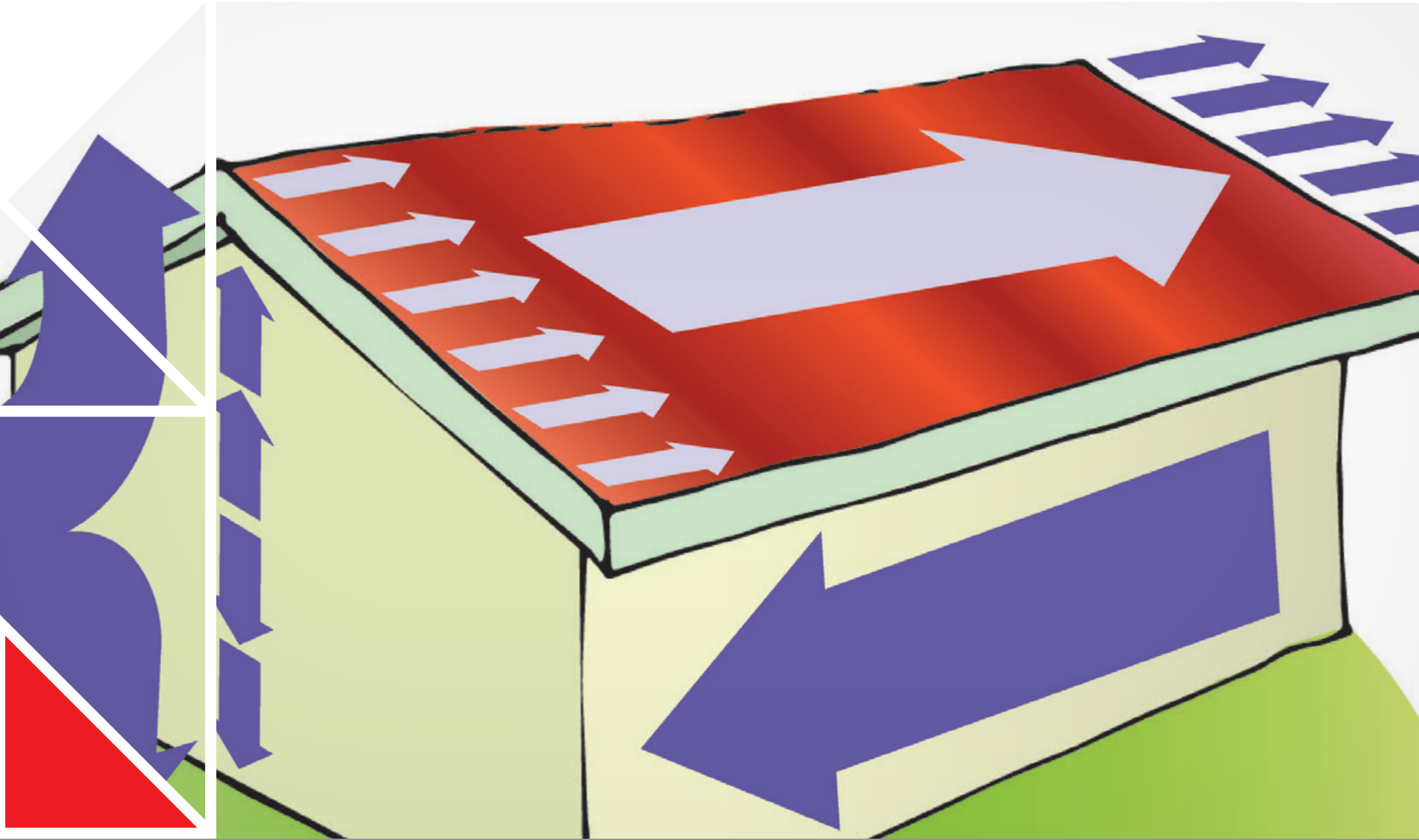
ISSUE 616 BULLETIN



WALL BRACING IN NZS 3604:2011 BUILDINGS

December 2017

- Wind and earthquakes can generate significant forces on a building.
- Bracing must be designed and incorporated into a building so that the structure can withstand these forces.
- This bulletin describes how to calculate the wind and earthquake bracing demand and detail bracing for walls 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 designed and incorporated into the building to withstand these forces.

1.0.2 This bulletin describes how to calculate the wind and earthquake bracing demand and detail bracing for walls using 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 non-specific design 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 Some bracing system manufacturers provide online calculators that use P21 bracing values from tested systems for buildings within the scope of NZS 3604:2011.

1.0.4 Bracing of subfloors and roofs is covered in Bulletin 617 *Subfloor and roof 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 for wind and earthquake.
- Selecting bracing systems and locating bracing elements such that bracing capacity for wind and earthquake meets or exceeds the relevant demand and provides good distribution of wall bracing throughout the building.

2.0.2 Wall bracing design can be an iterative process. As the design develops, bracing placement and bracing systems may need to be adjusted to achieve an even distribution of bracing.

2.0.3 NZS 3604:2011 section 5 provides information to establish bracing demand for wind and earthquakes. Further requirements for wall bracing appear in these clauses:

- 8.3.1 – adjustment of bracing elements for length and height.
- 8.3.2 – reinforced concrete and reinforced masonry.
- 8.3.3 – dragon ties.
- 8.7.3.3 – connection of joints in top plates.
- 8.7.3.4 – connection of top plates of internal and external bracing walls.

3 BRACING DESIGN USING NZS 3604:2011

3.0.1 Designers calculating bracing requirements using NZS 3604:2011 must be familiar with the scope of the standard. For buildings outside the scope of NZS 3604:2011, specific engineering design is required.

3.1 SITE INFORMATION

3.1.1 Site characteristics must be established, particularly the surrounding terrain and soil structure.

These are some possible sources of information:

- **For wind:** Wind region and lee zone maps (NZS 3604:2011), and to determine the overlying wind zone, use BRANZ Maps, territorial authority maps and websites, site investigation, Google Earth and topographic maps. These resources give the overarching zone, but assessment of the specific site conditions should be carried out as a site may be subject to higher wind speed than the zone indicates.
- **For earthquake:** Earthquake zone maps (NZS 3604:2011), territorial authority maps and websites, site subsoil class and geotechnical investigations.

