Plywood shear walls – Worked Examples

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Plywood has been used for bracing in residential buildings for many years using the Bracing unit methodology adopted by NZS3604.

This paper is based on a presentation that was given at a Timber Design Society seminar and is aimed at enabling structural engineers to carry out specific design of plywood bracing elements in low rise multi-storey buildings of up to 5 or 6 storey’s.

Plywood shear walls consist of:
- Plywood, to transfer shear forces
- Chords, to resist tension/compression generated by the over turning moments
- Base connections to transfer shear to foundations.

Capacity design:
Energy is absorbed by the yielding of a ductile link in the structural load path. This ductile link in the plywood shear walls is the nails.

Everything other than the nails are designed for the actions associated with the shear force over-strength capacity of the nailed connections, or alternatively everything other than the nails can be designed for an elastic level load.

The non ductile components of a plywood shear wall are the plywood, chords, chord connections, base shear connection and foundations.

Over strength value for nailed connections = 2.0 (NZS3603)

Use ductility level, $\mu = 3.0$ (coincides with the ductility of Gib bracing)

Design Tip:
Try to avoid mixing plywood and Gib board bracing elements acting in the same direction within a building as they may not be deflection compatible.

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The Combination of gravity loads (stabilizing loads) and lateral loads (over turning loads) may reduce the magnitude of the tension chord force, or even eliminate the tension chord force depending on the geometry.
Calculating chord forces – short or long wall

**Short Walls**  \( H >> d \)

\[
V_3 = (v_3 h_3) + (v_2 h_2) + (v_1 h_1)
\]

\[
T = C = \frac{M}{j d}
\]

**Long Walls**  \( H << d \)

\[
\sigma = \frac{M}{z} \quad z = \frac{bd^2}{6}
\]

Each stud resists tension and compression.
The \( T, C \) force in each stud.
\( T, C = \sigma \times b \times \) stud spacing
\( @ \) stud location with wall.
Shear wall calculations

Design Steps

- Calc overturning moment
- Calc chord tension compression- design chords & connections
- Calc shear flow- design plywood nailed connections
- Calc base shear – design plywood sheathing and base shear connection

Design tip-
Design nailed connection first as this is likely to be the most difficult design component to achieve.

Shear wall deflection calculations

Generally based on NZS36003 cl 5.2.5

\[
M_{o/f} = V_3 h_3 + V_2 h_2 + (V_1 h_1)
\]

\[
T = C = \frac{M_{o/f}}{jd}
\]

Shear flow \( q^* = \frac{V^{*}\text{base}}{d} \) (n/mm)

Plywood

\( V^* < 0.5k_1k_8f_{p\text{td}} \)

Seismic deflections. Calc \( \Delta @ \mu=3.0 \); Multiply this figure by \( \mu(3.0) \) to get \( \Delta @ \text{ULS} \)
Nail Slip
In the absence of specific test data, slip in nailed joints may be determined from NZS3603 clause 4.2.2.3 which has the following information:

(a) A load equal to 1.25 times the nominal short term strength of a single nail gives an average slip of 2.5 mm.

(b) From 0 to 0.5 mm slip, the slip can be calculated from

\[ \delta = \frac{k_{37} (0.8) P^2}{Q_n^2} \]  

(Eq. 4.4)

Where:

\[ K_{37} \] = is given in table E1 in Appendix E

\[ P \] = applied nail load

\[ Q_n \] = nominal strength for a single nail with short term loading (\( k_i = 1 \))

(c) From 0.5 mm to 2.5 mm slip, interpolate linearly between (a) and (b)

(d) Above 2.5 mm slip, the load may increase 20% to 40% to give maximum load at a slip between 6 mm and 10 mm

Each of these components is illustrated below for 2.8 mm nails.
**Foundation Design**

Foundations hold down shear walls by providing resistance to overturning. This can be by pure mass or by using the geometry to increase resisting moment lever arms.

Design foundations for elastic loads or for the forces generated by the over strength capacity of the nails in the shear wall.

Foundations spread load to the ground limiting the loads to below the bearing capacity of the founding ground by the means of the foundation type and geometry.

**Shear wall load paths**

- Bearing pressure

- Mass footing

- Piled foundation

**Flexural strip footing**

Two load paths exist for shear walls

i. Overturning moment C,T chord forces – load path

ii. Shear force – load path

Diaphragms can collect cumulative shear forces from offset walls above together with the lateral loads of the particular floor diaphragm in question.
**Shear wall design tips**

You can assess each level for design actions, calculate nail spacings and plywood thickness for each level, however it is recommended to design for all levels for the worst case base level design actions. Plywood thickness and nail spacings have a significant affect on shear wall displacements. Displacement will often govern the design so having conservatively design ply and nail spacings for the upper storeys will often result in your design working in fewer iterations when assessing displacements.

**Chords:** Timber is difficult to connect in tension. If the chord tension force is greater than say 20kN use steel SHS members for chords which can be easily bolted together to transfer tension forces.

**Base connection:** ensure that the amount of stretch expected in the tension chord will not be so great as to rip out the base shear connections as the wall tries to lift off its foundations during overturning actions.

**Typical floor/wall details**

![Shear load paths from diaphragms](image)

- **Shear load paths**
- **Paths down wall**

![Single stud Double Lining Platform framing](image)

- **Single stud Double Lining Platform framing**

- **Single stud Double Lining Balloon framing**

- **Double stud Single lining Platform framing**
  
  (Most common in greater than 4 storey's multi unit developments)
Steel Chord Details