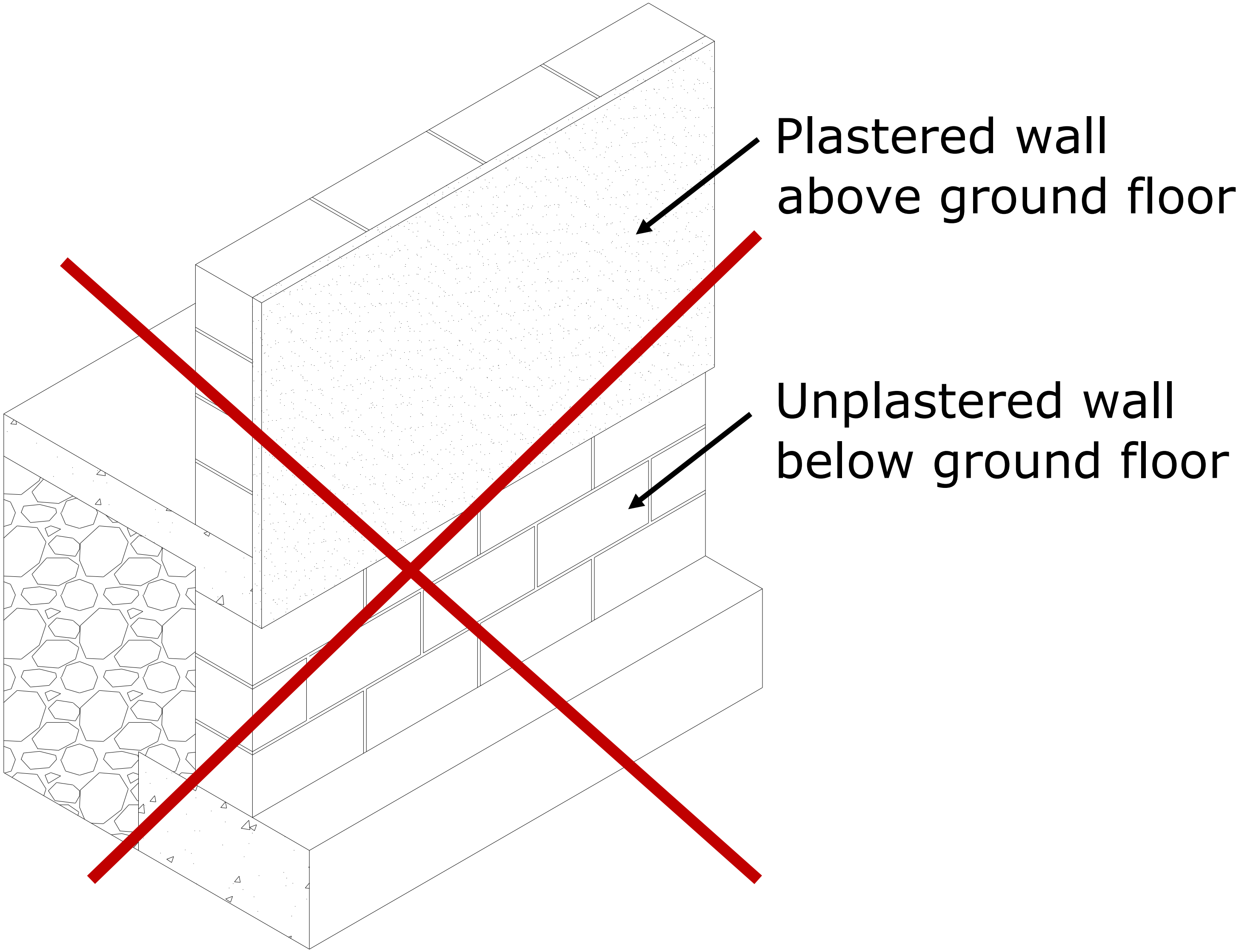
No.	Construction Methods	Comment
5	Strip beam formwork.	
6	Install and compact well graded granular fill in placed layers not exceeding 200mm (8”)	To prevent floor settlement.
7	Install mass concrete (1:3:6) blinding layer, or use compacted crusher run (max 2” diameter size well graded stone) as final fill layer.	To prevent damage to the Damp Proof Membrane (DPM)
8	Install the DPM (See A 6)	To restrict moisture access.
9	Install T6@200 each way (eg. BRC Ref.A142)	To limit the width of cracks.



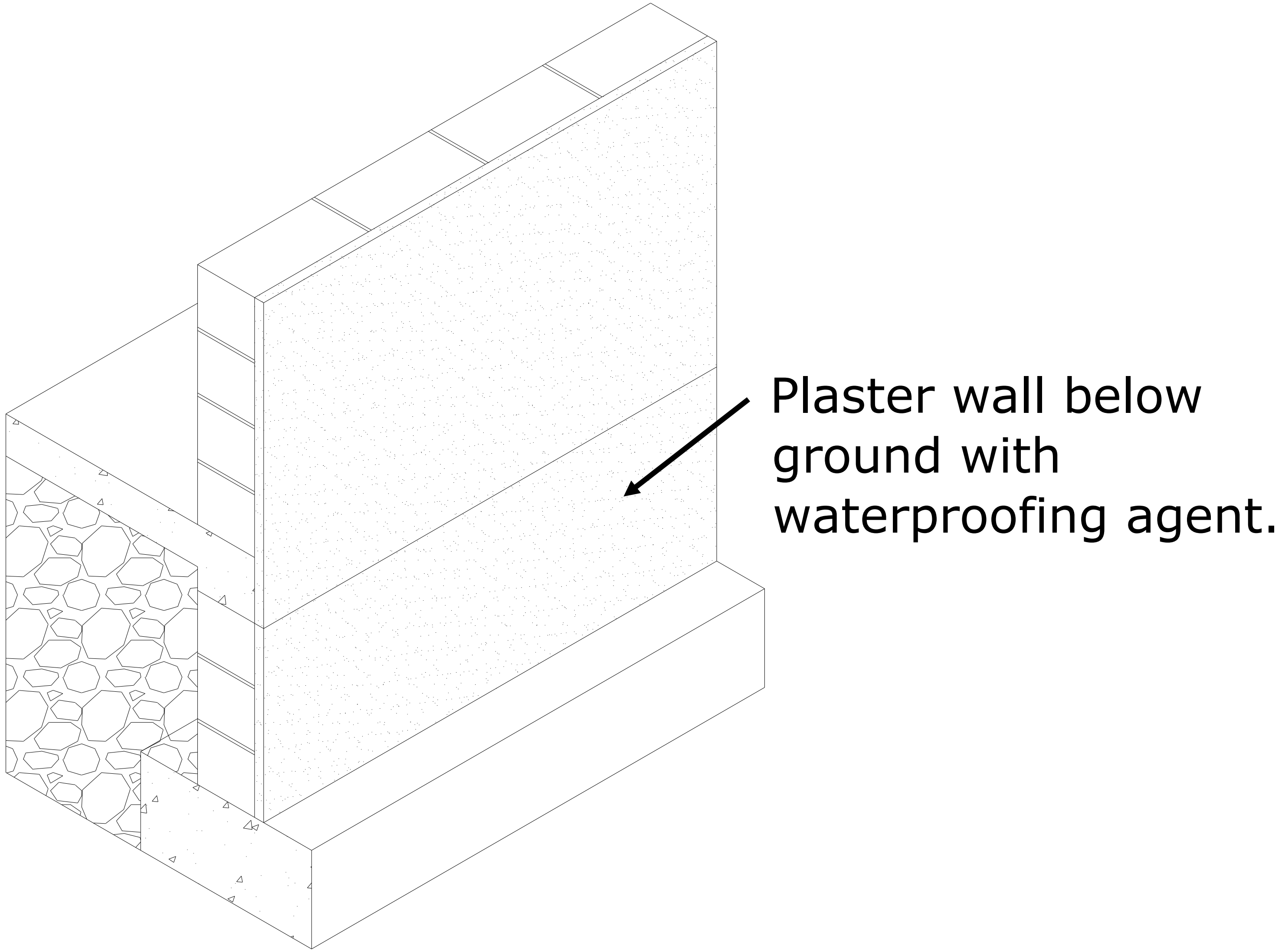
No.	Construction Methods	Comment
10	Pour, compact, trowel finish, and cure concrete (3,600 psi at 28 days)	For durability and structural safety.
11	Seal the joint between the beam and wall.	To prevent any insects from migrating through the crack.



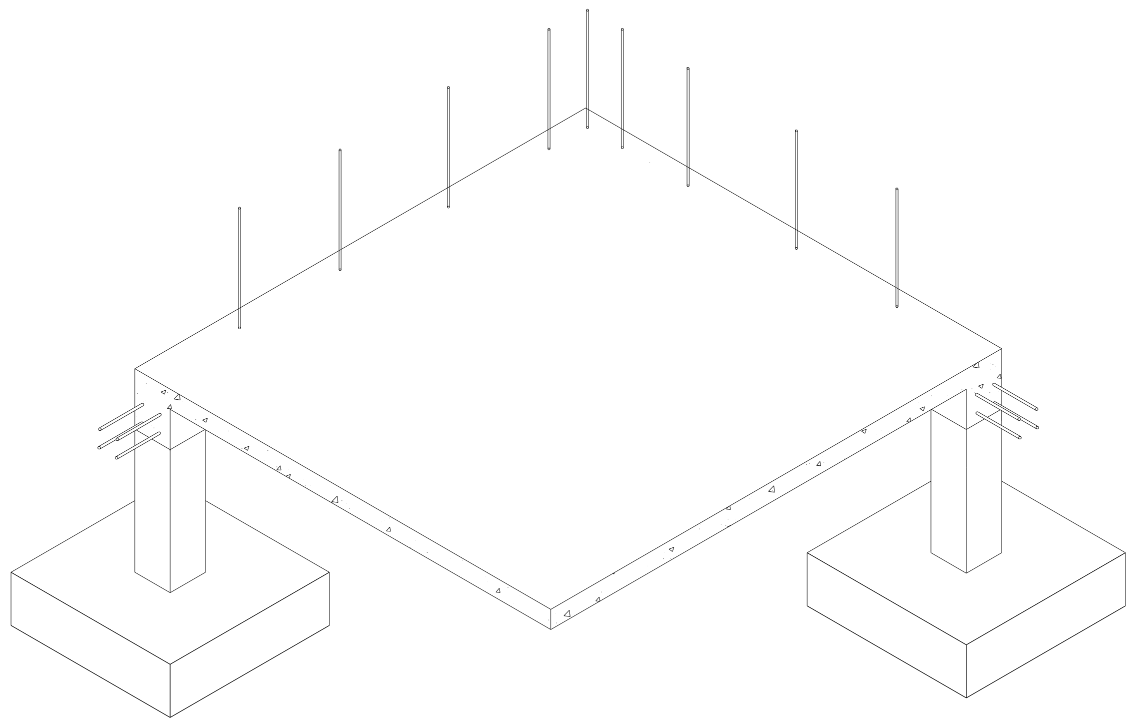
Plaster Foundation Walls



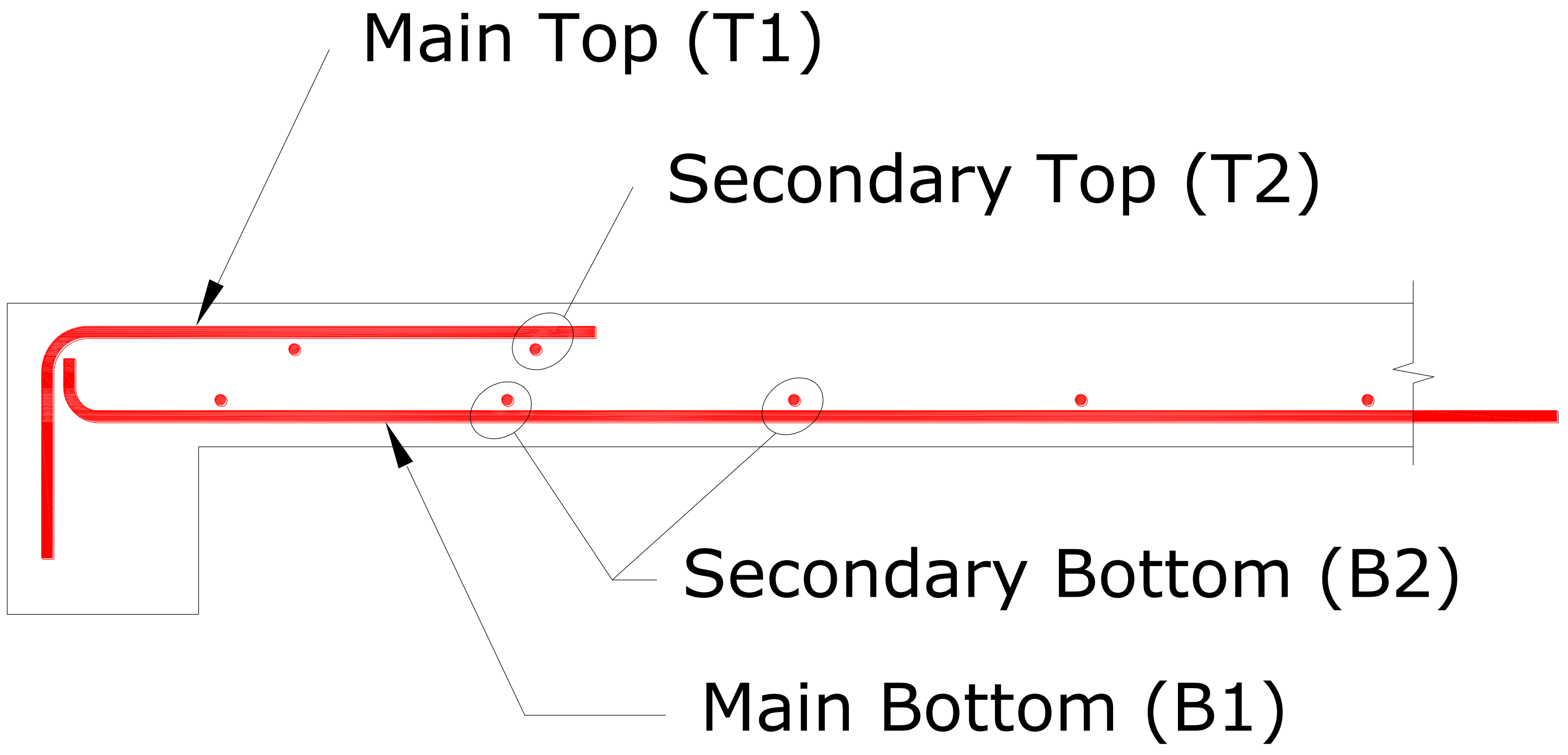
Plaster Foundation Walls



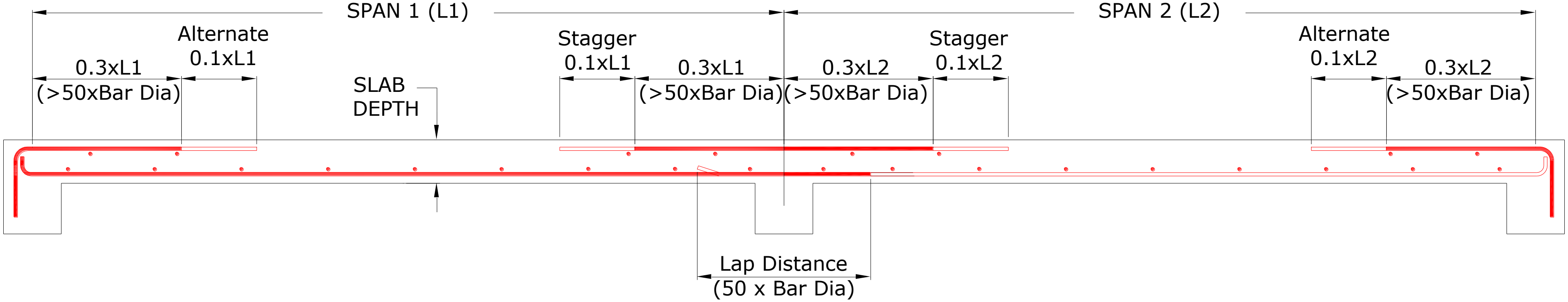
B 3.2 Suspended RC Floor Slab on Beams.

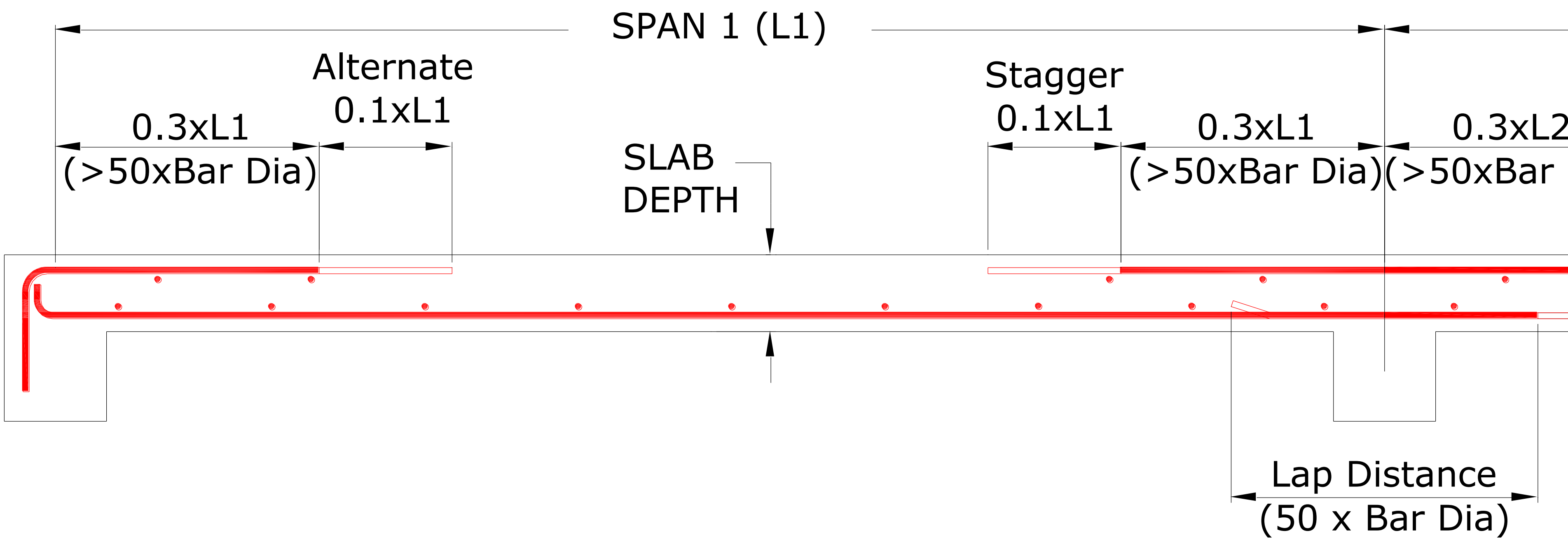


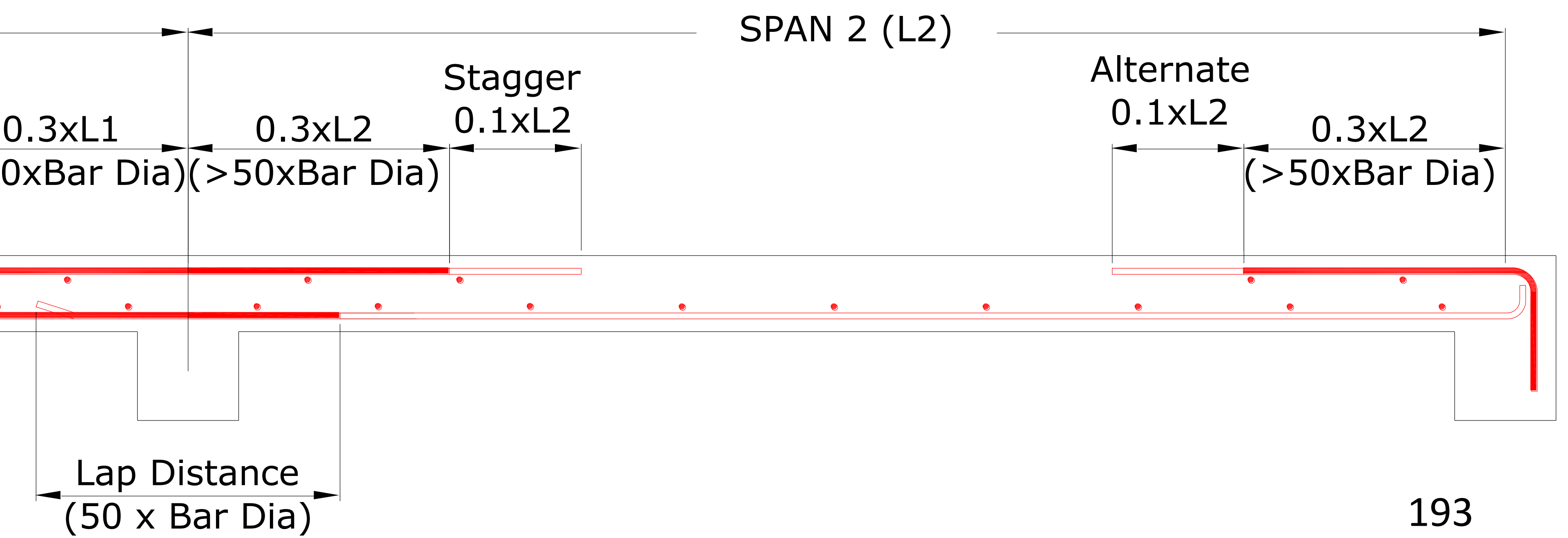
Location of slab reinforcing bars



Reinforcement for suspended slab




SPAN 1 (L1)
Alternate
0.1xL1
0.3xL1
(>50xBar Dia)
SLAB
DEPTH
Stagger
0.1xL1
0.3xL1
(>50xBar Dia)
0.3xL2
(>50xBar
Lap Distance
(50 x Bar Dia)


SPAN 2 (L2)
Stagger
0.1xL2
0.3xL1
0xBar Dia)
0.3xL2
(>50xBar Dia)
Alternate
0.1xL2
0.3xL2
(>50xBar Dia)
Lap Distance
(50 x Bar Dia)

Slab Thickness and Reinforcement

Slab Thickness mm (inch)	Span between supporting walls.					
	1.8 m (6 ft)	2.4 m (8 ft)	3 m (10 ft)	3.6 m (12 ft)	4.3 m (14 ft)	4.8 m (16 ft)
100 (4”)	T12@300					
125 (5”)	T12@300	T12@300				
150 (6”)		T12@300	T12@300			
175 (7”)			T12@300	T12@300		
200 (8”)				T12@300	T12@250	T12@200
225 (9”)					T12@280	T12@225

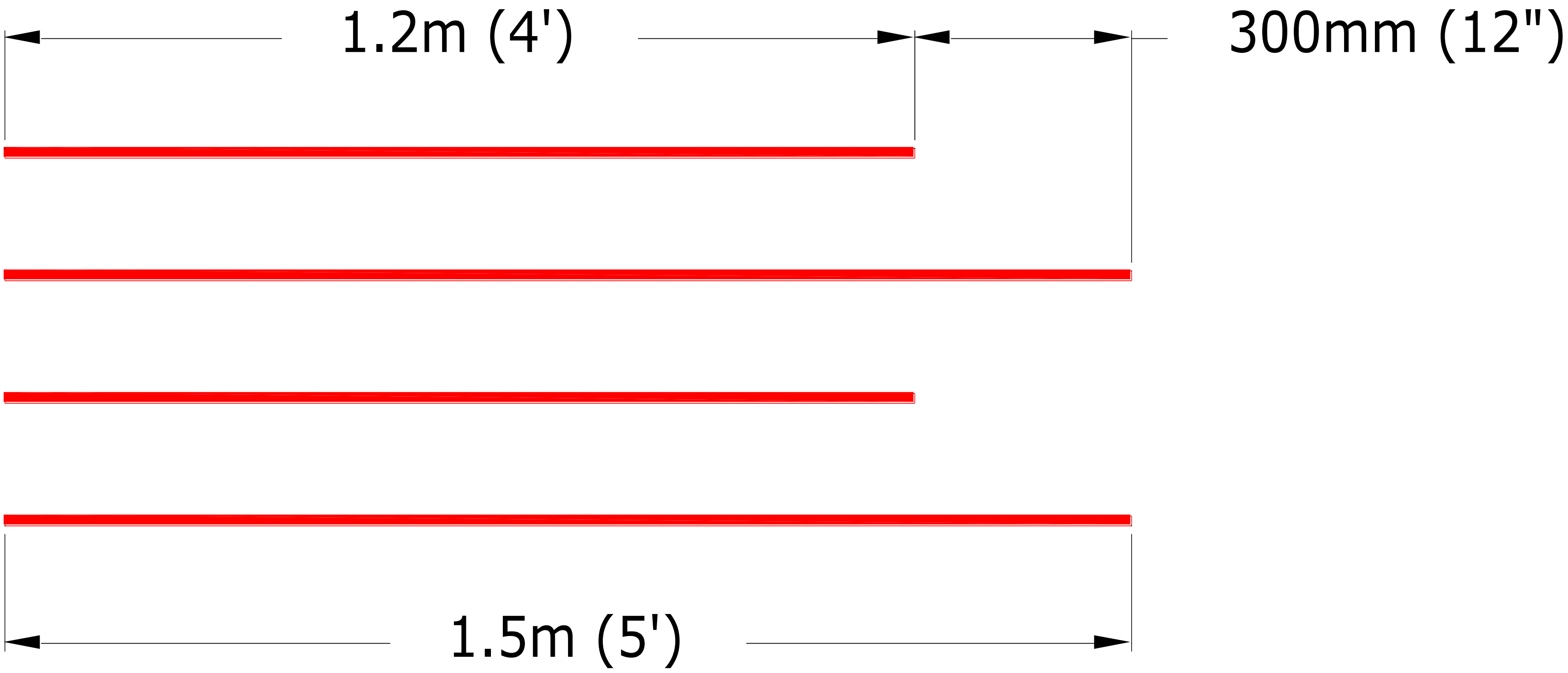
Secondary rebars = T10@300 mm

Note: 300mm = 12”, 280mm = 11”, 250mm = 10”

Note: Use the thicker slab thickness for higher than normal loads.

