APPLICATION OF PRESCRIPTIVE MEASURES TO SLOPES AND RETAINING WALLS

GEO REPORT No. 56
(Second Edition)

H.N. Wong, L.S. Pang, A.C.W. Wong, W.K. Pun & Y.F. Yu

GEOTECHNICAL ENGINEERING OFFICE

CIVIL ENGINEERING DEPARTMENT

THE GOVERNMENT OF THE HONG KONG

SPECIAL ADMINISTRATIVE REGION

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PREFACE

In keeping with our policy of releasing information which may be of general interest to the geotechnical profession and the public, we make available selected internal reports in a series of publications termed the GEO Report series. A charge is made to cover the cost of printing.

The Geotechnical Engineering Office also publishes guidance documents as GEO Publications. These publications and the GEO Reports may be obtained from the Government's Information Services Department. Information on how to purchase these documents is given on the last page of this report.

R.K.S. Chan
Head, Geotechnical Engineering Office
December 1999

FOREWORD

In February 1995, the Geotechnical Engineering Office (GEO) initiated a research and development study on prescriptive measures, with a view to formulating a prescriptive design methodology and promoting good practice in the application of prescriptive measures to slope works in Hong Kong. The first phase of the study, Phase 1, aims to review the role of the prescriptive approach in soil cut slope works, identify suitable items of prescriptive measures and recommend guidelines for their application.

In October 1995, an interim report (Pang, 1995) presenting the primary findings of the study was issued. After extensive consultation within the GEO, among local geotechnical engineering practitioners and with the Slope Safety Technical Review Board, the GEO disseminated the findings and recommendations of the Phase 1 study in the first edition of this Report in October 1996.

Subsequent to the publication of the first edition of this Report, the GEO carried out Phase 2 of the study, with the aim of improving the guidelines given therein and extending the scope of application of prescriptive measures. Findings of the Phase 2 study have been disseminated in several reports (Wong & Pun, 1999; MMBP & VLA, 1999).

This Report recommends improved guidelines on the application of prescriptive measures, consolidating the findings of the Phases 1 and 2 studies. Typical details of the recommended items of prescriptive measures and guidelines on their use are given. These serve to present a recommended standard of good practice for the application of prescriptive measures to improvement works on existing slopes and retaining walls. A review of the performance of prescriptive measures will be the subject of future study. Practitioners are encouraged to send, at any time, feedback and suggestions related to the use of prescriptive measures to the GEO.

The Phase 1 study was carried out by Dr L S Pang under the supervision of Mr H N Wong. The Phase 2 study was carried out by Dr L S Pang and later Mr A C W Wong and Dr Y F Yu under the supervision of Mr W K Pun. Mitchell, McFarlane, Brentnall & Partners International Limited and Victor Li & Associates Limited served as consultants to the GEO and assisted in the development of the improved guidelines for prescriptive soil nail design for soil cut slopes. Colleagues in the Planning Division provided advice on the geological aspects of the study. Useful suggestions and comments have been received from many other colleagues in the GEO and geotechnical engineering practitioners during the studies. All contributions are gratefully acknowledged.

P. L. R. Pang
Chief Geotechnical Engineer/Special Projects

ABSTRACT

Improvement works to slopes and retaining walls may be designed, as an alternative to using the conventional analytical methods, by the prescriptive approach. This approach entails the use of prescriptive measures, which are pre-determined, experience-based, and suitably conservative modules of works prescribed without detailed ground investigations and design analyses. Given due recognition of and allowance for the limitations in the use of prescriptive measures, the prescriptive approach provides an efficient and practical means of improvement to slopes and retaining walls. The approach is particularly useful for improving the large number of old man-made slopes and retaining walls in Hong Kong.

Various types of prescriptive measures have been developed for soil cut slopes and masonry retaining walls based on studies of Hong Kong practice in slope improvement works and case histories on conventional analytical design for the Landslip Preventive Measures Programme being implemented by the Geotechnical Engineering Office. In this Report, the scope of application of a range of items of prescriptive measures, as preventive maintenance, urgent repair and upgrading works, is recommended. Typical details of the recommended items of work are presented, and the procedures for their use are described. Guidelines on the prescriptive use of vegetation cover for improving the appearance and reducing the risk of surface erosion of soil cut slopes are also given.

The Report serves to present a recommended standard of good practice for applying prescriptive measures to improvement works on soil cut slopes and masonry retaining walls.

CONTENTS

1. INTRODUCTION

The use of prescriptive measures is not a new concept, and the prescriptive design approach has already been adopted in some types of slope works in Hong Kong, e.g. rock slope stabilisation works and surface recompaction of loose fill slopes. The development of prescriptive measures for general use in slope works has been considered by the Geotechnical Engineering Office (GEO) for over ten years (e.g. Malone, 1985; Geoguide 1 (GEO, 1993); Wong & Premchitt, 1994; Wong & Ho, 1995; Geoguide 5 (GEO, 1999)). It is recognised, from the successful use of prescriptive measures in previous applications and from the findings of slope and landslide studies over the years, that the prescriptive approach could have a much wider scope of application with further development of the methodology and experience in their use. It is also noted that the conventional analytical design approach has been streamlined and pruned down from that stated in the Geotechnical Manual for Slopes (GCO, 1984) by some designers through the use of simplified geological models and generalised soil shear strength parameters. This applies particularly to the design of improvement works on old man-made slopes, an area to which the prescriptive approach can be usefully applied.

2. GLOSSARY OF TERMS

The terms used in this Report have the meanings given below:

Prescriptive measures. Pre-determined, experience-based and suitably conservative modules of works prescribed to a slope or retaining wall to improve its stability or reduce the risk of failure, without detailed ground investigations and design analyses. Some examples are illustrated in Figure 1. These generally involve conventional and conservative details in design, and attention to specification and control of materials, workmanship, protection and maintenance procedures (adapted from Geoguide 1 and CEN (1994)).

Preventive maintenance works. Works of preventive nature to reduce the rate of deterioration of a slope or retaining wall (adapted from Geoguide 5). These generally involve the use of prescriptive measures, and are more substantial than routine maintenance works.

