GUIDELINES FOR SLOPE DESIGN

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SLOPE ENGINEERING BRANCH, PUBLIC WORKS DEPARTMENT MALAYSIA
PREFACE

The following guidelines are intended to be used for Slope Design and also to complement other relevant technical guidelines such as the *Arahan Teknik*. It is to be used as a supplement to other geotechnical manuals such as Geotechnical Manual for Slopes published by Geo Hong Kong, British Standards and other accepted standard practices.

These guidelines were prepared by Slope Engineering Branch, Jabatan Kerja Raya (JKR), Malaysia based on current technical requirements, design materials and accepted engineering practices implemented in JKR and were formulated to provide assistance to the designer in the design and assessment of slope stability, safety and mitigation by complementing existing design policies, manuals, and directives recognised by JKR.
ACKNOWLEDGEMENT

We would like to extend our heartfelt appreciation to all who have contributed towards the realisation of the Guidelines for Slope Design especially:

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1. Introduction

Over the years, JKR had been involved in the design and construction of slopes especially in road construction in hilly terrain. The design of roads was usually based on the conventional technique of balancing cut and fills with the slope gradient of 1V:1H to 1V:1.5H for the cut areas and 1:2 for the fill areas. Landslide records from years 1966 to 2003 show that 42% of landslides occurred in hilly terrain areas and more than 90% occurred in developed areas (infra/residential/commercial), shown in Figure 1.

In 2004, Malaysian Government directed JKR to establish a new branch called the Slope Engineering Branch. This branch has since been involved in mitigation, research and development, risk management, safety and planning on slope and etc. The branch has also been tasked with investigation works for landslides under a working committee called Jawatankuasa Kumpulan Kerja Tanah Runtuh (Landslide Group Working Committee). The Committee is headed by JKR with the Slope Engineering Branch acting as the Secretariat.

Most of the investigations carried out thus far revealed that causes of landslides were due to physical, geological and human elements. Based on landslide forensic statistical data for large scale failure from year 2004 to 2007, it was found that about 57% of landslides were due to human factor, whereas 29% were attributed to physical factor and 14% caused by various geological factors.
(Table 1). It was also discovered that most of the landslides occurred at man-made slopes. This prompted, the Director General of JKR to direct the Slope Engineering Branch to formulate guidelines for slope design in tandem with country’s geology towards minimising landslide risks especially at man-made slope areas.

2. Objectives

The main objectives for formulating these guidelines are:

i. To stipulate guiding principles to JKR and other engineers involve in slope design
ii. To minimise risks in slope failure disasters
iii. To increase stability of slope
iv. To create awareness of the risks involved in slope design
v. To further enhance existing geotechnical requirements in slope design

3. Methodology

The methodologies used are:

i. Study of landslide forensic statistics.
ii. Adopted Factor of Safety from international standard such as GEO Hong Kong and British Standard.
iii. Study of existing typical cross section of slope features.
iv. Study of SI requirements, drainage system, survey data and etc.
v. Review of historical data/records such as design report, as built drawing, survey data, SI data and etc.
4. Designer Responsibility

The designer shall search and study all reports on feasibility study, development plans and investigations related to the works so as to enable full understanding of factors which may affect the works. Notwithstanding requirements stipulated herein the designer should satisfy the aspects of aesthetics, functional and safety requirements, suitability and effectiveness, completed to the intent of the works.

5. Survey Data

5.1. General

The Designer shall carry out detailed topographical, hydrological and land surveys of the proposed site and areas that may be affected by the works, which may be necessary to supplement available survey information for the satisfactory execution of design and construction of the works. Survey plans shall be prepared in scales appropriate to their purpose and follow “Guidelines for Presentation of Engineering Drawing” – Arahan Teknik (Jalan) 6/85. The designer shall be responsible for the accuracy of survey data that is used in design work.

6. Site Investigation

6.1. General

The designer shall undertake his own additional soil investigation and material surveys for the purpose of preparation of the engineering design and construction of the works. The preliminary site investigation results, if provided by the client are to be used as a preliminary/general guide only. The client is not obliged to guarantee the completeness and accuracy of the preliminary soil investigation results. All site investigation
works should comply with BS 5930, BS 1377, GEO Hong Kong guide to Site Investigation and JKR Specification for SI Works (Nota Teknik 20/98).