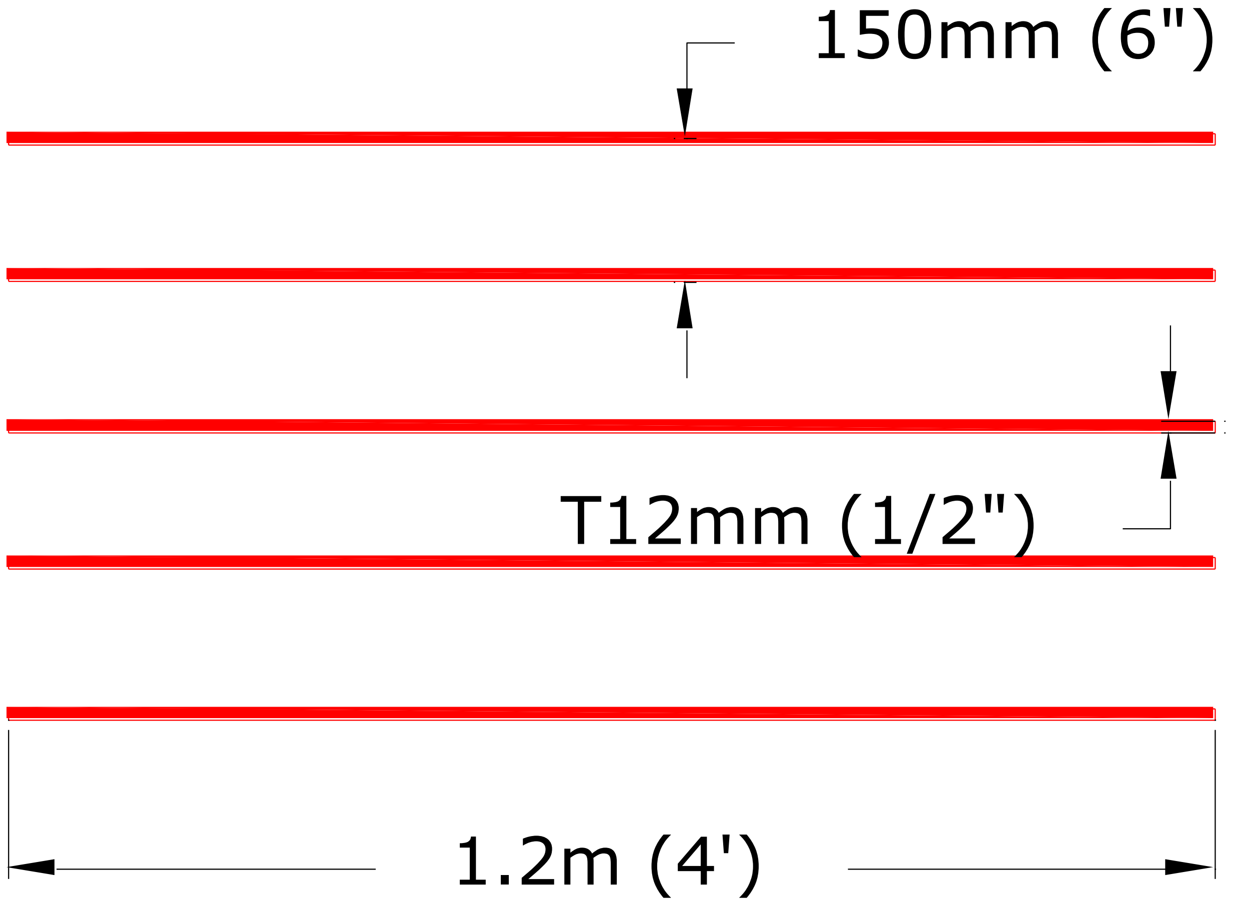
1.2m long bars with a 300mm stagger

1.2m and 1.5m long bars alternately placed



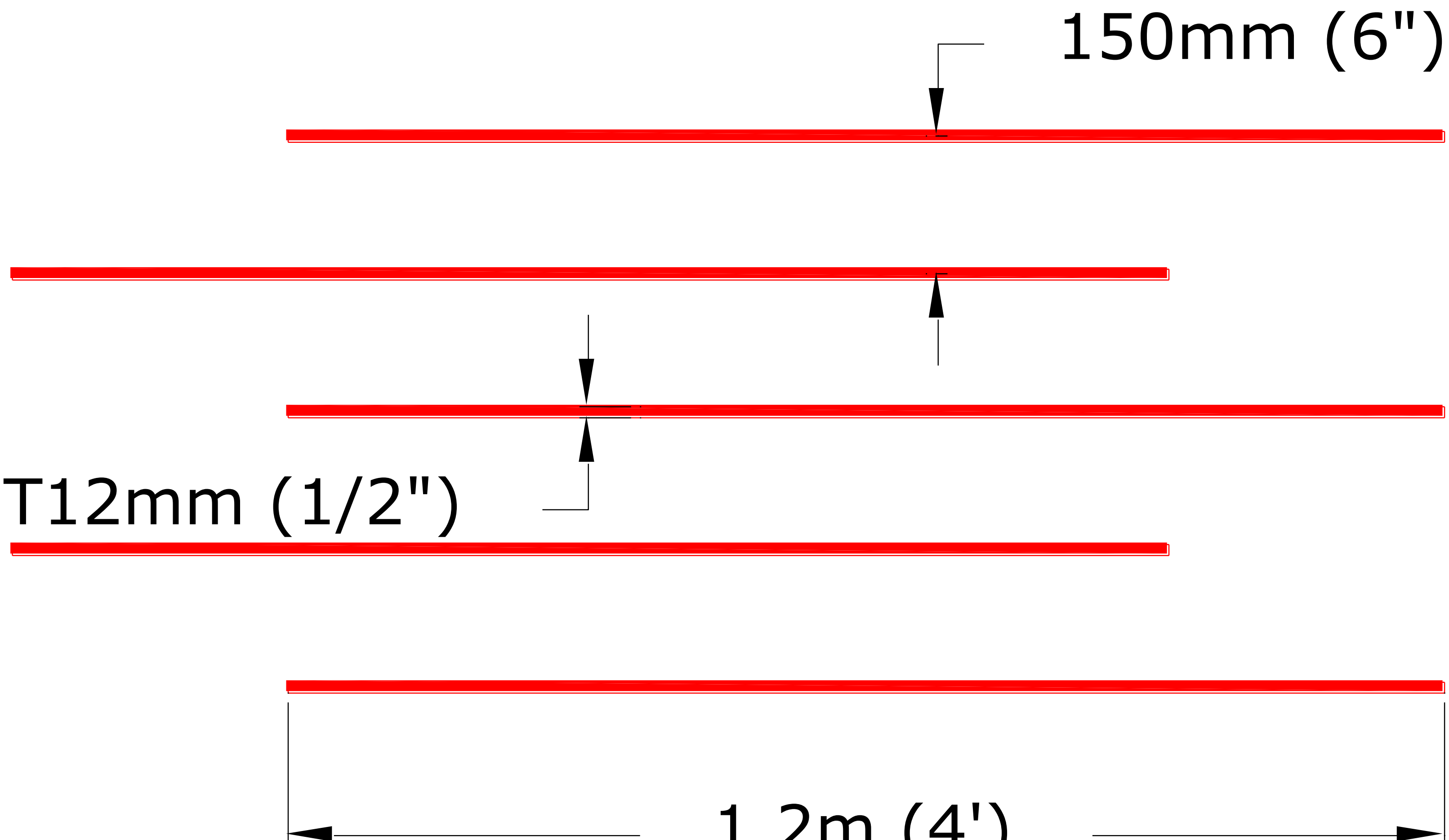
5T12@150

5 High Yield 12mm dia bars 150mm apart

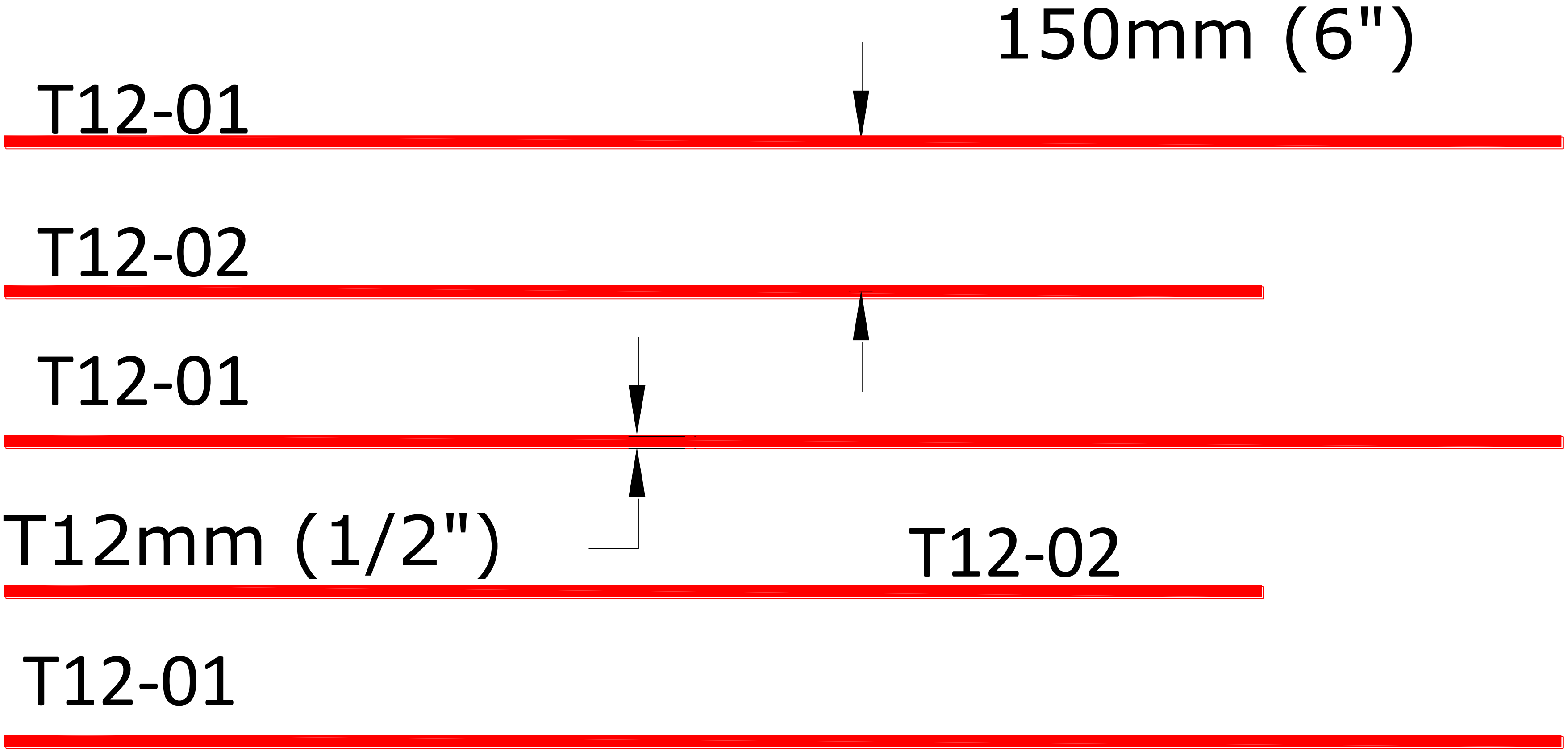


5T12@150 stg

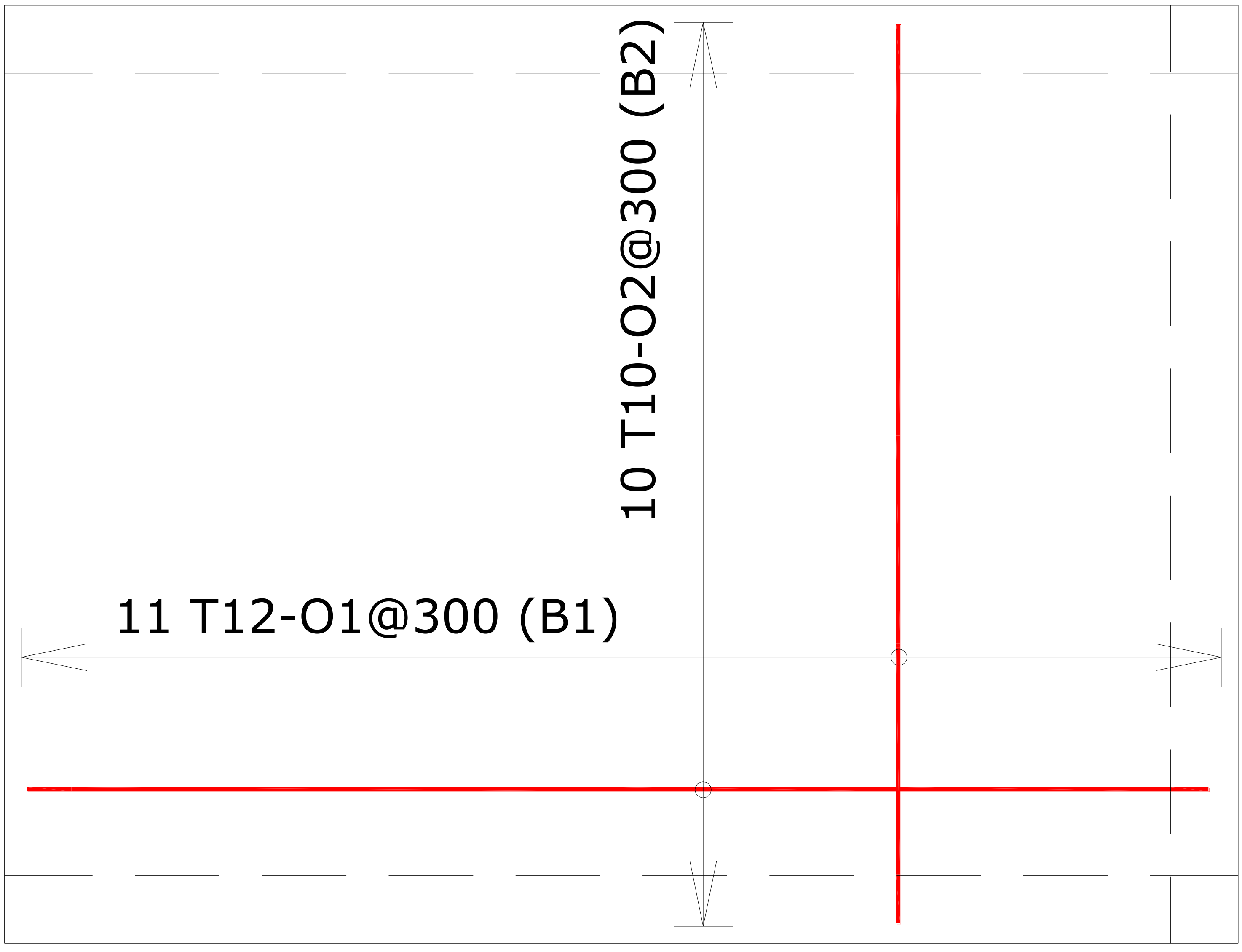
5 T12mm @ 150mm apart - staggered



3T12-01 + 2T12-02@150 alt
3+2 T12mm @ 150mm alternately placed



Plan of Slab



Eg. 11 T12-01@300 B1 Stg

11 = Number of bars

T = High yield/tension (460 MPa) (R = Mild steel)

12 = Bar diameter (mm)

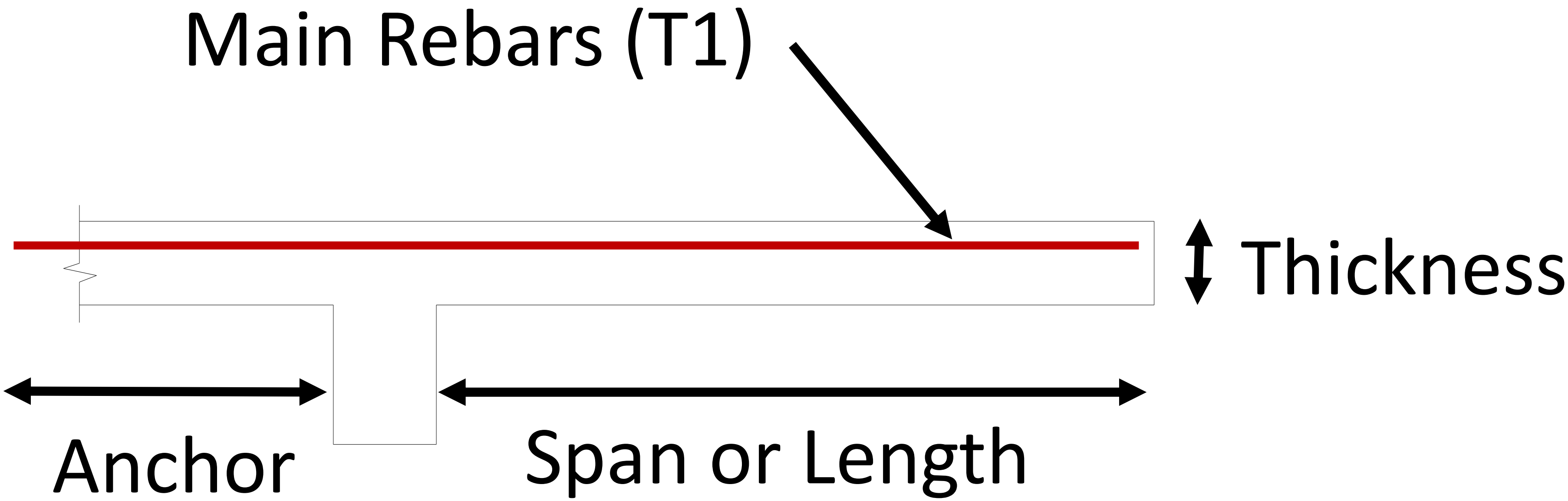
01 = Bar mark (for bar bending schedule)

300 = Bar spacing (mm)

B1 = Bar position (T1, T2, B1, B2)

Stg = Staggered (AP or alt = Alternately placed)

Cantilevered Slab



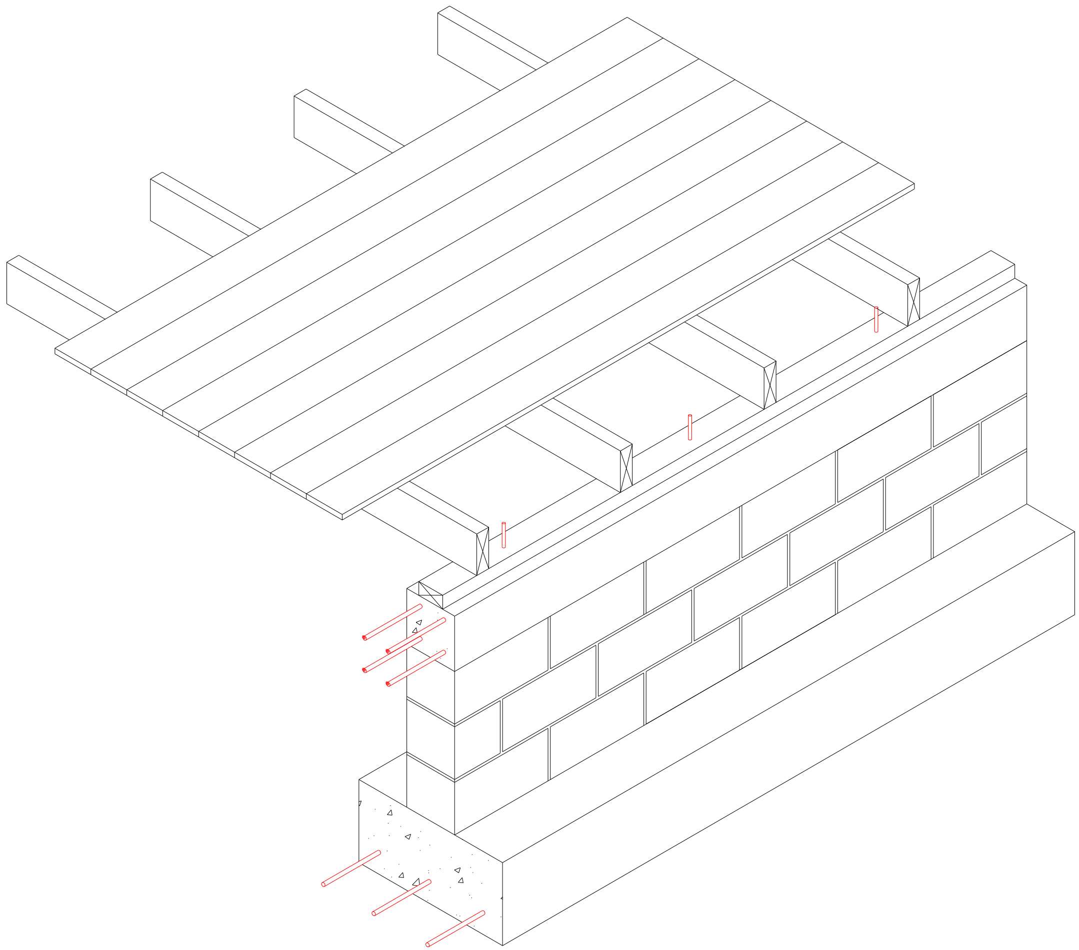
Cantilever Slab Thickness and Rebars

Span or Length (m)	Slab Thickness mm (in)	Main Rebars (T1)
1.2 (4’)	150 (6”)	T12@300
1.8 (6’)	200 (8”)	T12@300
2.4 (8’)	250 (10”)	T12@200
3.0 (10’)	300 (12”)	T16@300

Secondary Rebars: T10@300

Min Anchor: Greater of 1.5 x Cantilever span, 0.3 x Supported Span, or 50 x bar diameter.

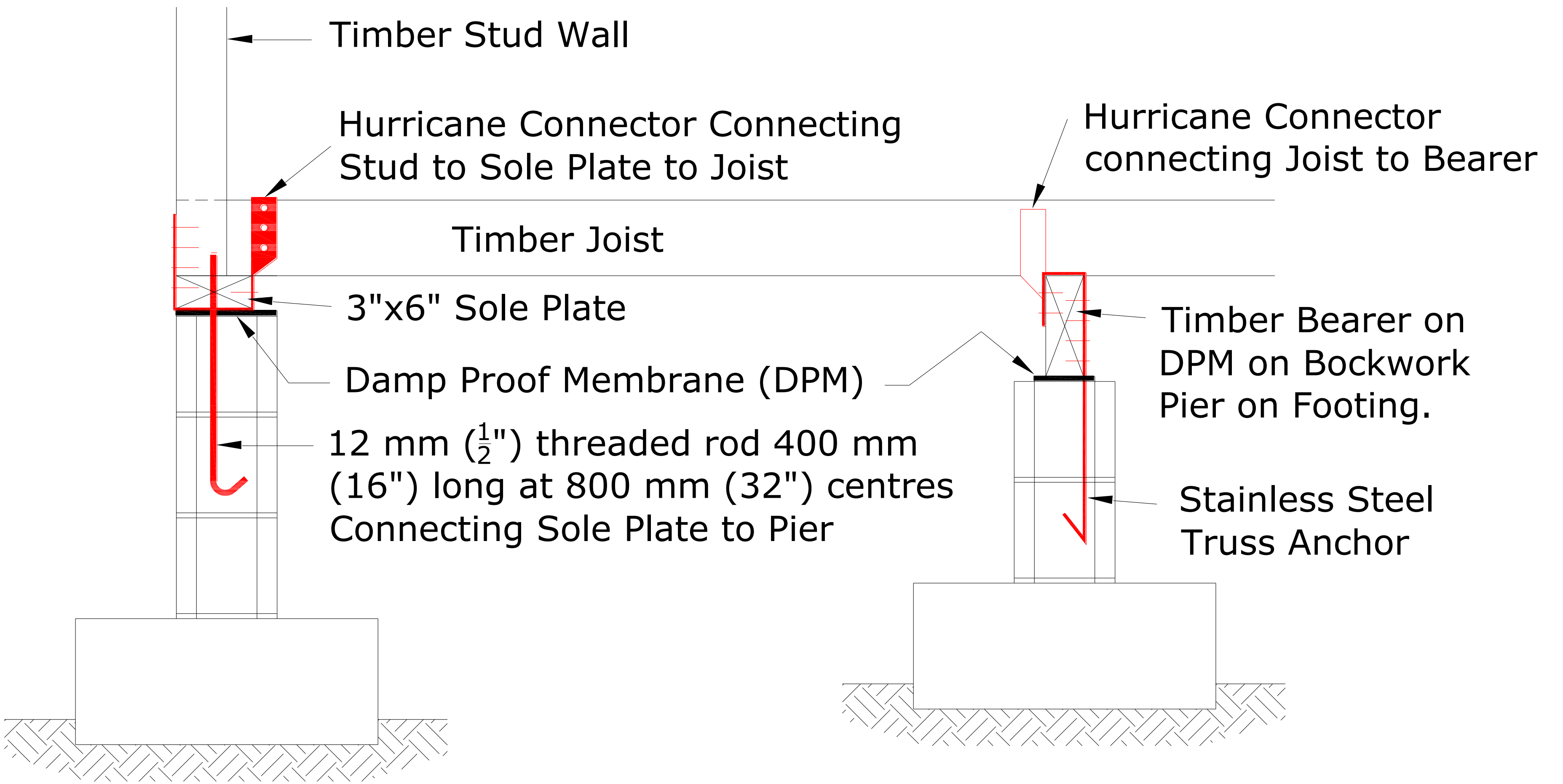
B 3.3 Suspended Timber Floor



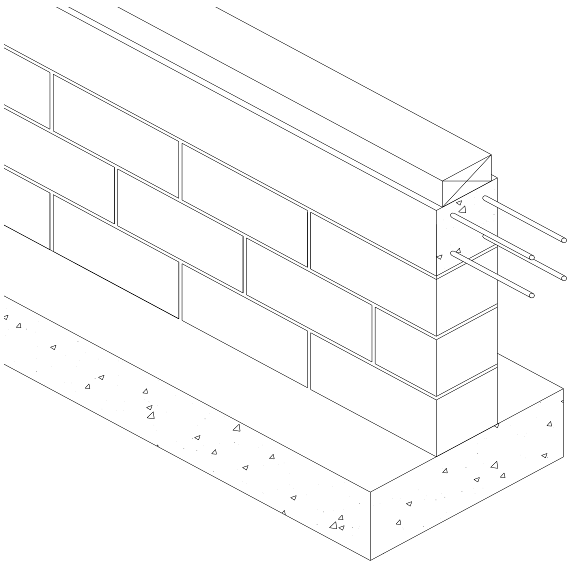
Using Timber on Concrete

- When placing timber on concrete, always put a damp proof membrane between the timber and the concrete member.
- If the size of timber joists are not available, then reduce the joist span by installing a timber beam/bearer on concrete or masonry piers.

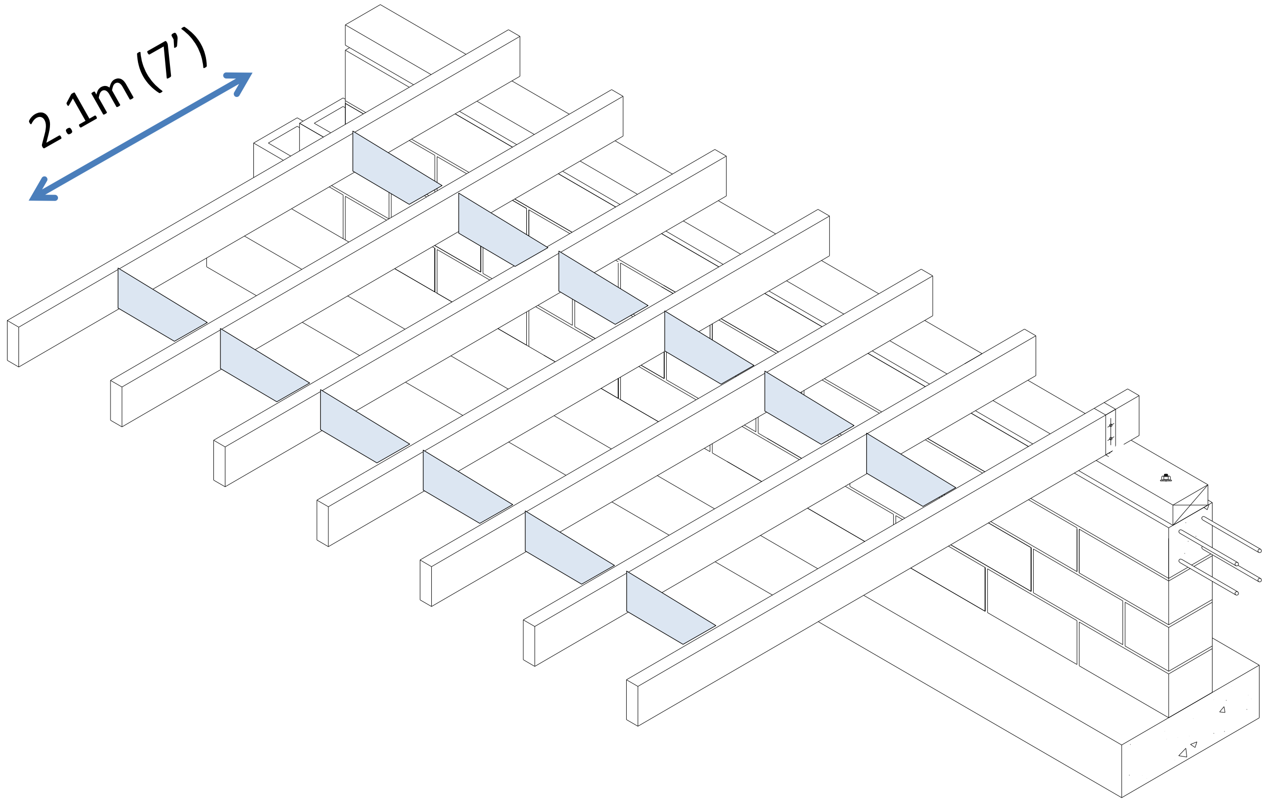
Joist Connections



No.	Construction Methods	Comment
1	Excavate footing and slab areas to a good bearing layer, and construct RC strip footings, and the block wall and RC beam using Items 1 to 17 of Section B 2.3.	To reduce settlement.
2	Install the damp proof membrane on the beam.	To reduce timber rot.
3	Bolt 75x150mm (3”x6”) timber sole plate/sill to the RC ring beam using the embedded 12mm (1/2”) diameter anchor bolts.	To connect the wall to the foundations.
4	Connect timber joists to sole plate and timber studs. The distance between the bottom of the joist and the grade beneath should not be less than 460mm (18”).	To reduce timber rot.



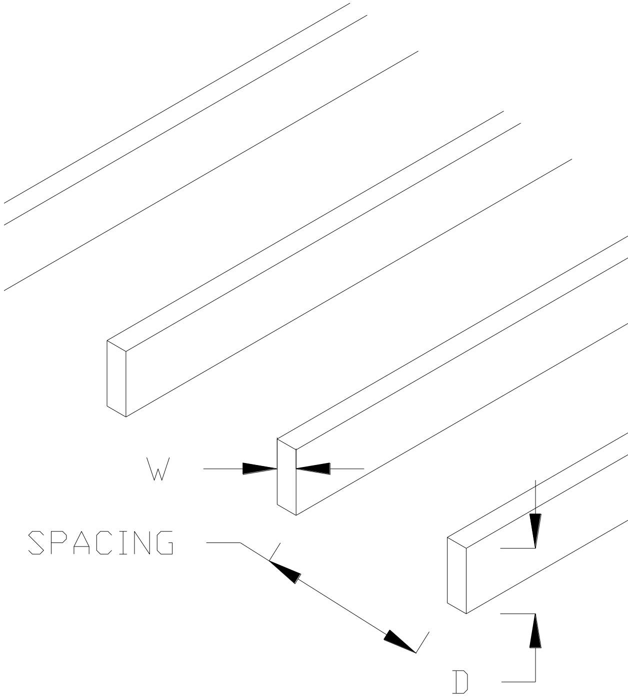
No.	Construction Methods	Comment
5	Install 25mm (1”) thick tongue and groove floor planks to the joists.	To support floor loads.
6	If the joist depth is 200 mm (8”) or more, then install joist bracing at 2.1 m (7’) intervals.	To reduce movement.



Floor covering removed to reveal solid bridging bracing.

Joist Sizes at 400mm Spacing

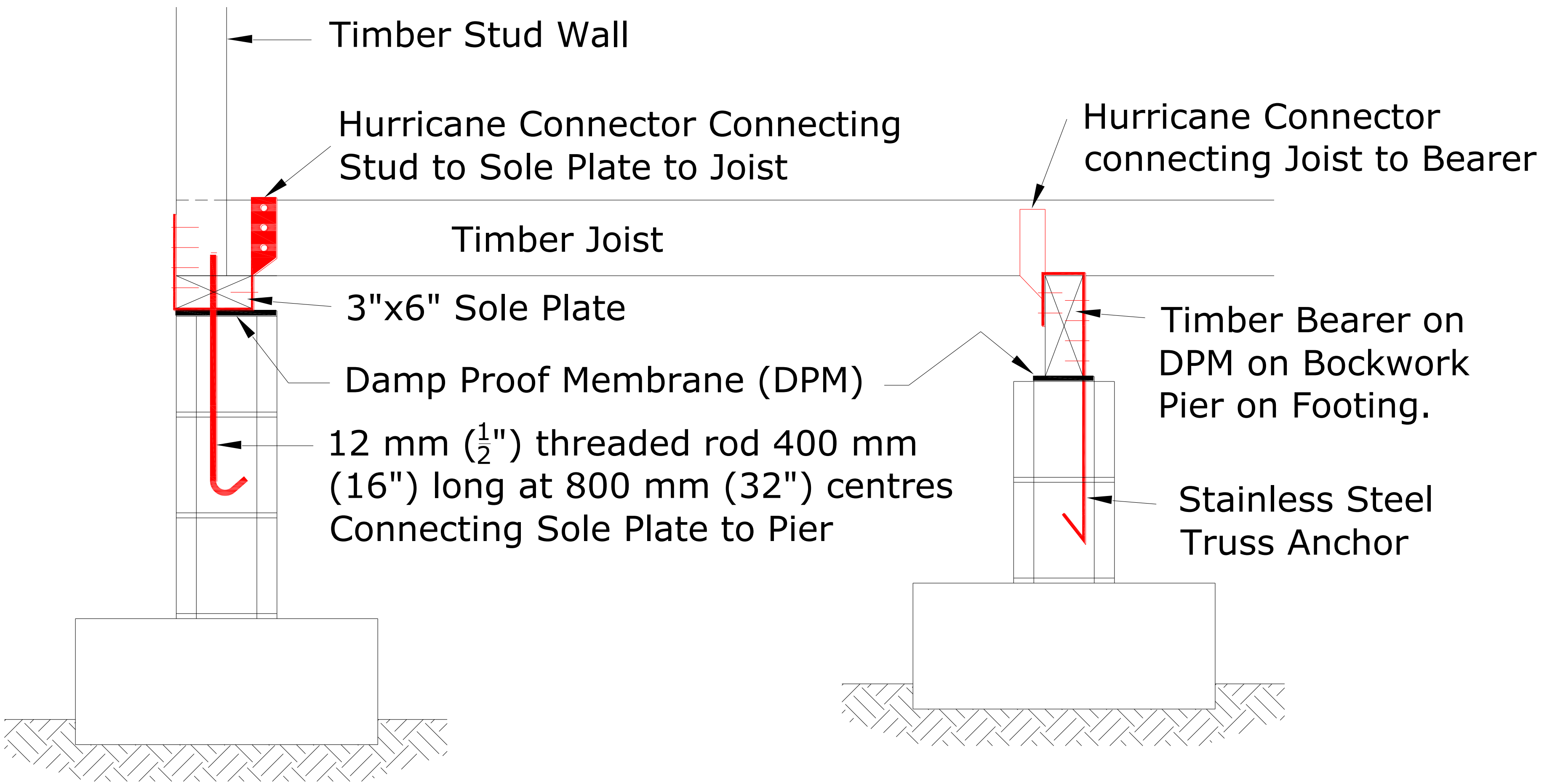
Span Range	**Joist Size at 400mm centres**	
	Pine	Greenheart
1.5-1.8 m (5-6ft)	50x150 mm (2”x6”)	50x150 mm (2”x6”)
1.8-2.4m (6-8ft)	50x200, 75x150 (2”x8”, 3”x6”)	50x150 mm (2”x6”)
2.4-3.3 (8-10ft)	50x250, 75x200 (2”x10”, 3”x8”)	50x200, 75x150 (2”x8”, 3”x6”)
3.3-3.6m (10-12’)	75x200 mm (3”x8”)	50x200 mm (2”x8”)
3.6-4.3m (12-14’)	75x250 mm (3”x10”)	50x250, 75x200 (2”x10”, 3”x8”)
4.3-4.8m (14-16’)	75x300 mm (3”x12”)	75x250 mm (3”x10”)



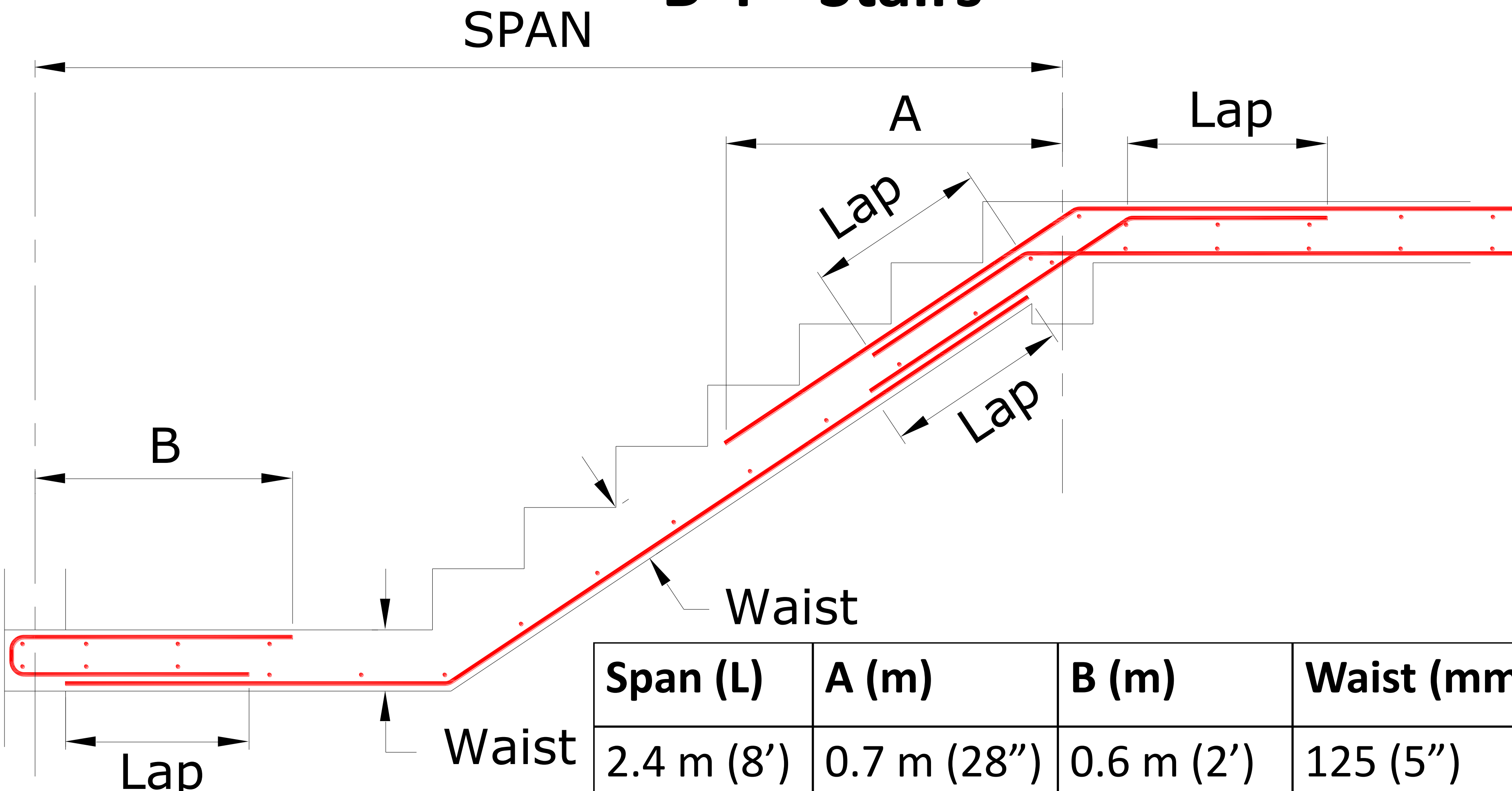
Joist Sizes at 600mm Spacing

Span Range	Joist Size at 600mm centres	
	Pine	Greenheart
1.5-1.8 m (5-6ft)	50x150 mm (2”x6”)	50x100 mm (2”x4”)
1.8-2.4m (6-8ft)	50x200, 75x150 mm (2”x8”, 3”x6”)	50x150 mm (2”x6”)
2.4-3.3 (8-10ft)	75x200 mm (3”x8”)	50x150 mm (2”x6”)
3.3-3.6m (10-12’)	75x250 mm (3”x10”)	50x200, 75x150 mm (2”x8”, 3”x6”)
3.6-4.3m (12-14’)	75x300 mm (3”x12”)	50x200, 75x200 mm (2”x8”, 3”x8”)
4.3-4.8m (14-16’)	100x300 mm (4”x12”)	50x250, 75x200 mm (2”x10”, 3”x8”)

Install Bearer to Break Span



B 4 Stairs



Span (L)	A (m)	B (m)	Waist (mm)
2.4 m (8’)	0.7 m (28”)	0.6 m (2’)	125 (5”)
3 m (10’)	0.9 m (3’)	0.6 m (2’)	150 (6”)
3.6 (12’)	1.1 (3’-6”)	0.6 m (2’)	175 (7”)
4.2 (14’)	1.3 (4’-3”)	0.65 (26”)	200 (8”)

Stairs are designed similar to slabs.