Upgrading works. Works carried out to upgrade a substandard slope or retaining wall to the requirements stipulated in the current geotechnical standards (adapted from Geoguide 5).

Urgent repair works. Works carried out to render an area affected by a landslide temporarily safe. Since permanent remedial works may take some time to initiate and complete, urgent repair works are aimed at ensuring that the area will not deteriorate in the interim to an extent that would pose an immediate danger.

It should be noted that the primary objective of preventive maintenance and urgent repair works is to reduce the rate of deterioration of a slope or retaining wall. If appropriate prescriptive measures are used, then the probability of failure will also be reduced. In some cases, the works carried out may suffice for meeting the required geotechnical standards for upgrading.

3. ADVANTAGES AND LIMITATIONS OF PRESCRIPTIVE MEASURES

The following are the advantages of using prescriptive measures over conventional analytical design methods:

(a) Technical benefits in enhancing safety and reducing the risk of failure, by incorporating simple, standardised and suitably conservative items of works to deal with uncertainties in design that are difficult to quantify, and using experience-based knowledge to supplement analytical design.

(b) Savings on time and human resources, by eliminating detailed ground investigations and design analyses (see Figure 2). The savings can be significant, particularly in a safety screening and improvement works programme in which a large number of slopes have to be dealt with by limited available staff resources.

There are, however, some inherent limitations if the prescriptive approach is adopted alone. These include:

(a) the items to be prescribed are at best limited to application to situations within the bounds of past experience, and

(b) the approach may result in more failures than design by detailed ground investigation and analysis, particularly for slopes affected by adverse geological and groundwater conditions.

Provided that designers acknowledge and work within these limitations, prescriptive measures could be adopted as effective slope improvement works and landslide risk mitigation provisions. Guidance given in this Report is aimed at minimising the risks associated with the above limitations. Relative cost-benefit of the prescriptive design approach and the analytical design approach is not examined in this study.

4. APPLICATION OF PRESCRIPTIVE MEASURES

4.1 General

Since prescriptive measures are experience-based, their general application has been developed in a phased manner. Trial-and-test should continue so that, with further experience gained, further improvements can be made and new areas of application can be sought.

4.2 Prescriptive Measures for Soil Cut Slopes

4.2.1 Scope of Application

Prescriptive measures have been developed for use in soil cut slopes in three categories of works, viz. preventive maintenance, urgent repair and upgrading works. The recommended scope of application covers soil cut slopes which satisfy the qualifying criteria given in Table 1.

4.2.2 Types and Details of Prescriptive Measures

Prescriptive measures for soil cut slopes may broadly be classified into the following three types according to the design objectives (Table 2):

(a) Type 1 - surface protection, local trimming and drainage,

(b) Type 2 - subsurface drainage, and

(c) Type 3 - structural support.

Seventeen items of prescriptive measures, including seven items for Type 1, nine items for Type 2 and one item for Type 3, are recommended. Typical details of the items of the prescriptive measures, given in Figures A1 to A12 in Appendix A, have been devised to facilitate convenient application. The extent of application of the various items to the slope and the key dimensions should be specified by the designer to suit the actual site conditions.

4.2.3 Recommended Procedures for Application

The recommended procedures for application of prescriptive measures to soil cut slopes are:

(a) Check that the slope satisfies the criteria for application of prescriptive measures (Table 1). It is recommended that for preventive maintenance and upgrading works, an Engineer Inspection in accordance with Geoguide 5 should be carried out prior to the specification of prescriptive measures.

(b) Identify possible problems affecting slope stability based on information obtained from site inspections and a review of available records of previous landslides, services, surface water pathways, maintenance and stability assessments.

(c) Determine the design objectives and the required items of prescriptive measures with reference to Table 2 and the guidance given in Section 4.2.4.

(d) Refer to the typical details of the relevant items of prescriptive measures (see Appendix A) and specify the key dimensions for each item and the extent of application to the slope to suit the actual site conditions.

(e) Complete Part A of the "Record Sheets for Prescriptive Measures Application" (Sheet 1, Figure 3) in all cases of using prescriptive measures.

(f) Inspect the slope and record details of any visible slope forming materials and adverse geological or groundwater conditions present during the various stages of construction. This can be most effectively done at the time when the old slope surface cover or vegetation is being removed, and during excavation for subsurface drainage works and drilling for raking drains or soil nails. The designer may seek geological advice on the presence of any adverse geological conditions as he considers necessary.

(g) Confirm that the criteria for application are met (Table 1), review the suitability and adequacy of the items of prescriptive measures specified, and make suitable amendments if needed.

(h) Complete Part B of the "Record Sheets for Prescriptive Measures Application" (Sheet 2, Figure 3), giving sufficient documentary evidence on verification that the slope satisfied the qualifying criteria. In cases of using prescriptive measures in preventive maintenance, record the recommended works in the Record Sheets for Engineer Inspections for Maintenance (see Figure 6 of Geoguide 5) also.

4.2.4 Guidance on Application

In selecting the appropriate items of prescriptive measures to be used, the designer should take due account of the nature of the slope forming materials, the geological conditions, the groundwater conditions, the nature and locations of services, the surface water pathways, the performance history of the slope, the consequence of failure, site constraints, and the type and level of improvement required to be achieved.

General guidance on the use of the various items of prescriptive measures, which aim to tackle different factors that could trigger slope instability, is summarised in Table 3. Supplementary technical guidance is given in Appendix A.

As shown in Table 1, items of Types 1 and 2 prescriptive measures should normally be adopted in all cases for improving slope stability or as contingency provisions.

For urgent repair works, whether soil nails are required depends on the scale and mechanism of failure, the consequence of further landslides and the need to provide structural support to render the area affected by the landslide temporarily safe. Guidance on situations under which soil nails are to be used in urgent landslide repairs is given in Table 4.

For upgrading works on existing slopes using prescriptive measures, soil nails should be used.

For slopes that have experienced major or multiple minor failures, the causes of the failures should first be investigated and understood. Prescriptive measures may be used as upgrading works if the investigation confirms that all the qualifying criteria are met. The scope of the investigation depends on the nature of failure and does not necessarily require detailed ground investigation. For example, multiple minor washout failures in a slope due to lack of surface drainage can be identified by site reconnaissance. In this case, appropriate surface drainage should be provided in addition to other items of prescriptive measures.

