TWfNZ TGN 03:22 - July 2022

TWf NZ TECHNICAL GUIDANCE NOTE

Temporary Works forum NZ
Promoting best practice in the construction industry.

Precast Panel Propping Design

New Zealand Best Practice Guidance

1.0 INTRODUCTION

This technical guidance note is provided to assist anyone involved in the design and management of temporary propping schemes for precast concrete panels.

The design requirements for propping concrete panels during construction is a subject often misunderstood in the industry. This note is intended to serve as a reference document for temporary works designers and to clarify some common misconceptions. This will improve consistency of panel propping designs across New Zealand, and therefore reduce the risk across the industry.

It should be noted that this guidance has been based on ultimate limit state design as this aligns with New Zealand standards and allows for direct comparison to permanent structure capacities (existing footings, panels and steelwork etc.). The same design principles can be applied to permissible design however this is not covered in this guidance.

All temporary works propping designs should be co-ordinated in accordance with TWfNZ GPG01:19 *Temporary Works Procedural Control: Good Practice Guideline*.

It is recommended that an assessment of the design complexity of the propping and risk posed in the event of failure is carried out to determine the temporary works category of the scheme and competency requirements of personnel involved in design and verification. This guidance is intended to be relevant for low to medium risk/complexity propping designs (Categories 1-2 in accordance with TWFNZ GPG01:19).

2.0 EXISTING STANDARDS AND GUIDANCE

1. Temporary Works Forum NZ (2019), TWfNZ GPG01:19 *Temporary Works Procedural Control: Good Practice Guideline*
2. WorkSafe NZ (2018), *Safe work with precast concrete: Handling, transportation and erection of precast concrete elements*
3. Health and Safety at Work Act 2015 (HSWA)

3.0 CONSIDERATION OF DESIGN REQUIREMENTS

Before designing panel propping the following should be considered and/or carried out:

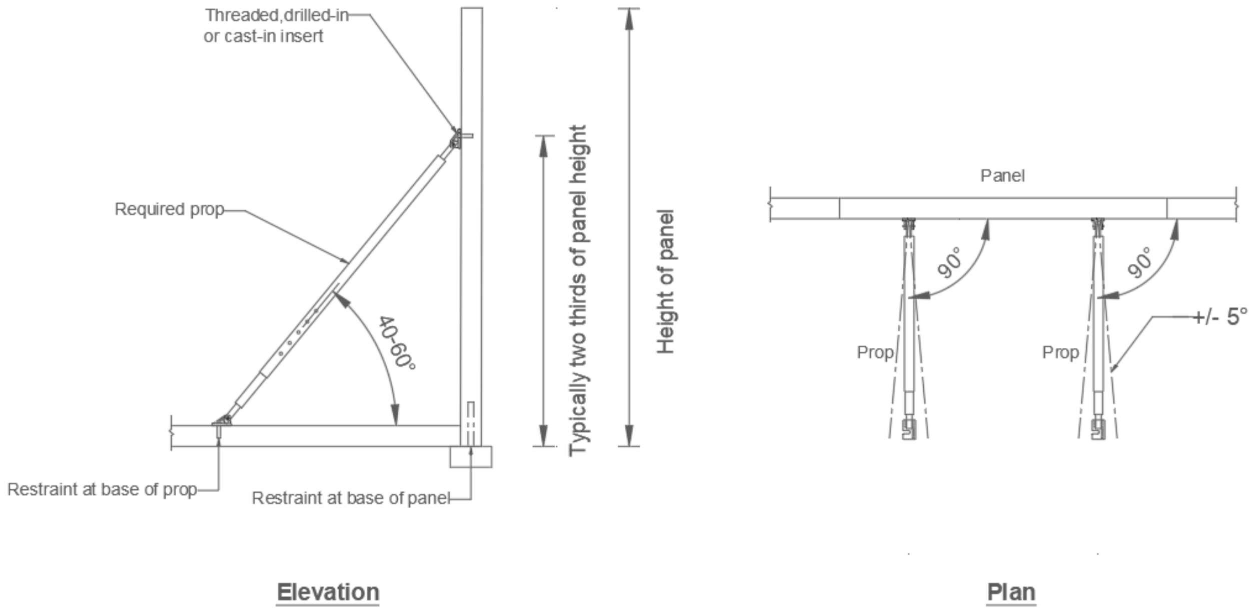
- Inspect structural/shop drawings in detail.
- Review the structural engineers design features report to determine if any unique or specific site conditions/environmental loads that need to be taken into consideration.
- Sequence of panel landing.
- Site conditions.
- Site location and setting for determining environmental loads (earthquake, wind)
- Any special loading requirements (for example other precast elements supported by the panel or adjacent in-situ pours).
- Opportunities to tie propping to permanent structure.
- Requirements for ballasts, sacrificial footings, or piles (including ground conditions).
- Coordination of panel props with permanent works (permanent works that are in place at the time or will need to be installed before the panel props can be removed).