Stair Depths and Reinforcement

Stair Waist Thickness mm (inch)	Span between supporting walls or beams.					
	1.8 m (6 ft)	2.4 m (8 ft)	3 m (10 ft)	3.6 m (12 ft)	4.3 m (14 ft)	4.8 m (16 ft)
100 (4”)	T12@300					
125 (5”)	T12@300	T12@300				
150 (6”)		T12@300	T12@300			
175 (7”)			T12@300	T12@300		
200 (8”)				T12@300	T12@250	T12@200
225 (9”)					T12@280	T12@225

Secondary rebars = T10@300 mm

Note: 300mm = 12”, 280mm = 11”, 250mm = 10”

Note: Use the thicker stair thickness for higher than normal loads.

Home

B 5 Walls
(Including Beams & Wall Stiffeners)

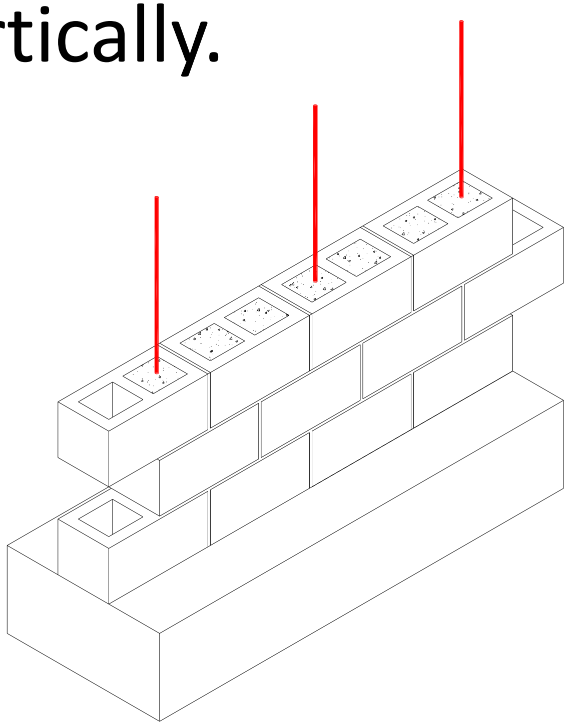
Two types of walls will be reviewed in this section:

5.1 Concrete block walls.

5.2 Timber walls.

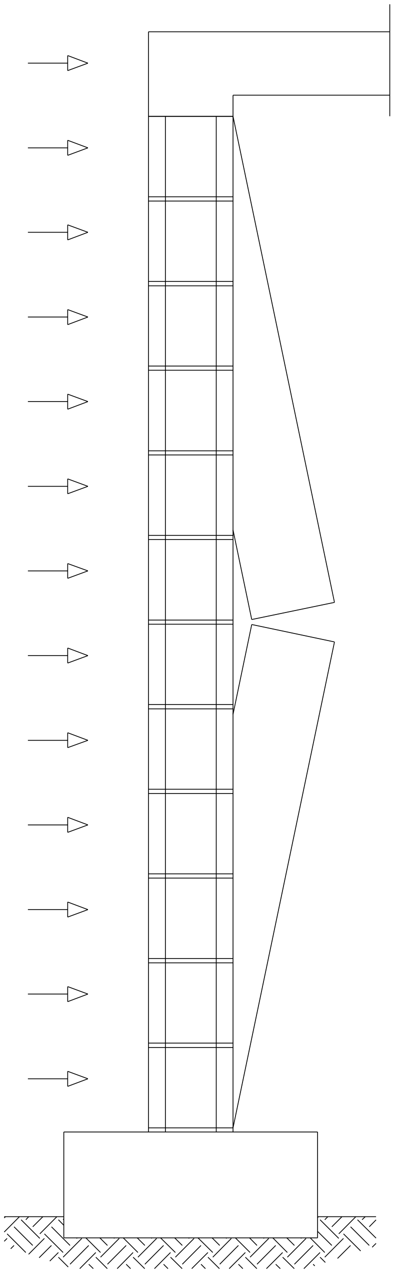
B 5.1 Concrete Block Walls

- Walls can fail in both horizontal and vertical planes.
- Therefore, walls must be reinforced both horizontally and vertically.



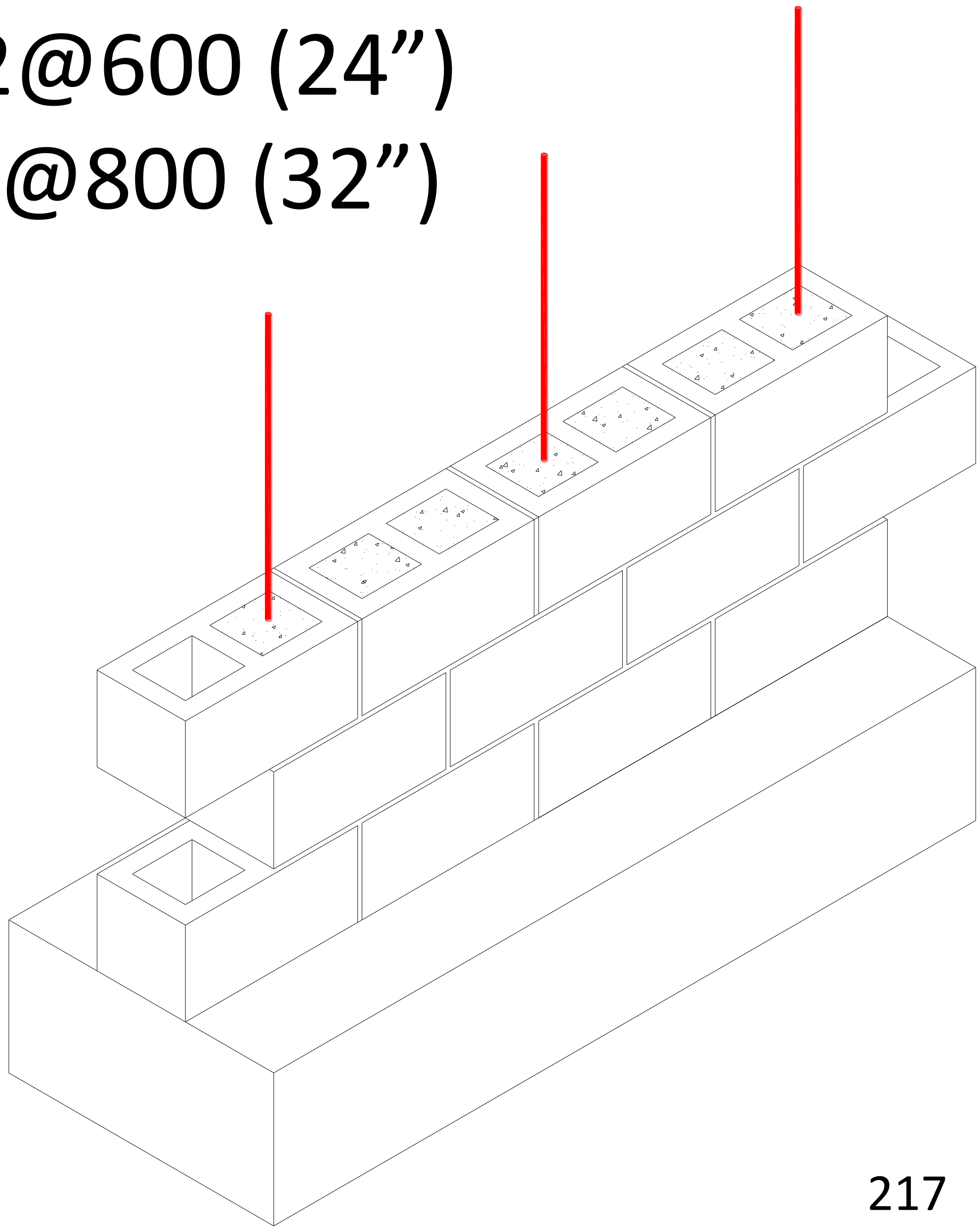
Vertical Plane Failure

Vertical reinforcement can help to strengthen the wall.

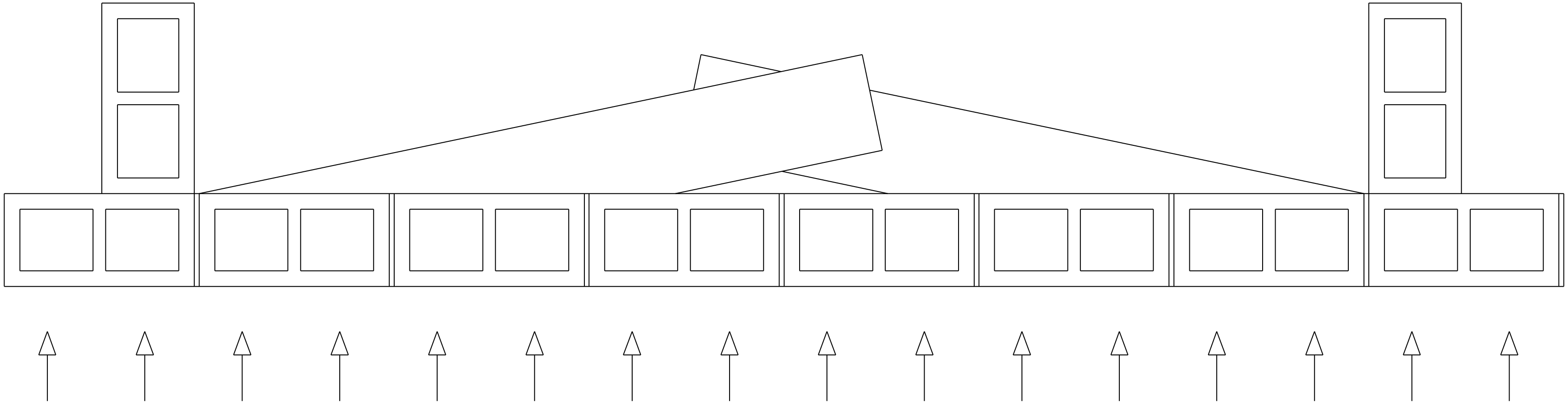


Vertical Reinforcement

- External Walls: T12@600 (24”)
- Internal Walls: T12@800 (32”)



Horizontal Plane Failure

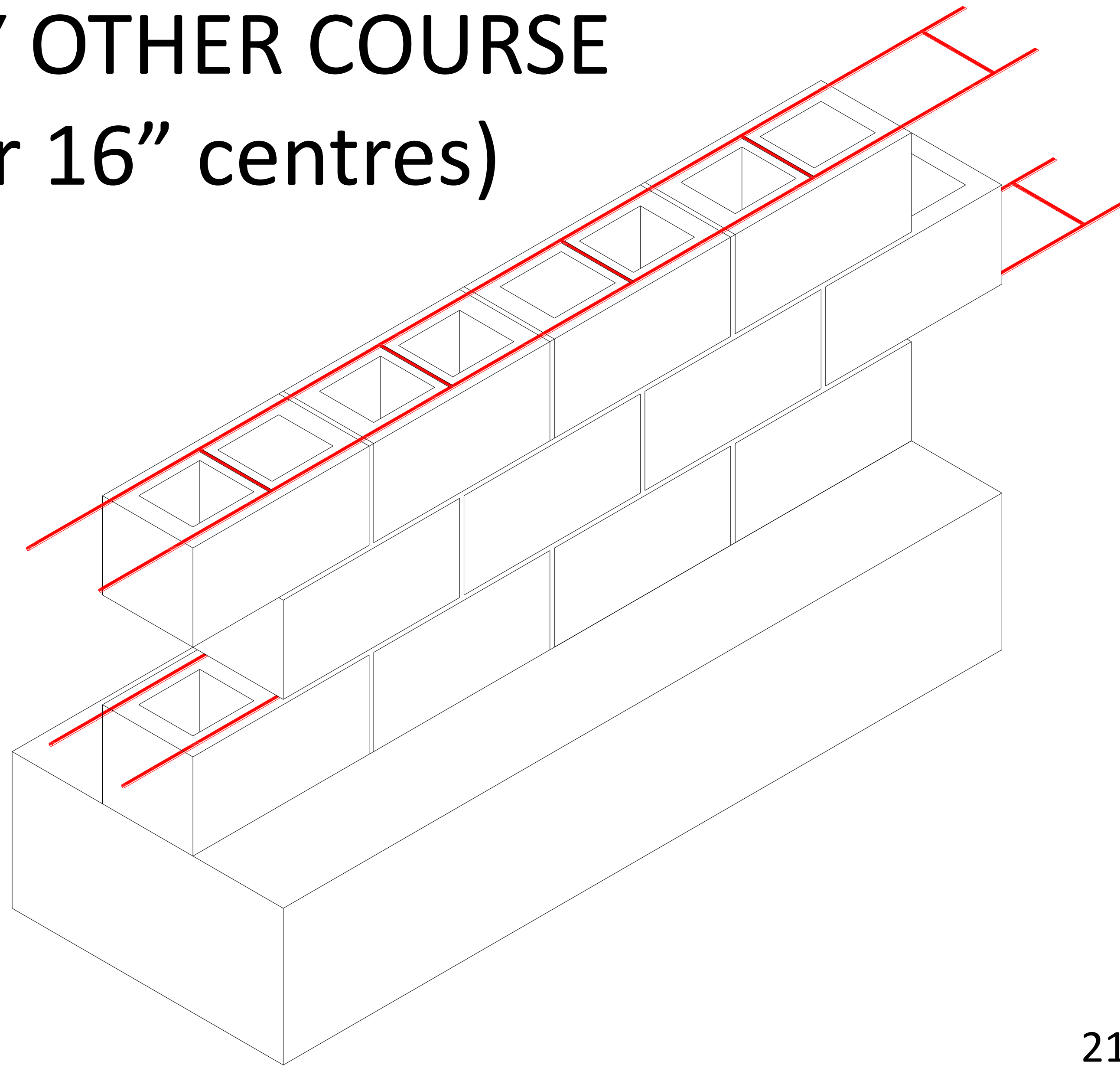


Horizontal reinforcement (Brickforce or equivalent) can help to strengthen the wall.

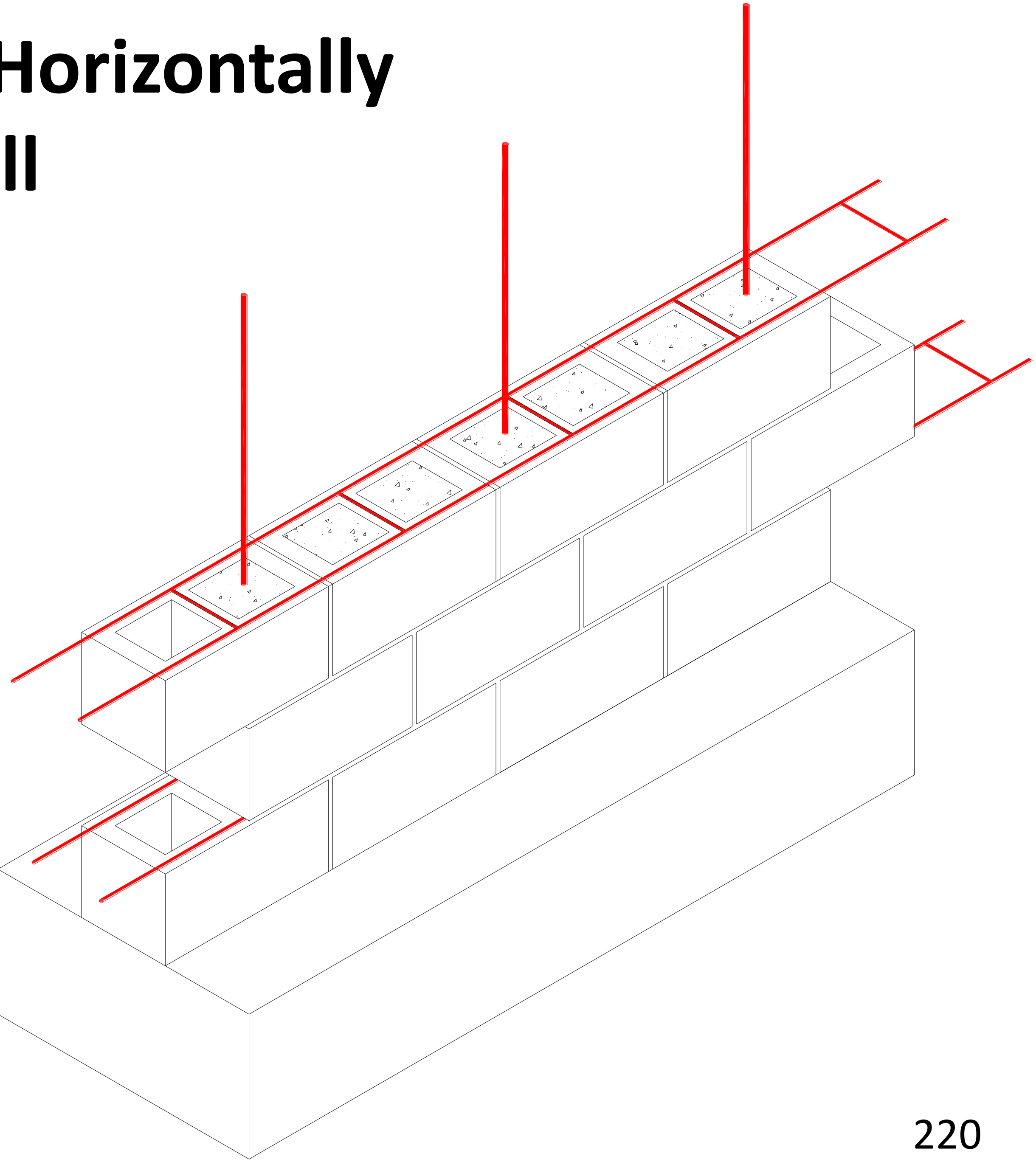
Horizontal Reinforcement – Galvanized

USE EVERY OTHER COURSE

(400mm or 16” centres)



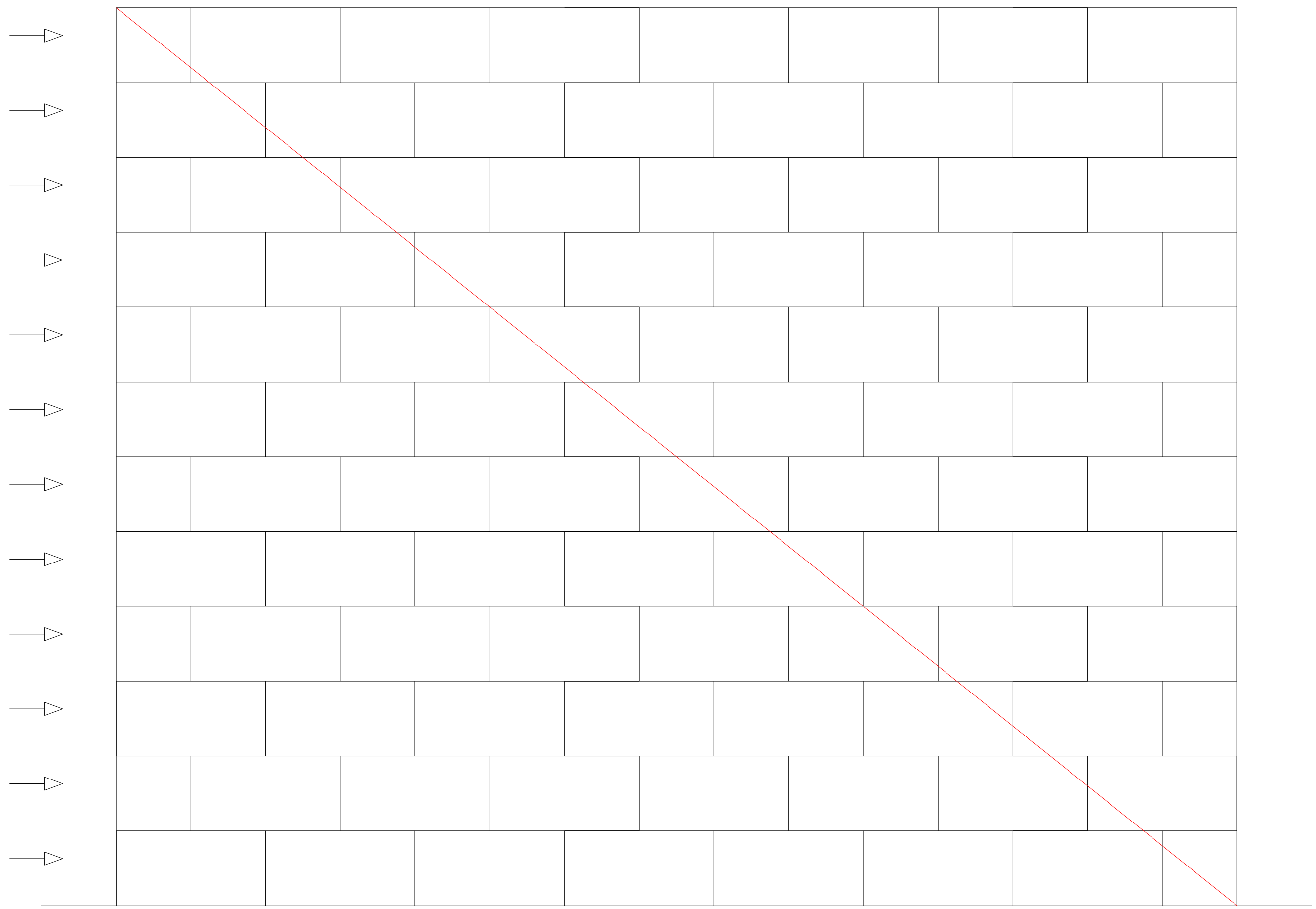
Vertically and Horizontally Reinforced Wall



Shear Failure

Home

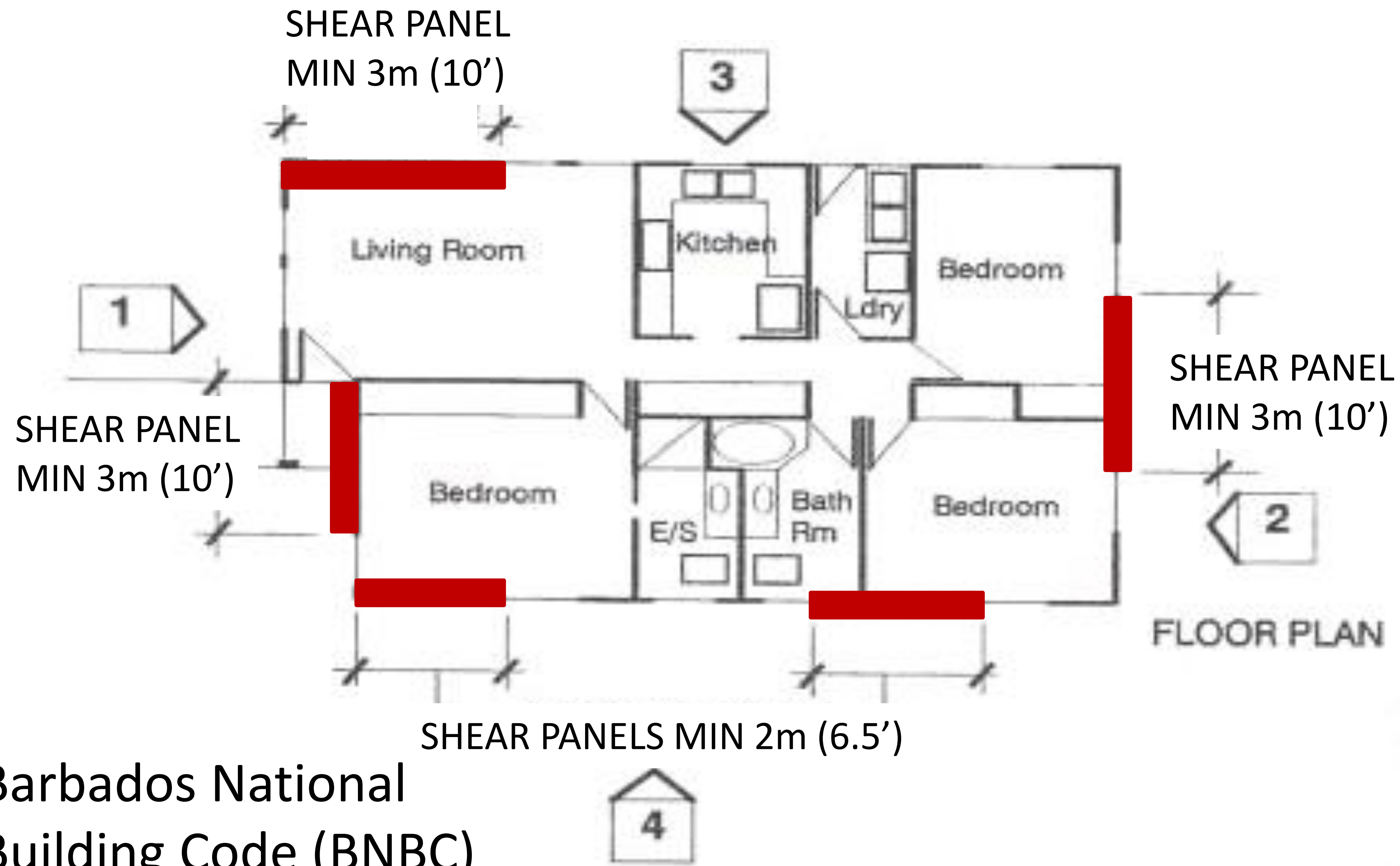
Shear walls can strengthen the building.



Out of plane wall shear crack.

Damaged Wall.

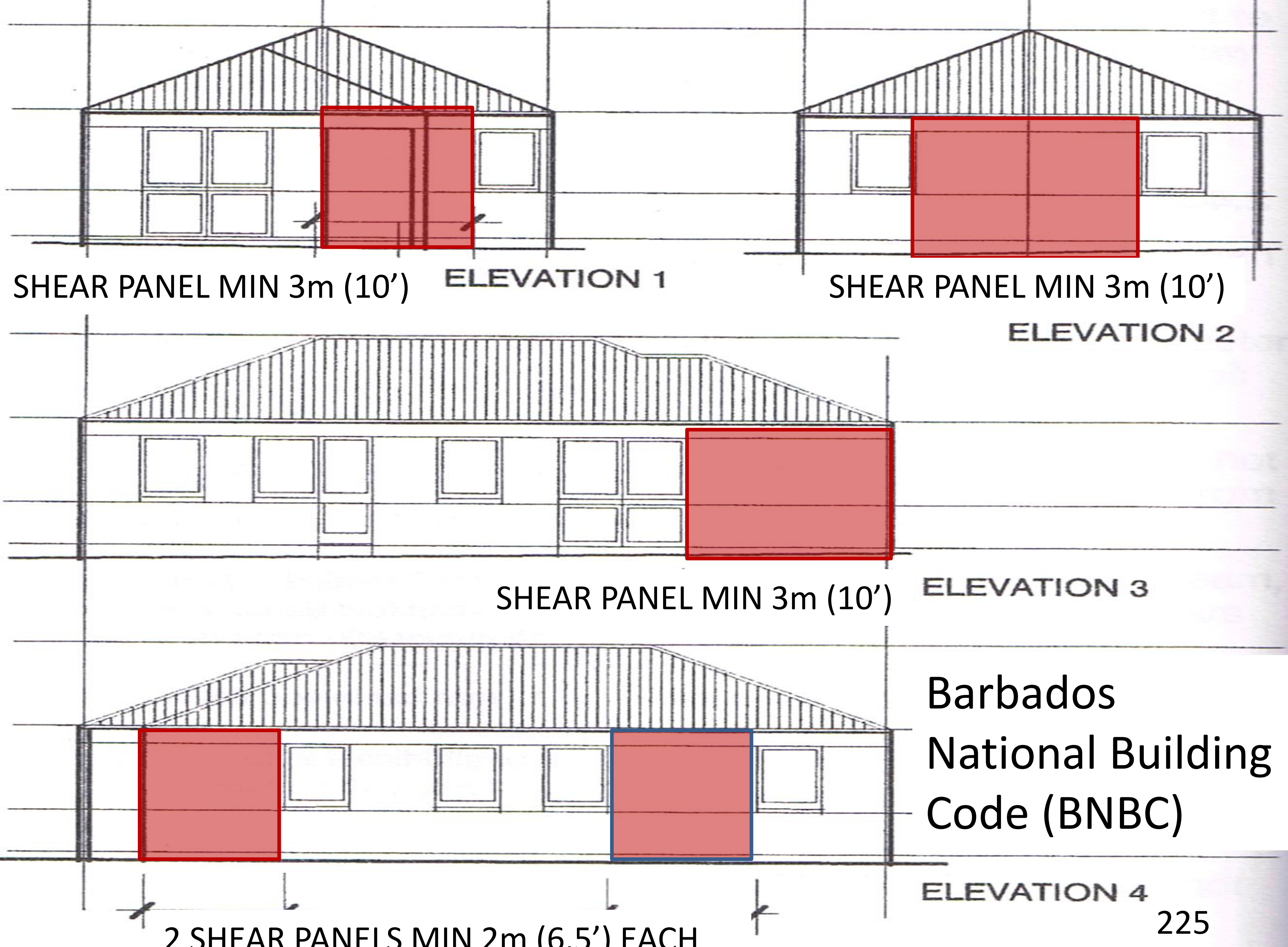
Critical Rebar Missing



Barbados National
Building Code (BNBC)

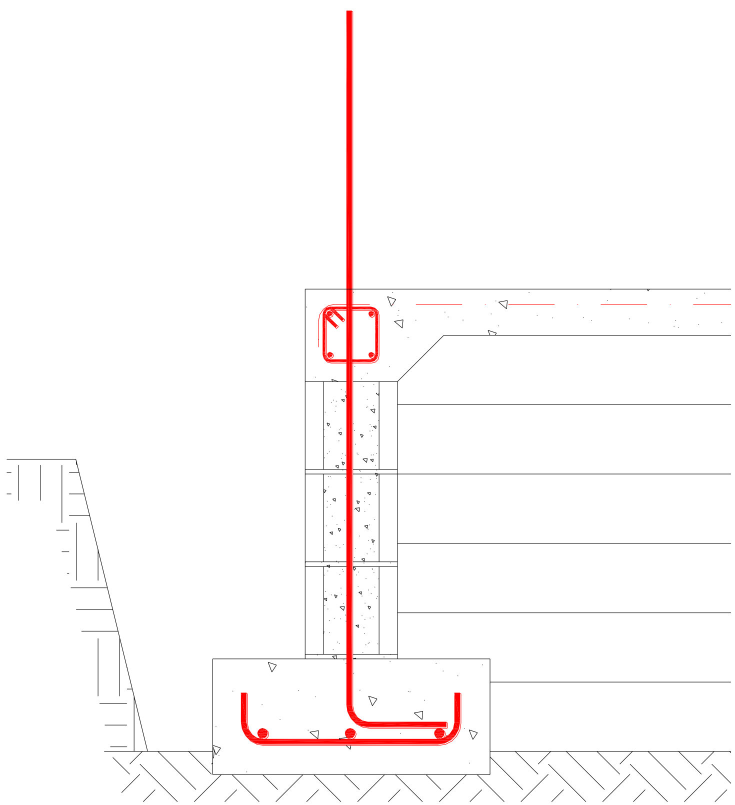
Figure 2.405A
EXAMPLE PLAN - SINGLE STOREY DWELLING

Barbados National Building Code (BNBC)

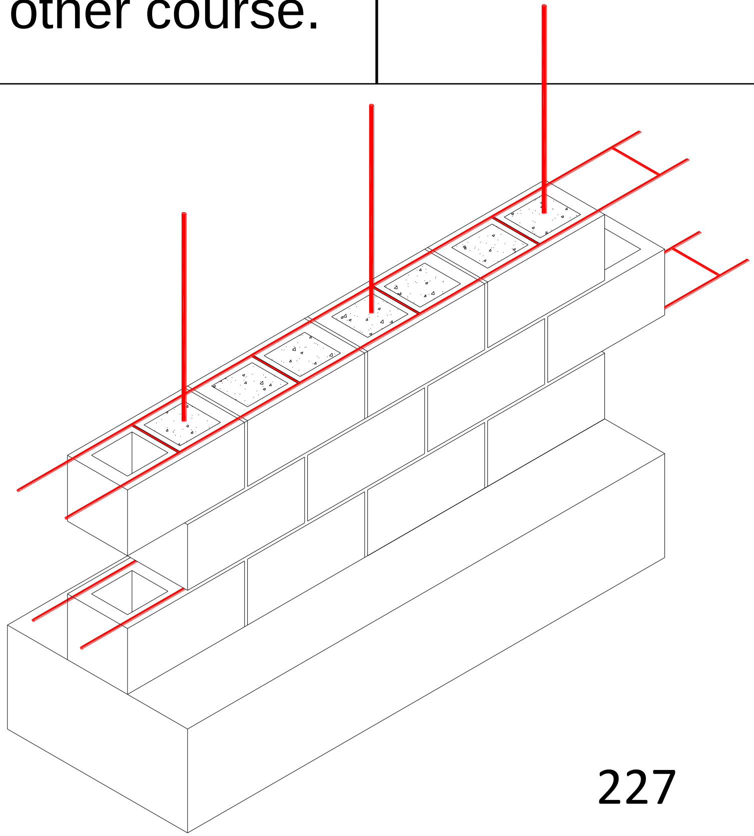


B 5.1 Concrete Block Walls

No.	Construction Methods	Comment
1	After the reinforced concrete floor slab has been constructed, the wall starter bars should be extended at least 600mm (2 ft) above the slab level.	To connect the wall to the floor.

