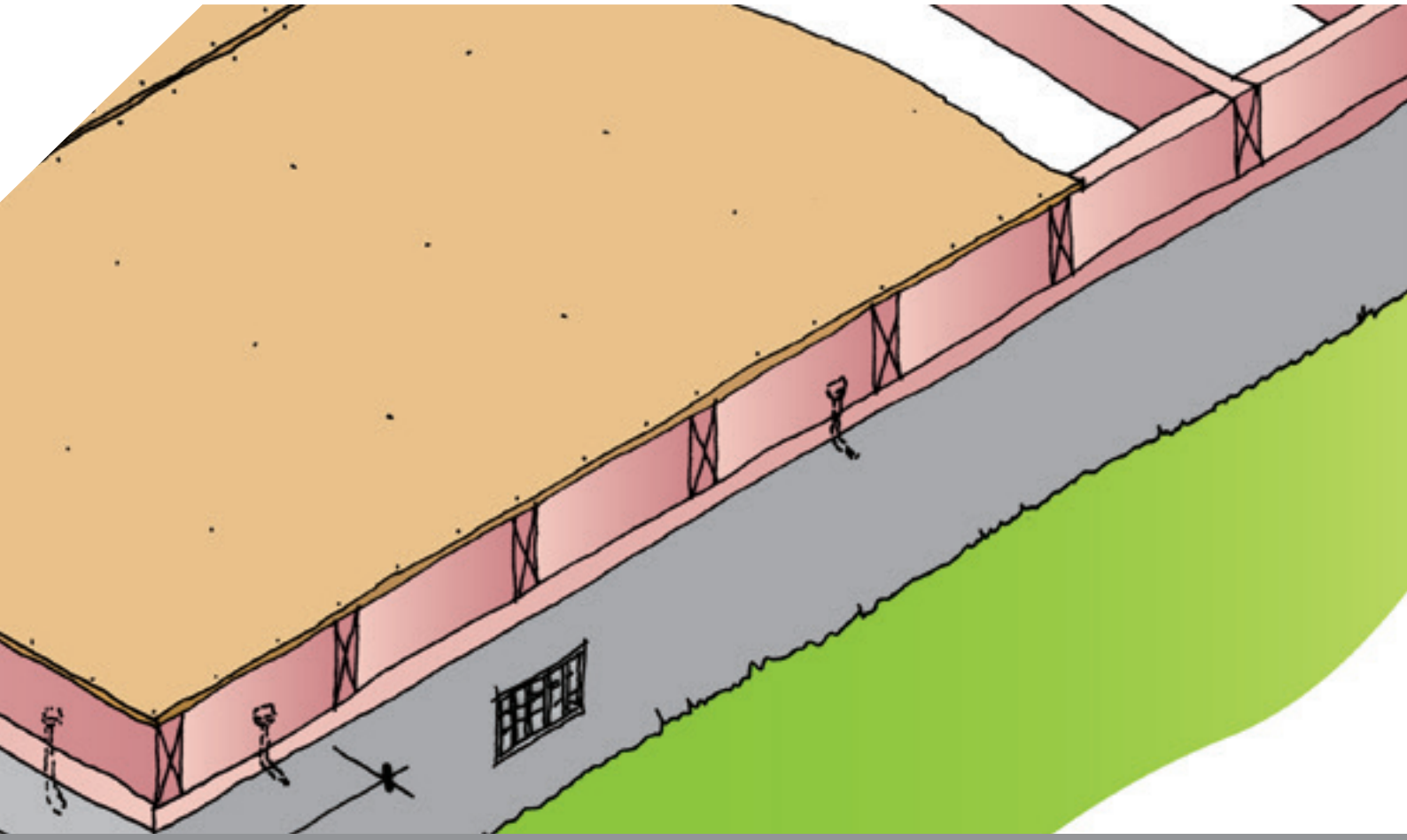
BRANZ

ISSUE 617 BULLETIN



SUBFLOOR AND ROOF BRACING IN NZS 3604:2011 BUILDINGS

December 2017

- Wind and earthquakes can generate significant forces on a building.
- Bracing demand must be calculated and sufficient bracing incorporated into a building so that the structure can withstand these forces.
- This bulletin describes the bracing for subfloors and roofs of buildings within the scope of NZS 3604:2011 *Timber-framed buildings*.

1 INTRODUCTION

1.0.1 Wind and earthquakes can generate significant forces on a building. Bracing must be calculated, designed and incorporated into the building to withstand these forces.

1.0.2 This bulletin uses the methodology in NZS 3604:2011 *Timber-framed buildings*. The clause and table references throughout this bulletin apply to that standard. This is a manual method using values from the tables in NZS 3604:2011. Buildings outside the scope of NZS 3604:2011 require specific engineering design.

