JKR 21500-0011-10

GUIDELINES FOR SLOPE DESIGN

First Published: January 2010

SLOPE ENGINEERING BRANCH, PUBLIC WORKS DEPARTMENT MALAYSIA

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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:

Dato Prof. Ir. Dr. Ashaari bin Mohamad

En. Ahmad Shuhaimi bin Ibrahim

Dr. Che Hassandi bin Abdullah

Ir. Kamar bin Kassim

Ir. Shabri bin Shaharom

Ir. Ab. Hamid bin Hj. Md Daud

En. Mohd Jamal bin Sulaiman

En. Kamal Bahrin bin Jaafar

En. Mohd Anuar bin Mohd Yusof

En. Mohd Asri bin Md Isa

En. Syamsul Amri bin Mohd Ishak

En. Amrin bin Mohd Ihsan

En. Mohammad Zaid bin Mohd Karim

En. Zahirudin bin Badarudin

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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, hydroglogic 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 and c_h) and permeability of subsoil, etc.
iv. Shear strength parameters include effective (c' and Ø') 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 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

GEO (1993). Geotechnical Manual for Slopes. 295p

GEO(1987). Guide to Retaining Wall Design, Hong Kong Government Printer, 254p

British Standard Institution (1999). Code of Practices for Site Investigation (BS 5930:1999), British Standard Institution, London, 206p

British Standard Institution (1994). Code of Practices for Earth Retaining Structures (BS 8002:1994). British Standard Institution, London, 110p

British Standard Institution (1989). Code of Practices for Ground Anchorages (BS 8081:1989). British Standard Institution, London, 176p

British Standard Institution (1989). Code of Practices for Foundations (BS 8004:1986). British Standard Institution, London, 125p

British Standard Institution (1995). Code of practice for trengthened/reinforced soils and other fills (BS 8006:1995). British Standard Institution, London, 176p

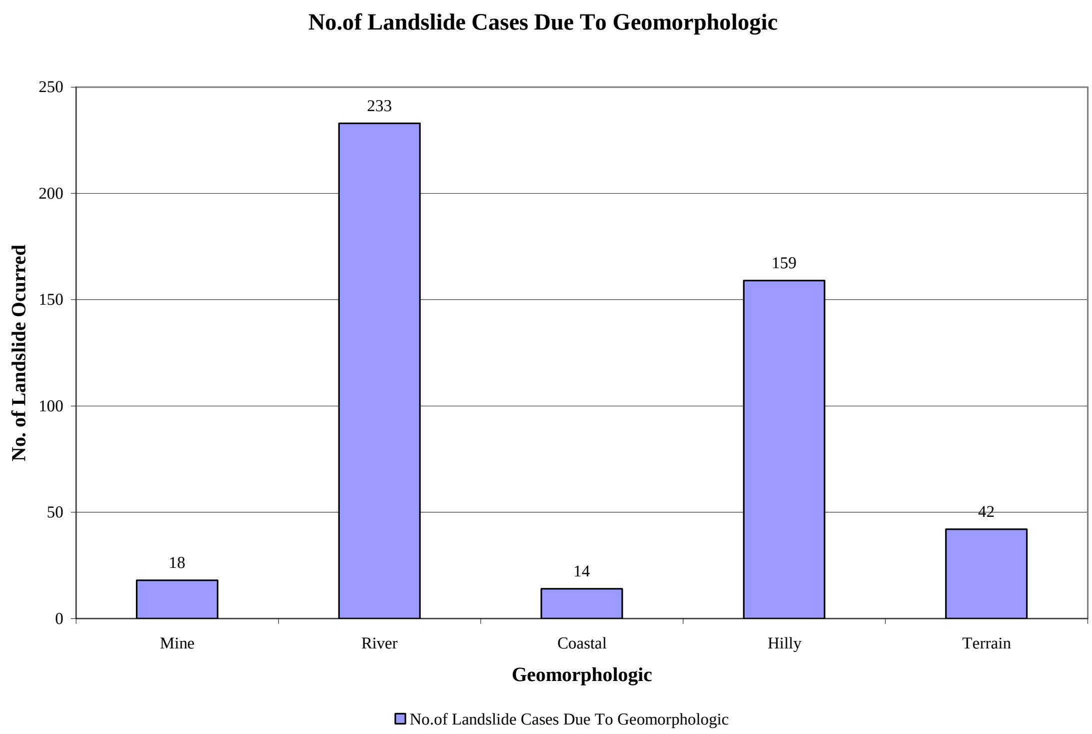
REAM GL 3/2002. Guideline For Road Drainage Design – Volume 4: Surface Drainage. 57p

REAM GL 3/2002. Guideline For Road Drainage Design – Volume 5: Subsoil Drainage. 33p