6.2. Design Data
All details of the geotechnical design shall be based on the data interpreted from the preliminary SI report and any additional Soil Investigation carried out by designer. All detail design shall be accompanied by a summary of the results of field exploration and laboratory investigation.

6.3. Design Soil Parameters
Design soil parameters, shall be shown in figures/photos together with selected values that include but not limited to the following:
   i. Basic soil properties, e.g., unit weight, liquid and plastic limit, etc.
   ii. Chemical properties of subsoil and its effect to the foundation structures
   iii. Consolidation parameters, compression and recompression indices, drainage path, coefficient of consolidation \( (c_v \text{ and } c_h) \) and permeability of subsoil, etc.
   iv. Shear strength parameters include effective \( (c' \text{ and } \phi') \) and total stress strength \( (s_u) \).
   v. Groundwater level/ regime and prediction.

7. Engineering Geological Mapping and Investigation

Independent geological mapping of the subject area should be carried out at an appropriate scale which shows sufficient detail to adequately define the geologic conditions present such as rock type, structural geology, the nature of the rock slope and groundwater conditions. Existing geological maps should be treated as
Guidelines for Slope Design

a basis for understanding the site conditions. If available geological maps are used to portray site conditions, they must be field checked and updated to reflect geologic, topographic, and/or changes which have occurred since the map publication. It is necessary for the geologist to extend mapping into adjacent areas where mapping have not been carried out previously to adequately define geological conditions relevant to the project area.

For the rock slope and adjacent rock exposure, discontinuity data collection and analysis should be carried out to aid identifying the possible modes of failure. Rock outcrop mapping is the best field way to obtain discontinuity data. If little or no exposure is available on the slope, knowledge of local geology may permit extrapolation from outside the slope. Where extrapolation is necessary, the designer should determine whether the rock mass and discontinuity pattern in the area of the data collection is akin to those of the slope by considering local geological conditions.

8. Independent Check on Slope Stabilisation

All geotechnical designs shall be independently checked by Independent Geotechnical Checker (IGC). The IGC is to be appointed by the contractor and the prior appointment is subjected to the approval of the Project Director (P. D). The IGC shall have working experience in the geotechnical work at least:-

i. PhD : 5 years; or
ii. Master : 10 years; or
iii. Bachelor : 12 years
9. Earthworks

9.1. Fill Material

Materials used in the construction of fill slopes and embankments shall if it is suitable, as far as possible be those excavated from adjacent cuts. Rocks excavated from the cuts may be used as material for fills if they are crushed to acceptable grading envelopes, with maximum size of individual pieces not larger than 100mm. Drying out of the fill material during hauling and handling from cut to position of placing shall have to be allowed for.

10. Settlement Analysis

Settlement analysis shall be carried out for the fill slopes and embankments depending on the subsoil conditions encountered. Design of fill slopes or embankment shall be based on 90% settlement during construction.

If ground improvement methods are used, the settlement analysis will consider the type of the ground improvement method used. The total settlement for 7 years post construction should be referred to Table 1.

11. Engineering Analysis

11.1. Slope Stability Analysis

Slope stability analysis, including establishing design criteria and performing calculations, will be required for all cut, fill and natural slopes.
The data to be utilised in the slope stability analysis shall be based on detailed site plans, detailed field descriptions, on-site exploration data and laboratory test data. It is the responsibility of the geotechnical engineer to determine the weakest potential failure surface based on the above factors. In performing any analysis, the worst possible conditions must be utilised.

Slope stability analysis shall include;

i. Stability analysis for the temporary stability measured during construction.

ii. Cut and fill slope stability analysis should include both circular and non-circular analysis and in multi mode of failure.

iii. Any slope that is influenced by surcharge load shall be analysed taking into consideration of this surcharge load.