1.0.3 Wall bracing is covered in Bulletin 616 *Wall bracing in NZS 3604:2011 buildings*. The two bulletins should be read together.

2 GENERAL CONSIDERATIONS

2.0.1 Bracing design typically involves three steps:
- Gathering key information about the building, the site, and for wind, the surrounding landforms.
- Establishing bracing demand by determining the worst-case demand for wind and earthquake.
- Selecting bracing systems and locating bracing elements to meet or exceed demand.

2.0.2 Bracing design is an iterative process. As the design develops, bracing line placement and bracing systems may need to be adjusted to achieve the best solution.

2.0.3 NZS 3604:2011 section 5 provides information to establish bracing demand for wind and earthquake loads. Section 6 covers foundation and subfloor bracing, while section 10 covers roof bracing. Specific requirements for subfloor and roof bracing are given in clauses:
- 6.7 – cantilever piles
- 6.8 – braced piles
- 6.9 – anchor piles
- 7.3 – floor diaphragms
- 10.3 – systems to resist horizontal loads (roofs)
- 10.4.2 – roof plane diagonal braces
- 10.4.3 – roof space diagonal braces.

2.1 BRACING LINES

2.1.1 Bracing lines are imaginary lines running along and across the building to determine wall and subfloor bracing. Bracing lines normally run parallel to external walls. They are used to help locate subfloor bracing elements and to ensure that bracing is evenly distributed across the subfloor.

2.1.2 Subfloor bracing lines must be spaced at 5 m maximum. However, subfloor bracing is always along lines of piles, which must be located within 200 mm of a loadbearing or bracing wall in the floor above.

3 SUBFLOOR BRACING

3.0.1 The designer:
- selects the foundation system – slab on ground or suspended timber floor
- selects the subfloor system that is suited to the floor height above ground – for example, anchor piles can't be used if the pile height is more than 600 mm
- decides on the bracing system – a combination of perimeter foundation wall, floor diaphragm, cantilever piles, braced piles and anchor piles
- determines the layout of the subfloor structure
- positions the bracing lines
- determines bracing demand for wind (Table 5.5) and earthquake (Table 5.8)
- distributes the bracing evenly on the bracing lines, along and across the building
- provides bracing capacity to meet (or exceed) the bracing demand in both directions
- specifies all subfloor elements.

3.1 SUSPENDED FLOORS GENERALLY

3.1.1 The bracing demand for suspended floors (rather than a concrete floor that is in direct contact with the ground) must be specifically calculated. For suspended floors, the seismic weight of the building is supported by a relatively flexible subfloor structure, which can be up to 3 m high.

3.1.2 Experience has shown that suspended floors with perimeter foundation walls (Figure 1) perform well in earthquakes. However, NZS 3604:2011 allows suspended floors supported solely by piles as long as sufficient resistance to lateral loads is provided by anchor, cantilevered or braced piles.

3.1.3 Requirements for piles used as subfloor bracing elements are given in section 6 of NZS 3604:2011. For durability requirements, refer to section 4 of NZS 3604:2011.

3.1.4 Driven timber piles (clause 6.6) may be used as cantilever piles or braced piles.

3.1.5 Cantilever piles (clause 6.7 of NZS 3604:2011 and Figure 2 below) are driven piles that have:
- maximum height above cleared ground of 1.2 m
- no pile within a 6 m wide strip of building plan area more than twice as high above cleared ground level as any other pile within that area.

3.1.6 The bracing capacity of a cantilever pile is 70 bracing units (BU) for wind and 30 BU for earthquake (see Table 5.11 of NZS 3604:2011).

3.1.7 Location of piles must also take account of the location of loadbearing or bracing walls above – lines of piles must be within 200 mm of such walls.

3.1.8 Pile-to-bearer fixings:
- must be 6 kN minimum capacity in a horizontal direction both parallel and perpendicular to the bearer or
- the cantilever pile must be notched to accept the bearer, with an M12 bolt and 50 x 50 x 3 mm hot-dip galvanised washers.

3.1.9 The floor joist closest to a cantilever pile must be fixed to the bearer with fixings of 6 kN minimum capacity in both directions.

