BRANZ

ISSUE 615 **BULLETIN**

CRITICAL CONNECTIONS

October 2017

- Critical connections in a building occur where loads are transferred from one structural element to another.
- Failure of a connection is likely to result in loss of structural integrity.
- This bulletin describes critical connections of timber-framed buildings and the fixings required to meet design loads.

1 INTRODUCTION

1.0.1 Loads imposed on buildings are transferred through framing via load paths. The connections between elements within a load path are critical to a building's structural integrity. If connections fail, load transference will not occur, and the building (or part of it) may fail.

1.0.2 Critical connection locations are:
- roof framing
- roof to wall
- wall and wall to floor/subfloor
- subfloor to foundation (suspended timber floor).

1.0.3 NZS 3604:2011 *Timber-framed buildings* specifies connections at the critical areas of timber-framed buildings. It gives fixing capacities in kilonewtons (kN) to allow manufacturers to develop proprietary fixings that meet or exceed NZS 3604:2011 requirements.

1.0.4 This bulletin outlines the critical connections for light timber-framed buildings and explains where the required fixing type and capacity can be found in NZS 3604:2011.

2 TYPES OF CONNECTIONS

2.0.1 Connections consist of:
- connectors such as straps, hangers, angles, plates and cleats
- fasteners such as nails, screws and bolts.

2.0.2 Tables in NZS 3604:2011 specify connections based on timber size, span, moisture and exposure levels, wind zone and light or heavy claddings.

2.0.3 Conditions outside the scope of NZS 3604:2011 require specific engineering design.

2.0.4 NZS 3604:2011 uses letters to identify each type of fixing (Figure 1).

2.0.5 Table 1 describes fixing types, alternative fixing capacities and the tables in the standard where they can be found. Fixings in each colour-shaded group can be used in the same location but may have different fixing capacities.

2.0.6 Each fixing type has a capacity based on the configuration of the connection, load direction (e.g. gravity or uplift) and the in-service environment (wet or dry). There may be situations where the fasteners are the same but have different capacities. For example, fixing types I and O both use 2/M12 bolts but the fixing capacities are rated differently. Fixing type I connects a ridge beam to its supporting studs for use in dry internal environments, while fixing type O is for exposed situations (wet) to connect a veranda beam to post connections.

3 ROOF FRAMING AND ROOF-TO-WALL CONNECTIONS

3.1 RAFTER CONNECTIONS

3.1.1 Figures 2–5 describe rafter connections.

Table 1. Fixing type and capacity reference guide (from NZS 3604:2011 Table 2.2[1]).

Fixing type	Description (and NZS 3604:2011 figure reference)	Alternative fixing capacity (kN)	See NZS 3604:2011 table
A	2/90 x 3.15 end nails	0.7	8.18
B	2/90 x 3.15 end nails + 2 wire dogs	4.7	
C	2/90 x 3.15 end nails + strap fixing (see Figure 8.12)	8.5	
D	4/90 x 3.15 end nails + 2 strap fixing (double stud)	16.0	
E	2/90 x 3.15 skew nails + 2 wire dogs	4.7	10.1, A10.1, 10.7, A10.7, 10.11, A10.11, 10.14, 10.15, 15.6, A15.6, 15.10, A15.10
F	2/90 x 3.15 skew nails + strap fixing (see Figure 10.6)	7.0	
G	10/90 x 3.15 nails (5 each side)	4.7	10.2, A10.2, 15.7, A15.7
H	1/M12 bolt	8.5	
I	2/M12 bolts	16.0	
J	2/M16 bolts	24.0	
K	6/90 x 3.15 nails	3.0	10.5, A10.5
L	2/M12 bolts	9.8	
M	2/M16 bolts	13.0	
N	6/100 x 4.0 HDG nails (hand-driven)	4.7	10.8, A10.8, 15.8, A15.8
O	2/M12 bolts (see Figure 9.3(C))	6.8	
P	2 HDG 'flat' straps (see Figure 9.3(B))	13.7	
Q	2 HDG 'tee' straps (see Figure 9.3(A))	25.5	
R	1/90 x 3.15 nail	0.55	10.10, A10.10, 10.12, 15.9, A15.9
S	2/90 x 3.15 nails	0.8	
T	1/10 g self-drilling screw, 80 mm long	2.4	
U	1/14 g self-drilling type 17 screw, 100 mm long	5.5	

Note: Capacities are associated with fixing type, not fasteners. See individual selection tables for the appropriate fixing type for the application.

3.1.2 NZS 3604:2011 Table 10.1(a) specifies fixing types for ordinary and hip rafter connections and types, based on rafter size, spacing and span, as follows:
- Type E = 2/90 x 3.15 mm skew nails plus two wire dogs (4.7 kN capacity).
- Type F = 2/90 x 3.15 mm skew nails plus strap fixing as shown in NZS 3604:2011 Figure 10.6 (7.0 kN capacity).

3.1.3 NZS 3604:2011 Table 10.1(b) specifies 4.7 kN fixings (type E) for valley rafter connections based on rafter size, spacing and span.

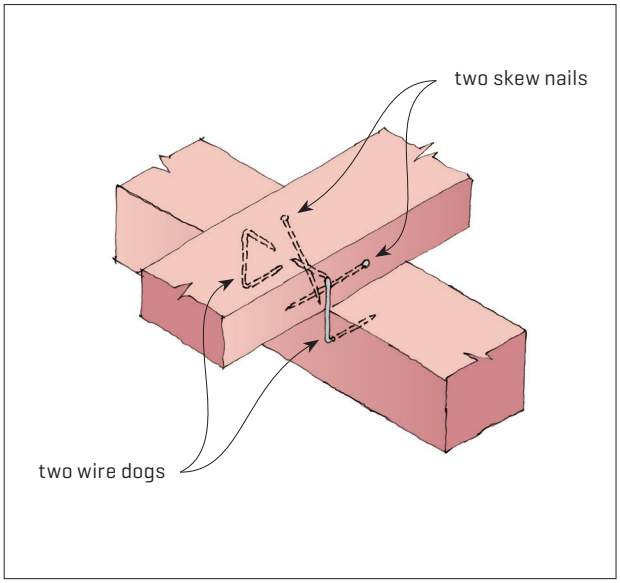


Figure 1. Type E fixing.