3.2 BUILDING INFORMATION

3.2.1 Wind loads are based on the area of the building elevation facing the wind, while earthquake loads are based on building area and weight.

3.2.2 Key building dimensions required to calculate wind bracing demand (Figures 1–3) are:

- length and width
- roof pitch
- height – H = overall height to ridge, h = height from eaves to ridge.

3.2.3 H may have different values for different sections in a building. For example:

- for a subfloor, H = height from ground to apex (use Table 5.5)
- for a single or upper floor level, H = single or upper finished floor level to roof apex (use Table 5.6)
- for a lower finished floor level, H = lower finished floor level to roof apex (use Table 5.7)

3.2.4 To determine h:

- for roof height above the eaves, h = apex of roof to bottom of eaves (use Tables 5.5, 5.6 and 5.7)
- for a monopitch roof, roof height above the eaves is the difference between lower eaves height and roof apex.

3.2.5 Key building information to calculate earthquake bracing demand (Figures 1–3) are:

- floor plan area in m^2
- cladding weights, which are classified as:
  - light – <30 kg/m^2 (such as timber weatherboards)
  - medium – between 30 kg/m^2 and 80 kg/m^2 (such as stucco)
  - heavy – 80–200 kg/m^2 (such as masonry veneer).

4 BRACING FOR WIND

4.0.1 The greater the building surface area, the more wind force applies and the stiffer the building must be to resist this wind force. This wind force is the bracing demand, and it is expressed in bracing units (BU) required.

4.0.2 Wind bracing demand is calculated in two directions – across and along the building.

4.0.3 For a gabled building, wind blowing along the ridge exerts pressure on the gable wall. This pressure requires bracing elements parallel to the wind direction – the external side walls and internal walls at right angles

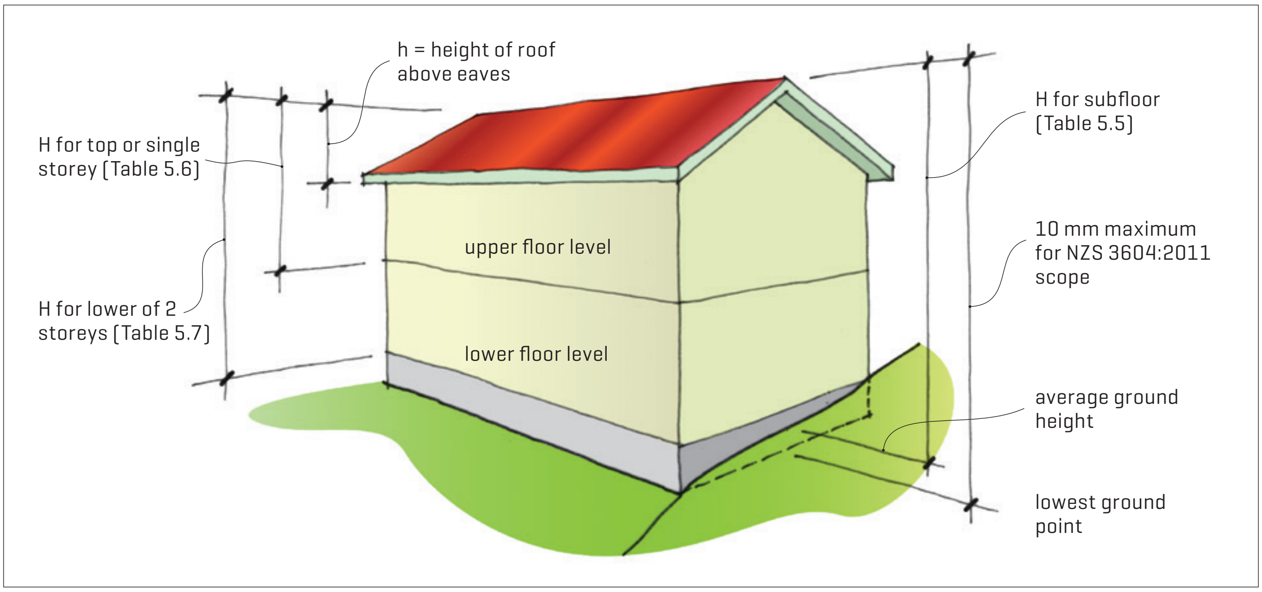


Figure 1. How to work out H and h.