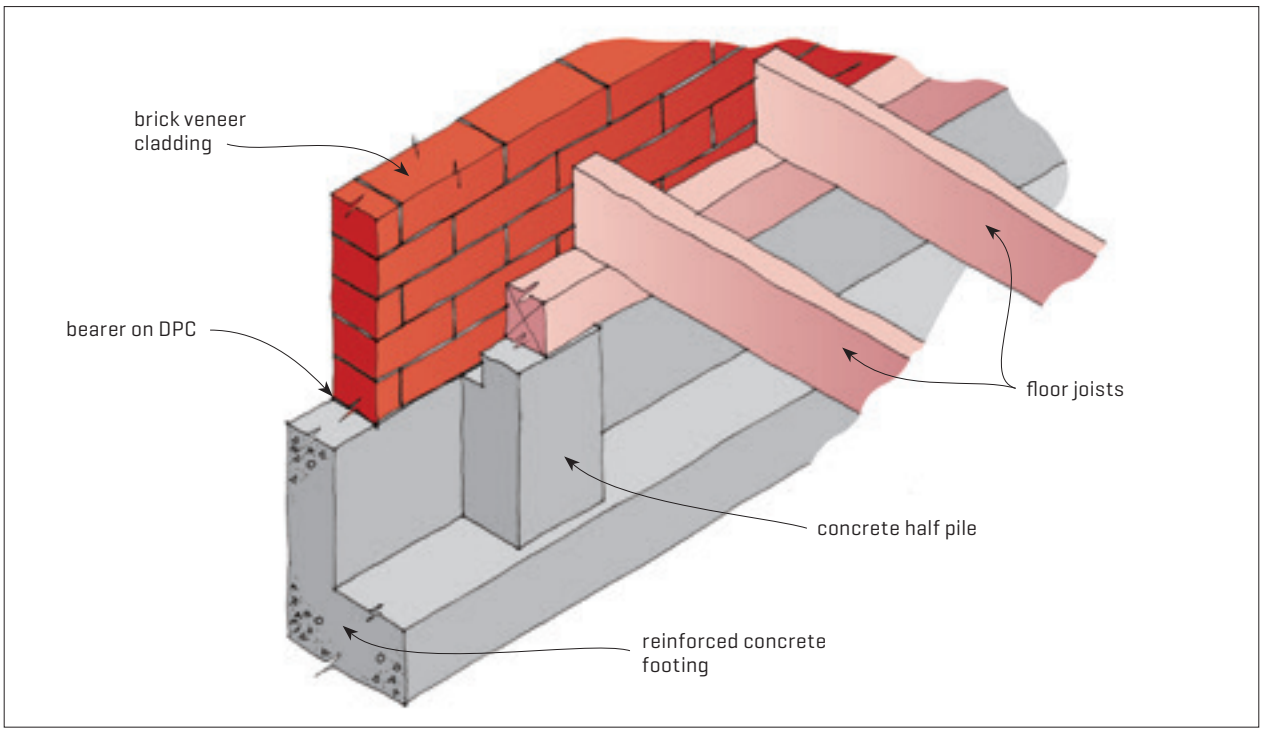


Figure 1. Suspended floor structure with semi-detached or half piles integrated into continuous foundation wall.

3.2 BRACED PILE SYSTEMS

3.2.1 A braced pile system (clause 6.8) is a pair of piles connected by a single diagonal brace. A braced pile system may be repeated as a series of braced piles with the braces sloping in the same direction.

3.2.2 The brace is fixed to the bottom of one pile and either:
- the top of the other braced pile or
- a bearer within 200 mm of the top of the other pile or
- a joist within 200 mm of the top of the other pile.

3.2.3 To avoid overloading the pile-bearer fixing, only one brace may be attached to the top of a pile. To avoid overloading the pile footing, two braces may be attached to the bottom of a pile only if they are at right angles to each other and not in line.

3.2.4 The bracing capacity of a braced pile system is 160 BU for wind and 120 BU for earthquake.

3.2.5 Braced pile footings are:
- 450 mm deep x 350 x 350 mm if square piles or 400 mm diameter for round piles or
- driven piles.

3.2.6 The maximum height of a braced pile is 3 m above cleared ground level for timber and 1.5 m if concrete or masonry. The minimum height is 3 times the distance from cleared ground level to the lower brace fixing.

3.2.7 Clause 6.8.3 defines the requirements of the braces:
- They must be a continuous length of timber.
- Braces 3 m or less – 90 x 70 mm.
- Braces 5 m or less – 90 x 90 mm.
- Angle of brace – 10–45° (or 6° minimum if the brace is connected to a bearer or joist).
- Lower end no closer than 150 mm to cleared ground.

3.2.8 Clause 6.8.4 sets out the brace connection requirements. The brace must be connected at each end by an M12 bolt or an alternative fixing with a minimum capacity of 17 kN in both tension and compression along the brace. Specific requirements vary depending on whether the brace is fixed to a pile, joist or bearer.