- Coordination of panel props with other temporary works – adjacent shoring, panel lifting points, and formwork for stitch joints etc.
- Consideration of the removal of props from inside complete structures
- Consideration of the location of panel lifting points
- Consideration of panel geometry with respect to openings, penetrations etc. which may limit where fixings can be located and alter loading requirements.
- Consideration of adjacent site operations with respect to space restrictions and isolation/ protection of props from vehicle and plant impact.
- Access for EWPs or other access equipment.

4.0 PRECAST PANEL PROPPING RULES OF THUMB

The following rules of thumb should be utilised as a starting point for design. Note that geometric or methodology constraints may call for modifications to these guidelines and this is acceptable if careful consideration and analysis is applied (Refer to Figure 1: Recommended concrete panel bracing)

- **Fix props at two thirds the height of the panels**. This is to limit loading on the panels and excessive kick-back at the base of panels (refer to Section 5 for guidance on calculating demands).
- **Ideally props should be installed at 40-60 degrees**. Steeper angles will result in high vertical loads on the anchors and hold-down elements.
- **Minimum two props (or other supports) per panel**. One brace can be used where another part of the panel is securely fixed to an existing part of a structure; however, this configuration needs to be specified by a competent person as part of the design.
- **Position props no more than 5 degrees from perpendicular in plan**. If this cannot be achieved secondary loading effects may need to be considered.
- **If more than two props are required, props should be spaced to ensure equal loading on the props and fixings**. Load redistribution based on relative stiffness of props and other supporting elements can be considered with appropriate analysis.
- **For narrow panels, additional bracing perpendicular to the face may be required to provide stability.**



Elevation

Plan

Figure 1: Recommended concrete panel bracing- elevation (left) and plan (right).

5.0 DESIGN ACTIONS

Typical temporary panel supports intended to be in service for less than six months should be designed for a minimum of:

Wind: Loadings in accordance with AS/NZ 1170.2, for a 1/100 APE event in the appropriate region and calculate coefficients as a standalone panel. Refer to Appendix D, Section D2 of AS/NZ 1170.2.

Seismic: Loadings in accordance with NZ 1170.5, this should be calculated using the appropriate seismic coefficient for a 1/100 event, for elastic loads (μ=1.0) for panels on the ground. The load can be distributed uniformly along the height of the structure in most cases. For suspended panel or panels seated on suspended floors, seismic loadings should be derived in accordance with Section 8, of NZ 1170.5, “Parts and Components”.

Construction: Consider any other loading requirements (for example supported structural elements or backfill against panels).

For temporary works which will remain in place for more than 6 months or where there is an interface with high importance level structure or infrastructure, the loadings should be adjusted in accordingly. Additionally if the propping is to be in place for longer than originally intended the designer should be notified and propping system reassessed.