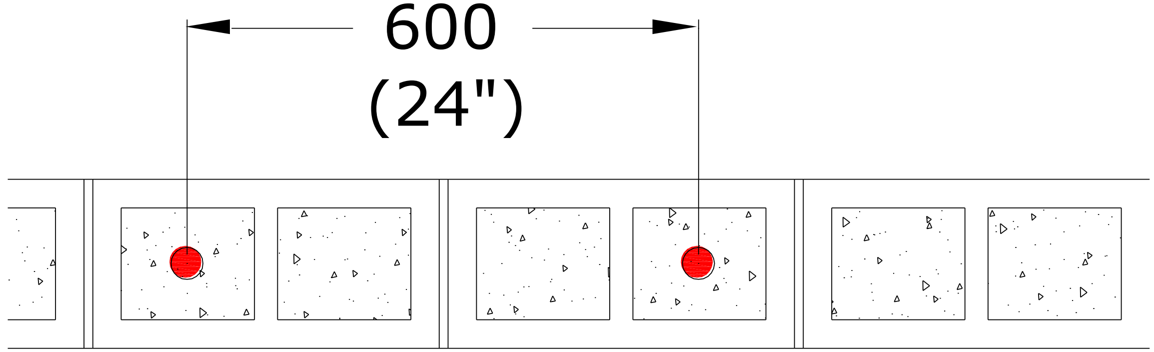


No.	Construction Methods	Comment Home
2	Construct reinforced masonry walls as follows. 1. Reinforce external walls with 12mm diameter rebars at 600mm (24”) centres. Fill only those cores containing rebars 3 courses at a time. 2. Internal walls can be reinforced with 12mm diameter bars at 800mm (32”) centres. 3. Install horizontal reinforcement every other course.	To strengthen the walls.

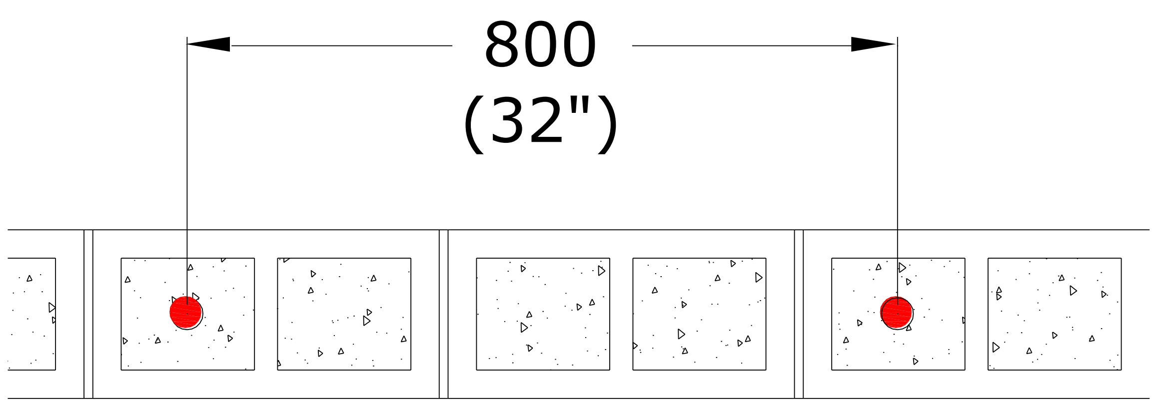


Walls Below Ground

External Walls



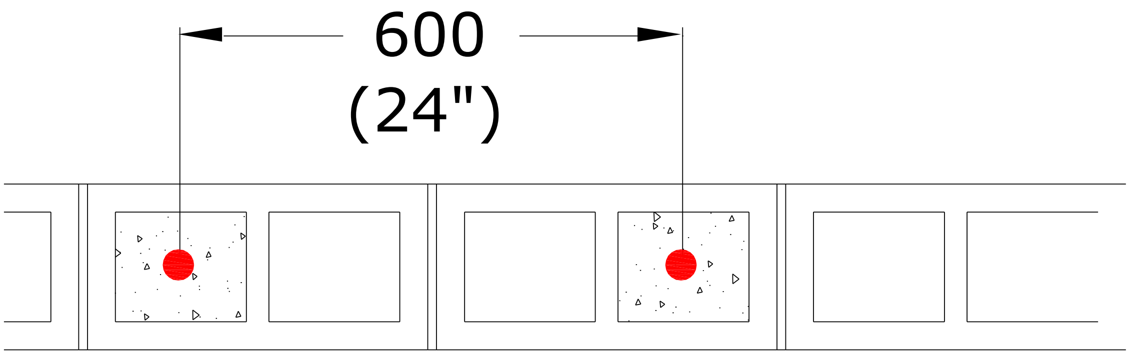
Internal Walls



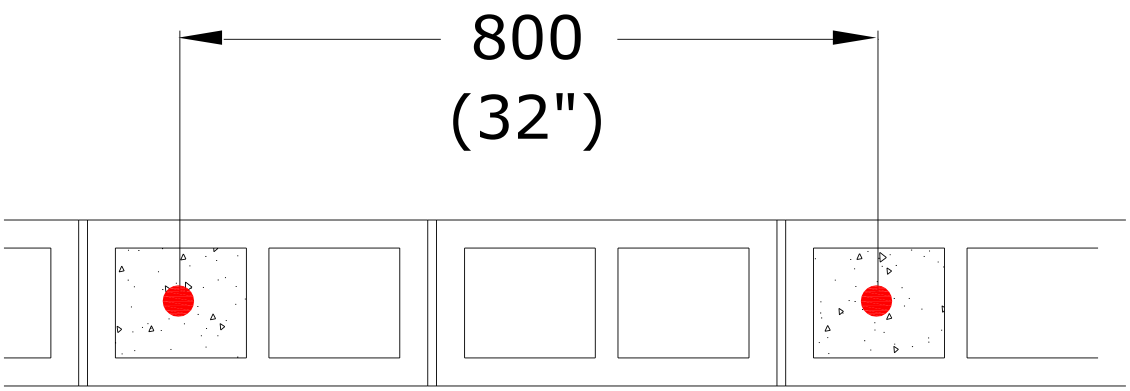
Fill all cores with 1:3:6 grout every 3 courses.

Walls Above Ground

External Walls



Internal Walls

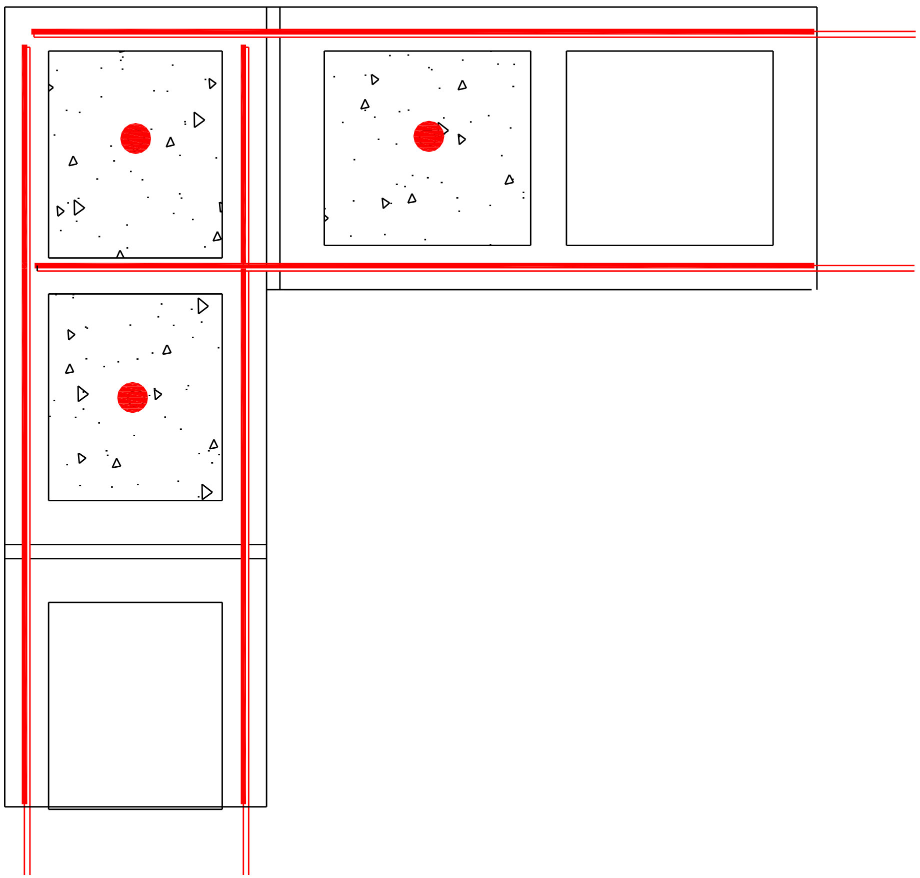


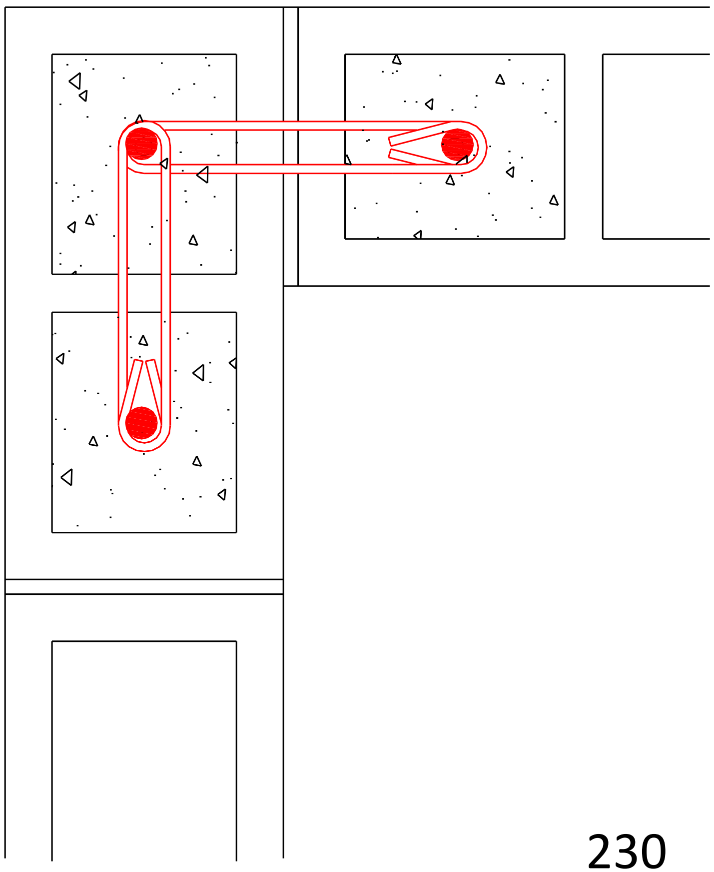
Fill reinforced cores with 1:3:6 grout every 3 courses.

Corner Reinforcement

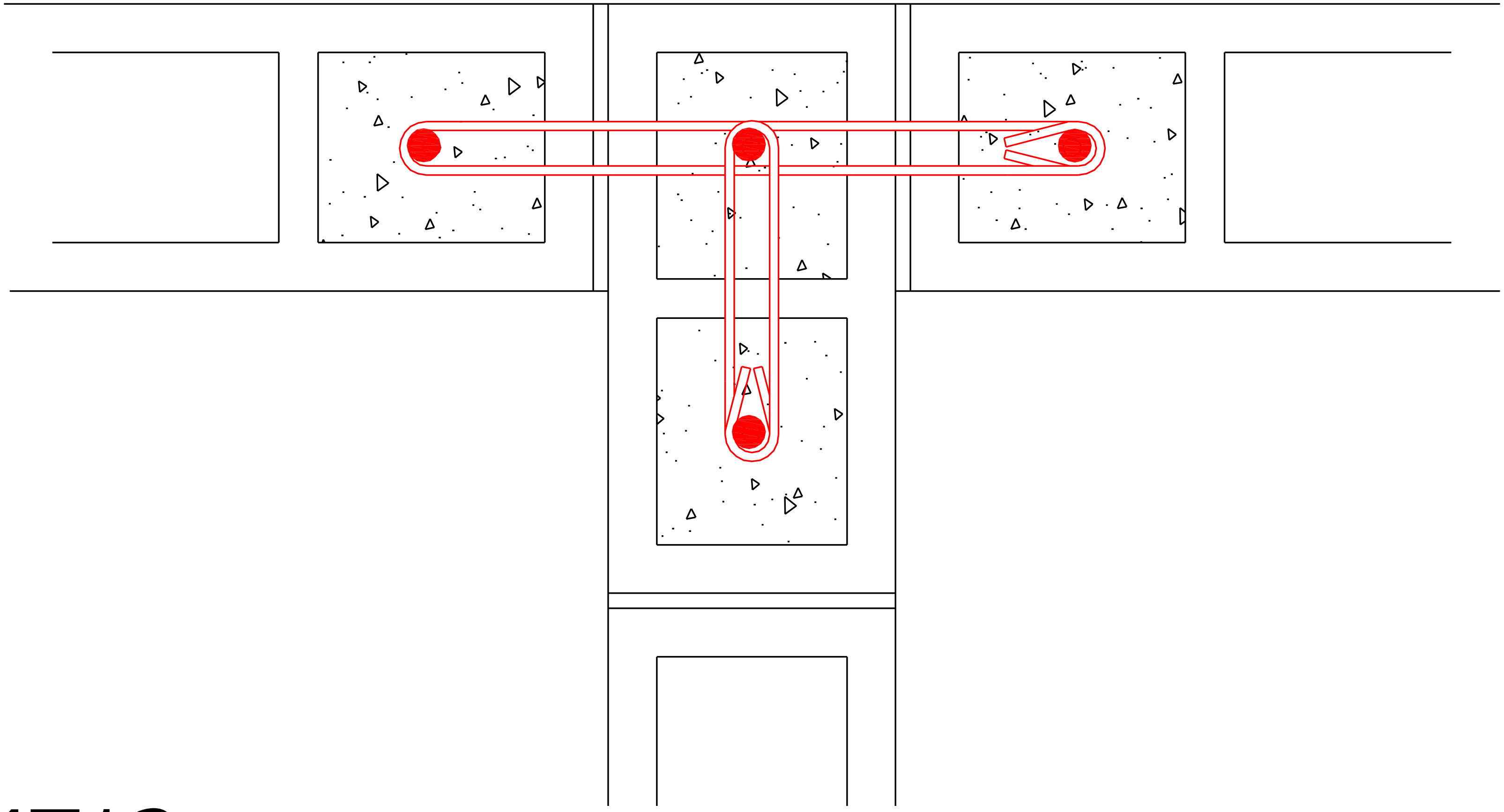
3T12 with R6@400 mm (16”) ties

Brickforce@400 mm (16”) - not in same course as R6 ties





T Junction

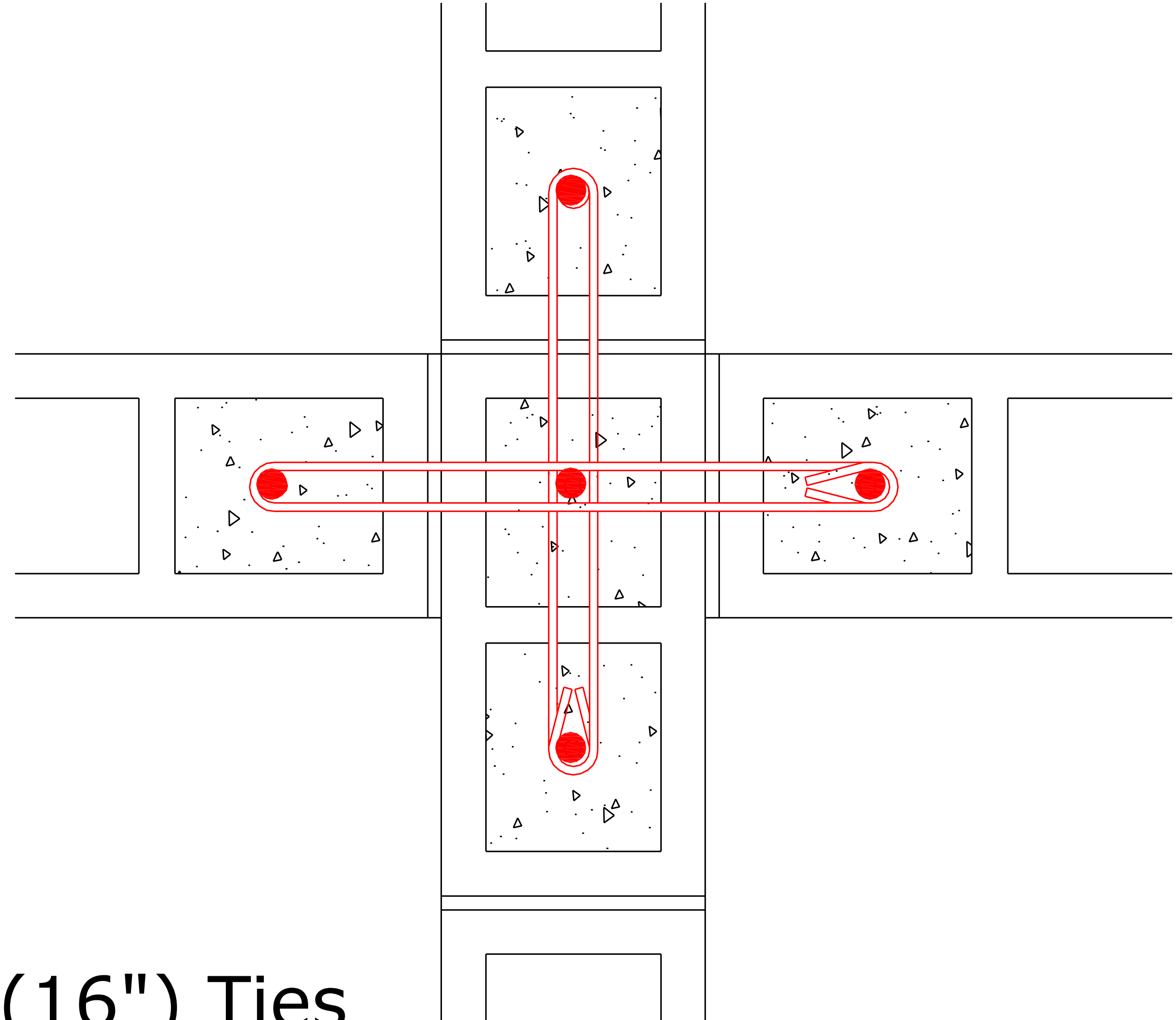


4T12

R6@400 (16") Ties

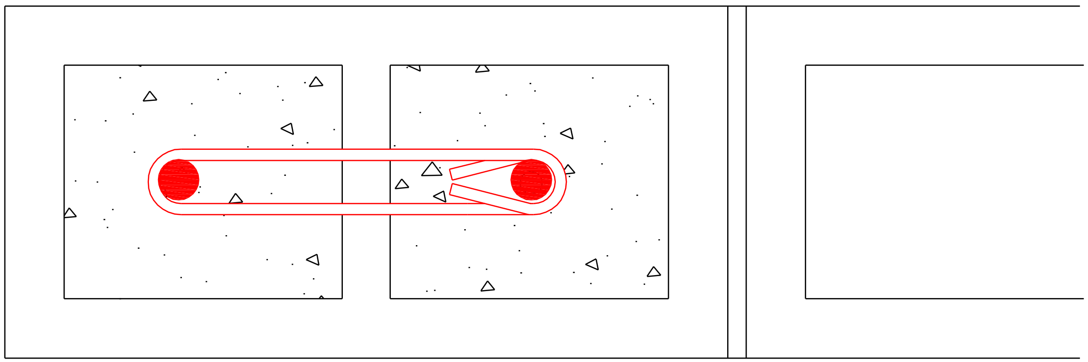
BRC Brickforce@400 (16")

X Junction



5T12
R6@400 (16") Ties
BRC Brickforce@400 (16")

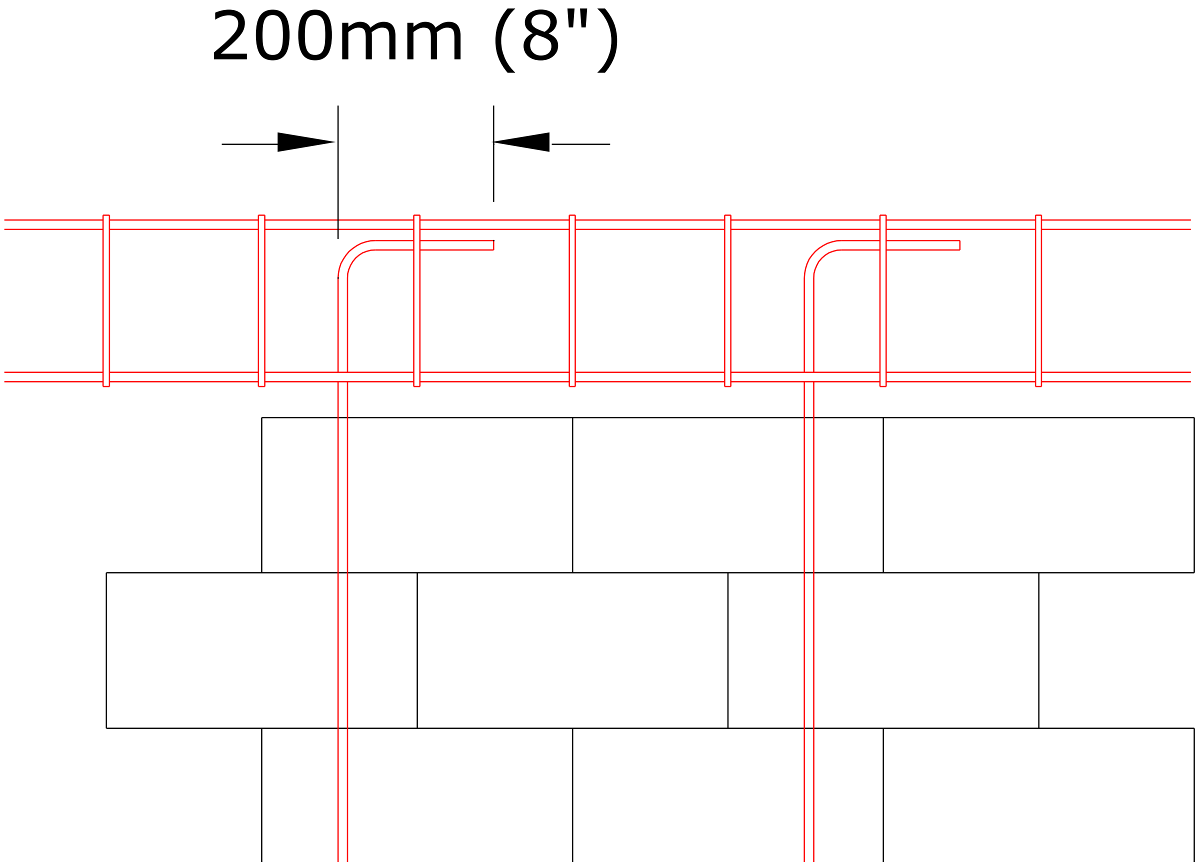
Wall End (including windows & doors)

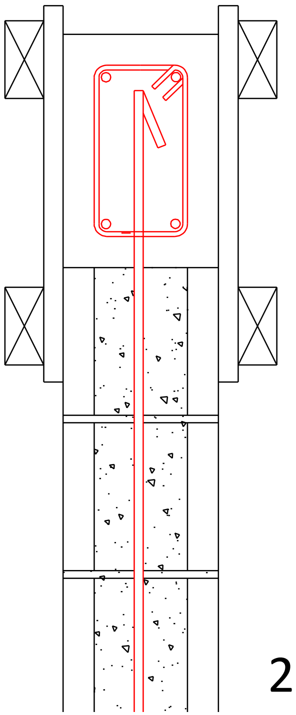


2T12
R6@400 (16") Ties
BRC Brickforce@400 (16")

No.	Construction Methods	Comment
3	Erect formwork to fit the 200 mm x 300 mm ring beam on the wall (not suspended).	To prevent deformation and leakage.
4	Install reinforcement (4xT12mm diameter bars + R6 mm (1/4”) diameter links at 200 mm (8”) centres.)	To tie the wall together.

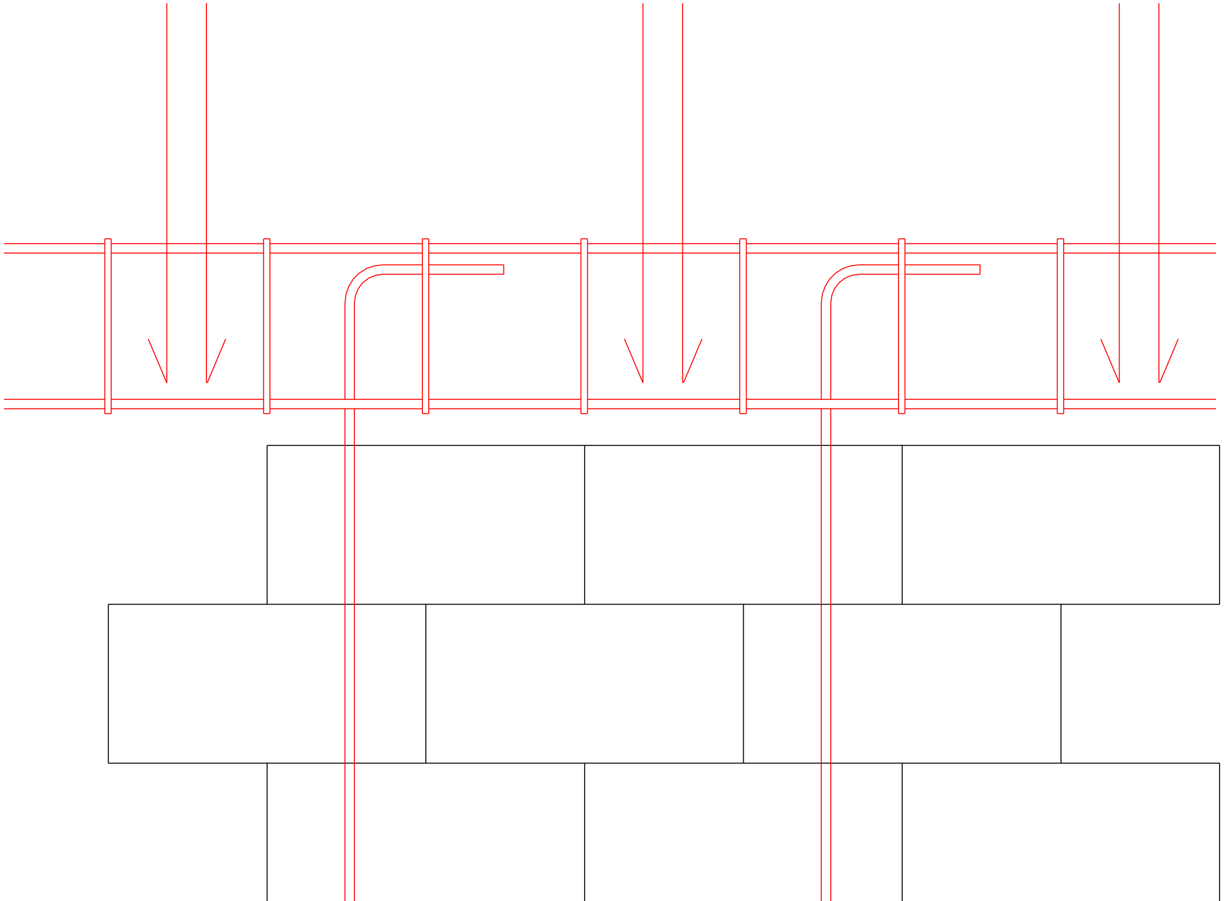
Home

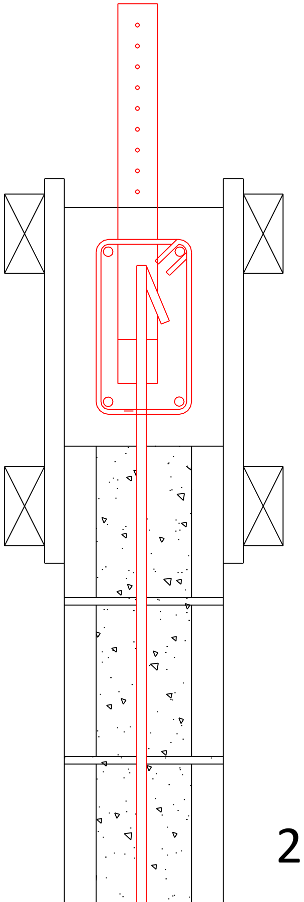




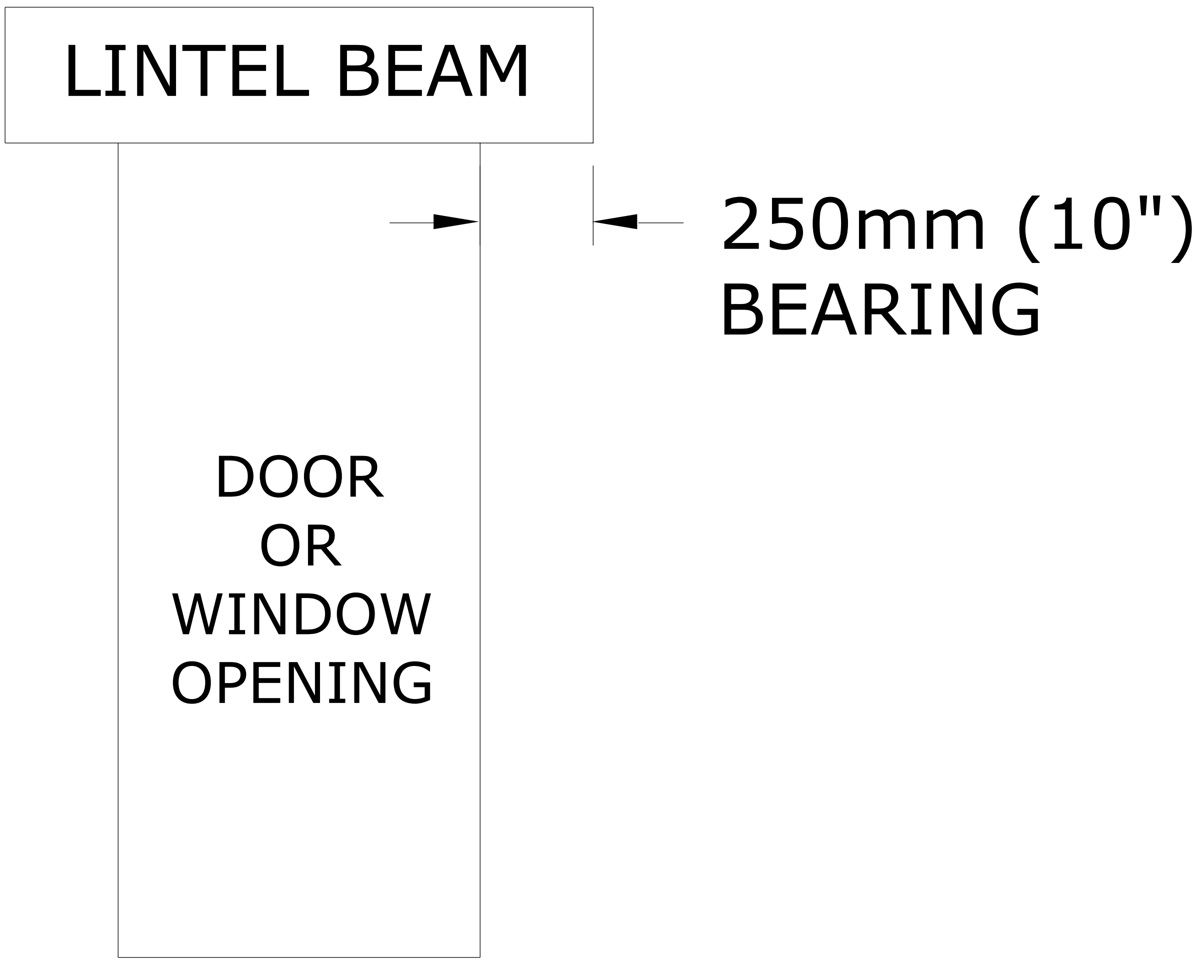
No.	Construction Methods	Comment
5	Insert stainless steel hurricane rafter straps at the rafter spacing.	To connect the rafter to the wall.
6	Pour, compact, trowel finish, and cure concrete (3600 psi at 28 days)	For durability and structural safety.
7	Strip formwork after 7 days minimum.	To use again.

Home





5.1.2 Lintel beams are used over door and window openings



Dislodged lintel beam.