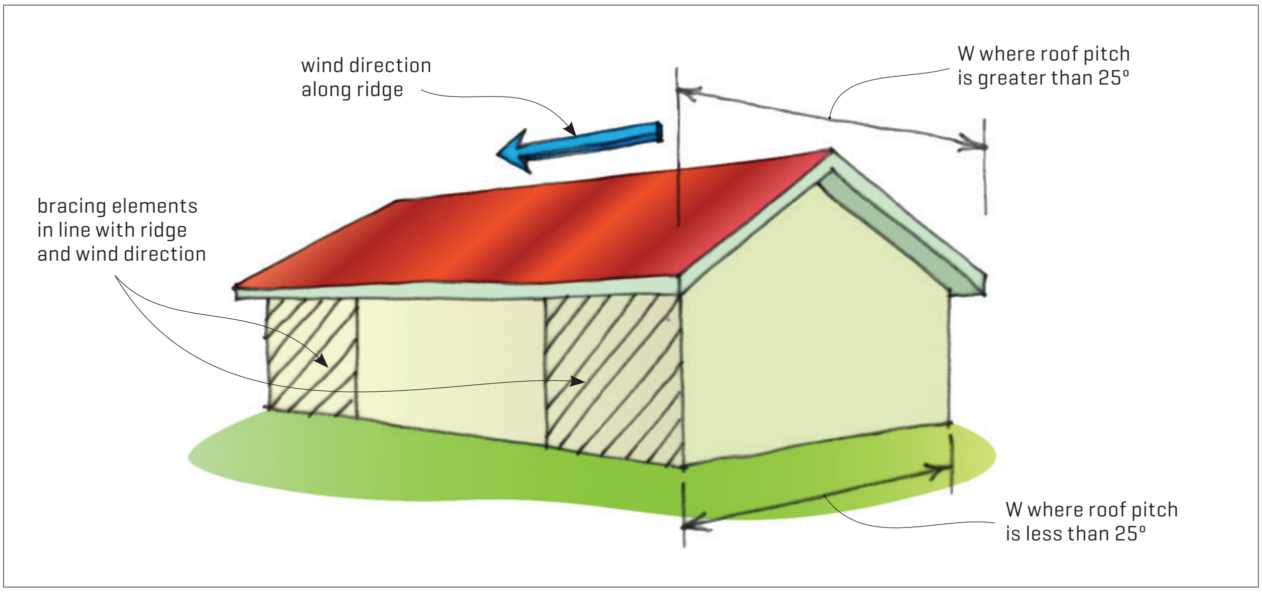


Figure 2. Bracing for wind along the ridge.

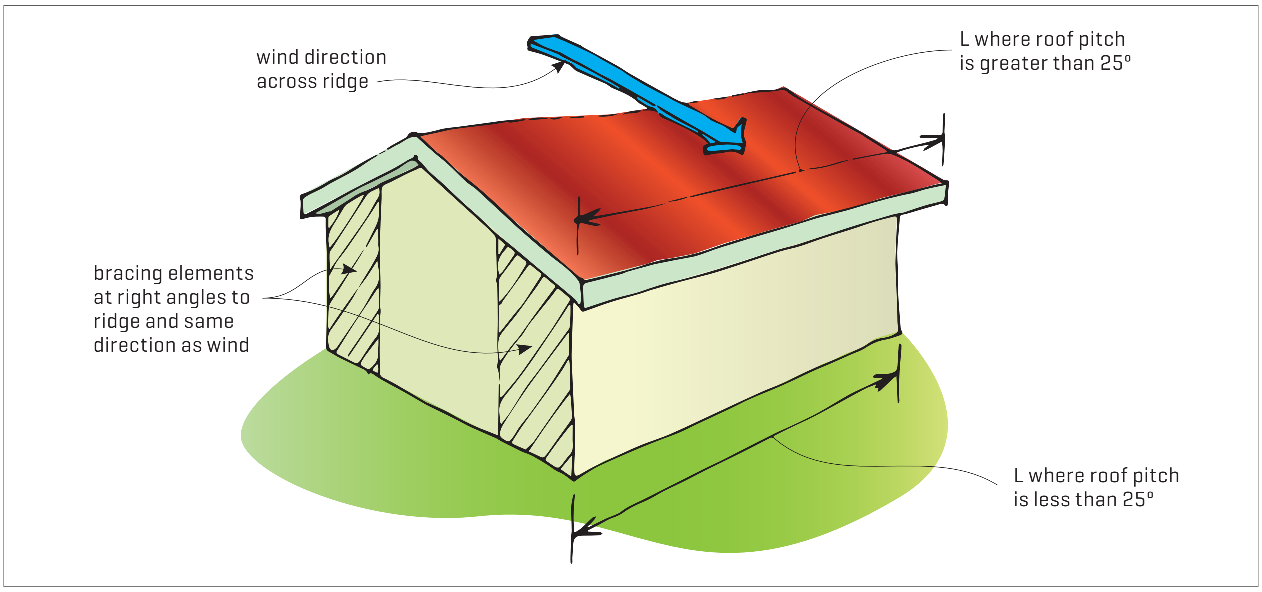


Figure 3. Bracing for wind across the ridge.

to the gable wall (Figure 4). Conversely, the pressure exerted by wind blowing across the ridge must be resisted by the gable walls and internal walls parallel to the gable walls.

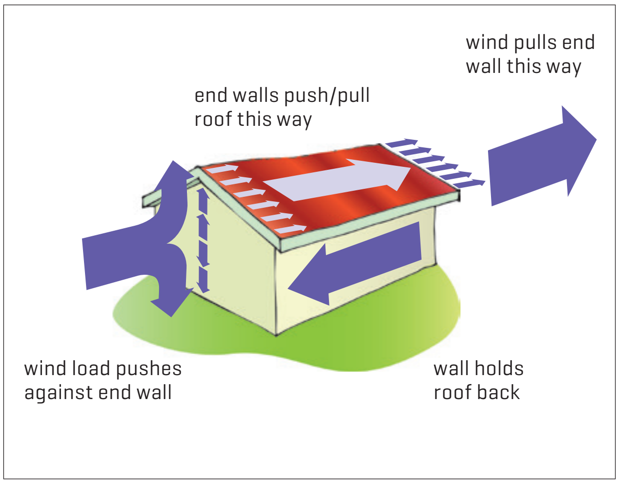


Figure 4. What wind is trying to do.

4.0.4 For buildings with a hipped roof, use the across direction for all wall bracing.

4.1 DETERMINE THE WIND ZONE

4.1.1 Wind zone may be determined by following the procedure in NZS 3604:2011 or online using territorial authority maps, proprietary information or BRANZ Maps. Note that local conditions and landform must be assessed to ensure there are no features that may increase the wind load at the specific site.

4.1.2 Information required for wind bracing calculations is based on the wind zone, which is determined from the wind region/lee zone, ground roughness, site exposure and topographic class.

4.1.3 The wind region and lee zone must be determined (Table 5.1 of NZS 3604:2011). The two wind regions are W (the Cook Strait region) and A (everywhere else). In the lee zones associated with mountains, wind speed and uplift may be significantly greater than on the upwind side of the mountain.

4.1.4 Ground roughness in all directions is determined by considering the obstructions that modify wind. Use the most severe condition to establish the ground roughness classification.

- Urban terrain – more than 10 obstructions (houses or trees over 3 m high) per hectare.
- Open terrain – grazed pastures, cropping or areas adjacent to beaches and the sea or to airfields and other areas with only isolated shelter. Within 500 m of the urban/open boundary, select open terrain.