6.0 CALCULATING ACTIONS

A common method for calculating propping actions involves calculating a resultant point load and taking moments around the base of the panel. However, this can lead to underestimation in loading calculations, particularly in nonstandard layouts. The following equations can be used to calculate the actions on a simple rectangular precast panel arrangement (refer to Figure 2 for the calculation inputs).

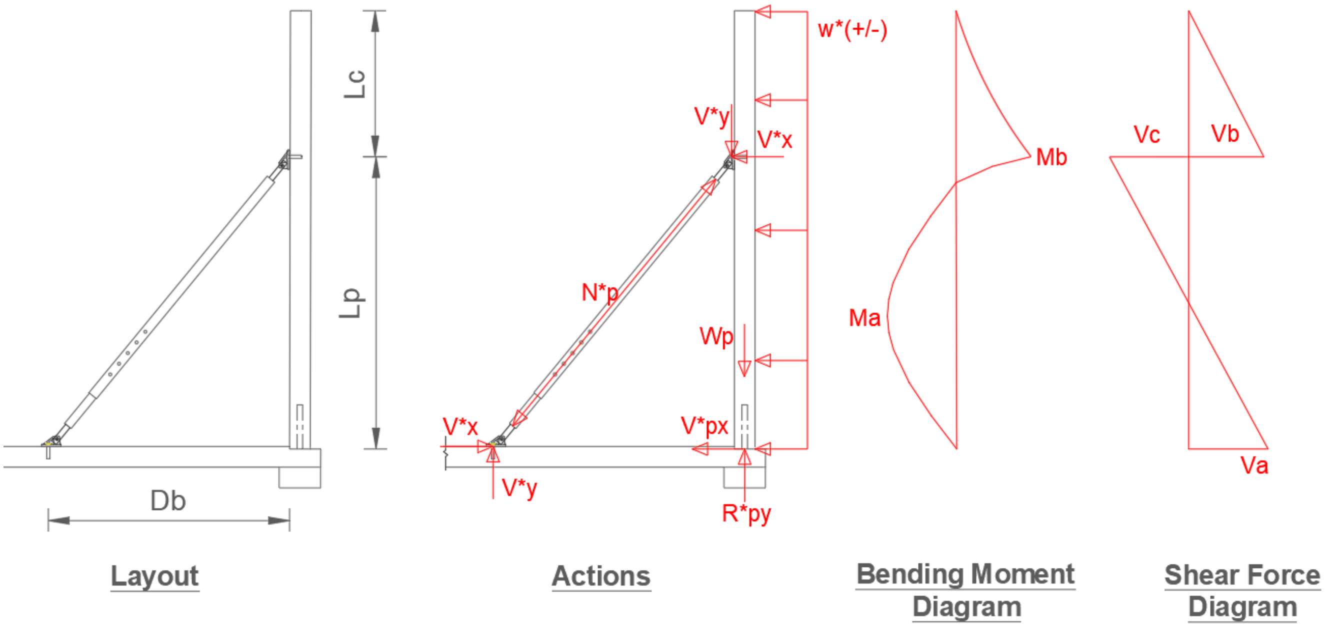


Figure 2: Calculation inputs and outputs (the environmental loads can be in either direction and also parallel to the panels).

Inputs:

$$w^* = \text{Governing distributed tributary load per prop } (kN/m)(\text{refer to Section } 5 : \text{Design Actions})$$