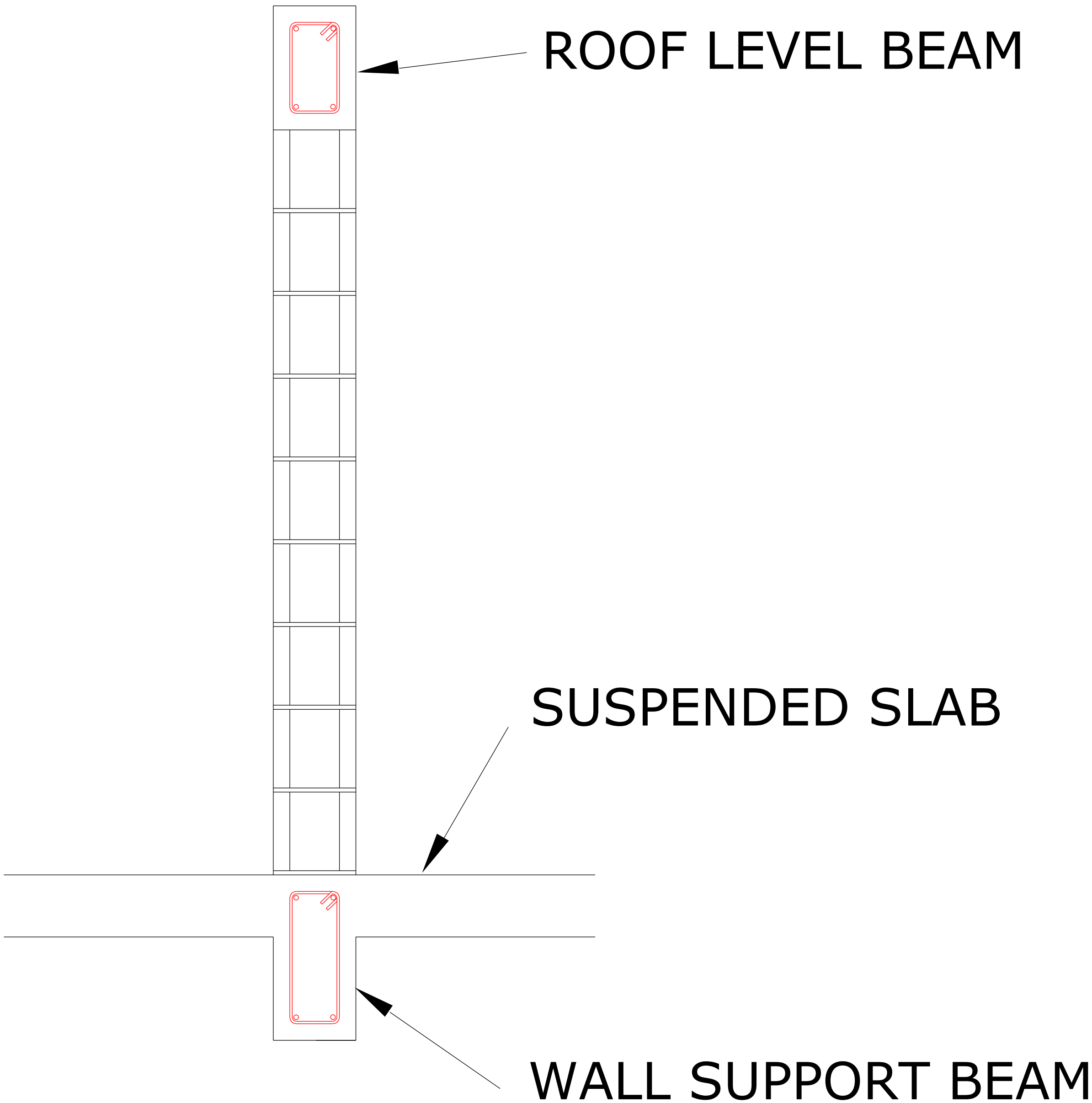
Lintel Beam Sizes and Reinforcement

Span of Lintel m (ft)	**Beam size (width x depth)**	**Main Rebar Number x Size**	**Links Dia @ mm centres**
Up to 1.0 m (0 to 3')	150x200 mm (6"x8")	4xT12	T6@150 mm
1.0 to 1.8 m (3' to 6')	(200x200 mm (8"x8")	4xT12	T6@150 mm
1.8 to 2.4 m (6' to 8')	200x300 mm (8"x12")	2xT12 (top) 2xT16 (bottom)	T8@150 mm

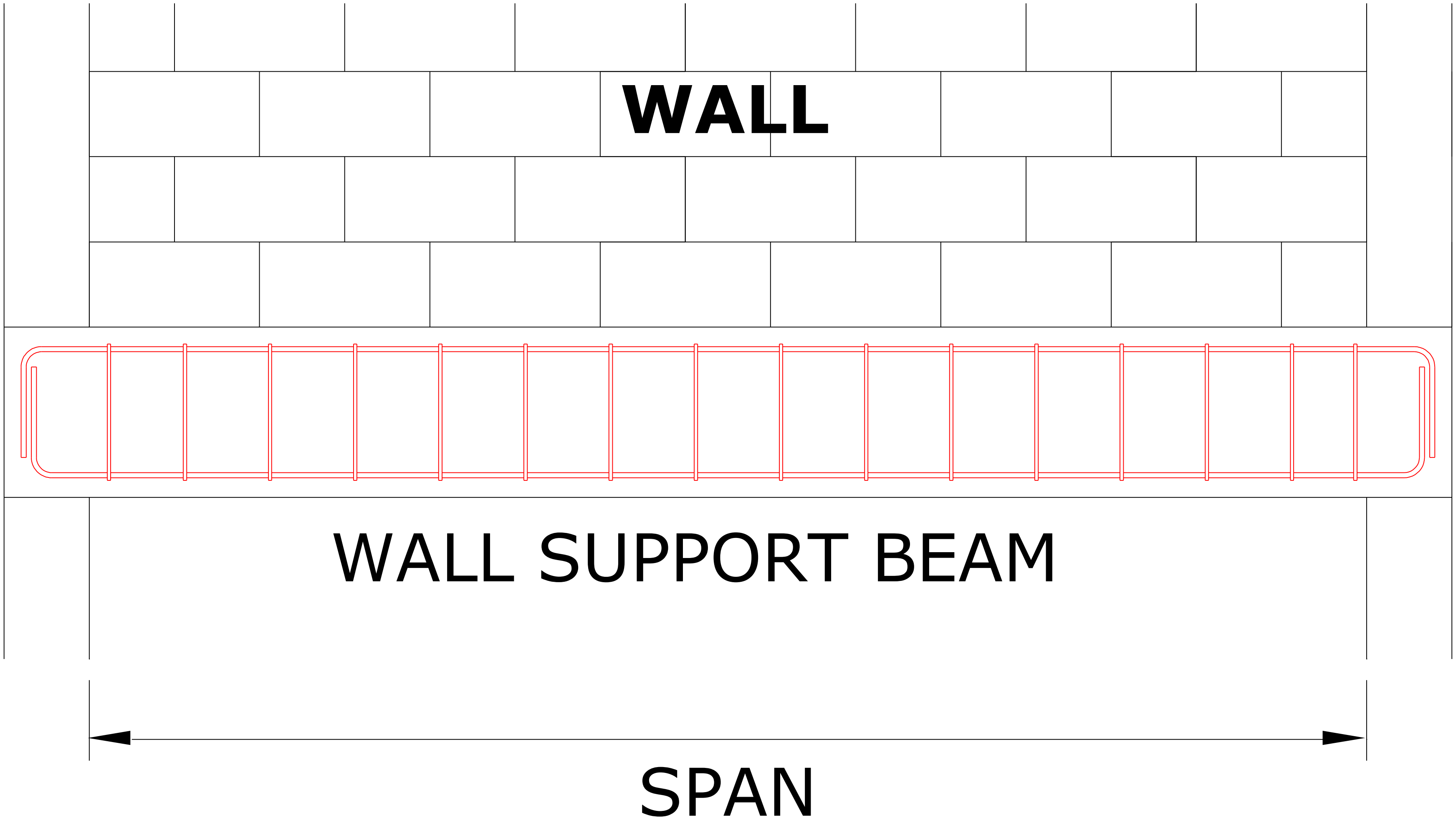
Note 1: Lintel seat = 250 mm (10") minimum

Note 2: Not to be used for supporting floor loads.

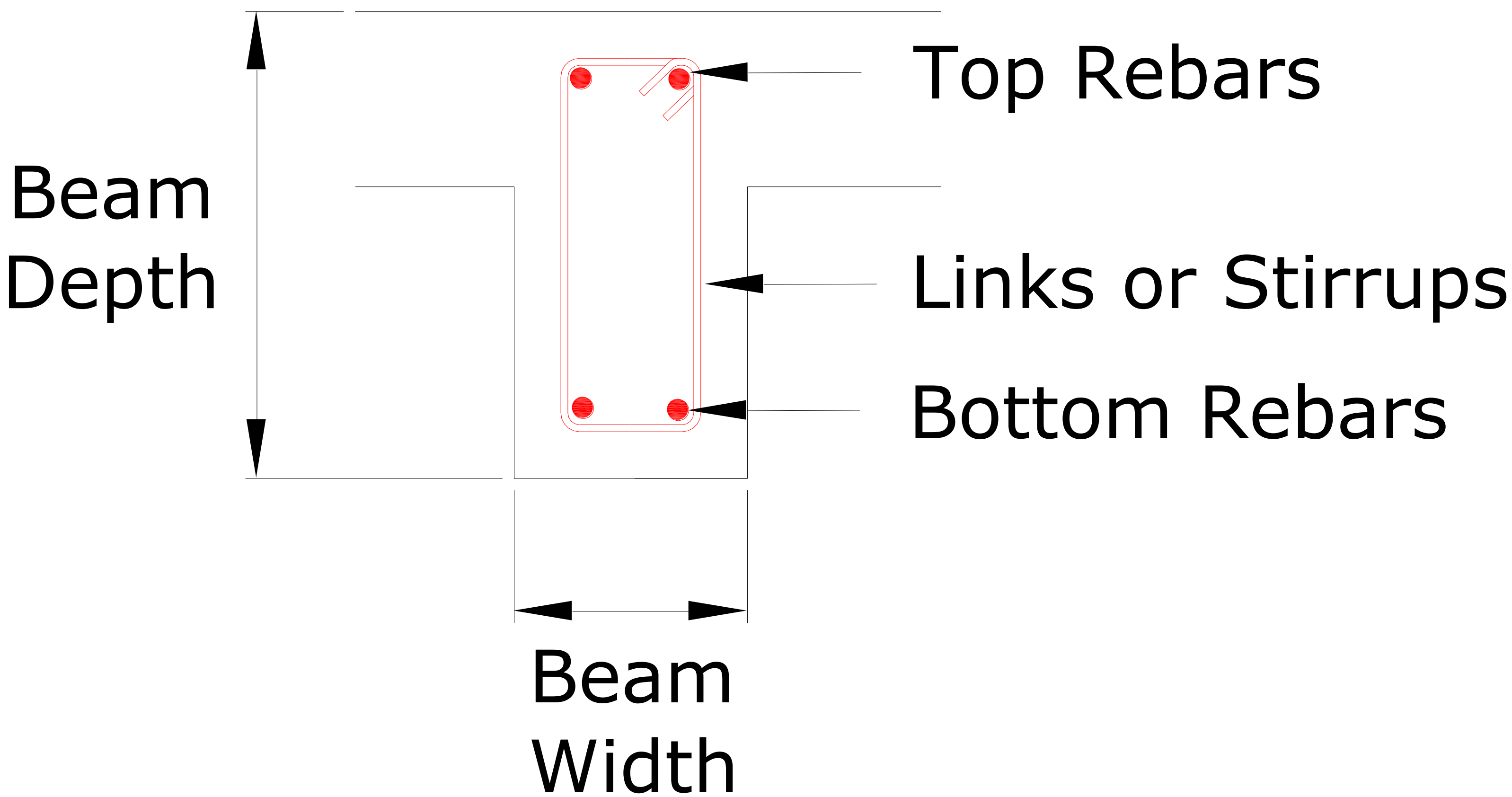
5.1.3 Wall Support Beam



Wall Support Beam



Beam Reinforcing Bars (Rebars)



Suspended Beam Sizes and Reinforcement (200 mm (8” wide) beams supporting walls)

Maximum Span (m)	Minimum Depth (mm)	Top Rebars	Bottom Rebars	Links @ Spacing (mm)
2.4 m (8’)	325 mm (13”)	2T12	2T16	T6@150 (6”)
3.0 m (10’)	350 mm (14”)	2T12	2T16	T6@150 (6”)
3.6 m (12’)	375 mm (15”)	2T16	2T20	T8@200 (8”)
4.3 m (14’)	400 mm (16”)	2T20	2T25	T8@200 (8”)

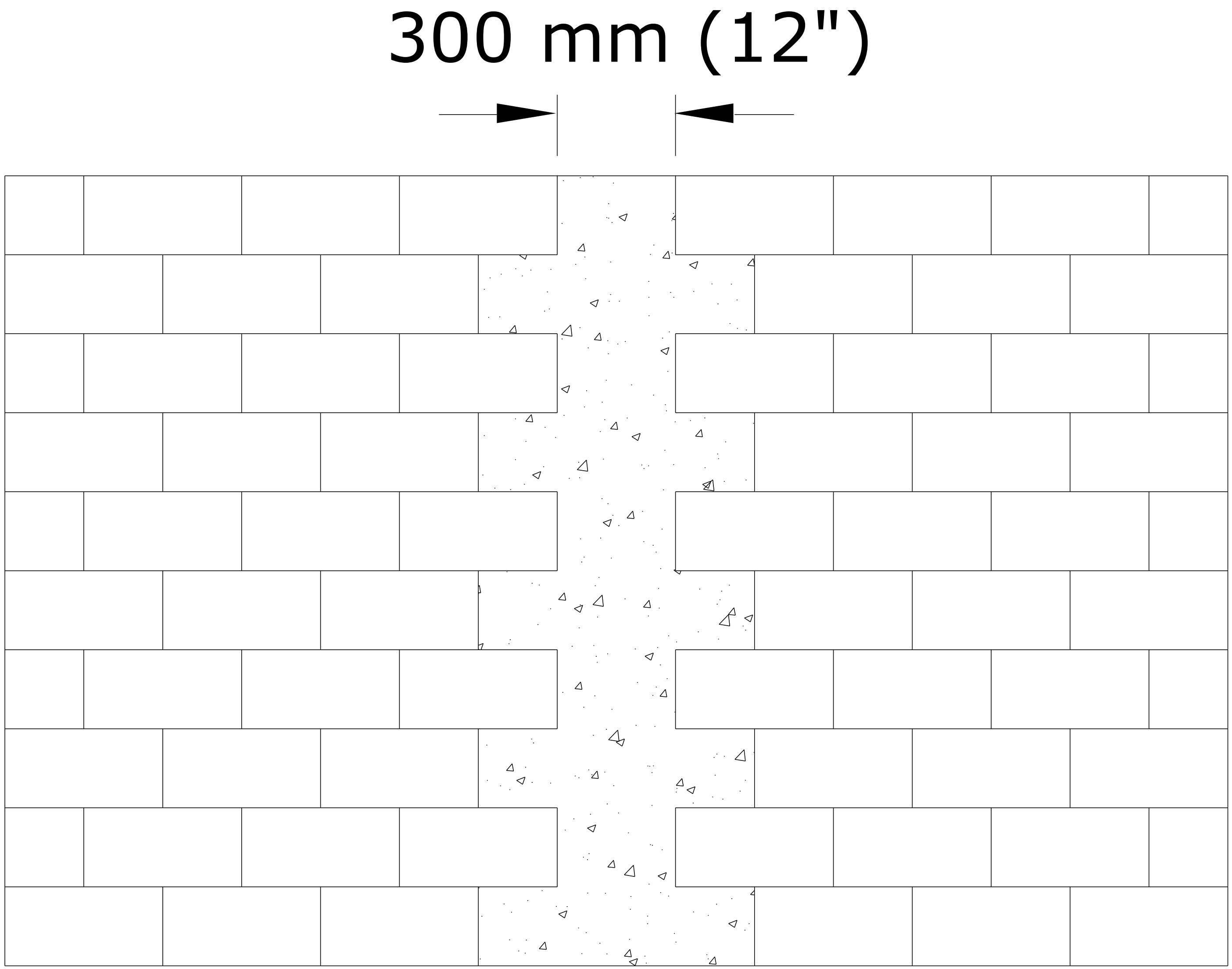
5.1.4 Embedded Pipes

1. Plan properly with electricians, plumbers, telephone, and security personnel.
2. Place pipes in block cavities during construction and cap them.
3. No horizontal or diagonal chases for pipes or conduits should be permitted.
4. If a vertical chase is needed to install a pipe in an open core, then the core shall be grouted solid after the pipe has been installed.

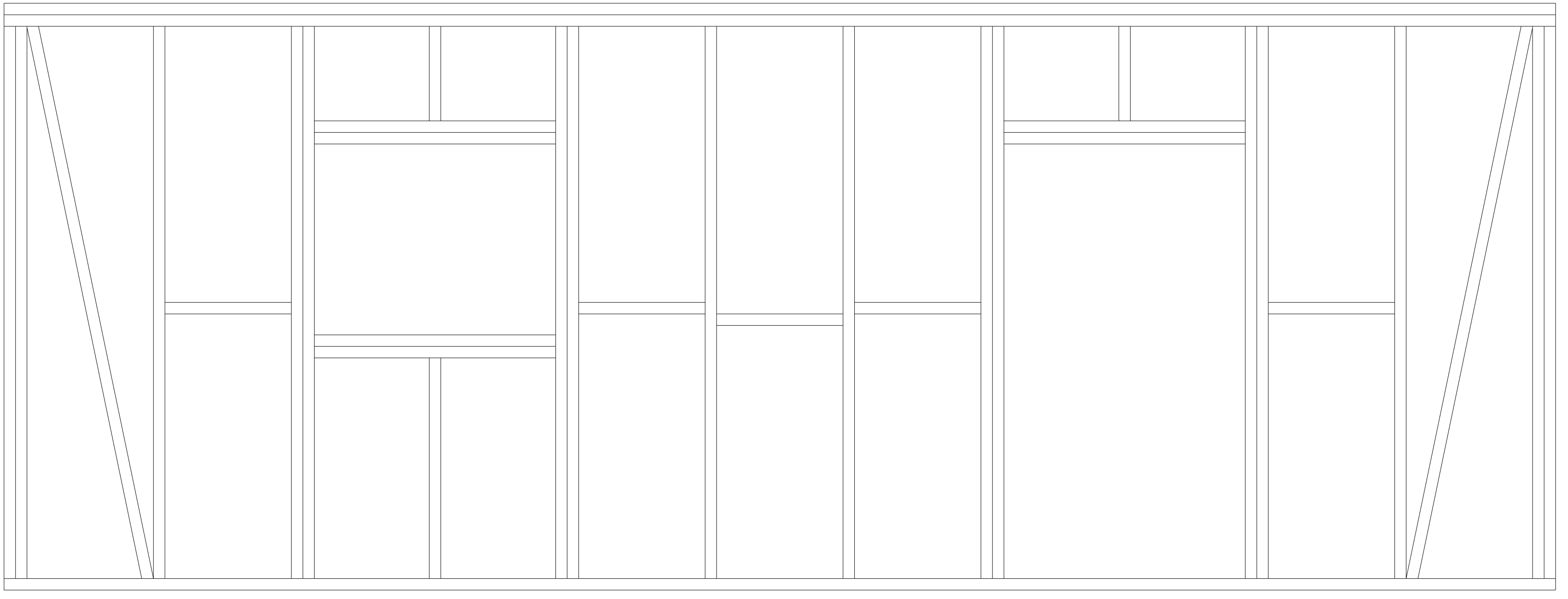
5.1.5 Concrete Stiffeners

1. Concrete stiffeners are required every 7.6m (25 ft) of unbraced wall.
2. If the unbraced length is long, then install multiple stiffeners at 6m (20 ft) maximum spacing.
3. Use 4 T12 anchored to the foundation and perimeter beam. Links: T6@300mm (12") centres.
4. Stiffeners must be at least 300mm (1 ft) wide x the wall thickness.

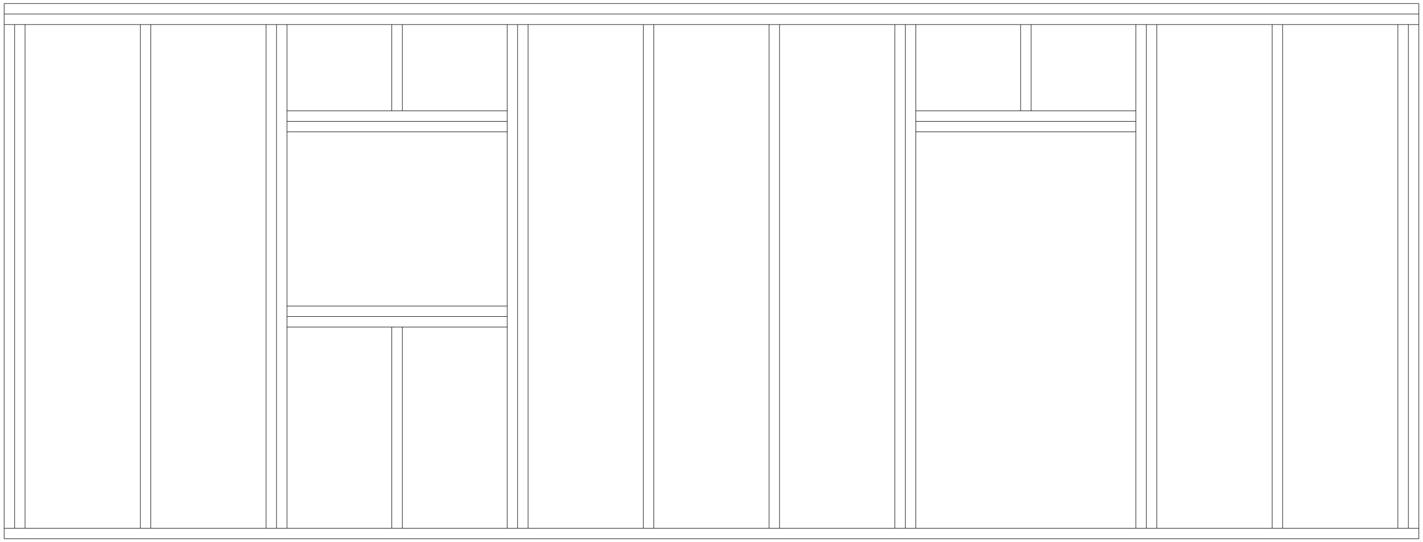
Tie concrete stiffener to wall.



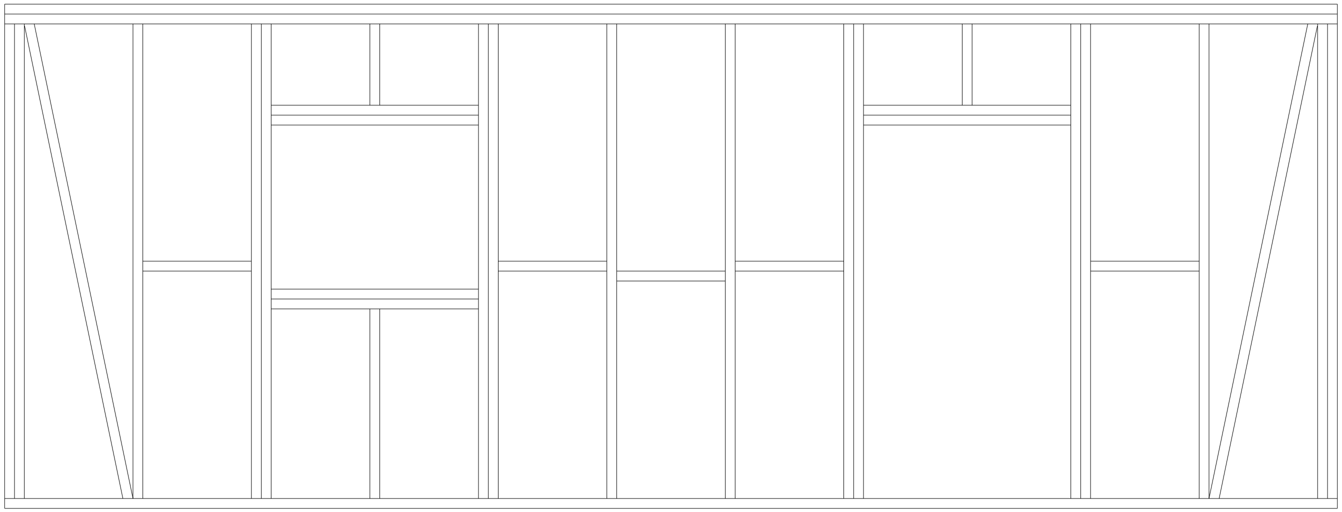
B 5.2 Timber Walls

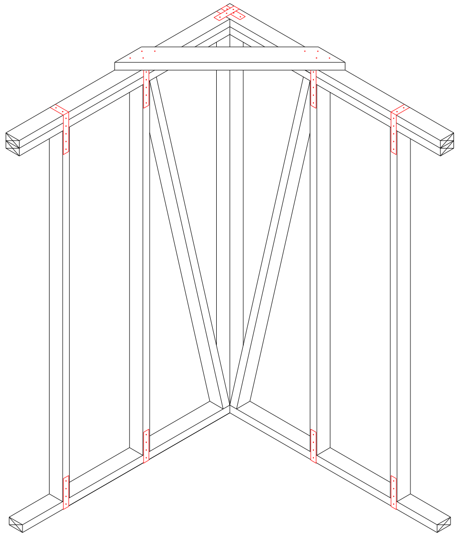


No.	Construction Method	Comment
1	The reinforced concrete floor slab should have been constructed, or the timber sole (bottom) plate or timber beam should have been placed.	To support the walls.
2	Erect 2.4 m (8’) high 50x100mm (2”x4”) timber studs. Pine studs at 450mm (18”) centres. Greenheart studs at 600mm (24”) centres.	To support the wall sheathing and roof loads.
3	Install additional studs. Double studs are required at corners, and the sides of windows and doors.	To strengthen the wall.



No.	Construction Methods	Comment
4	Install top plate. Can be 100x100mm (4”x4”) or two 50x100mm (2”x4”) Connection: 3mmx25mm stainless steel straps with 4x65mm nails in each member.	To tie the wall together.
5	Install horizontal bracing (noggin) and lintels.	To brace the wall.
6	Install three diagonal bracing members at all corners.	To facilitate stability and reduce movement.
7	Install timber sheathing on external wall.	To reduce movement.





Timber Shear Wall bracing

Exterior walls

- 20 mm (3/4”) tongue and groove boarding, or
- 10 mm (3/8”) plywood sheets.

Interior Walls

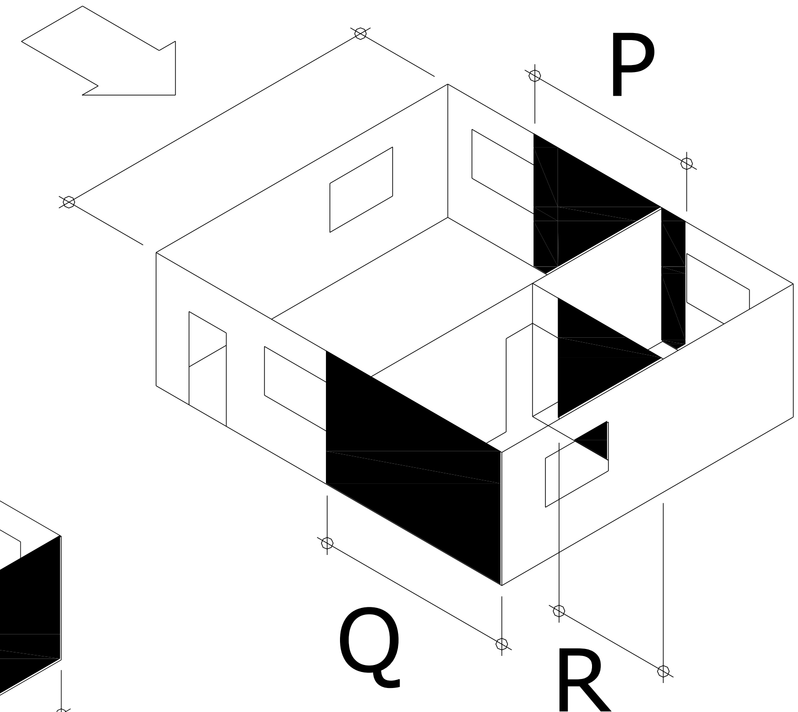
- Cross bracing with timber or galvanized metal strap, or
- 20 mm (3/4”) tongue and groove boarding, or
- 10 mm (3/8”) plywood sheets.

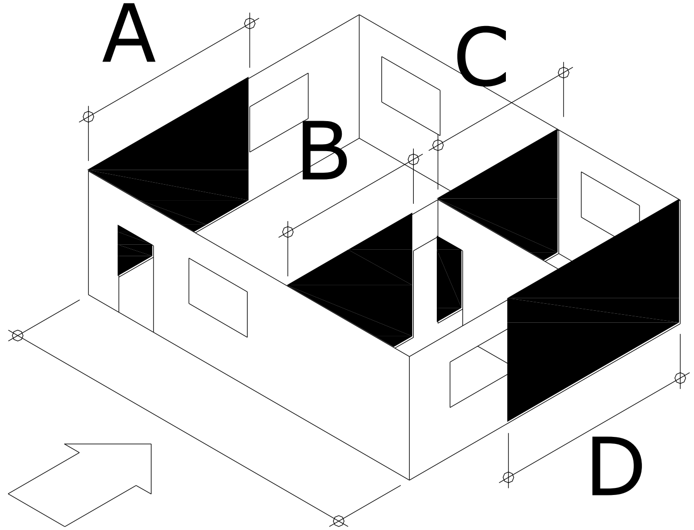
Timber Shear Walls

P+Q+R > 2xW2

WIND DIRECTION 2

(W2)





(W1)

WIND DIRECTION 1

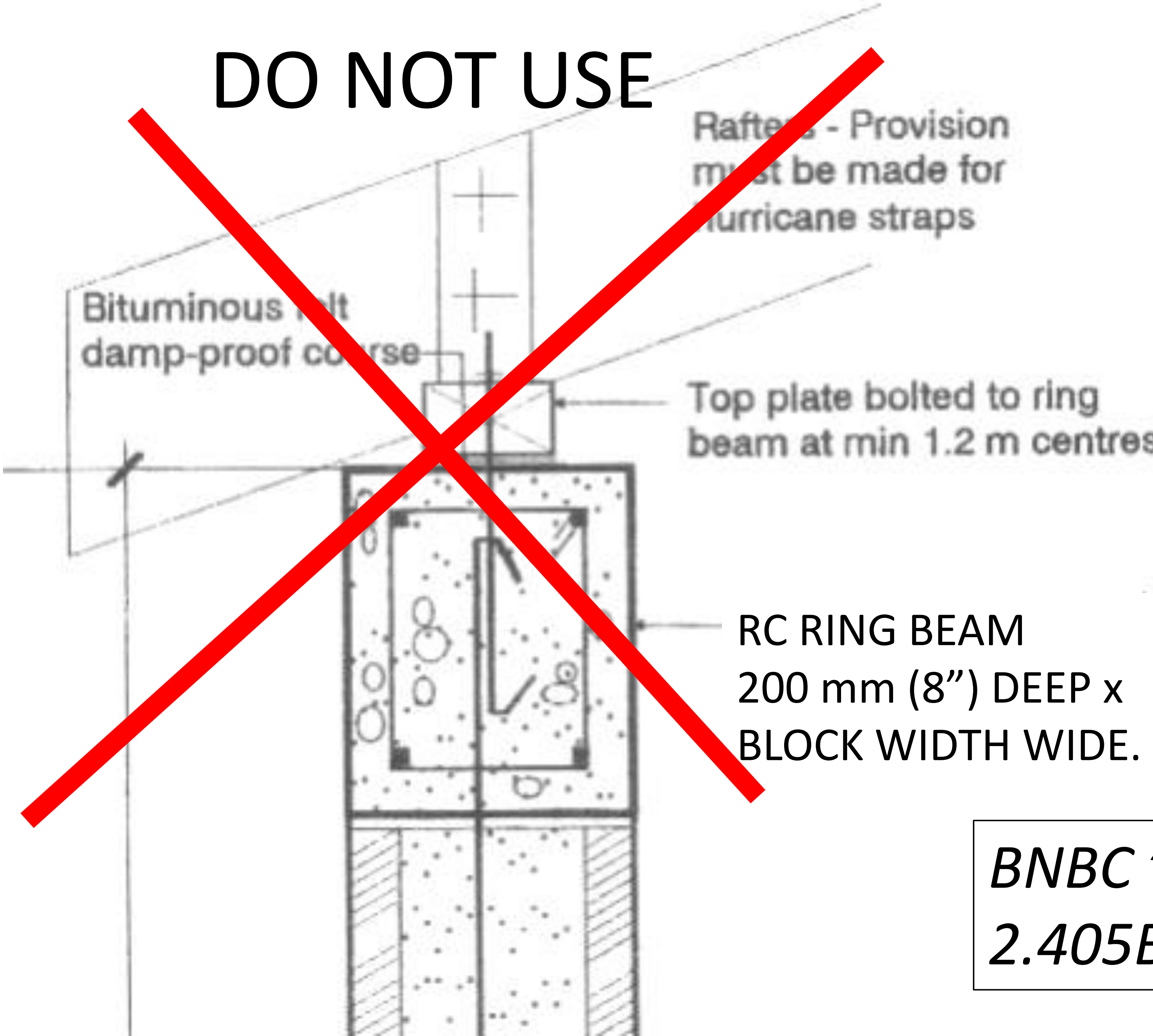
A+B+C+D > 2xW1

B 6.0 Roofs

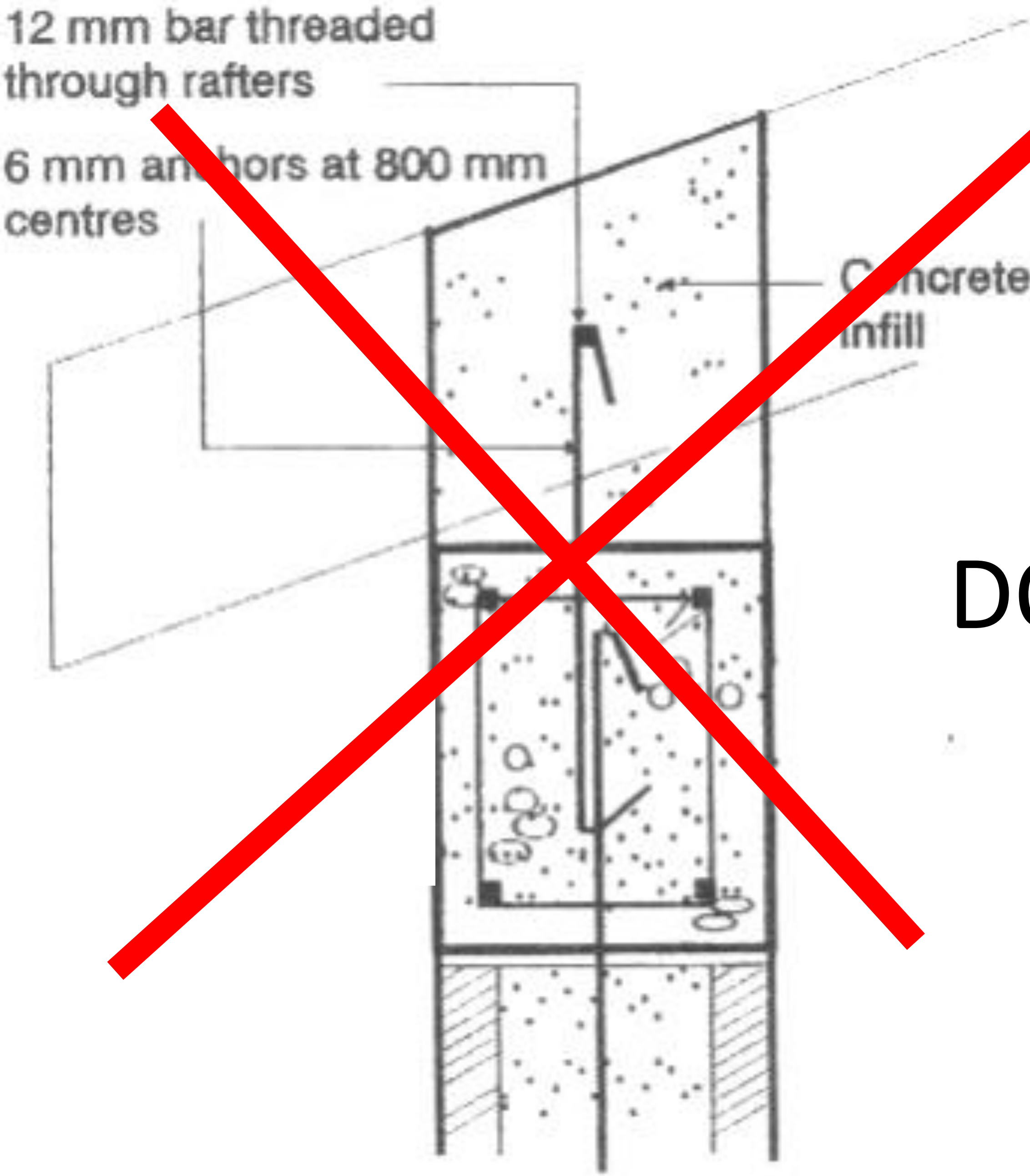
B 6.1 Timber Structure on Concrete Block Wall

No	Construction Method	Comment
1	Erect the roof framing falsework and erect the hip and ridge members.	To facilitate the roof's geometry.
2	Connect the truss anchors to the rafters. Connect the rafters to the hip and ridge members with hurricane connectors.	To connect the roof timber members together.
3	Install timber purlins.	To support the roof covering.
4	Install timber sheathing and battens (if required).	To support the roof covering.
5	Install the roof covering.	To waterproof roof.