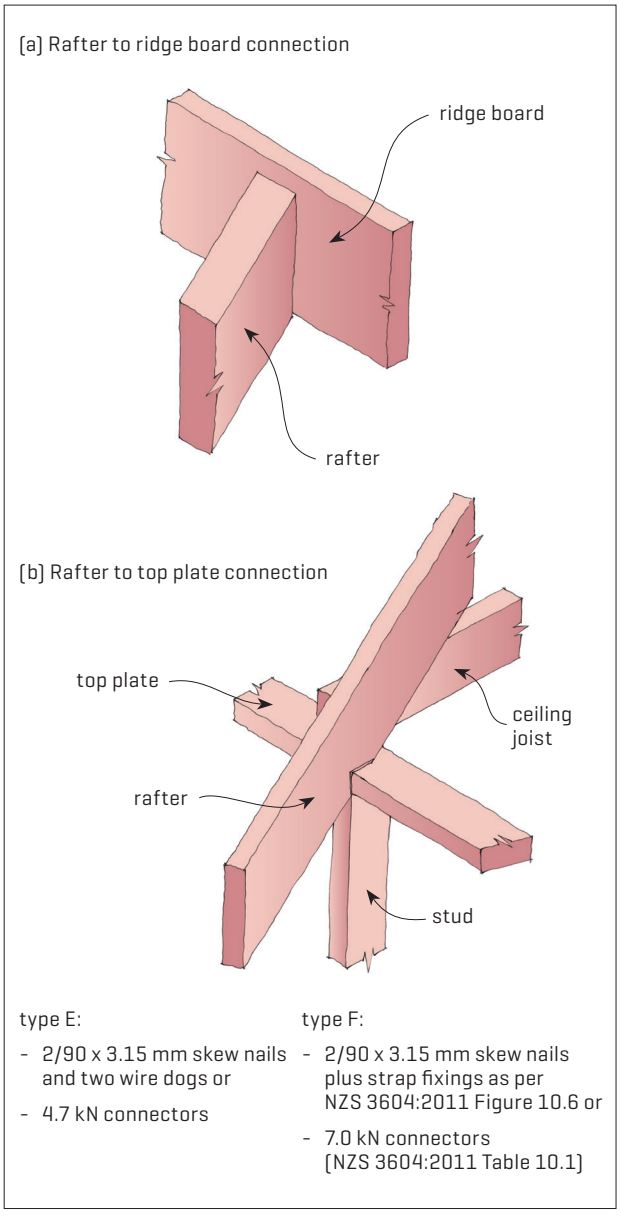


Figure 2. Rafter to ridge board and top plate connections.

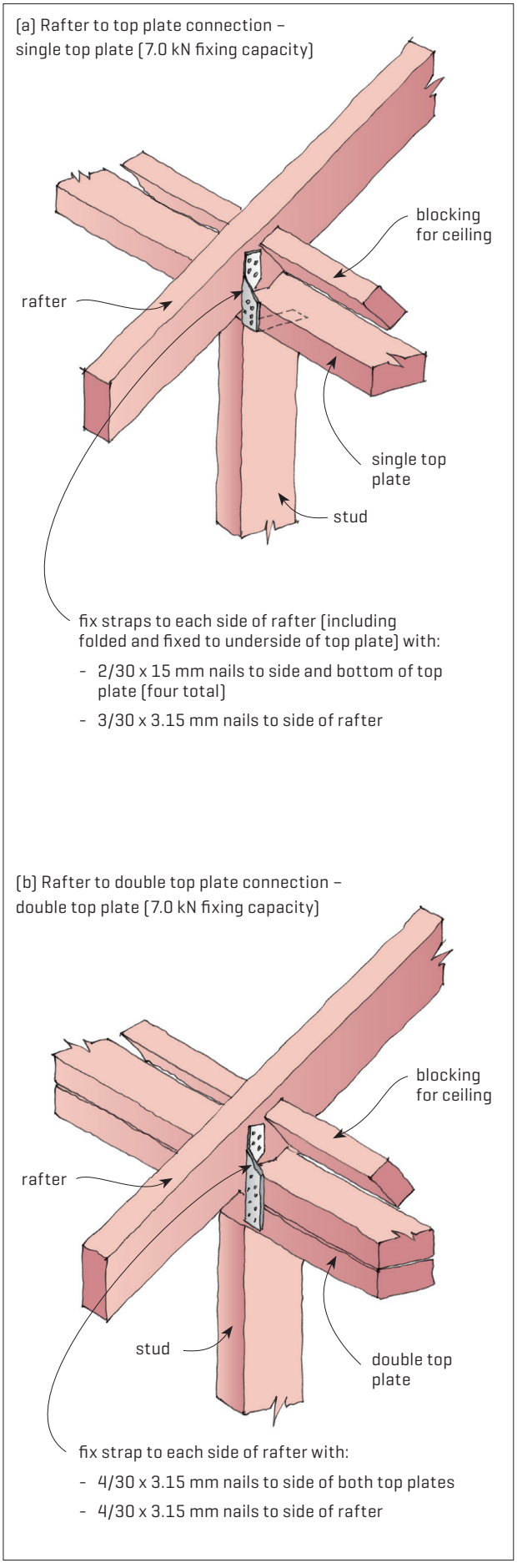


Figure 3. Fixing straps to rafters.

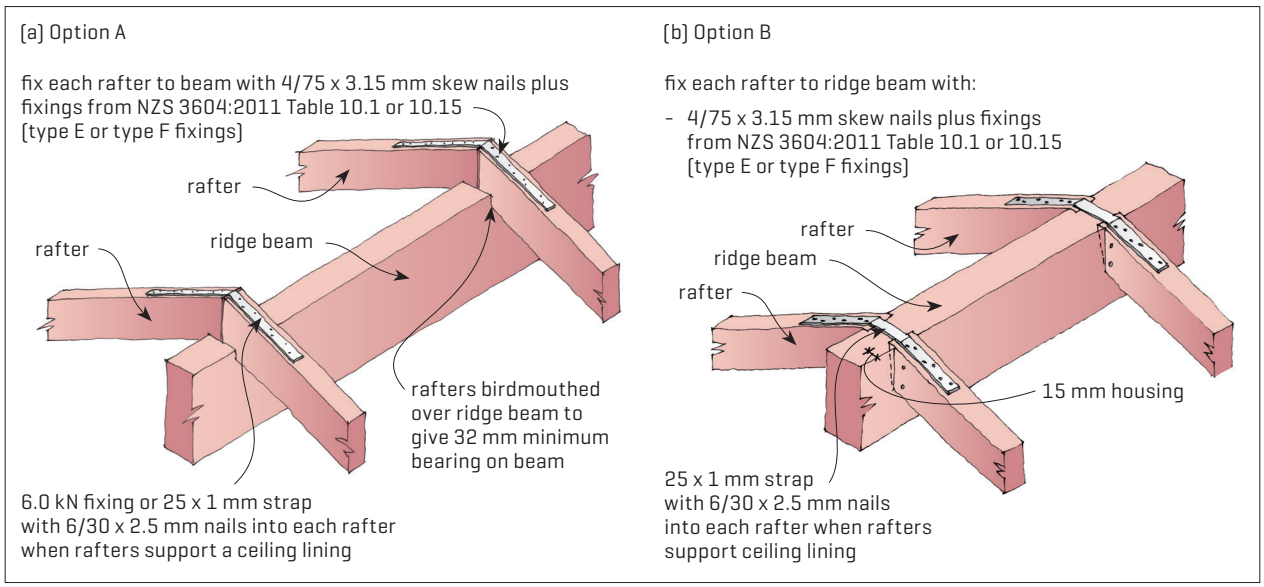


Figure 4. Rafter to ridge beam connections from NZS 3604:2011 Figure 10.5.