$L_c \ = \ Height\ of\ panel\ above\ top\ prop\ fixity\ (m)$

$L_p \ = \ Height\ of\ top\ prop\ fixity\ above\ base\ (m)$

$D_b \ = \ Distance\ of\ prop\ base\ to\ panel\ base\ (m)$

$W_p \ = \ Tributary\ weight\ of\ panel\ (kN)$

Equations:

$$V_x^* = \frac{w^*}{2L_p}(L_p + L_c)^2,\ horizontal\ load\ on\ prop\ fixings\ (kN) \tag{1}$$

$$V_y^* = \frac{L_p}{D_b} \times V_x^*,\ vertical\ load\ on\ prop\ fixings\ (kN) \tag{2}$$

$$V_{px}^* = V_a = \frac{w^*}{2L_p}\left(L_p^2 - L_c^2\right),\ horizontal\ load\ on\ base\ of\ panel (kN) \tag{3}$$

$$R_{py(max,\mathrm{min})}^* = W_p \pm V_y^*, max/min\ tributary\ vertical\ load\ at\ base\ of\ panel \tag{4}$$

$$N_p^* = \frac{\sqrt{L_p^2 + D_b^2}}{D_b} \times V_x^*, axial\ load\ on\ prop\ (kN)(tension\ or\ compression) \tag{5}$$

$$Ma = \frac{w^*}{8L_p^2}(L_p + L_c)^2(L_p - L_c)^2, span\ moment\ A\ in\ panel(kN.m) \tag{6}$$

$$Mb = \frac{w^* L_c^2}{2},\ cantilever\ moment\ B\ in\ panel\ (kN.m) \tag{7}$$

$$Vb = w^* L_c\ , shear\ B\ at\ panel\ support\ (kN) \tag{8}$$

$$Vc = \frac{w^*}{2L_p}\left(L_p^2 + L_c^2\right),\ shear\ A\ at\ panel\ support \tag{9}$$

Note these equations have been derived based on first principle statics and should be applied with care and engineering judgement by a suitably competent person.

7.0 SPECIFYING REQUIRED PROPS

Props should be based on calculated loads and geometry/layout. It is crucial to understand how the supplier defines prop capacities; they are generally presented as working load limits (WLL). As NZS1170 wind and earthquake actions are ultimate loads, comparing ULS loads to WLL capacities is on the safe side but very conservative. A comparison of ULS loads to ULS capacities can be made if the designer has sufficient information to determine the prop ULS capacity, making due allowance for the potential 'used' condition and 'repeated-use' nature of the props. If, for example, the prop has a factor of safety (FoS) of 2.0 to convert the WLL capacity to a ULS capacity, the capacity can be multiplied by the FoS and the appropriate material capacity reduction factor. The appropriate conversion should be verified with prop supplier as the capacity may be based on testing or other means and may require additional reduction factors.

The effect of prop length on its design capacity should be considered as some props provide varying WLLs depending on extension.

8.0 SPECIFYING REQUIRED ANCHORS

Size anchors based on calculated loads and geometry/layout. Ensure:

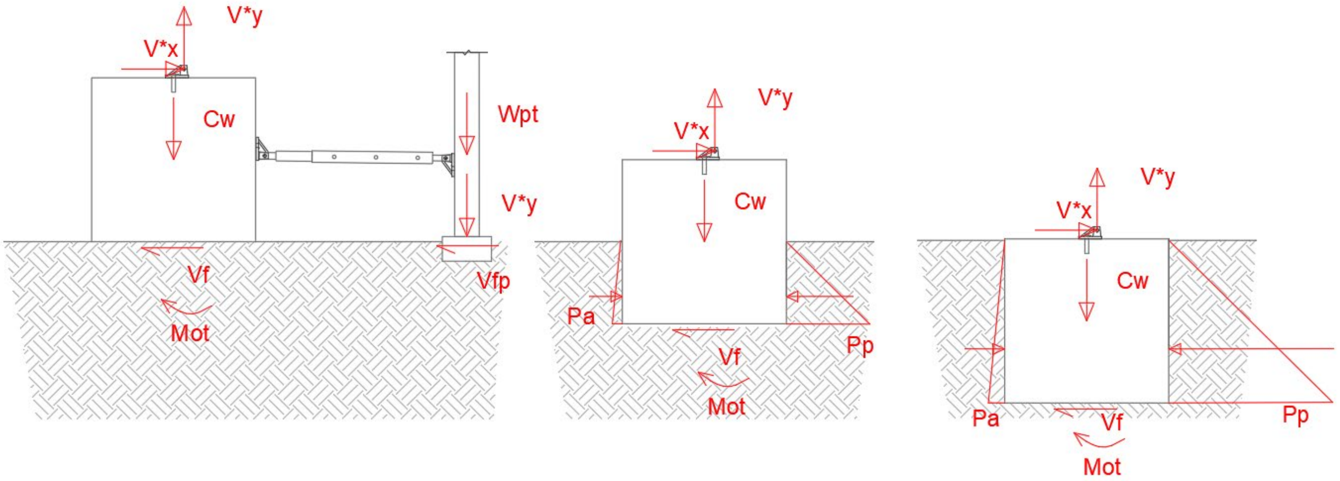
- Manufacturer supplied capacity (with appropriate conversion) > applied loads.