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



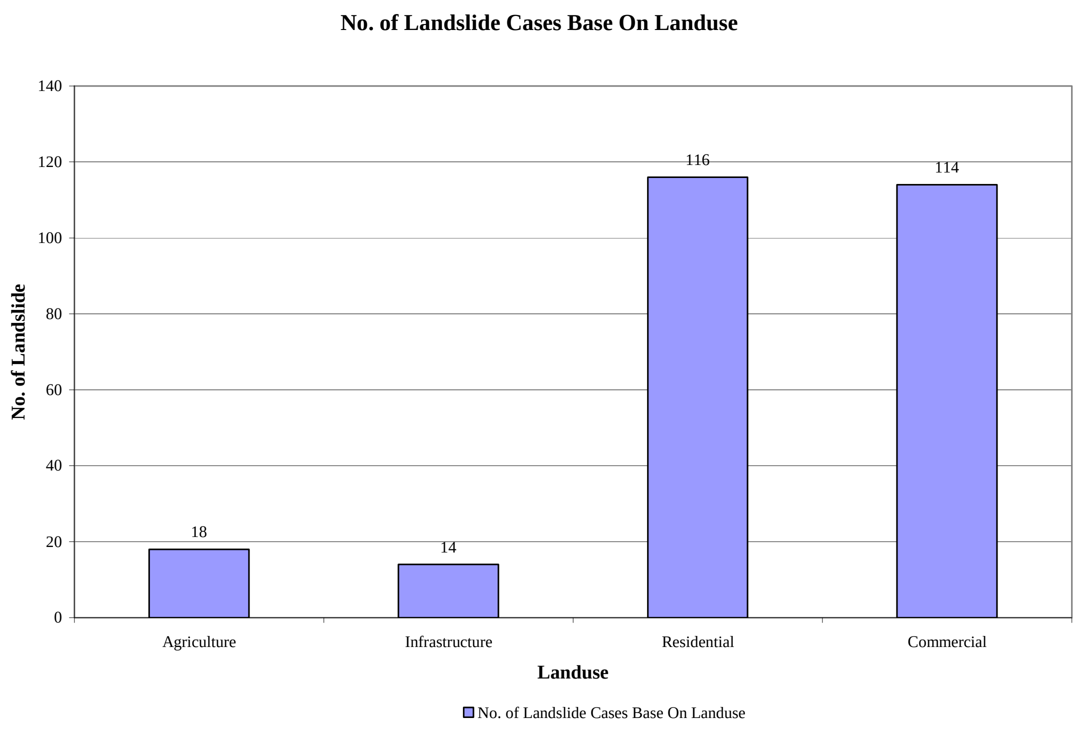


Table 1 : Landslide forensic statistic data for large scale failures from year 2004 to 2007

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

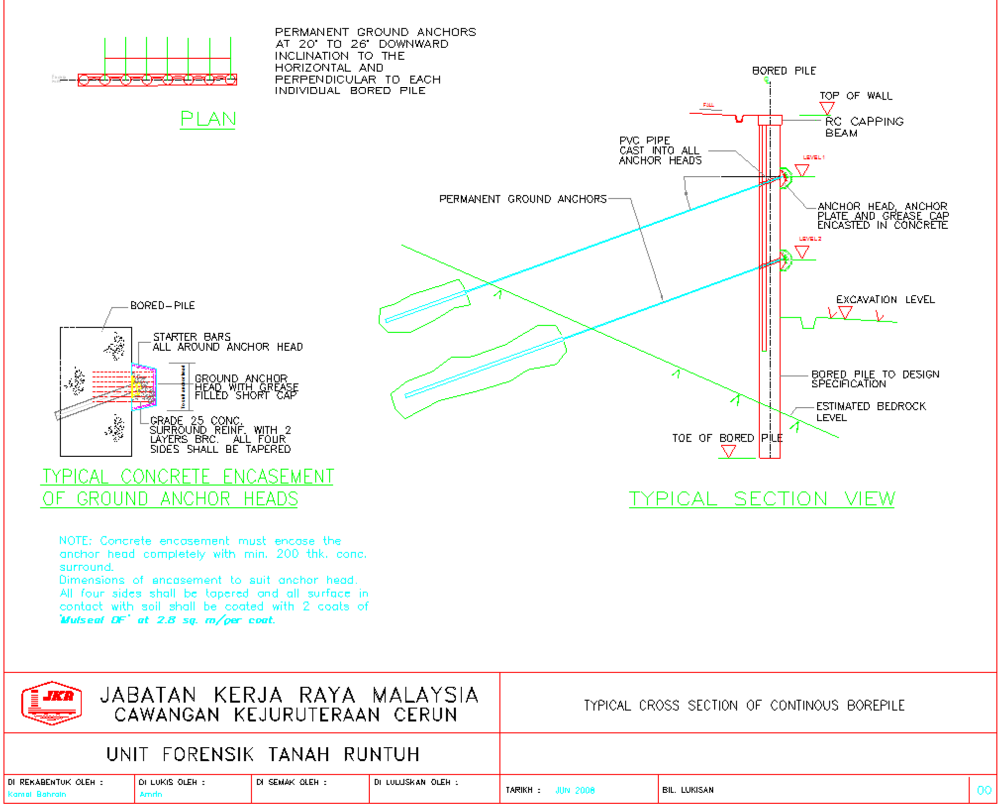
Table 2: SOME TYPICAL GEOTECHNICAL DESIGN CRITERIA FOR SLOPES DESIGN

DESIGN COMPONENT	MODE OF FAILURE	MINIMUM FACTOR OF SAFETY	MAXIMUM PERMISSIBLE MOVEMENTS		
			VERTICAL	LATERAL	DIFFERENTIAL
1. Unreinforced Slopes	1.1 Local & Global Stability (cut & fill slopes) 1.2 Bearing (fill)	1.3 2.0	Analysis should be according to GEOTECHNICAL MANUAL FOR SLOPES (1984), GEO Hong Kong		
2. Reinforced or Treated Slopes (not on soft ground)	2.1 Local & Global Stability (cut & fill slopes) 2.2 Bearing (fill)	1.5 1.5			
3. Permanent Anchors	3.1 Tensile Resistance 3.2 Resistance at Soil Grout Interface 3.3 Creep/Corrosion	2.0 3.0	Geo Spec 1 (1989), GEO Hong Kong BS 8081		
4. Rigid Retaining Structures	4.1 Overturning 4.2 Sliding 4.3 Overall Stability 4.4 Bearing	2.0 1.5 1.5 2.0	15mm along face of wall Geoguide 1 (1983), GEO Hong Kong	15mm along face of wall	1 : 150 along face of wall
5. Reinforced Fill Walls/Structures	External Stability Internal Stability	BS 8006	± 5mm per metre height	± 15mm from reference alignment	1 : 100 along face of wall
6. Individual Foundation Piles (mainly under axial loads)	6.1 Shaft Resistance 6.2 Base Resistance	2.0 2.0	12mm along axis of pile at pile head at design load. 38mm or 10% pile size at pile head at twice design load. BS 8004		
7. Individual Foundation Loads (mainly under lateral & bending loads perpendicular to axis of pile)	Ultimate Lateral Resistance	2.5	12mm along axis of pile at pile head at design load. BS 8004	12mm perpendicular to axis of pile at design load	
8. Pile Group	Block Bearing Capacity	2.0	12mm at Working Load BS 8004		
9. Piles as Retaining Structures	As for 4, 6 & 7 above	As for individual foundation piles	As 4 above for rigid retaining structures BS 8004		
10. Embankment on Soft Ground	10.1 Bearing (short term) 10.2 Local & Global Slope Stability (long term)	1.4 1.2	7 years post construction settlement : (i) within 10m from bridge approach < 100mm (ii) road < 250mm		