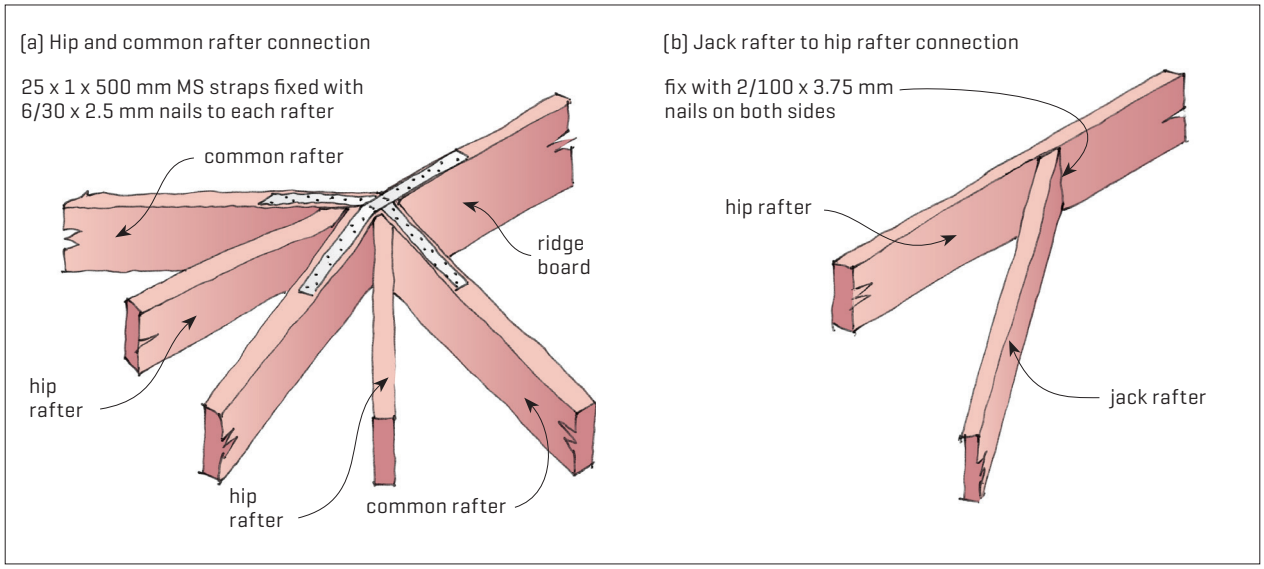


Figure 5. Rafter to rafter connections.

3.2 ROOF TRUSS CONNECTIONS

3.2.1 NZS 3604:2011 provides fixing types and capacities (Figure 6) for a maximum roof truss reaction of 16.0 kN in up or down directions. Where loads are greater, truss connections require specific engineering design.

3.3 RIDGE BEAM SUPPORT

3.3.1 End support and resistance to uplift for ridge beams must be provided by gable end wall framing or internal posts (Figure 7).

3.4 UNDERPURLINS, STRUTS AND STRUTTING BEAMS

3.4.1 Underpurlins support rafters at an intermediate point along their length. They are supported by underpurlin struts or strutting beams, which are supported off internal loadbearing walls.

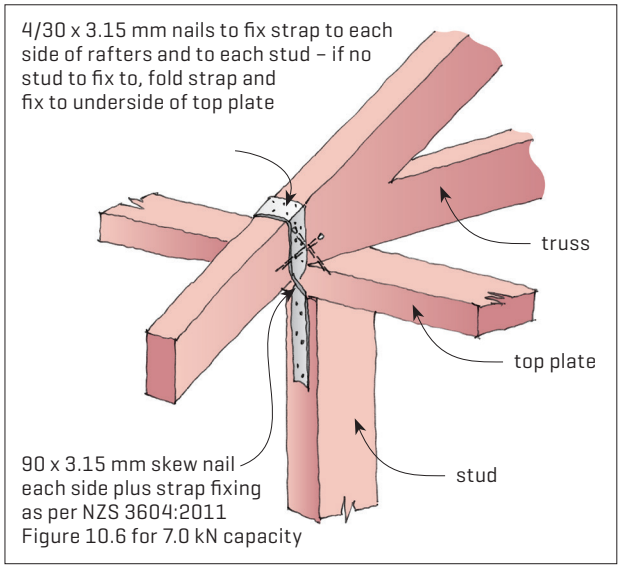
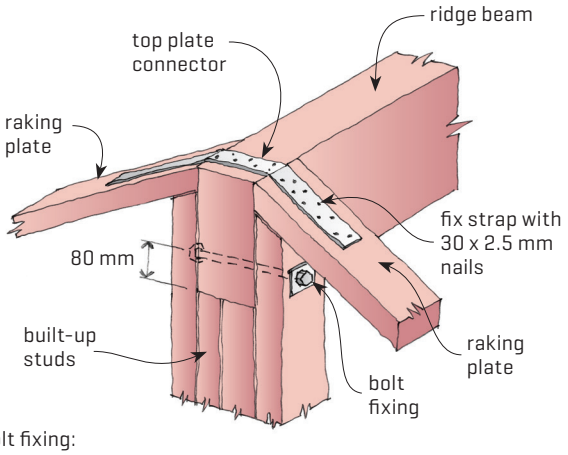


Figure 6. Truss to single top plate showing type F connection (NZS 3604:2011 Table 10.14, 10.15 and Figure 10.6).



bolt fixing:
- type H: 1/M12 bolt (8.5 kN)
- type I: 2/M12 bolts (16.0 kN)
- type J: 2/M16 bolts (24.0 kN)

(Note: bolt fixings include 50 x 50 x 3 mm washers)

Figure 7. Ridge beam to wall connection (NZS 3604:2011 Table 10.2).

3.4.2 NZS 3604:2011 Table 10.5 provides details for underpurlin sizes, spans, loaded dimensions and fixings. Table 10.5 describes fixing types L and M. These use M12 and M16 bolts, which are not shown in Figures 10.11 and 10.12.

3.4.3 NZS 3604:2011 Table 10.7 and Figure 10.13 describe the fixings for strutting beams.

3.5 OUTRIGGERS AND FLYING RAFTERS

3.5.1 Overhanging gables are vulnerable to wind uplift forces. NZS 3604:2011 clause 10.2.1.15 describes the requirements for cantilevered purlins or outrigger framing but it contains some errors.

3.5.2 BRANZ *Build* 142 'Constructing timber outriggers' provides alternative tables adapted from Table 10.9 in NZS 3604:2011 and clarifies the following:
- Table 10.10 fixings for purlins on the flat are suitable for the cantilever distances given in 10.2.1.15.2(a).
- For 10.2.1.15.2(b), use Table 10.9 for purlins on edge when cantilevered, not Table 10.8(a).
- For 10.2.1.15.3, use Figure 10.16(B), not Figure 10.16(A).
- For 10.2.1.15.3(a), use Figure 10.16(B), not Figure 10.17.

3.6 PURLINS AND TILE BATTENS

3.6.1 Purlins or tile battens span across and are fixed to rafters or trusses.

3.6.2 Tile batten spacing is determined by tile size (400 mm maximum spacing) while purlin spacings are based on roof cladding span and rafter spacing. Graded timber must be used for purlins, while battens can be ungraded.

3.6.3 NZS 3604:2011 Tables 10.10 and 10.11 give purlin sizes and fixings to rafters and trusses. Figure 10.20(B) gives fixings for purlins laid over sheet sarking or ceiling sheet lining material that is 20 mm maximum thick.

3.6.4 NZS 3604:2011 clause 10.2.1.16.7 states that tile batten sizes and fixings should be taken from Table 10.12. Do not use Tables 10.10 and 10.11 as referenced in clause 10.2.1.16.5.

3.7 ROOF BRACING

3.7.1 NZS 3604:2011 fixing requirements for roof bracing are given in Figures 8–13.

3.8 VERANDA POSTS AND BEAMS

3.8.1 Wind uplift forces can be greater on veranda roofs that are open to wind exposure.

3.8.2 NZS 3604:2011 section 9 deals with posts supporting roofs. Table 9.2 gives connection capacities based on the area of roof supported, wind zone and roof cladding weight. Post/beam connection details are shown in Figure 14.

3.8.3 NZS 3604:2011 Table 10.8 sets out veranda beam sizes and fixings for all wind zones based on beam span and loaded dimension.

3.8.4 The post connections in NZS 3604:2011 Tables 9.1 and 9.2 may be applied to carports. The veranda beam table only applies to verandas.

4 WALL AND WALL-TO-FLOOR CONNECTIONS

4.0.1 Wall and wall-to-floor connections resist vertical downwards and upwards and in-plane and out-of-plane loads that occur at studs, lintels and top and bottom plates.