- The anchors will comply with all the manufacturers' requirements including embedment, substrate depth, and edge distance and installation instructions.
- The seismic capacity of post installed anchors should be calculated based on EOTA TR045 to comply with Amendment 3 to NZS 3101, Clause 17.5.5. An allowance should be made for cracked concrete.
- For critical situations:
    - Consider cast-in or through-bolting instead of post-installed anchors.
    - Consider capacity design principles. For example, understanding the flexural capacity of the precast wall and considering how a flexural mechanism might limit the maximum seismic load to the prop.
- Drop-in and impact-setting anchors should not be used for Panel Propping.
- Anchors which rely solely on chemical adhesion should not be used as bracing anchors unless each fixing is individually proof tested to the WLL.
- The appropriate concrete strength at the time of propping should be considered (typically 20-25 MPa).

9.0 HOLD-DOWN REQUIREMENTS

The propping designer needs to verify that sufficient hold-down can be engaged to ensure equilibrium of the propping system. Common structures utilised for hold-down include:

- Concrete ballasts placed above ground (an additional specially designed brace or other mechanical means should be added to prevent sliding.
- Partially or fully buried concrete ballasts.
- Fixing to the concrete slab or foundation elements (a check to ensure the structure has sufficient capacity to engage the required dead-weight).
- Concrete tension piles.
- Screw pile type anchors.



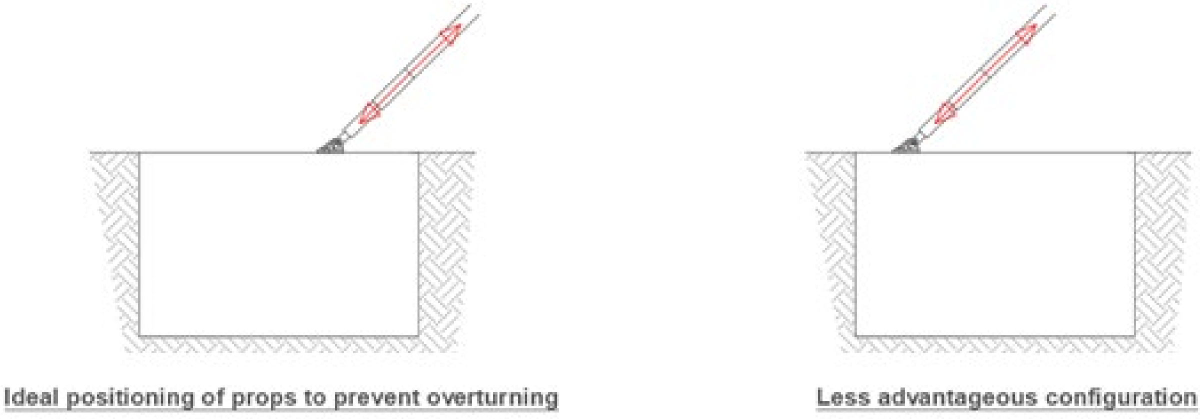
Above Ground with Second Prop

Partially Buried

Fully Buried

Figure 3: Simplified sliding and uplift actions on concrete ballasts used for panel restraints.