4.1.5 Site exposure considers shelter provided by obstructions. There are two classes:

- Sheltered – at least two rows of similarly sized, permanent obstructions at the same ground level all around.
- Exposed – steep sites (defined in Table 5.2) or sites adjacent to playing fields, open spaces, motorways, beachfronts, large rivers or wind channels wider than 100 m.

4.1.6 Topographic class (T1–T4) refers to hills. Wind accelerates as it flows over hills, through gorges and over mountains. NZS 3604:2011 Table 5.2 refers to Figure 5.2 to identify topography, but the alternative figures given here may be easier to follow.

4.1.7 The smoothed hillside gradient is the average slope of a hill or ridge upwind of the site. The slope is measured over the lesser of a distance (L) from the hill crest of 3 x the total height (H) above the valley floor or 500 m.

4.1.8 In steeper country where L extends from the crest across to the next hill, it should be taken as the distance to the valley floor and may be less than 500 m (Figure 5).

4.1.9 The smoothed gradient (Figure 6) is expressed as a ratio – change in level (h)/distance (L) – and defined in Table 5.2 as:

- gentle – maximum slope 1:20
- low – maximum slope 1:10
- mild – maximum slope 1:6.7
- moderate – maximum slope 1:5
- steep – steeper than 1:5 (not maximum 1:5 as shown in Table 5.2).

4.1.10 Once the smoothed gradient is determined, the position of the building site in relation to the crest of a hill or escarpment (long steep slope or cliff) must be considered (Figure 7):

- Within distance H (or 2H downwind for an escarpment), it is in the crest zone, where wind acceleration is a maximum.
- Between 1H and 3H from the crest (or 2H–6H downwind for an escarpment), it is in the outer zone.
- Further than 3H (or 6H for an escarpment), it is classed as T1 because wind acceleration is not considered significant.

4.1.11 Use Table 5.3 to determine the topographic class of the site, using criteria established from Table 5.2. (Ignore row 4 of Table 5.2, as site exposure is more relevant to Table 5.4.) Four classes are identified – T1–T4. Sites outside the outer and crest zones and gently undulating sites (flatter than 1:20) are classed as T1. Sites known to have accelerated wind flows are classed as T4.

4.1.12 Use Table 5.4 to determine the wind zone, by entering:

- region – A or W
- ground roughness – urban or rural
- topographic class – T1–T4
- site exposure – sheltered or exposed.

4.1.13 Six wind zones are identified as:

- L = low – maximum ultimate limit wind speed 32 m/s
- M = medium – maximum 37 m/s
- H = high – maximum 44 m/s
- VH = very high – maximum 50 m/s
- EH = extra high – maximum 55 m/s
- SED = specific engineering design.

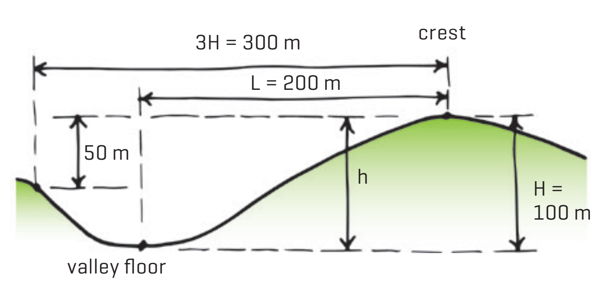


Figure 5. Determining topographic zone in steep hillside.

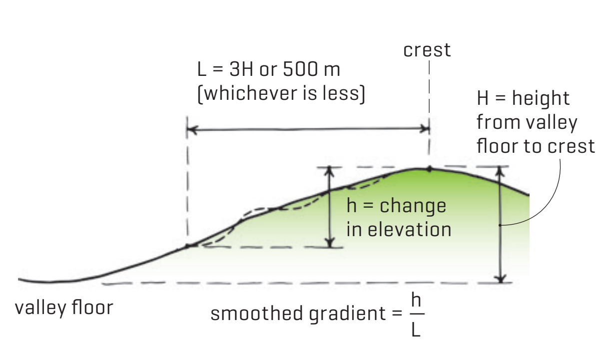


Figure 6. Smoothed gradient.

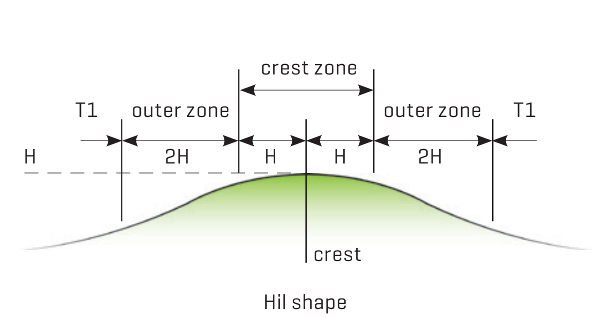


Figure 7. Building sites adjacent to a crest.

4.1.14 If the site is in a lee zone, increase the wind zone by two steps – low becomes high, and medium becomes very high. High and above require specific engineering design.

4.2 ESTABLISH WIND BRACING DEMAND

4.2.1 Once the wind zone is known, wind bracing demand can be calculated. Figures 2 and 3 above illustrate the direction of wind loads, and Figures 1–3 identify the dimensions H, W and L. These dimensions are applied to Tables 5.5–5.7 to determine the wind bracing demand across and along the building ridge.
- Single or upper storey walls – Table 5.6.
- Lower of 2 storeys – Table 5.7.

4.2.2 The tables relate to the default wind zone – high. For different zones, multiply by the relevant factor from the table at the bottom of each page.

4.2.3 The calculations are:
- total bracing demand across (BU) = [wind bracing demand across (BU/m)] x [wind zone factor] x [building length L (m)]
- total bracing demand along (BU) = [wind bracing demand along (BU/m)] x [wind zone factor] x [building width W (m)].

4.2.4 For a building with a hipped roof, use the across calculation for both directions.

5 BRACING FOR EARTHQUAKE

5.0.1 Key information must be gathered for earthquake bracing demand to be calculated, including earthquake zone, subsoil type, building size, cladding weight and floor loading.