DO NOT USE



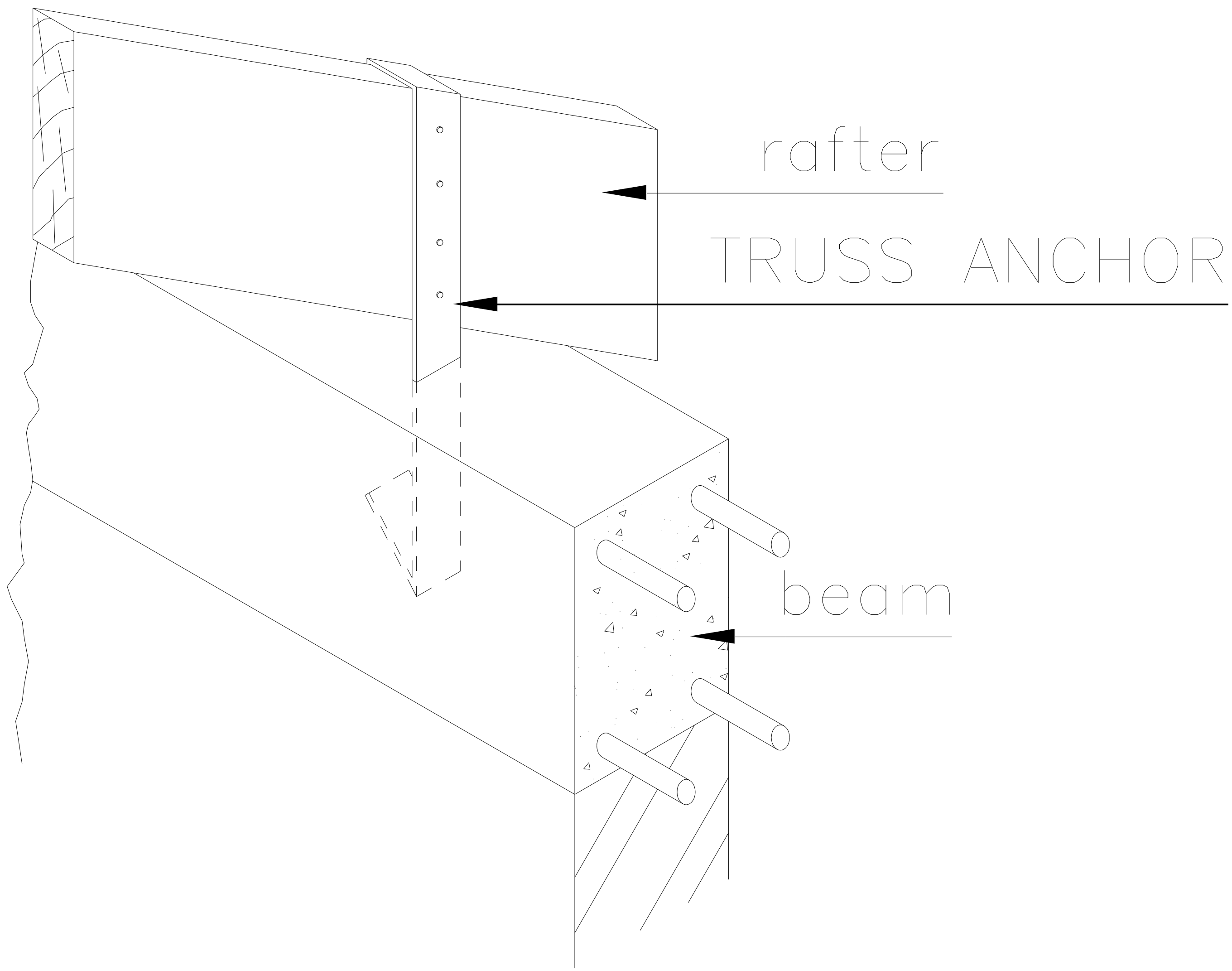
BNBC ’93
2.405B



DO NOT USE

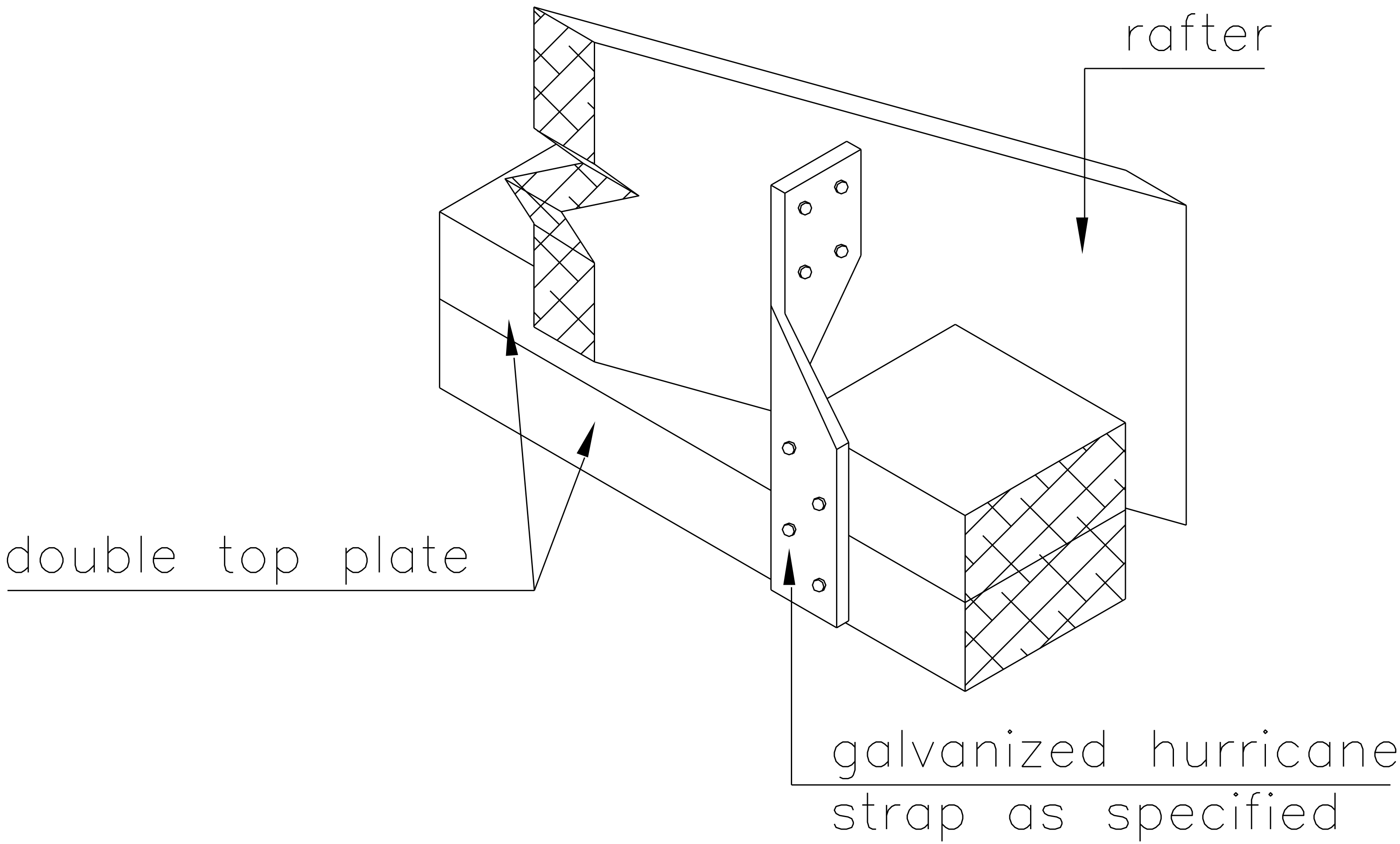
BNBC 2.405B

TRUSS ANCHOR



B 6.2 Timber Structure on Timber Wall

No.	Construction Methods	Comment
1	Erect the roof framing falsework and erect the hip and ridge members.	To facilitate the roof’s geometry.
2	Connect the rafters to the top plate and hip and ridge members with hurricane connectors.	To connect the roof timber members together.
4	Install timber purlins.	To support the roof covering.
5	Install timber sheathing, waterproofing, and battens (if required).	To support the roof covering.
6	Install roof covering.	To waterproof roof.



Rafter & top plate connection

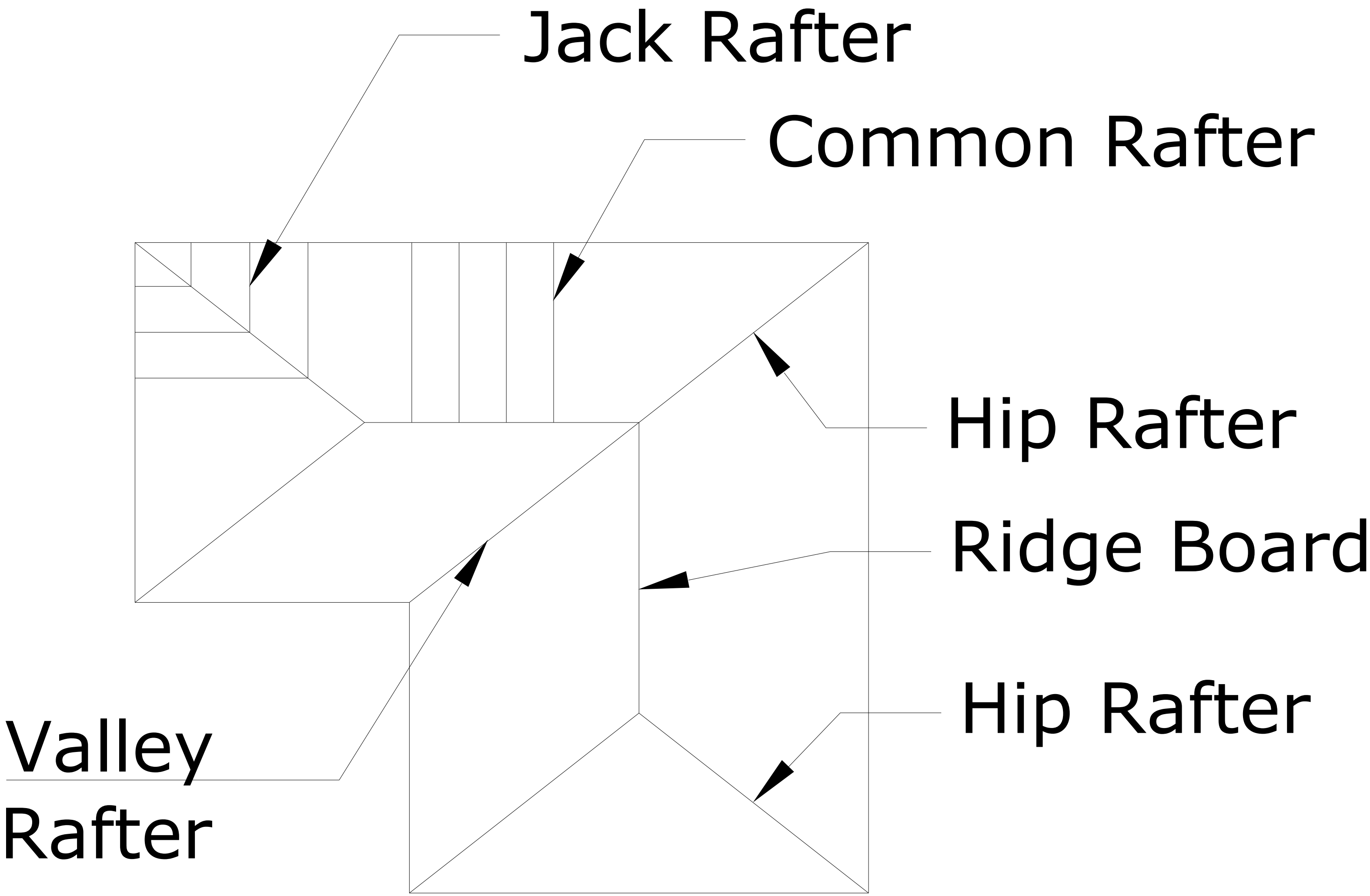
Rafter Sizes at 400mm Centres

Span	Rafter Size at 400mm (16”) centres	
	Pine	Greenheart
1.5-1.8 m (5-6ft)	50x100 (2”x4”)	50x100 (2”x4”)
1.8-2.4m (6-8ft)	50x150 (2”x6”)	50x100 (2”x4”)
2.4-3.3 (8-10ft)	50x200 (2”x8”)	50x150 (2”x6”)
3.3-3.6m (10-12’)	50x250, 75x200 (2”x10”, 3”x8”)	50x150 (2”x6”)
3.6-4.3m (12-14’)	75x250 (3”x10”)	50x200, 75x150 (2”x8”, 3”x6”)
4.3-4.8m (14-16’)	75x250 (3”x10”)	50x200, 75x150 (2”x8”, 3”x6”)

Rafter Sizes at 600mm Centres

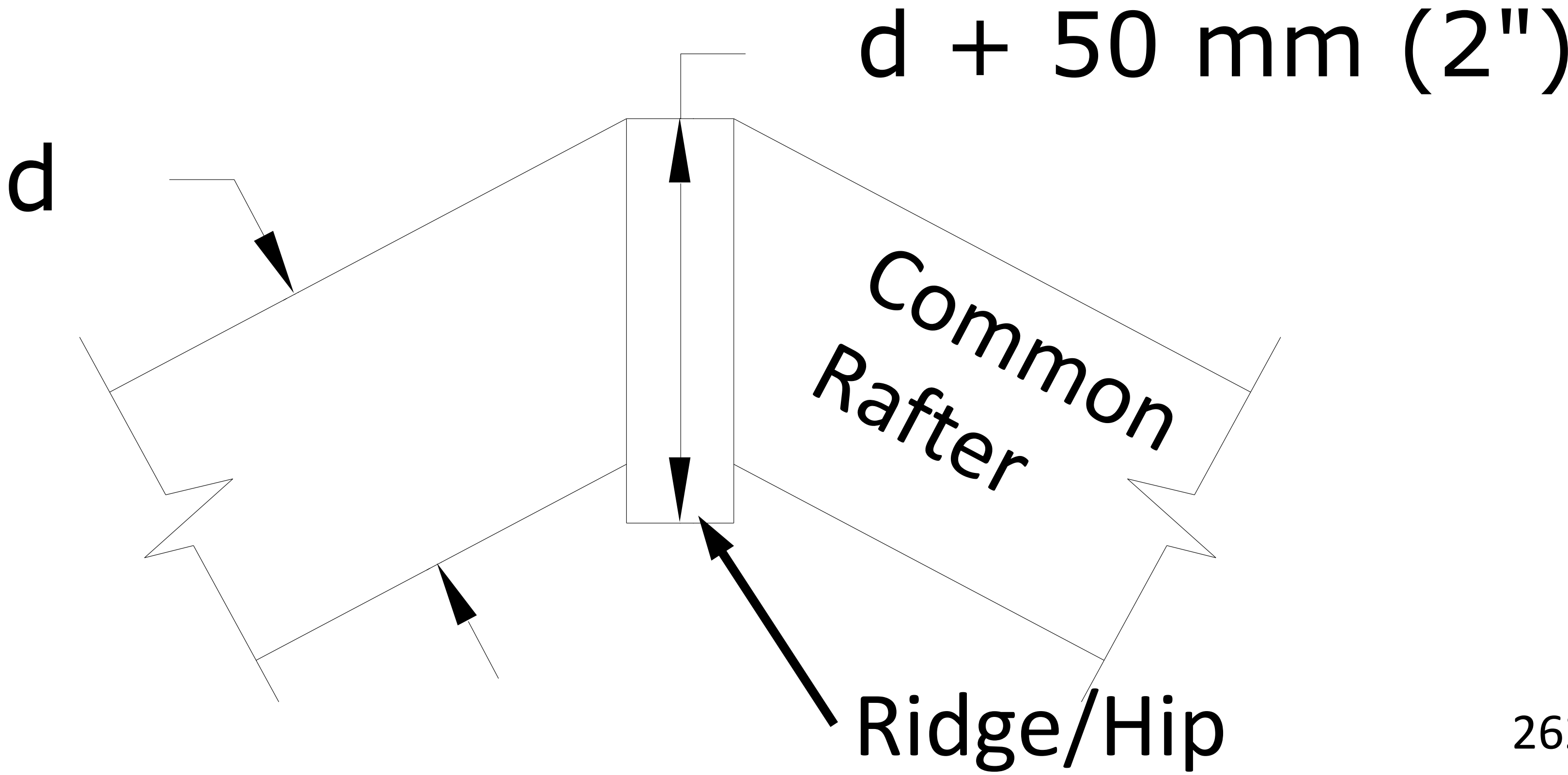
Span	Rafter Size at 600mm (24”) centres	
	Pine	Greenheart
1.5-1.8 m (5-6ft)	50x150 (2”x6”)	50x100 (2”x4”)
1.8-2.4m (6-8ft)	50x200, 75x150 (2”x8”, 3”x6”)	50x150 (2”x6”)
2.4-3.3 (8-10ft)	50x250, 75x200 (2”x10”, 3”x8”)	50x150 (2”x6”)
3.3-3.6m (10-12’)	75x250 (3”x10”)	50x200, 75x150 (2”x8”, 3”x6”)
3.6-4.3m (12-14’)	75x250 (3”x10”)	50x200, 75x150 (2”x8”, 3”x6”)
4.3-4.8m (14-16’)	75x300mm (3”x12”)	50x250, 75x200 (2”x10”, 3”x8”)

Roof Framing



Hip, Valley and Ridge Depths

- **Hip, Valley** and **Ridge** depths (d) should be 50 mm (2”) greater than the **Common Rafters**.




09/11/20

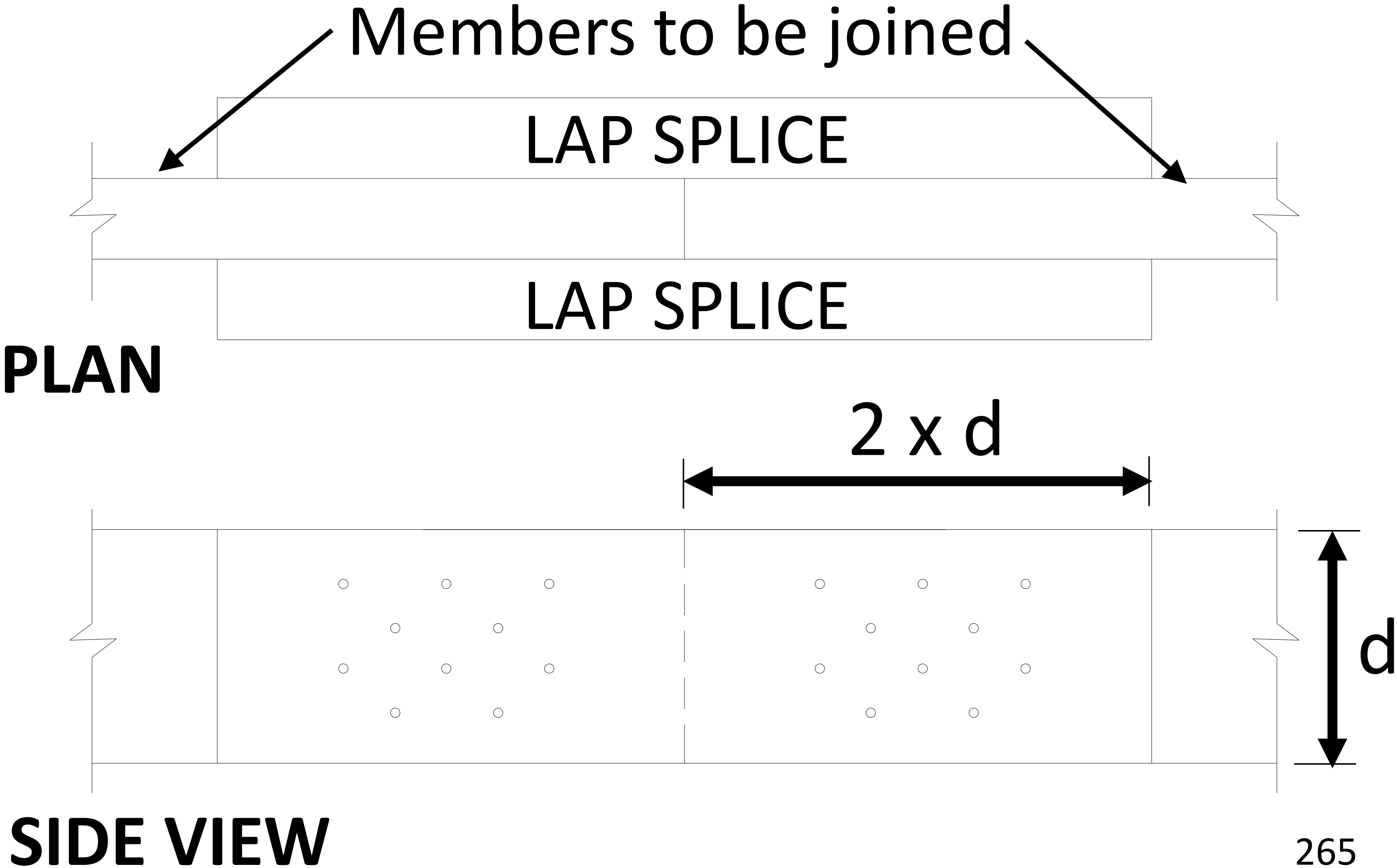
Hip, Valley and Ridge Joints

- Hip, Valley and Ridge members should be continuous. If they must be joined, then:

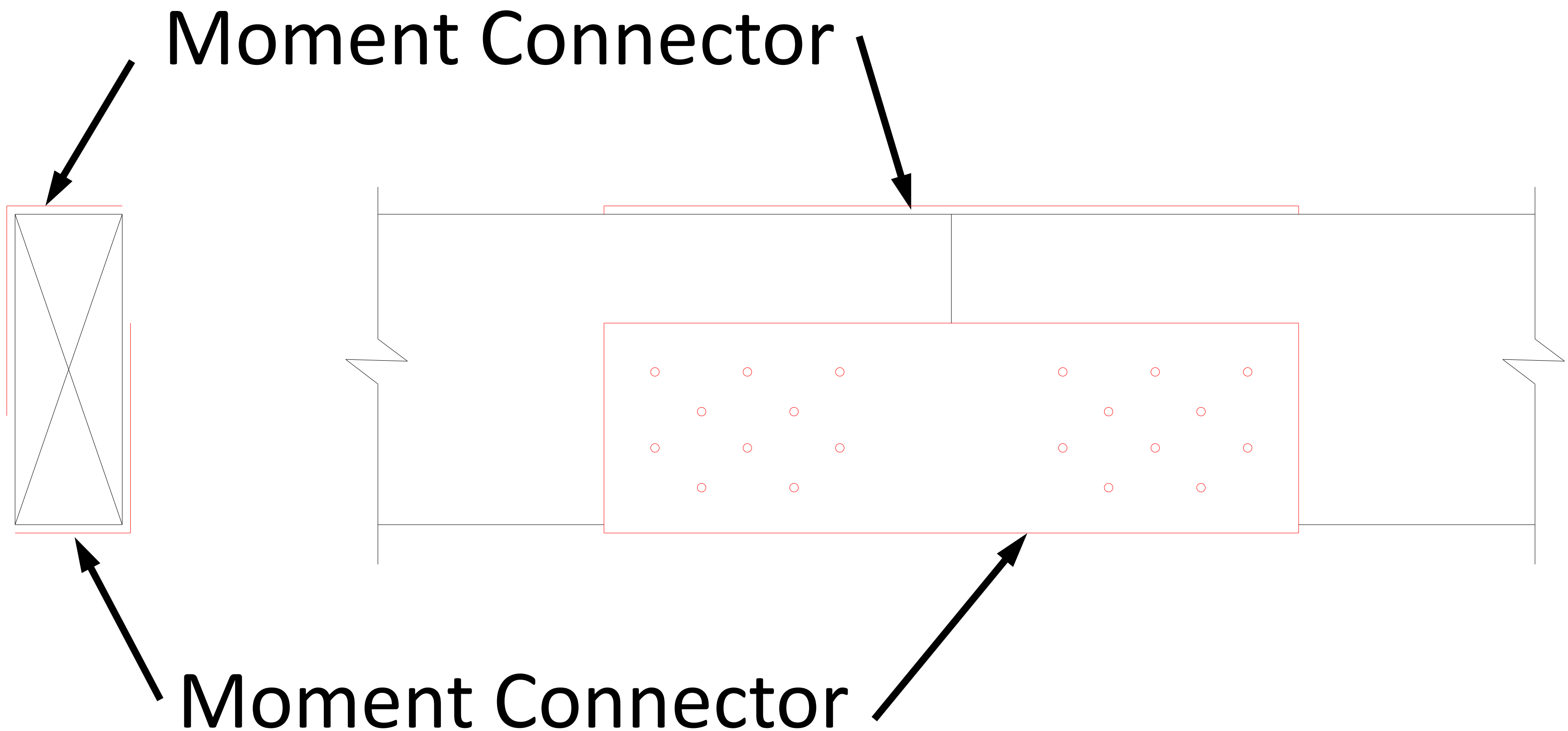
a) lap the joint with the same size timber, extending at least 2 x depth of the member either side of the cut joint, or

b) Strengthen the joint with 2 no. moment connectors at each joint (BRC or equivalent).

Hip, Valley and Ridge Joints



Hip, Valley and Ridge Joints



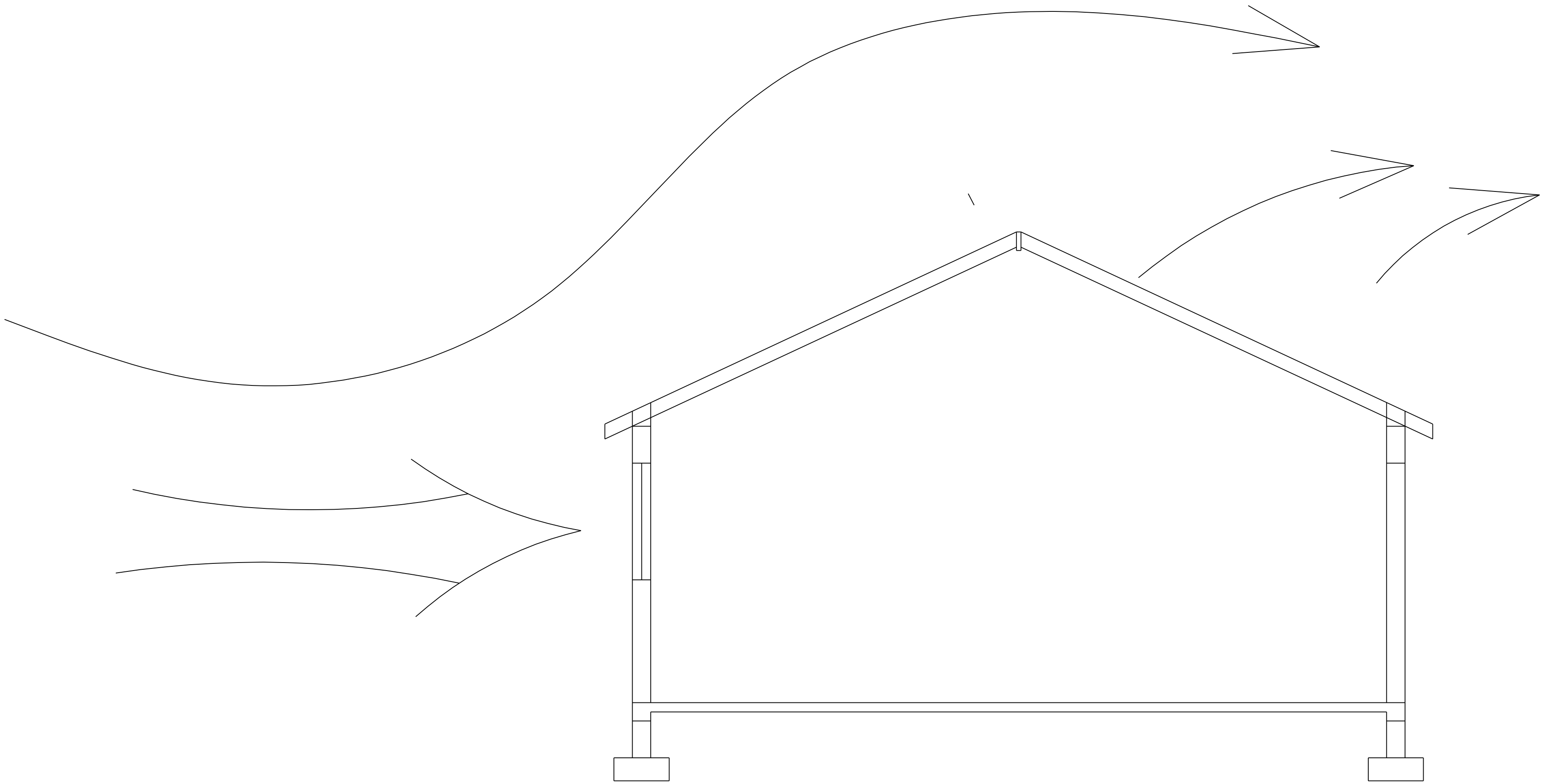
6.3 Reducing the Span

Rafter sizes can be reduced by reducing the span by:

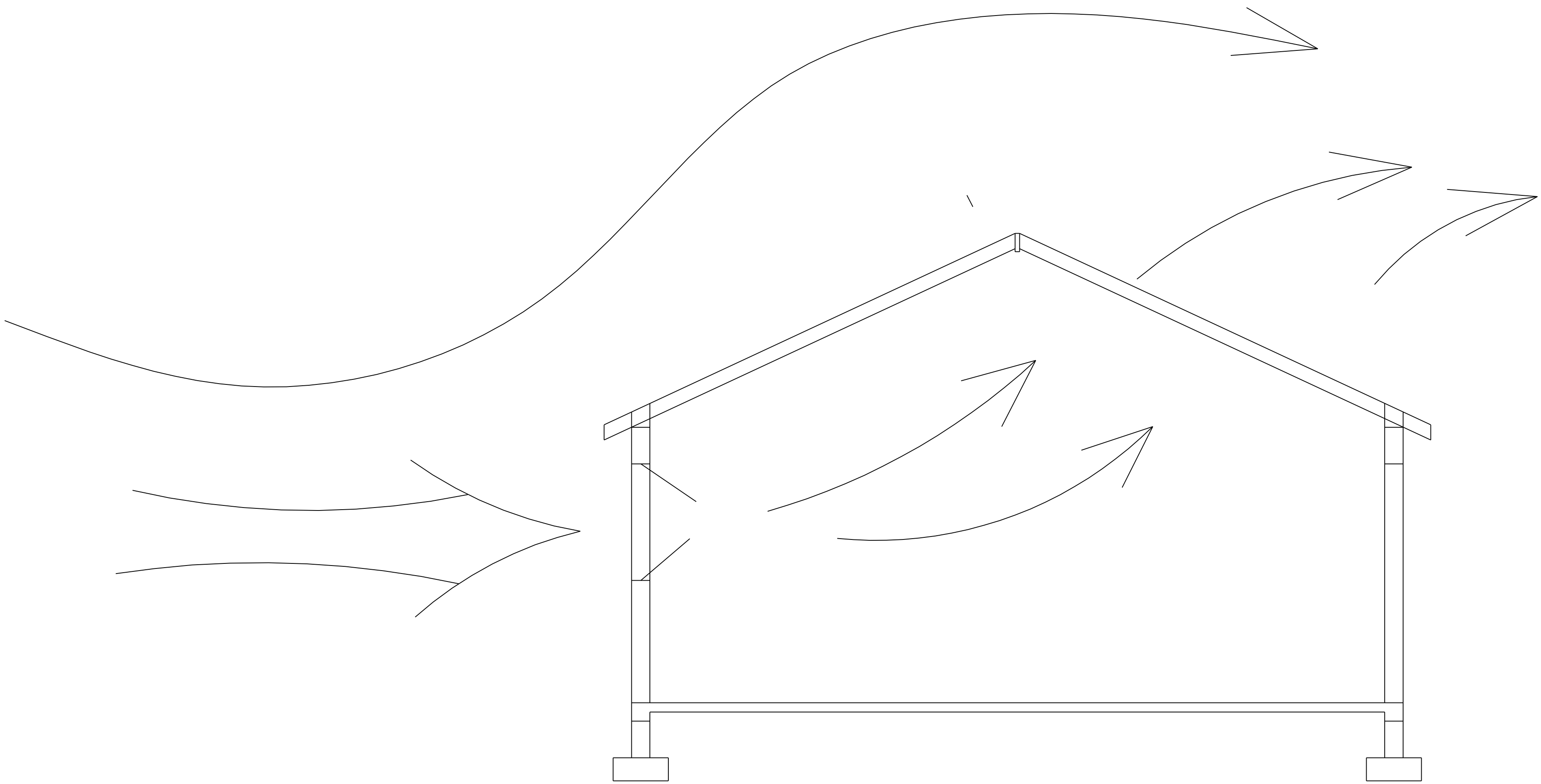
1. Supporting the rafter on an internal wall.
2. Installing a collar tie at a lower level (to make an A frame).
3. Building a truss.