12. Rock slopes

All Rock slopes shall be analysed and designed. Preliminary consideration can be used using 4V:1H for weathering grade I and 3V:1H for weathering grade II. If analysis indicates that it is unstable, it shall be designed to a better gradient and/or requiring extensive stabilisation measures. The type of stabilisation measures to be used can be one of the following:

- permanent rock anchors
- rock dowels
- rock bolting
- buttress walls
- counter forts
- relieved drains, etc.
13. Cut Slopes

These include cut slopes in residual soils and in completely decomposed rock. All untreated slopes shall be designed with minimum of 2m berm width and maximum 6m berm height with a Factor of Safety greater than 1.3. Stabilisation measures can be considered when the design is inadequate. Stabilisation measures may include the following:

- soil nailing with slope surface protection
- permanent ground anchors
- retaining walls, etc.

The minimum global Factor of Safety for treated slopes shall be 1.5.

Due to maintenance reasons and to minimise risk to the users, the maximum number of berms for cut slopes shall be restricted to 6 berms. If the design shows that more than 6 berms are required, other solutions such as tunnel, rock shade, bridges etc. shall be considered.

14. Fill Slopes and Embankments

All untreated fill slopes and embankments shall be designed with 2m berm width and 6m berm height with a minimum Factor of Safety of 1.3. Stabilisation measures can be considered when the design is inadequate. Stabilisation measures may include the following:

- geogrid/geotextiles reinforcement
- reinforced concrete retaining structure
- reinforced fill structure
- replacing the fills with elevated structures
The minimum global Factor of Safety for treated slopes shall be 1.5. Due to maintenance reasons and to minimise risk to the users, the maximum number of berms for fill slopes shall be restricted to 6 berms. If the design shows that more than 6 berms are required, other solutions such as bridges, viaduct etc. shall be considered.

15. Drains

15.1. Surface Drains
Surface drains in slope faces shall be provided in addition to normal cut off drains (interceptor drains) at the top of slope. Down slope surface drains shall be provided for all cut and filled slope surfaces. The drains shall be cascade drain with handrail for ease of maintenance in the future. All surface drains shall be cast in situ and shall be designed to follow “Guideline For Road Drainage Design – Volume 4: Surface Drainage” – REAM GL 3/2002.

15.2. Subsurface Drains
Subsurface drains such as horizontal drains and drainage blankets shall be provided for cut and fill slopes and for areas where the groundwater level is found to be high. All subsurface drains shall be designed to follow “Guideline For Road Drainage Design – Volume 5: Subsoil Drainage” – REAM GL 3/2002.

16. Reinforced Structures

Reinforced structures shall be designed according to BS 8006. The types of foundations for the reinforced structures shall be designed based on the subsoil profile and geotechnical properties of footing subsoil at each location.
17. Geotechnical Design Criteria for Geotechnical Works

Some of geotechnical design criteria for geotechnical work are as shown in Table 2.
18. References


Arahan Teknik (Jalan) 6/85 (Pindaan 1/88). Guidelines for Presentation of Engineering Drawings, 17p

Nota Teknik (Jalan) 20/98. Design Review Checklist for Road Projects, 110p
Figure 1: Landslide Cases Due to Geomorphologic and Base on Landuse

No. of Landslide Cases Due To Geomorphologic

No. of Landslide Cases Base On Landuse
Table 1: Landslide forensic statistic data for large scale failures from year 2004 to 2007

<table>
<thead>
<tr>
<th>Item</th>
<th>Location</th>
<th>Date of Incident</th>
<th>Type of Damage</th>
<th>Failure Causes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Slope failure at Taman Harmonis, Gombak, Selangor.</td>
<td>November 5, 2004</td>
<td>1 fatality. 1 bungalow damage.</td>
<td>Human factor</td>
</tr>
<tr>
<td>2.</td>
<td>Slope failure at Kampung Pasir, Hulu Kelang, Selangor.</td>
<td>May 31, 2006</td>
<td>4 fatalities. 3 houses damage.</td>
<td>Human factor</td>
</tr>
<tr>
<td>3.</td>
<td>Slope failure at KM 8.5 Jalan Persekutuan 606 Sepanggar, Sabah.</td>
<td>June 26, 2006</td>
<td>1 fatality. 2 houses damage</td>
<td>Physical factor</td>
</tr>
<tr>
<td>4.</td>
<td>Slope failure at Section 10, Wangsa Maju, Kuala Lumpur.</td>
<td>October 9, 2006</td>
<td>Structural damage at 2 apartment blocks.</td>
<td>Human factor</td>
</tr>
<tr>
<td>5.</td>
<td>Slope failure at Federal Government Quarters Putrajaya, Precint 9 (Phase II), Putrajaya, Wilayah Persekutuan.</td>
<td>22 Mac 2007</td>
<td>23 car damage</td>
<td>Geological factor</td>
</tr>
<tr>
<td>6.</td>
<td>Slope failure at KM 100 Jalan Persekutuan from Butterworth to Ipoh.</td>
<td>November 22, 2007</td>
<td>1 lorry damage. Functional damage on PLUS Expressway for 8 hours.</td>
<td>Human factor</td>
</tr>
<tr>
<td>7.</td>
<td>Slope failure at Bukit Cina, Kapit, Sarawak.</td>
<td>December 26, 2007</td>
<td>4 fatalities. 12 houses damage.</td>
<td>Physical factor</td>
</tr>
</tbody>
</table>
Table 2: SOME TYPICAL GEOTECHNICAL DESIGN CRITERIA FOR SLOPES DESIGN