5.0.2 NZS 3604:2011 Figure 5.4 identifies earthquake zones 1–4, representing the earthquake hazard or potential intensity. This figure has been amended by Acceptable Solution B1/AS1 clause 3.1.2 (Amendment 11, August 2011) for the Canterbury earthquake region.

5.0.3 Subsoil classes reflect the different impacts an earthquake can have depending on the depth and type of subsoils. NZS 3604:2011 (5.3.3) classifies site subsoils as:
- A – strong rock
- B – rock
- C – shallow soil sites
- D – deep or soft soil sites
- E – very soft soil sites.

5.0.4 Local information may be available from the territorial authority or GNS Science QMAPS. If no site-specific information is available, default to class E (the worst-case scenario).

5.0.5 Building parameters to be considered:
- Building levels – calculate bracing demand for each level (subfloor, ground floor, first floor) so suitable bracing systems can be incorporated at each level.
- Building size – earthquake demand is based on the floor area of the building (m²).
- Cladding weight – heavier claddings create greater bracing demand.
- Floor live loads – the default load under NZS 3604:2011 is 2 kPa or less. If the floor load is 3 kPa, use section 14 of NZS 3604:2011.
- Presence of heavy chimneys.

5.1 ESTABLISH EARTHQUAKE BRACING DEMAND

5.1.1 Earthquake demand is based on the floor area and is the same in both directions.

5.1.2 NZS 3604:2011 Tables 5.8–5.10 provide information to calculate the bracing demand with default soil type D/E and earthquake zone 3. Each table has values for different combinations of cladding weight, roof cladding weight and roof pitch:
- Table 5.8 – bracing demand for subfloor structure and walls of single-storey buildings on subfloor framing. (For floor live loads above 2 kPa, use Table 14.1.)
- Table 5.9 – bracing demand for 2-storey buildings on subfloor framing. (For floor live loads above 2 kPa, use Table 14.2.)
- Table 5.10 – bracing demand for single and 2-storey buildings on concrete slab on ground. (For floor live loads above 2 kPa, use Table 14.3.)

5.1.3 Use the multiplication factors at the bottom of the tables for the specific earthquake zones and soil class.

5.1.4 NZS 3604:2011 identifies situations that require additional bracing demand:

- Concrete masonry lower storey (5.3.4.2) – use the values for a single-storey building with heavy subfloor cladding from Tables 5.8, 5.9 or 5.10 as appropriate.
- A part-storey in a roof space (C5.3.4.3) – the values from Tables 5.8, 5.9 or 5.10 must be increased by 4 BU/m² before application of any multiplier.
- A part-storey in a timber-framed basement (C5.3.4.4) – the building must be considered as two buildings, one 2-storey and one single storey, each with separate bracing demand.
- Masonry or concrete chimneys that rely on the building structure for lateral support. Calculate as described in B1/AS3.

5.1.5 The calculation is:

- total bracing demand (BU) = bracing demand (BU/m²) x multiplication factor (for soil type and earthquake zone) x floor area (m²).

6 WALL BRACING DESIGN

6.0.1 Once bracing demand has been determined, select bracing elements to meet or exceed the worst-case demand in each direction (across and along), distributed along the bracing lines.

6.0.2 Wall bracing design involves:

- positioning bracing lines
- selecting the bracing system(s)
- determining the position and length of bracing elements
- distributing bracing evenly on bracing lines
- providing bracing capacity to meet or exceed bracing demand in both directions for both wind and earthquake
- specifying bracing elements.

6.0.3 Building shape must be identified:

- Each wing or block extending more than 6 m from the rest of the building must provide sufficient bracing individually. The common wall between wings or blocks must have a minimum bracing capacity equal to the sum of the demand from each wing or block.
- With split levels, each level must provide sufficient bracing individually. There must be a wall and subfloor bracing line at the location of the discontinuity (Figure 8).
- When a building has a step of 100 mm or more in floor or ceiling level, there must be a bracing line in the lower storey at the location of the discontinuity. Lower-storey bracing element(s) must be continuous from the lower floor level to the underside of the highest ceiling level (Figure 9).

6.1 BRACING ELEMENTS

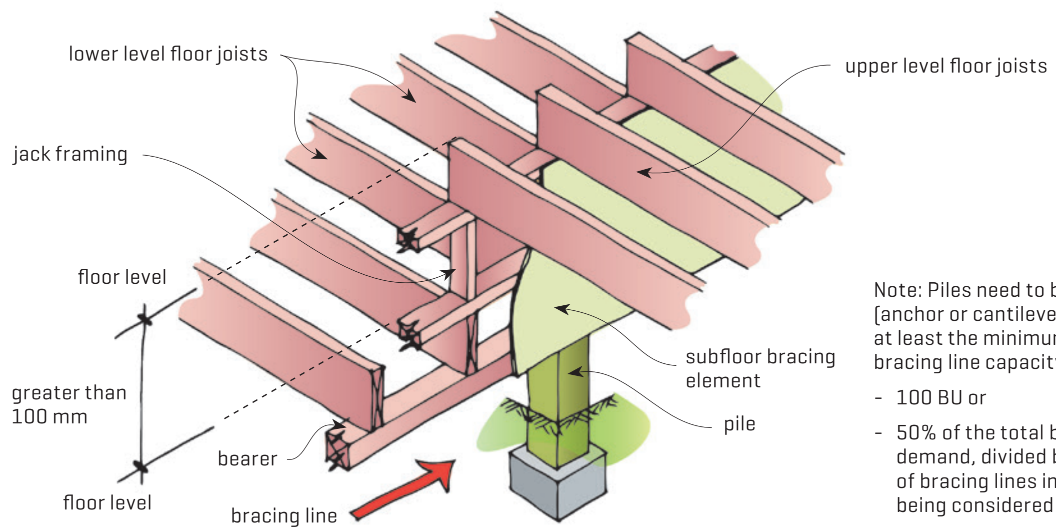
6.1.1 Bracing elements are building components that resist horizontal forces imposed by wind or earthquake. Bracing elements should be located close to external wall corners and distributed evenly throughout the building, rather than concentrated at ends or outside walls or in an unbalanced plan configuration. For even distribution, it is usually better to have more bracing lines than fewer.