4.3 Prescriptive Design of Skin Walls for Masonry Retaining Walls

4.3.1 Scope of Application

The prescriptive approach has been developed for stability assessment and design of skin walls as upgrading works for masonry retaining walls. The recommended scope of application covers masonry retaining walls which satisfy the qualifying criteria given in Table 5. Where not all of the qualifying criteria are satisfied, the skin wall may be considered as preventive maintenance works.

4.3.2 Recommended Procedures for Application

The recommended procedures for prescriptive design of skin walls as upgrading works for masonry retaining walls are described below:

(a) Determine the wall geometry and ground profile by field measurement, such as weephole probing, and survey. Field measurement of wall geometry should still be carried out to verify the actual geometry of the wall even where as-built drawings of the wall showing the wall dimensions are available. Where the thickness of the wall varies approximately linearly with wall height, the wall thickness at about mid-height of the wall may be taken as the average wall thickness. For walls with a stepped back face, the average wall thickness may be taken as the weighted average of the thickness of all steps taking into account the height of the steps. It is recommended that an Engineer Inspection in accordance with Geoguide 5 should be carried out prior to the specification of prescriptive measures.

(b) In the Engineer Inspection, undertake a thorough desk study and site reconnaissance in accordance with Geoguide 2 (Geotechnical Control Office, 1987) to determine whether there is sufficient information on the ground and groundwater conditions for the assessment of the qualifying criteria. A detailed site inspection check should always be carried out to identify whether any exposed or buried water-carrying services are present in the vicinity of the wall (see Hong Kong Government, 1996). If such services are present, checks should be carried out with the owner to assess whether there is any leakage from the services, and recommendations to carry out regular check of the services should be made.

(c) If there is insufficient information to assess the qualifying criteria with confidence, there will be a need to carry out additional ground investigation. Simple techniques are often adequate. For example, trial pits at suitable locations at the toe of the wall are useful in revealing the nature of the foundation and likelihood of the presence of a high permanent groundwater level. Trial pits and GCO probing at suitable locations behind the wall are suitable for assessing the wall thickness and the nature of the retained ground and the foundation. Engineering judgement has to be made on the likely permanent and transient rise in groundwater level based on the results of the desk study, site reconnaissance and ground investigation. Due account should be taken of the presence of deteriorating water-carrying services behind, and in the vicinity of, the wall.

(d) Check that the masonry retaining wall satisfies the qualifying criteria for adoption of the prescriptive design approach (Table 5).

(e) Refer to the guidelines on prescriptive design of skin wall given in Appendix B and determine whether a skin wall is required. If so, specify the dimensions and details of the skin wall.

(f) Complete Part A of the "Record Sheet for Prescriptive Skin Wall Application" (Sheet 1, Figure 4).

(g) During the construction stage, confirm that the criteria for application are met (in particular, the nature of the retained ground and wall foundation, and the groundwater conditions), review the suitability and adequacy of the prescriptive measures specified, and make suitable amendments if needed. If the ground has been significantly disturbed during trench excavation for the skin wall construction, the loose material should be removed and the area compacted before concreting of the skin wall to achieve a good foundation for the wall.

(h) Complete Part B of the “Record Sheet for Prescriptive Skin Wall Application” (Sheet 2, Figure 4), giving sufficient documentary evidence on verification that the wall satisfied the qualifying criteria. In cases where the skin wall is to be considered as preventive maintenance works, record the recommended works in the Record Sheets for Engineer Inspections for Maintenance (See Figure 6 of Geoguide 5) also.

4.4 Prescriptive Use of Vegetation Cover for Soil Cut Slopes

Vegetation cover, following the guidelines given in Appendix C, can be prescribed as surface protection to existing soil cut slopes where preventive maintenance or upgrading works are to be carried out for such slopes using prescriptive measures in accordance with the recommendations given in this Report.

4.5 Other Measures

Other items of prescriptive measures are available. Some of these measures have already been successfully adopted in slope improvement works (e.g. protection, local trimming, drainage and structural support works for rock slope stabilisation, and recompaction of the surface 3 m for loose fill slopes). Guidelines on their use are given in the relevant guidance documents (e.g. GCO, 1984). Their use within the established limits of experience should continue in accordance with current practice.

5. PERSONNEL

The prescriptive measures should be specified by a geotechnical engineer professionally qualified and experienced in Hong Kong, as should the construction review. A suitable qualification is Registered Professional Engineer (Geotechnical), information on which can be obtained from the Engineers Registration Board. For preventive maintenance works which involve only surface protection and surface drainage prescriptive measures, the prescriptive design and construction review may also be carried out by a professionally qualified civil engineer competent in site formation and drainage works.

For preventive maintenance works, it is preferable and often more cost-effective to ask the same professional engineer who undertakes the Engineer Inspection for the slope to also specify the items of prescriptive measures required as part of the preventive maintenance recommendations. This should be arranged as far as possible.

Construction review should include inspection of the site and assessment of the geology, slope-forming materials and groundwater conditions during various stages of construction, a review of the suitability and adequacy of the specified prescriptive measures items (including type, dimensions and extent of application), and giving recommendations on any design modifications necessary to take into account the actual site and ground conditions revealed. It should always be carried out for prescriptive measures specified as upgrading and preventive maintenance works. It should also be undertaken for prescriptive measures specified as urgent repair where practicable. The professional engineer undertaking this work should be familiar with all available information collected in the desk study and site reconnaissance. Where it is possible to arrange for the same professional engineer who has specified the prescriptive measures items to carry out the construction review, this should be done.

6. STATUS OF SLOPE FEATURES IMPROVED BY PRESCRIPTIVE MEASURES

Where prescriptive measures have been applied to a slope or retaining wall as upgrading works in accordance with the recommendations of this Report, the slope or retaining wall can be taken to have been upgraded to acceptable geotechnical standards.