Home

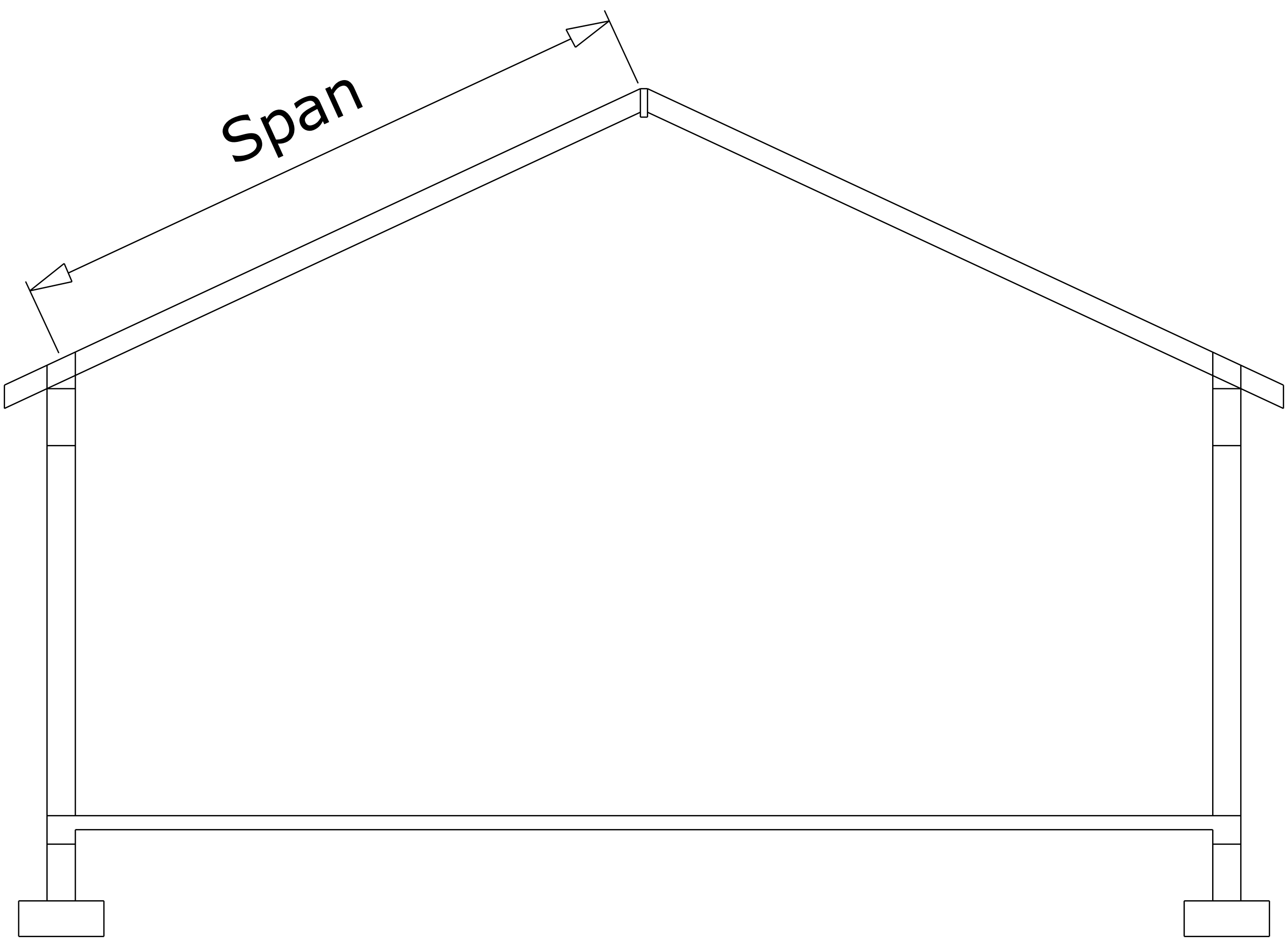
Air Tight Building Envelope – Suction Effect on Rafter



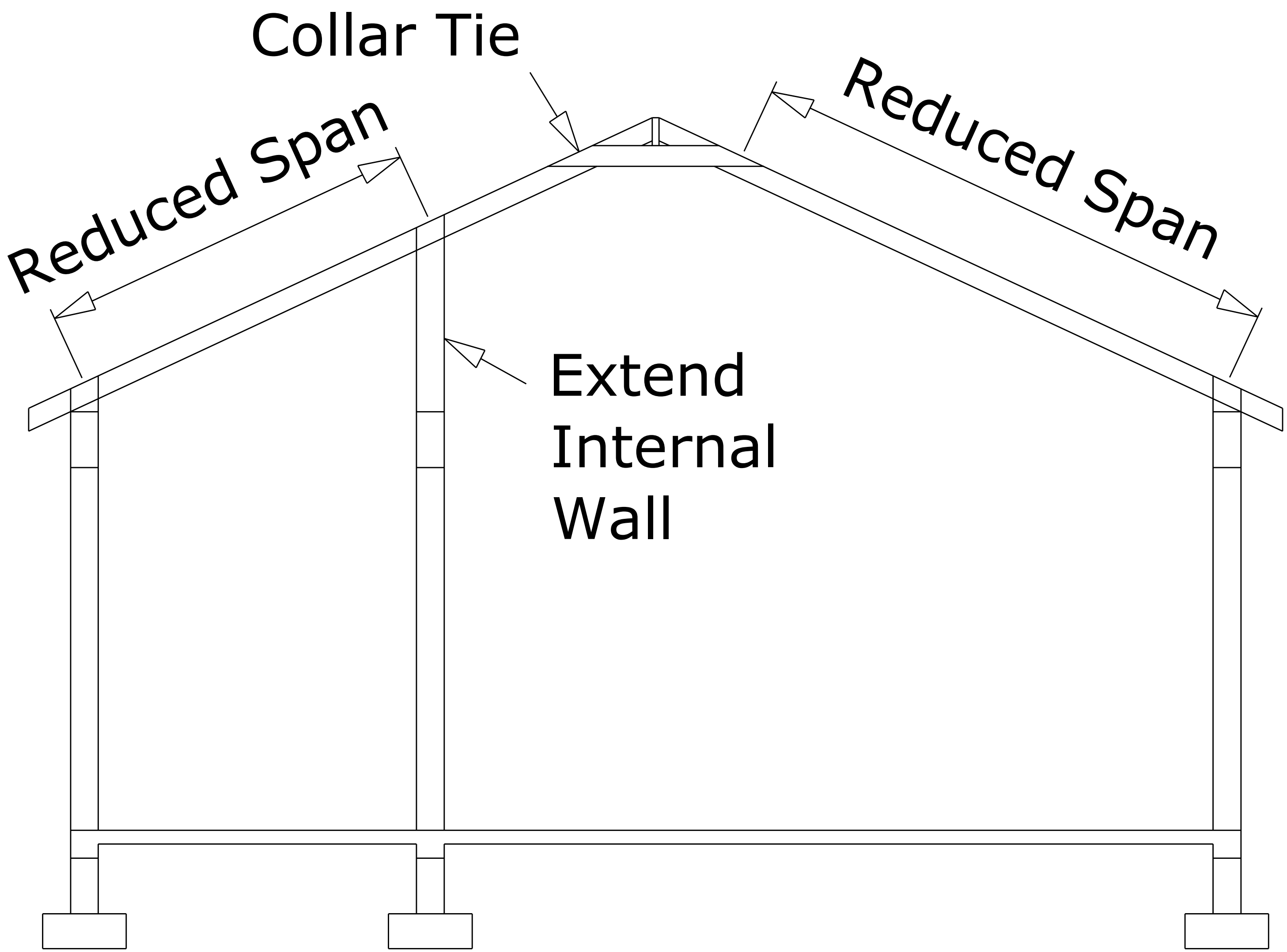
Air Tight Building Envelope – Blowing and Suction Effect on Rafter



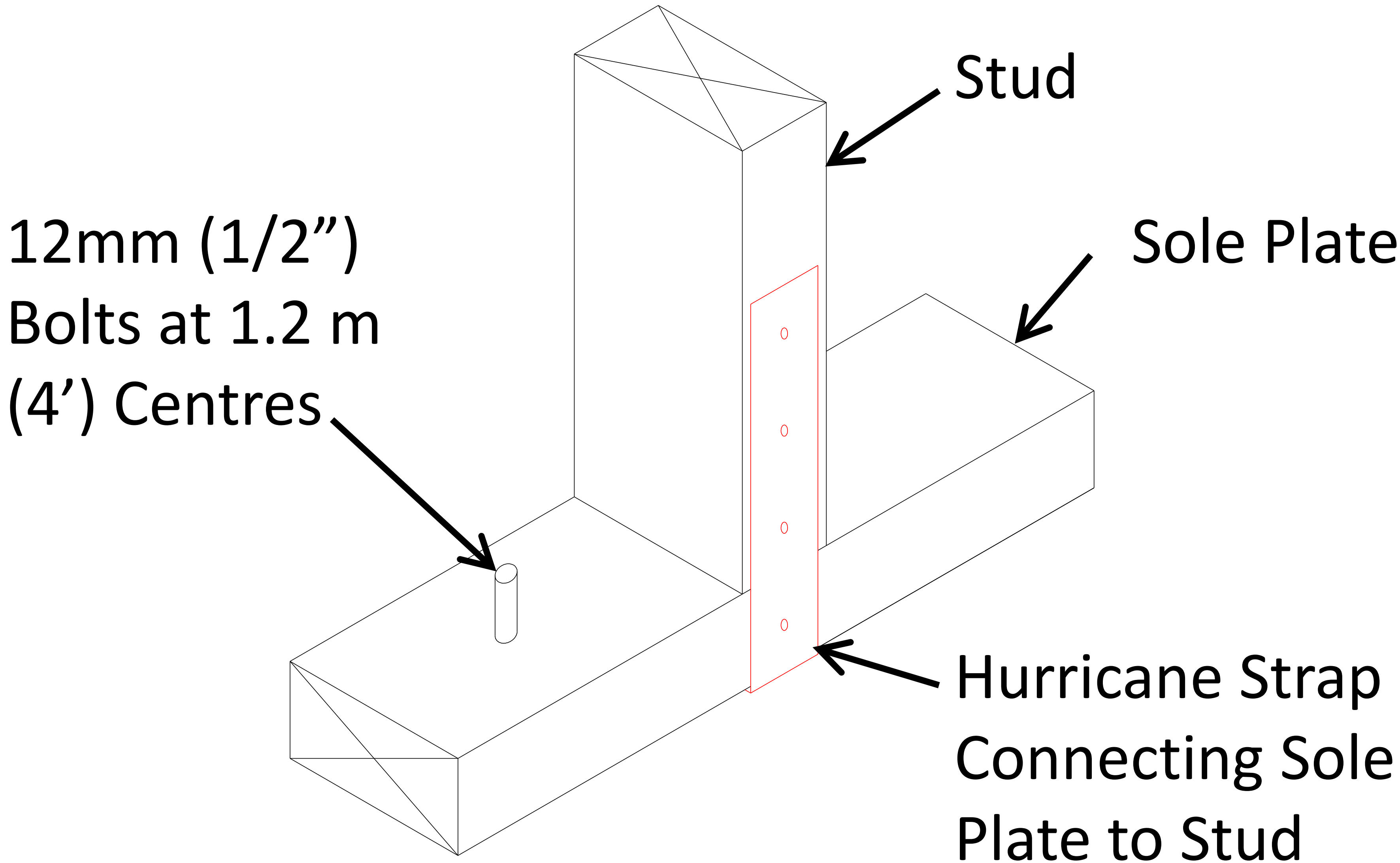
Rafter Span



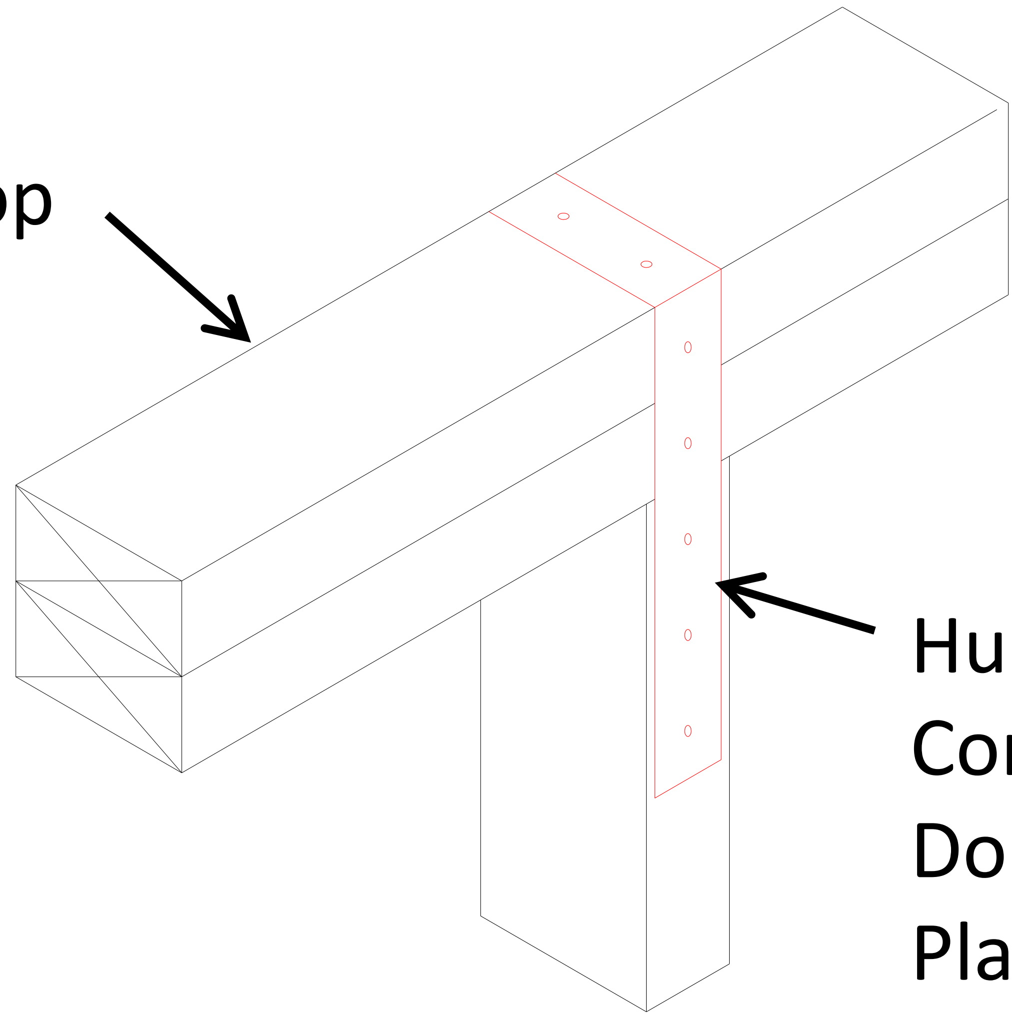
Reduced Rafter Span



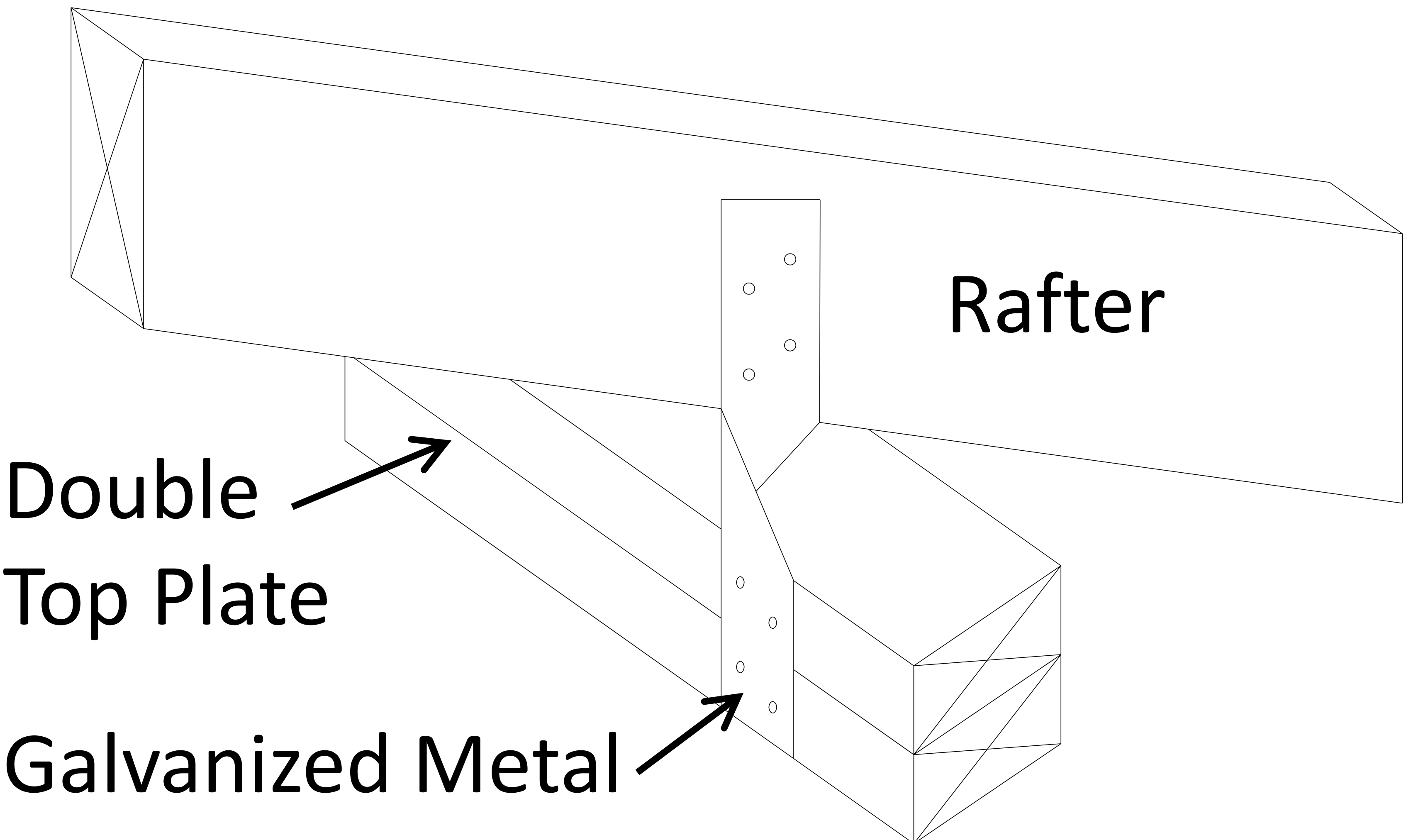
6.4 Roof Connections.
Stud-Sole Plate-Floor Connections



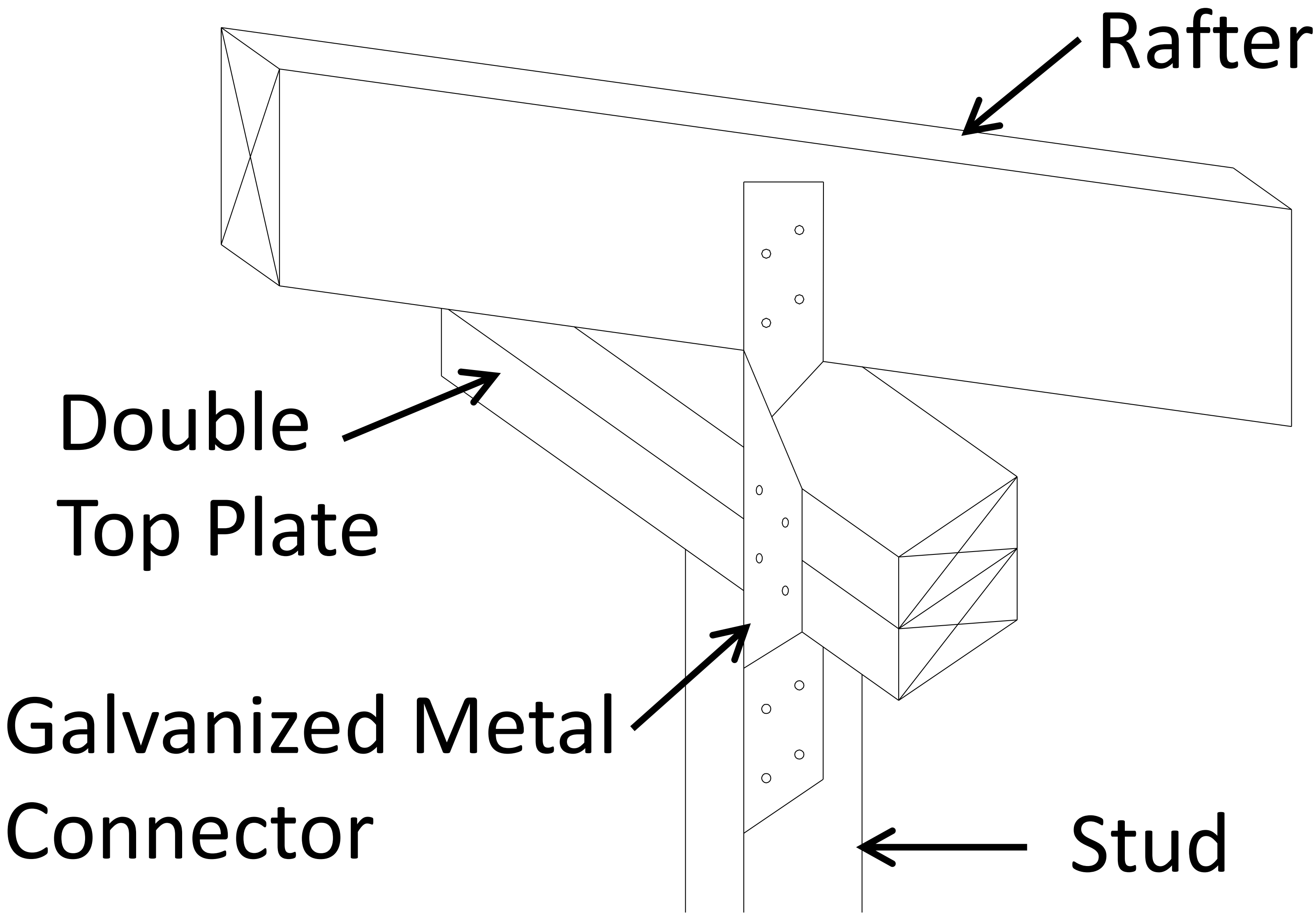
Top Plate-Stud Connection



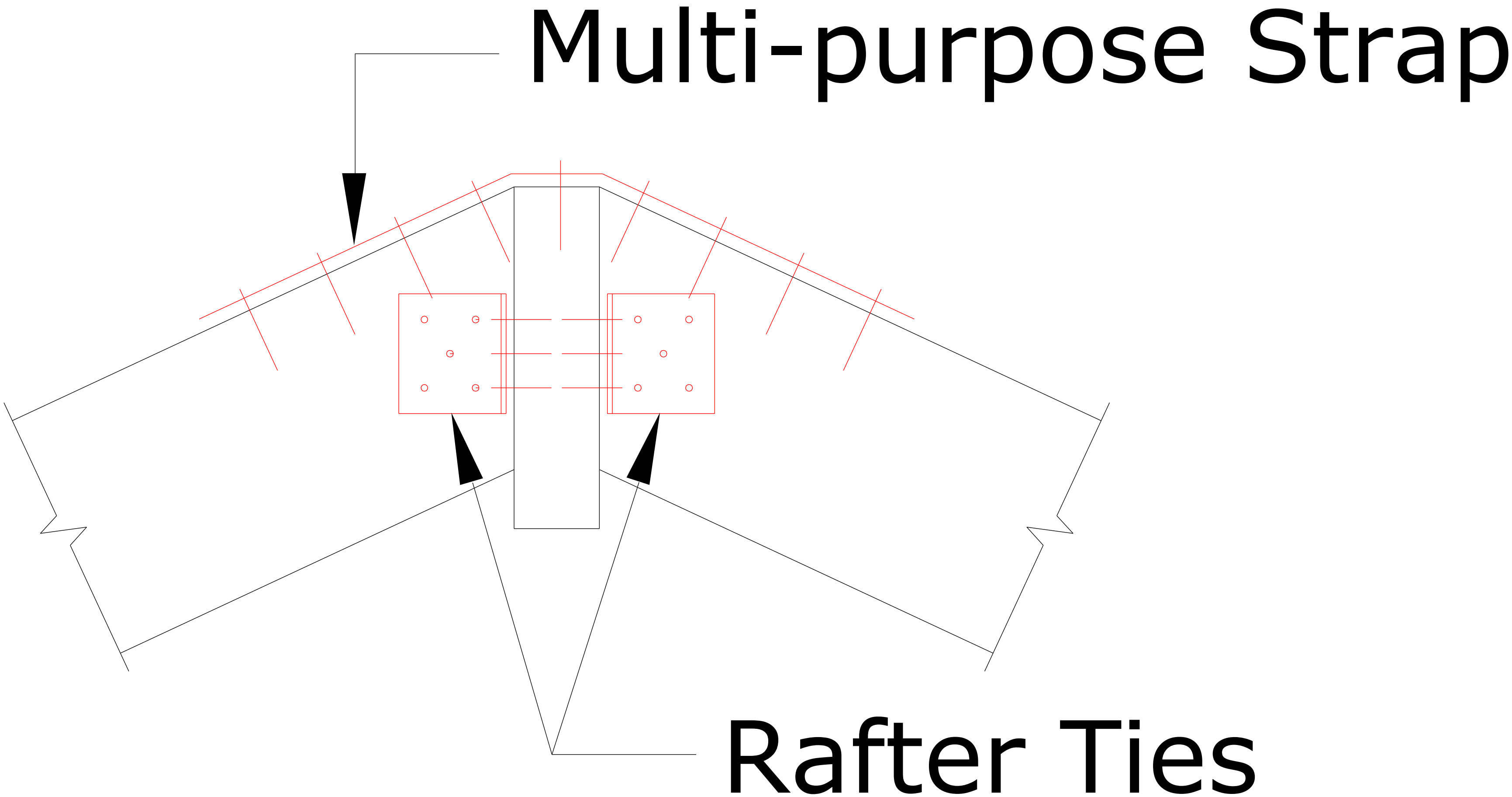
Rafter - Top Plate Connection



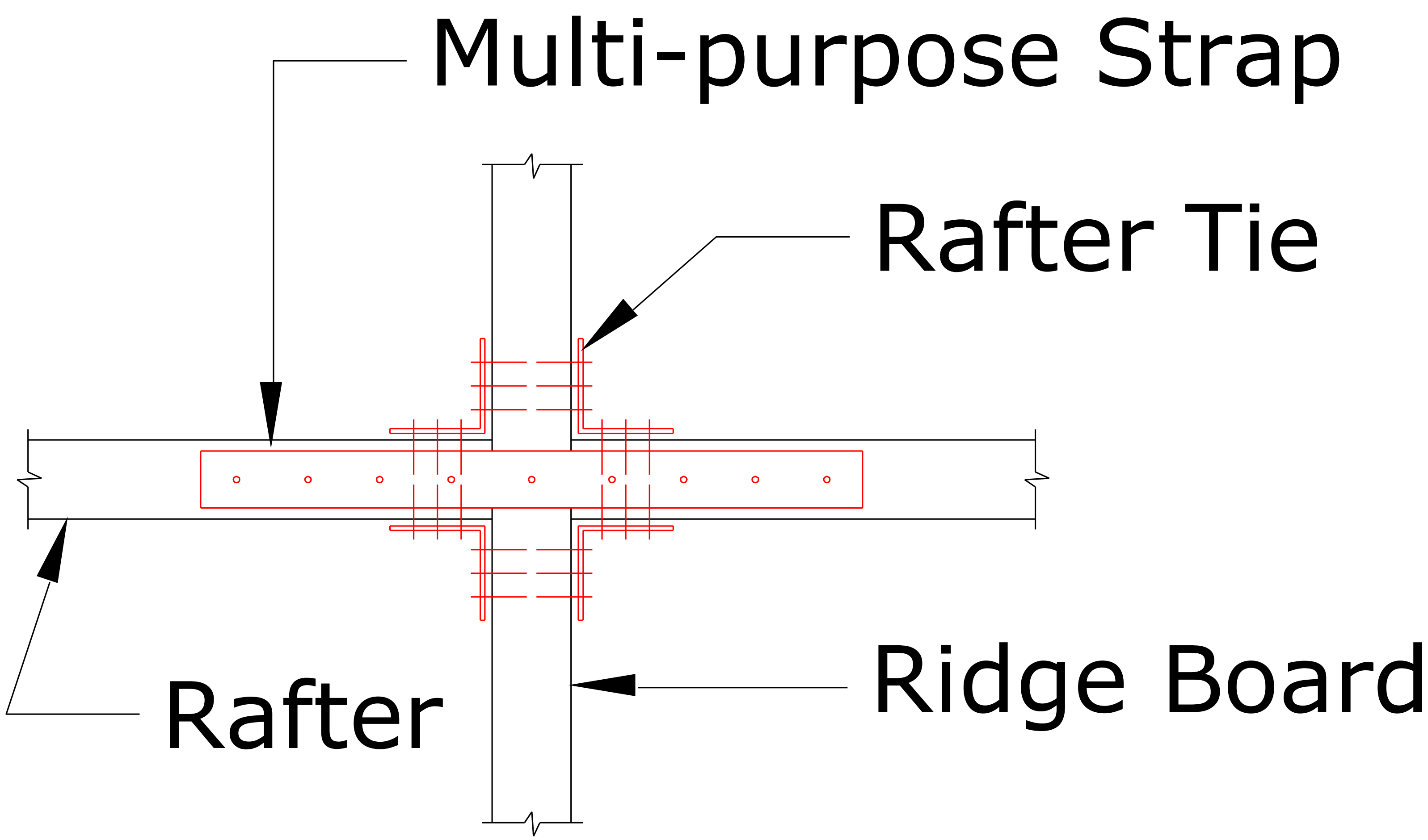
Rafter - Top Plate – Stud Connection



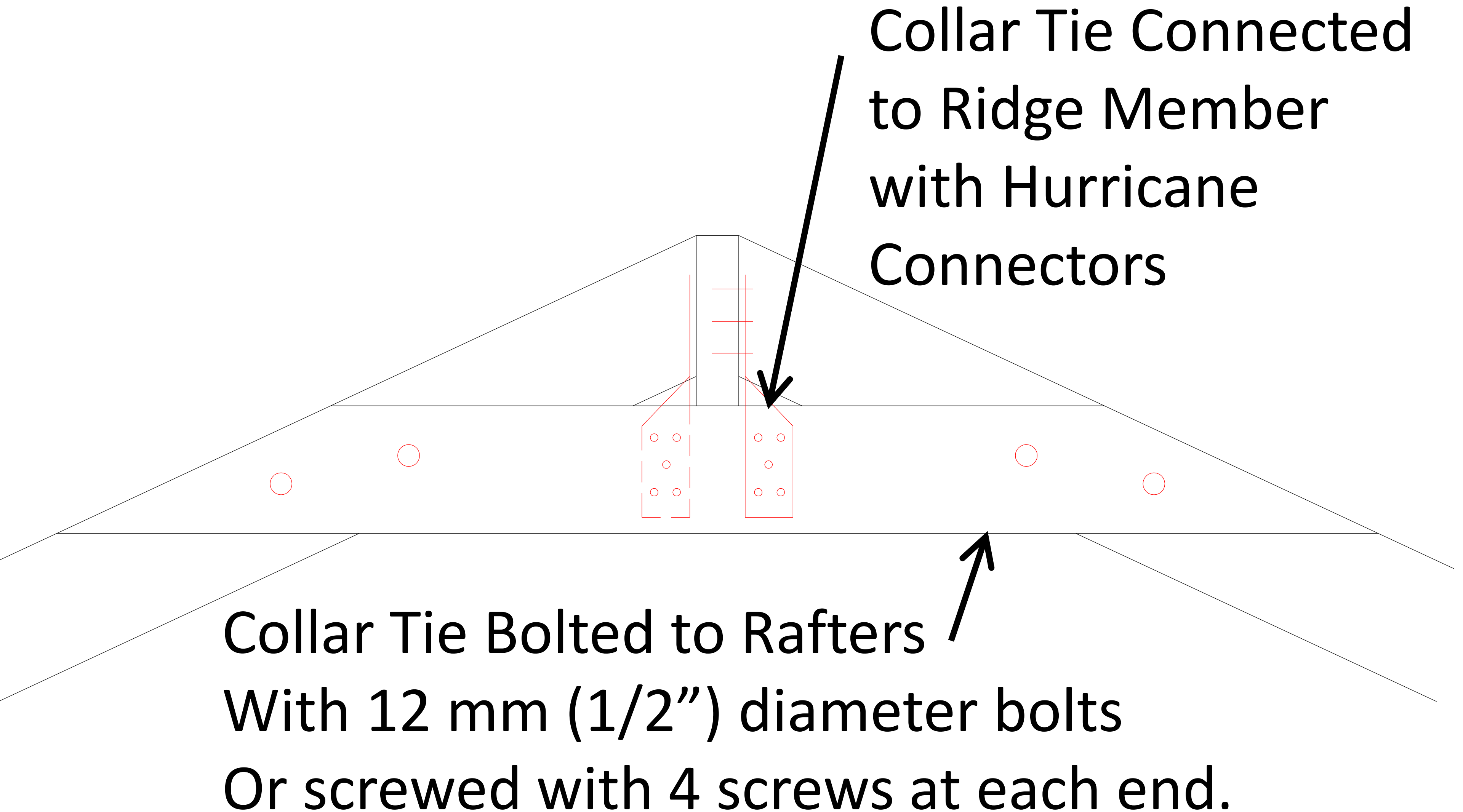
RAFTER/ RIDGE BOARD CONNECTIONS
- ELEVATION -