6.2 BRACING LINES

6.2.1 Bracing lines are imaginary lines running along and across the building (Figure 10). They are used to locate bracing elements evenly within the building. Bracing lines in each storey are considered separately. They generally do not need to coincide with bracing lines in the storey below or with subfloor lines of support. Bracing line location can be determined before or after bracing demand.

6.2.2 Bracing lines must be:

- parallel to external walls
- spaced at 6 m centres maximum in each direction for walls (unless there is a floor or ceiling diaphragm)



Note: Piles need to be braced (anchor or cantilevered) and meet at least the minimum required bracing line capacity of:

- 100 BU or
- 50% of the total bracing demand, divided by the number of bracing lines in the direction being considered

Figure 8. Bracing design where floor is discontinuous.

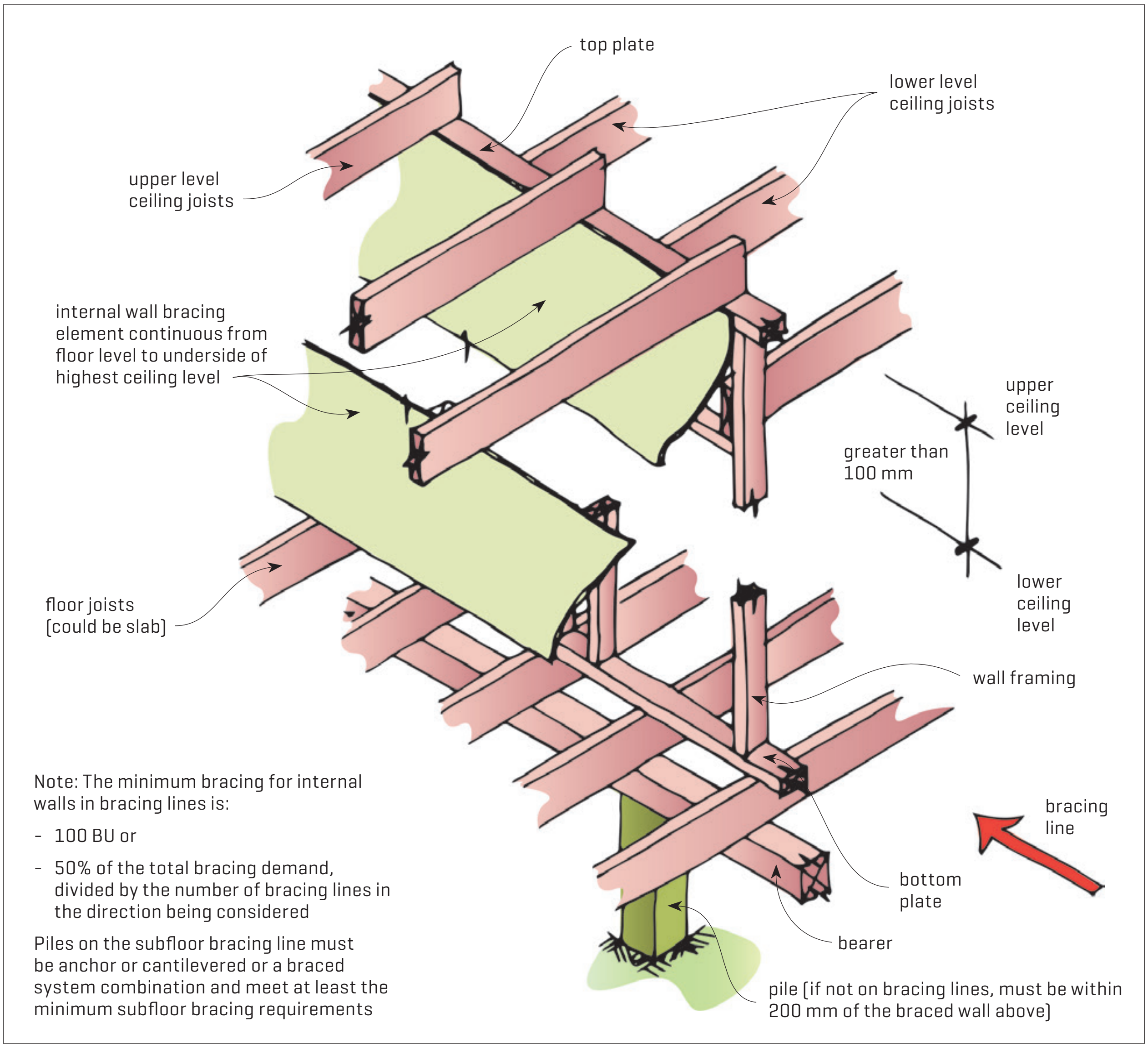


Figure 9. Bracing design where ceiling is discontinuous.

- up to 7.5 m centres where dragon ties provide lateral support to the external walls.

6.2.3 Bracing lines can be considered a single bracing line when less than 1 m apart. When over 2 m apart, they can be considered as separate bracing lines. External walls up to 2 m apart can be considered as part of a single bracing line. Walls within 1 m of an internal bracing line can be considered as part of that line.

6.3 MINIMUM BRACING LINE CAPACITY

6.3.1 The minimum bracing capacity of a bracing line is the greater of:

- 100 BU or
- 50% of the total bracing demand, divided by the number of bracing lines in the direction being considered or
- for external walls, 15 BU/m of external wall length for each external bracing line.

6.4 WALLS AT ANGLES TO BRACING LINES

6.4.1 Braced walls less than 6 m long at an angle to the bracing lines can contribute to the bracing at a reduced value. The bracing capacity of the relevant bracing element is multiplied by the cosine of the angle between the element and the bracing line (NZS 3604:2011 5.4.4).