4.1 LINTEL SUPPORT

4.1.1 NZS 3604:2011 Table 8.19 gives lintel to trimmer stud fixing.

4.2 SECURING LINTELS AGAINST UPLIFT

4.2.1 Lintels supporting rafters or trusses may be required to be secured against uplift based on wind zone, loaded dimension and maximum span (NZS 3604:2011 Table 8.14). Fixings to resist uplift are given in Figure 15. The bottom of both trimming studs must be fixed to a concrete floor slab as shown in NZS 3604:2011 Figure 8.12 or with an alternative fixing capacity of 7.5 kN in tension along the line of the trimming stud.

4.3 TOP PLATES

4.3.1 Top plates transfer and distribute loads from rafters and ceiling joists to wall studs.

4.3.2 Top plate fixings (NZS 3604:2011 Table 8.18) are based on roof member spacing, wind zone, roof type and loaded dimension of the wall. In addition, when a truss lands on a top plate more than 150 mm from the face of a stud, fix the strengthener under the top plate as in Figure 16.

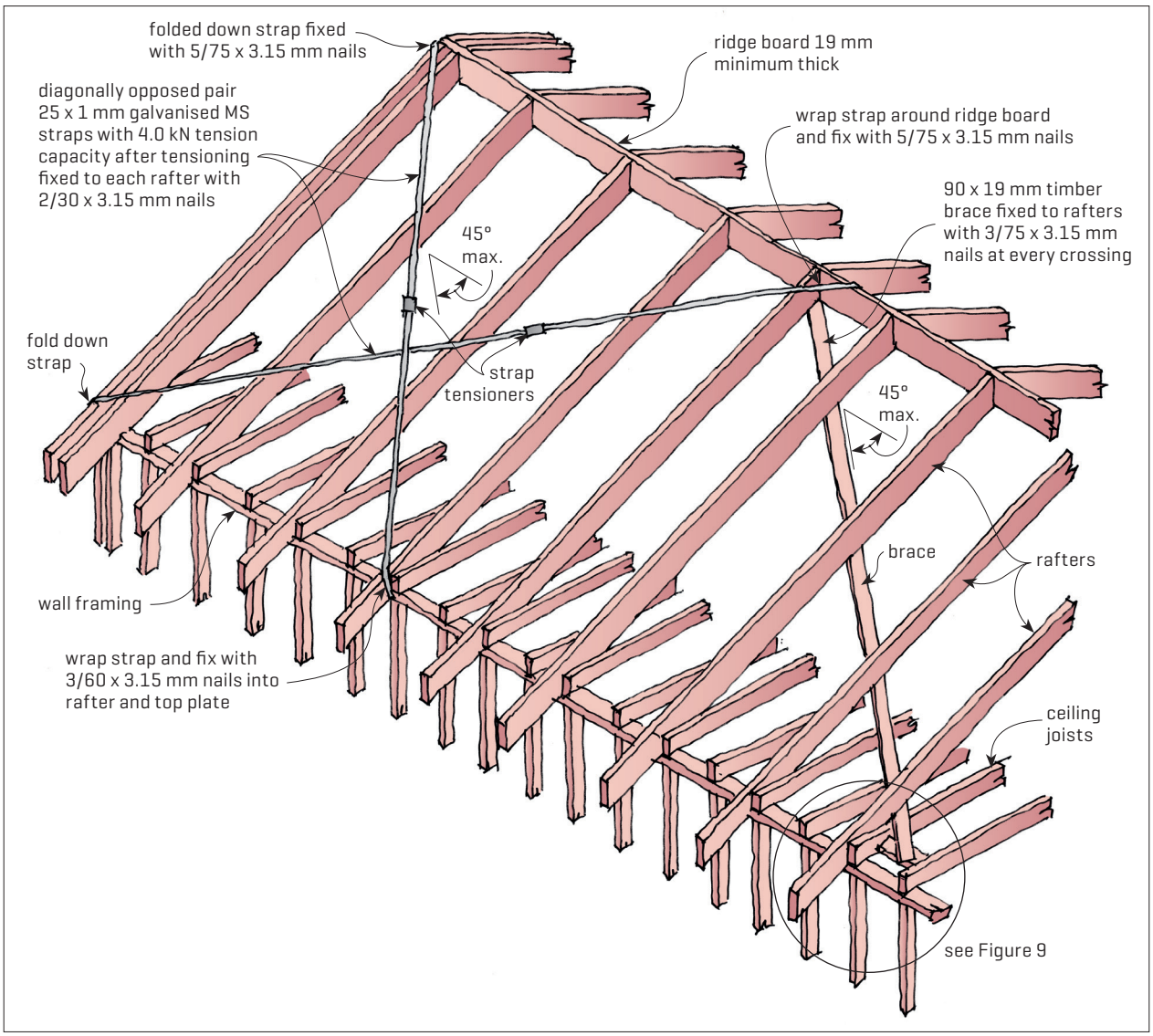


Figure 8. Fixing roof plane bracing.

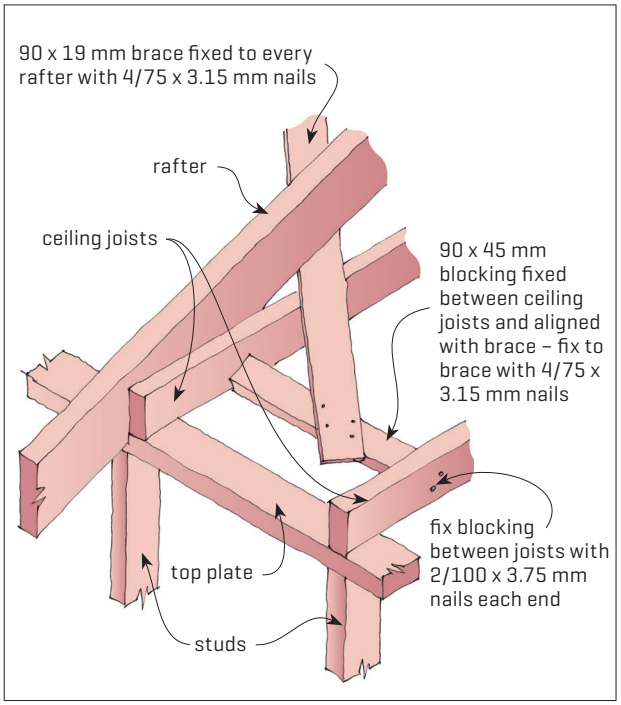


Figure 9. Fixing detail of timber roof plane brace connection to blocking between ceiling joists.

4.4 JOINTS IN TOP PLATES

4.4.1 Joints in top plates must be made over support such as a stud or blocking.

4.4.2 For walls that are not braced, joints may be halved and nailed or butted and nailed over blocking. An alternative fixing must have a 3.0 kN capacity in tension and compression.

4.4.3 For braced walls of single-storey buildings, top plate connections are based on the bracing capacity of the wall (Figure 17).

4.4.4 For braced walls at right angles to each other, top plate connections are as shown in Figure 18.

4.5 DRAGON TIE CONNECTIONS

4.5.1 Dragon ties (NZS 3604:2011 section 8.3.3) are fixed directly to:

- top plates with 3/100 x 3.75 mm hand-driven nails or 5/90 x 3.15 mm power-driven nails
- joist, truss or rafter with 2/100 x 3.75 mm hand-driven nails or 2/90 x 3.15 mm power-driven nails.