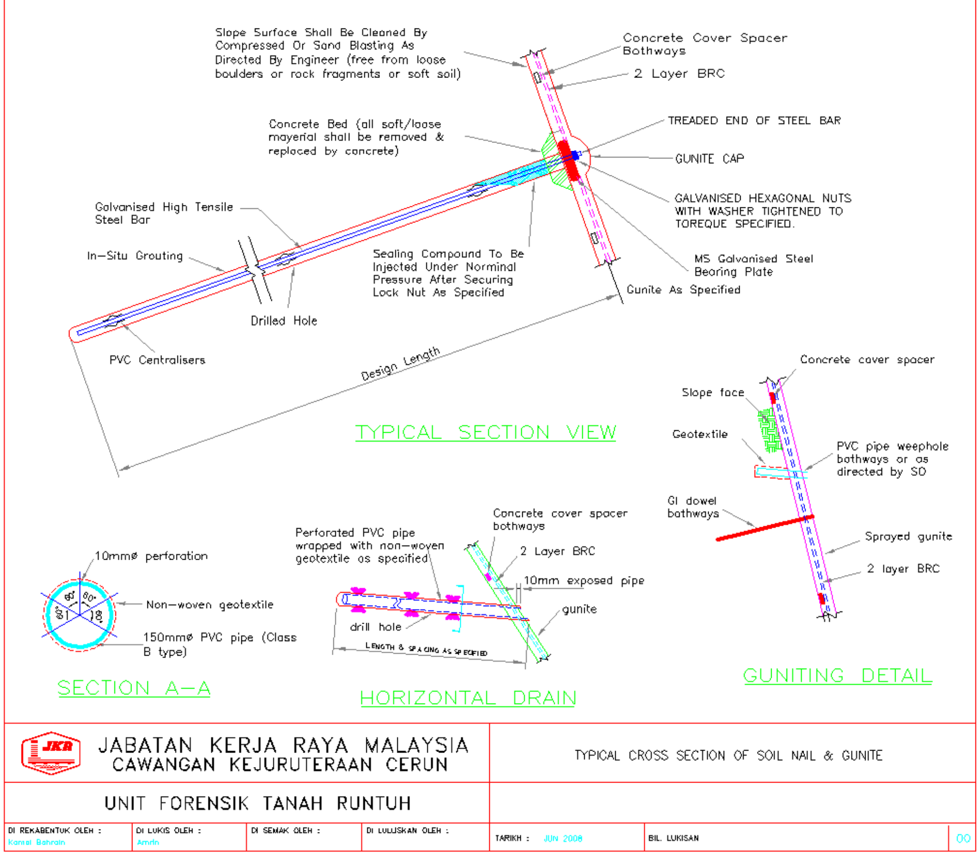
Appendix A:

Details of typical soil slope stabilisation methods

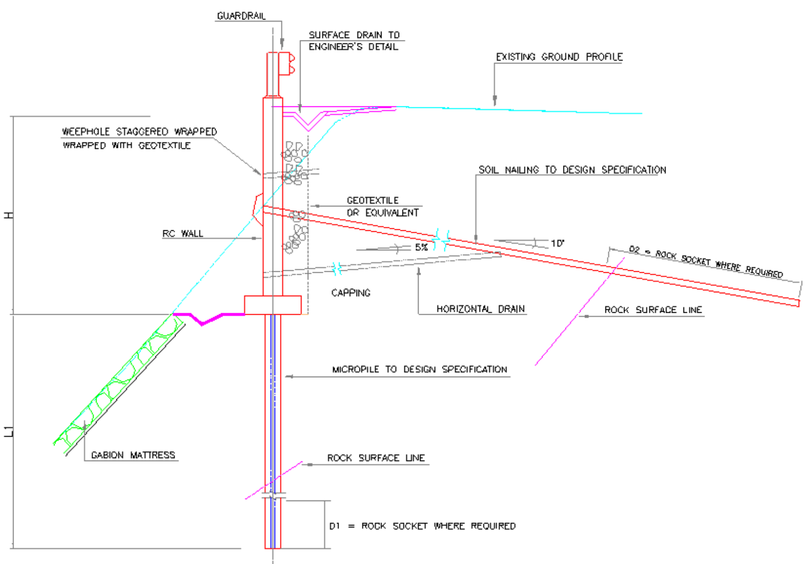
Typical Layout of Contiguous Bored Pile



Typical Layout of Gunite And Soil Nail



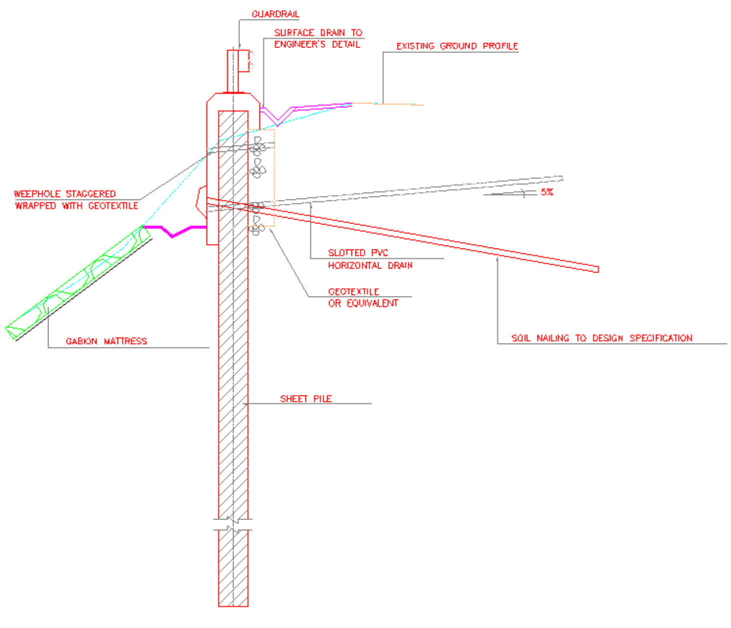
Typical Layout of RC Wall And Micro Pile