Consideration should be given to where on the ballast or footing the props are to be fixed. If the props are fixed in a way that destabilises the block, this should be accounted for in the calculations.



Ideal positioning of props to prevent overturning

Less advantageous configuration

Figure 4: Ideal and less advantageous configurations of fixings to ballasts or footings for stability.

As NZS 1170 wind and earthquake loads are ultimate loads utilising factors of safety on the hold-down is not required. The following load combinations based on AS/NZS 1576.1:2019: Scaffolding and AS/NZS 1170.0:2002 Structural design actions: General principles, should be used to calculate required hold-down.

Dead weight (permanent action), wind actions and earthquake action combinations produce net stabilising and net destabilizing effects which can be determined as follows.

$$E_{d,stb} = [0.9G + 0.9C_w + \emptyset R], net\ stabilising\ effects \quad (10)$$

$$E_{d,dstb} = [W_u, EQ_u + 1.2\ G], net\ destabilising\ effects \quad (11)$$

Where:

$G, W_u, EQ_u = \text{dead, wind and earthquake actions}$

$C_w = \text{ weight of all counterweights used to resist instability}$

$\emptyset R = \text{design capacity of all structural components designed to resist instability.}$

$$Ensure: E_{d,stb} > E_{d,dstb} \quad (12)$$

It is important that the designer follows the design load paths to the ground and ensures the ground provides sufficient resistance.

The following are a few points that should be considered:

- Uplift is unlikely to govern in ballast design but will have a significant effect on sliding and overturning of the blocks.
- Buried ballasts or footings should be checked in accordance with B1:VM4.
- The appropriate coefficient of static friction should be used for the given situation. Recommended static friction coefficients for propping design are included below. Friction coefficients for further material combinations can be found in *Friction in Temporary Works* (Gorst et al., 2003).

Interface	Coefficient of static friction
Concrete – concrete	0.4
Concrete – granular soil	0.4
Concrete – ribbed plastic packers	0.2
Stacked ribbed plastic packers	0.2

Table 1: Recommended coefficients of friction for common interfaces

- For robustness and redundancy it is recommended that panel bases are not restrained solely by friction. Ideally panel bases should be secured by bolts, starters or secondary props in conjunction with friction
- Triangulating props by adding a second prop from the ballast will make the structural system more robust but may not be practical due to space constraints (refer to Figure 5). The ballast may be less likely to overturn or slide without moving the panel or failure of the fixings (though a stability check should always be undertaken). Additionally due to equilibrium the full weight of the panel and ballasts will contribute to frictional resistance.
- Where concrete ballasts are to be used the designer should consider the need for reinforcement.
- Concrete ballasts not poured continuously should be reinforced.
- When screw piles are utilised it should be confirmed that a design has been undertaken by a suitably competent engineer. This design should include analysis of the shear and rotational effects of the props loading upon the pile.

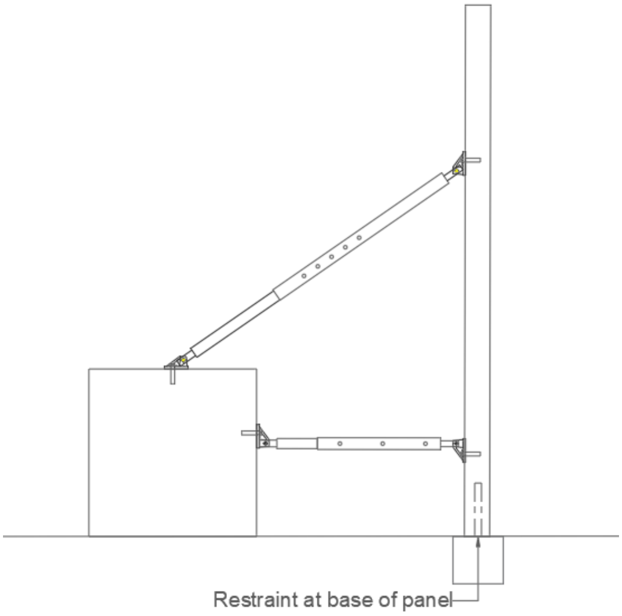


Figure 5: Triangulation of props to prevent ballasts from sliding or overturning.

