Plywood shear walls – Worked Examples

Warwick Banks[1]

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.

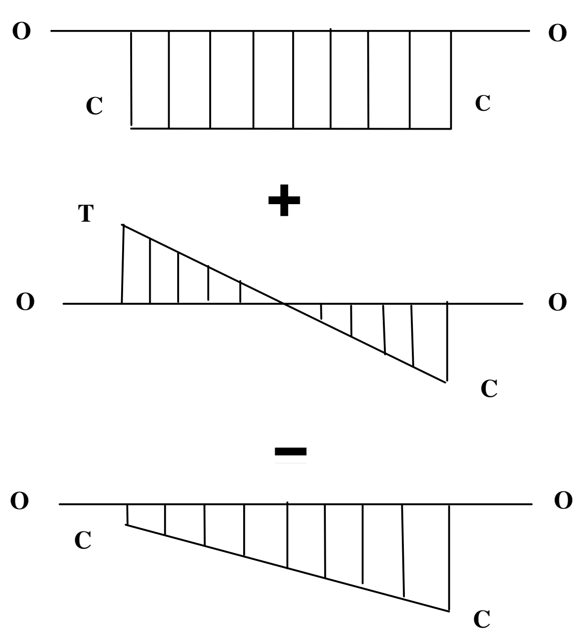
Everything other than the nails are designed for the actions associated with the shear force over-strength capacity of the nailed connections, or alternatively everything other than the nails can be designed for an elastic level load.

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)

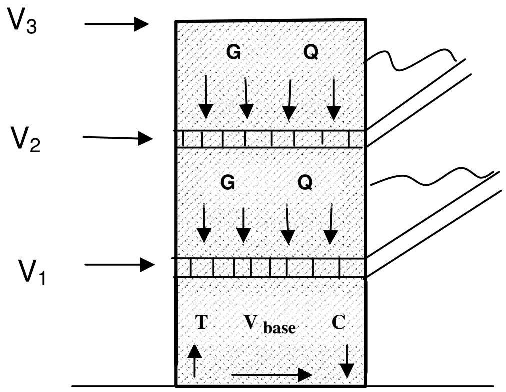
Use ductility level, μ = 3.0 (coincides with the ductility of Gib bracing)

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.



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.

[1] Warwick Banks, Technical Manager, Carter Holt Harvey Wood Products



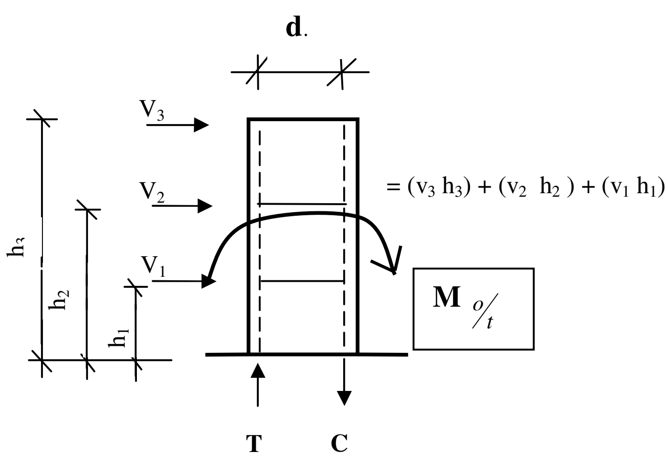
Shear walls may support gravity loads from floors also.

Stress Distribution

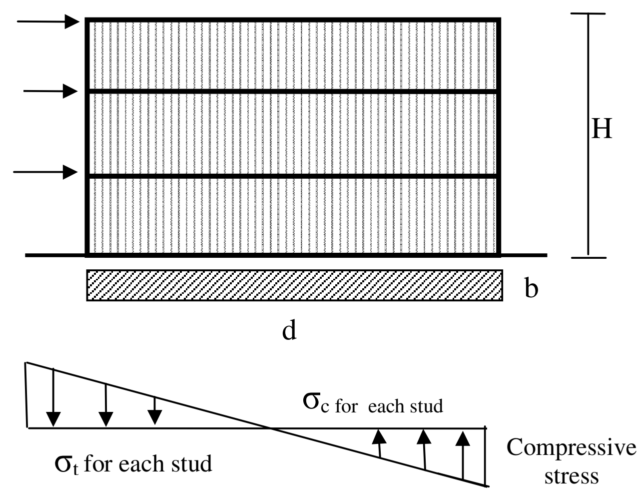
Calculating chord forces – short or long wall