<table>
<thead>
<tr>
<th>DESIGN COMPONENT</th>
<th>MODE OF FAILURE</th>
<th>MINIMUM FACTOR OF SAFETY</th>
<th>MAXIMUM PERMISSIBLE MOVEMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>VERTICAL</td>
<td>LATERAL</td>
</tr>
<tr>
<td>1. Unreinforced Slopes</td>
<td>1.1 Local &amp; Global Stability</td>
<td>1.3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(cut &amp; fill slopes)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.2 Bearing (fill)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Reinforced or Treated Slopes</td>
<td>2.1 Local &amp; Global Stability</td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td>(not on soft ground)</td>
<td>(cut &amp; fill slopes)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.2 Bearing (fill)</td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td>3. Permanent Anchors</td>
<td>3.1 Tensile Resistance</td>
<td>2.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Resistance at Soil Grout Interface</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3.3 Creep/Corrosion</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Rigid Retaining Structures</td>
<td>4.1 Overturning</td>
<td>2.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4.2 Sliding</td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4.3 Overall Stability</td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4.4 Bearing</td>
<td>2.0</td>
<td></td>
</tr>
<tr>
<td>5. Reinforced Fill</td>
<td>External Stability</td>
<td>BS 8006</td>
<td>± 5mm per metre height</td>
</tr>
<tr>
<td>Walls/Structures</td>
<td>Internal Stability</td>
<td>BS 8006</td>
<td>± 15mm per metre height</td>
</tr>
<tr>
<td>6. Individual Foundation Piles</td>
<td>6.1 Shaft Resistance</td>
<td>2.0</td>
<td></td>
</tr>
<tr>
<td>(mainly under axial loads)</td>
<td>BS 8004</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>6.2 Base Resistance</td>
<td>2.0</td>
<td></td>
</tr>
<tr>
<td>7. Individual Foundation Loads</td>
<td>Ultimate Lateral Resistance</td>
<td>2.5</td>
<td></td>
</tr>
<tr>
<td>(mainly under lateral &amp;</td>
<td>BS 8004</td>
<td></td>
<td></td>
</tr>
<tr>
<td>bending loads perpendicular to</td>
<td>BS 8004</td>
<td></td>
<td></td>
</tr>
<tr>
<td>axis of pile)</td>
<td>BS 8004</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Pile Group</td>
<td>Block Bearing Capacity</td>
<td>2.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>BS 8004</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Piles as Retaining Structures</td>
<td>As for 4, 6, 7 above</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>BS 8004</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Embankment on Soft Ground</td>
<td>10.1 Bearing (short term)</td>
<td>1.4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Local &amp; Global Slope Stability</td>
<td>1.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(long term)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>7 years post construction settlement</td>
<td>&lt; 100mm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(i) within 10m from bridge approach</td>
<td>&lt; 250mm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(ii) road</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix A:

Details of typical soil slope stabilisation methods
Typical Layout of Contiguous Bored Pile

NOTE: Concrete encasement must encase the anchor head completely with min. 300 lb. class. cement.
Dimensions of encasement to suit anchor head.
All four sides shall be troweled and all surface in contact with tidal water shall be coated with 2 coats of
Hotlak BF at 2.5 kg./sq. m. per coat.
Typical Layout of Gunite And Soil Nail