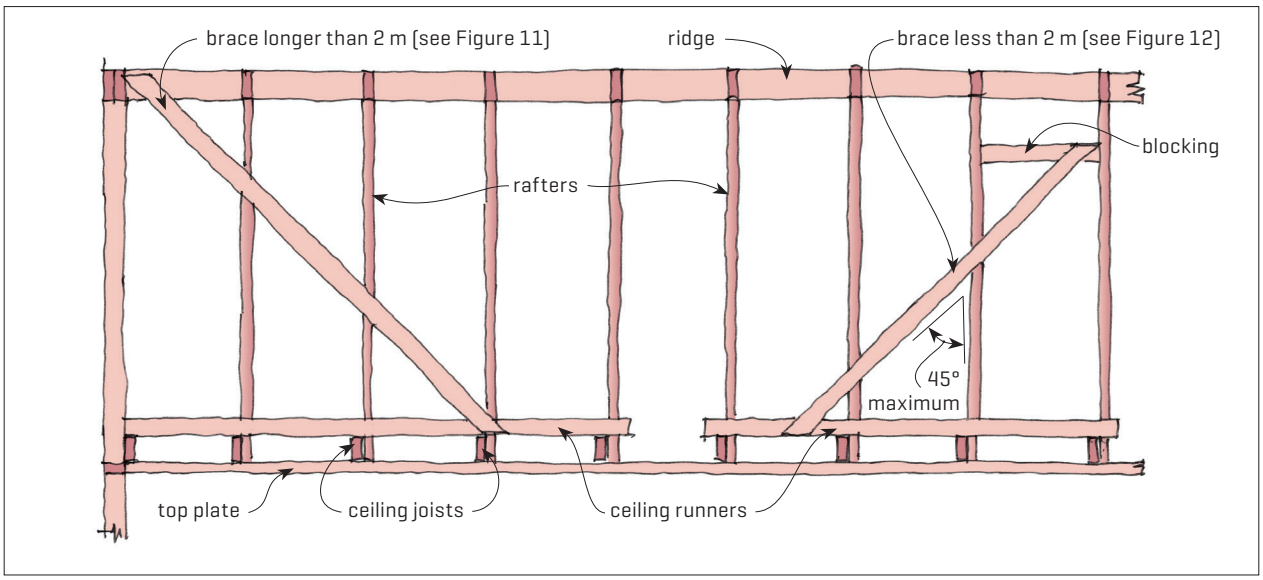


Figure 10. Diagrammatic section of bracing within a roof space.

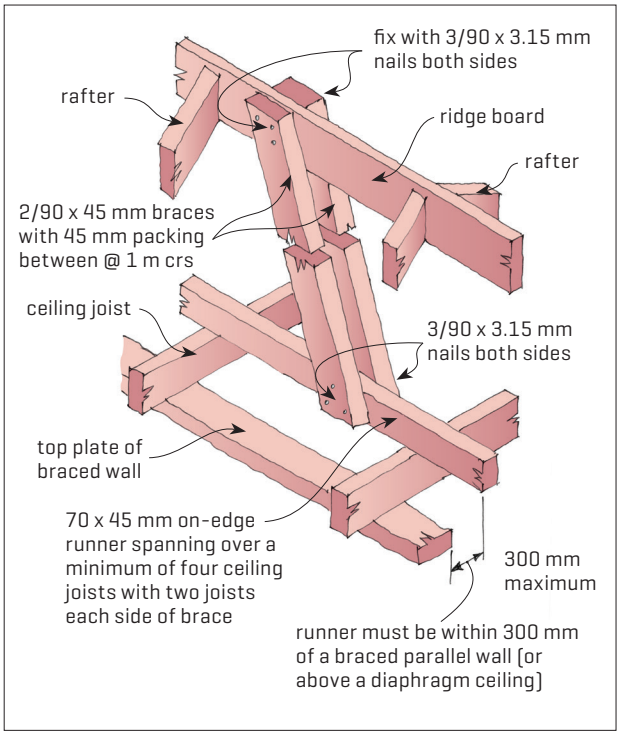


Figure 11. Fixing detail of roof space bracing longer than 2 metres.

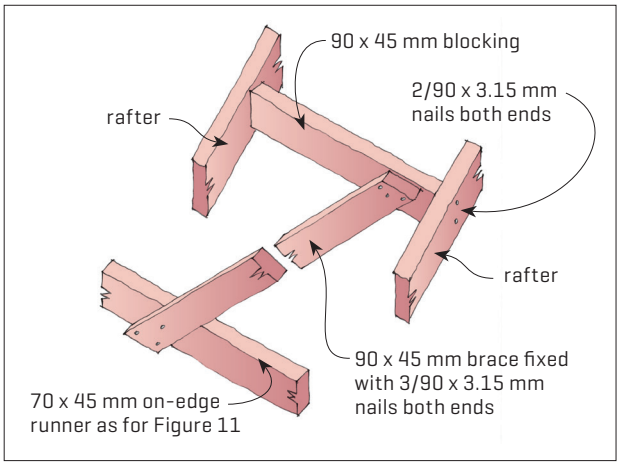


Figure 12. Fixing detail of roof space bracing less than 2 metres.

4.5.2 Fix blocking to the top plate or spanning between joist, truss or rafter with 4/100 x 3.75 mm hand-driven nails, or 6/90 x 3.15 mm power-driven nails.

4.6 CEILING DIAPHRAGM CONNECTIONS

4.6.1 Install ceiling diaphragms (NZS 3604:2011 section 13.5) with nails or screws at:

- 150 mm centres maximum around the diaphragm boundary and sheet perimeter
- 300 mm centres maximum to intermediate supports
- 10 mm minimum from the edge of the sheet.

4.7 BOTTOM PLATES TO CONCRETE SLAB ON GROUND

4.7.1 Bottom plates of walls for slabs on ground must be able to resist uplift forces using cast-in bolts or proprietary anchors.

4.7.2 Cast-in bolts are installed as shown in Figure 19.

4.7.3 Table 2 gives the minimum fixing capacities (NZS 3604:2011 clauses 7.5.12.3 (external walls) and 7.5.12.4 (internal walls)) for proprietary anchors.

Table 2. Minimum holding capacities for proprietary anchors (non-bracing wall).

	Type of force	Capacity (kN)
External walls	horizontal in-plane (along wall)	2.0
	horizontal out-of-plane (across wall)	3.0
	vertical (uplift)	7.0
Internal walls	horizontal in-plane (along wall)	2.0
	horizontal out-of-plane (across wall)	2.0