3.3 ANCHOR PILES

3.3.1 Anchor piles (clause 6.9) may be connected to a bearer only or to a joist and a bearer. Fixings are:
- M12 bolts with 50 x 50 x 3 mm square washers or 55 mm diameter x 3 mm round washers or
- an alternative fixing with a capacity of 12 kN in both tension and compression along the bearer or joist.

3.3.2 The bracing capacity of an anchor pile is 160 BU for wind and 120 BU for earthquake.

3.3.3 Controlling dimensions (from cleared ground level) for anchor piles are:
- maximum height to the highest fixing – 600 mm
- minimum height – 300 mm (or 150 mm if a DPC is used between the pile and the bearer)
- minimum depth to underside of footing – 900 mm
- minimum footing thickness – 100 mm.

3.4 FLOOR DIAPHRAGMS

3.4.1 Clause 7.3 of NZS 3604:2011 covers the use of ground and upper floor diaphragms to distribute horizontal loads (Figures 3 and 4). Criteria include the following:
- Maximum length – 12 m.
- Aspect ratio (length divided by width) – 2:1 or less (for example, no larger than 12 x 6 m). (NZS 3604:2011 does allow 2.5:1 for single storey.)
- The perimeter must be directly connected to wall or subfloor bracing elements.

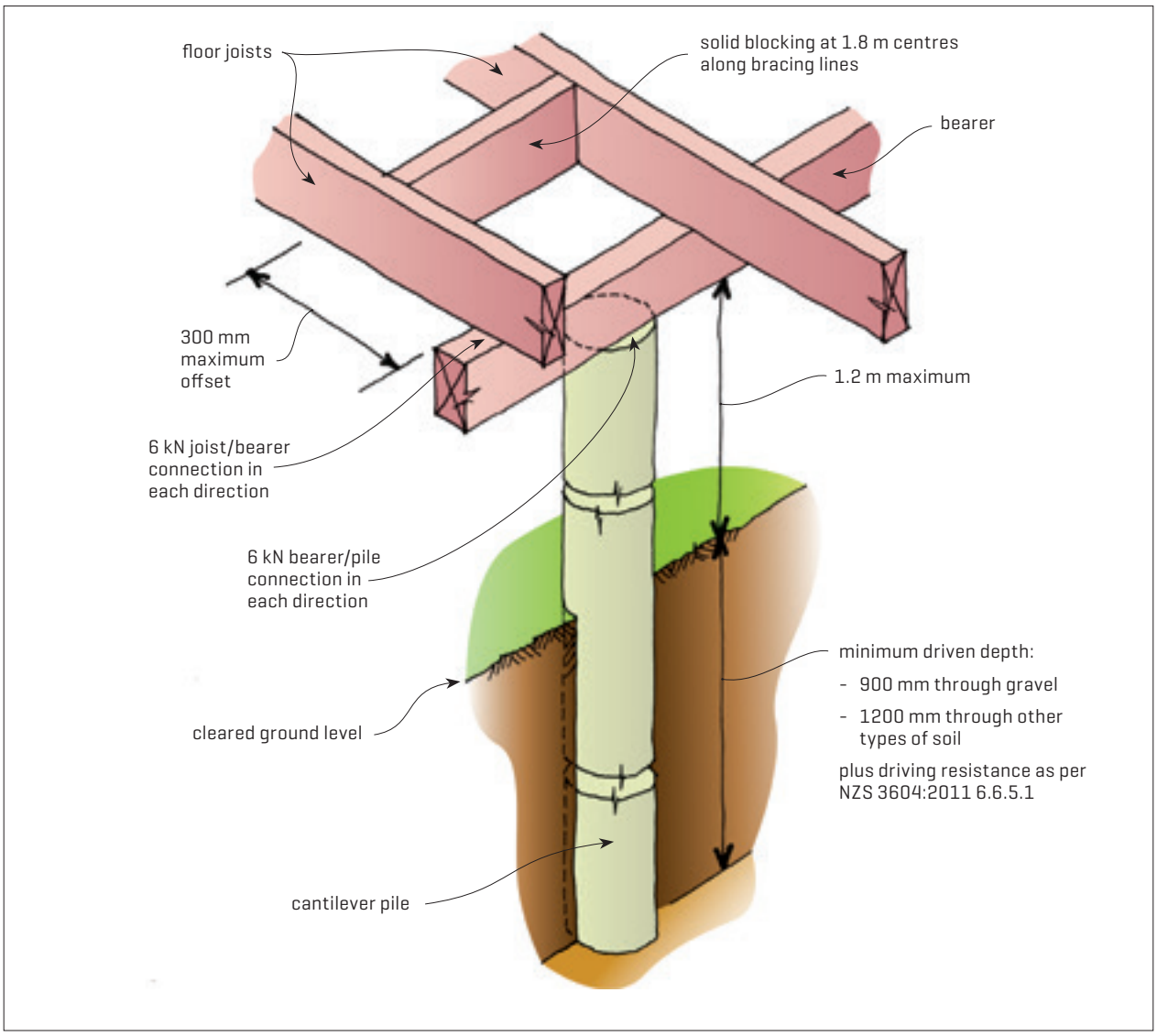


Figure 2. Cantilever piles.