6.5 DRAGON TIES

6.5.1 Dragon ties (clauses 8.3.3.1–8.3.3.4 of NZS 3604:2011 and Figure 11 below) are a continuous length of 90 x 35 mm timber fixed diagonally across top plates at external corners. They may be used with a braced wall system to allow spaces up to 7.5 x 7.5 m without the need for a ceiling diaphragm.

6.5.2 Dragon ties must:

- be located at external corners only
- be used in pairs, one at each end of the wall
- have a minimum wall bracing capacity of 100 BU
- be a maximum 7.5 m from the corner to the first bracing line
- be a maximum 2.5 m from the corner to the end of the dragon tie
- be fixed at a 40–50° angle to both external walls.

6.5.3 Dragon ties must be connected to the top plates of the two adjacent external walls (and to any

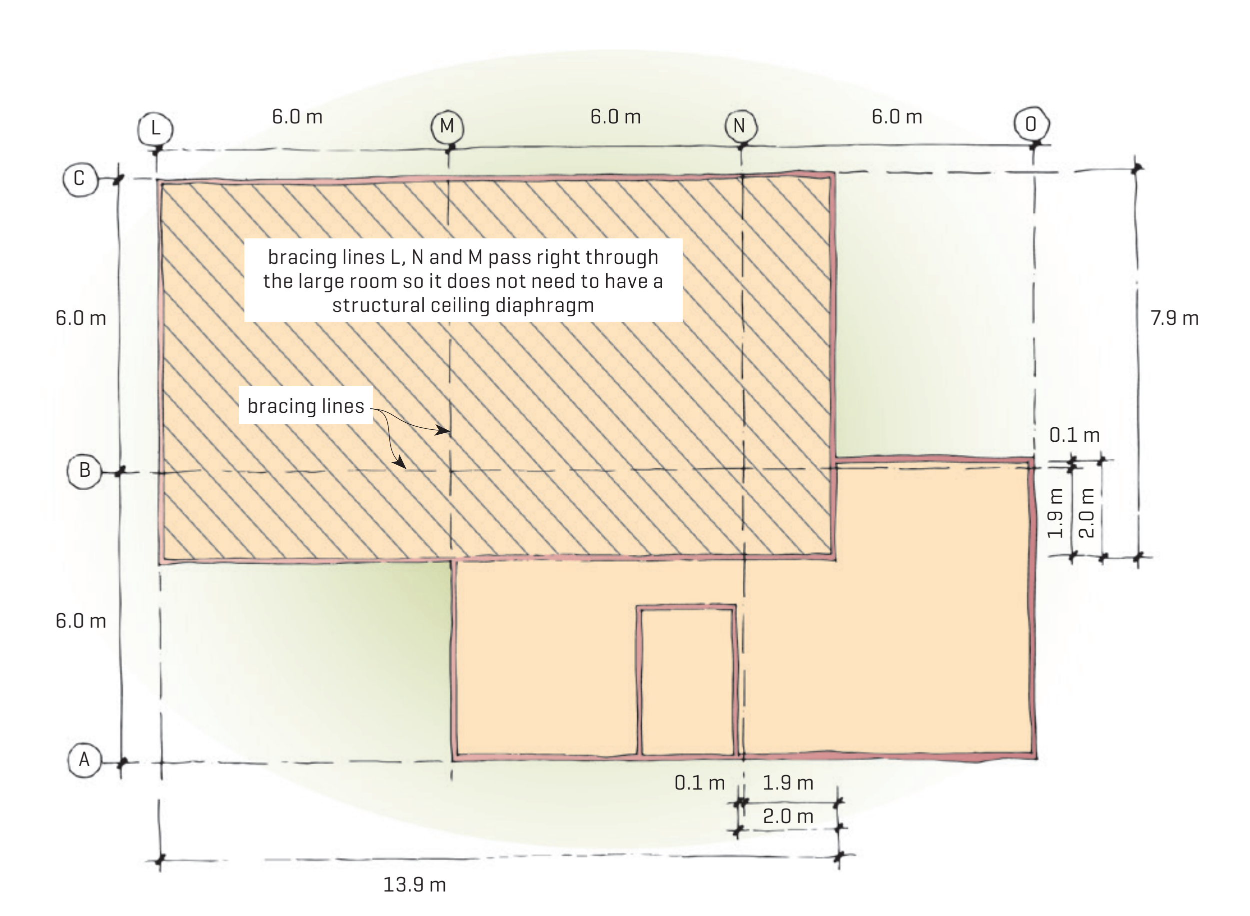


Figure 10. Several bracing lines go through the large hatched room.