TYPICAL SECTION VIEW

JABATAN KERJA RAYA MALAYSIA CAWANGAN KEJURUTERAAN CERUN				TYPICAL CROSS SECTION OF RC WALL & MICROPILE		
UNIT FORENSIK TANAH RUNTUH						
DI REKABENTUK OLEH : Kamal Bahrain	DI LUKIS OLEH : Amrin	DI SEMAK OLEH :	DI LULUSKAN OLEH :	TARIKH : JUN 2008	BIL. LUKISAN	00

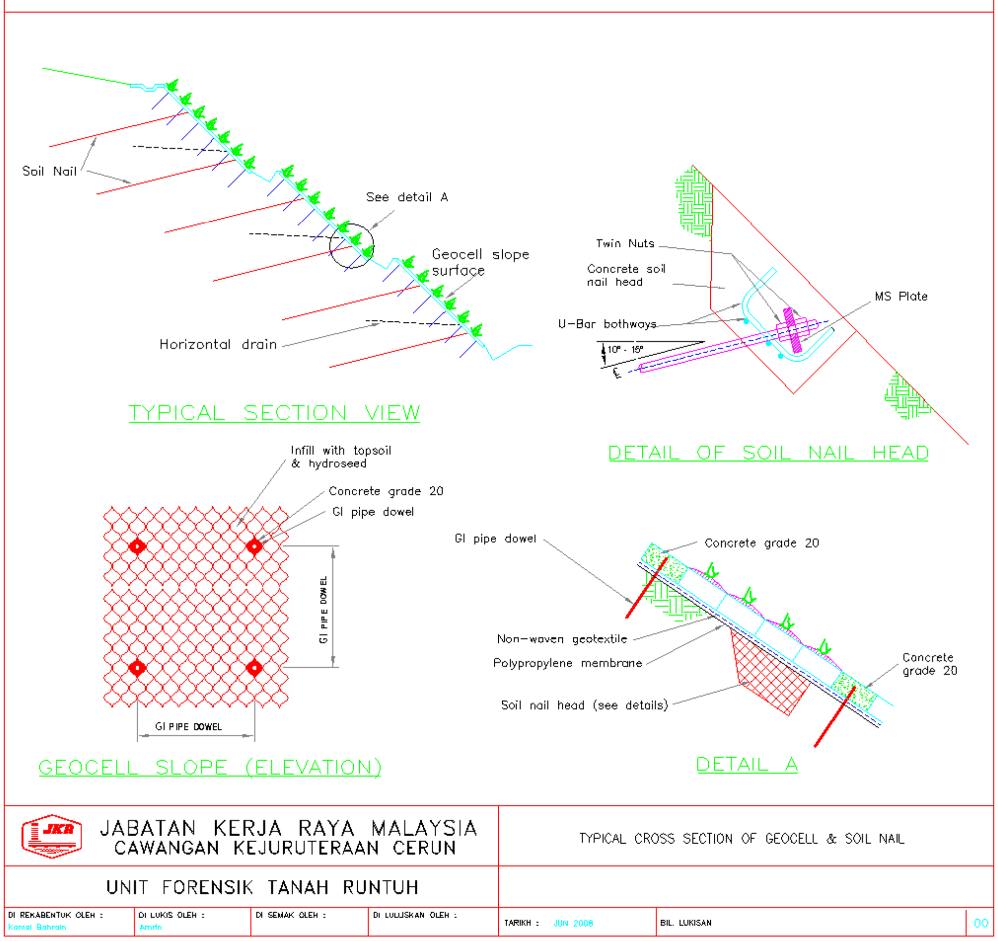
Typical Layout of RC Wall And Sheet Pile



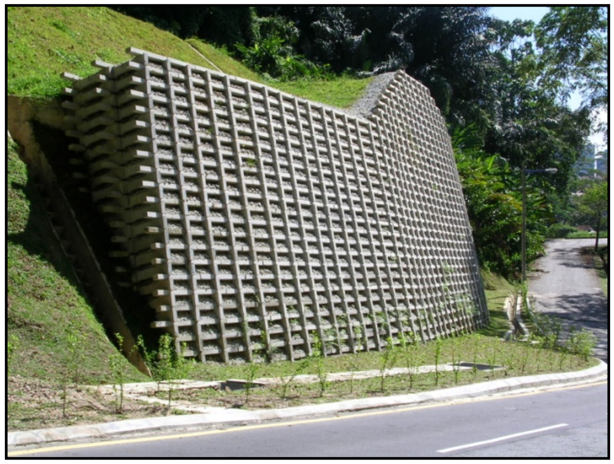
TYPICAL SECTION VIEW

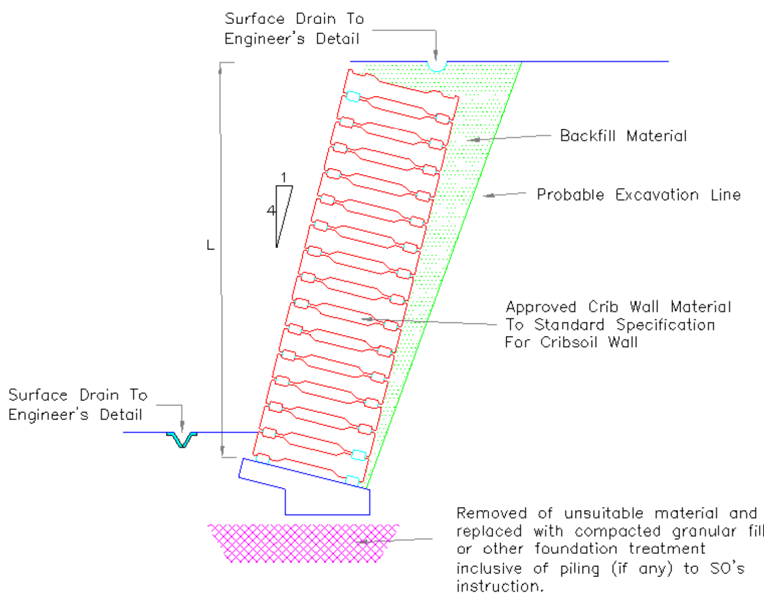
JABATAN KERJA RAYA MALAYSIA CAWANGAN KEJURUTERAAN CERUN				TYPICAL CROSS SECTION OF RC WALL & SHEETPILE		
UNIT FORENSIK TANAH RUNTUH						
DI REKABENTUK OLEH : Kamal Bahrain	DI LUKIS OLEH : Amrin	DI SEMAK OLEH :	DI LULUSKAN OLEH :	TARIKH : JUN 2008	BIL. LUKISAN	00