Where prescriptive measures have been applied to a slope as preventive maintenance or urgent repair works in accordance with the recommendations of this Report, the prescriptive measures can be taken to have improved the slope to reduce the rate of deterioration, and to have met a recommended standard of good practice for slope preventive maintenance and urgent landslide repair respectively. Where such prescriptive measures applied meet the standard required for upgrading works in accordance with the recommendations of this Report, then the slope can also be taken to have been upgraded to acceptable geotechnical standards.

Slopes improved by prescriptive measures should be maintained in accordance with the guidelines given in Geoguide 5. However, raking drains used as prescriptive measures should not be considered as “Special Measures” as defined in Geoguide 5, and the monitoring requirements stipulated in Section 5 of Geoguide 5 are not applicable to these drains. Regular inspections and routine maintenance of the raking drains should however be carried out.

7. PERFORMANCE REVIEW OF PRESCRIPTIVE MEASURES

A systematic performance review will be carried out by the GEO to assess the effectiveness of the recommended items of prescriptive measures and to identify areas for further development and improvement. The review will include an examination of construction and detailing problems encountered in applying the recommended items of prescriptive measures, and an evaluation of any refinements required to be made to the recommendations given in this Report. To facilitate the review and further development, responsible professional engineers are requested to complete record sheets on their certification of satisfactory completion of the prescriptive works in all cases of application of prescriptive measures, and to provide feedback to the GEO.

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LIST OF TABLES

Table 1 - Scope of Application of Prescriptive Measures to Soil Cut Slopes

<table>
<tr><th rowspan="2">Types of Slope Improvement Works</th><th colspan="3">Qualifying Criteria for Application</th><th rowspan="2">Prescriptive Measures Required</th></tr>
<tr><th>Consequence[1]</th><th>Geometry</th><th>Engineering and Geology</th></tr>
<tr><td>Preventive Maintenance Works</td><td colspan="3">(Qualifying criteria not applicable)</td><td>Types 1 & 2, and sometimes Type 3 (see Section 6)</td></tr>
<tr><td rowspan="3">Urgent Repair Works to Landslides</td><td>Groups 1 & 2 facilities affected</td><td>Height of landslide scar ≤ 10 m and landslide volume ≤ 100 m^3</td><td rowspan="6">- Apply only to existing soil cut slopes[2] judged to require improvement works.
- Apply to slopes confirmed on site as comprising colluvial, residual or saprolitic soils of granitic or volcanic origin that do not contain loose or soft materials. Also apply to slopes comprising other materials with similar shear strength properties, with the exception of alluvial and marine deposits and sedimentary rocks containing argillaceous layers.
- Apply only if no observable or recorded adverse geological material (e.g. significantly kaolinised granite and volcanics, weathered dykes, and sedimentary layers within volcanic formations) and adverse discontinuities (e.g. adversely-oriented, persistent, clay- or silt-infilled discontinuities, pre-existing shear surfaces or zones, and well-developed discontinuities that are slickensided or heavily coated with dark minerals or kaolinite).
- Apply only if no observable or recorded adverse groundwater conditions, i.e. no signs of a high permanent[3] groundwater table over a significant area of the slope. As a general guide, the average pore water pressure ratio, r_u, for the slope should not exceed 0.1.</td><td rowspan="3">Types 1 & 2, and sometimes Type 3 (see Table 4)</td></tr>
<tr><td>Group 3 facilities affected</td><td>Height of landslide scar ≤ 15 m and landslide volume ≤ 200 m^3</td></tr>
<tr><td>Groups 4 & 5 facilities affected</td><td>Height of landslide scar ≤ 20 m and landslide volume ≤ 400 m^3</td></tr>
<tr><td rowspan="3">Upgrading Works</td><td>Groups 1 & 2 facilities affected</td><td>Slope height ≤ 10 m</td><td rowspan="3">Types 1, 2 & 3</td></tr>
<tr><td>Group 3 facilities affected</td><td>Slope height ≤ 13 m</td></tr>
<tr><td>Groups 4 & 5 facilities affected</td><td>Slope height ≤ 18 m</td></tr>
</table>

Notes:
(1) The various groups of facilities are given in Table A1, Appendix A.
(2) Soil cut slopes include cuttings in a weathered rock mass in the Residual Soil, PW0/30 and/or PW30/50 zone as defined in Geoguide 3 (GCO, 1988), with or without overlying colluvium. Where substandard fill (or loose or soft colluvium) is present and the size of the fill body (colluvium mass) meets GEO's slope registration criteria, the fill body (colluvium mass) should be dealt with using the conventional approach.
(3) "Permanent" refers to "typical wet season water level" as described on p. 60, GCO (1984).
(4) If a slope that was designed and checked to be up to the current geotechnical standards has failed, then the prescriptive design approach may not be applicable and the slope should be investigated to determine suitable urgent repair or upgrading works.
(5) The application of prescriptive measures as upgrading works should generally be limited to slopes which have not experienced any major or multiple minor failures. Where there are major or multiple minor failures on the slope or at areas adjacent to the slope, the causes of the failures should first be investigated and understood. Prescriptive measures may be applied but these may be treated as upgrading works only if the investigation can confirm that all qualifying criteria (geometry, engineering and geology) are met.

Table 2 - Prescriptive Measures for Soil Cut Slopes

Type	Prescriptive Measures	Primary Design Objectives	Item No. and Description of Works	Details
1	Surface protection and local trimming	- Improve surface protection - Improve local stability	1.1.1 Cover slope face with shotcrete	Figure A1
			1.1.2 Locally trim and remove loose materials	-
			1.1.3 Fill local areas with no-fines concrete: (a) at upper part of slope (b) at lower part of slope or on berm	(a) Figure A2 (b) Figure A2
			1.1.4 Cover upslope area with shotcrete	Figure A3
	Surface drainage	- Improve surface drainage	1.2.1 Provide surface drainage channels	CED Drg No. C2409B
			1.2.2 Provide slope crest channel with upstand	Figure A3
2	Subsurface drainage	- Improve subsurface drainage - Provide contingency subsurface drainage measures	2.1 Provide drainage behind impermeable slope surface cover: (a) with no-fines concrete toe (b) with relief drains	(a) Figure A4 (b) Figure A5
			2.2 Cover slope face with no-fines concrete: (a) at upper part of slope (b) at lower part of slope or on berm	(a) Figure A6 (b) Figure A7
			2.3 Provide raking drains: (a) at upper part of slope (b) at lower part of slope (c) at specific seepage or potential seepage areas	(a) Figure A8 (a) Figure A9 (c) CED Drg No. C2403
			2.4 Provide counterfort drains at upper part of slope	Figure A10
			2.5 Provide toe drain	Figure A11
3	Structural support	- Provide support to improve overall slope stability	3.1 Provide soil nails	Figure A12