Props Tied to Permanent Structure

Often the base props supporting panels will need to be tied to existing structures. Once again it is important that the load-paths are followed to the ground and that the permanent structure can resist the localised applied loads. Smaller panels can be fixed to the concrete floor slab, whereas larger multi-storey panels may need to be secured to reinforced ground beams. It is important that when props are tied to a concrete permanent structure it is confirmed the structure has sufficient strength and reinforcement to engage the required hold-down weight and resist the imposed load.

10.0 SPECIFYING OTHER REQUIREMENTS

Other components that may require design may include:

- Temporary cleats tying perpendicular panels together, fixed in place with appropriately designed anchors.
- Base restraints to ensure the base of the panels cannot slide. This can consist of small props or brackets. Panels seated in grout tubes may have sufficient sliding resistance.
- The in-plane overturning of the panels may require verification for some panels.
- Flying shores to support hallways and lift-shafts.

- The panels should be confirmed to have sufficient capacity to resist the calculated flexural and shear propping loads.

11.0 CONCLUSIONS

The conclusion of this technical guidance is that designs of precast panel propping should at a minimum include:

- Requirements/ constraints of the individual project.
- Panel propping rules of thumb as a starting point for design.
- Calculation of loading demands on the panels for wind, seismic and construction actions.
- Size props by comparing the ULS capacity to the ULS demands.
- Specification of any post installed anchors based on EOTA TR045 to comply with Amendment 3 to NZS 3101, Clause 17.5.5 for seismic action.
- Specification of anchors that will comply with the manufacturers' requirements including embedment, substrate depth, and edge distance and installation instructions.
- Verification that there is design load paths to the ground/permanent structure and the ground/permanent structure provides sufficient force resistance.
- Consideration of bespoke solutions to solve any project related challenges.
- Clear communication of temporary works designs and robust change control following the principles established in TWfNZ GPG01:19 *Temporary Works Procedural Control: Good Practice Guideline*

REFERENCES:

1. American Wood Council (2007), *Design Aid No.6, Beam Formulas with Shear and Moment Diagrams.*
2. European Organisation of Technical Approvals (2013), *TR045 Design of Metal Anchors For Use In Concrete Under Seismic Actions*
3. Gorst, Williamson, Pallett & Clark (2003), *Friction in Temporary Works*
4. Ministry of Business, Innovation and Employment (2017), *Verification Method B1/VM4: Foundations*
5. Standards New Zealand (2002)*, AS/NZS 1170.0:2002 Structural Design Actions, Part 0: General Principles*
6. Standards New Zealand (2002), *AS/NZS 1170.1 Supplement 1:2002 Structural design actions - Part 1: Permanent, imposed and other actions - Commentary (Supplement to AS/NZS 1170.1:2002)*
7. Standards New Zealand (2021), *AS/NZS 1170.2:2021 Structural Design Actions, Part 2: Wind Actions*
8. Standards New Zealand (2004), *NZS 1170.5:2004 (A1 excl.) Structural Design Actions - Part 5: Earthquake design actions - New Zealand*
9. Standards New Zealand (2006), *NZS 3101.1&2:2006 Concrete structures standard. The design of concrete structures.*
10. Standards New Zealand (2019), *AS/NZS 1576.1:2019:Scaffolding - Part 1: General requirements*
11. Temporary Works forum New Zealand (2019), *TWf(NZ) GPG01:19 Temporary Works Procedural Control: Good Practice Guideline*

TWf
NZ