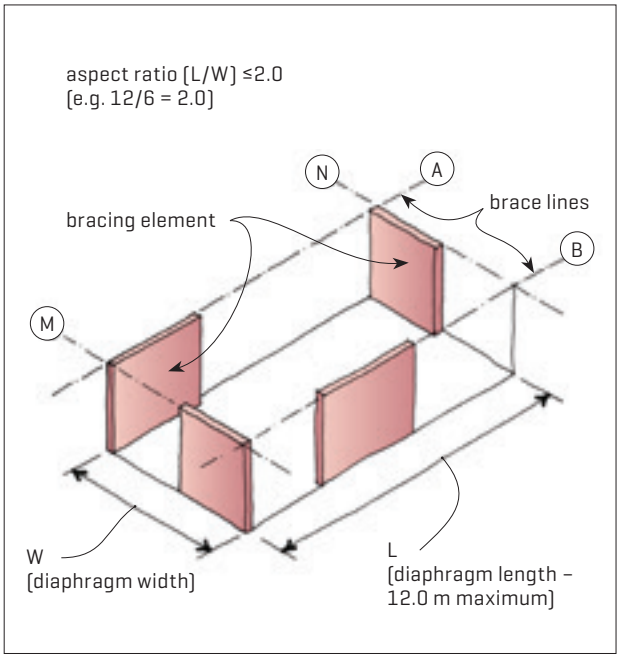


Figure 3. Bracing lines supporting diaphragms.

- For upper floors – be connected to braced external walls with a bracing capacity the greater of 100 BU or 15 BU/m length of diaphragm. Alternatively, a first-floor diaphragm of a 3-storey building must be supported by a full storey height reinforced concrete masonry wall.
- For 1-storey buildings, a ground floor diaphragm must be supported either by a continuous foundation wall or an evenly distributed perimeter pile bracing system.
- For 2-storey buildings, the ground floor diaphragm must be supported by a continuous foundation wall as specified in paragraph 5.5.3.2(a).
- Cut-outs such as stairwells are not permitted – where required, they must be specifically designed.
- Where two diaphragms are connected to the same bracing line, the bracing capacity of that line must be greater than the sum of the required capacity of each diaphragm.
- Paragraph 7.3.1 specifies minimum requirements for flooring material, sheet size and fixings, joist support and subfloor connections and foundation wall design.