Typical Layout of Geocell Protection



Typical Layout of Crib Wall

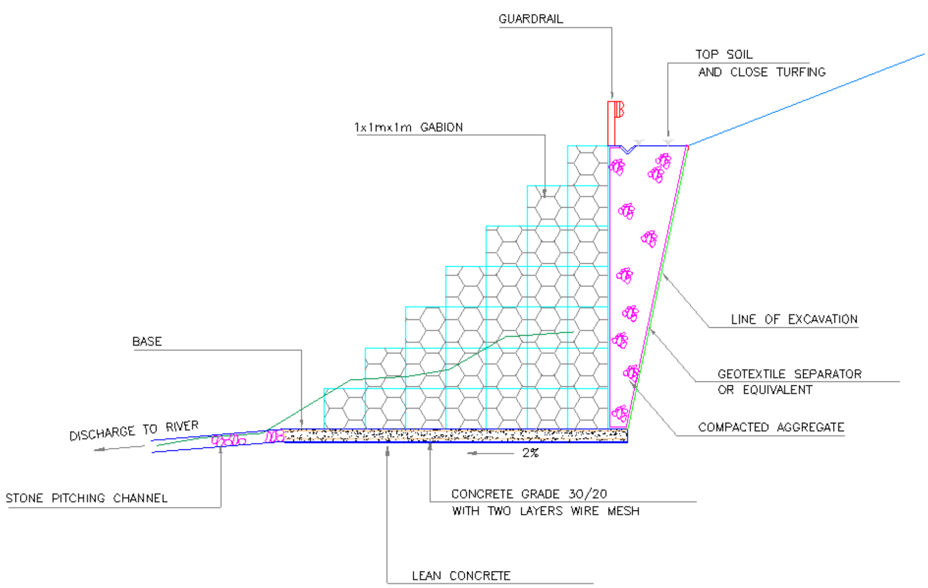




TYPICAL SECTION VIEW

JABATAN KERJA RAYA MALAYSIA CAWANGAN KEJURUTERAAN CERUN				TYPICAL CROSS SECTION OF CRIBWALL	
UNIT FORENSIK TANAH RUNTUH					
DI REKABENTUK OLEH : Kamal Bahrain	DI LUKIS OLEH : Amrin	DI SEMAK OLEH :	DI LULUSKAN OLEH :	TARIKH JUN 2008	BIL. LUKISAN 00

Typical layout of Gabion Wall

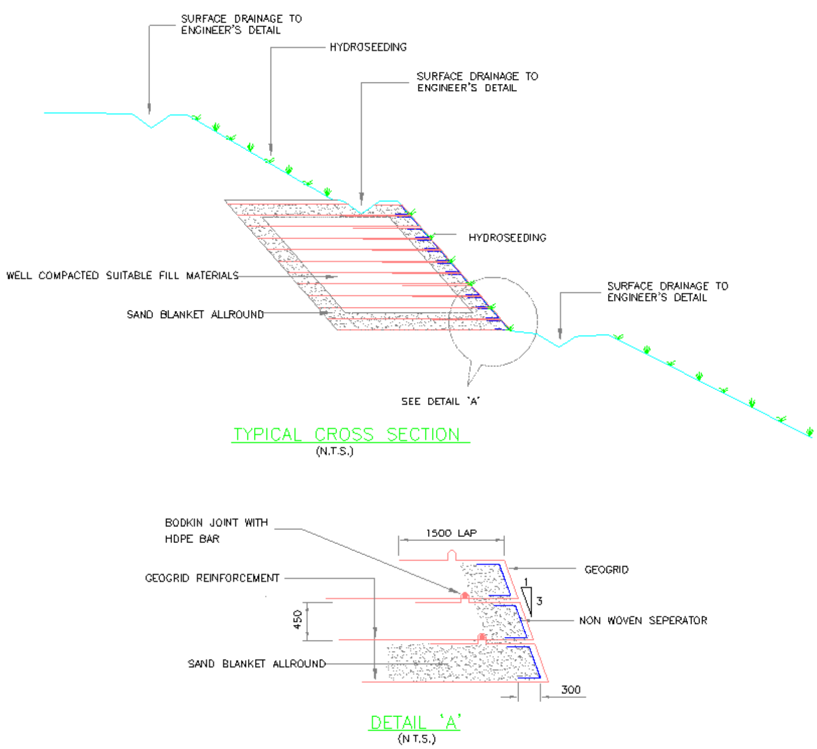


TYPICAL SECTION VIEW

JABATAN KERJA RAYA MALAYSIA CAWANGAN KEJURUTERAAN CERUN	TYPICAL CROSS SECTION OF GABION WALL
UNIT FORENSIK TANAH RUNTUH	

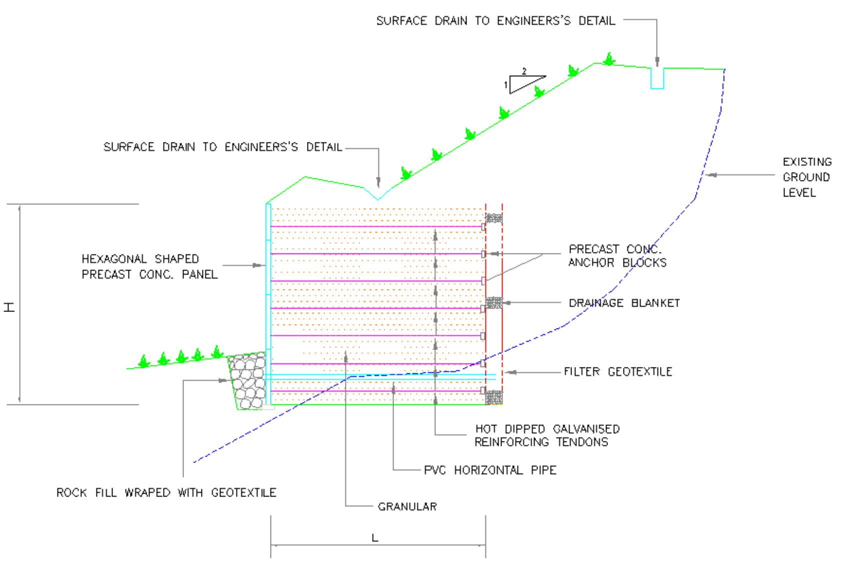
DI REKABENTUK OLEH :	DI LUKIS OLEH :	DI SEMAK OLEH :	DI LULUSKAN OLEH :	TARIKH :	BIL. LUKISAN	
Kamal Bahrain	Amrin			JUN 2008		00