![Typical Layout of Gunite And Soil Nail](image)

**TYPICAL SECTION VIEW**

**SECTION A-A**

**HORIZONTAL DRAIN**

**GUNITE DETAIL**

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**JABATAN KERJA RAYA MALAYSIA**

**CAWANGAN KEJURUTERAAN CERUN**

**UNIT FORENSIK TANAH RUNTUN**

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17
Guidelines for Slope Design

Typical Layout of RC Wall And Micro Pile

TYPICAL SECTION VIEW

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CAWANGAN KEJURUTERAAN CERUN

UNIT FORENSIK TANAH RUNTUH

18
Typical Layout of RC Wall And Sheet Pile
Typical Layout of Geocell Protection

Typical Section View

Geocell slope surface
See detail A
Horizontal drain

Detail of Soil Nail Head

Concrete grade 20
Cl pipe drain
Infill with basis and hydroseed

Detail A

Concrete grade 20

Non-woven geotextile
Polypropylene membrane
Soil nail head (see details)

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CAWANGAN KEJURUTERAAN CERUN

Typical Cross Section of Geocell & Soil Nail

UNIT FORENSIK TANAH RUNTUKH

20
Typical Layout of Crib Wall

Surface Drain To Engineer's Detail

Backfill Material

Probable Excavation Line

Approved Crib Wall Material To Standard Specification For Crib Wall

Removed of unsuitable material and replaced with compacted granular fill or other foundation treatment inclusive of piling (if any) to SO's instruction.
Typical layout of Gabion Wall
Guidelines for Slope Design

Typical Layout of Geogrid Protection

[Image of typical layout]

TYPICAL CROSS SECTION
(Details)

[Diagram of typical cross section]

DETAIL 'A'
(Details)

TYPICAL CROSS SECTION OF GEOGRID WALL

UNIT FORENSIK TANAH RUNTUH

Typical Cross Section of Geogrid Wall
Typical Layout of Reinforced Earth Wall
Typical Layout of Horizontal Drain And Close Turfing
Typical Layout of Rock Fill

1. Rock fill shall be placed in a graded or an approximately horizontal surface in several segregations in the thickness of large voids.
2. Each layer of rock fill shall be compacted to a lower bearing value of 37%.
3. The lower bearing value shall be retested in situ after compaction.
4. The amount of rock fill used for the embankment shall be based on the rock fill's load capacity and the foundation's stability.
5. Each layer shall be compacted to a minimum resistance of 37%.
6. The thickness of each layer shall be 150mm unless otherwise approved by the Engineer or design (in increments of 150mm).

PRESCRIPTIVE CROSS SECTION FOR ROCK FILL
Appendix B:

Details of typical rock slope stabilisation methods
Figure 2: Details of typical rock slope stabilisation methods
Figure 3: Details of typical rock fall control measures
Guidelines for Slope Design

Typical Layout of Rock Netting

NOTES:
1.0. QUANTITIES OF TREES, BUSHES AND OTHER VEGETATION MUST CORRESPOND TO SITE.
2.0. RIVET ROCK NETTING TO DEVICE LOUZE ROCK WALL MATERIAL AT THE SLOPE FACE OF NETTING SHEETS AND FROM THE INCLUSION OF SMALL ROCK OR SOIL DIRT OR BRUSHWOOD AT SITE.
3.0. PLACING OF THE NETTING SHEETS OVER THE SURFACE OVER WHICH THE SHEETS ARE TO BE LOCATED AND ALONG THE NATURAL SLOPE.
4.0. ENSURE THE NETTING SHEETS ARE FASTENED TO THE SLOPE TO THE SOIL AND NOT TO THE NETTING SHEETS.
5.0. TYPICAL CROSS SECTION AT CH. 1960.0

TYPICAL CROSS SECTION OF ROCK NETTING

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CAWANAN KEJURUTERAAN CERUN

UNIT: FORENSIK TANAH RUNTUT

TYPICAL CROSS SECTION OF ROCK NETTING

30
Types of Rock Slope Stabilization Protection

Photo 1 - Soil Nail And Netting

Photo 2 - Fencing