

# Technical Direction

## Geotechnology

GTD 2018/001 | RMS 18.748 – 22 February 2018

### Geotechnical Design for Remediation of Existing Slopes and Embankments

Summary:	Audience:
This technical direction specifies the minimum factor of safety in the design for remediation of existing soil slopes and fill embankments.	<ul style="list-style-type: none"> <li>• Designers</li> <li>• Project Managers</li> <li>• Contract Managers</li> </ul>

### Background

For new infrastructure projects, typical Scope of Works and Technical Criteria (SWTC) requires slopes and batters to achieve an Assessed Risk Level (ARL) four or better. The ARL is assessed in accordance with the Roads and Maritime Services *Guide to Slope Risk Analysis* (Roads and Maritime, 2014). Furthermore, soil slopes and fill embankments shall be designed with a minimum long term Factor of Safety (FOS) of 1.5 and a minimum short term FOS of 1.2 to 1.3.

In contrast to new works, design for remediation of existing slopes and embankments only targets an ARL 3 or better in accordance with the *Slope Asset Management Policy PN 292*. This is less stringent than that of new works. If the design standard for new works is also adopted for remedial works, the associated repair costs could be unnecessarily high in many situations and might exceed the minimum ARL requirements. A rational approach is warranted to improve the cost effectiveness of slope remedial works in order to optimise network functionality and to be consistent with the strategy in slope management.

### Approvals:

<b>Owner:</b>	Samuel Henwood Director Pavements & Geotechnical	<b>Review Date:</b>	No later than three years after effective date
<b>Authorised by:</b>	Chris Harrison Director of Engineering	<b>Effective Date:</b>	22 February 2018

## Purpose and scope

This technical direction stipulates a set of minimum acceptable FOS required for the remediation of existing soil slopes and fill embankments affecting the road network of Roads and Maritime Services. The criteria adopted for selecting the minimum FOS in this technical direction targets an ARL 3 or better.

This technical direction does not apply to the following situations:

- Internal, sliding, overturning and bearing stability assessment of retaining structures, for which appropriate codes and standards shall be used
- Remedial works of any new infrastructures less than 10 years old since the completion of the construction
- Emergency repair works which are not required to achieve an ARL 3 or better.

Costs on future maintenance and monitoring have not been considered in deriving the minimum FOS in this technical direction. As a general rule, adopting a lower FOS could result in higher maintenance and monitoring costs. These costs, together with design and construction costs, shall be taken into account in assessing remedial solutions for individual projects.

The minimum FOS in this technical direction depends on the consequence class defined in *Guide to Slope Risk Analysis*. The FOS shall be agreed with Roads and Maritime Geotechnical Engineering Unit before being adopted in the design.

## Geotechnical design requirements for slope remedial works

A slope risk assessment shall be carried out by an accredited geotechnical professional (AGP) in accordance with the *Guide to Slope Risk Analysis* to identify the consequence class of each potential failure mechanism. If the slope risk assessment report is out of date, an AGP shall reassess the consequence class for each potential failure mechanism.

Designers and reviewers of slope remedial works shall be geotechnical engineers or engineering geologists with proven experience in slope remediation design and are familiar with the *Guide to Slope Risk Analysis*. The designer shall review all available slope risk assessment reports, site investigation results, historical performance data and appropriate analyses to identify all potential failure mechanisms requiring remediation.

For each potential failure mechanism and the corresponding consequence class, the FOS adopted in the design shall not be lower than the minimum values in Table 1. Anticipated changes to the consequence class due to changes in site conditions associated with the remedial works (eg road realignment) shall be taken into account in the selection of FOS.

Table 1: Consequence class and minimum FOS

Consequence Class	C1	C2	C3	C4	C5
Long Term FOS	1.5	1.4	1.3	1.25	1.25
Short Term FOS	1.25	1.25	1.2	1.2	1.2

## Minimum level of site investigation and testing

Designers shall assess the adequacy of available site investigation and test results. Designers shall also take into consideration the characteristics and variability of subsurface conditions and groundwater conditions, the type of works to be carried out, and all other available information. Site investigation and testing for remediation design shall meet the minimum requirements in Table 2. Additional site investigation and testing shall be undertaken at the direction of the designers where necessary.

Table 2: Minimum Level of Site Investigation and Laboratory Testing

Consequence Class	Site Investigation and Laboratory Testing
C1, C2 and C3	<ul style="list-style-type: none"> <li>Examine aerial photographs and geological maps</li> <li>Undertake survey of topographical, geological and drainage features</li> <li>Identify any nearby underground and surface utilities</li> <li>Evaluate design and performance of nearby structures</li> <li>Carry out investigation, such as test pits and boreholes, at a typical spacing of 30 m with a minimum two locations for each site</li> <li>Undertake appropriate field tests to determine the design parameters, such as Standard Penetration Tests (SPT)</li> <li>Undertake suitable laboratory tests on undisturbed samples, including classification tests and shear strength tests such as consolidated undrained triaxial tests with pore pressure measurements.</li> <li>Install monitoring and instrumentation, including piezometers and inclinometers, where necessary.</li> </ul>
C4 and C5	<ul style="list-style-type: none"> <li>Examine aerial photographs and geological maps</li> <li>Undertake survey of topographical, geological and drainage features</li> <li>Identify any nearby underground and surface utilities</li> <li>Evaluate design and performance of nearby structures</li> <li>Carry out investigation such as test pits and boreholes</li> <li>Undertake field tests such as standard penetration tests (SPT)</li> <li>Undertake classification tests and/or other suitable tests to justify the geotechnical design parameters</li> <li>Install monitoring and instrumentation, including piezometers and inclinometers, where necessary.</li> </ul>