Typical Layout of Geogrid Protection



JABATAN KERJA RAYA MALAYSIA CAWANGAN KEJURUTERAAN CERUN				TYPICAL CROSS SECTION OF GEOGRID WALL		
UNIT FORENSIK TANAH RUNTUH						
DI REKABENTUK OLEH : Kamal Bahrain	DI LUKIS OLEH : Amrin	DI SEMAK OLEH :	DI LULUSKAN OLEH :	TARIKH : JUN 2008	BIL. LUKISAN	00

Typical Layout of Reinforced Earth Wall

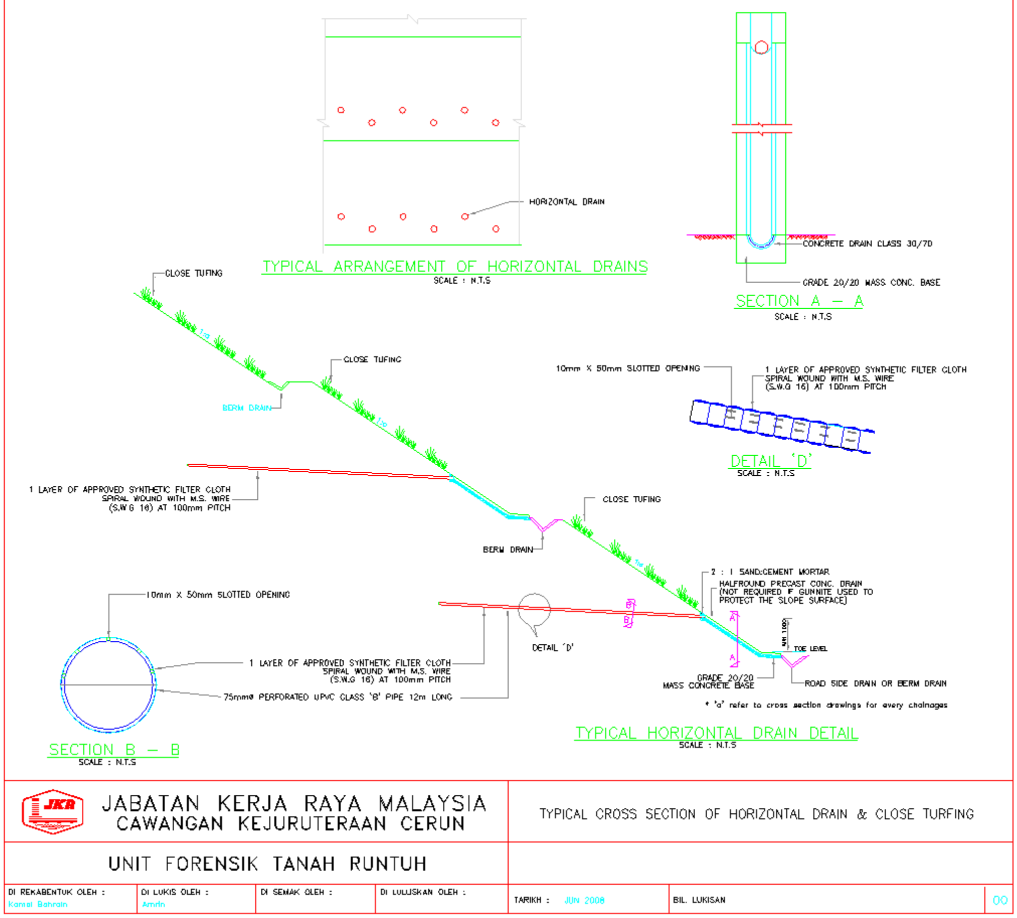


TYPICAL SECTION VIEW

JABATAN KERJA RAYA MALAYSIA CAWANGAN KEJURUTERAAN CERUN	TYPICAL CROSS SECTION OF REINFORCED EARTH WALL
UNIT FORENSIK TANAH RUNTUH	

DI REKABENTUK OLEH : Kamal Bahrain	DI LUKIS OLEH : Amrin	DI SEMAK OLEH :	DI LULUSKAN OLEH :	TARIKH : JUN 2008	BIL. LUKISAN	00

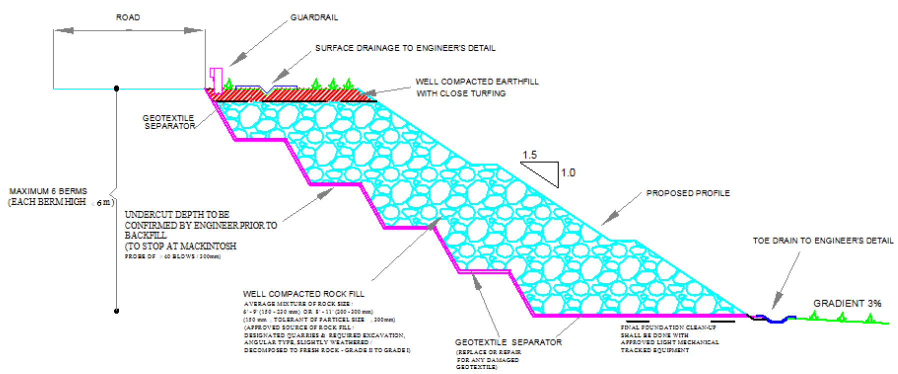
Typical Layout of Horizontal Drain And Close Turfing



Typical Layout of Rock Fill

COMPACTION OF ROCK FILL

1. Rock fill shall be placed & spread to an approximately horizontal surface to prevent segregation or the formation of large voids.
2. Each layer of rock fill shall be compacted by 10 tonne vibrating roller at speed ≤0.3 m/s.
3. The static mass of the roller transmitted to the ground shall not be less than 10 tonne.
4. The centrifugal force generated by the vibrating part of the roller shall not be less than 240 kN at the maximum frequency permitted.
5. Each layer shall be compacted by 6 passes (minimum) of the vibrating roller.
6. Maximum thickness of layer after compaction shall be at 500mm unless otherwise approved by the Engineer if larger size of materials are use.