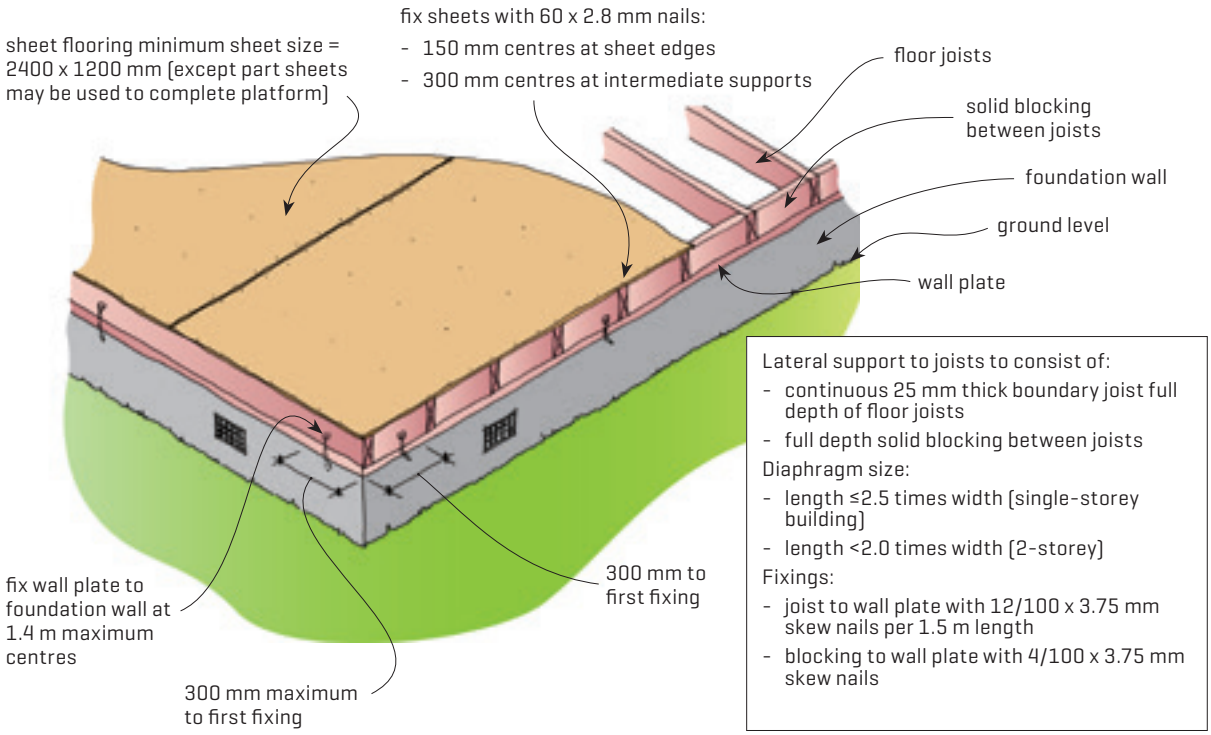


Figure 4. Floor diaphragms.

3.5 CEILING DIAPHRAGMS

3.5.1 Clause 13.5 of NZS 3604:2011 covers the use of sheet material ceiling diaphragms to distribute horizontal loads (Figures 5 and 6). Requirements include:

- a length not exceeding twice its width measured between supporting bracing elements
- a rectangular shape with no cut-outs (protrusions are permitted)
- a maximum dimension (NZS 3604:2011 clause 13.5.2) depending on the ceiling material, density and thickness, roof weight and diaphragm slope
- a minimum sheet size of 1800 x 900 mm except where building dimensions prevent their use.

3.5.2 Ceiling diaphragms do not need to be horizontal but must be continuous over the whole area. Any change in pitch (such as at a ridge or coved ceiling) is a break in continuity. See clause 8.7.3.3(c) and Figure 8.15 for top plate connections to transfer diaphragm loads into supporting walls.

4 ROOF BRACING

4.0.1 Roof plane and/or roof space bracing will be required except for:

- truss and framed roofs with sarking complying with NZS 3604:2011 clause 10.4.4
- a structural ceiling diaphragm complying with clause 13.5 and directly connected to the rafters
- roof planes less than 6 m² (such as porches or dormers)
- roofs with pitch <5° that are not used as decks, for egress or as roof gardens
- monopitch skillion roofs where the raked wall frames and the ridge wall frame extend and are braced up to the underside of the rafters and the ceiling lining is attached directly to the underside of the rafters.

4.1 MINIMUM ROOF BRACING REQUIREMENTS

4.1.1 Table 10.16 of NZS 3604:2011 summarises the minimum roof bracing requirements for roof areas, including any overhangs. It should be used for gable and hip roofs and monopitch roofs where the ceiling is not directly attached to the rafters.

4.1.2 Roof cladding is relevant to the calculation of bracing demand because heavier claddings create greater seismic bracing demand. The weight of a roof cladding (and sarking where used) is assessed as:

- light: <20 kg/m² (such as profiled metal roofing)
- heavy: >20 kg/m² and up to 60 kg/m² (such as concrete or clay tiles or slate).

4.1.3 Diagonal braces (roof plane or roof space) are required for:

- light roof: one for each 50 m² of roof area
- heavy roof: one for each 25 m² of roof area.

4.2 ROOF PLANE BRACES

4.2.1 Hip and/or valley braces for framed roofs:

- can be a full-length hip or valley, which is equivalent to one timber roof plane brace
- must be run as one continuous length of timber from top plate to the ridge
- must come as a minimum of two (NZS 3604:2011 Table 10.16 requires three, but this is an error)
- must be fixed in accordance with Table 10.1(b) of NZS 3604:2011 for valley fixings
- must be fixed in accordance with Table 10.1(a) of NZS 3604:2011 for hip fixings.