## Design load combinations

The following load combinations shall be considered for the long term and short term conditions. All applied loads shall be serviceability limit state loads:

- Long term conditions:
  - Gravity load + nominal vertical traffic live load.
- Short term conditions:
  - Gravity load + the most critical transient load (ie only one transient load at any time)
  - Transient loads include, but not limited to, earthquake load, traffic impact load, traffic braking load, wind load and rapid drawdown load
  - Return period of design earthquake events shall be 1 in 500 years.

## Minimum nominal vertical traffic live load

The minimum nominal vertical traffic live load shall be as follows:

- Carriageway, breakdown lane and shoulder: 20 kPa
- Footpath and cycleway: 10 kPa where there is no possibility of these areas be converted into carriageway, breakdown lane or shoulder in the future. Otherwise, 20 kPa shall be allowed in the design.

All loads above are serviceability limit state loads.

## Design strength parameters of soil and weathered rock

Designers shall select appropriate design strength parameters based on all available information such as laboratory test and in-situ test results. Back analysis should also be carried out to assess the suitability of the adopted design parameters.

Designers should assess the site conditions and consider whether peak strength, residual strength or constant volume strength parameters are to be adopted for each material type. In general, residual strength parameters should be used for materials within the existing sliding/shear zone. Constant volume strength parameters should be used for poorly compacted fill, loose soils and reinforced fill as per Roads and Maritime specification *R57 Design of Reinforced Soil Walls*. Peak strength parameters could be used in all other cases depending on the site conditions.

All design strength parameters shall be characteristic values as defined in *AS 5100.3 Bridge design Foundation and soil-supporting structures*.

## Design ground water table

Design ground water table shall be one with a return period of one in 10 years. The determination of design ground water table shall consider storm response as well as seasonal response. The design ground water table shall be either of the following cases, whichever is more critical:

- A one in 10 year return period storm rise added to a typical wet season water level

or;

- A typical storm rise added to a one in 10 year return period seasonal rise.

Alternatively, the design ground water table may be taken as at least 2 m above the maximum observed ground water table or a conservative prediction if the ground water table will be substantially altered after the construction.

## Stability during construction

Stability of slopes during construction shall be considered and addressed in the design. Generally, a minimum FOS of 1.2 may deem to be satisfactory for intermediate construction stages. However, the acceptance criteria (such as design FOS) depend on the nature of the intermediate construction stages (such as scale and duration), consequence of failure, risk management and contingency plans, degree of emergency and other factors. The designer shall select a set of appropriate acceptance criteria for each intermediate construction stage, taking into account of all relevant facts. The selected acceptable criteria for all intermediate construction stages shall be stated in the design documentation and shall be agreed with Roads and Maritime Geotechnical Engineering Unit.

Designers shall consider impacts of all construction activities on slope stability and affected structures in each construction stage. These considerations include, but not limited to, construction loads and temporary excavation for construction of stormwater drainages, pavement, kerbs and verges.

## Slope management and monitoring

Upon completion of the remedial works, the slopes shall be managed in accordance with Roads and Maritime *PN 292 Slope Asset Management*.

## Further advice

For further information, please contact Geotechnical Manager (Ground Engineering), Pavements and Geotechnical Section, Engineering Services Branch on 8837 0764.

## References

1. AS 5100.3 (2017) Bridge Design Part 3: Foundations and soil-supporting structures, Standards Australia, Sydney NSW.
2. Francisco Silva, T. William Lambe and W. Allen Marr (2008) Probability and Risk of Slope Failure, *Journal of Geotechnical and Geoenvironmental Engineering*, 2008.134: 1691-1699.
3. Geotechnical Engineering Office (2000a) Highway Slope Manual, Civil Engineering Department, The Government of the Hong Kong Special Administrative Region.
4. Geotechnical Engineering Office (2000b) Guide to Site Investigation, Civil Engineering Department, The Government of the Hong Kong Special Administrative Region.
5. Roads and Maritime Services (2014) Guide to Slope Risk Analysis, Version 4, Roads and Maritime Services, North Sydney, NSW.
6. Roads and Maritime Services (2016) Slope Asset Management, Version 1.0, Number PN 292, Roads and Maritime Services, North Sydney, NSW.
7. Specification RMS R57 Design of Reinforced Soil Walls, Roads and Maritime Services, North Sydney, NSW.



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