Short Walls H>>d

Long Walls H<<d



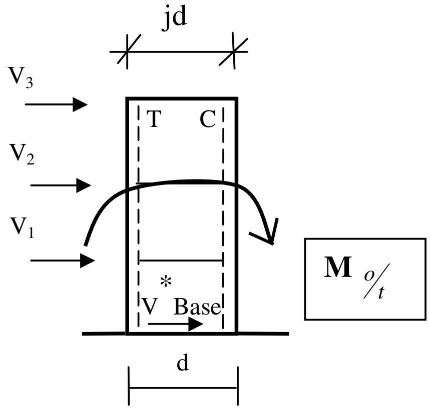
$$T = C = \frac{M_{o/t}}{jd}$$

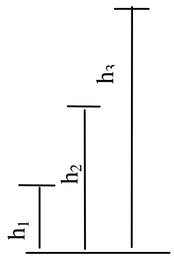


$$\sigma = \frac{M_{o/t}}{z} \qquad z = \frac{bd^2}{6}$$

Each stud resists tension and Compression
The T, C force in each stud.
T, C = σ x b x stud spacing
↑ @ stud location with wall

Shear wall calculations





Remember to share the shear flow between both sides of the walls ply lining if you have ply lining on both sides.

$$M_{o/t} = (V_3 h_3) + (V_2 h_2) + (v_1 h_1)$$

$$T = C = \frac{M_{o/t}}{jd}$$

Shear flow $q^* = \dfrac{V^* base}{d}$

(n/mm)

Plywood

$$V^* < \text{Ø}V = \text{Ø}\tfrac{2}{3} k_1 k_8 f_{ps} td$$

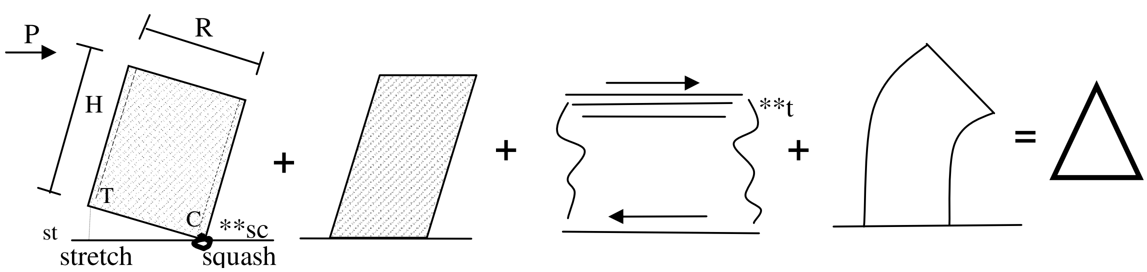
Design Steps

- 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



Chord effects

$$(S_c + S_t)\frac{H}{B}$$

$$S_c \,\&\, S_t \Rightarrow \frac{T_{or} CL}{AE}$$

L = original length
A= area of component
E= Young's Modulus of component

Plywood shear deformation

$$\frac{PH}{GBT}$$

Nail Slip

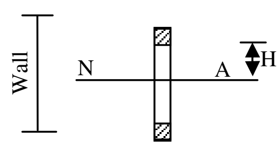
2(1+a) me_n

Refer cl.4.2.2.3 NZS3603

Wall flexural deformation

Calculate deflection of a canter lever using

$I_{wall} = I_{chords}$ @ NA



$$= 2\left[I_{\substack{chord\\itself}} + \left(areachordxh^2\right)\right]$$

Seismic deflections. Calc △@μ=3.0; Multiply this figure by μ(3.0) to get△ @ 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

$$\delta = \frac{k_{37}(0.8)p^2}{Q_n{}^2} \quad \text{.. (Eq. 4.4)}$$

Where :

