**Distributing lateral loads in timber-framed buildings**

Creating a compliant bracing distribution system can be a challenge in today’s open plan house designs. Even if you don’t design them, it is still important to understand how bracing works.

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**NZS 3604:1999 Timber framed buildings** is the principal design standard applying to residential and some commercial buildings that do not require specific engineering design. Building design that falls outside the scope of NZS 3604 must demonstrate compliance with the New Zealand Building Code by way of specific engineering design.

Many of today’s residential timber-framed buildings are significantly different from those when NZS 3604 was first used. Now open plan living spaces often have access routes that connect with the outside, and large glazed areas in exterior walls, including corners in exterior building lines. Our increased space awareness means the designer’s goal is to create a building that lets us experience the openness and connectivity between the various spaces. This type of design may create difficulties for achieving a compliant bracing distribution system within the scope of NZS 3604.

**Bracing at external corners**

Bracing is covered in sections 5 and 8 of NZS 3604. Clause 5.5.3 states, ‘Wall bracing elements shall be located as close as possible to the corners of external walls and evenly throughout the building’.

Consider a typical corner floor plan for part of an open plan building (see Figure 1). For wall line A, the nearest bracing to the corner would be the portion of wall immediately adjacent to the window opening.

So what sets the boundaries to this requirement? For example, does NZS 3604 set out a maximum distance that the nearest bracing element can set back from the corner? It doesn’t, but other specific bracing requirements for external walls are in:

- clause 5.5.5.3 – Bracing elements shall be evenly distributed along each line as far as possible
- clause 5.5.6.1 – Each external wall shall have a total bracing capacity of at least 10 BU/m length of wall.

The use of expansive glazed areas along exterior walls and into corners will require specific engineering design of the required cantilevered lintel. The beams/lintels that carry the roof loads above the window openings can be arranged to form part of a sway-resistant frame and not merely be simply connected at either end.

A sway-resistant frame can easily be identified by its connection at the tops of its support columns and the connection of the support column at its base to the foundation (see Figures 2 and 3). An understanding of both framing systems will enable the designer to verify the location and distribution of bracing into external corners. Both systems will carry vertical acting roof loads but only the sway-resistant frame will provide any resistance to horizontal loads.

**Even distribution**

The purpose for even wall bracing is set out in BRANZ Study Report 168 (2007) *The engineering basis of NZS 3604*. The broad engineering principles identified in the report are:

- symmetry of distribution of lateral force resisting elements to reduce torsion loadings in winds or earthquakes
- relatively even distribution of lateral force resisting elements to avoid concentrations of loading on individual elements and their connections to the rest of the structure
- ensuring bracing elements are spread out to the building extremities (like the corners of external walls) where they are more effective in resisting torsion loads.

The requirements for distribution are clearly set out in NZS 3604, clauses 5.5.5.1 to 5.5.5.4:

- Brace lines to be parallel with the external walls of the main building.
Brace lines not to be more than 6 m apart. Brace lines may be greater than 6 m apart when a structural diaphragm is used.

- Even distribution along each brace line as far as possible.
- Each internal brace line shall have a minimum capacity of 70 BU.

**Structural ceiling diaphragms**

A structural ceiling diaphragm is a horizontal load distribution system that functions on the deep beam principle of distributing lateral forces to the side walls, where conventional sheet wall bracing can provide the bracing resistance to the loads imposed. As with all load-carrying members in any structural element, connections form an important part of the system’s integrity and ability to perform.

In clause 5.5.5.2 structural diaphragms become a solution where the distance between brace lines exceeds 6 m. Clause 5.6.2 sets out the bracing capacity requirements for the perimeter walls that connect to the diaphragm and clause 13.5.2 and Table 13.3 set out the requirements for connections.

Figure 13.4 of NZS 3604 shows a ceiling batten forming the perimeter fixing for the connection between the ceiling sheet and the top plate. Table 8.19 gives the fixings required for such laminated top plates. However, proprietary bracing systems provide clearer requirements on how the perimeter of a diaphragm should be framed.

**Top plates and isolated bracing**

The requirements for top plates and/or framing members are set out in clause 8.7.3.4.

Top plates transmit the lateral forces through the building frame to the location of the bracing system. If framing members are to form part of the load path then it is important to carefully consider the connection detail (see Figure 8.16 of NZS 3604). This detail should ensure a connection of adequate capacity. Framing members must be in the same line as the brace line you want to connect to. NZS 3604 does not require the designer to follow the load path via framing members, but it is recommended practice so that the continuity of the load path from point of impact to resistance can be verified.

Although they have bracing capacity, internal walls may be isolated from the external bracing walls. Under these circumstances their bracing capacity may not contribute to the building’s stiffness due to a lack of suitable top plate or framing member connectivity between the isolated bracing system and the building structural frame. The provisions of 8.7.3.4 are to prevent this situation. An example could be a masonry wall in the middle of a large open space within the building.

**Identifying non-compliance**

Gaps can often appear in bracing designs that incorporate both architectural and engineering inputs. The following checks should be made to identify non-compliance problems:

- Bracing should be evenly distributed throughout the structure and as close to external corners as possible.
- Where required, brace lines must be continuous between the external walls of the structure by way of either top plate continuity and/or framing members with the appropriate connectors.
- When brace lines exceed 6 m separation, the appropriate design solutions must be incorporated (e.g. structural diaphragms).
- The critical load path between the point of load impact and resistance must be clearly defined along with appropriate connections.

**NZS 3604 sufficient**

NZS 3604 provides sufficient scope to cover most bracing systems in modern construction. Proprietary bracing systems can be relied upon to deliver their rated capacity on demand, given that the Standard requires all bracing systems to have their capacities determined by P21 tests.

Once the design falls outside the scope of NZS 3604 it is up to the structural engineer to define and evaluate the critical load paths. In some cases the specific engineering design will need no more than a framing member to connect with some proprietary bracing system, or it may need portal frames that are sway resistant. Once the loading demand is determined, the distribution is then achieved by using the rules in NZS 3604.