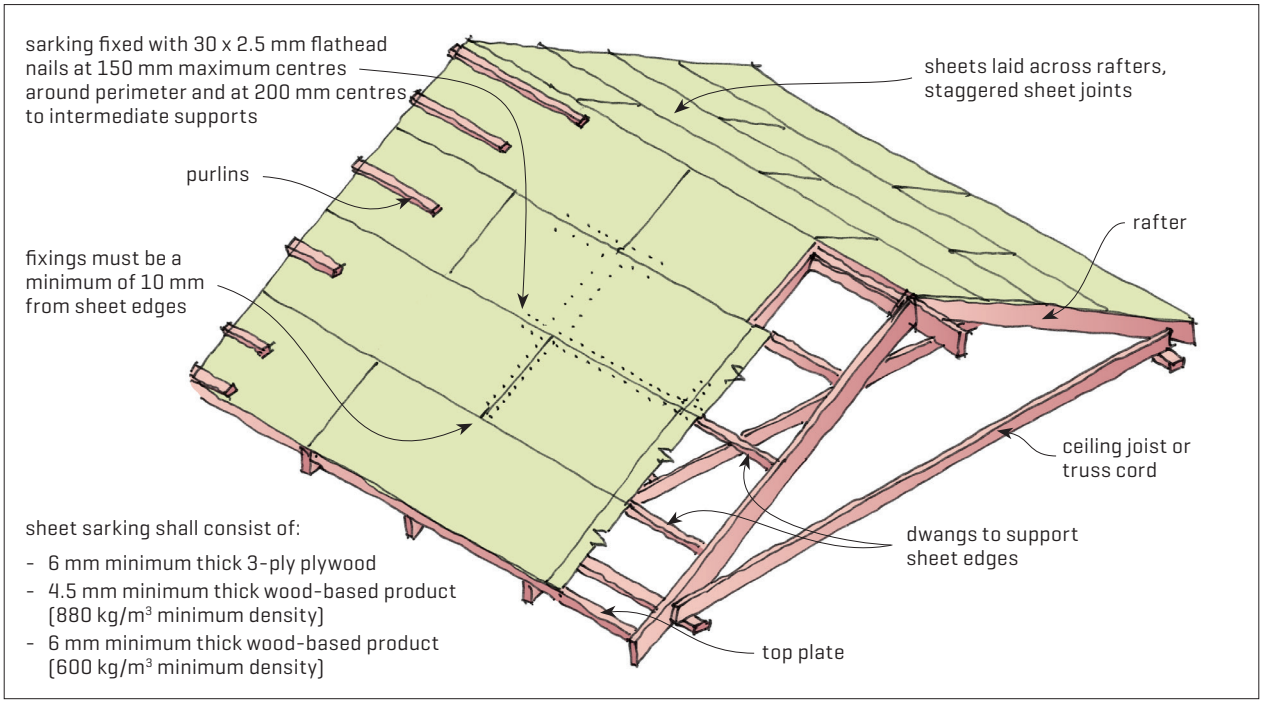


Figure 13. Fixing roof plane bracing using sarking.

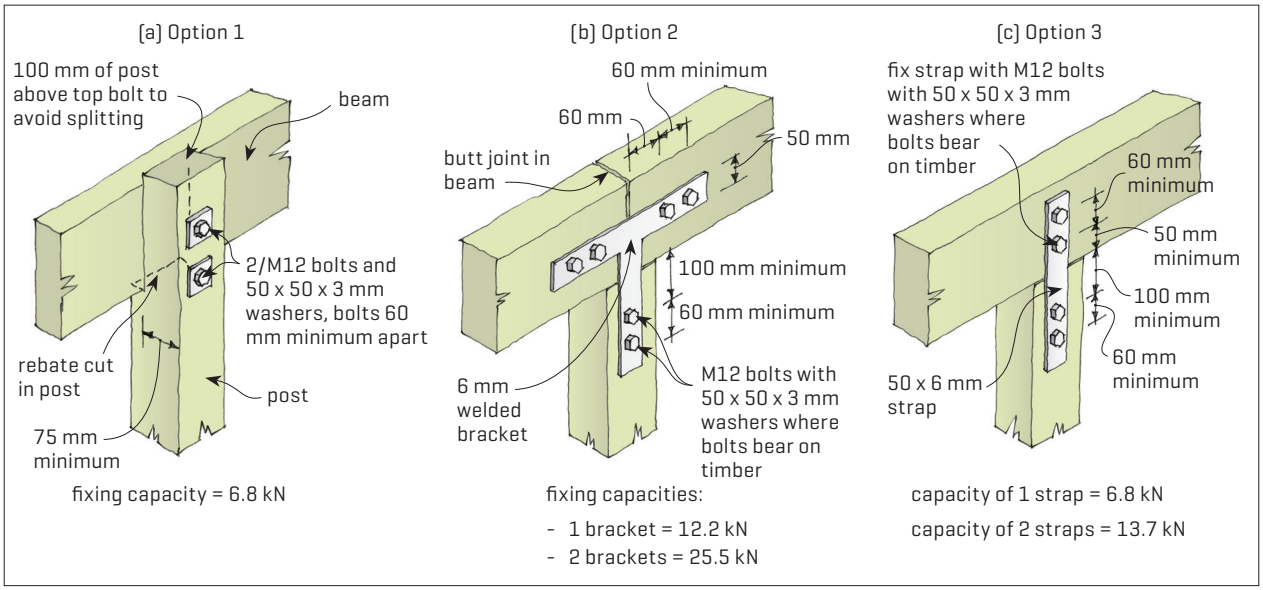


Figure 14. Veranda beam-to-post connections.

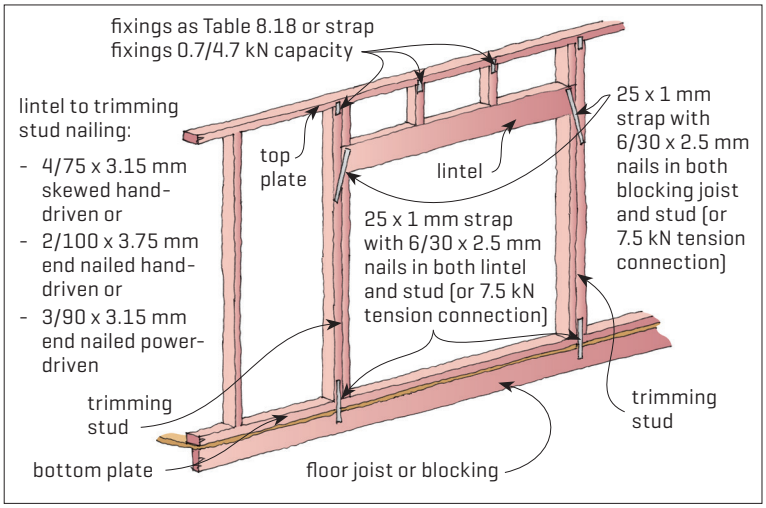


Figure 15. Lintel and trimming stud fixings to resist uplift.