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

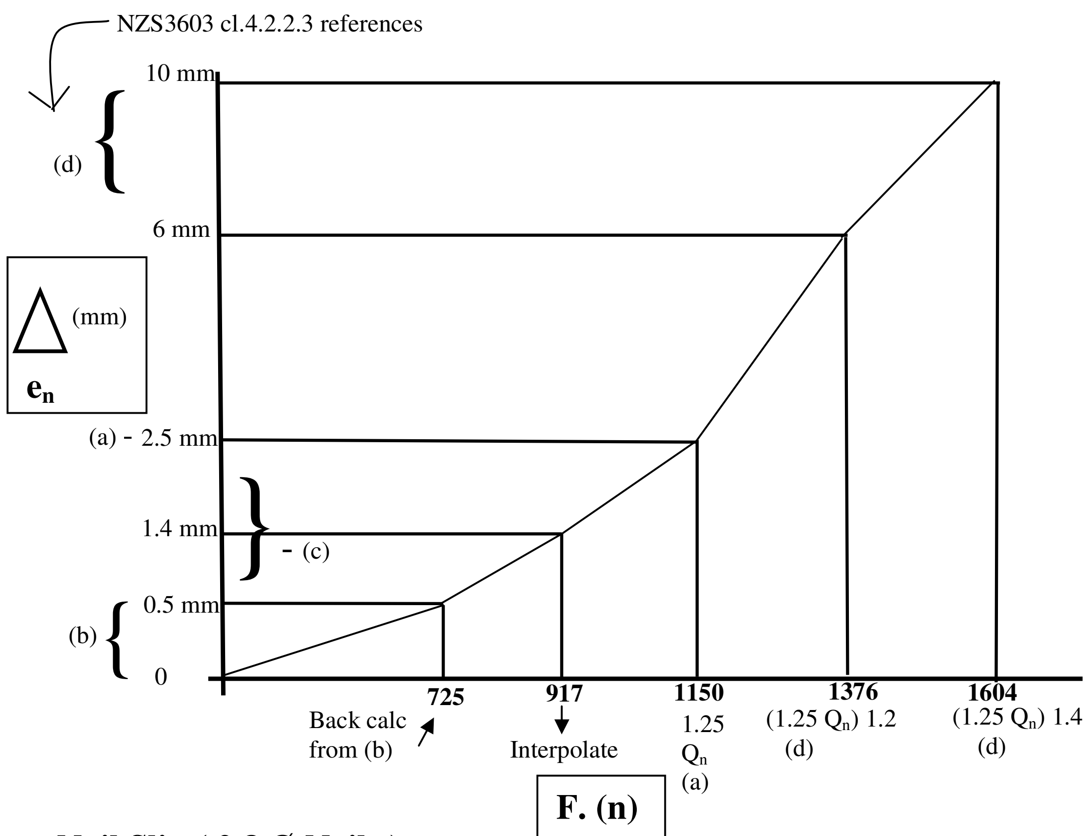
P = applied nail load

Q_n = nominal strength for a single nail with short term loading (k_1=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 componenets is illustrated below for 2.8mm nails.



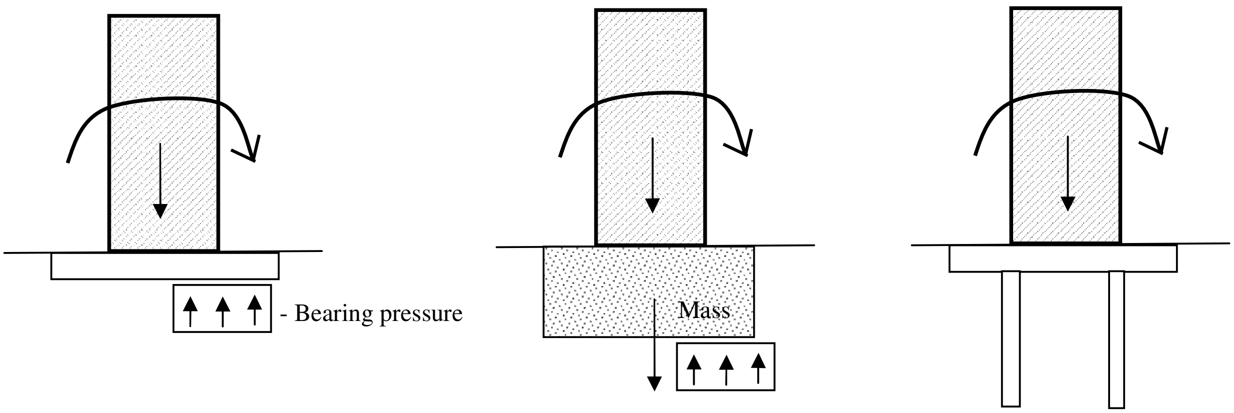
<u>Nail Slip</u> (2.8 Ø Nails)

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.

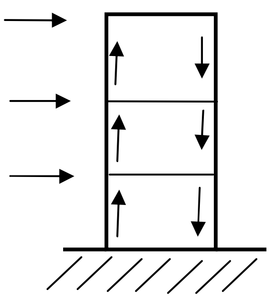
Design foundations for elastic loads or for the forces generated by the over strength capacity of the nails in the shear wall.