Table 3 - Guidance on the Use of Prescriptive Measures on Soil Cut Slopes

Typical Problem to Tackle	Prescriptive Measures											
	Type 1						Type 2					Type 3
	1.1.1	1.1.2	1.1.3	1.1.4	1.2.1	1.2.2	2.1	2.2	2.3	2.4	2.5	3.1
Deficient surface protection provisions	✓			~								
Deficient surface drainage provisions					✓	✓						
Concentrated discharge of surface water onto the slope	~			~	✓	✓						
Loose materials on the slope face		✓	~									
Locally over-steepened or depressed slope face		✓	✓									~
Infiltration via the area above the crest of the slope				✓					~	~		
Persistent subsurface seepage							~	~	✓			
Seepage, or signs of seepage, on existing impermeable slope surface cover							✓	✓	~			
Preferential flow paths							✓	✓	~	~		
Development of a perched water table									✓	✓		~
Rise in main groundwater table									✓		~	~
Over-steepening of the slope face	~			~	~	~	~	~	~			✓

Notes: (1) For details of prescriptive measures, see Table 2 and Appendix A.
(2) "✓" denotes that the item is almost always required and "~" denotes that the item is required in some cases only. More than one types of prescriptive measures may be used for a slope. In some cases, prescriptive measures may be used as a contingency provision.

Table 4 - Guidance on Situations under Which Soil Nails Are to Be Used in Urgent Repair Works to Soil Cut Slopes

Affected Facility Group	Slope Height (m)	Scale of Failure
1	5 - 10	Scar height > 3 m and failure volume > 10 m^3
2	5 - 10	Scar height > 5 m and failure volume > 25 m^3
3	10 - 15	Scar height > 10 m and failure volume > 50 m^3
4	15 - 20	Scar height > 10 m and failure volume > 100 m^3

Notes:
(1) This Table is for guidance only and the designer should exercise professional judgement on the need for soil nails in each particular case.
(2) For slopes affecting Group 5 facilities, soil nails are not normally required for urgent repair works.
(3) Where adopted, soil nails should be applied to the area in the immediate vicinity of the landslide judged to require structural support, in addition to the location where the landslide had occurred.

Table 5 - Scope of Application of Prescriptive Design of Skin Wall for Upgrading Existing Masonry Retaining Walls

Subject	Qualifying Criteria
Wall conditions	The wall satisfies the conditions for 'existing walls' stipulated in Section 7.3.3 of the Geotechnical Manual for Slopes (GCO, 1984), and its condition is no worse than wall condition Class B given in Table 6 and the Observed State of Wall Deformation (2) in Table 7.
Wall geometry, ground profile and surcharge loading (Figure B1(a))	(i) $2\ m \le H_e \le 8\ m$, $0^o \le \theta \le 10^o$, $\alpha \le 10^o$ and $\beta \le 10^o$, and (ii) the wall is not subject to a vertical uniform surcharge (q) exceeding 10 kPa or a total horizontal load (P) exceeding $0.2\ H_r^2$, where P is in kN/m and H_r is in metres.
Wall slenderness ratio, H_e/T_w (Figure B1 (a))	< 5
Retained ground and wall foundation	There should not be any observable or recorded presence of weak materials such as extensive kaolin-bearing layers, ground with extensive loose fill materials, etc.
Groundwater conditions	There should not be any observable or recorded signs of water which indicate that the groundwater level is higher than 1/3 of the retained wall height, H_r.

Table 6 - Classification of Visible Wall Condition for Existing Masonry Retaining Walls

Wall Condition Class	State of Distress and Wall Deformation Based on Inspection[1]
A	Minimal distress (e.g. wall fabric in good condition) and deformation.
B	Moderate distress (e.g. much mortar missing, minor dislocation of isolated masonry blocks) and/or deformation.
C	Onset of severe distress (e.g. missing or dislocation of some masonry blocks) and/or deformation.
D	Advanced stage of severe distress (e.g. missing or major dislocation of many masonry blocks) and/or deformation.

Notes:
(1) In general, the state of deformation of old masonry retaining wall can be assessed reliably by means of experience and engineering judgement. In case of doubt or in marginal cases, reference may be made to Table 7 for guidance.
(2) For walls without tie members, a conservative assessment should be made, with the overall wall visible condition downgraded by one class, where appropriate.
(3) If the condition of the wall is known to be deteriorating, the next wall condition class appropriate to the worst possible wall condition anticipated should be chosen instead.
(4) Dry-packed random rubble walls of 3 to 5 m high should be assigned a wall condition Class C, irrespective of the condition and deformation profile of the wall.
(5) Dry-packed random rubble walls of more than 5 m high should be assigned a wall condition Class D, irrespective of the condition and deformation profile of the wall.

Table 7 - Guidelines for Evaluation of the State of Wall Deformation for Existing Masonry Retaining Walls

Observed State of Wall Deformation	Forward Movement	Bulging
(1) Minimal Deformation	Forward movement of wall as indicated by: (a) long continuous movement cracks at wall crest sub-parallel to wall, total width at any section < 0.1% of wall height, or (b) sub-vertical through cracks in return wall of total width at each level < 0.1%h where h is height of measurement point from ground surface level in front of toe	Negligible bulging of wall
(2) Moderate Deformation	Forward movement as (1) except crack width totalling between 0.1%h and 0.2%h	Minor bulging of wall face noticeable to naked eye
(3) Onset of Severe Deformation	Forward movement as (1) except crack width totalling between 0.2%h and 0.6%h	Bulged profile of wall face sufficient to touch a vertical line drawn through wall toe, or maximum bulging of wall approaching or equal to 75 mm
(4) Advanced Stage of Severe Deformation	Forward movement as (1) except crack width totalling to a value >0.6%h	Bulging as (3) but protruding beyond a vertical line drawn through toe, or maximum bulging of wall > 75 mm

Note: When using this Table, engineering judgement is crucial since different walls are likely to present different degrees of difficulty in deformation determination. The proposed deformation limits shown in this Table should not be regarded as absolute.