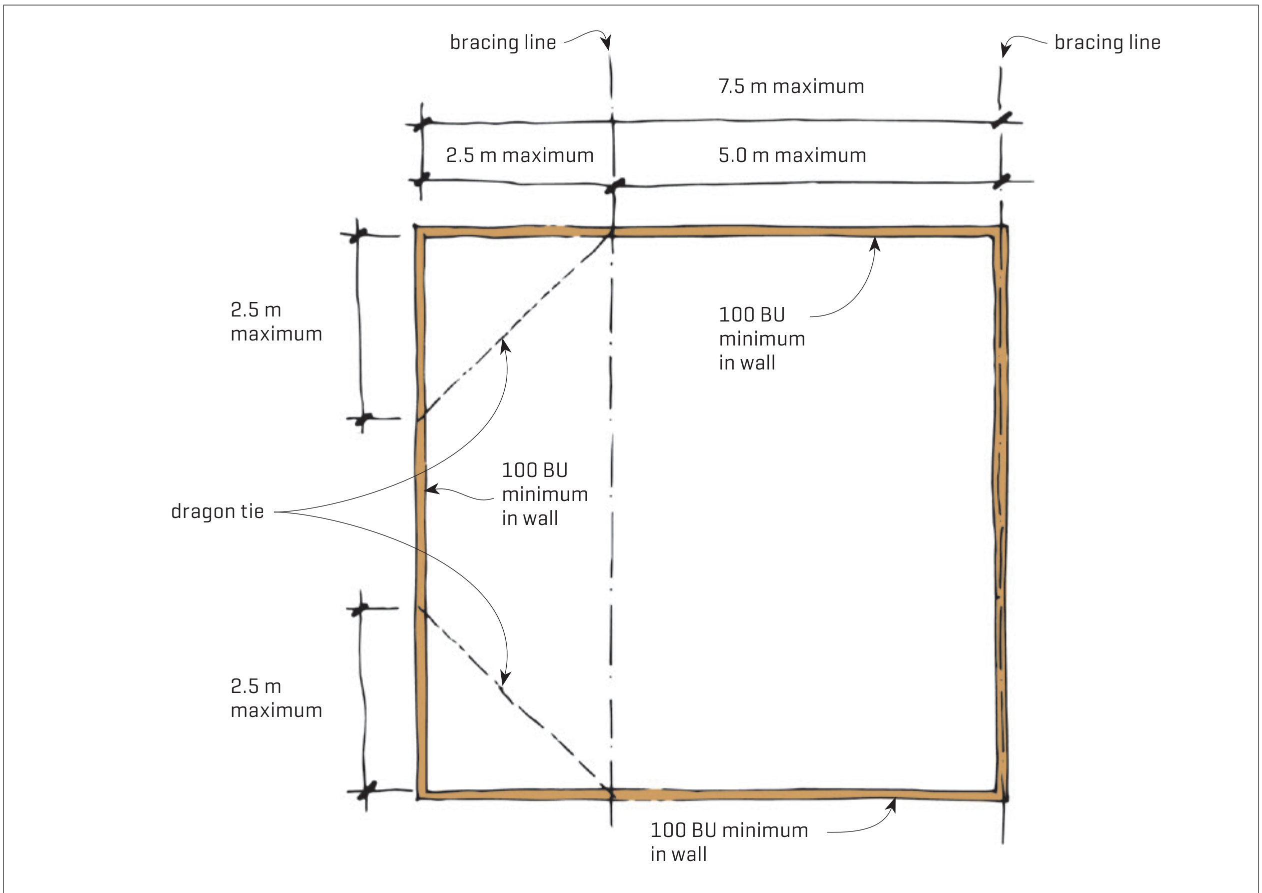


Figure 11. Dragon ties.

intermediate roof and ceiling members, such as ceiling joists, rafters or truss bottom chords):

- They must be connected either directly to the top plates or to blocking pieces no deeper than 90 mm and at least 70 mm wide.
- At the external wall, they must be fixed to the top plate within 100 mm of a joist, rafter or truss bottom chord.
- Where blocking is used, it must span between adjacent joists, trusses or rafters and be fixed to them.

6.5.4 Wall bracing ratings from bracing system manufacturers are proprietary. Do not combine elements from different manufacturers unless a tested rating of the combination is available. Check the manufacturer's literature to ensure no changes to fixings or other limitations are imposed. Ensure the information consulted is current.

6.6 LIMITATIONS ON BRACING ALLOCATION

6.6.1 The loads that can be resisted by wall bracing elements are limited by the strength of the connection between wall and floor structure.

6.6.2 Based on hold-down capabilities, maximum ratings for wall bracing elements that can be used in calculations are:

- for timber floors – 120 BU/m
- for concrete floors – 150 BU/m.

6.6.3 For example, a bracing element rated as 150 BU/m can contribute no more than 120 BU/m when attached to a timber-framed floor.

6.7 DE-RATING WALL BRACING CAPACITY

6.7.1 Bracing capacity is determined by testing a section of wall constructed to standard dimensions, defined in BRANZ Technical Paper P21. Where actual wall dimensions are different from the tested dimensions (in height or length), the bracing capacity must be adjusted as set out in clause 8.3.1:

- Length – multiply the tested bracing rating/metre by the wall element length (most bracing systems have a minimum applicable length).
- Height – the bracing capacity of wall bracing elements taller than 2.4 m is calculated by multiplying the bracing rating by 2.4/element height (m). For example, the capacity of a 2.7 m high wall is found by multiplying the BU value by 2.4/2.7 = 0.89.
- Bracing capacity of walls with sloping top plates is calculated as above using the average wall height.
- Elements less than 2.4 m high are rated as if they were 2.4 m.

6.8 BRACING RATINGS FOR RENOVATIONS OR REPAIRS

6.8.1 If building alterations involve removing walls, new bracing must be included to replace what has been removed so the capacity of the building is not reduced.

6.8.2 It can be difficult to allow for the contribution of existing bracing systems in older buildings. BRANZ has tested a selection of traditional construction systems and established bracing ratings for them. See "Bracing ratings", *Build 144*, page 24.

6.9 TRANSFERRING BRACING LOADS

6.9.1 Loads must be transferred through the building structure, and connections between bracing elements are critical. Refer to NZS 3604:2011:

- clause 8.7.3.3 and Figure 8.15 for connecting top plates in line
- clause 8.7.3.4 and Figure 8.16 for connecting top plates to external walls at right angles
- clause 8.7.4.1 and Figure 8.17 for lateral support of top plates.

6.9.2 If a wall containing bracing elements is supported by cantilever joists, additional vertical loads will be imposed on the joists and brace elements may not function correctly. Specific engineering design is required. Some joists may be doubled up.

6.10 DIAPHRAGMS

6.10.1 The design and installation of floor and ceiling diaphragms is covered in Bulletin 617 *Subfloor and roof bracing in NZS 3604:2011 buildings*.

7 MORE INFORMATION

BRANZ

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

BRANZ Study Report SR305 *Bracing ratings for non-proprietary bracing walls* – www.branz.co.nz/study_reports

Build articles – available from www.buildmagazine.org.nz

- "Walls at angles to bracing lines", *Build 137*
- "Wall bracing", *Build 133*
- "Braced wall layouts and diaphragms", *Build 147*
- "Specific bracing design", *Build 147*
- "Bracing ratings", *Build 144*

OTHER

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

New Zealand Building Code and Acceptable Solutions/Verification Methods B1 *Structure* – available from www.building.govt.nz

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

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