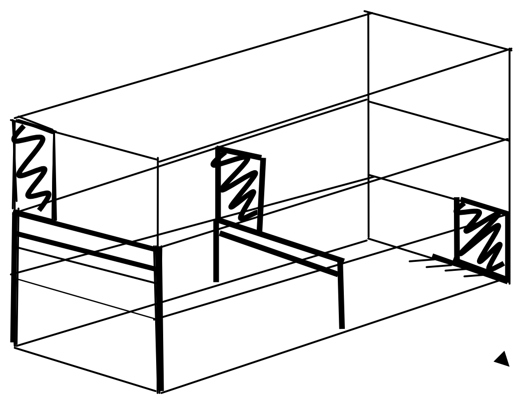
Foundations spread load to the ground limiting the loads to below the bearing capacity of the founding ground by the means of the foundation type and geometry.

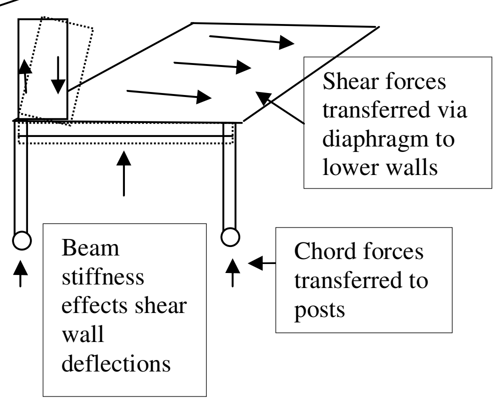


Flexural strip footing **Mass footing** **Piled foundation**

Shear wall load paths







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.

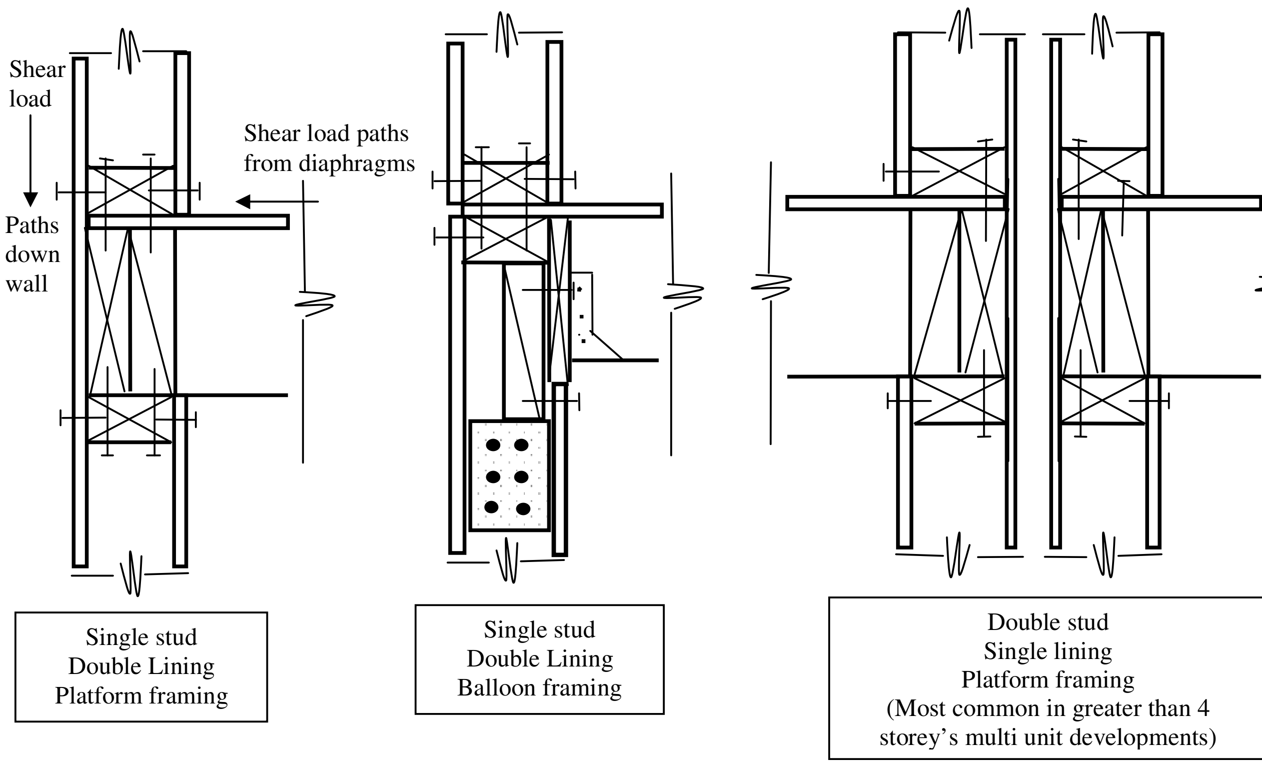
Shear wall design tips

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



Steel Chord Details