LIST OF FIGURES

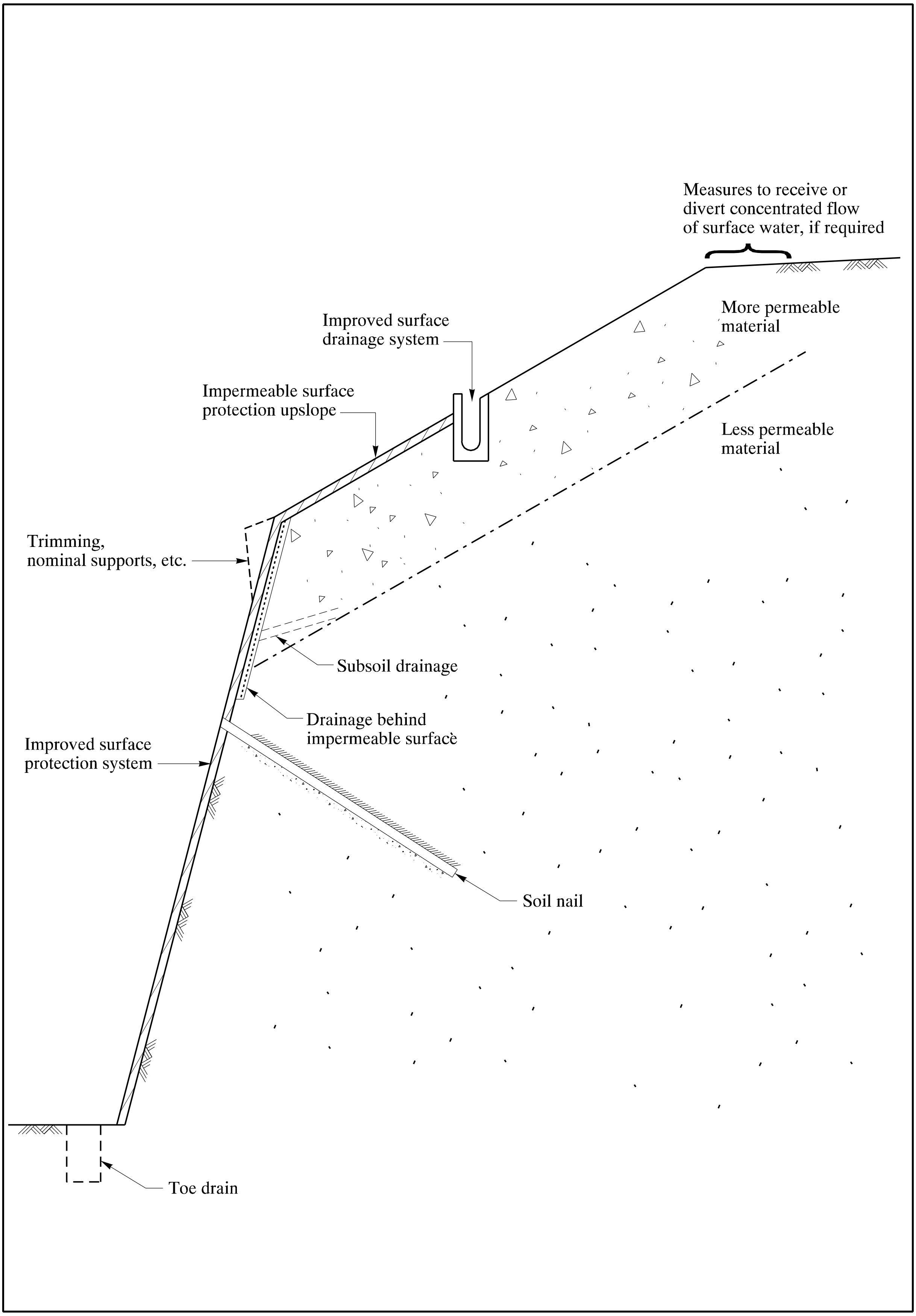
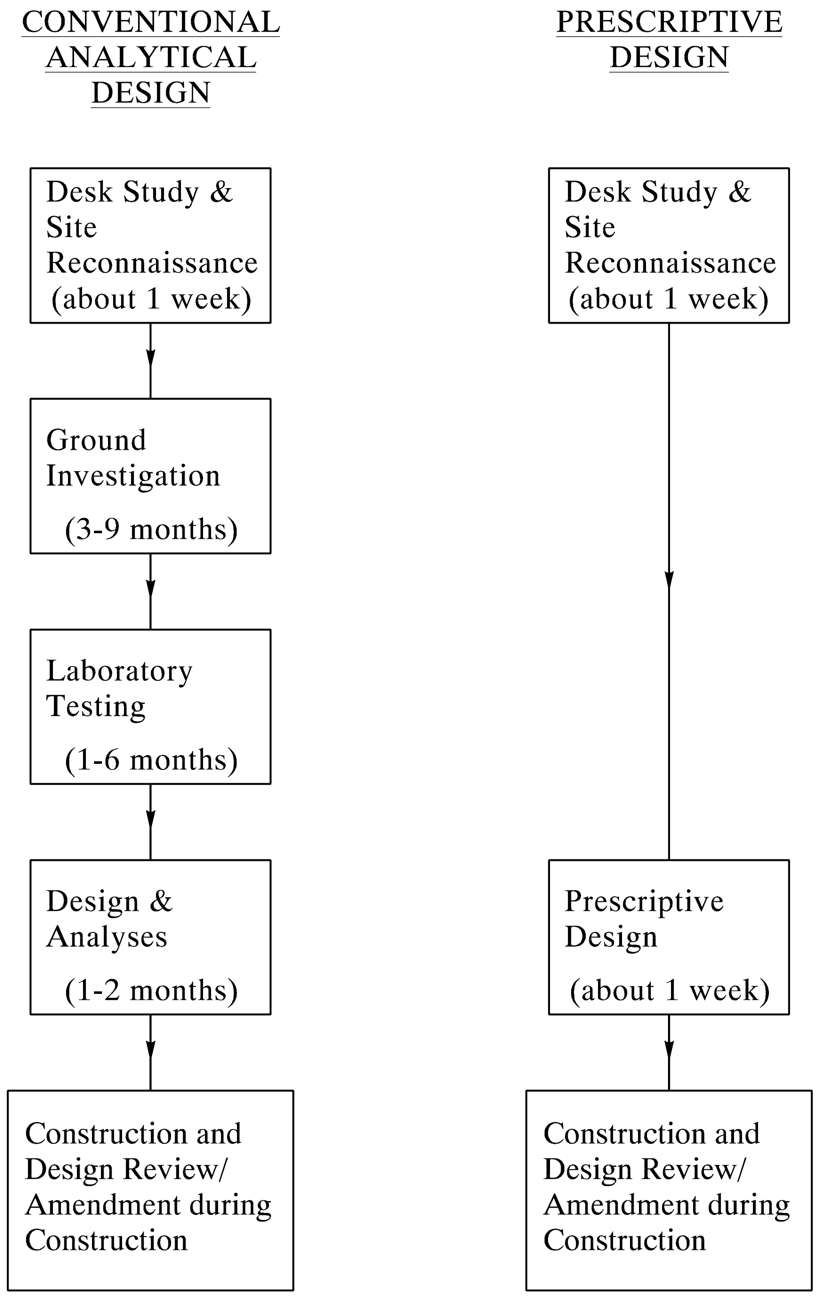