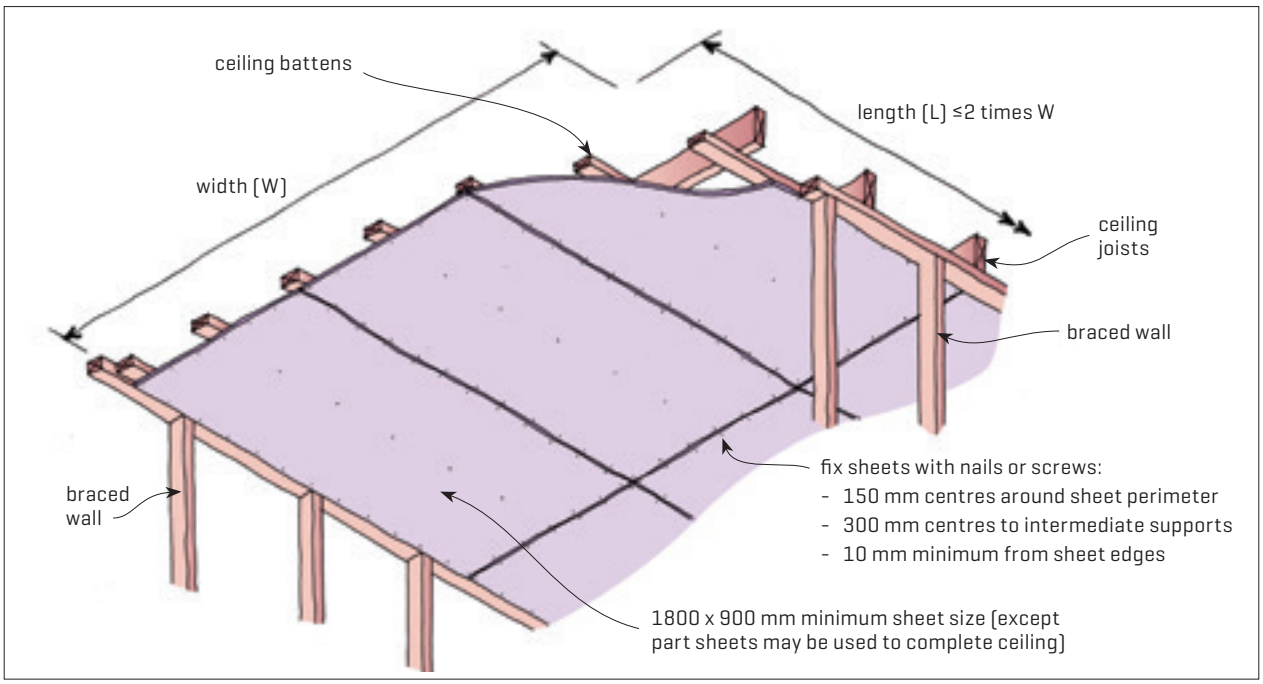


Figure 5. Ceiling diaphragms.

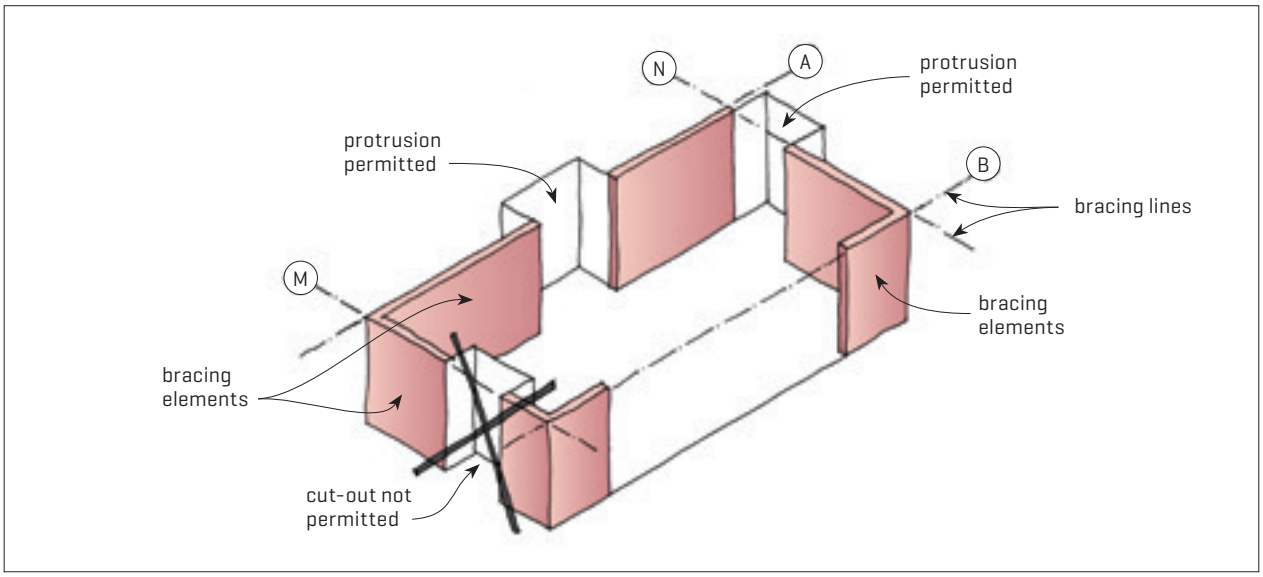


Figure 6. Ceiling diaphragm protrusions and cut-outs.