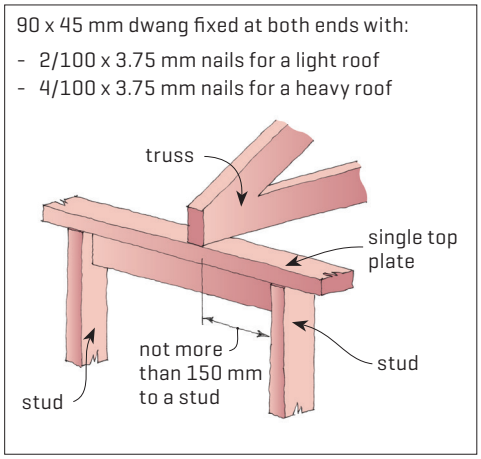
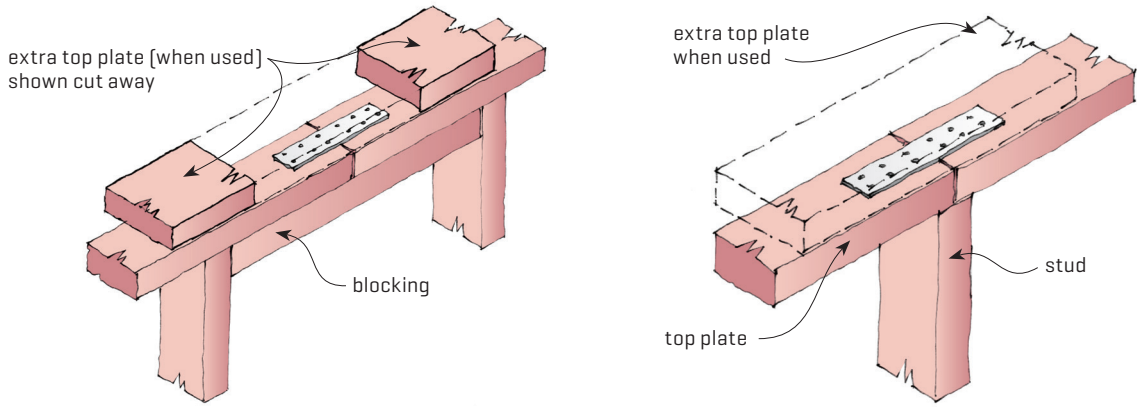
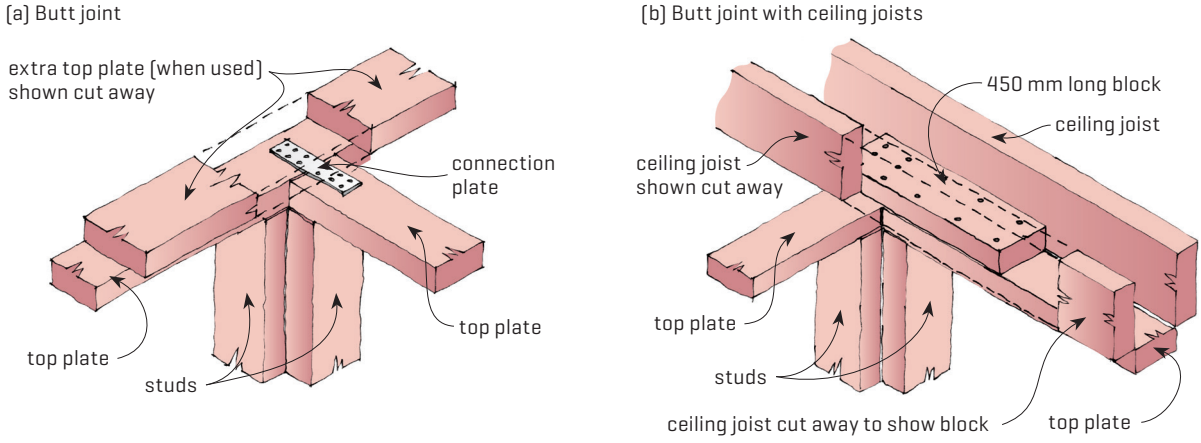


Figure 16. Fixings for top plate strengthened with a dwang (as required by NZS 3604:2011 clause 8.7.1.1(c) and Figure 8.13).



- less than 100 bracing units (BUs) – 3.0 kN capacity connection in tension and compression along the plate
- more than 100 BUs and walls to which ceiling diaphragms are attached – 6.0 kN capacity connection in tension and compression along the plate

Figure 17. Connecting top plates in braced walls.



- total bracing capacity of each wall less than 125 BUs and at least one external wall – 6.0 kN capacity connection
- total bracing capacity of each wall less than 250 BUs and at least two external walls – 6.0 kN capacity connection
- total bracing capacity of each wall more than 250 BUs and at least two external walls – 2.4 kN per 100 BUs

Figure 18. Connecting top plates in braced walls at right angles.

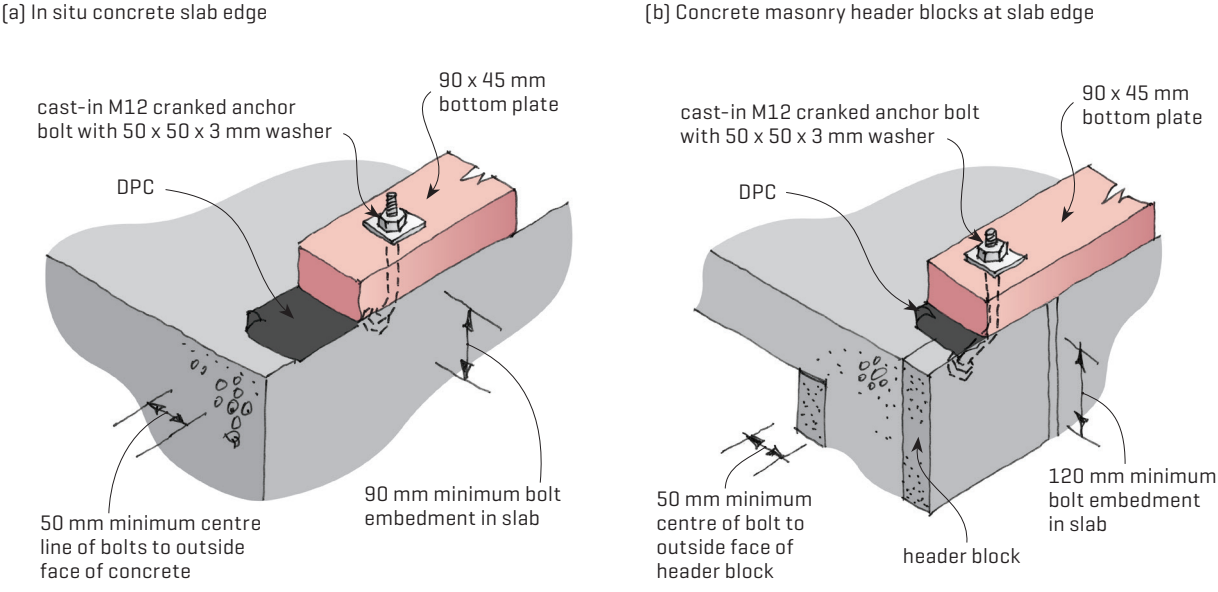


Figure 19. Cast-in bolts

4.7.4 Proprietary anchors must be installed at 900 mm centres maximum where the slab edge is in situ concrete and 600 mm centres maximum where it is concrete masonry header blocks. Anchors should be no more than 150 mm from each end of every plate.

5 SUBFLOOR-TO-FOUNDATION CONNECTIONS

5.0.1 Suspended timber floor structures must resist downwards and uplift vertical loads and horizontal or lateral loads.

5.1 PILE CONNECTIONS

5.1.1 Ordinary pile connections against gravity and uplift are shown in Figure 20.

5.1.2 Cantilever pile connections:

- Pile to bearer (timber and concrete) – 6.0 kN capacity connection in both horizontal directions parallel and perpendicular to the bearer.
- Timber pile to bearer – bearer seated on rebated pile and fixed with M12 bolt or 12 mm diameter threaded rod and 50 x 50 x 3 mm washers (70 mm minimum of timber pile cross-section must remain to support bolt).
- Bearer to joist (closest to cantilever pile) – 6.0 kN minimum horizontal capacity in both directions at right angles to one another.

5.1.3 Braced pile connections are shown in Figure 21. Where joists are parallel to the brace and the brace is attached to the:

- pile – attach the two floor joists immediately above the upper end of the brace with 6.0 kN minimum capacity connections in the horizontal direction to brace
- joist – use Figure 21(b) connection.

5.1.4 Anchor pile connections to:

- bearers and joists – M12 bolts or 12 mm diameter threaded rod with 50 x 50 x 3 mm washers or minimum 12.0 kN capacity connections in tension and compression
- bearers only – M12 bolts or 12 mm diameter threaded rod with 50 x 50 x 3 mm washers or minimum 12.0 kN capacity connections in tension and compression.

5.2 JOISTS TO BEARERS

5.2.1 Joists are connected to bearers with 2/100 x 3.75 mm hand-driven skew nails or 3/90 x 3.15 mm power-driven skew nails.