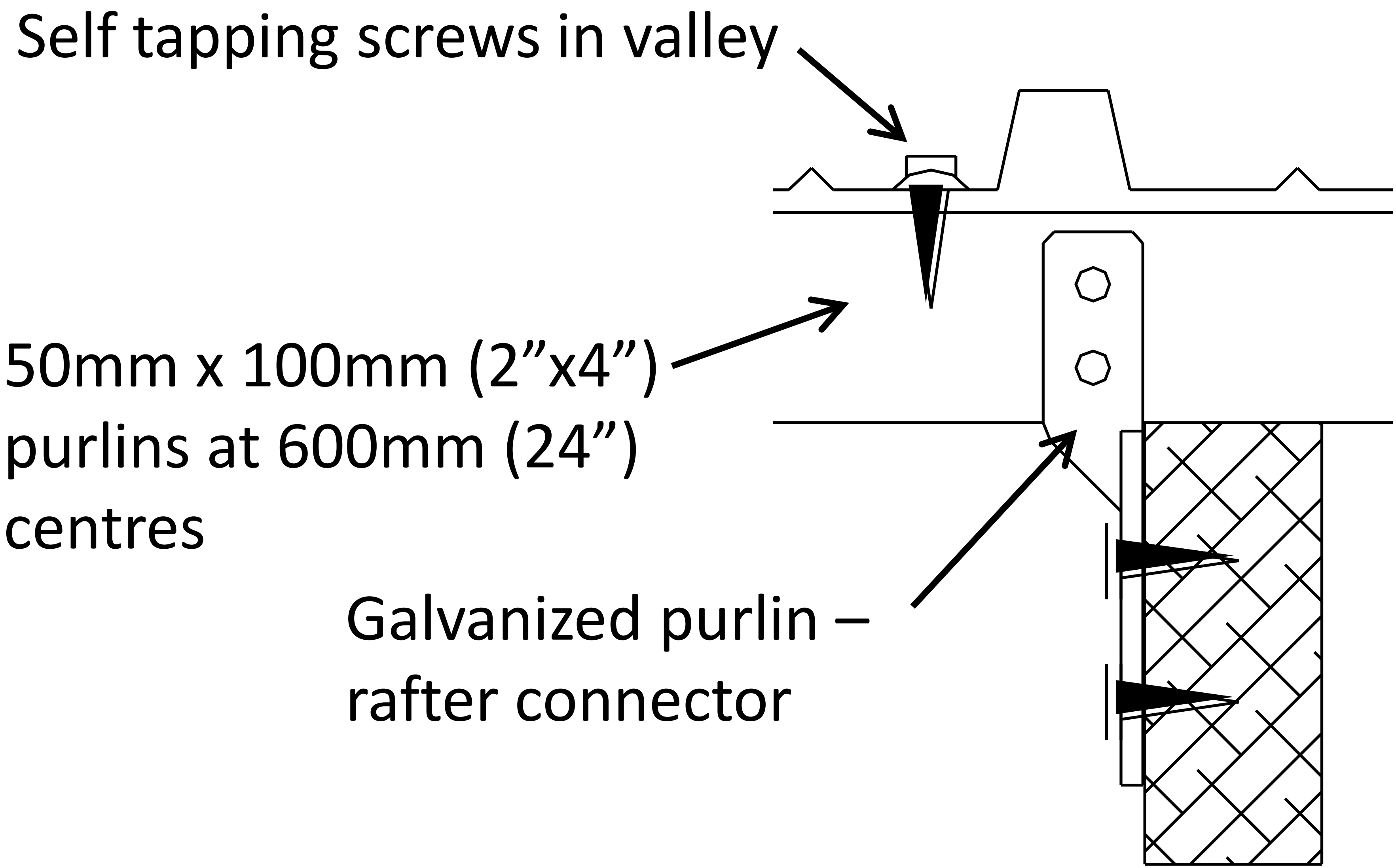
RAFTER/ RIDGE BOARD CONNECTIONS
- PLAN -



Collar Tie Connections

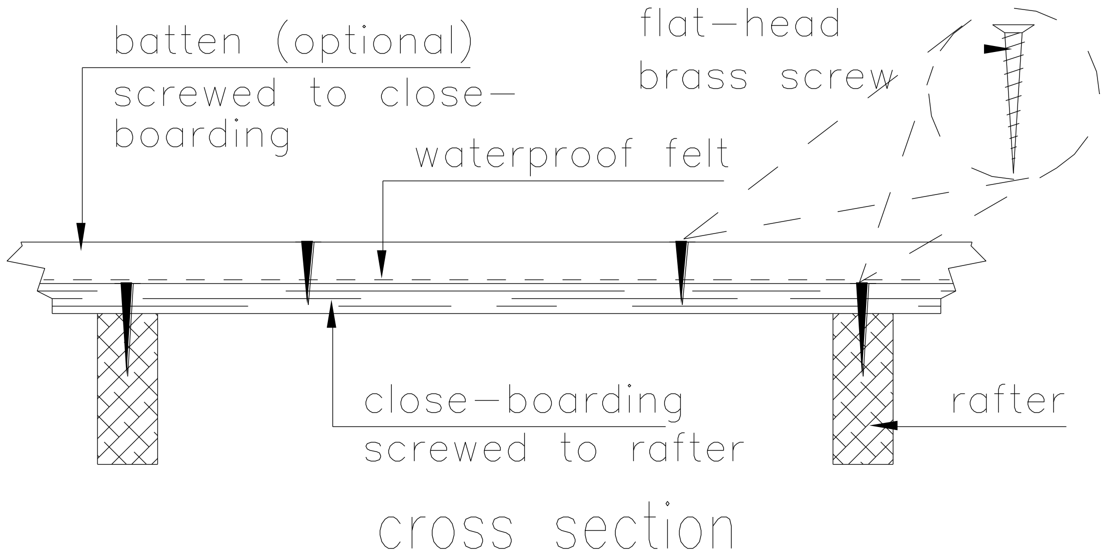


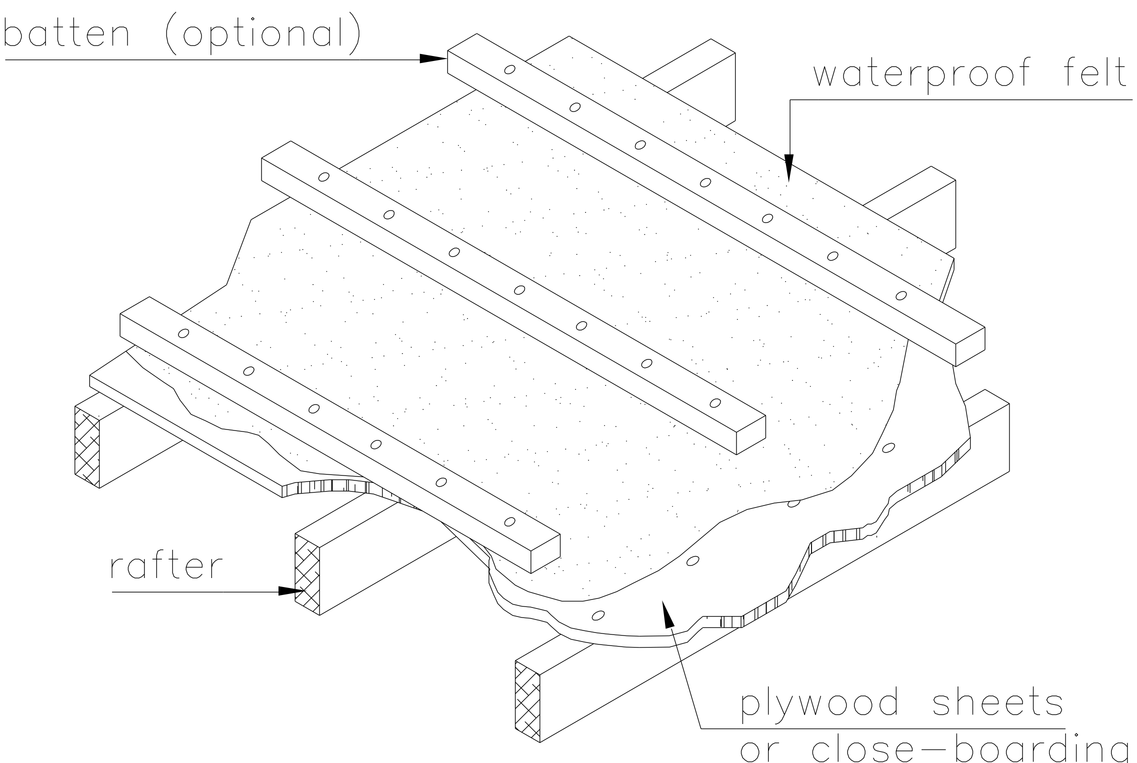
SHEETING/ PURLIN/ RAFTER CONNECTION

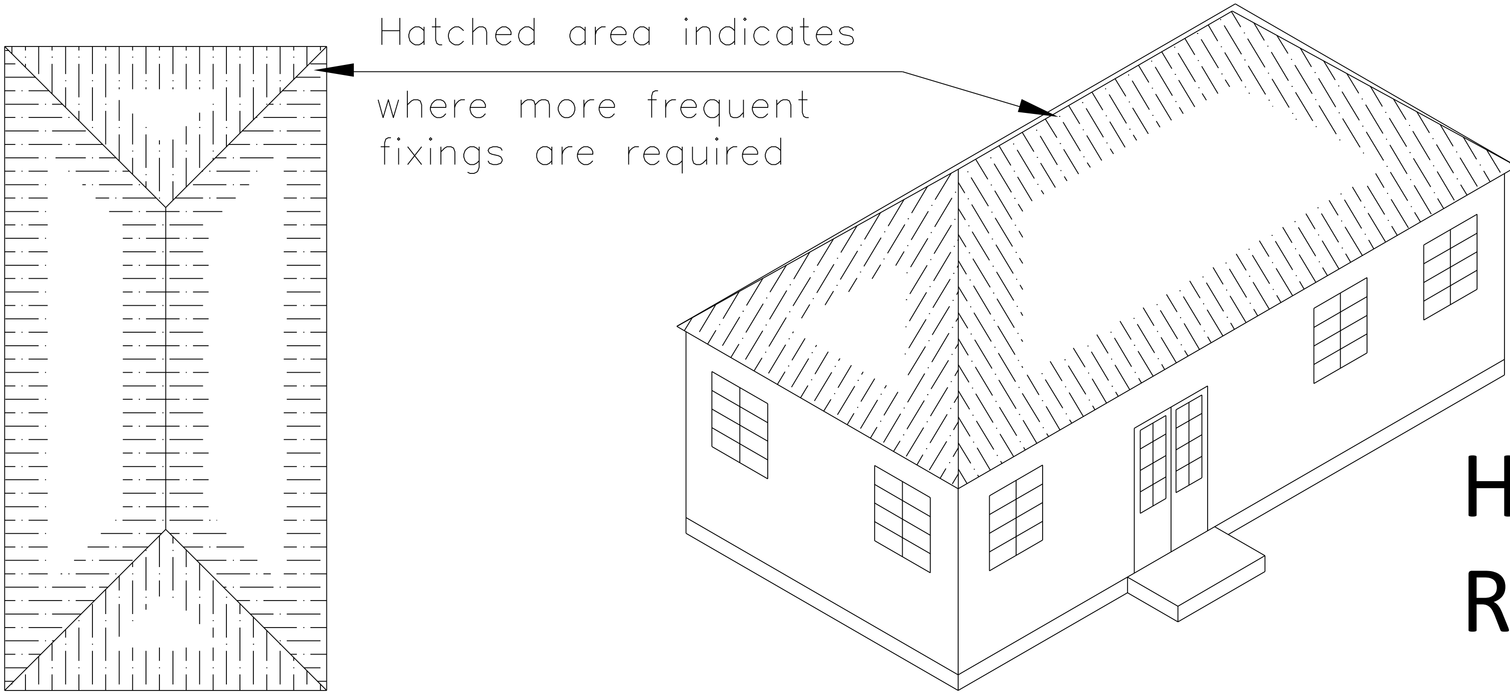


CLOSEBOARD CONNECTIONS FOR TILES AND SHINGLES

Source for this and next slide: United Insurance Booklet.

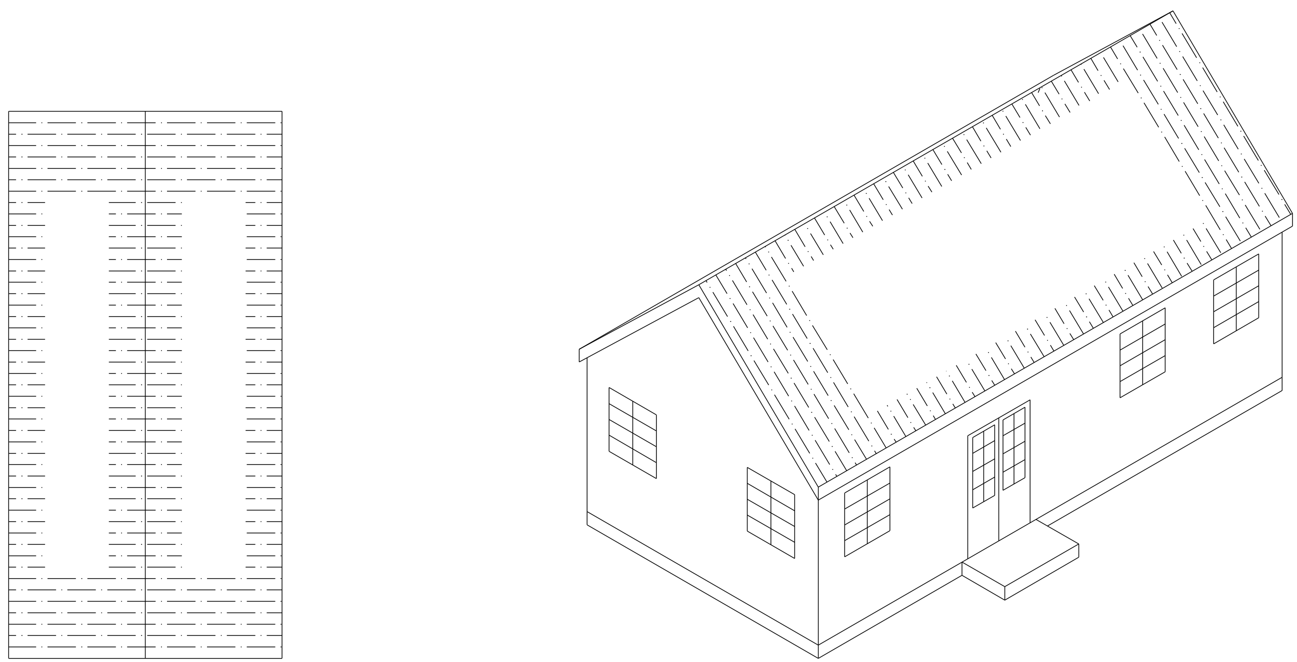




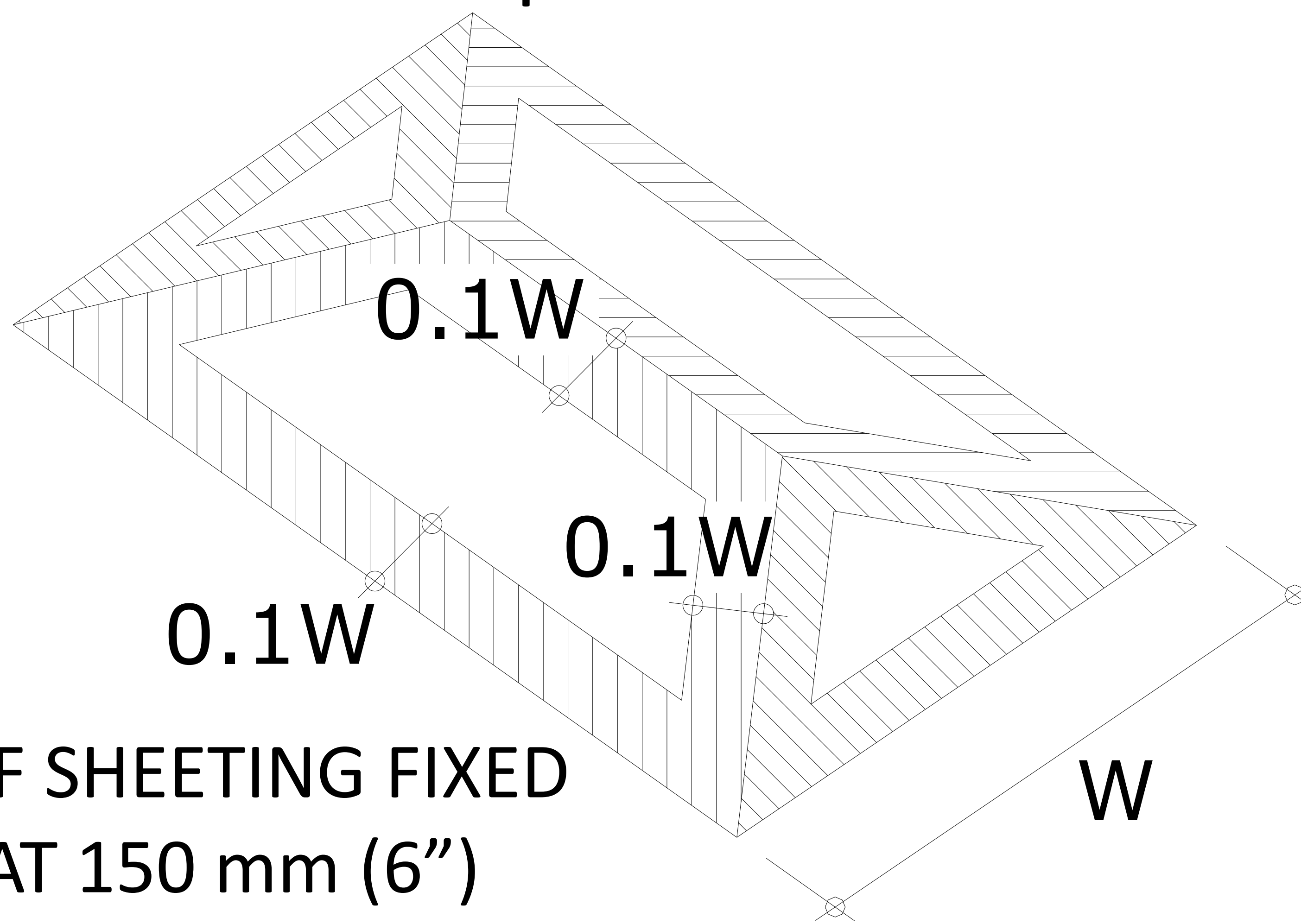


HIPPED
ROOF

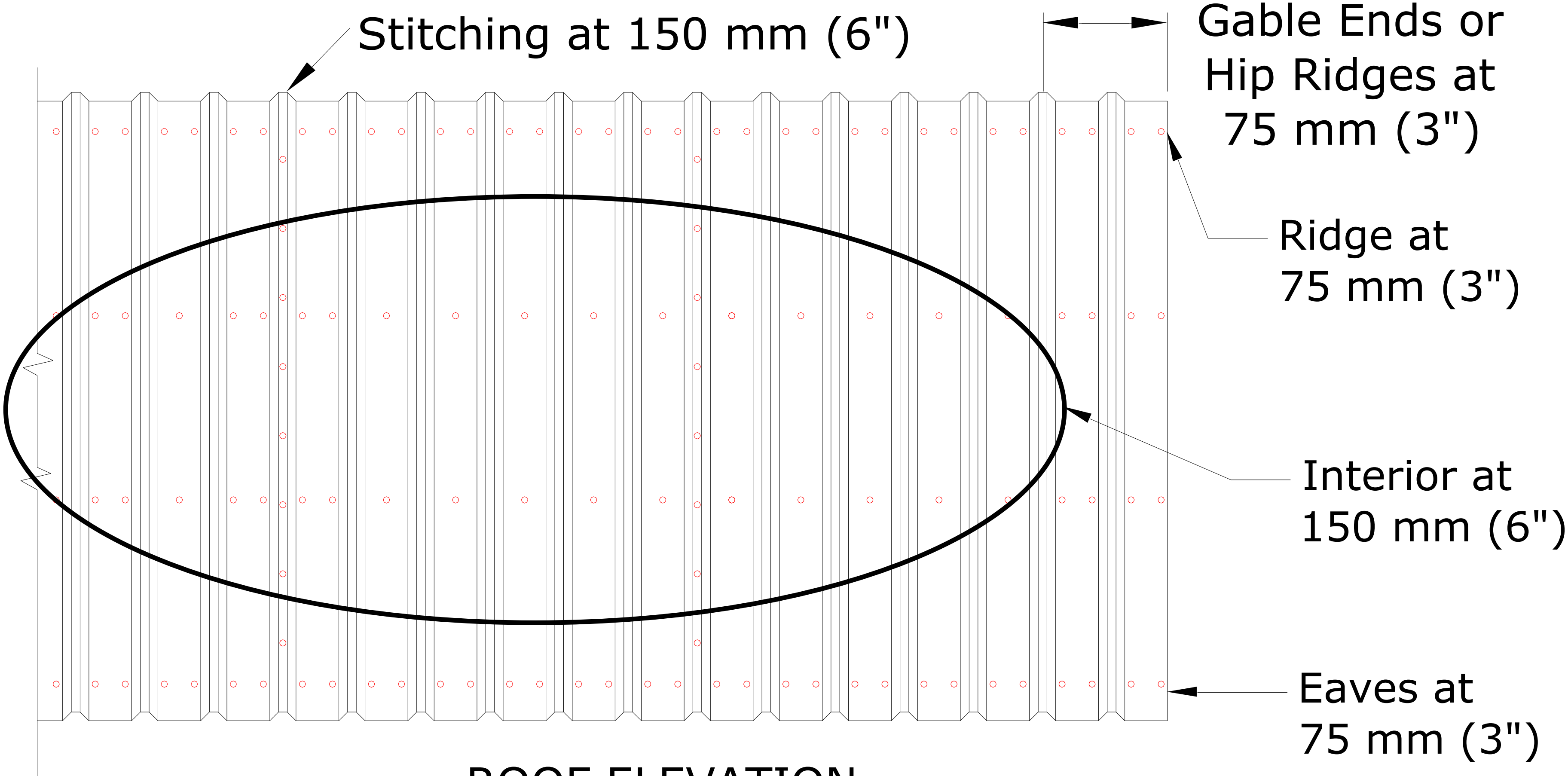
GABLE
ROOF



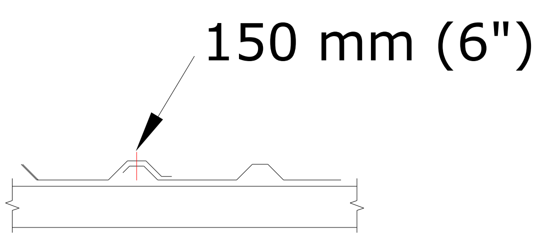
Connections to be at 75 mm (3”) centres in shaded areas. Not less than 2 purlins are to be located in the eaves and apex shaded areas.



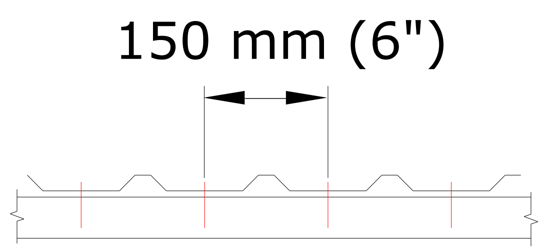
0.5 mm ROOF SHEETING FIXED TO PURLINS AT 150 mm (6”) CENTRES IN UNSHADED AREAS.



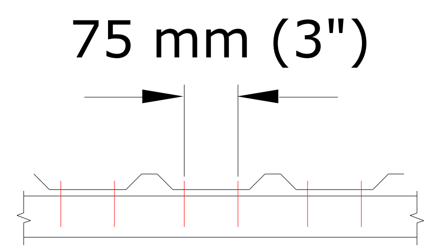
ROOF ELEVATION



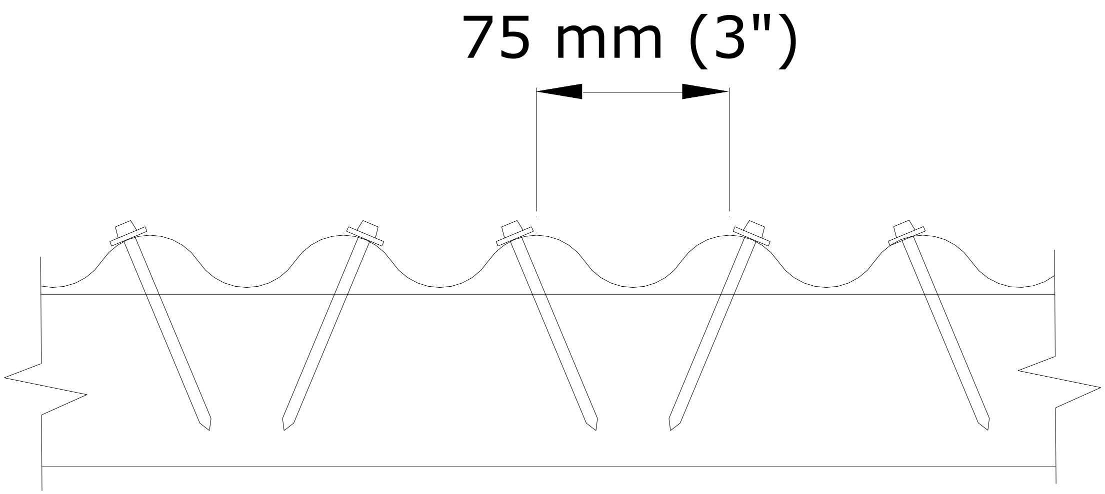
STITCHING



AT THE INTERIOR

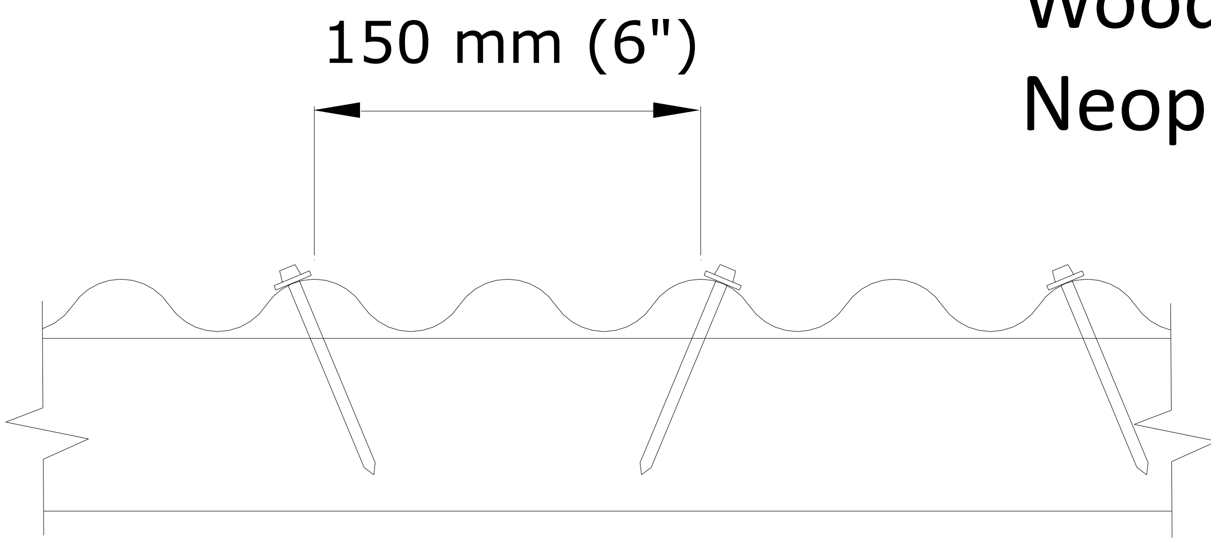


AT EDGES



AT EDGES

60 mm (2.5”) long Wood Grip Screws with Neoprene washers.



AT THE INTERIOR

C. AFTER CONSTRUCTION

C. Maintenance & Repairs

C 1. Construction Phases

There are 4 principal construction phases, all of which have costs attached to them.

1. Design
2. Construction
3. Maintenance
4. Demolition

Neglecting the maintenance requirements can hasten the start of the demolition phase. Addressing the building's maintenance can prolong the design life of the building.

C 2. Progressive Weakening

- Corrosion - steel
- Moisture penetration – roof, walls
- Insect damage - timber
- Biological degradation – timber
- Root penetration – foundations, walls
- Air pollution - concrete
- Sunlight UV – paint, pipes, plastic gutters
- Heat – paint, curing concrete
- Soil chemistry – foundations

C 3. Use Strong and Durable Materials

1. Use compacted concrete and grout.
2. Protect reinforcement with adequate concrete cover.
3. Use strong blocks and mortar.
4. Use suspended ground floor slabs or slabs supported on well compacted fill on rock.
5. Use treated timber.
6. Use stainless steel straps and fixings.
7. Use stainless steel or bronze hinges.
8. Use cleaned and cemented schedule 80 PVC pipes externally.

C 4. Protect Vulnerable Elements

1. Use paint with fungicide (eg. Trowel Plastic).
2. Seal all open spaces (around pipes, around openings, between rafters.)
3. Install roof gutters and discharge stormwater away from foundations.
4. Seal joints and paint all exposed timbers.
5. Apply waterproofing agent (Vandex, Penetron, Xypex) to basement walls, and install a drain.

C 5. Inspections

Building Elements	Maintenance Inspections	Maintenance Activities
❑Timber floor ❑Timber walls ❑Timber roof framing structure	❑Inspect the timbers for insect damage, wet rot, splitting, loose joints, bleeding, twisting and warping. ❑Inspect the timber joints for looseness, corroded metal connections, damaged connections, and splitting at connections. ❑Inspect the walls for racking and misalignment. Inspect floors for excessive deflection.	❑Treat the ground for termites every 5 years. ❑Strengthen or replace damaged timbers. ❑Treat mildly corroded metal connectors. ❑Replace severely corroded metal connectors. ❑ Ensure that the timbers with evidence of wet rot are not exposed to water.

Building Elements	**Maintenance Inspections**	**Maintenance Activities**
Block walls	Inspect the walls for cracks, misalignment, rising damp, and fungus.	Obtain Engineering advice.
RC slabs RC beams RC columns	Inspect the RC members for cracks, sandy surface, spalling (blow outs), rust stains, and exposed reinforcement.	Obtain Engineering advice.
Roof covering	Inspect the ceiling for water damage. Inspect the roof covering for corrosion, excessive wear. Inspect the connections for missing connectors, corroded connectors, loose connectors.	Replace damaged roof covering and connections.

D. SUCCESSFUL CONTRACTING

D. SUCCESSFUL CONTRACTING

D.1 Review drawings

Layout drawings should contain enough information for the builder to, inter alia (among other things):

1. Set out the building.
2. Locate all walls (including manholes and wells).
3. Locate all windows and door openings.
4. Identify the heights of walls, openings, ceilings and roofs.
5. Locate electrical fixtures, switches, and panels.
6. Locate plumbing fixtures.
7. Obtain all plumbing and electrical fixtures.
8. Obtain all floor, wall, ceiling, and roof finishes.
9. Build/obtain all cabinets (bathroom, kitchen, pantry, bedroom), doors and windows.

D.2 Builder's Responsibilities

The builder must determine, inter alia, the quality of materials, including concrete and rebar strength, and:

1. foundation types, sizes, and reinforcement.
2. foundation wall thicknesses and reinforcement.
3. slab thicknesses and reinforcement.
4. above grade wall reinforcement.
5. beam sizes and reinforcement.
6. roof framing.
7. plumbing and electrical pipe sizes and slopes.

Home

D.3 Before you submit your quotation

(If you fail to plan, then you plan to fail.)

1. Study the drawings and identify any missing information from D.1 that you are responsible for.
2. Overlay a grid, and identify any offset dimensions that you cannot calculate.
3. Request all missing information from the Client.
4. Identify any information from D.2 that you are uncomfortable with and seek expert assistance.
5. Get a competent plumber, electrician, and finishers and obtain their quotes.

D.4 Economical Building Tips

1. Have easily verifiable setting out dimensions.
2. Investigate the ground before designing the foundation.
3. Reduce rafter spacing to 500 mm (20”).
4. Use a hipped roof shape.
5. Compare Porcelain 2^{nd} choice tiles’ cost.
6. Try laying tiles diagonally.
7. Use Stainless Steel straps and nails.
8. Use 32” wide doors for later wheelchair access.

9. Obtain quotes for pre-cast floors (reduced formwork).
10. Compare Granite counter-top cost.
11. Set kitchen counter at a comfortable height.
12. Use deep kitchen sinks.
13. Use ring beams to support windows and doors.
14. Compare the cost of laminated glass.
15. Try exterior paint with fungicide.
16. Design something special and unique.
17. Use screw type electrical light bases.

18. Add fibermesh to concrete floors and mortar.
19. Use best quality plumbing pipes and connections outside (Schedule 80).
20. Watch plumber (should test pipes, use pipe cleaner, cement, quarter turn, then hold pipe)
21. Watch electrician (should cap pipes, cement pipe connections, have uniform switch and fixture levels)
22. Reduce the amount of bridging interest.
23. Add bridging interest to building cost when budgeting.
24. Include adjudicator and approved sample maintenance in contract.

Thank you.

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