4.2.2 Timber roof plane braces:
- must be a single length of timber – 90 x 19 mm
- must be run at 45° from ridge to supporting wall
- are fixed to the underside of rafters or to truss top chords in accordance with clause 10.4.2.3 and Table 10.18.

4.2.3 Steel straps:
- are diagonally opposing pairs of steel strap braces
- must have a minimum capacity of 4.0 kN (in tension)
- are fixed to each top chord or rafter and to the top plate as per Table 10.18
- are fixed to the top plate and ridge board as described in clause 10.4.2.3(b).

4.2.4 Sheet sarking or the ceiling of a skillion roof may also be used as a roof plane brace.

4.2.5 Requirements for roof space diagonal braces:
- Run alternately in opposing directions when more than one is required.
- Must be continuous 90 x 45 mm SG8 members (Table 10.17) – single member where length less than 1.85 m long and 2 x 90 x 45 mm when the span is more.
- Fixed at the bottom to a brace runner in accordance with clause 10.4.3.4 to transfer roof loads into walls containing wall bracing elements.
- Fixed at the top to the ridge or to a 90 x 45 blocking piece fixed between adjacent top chords or rafters in accordance with Table 10.18.
- Must be distributed as evenly as possible over the length of the roof.

5 BRACING RATINGS FOR RENOVATIONS OR REPAIRS

5.0.1 For renovations or repairs of older buildings, it can be difficult to allow for the contribution of existing bracing systems. BRANZ has tested a selection of traditional construction systems and established bracing ratings for them. See "Bracing ratings", *Build* 144, page 24.

6 GLOSSARY

braced pile system
A pair of piles connected by a diagonal brace.

bracing
Any method employed to provide resistance to lateral loads from wind and earthquake.

bracing capacity
Bracing strength of a whole building or of elements within it. Measured in bracing units (BU).

bracing demand
The horizontal force exerted on a building (or building element) by wind or earthquake action. Measured in bracing units (BU).

bracing element
A part of the building that performs a bracing function. Must extend from bottom plate to top plate.

bracing line
A notional line along or across the building plan for controlling the distribution of bracing elements.

bracing rating
The lateral load resistance assigned to a subfloor or wall bracing system when tested in accordance with BRANZ Technical Paper P21.

bracing system
A combination of building elements and fixings designed to provide bracing capacity.

bracing unit (BU)
A measure of either the horizontal force (bracing demand) on the building (1 kN = 20 BU) or the bracing capacity (resistance to force) of building elements.

dead load
The weight of items in a building that are permanent such as the building itself and fixed components.

diaphragm
A floor or ceiling capable of transferring loads within its own plane to bracing elements in the structure below.

dragon tie
A member fixed diagonally across the top plates at a building corner if there is no ceiling diaphragm. It supports the top plates against wind loads and prevents the walls from spreading.

driven pile
A timber pile hammered into the ground to form foundations.

live load
The weight of items in the building that are not permanent such as loads from people, movable items such as furniture, appliances and equipment.

load
Gravity force applied to a structure.

part storey
May be a basement or in a roof space and must have a floor area less than half the ground floor area of the relevant building wing or block.

sarking
Boards or sheet material fixed to rafters, trusses or purlins. It may also serve as a ceiling lining.

specific engineering design (SED)
Requires calculation and design beyond the scope of NZS 3604:2011.

subfloor brace
A bracing element below ground floor level.

wind zone
NZS 3604:2011 sets out wind zones according to maximum ultimate limit state wind speeds. The zones are low (<32 m/s), medium (37 m/s), high (44 m/s), very high (50 m/s) and extra high (55 m/s).

wing (or block)
Any part of a building projecting more than 6 m from the rest of the building.

ultimate limit state
The design criteria to ensure a building will not collapse or experience a loss of support that could harm people.

7 MORE INFORMATION

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BRANZ Maps – www.branz.co.nz/branz-map

Build articles – available from www.buildmagazine.org.nz
- "Bracing for suspended floors", *Build* 136
- "Roof bracing", *Build* 134
- "Specific bracing design", *Build* 147
- "Cantilevered joists", *Build* 127
- "Subfloor bracing", *Build* 132
- "Bracing for monopitch roofs", *Build* 145
- "Bracing for steps in floor or ceilings", *Build* 136
- "Spacing those bracing lines", *Build* 149
- "Bracing ratings", *Build* 144.

OTHER
NZS 3604:2011 *Timber-framed buildings* – available from www.standards.co.nz

New Zealand Building Code – available from www.building.govt.nz

GNS QMAPS – available from the GNS Science website www.gns.cri.nz

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