5.3 WALL PLATES TO FOUNDATION WALLS

5.3.1 Wall plates may be fixed to foundation walls as follows:

- Cast-in M12 bolts with 50 x 50 x 3 mm washers, embedded at least 75 mm into the concrete, cranked (bent), spaced at maximum 1.4 m centres and no more than 300 mm from the end of the plates at the corners.
- Cast-in R10 steel rods bent at least 90°, embedded at least 75 mm into the concrete, spaced at maximum 900 mm centres and no more than 300 mm from the end of the plates at the corners.
- Proprietary anchors complying with NZS 3604:2011 clause 7.5.12.2 (150 mm from each end of plate and spaced at 600 mm centres maximum).

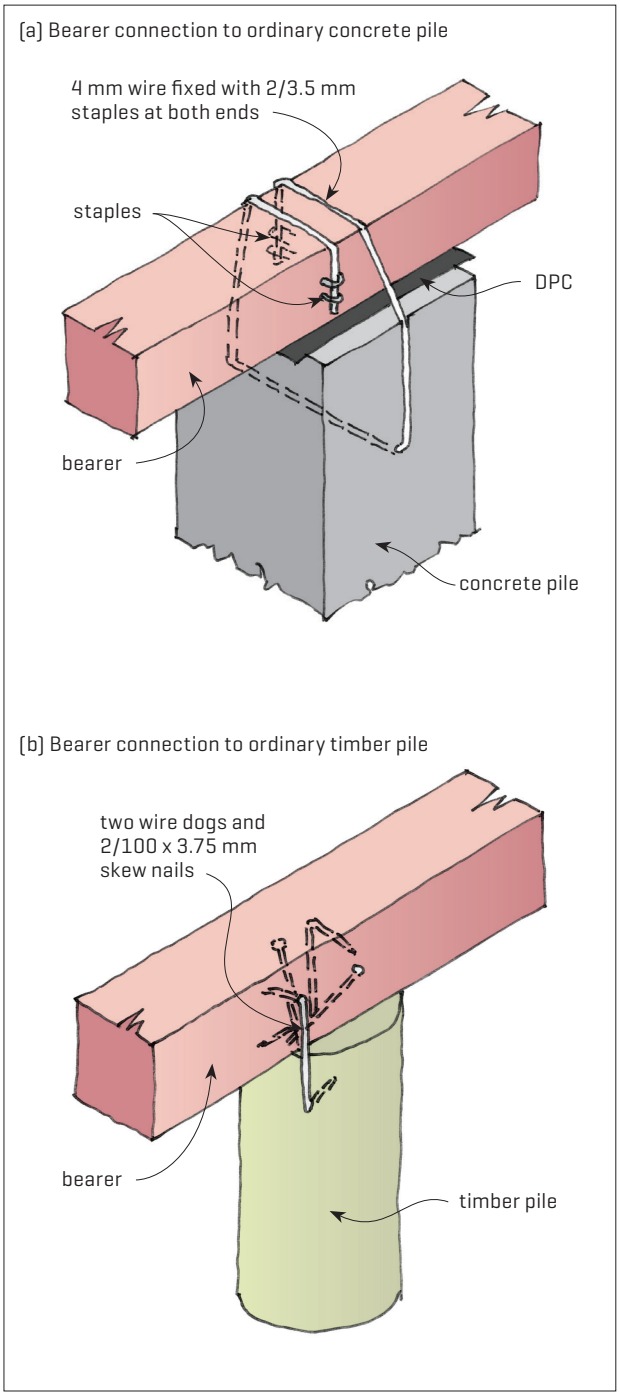


Figure 20. Ordinary pile-to-bearer connections.

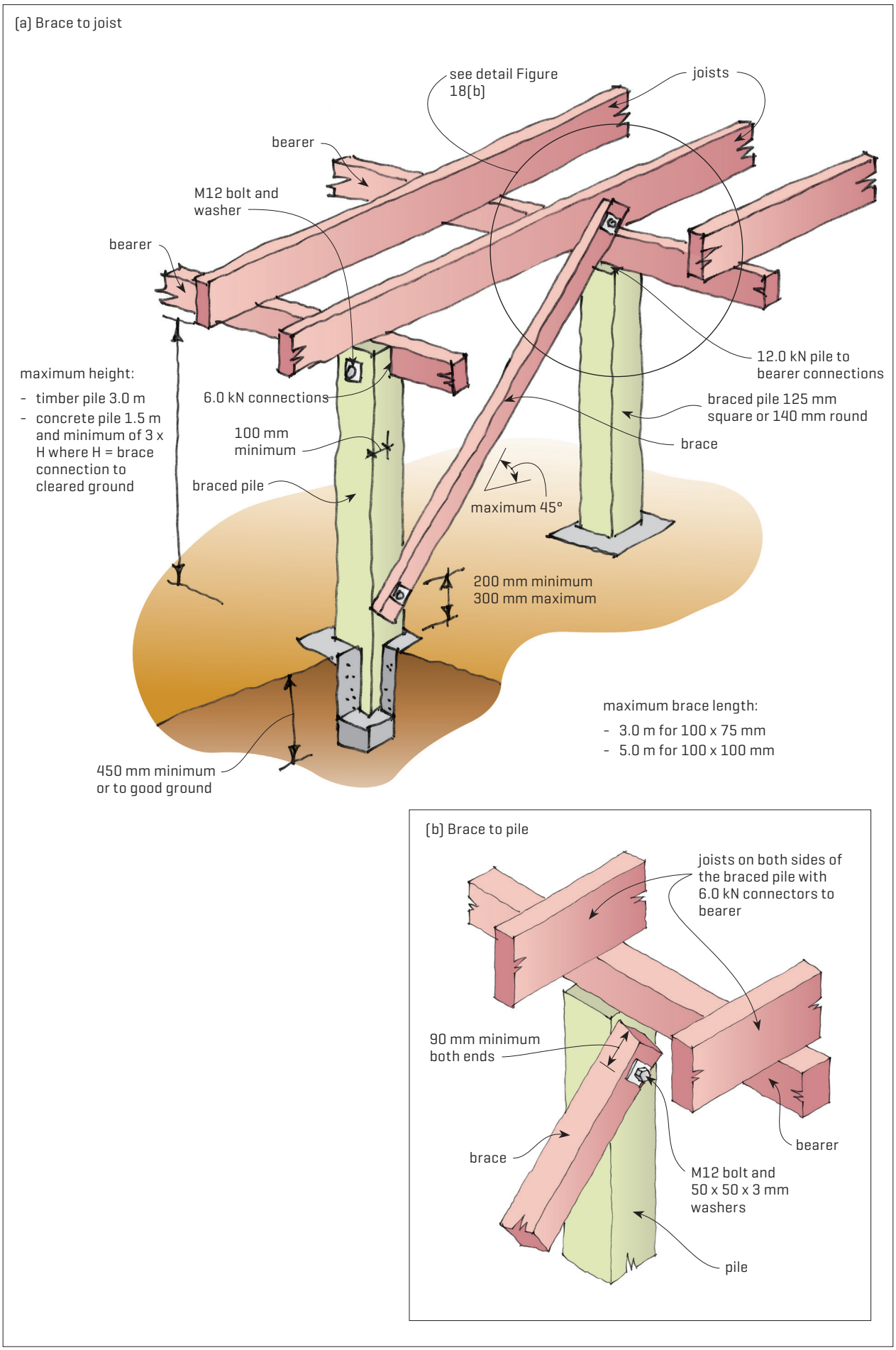


Figure 21. Braced pile connections.

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