PRESCRIPTIVE CROSS SECTION FOR ROCK FILL

JABATAN KERJA RAYA MALAYSIA CAWANGAN KEJURUTERAAN CERUN				TYPICAL CROSS SECTION OF ROCKFILL		
UNIT FORENSIK TANAH RUNTUH						
DI REKABENTUK OLEH : Kamal Bahrain	DI LUKIS OLEH : Amdn	DI SEMAK OLEH :	DI LULUSKAN OLEH :	TARIKH : JUN 2008	BIL. LUKISAN	00

Appendix B:

Details of typical rock slope stabilisation methods

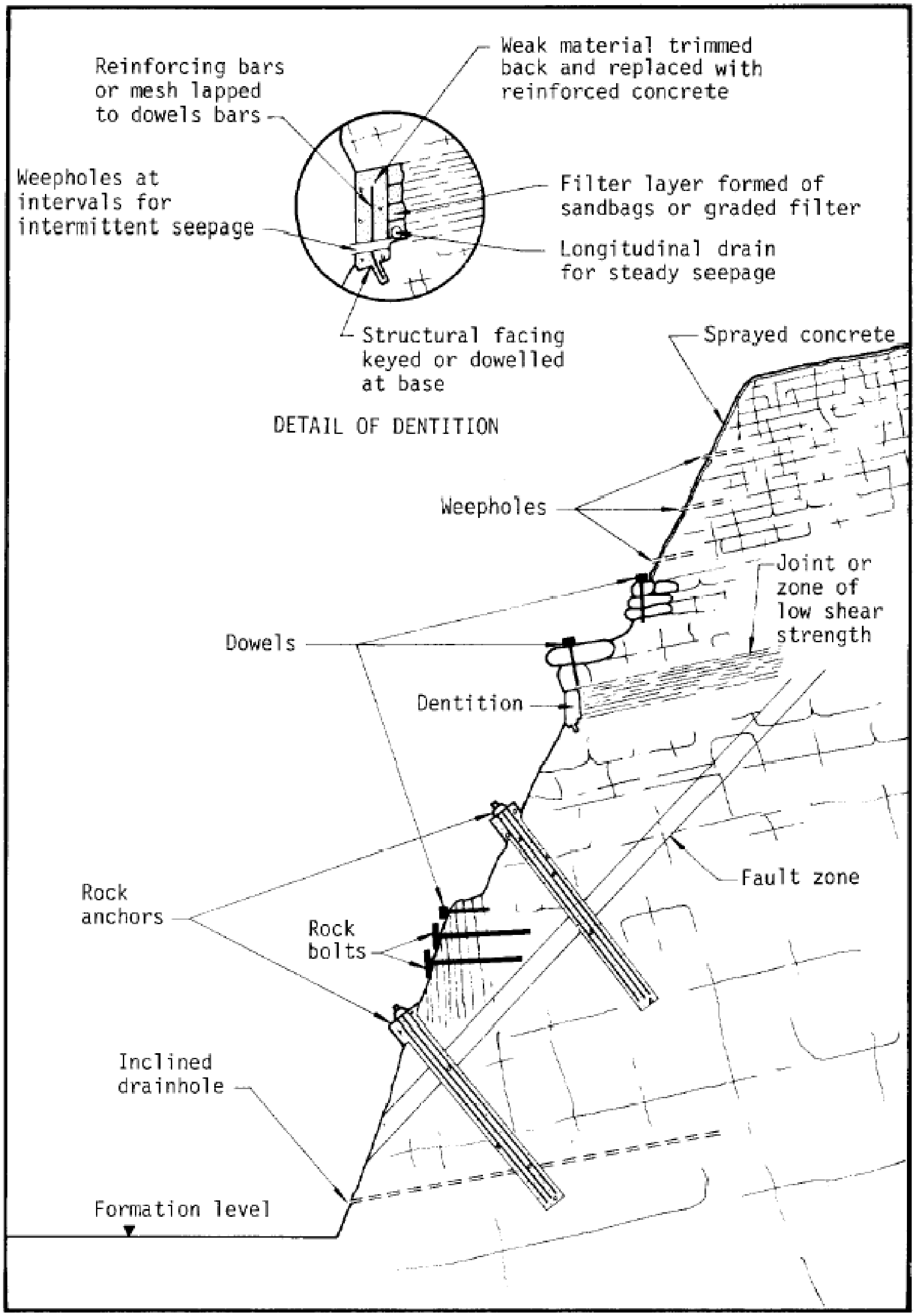


Figure 2: Details of typical rock slope stabilisation methods

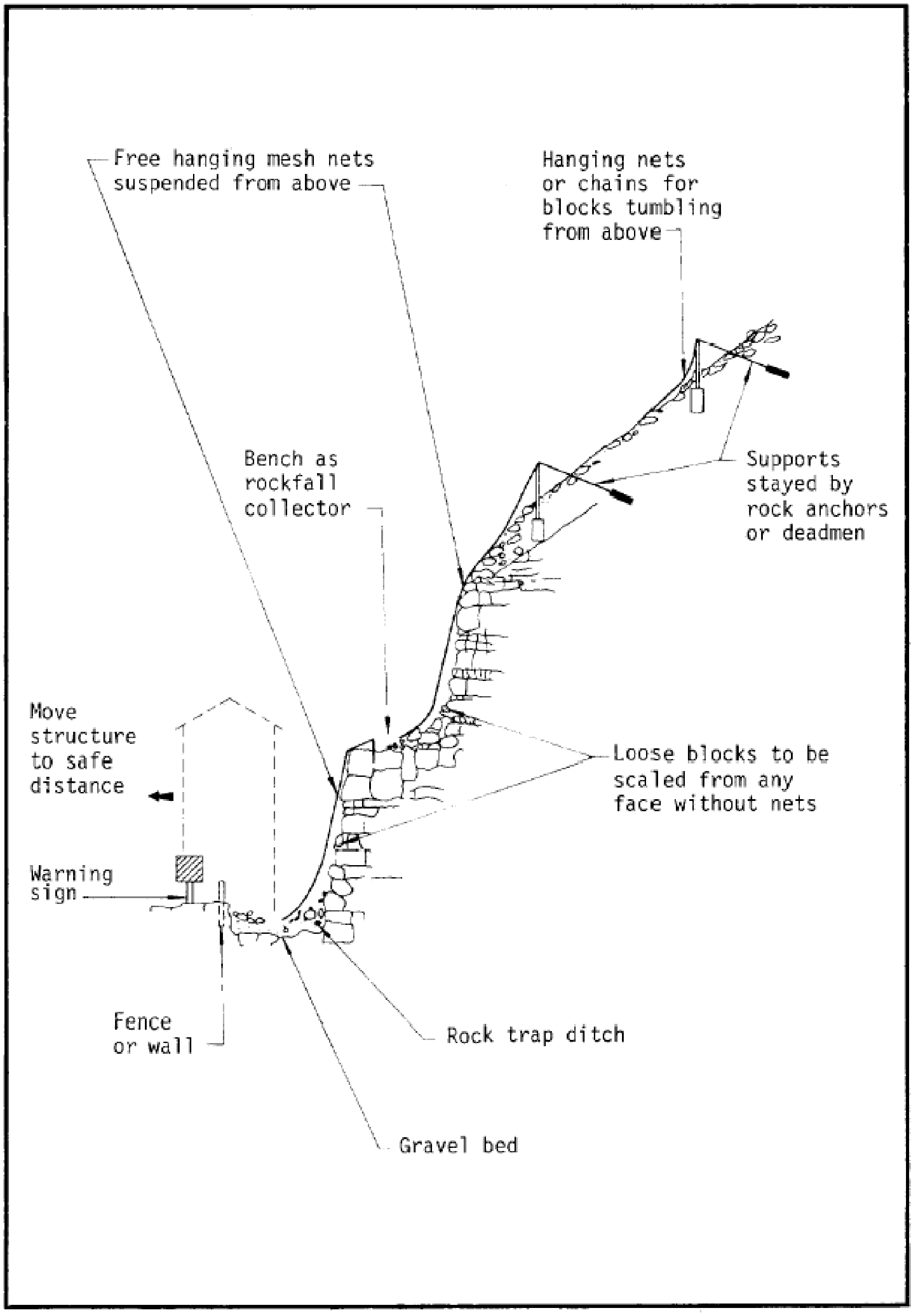
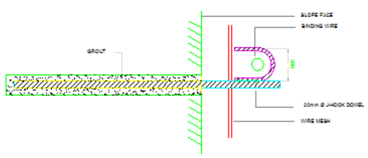


Figure 3: Details of typical rock fall control measures

Typical Layout of Rock Netting



DETAIL 'A'
(N.T.S)

NOTES:

1.O CLEARING OF TREES, BUSHES AND OTHER VEGETATION MUST COMMENCE FIRST.

2.0 NEXT, ROCK SCALING TO REMOVE, LOOSE ROCKSOIL MATERIAL AT THE RELATED AREA OF NETTING UPON INSTRUCTED FROM THE ENGINEERING GEOLOGIST OR ENGINEER AT SITE.

3.0 PLACING OF THE NETTING SHEETS OVER THE SURFACE TO BE PROTECTED BY LIFTING ONE END AND PLACING THE SHEET DIRECTLY AGAINST THE FACE.

