NEW ZEALAND GEOTECHNICAL SOCIETY INC
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NZGS GEOTECHNICAL ENGINEERING BASICS

RETAINING WALLS (PART 2) – EMBEDDED CANTILEVER AND ANCHORED

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1. CHARACTERIZE THE SITE AND DETERMINE WALL TYPE

Develop ground model

- Consider local soil conditions (previous investigations e.g. NZGD, geological maps, geomorphology of the area) and site-specific ground investigations / laboratory testing
- Consult with others that are familiar with the area
- Understand groundwater levels
- Develop suitable cross sections
- See NZGS Ground Model poster

Determine soil and rock parameters

- Use direct measurement of properties in the lab, or correlation of properties from in-situ field testing
- Soil parameters
  - Undrained ("short term") – consider total stress and undrained shear strength if water content of the soil cannot change rapidly e.g. saturated soils with low permeability
  - Drained ("long term") – consider effective stress and cohesion and friction angle if water content of soil can change rapidly e.g. cohesionless soils with high permeability
- Rock parameters – consider mode of failure and appropriate strength parameters (e.g. Mohr-Coulomb, Hoek-Brown)
- Grout-to-ground pullout capacity for anchors – should be supported by ground anchor performance and proof testing at the site or in similar soils, and consider construction methodology

Determine wall geometry and loading

- Consider head slope, toe slope, and berms
- Determine surcharge
  - Design for maximum surcharge loading likely to be experienced throughout the life of the structure
  - For Waka Kotahi roads and bridges, consider 12 kPa (normal) and 24 kPa (overload) in accordance with Waka Kotahi Bridge Manual
  - Consider council guidance (e.g. TCC)
  - A general rule of thumb is to consider any surcharge that is applied within a 45° line taken from the base of the wall to the ground surface above the wall. However, this depends on the ground conditions, type of surcharge, etc. (e.g. a steeper line may be considered for strong rock, and shallower line for weak material)

Select wall type

	Wall Type	Advantages	Disadvantages
Part 2	Embedded Cantilever	Cost effective, low-medium construction risk, requires little space	Limits on retained height
Part 2	Propped	Allows for greater retained height with less embedment than cantilever walls, limits wall deflections	Props obstruct excavation works
Part 2	Anchored	Allows for greater retained height with less embedment than cantilever walls, limits wall deflections	Anchors may cross boundaries and may be removed (temporary) after construction

2. CALCULATE FORCES

Load cases

- Retaining structures are considered as buildings and subject to the requirements of the NZ Building Code – NZS1170.0:2002 specifies combinations of actions to be considered
  - Static – Static earth pressure + groundwater pressure + surcharge (dead and live loads)
  - Seismic – Earthquake earth pressure + water pressure + surcharge (dead)
  - Temporary cases, if applicable (e.g. raised groundwater, additional surcharges, future service maintenance)
- For Waka Kotahi roads and bridges, consider load factors from Waka Kotahi Bridge Manual Section 3.5, and displacement limits from Waka Kotahi Bridge Manual Section 6.1.2

Determine forces

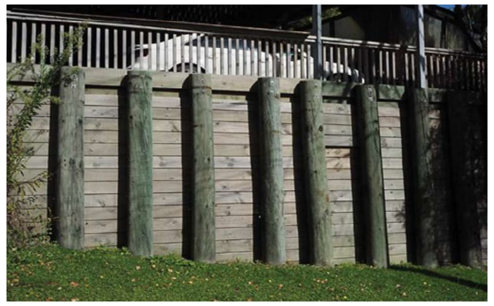
- Earth pressures (static and seismic)
- Surcharge pressure (uniformly distributed loads, line loads, and point loads)
- Compaction pressure, if applicable
- Groundwater pressure, if applicable

Static earth pressure

- Rankine and Coulomb methods
- At-rest pressure (K0)
  - Use for stiff walls or cases where no significant movement is acceptable at SLS
  - Calculate with Jaky equation, $K0 = 1 - \sin\phi'$
  - For backslopes, refer to Module 6 Figure 6.1
- Active pressure for flexible walls (Ka)
  - Use for flexible walls where wall movement is acceptable – approx. 0.4% of wall height
  - Calculate with Coulomb and Rankine theories, assumptions discussed in NZGS Workshop on Lateral Earth Pressures
- Passive pressure (Kp)
  - Log-spiral method described in NAVFAQ DM7-02