Figure 1 - Typical Prescriptive Measures for Soil Cut Slopes



Notes:
(1) The time ranges given above are typical for upgrading works.
(2) The time ranges required for prescriptive design of urgent repair works and slope preventive maintenance works are expected to be less than those shown above.

Figure 2 - Comparison of the Procedures for Conventional Analytical Design and Prescriptive Design

Part A - Prescriptive Measures for Soil Cut Slopes

Slope Reference No. ______________________	Location (Address) _____________________________
Slope Geometry and Consequence Category	**Qualifying Criteria**
Slope Gradient: (degrees) Slope Height: (m) Upslope Gradient: (degrees) Group of Facilities Affected: 1/2/3/4/5* Consequence-to-life Category: 1/2/3* Records of Engineer Inspection available: Yes/No* If yes, date of inspection: HKGS Geology Map Sheet No.:	1. Within consequence and geometry limits. ☐ Yes 2. Slope-forming material confirmed on site as acceptable. ☐ Yes 3. No adverse geological conditions present. ☐ Yes 4. No adverse groundwater conditions. ☐ Yes

Records of Landslide

Date of Landslide	Scar Height (m)	Failure Volume (m^3)	GEO Incident No.
1.______________(Current*)	__________________	____________________	___________________________
2.______________	__________________	____________________	___________________________
3.______________	__________________	____________________	___________________________

Type of Improvement Works

☐ Preventive Maintenance ☐ Urgent Repair to the Current Landslide ☐ Upgrading works (LPM*)

Design Objective	Prescriptive Measures Recommended	Figure No.
☐ Improve surface protection ☐ Improve local stability	☐ 1.1.1 Cover slope face with shotcrete ☐ 1.1.2 Locally trim and remove loose materials 1.1.3 Fill local areas with no-fines concrete: ☐ (a) at upper part of slope ☐ (b) at lower part of slope or on berm ☐ 1.1.4 Cover upslope area with shotcrete	A1 - A2 A2 A3
☐ Improve surface drainage	☐ 1.2.1 Provide surface drainage channels ☐ 1.2.2 Provide slope crest channel with upstand	- A3
☐ Improve subsurface drainage ☐ Provide contingency subsurface drainage measures	2.1 Provide drainage behind impermeable slope surface cover: ☐ (a) with no-fines concrete toe ☐ (b) with relief drains 2.2 Cover slope face with no-fines concrete: ☐ (a) at upper part of slope ☐ (b) at lower part of slope or on berm 2.3 Provide raking drains: ☐ (a) at upper part of slope ☐ (b) at lower part of slope ☐ (c) at specific seepage or potential seepage areas ☐ 2.4 Provide counterfort drains at upper part of slope ☐ 2.5 Provide toe drain	 A4 A5 A6 A7 A8 A9 - A10 A11
☐ Provide support to improve overall slope stability	☐ 3.1 Provide soil nails, with a FOS increase in range: A/B/C* (See Table A2)	A12
☐ Others (please specify) _________________________	☐ Other measures (please specify) ____	

Attachments:

☐ Site location plan ☐ Photographs ☐ Records of Engineer Inspections

☐ Plan, sketches/drawings showing locations/layout/key dimensions of the proposed prescriptive measures

Designed by: Post:	Signature: Date:	Checked by: Post:	Signature: Date:

'*' Delete where appropriate

Figure 3 - Indicative Record Sheets for Prescriptive Measures Application to Soil Cut Slope (Sheet 1 of 2)

Part B - Design Amendments and Site Inspection Records

Design Amendments[1]	Reasons for Amendments	Designed by (name & post)	Initial (+ Date)	Checked by (name & post)	Initial (+ Date)

Post-construction Design Review Recommended: ☐ Yes ☐ No
If yes, give actions to be taken (e.g. site inspection after heavy rainstorms to check adequacy of surface or subsurface drainage measures installed for a period covering an intense rainstorm). ____________________
____

Notes:
(1) Sketches/drawings showing the design amendments should be attached.
(2) Sketches, notes and photographs which record the observations made at site inspections prior to and during construction of prescriptive measures, as well as documentary evidence on verifying that the slope satisfied the qualifying criteria, should also be attached. They should be clearly marked as 'Site Inspection Records'.

