NEW ZEALAND GEOTECHNICAL SOCIETY INC
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NZGS GEOTECHNICAL ENGINEERING BASICS
RETAINING WALLS (PART 1) – GRAVITY, MSE AND RSS

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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 level
- Develop 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
- Undrained ("short term") conditions – 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") conditions – consider effective stress and cohesion and friction angle if water content of soil can change rapidly e.g. cohesionless soils with high permeability

Determine wall geometry and loading
- Consider head slope and toe slope
- 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. Tauranga CC)

Select wall type

	Wall Type	Pros	Cons
Part 1	Gravity Wall – relies on geometry and soil bearing to resist overturning	Relatively cheap, easily constructed	Foundations require space, may not be suitable for toe slopes
Part 1	MSE (Mechanically Stabilised Earth) Wall – gravity wall consisting of blocks of soil tied together by reinforcement systems (e.g. metal strips, geogrids), with facing elements RSS (Reinforced Soil Slope) – slope consisting of blocks of soil tied together by reinforcement systems, typically with no facing elements	No limit to height, easily constructed, tolerant to deformations	Requires space, may not be suitable for cuts

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 earth pressure + groundwater pressure + surcharge (dead and live loads)
  - 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

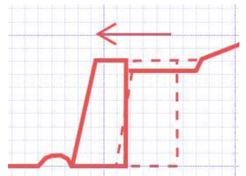
Determine forces
- Earth pressures (static and seismic)
- Surcharge pressure
- Compaction pressure
- Groundwater pressure, if applicable

Static earth pressure
- At-rest pressure
  - Use for stiff walls (e.g. buttressed concrete walls) or cases where no significant movement is acceptable at SLS
  - Calculate with Jaky equation, $K_o = 1 - \sin\phi'$
  - For backslopes, refer to Module 6 Figure 6.1
- Active pressure
  - 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
  - Log-spiral method described in NAVFAQ DM7-02
- Wall friction ratios are implied in the Module 6 worked examples

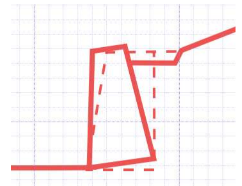
Seismic earth pressure
- Design guidance provided in Module 6
- Low to moderate risk walls – pseudo-static horizontal acceleration (e.g. Mononobe-Okabe equations for flexible walls, Module 6 Section 6.6.2 for stiff and rigid walls)
- High risk walls – more sophisticated analysis required (e.g. finite element method)
- Assess site soils for degradation of strength with shaking, and the implications for global stability

3. ASSESS STABILITY

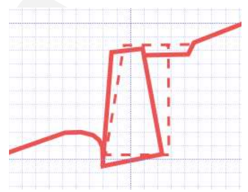
Consider different modes of failure for all load cases:
- **Sliding**
  - Methodology: B1/VM4
  - Consider adding a key beneath the foundation to improve sliding resistance



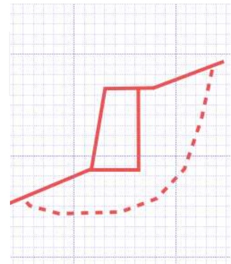
- **Overturning**
  - Methodology: Dimension foundation such that resultant force acts through the middle third of the footing
  - Consider battering the wall to reduce eccentricity



- **Bearing**
  - Methodology: B1/VM4
  - Consider constructing wall on wide concrete pad foundation



- **Global instability**
  - Methodology: Factor of safety calculated using limit equilibrium (e.g. Bishop analysis)
  - 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



- **Internal instability**
  - Use appropriate material codes including relevant strength reduction factors

For examples, refer to Worked Example 3 in Module 6 or Appendix C in B1/VM4.

MSE walls and RSSs have additional failure modes:
- **Tensile resistance** of reinforcement
- **Pull-out resistance** of reinforcement
- **Structural resistance** of face elements and face element connections (MSE only)

4. GENERAL CONSIDERATIONS

Drainage
- Consider free draining granular material or geocomposite drainage sheet, leading to a perforated pipe at base. Drainage material and perforated pipe should be wrapped in geotextile
- Avoid rounded gravels as drainage material, as these may settle during strong shaking
- Consider weep holes through concrete walls
- Surface water flows from above the wall should be managed to prevent water flowing over the wall face

Durability
- Timber – assess treatment as per NZS3602 Table 1
- Steel – assess corrosion protection as per SNZTS 3404:2018, NZS2312

Safety in Design
- 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

Other considerations
- Avoid clayey backfills (if practicable), as these can cause creep and expansion
- Consider sloping walls back, as this is less visually imposing and reduces applied loads
- If retaining rock, consider presence of defects

Design Software
- Geo5
- Slide2 / SlopeW
- Plaxis
- Manufacturer's software (Geofabrics, Cirtex, etc.)

Published Guidance
- MBIE/NZGS Module 6: Earthquake resistant retaining wall design, particularly Worked Example 3
- Waka Kotahi Bridge Manual
- AS 4678 Earth Retaining Structures
- FHWA (MSE and RSS walls)
- Earth Pressure and Earth-Retaining Structures, Third Edition (2014) Clayton et al.

CRIB WALL

GABION BASKET WALL

MECHANICALLY STABILISED EARTH (MSE) WALL

REINFORCED SOIL SLOPE (RSS)