Seismic earth pressure

- Design guidance provided in Module 6
- Low to moderate risk walls – pseudo-static horizontal acceleration (e.g. Mononobe-Okabe equations for flexible walls)
- High risk walls – more sophisticated analysis required (e.g. finite element method)
- Assess site soils for degradation of strength with shaking, and the implications for global stability


CANTILEVER TIMBER POST WALL


ANCHORED SECANT PILED WALL


ANCHORED TIMBER POST WALL

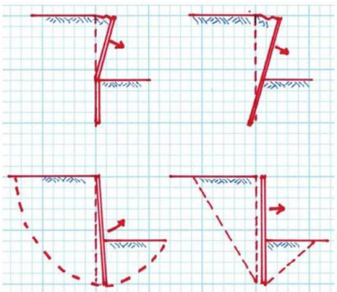
3. ASSESS STABILITY

For embedded walls, consider different modes of failure for all load cases:

- **Overturning**
  - Methodology: Assess the factor of safety in accordance with established design procedure
- **Structural failure**
  - Assess bending capacity of the posts using appropriate material codes including relevant strength reduction factors
- **Global stability**
  - Methodology: Factor of safety calculated using limit equilibrium (e.g. Bishop analysis) or more advanced methods (e.g. FEM)
  - Important to consider in circumstances where there is sloping ground above and/or below the wall, or weak layers near the toe of the wall

Tied-back / anchored walls have additional failure modes:

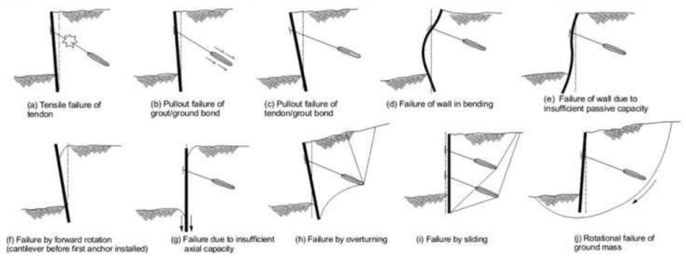
- **Ground anchor pull-out (geotechnical failure)**
- **Tendon extension and failure (structural failure)**
- For example, refer to Worked Example 4 in Module 6.



Design Softwares

- Wallap
- Plaxis
- Slide2 / SlopeW (global stability only)

Figure E.1: Possible modes of failure for tied-back retaining walls (Source: Sabatini et al, 1999)



4. GENERAL CONSIDERATIONS

Displacement behaviour of the selected retaining wall

- Rigid wall (generally no movement)
- Stiff wall (generally very small movements)
- Flexible wall (typically movements > 1%H)

Drainage

- For post and panel walls, consider free draining granular material or geocomposite drainage sheet, leading to a perforated pipe at base, wrapped in geotextile
- For sheet pile or secant pile walls, allow for hydrostatic water pressure behind the wall in absence of drainage
- Surface water flows from above the wall should be managed to prevent water flowing over the wall face or entering the wall / soil interface

Durability

- Timber – assess treatment as per NZS3602 Table 1
- Steel – assess corrosion protection as per SNZTS 3404:2018, NZS2312
- Consider whether single, double, or triple corrosion protection is required for ground anchors

Safety in Design

- Minimise the height of cut slopes, and stage cuts where necessary
- Clearly identify the responsibility for the design of temporary works
- If the ground above the wall is likely to be frequented by people, and the potential fall is greater than 1m, then a barrier to prevent people falling should be constructed near the top of the wall
- Allow for over-excavation in front of wall (typically 0.5 m of 10%H)

Other considerations

- Avoid clayey backfills, as these can cause creep and expansion
- Consider if embedment material is expansive, as it may contract away
- Consider sloping walls back, as this is less visually imposing and reduces applied loads

Published Guidance

- MBIE/NZGS Module 6: Earthquake resistant retaining wall design
- Waka Kotahi Bridge Manual
- FHWA (Tied-back walls)
- BS8081 (Ground anchors)
- ICE Specification for Piles and Embedded Retaining Walls, 2017
- CIRIA 758, 2019