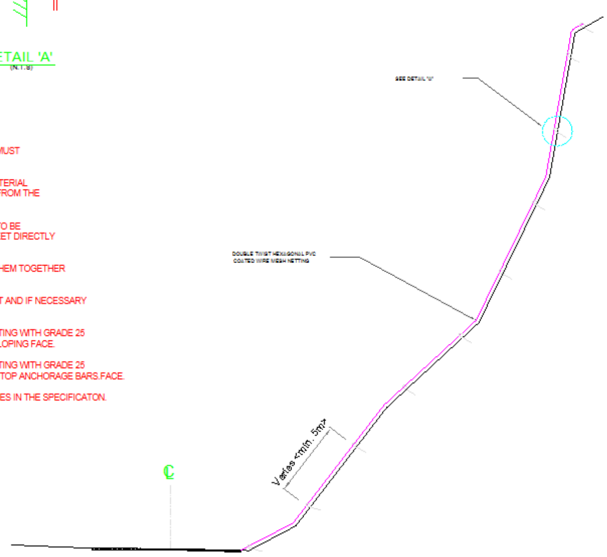
4.0 FIXING THE SHEETS TO THE WALLS/SLOPE AND FIXING THEM TOGETHER ACCORDING TO THE SPECIFICATION.

5.0 FINISHING AND FINAL FASTENING OF THE TOP, THE FOOT AND IF NECESSARY TO THE FACE.

6.0 16mm Ø 'J' HOOK DOWEL GALVANISED STEEL BAR GROUTING WITH GRADE 25 CEMENT WITH ADDITIVES FOR LENGTH OF 500mm FOR SLOPING FACE.

7.0 25mm Ø 'J' HOOK DOWEL GALVANISED STEEL BAR GROUTING WITH GRADE 25 CEMENT WITH ADDITIVES FOR LENGTH OF 1000mm FOR TOP ANCHORAGE BARS.FACE.

8.0 THE STEEL WIRE SHALL BE 2.7mm DIAMETER AS SPECIFIES IN THE SPECIFICATON.



TYPICAL CROSS SECTION AT CH. 1980.0
(N.T.S)

JABATAN KERJA RAYA MALAYSIA CAWANGAN KEJURUTERAAN CERUN				TYPICAL CROSS SECTION OF ROCK NETTING		
UNIT FORENSIK TANAH RUNTUH						
DI REKABENTUK OLEH : Kamal Bahrain	DI LUKIS OLEH : Amrin	DI SEMAK OLEH :	DI LULUSKAN OLEH :	TARIKH : JUN 2008	BIL. LUKISAN	00

Types of Rock Slope Stabilization Protection

Photo 1 - Soil Nail And Netting

Photo 2 - Fencing

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