Works commenced on	Works completed on	Works certified by (Name & Post)
________________________	________________________	______________________________

Figure 3 - Indicative Record Sheets for Prescriptive Measures Application to Soil Cut Slope (Sheet 2 of 2)

<table>
<tr><td colspan="4">Part A - Prescriptive Design of Skin Wall for Upgrading Existing Masonry Retaining Walls</td></tr>
<tr><td colspan="2">Wall Reference No. ____________________________</td><td colspan="2">Location (Address) ____________________________</td></tr>
<tr><td colspan="2">Masonry Wall Geometry and Consequence Category</td><td colspan="2">Qualifying Criteria</td></tr>
<tr><td colspan="2">Wall Height: (m)
Upslope Gradient: (degrees)
Downslope Gradient: (degrees)
Group of Facilities Affected: 1/2/3/4/5*
Consequence-to-life Category: 1/2/3*
Records of Engineer Inspection available: Yes/No*
If yes, date of inspection:
HKGS Geology Map Sheet No.:</td><td colspan="2">1. ‘Existing’ wall[1]. ☐ Yes
2. Within geometry limits. ☐ Yes
3. Wall condition Class A or B. ☐ Yes
4. No adverse geological conditions present. ☐ Yes
5. No adverse groundwater conditions (e.g. $H_w \geq 1/3 \times H_r$). ☐ Yes</td></tr>
</table>

<table>
<tr><td colspan="3">Records of Past Failure</td></tr>
<tr><td>Date of Incident</td><td>Failure Volume (m^3)</td><td>GEO Incident No.</td></tr>
<tr><td>1. ____________________</td><td>____________________</td><td>____________________</td></tr>
<tr><td>2. ____________________</td><td>____________________</td><td>____________________</td></tr>
<tr><td>3. ____________________</td><td>____________________</td><td>____________________</td></tr>
</table>

<table>
<tr><td colspan="4">Prescriptive Measures Recommended</td></tr>
<tr><td colspan="4">☐ Provide skin wall of thickness ______________ m</td></tr>
<tr><td colspan="4">☐ Other measures (please specify) ________________________________</td></tr>
<tr><td colspan="4">Attachments:
☐ Site location plan
☐ Photographs
☐ Records of Engineer Inspections
☐ Plan, sketches/drawings showing locations/layout/key dimensions of the proposed prescriptive measures</td></tr>
<tr><td>Designed by:

Post:</td><td>Signature:

Date:</td><td>Checked by:

Post:</td><td>Signature:

Date:</td></tr>
</table>

‘*’ Delete where appropriate

Figure 4 - Indicative Record Sheet for Prescriptive Skin Wall Application (Sheet 1 of 2)

Part B - Design Amendments and Site Inspection Records

Design Amendments[2]	Reasons for Amendments	Designed by (name & post)	Initial (+ date)	Checked by (name & post)	Initial (+ date)

Post-construction Design Review Recommended: ☐ Yes ☐ No
If yes, give actions to be taken (e.g. site inspection after heavy rainstorms to confirm absence of adverse groundwater condition)

____

____

Notes:
(1) The wall should satisfy the conditions for ‘existing wall’ stipulated in Section 7.3.3 of the Geotechnical Manual for Slopes.
(2) Sketches/drawings showing the design amendments should be attached.
(3) Sketches, notes and photographs which record the observations made at site inspections prior to and during construction of prescriptive measures, as well as documentary evidence on verifying that the wall satisfied the qualifying criteria, should also be attached. They should be clearly marked as ‘Site Inspection Records’.

Works commenced on	Works completed on	Works certified by (name & post)	Initial (+ Date)
____________	____________	____________	____________

Figure 4 - Indicative Record Sheet for Prescriptive Skin Wall Application (Sheet 2 of 2)

APPENDIX A

GUIDELINES ON THE USE OF PRESCRIPTIVE MEASURES FOR SOIL CUT SLOPES

CONTENTS

A.1 GENERAL

This Appendix provides technical guidance on the functions and use of different items of prescriptive measures recommended for soil cut slopes. It should be read in conjunction with the text, tables and figures of the main Report, where general principles of the proposed application are presented.

General guidance on recommended good practice for slope preventive maintenance works can be found in Geoguide 5 (GEO, 1999).

Where underground services are present and are judged to have a destabilising effect on a slope in the event of leakage, the guidance given in Geoguide 5 should be followed.

Some items of prescriptive measures may need to extend into adjoining land. The designer should check the land status and where necessary seek the agreement of the land owner before specifying the items.

A.2 TYPICAL DETAILS

Typical details for different items of prescriptive measures for soil cut slopes are shown in Figures A1 to A12.

A.3 SPECIFICATIONS

The works should comply with Hong Kong Government (1992). Where necessary, Particular Specification clauses should be included in the contract under which the works are to be carried out. Suitable clauses are available from the GEO.

A.4 TYPE 1 PRESCRIPTIVE MEASURES - SURFACE PROTECTION, LOCAL TRIMMING AND DRAINAGE

A.4.1 Surface Protection and Local Trimming

The slope surface protective cover on many old slopes in Hong Kong may not be satisfactory. Where the existing provisions are deficient (e.g. insufficient provision against surface infiltration), prescriptive measures for slope surface protection and erosion control should be provided. Shotcrete (Item 1.1.1, Table 2) may be used to provide an impermeable surface cover to protect the slope from surface infiltration and surface water. A surface protective cover may not be necessary for the less weathered portion (PW50/90 zone or better, as defined in Geoguide 3 (GCO, 1988)) of a slope formed in weathered rock. Also, consideration should be given to the possible adverse visual impact of shotcreting a slope. Reference should be made to Appendix C for guidelines on the prescriptive use of vegetation cover on soil cut slopes.

Where shotcrete is to be used, before application any landslide debris and loose material on the slope surface (Item 1.1.2, Table 2) should be removed to ensure proper contact between the shotcrete and the slope. Applying shotcrete directly to a slope surface with seepage should be avoided.

Locally over-steepened areas or depressions, e.g. landslide scars, may be trimmed and/or filled with no-fines concrete (Item 1.1.3, Table 2) to restore the slope profile in order to avoid local instability from developing.

Special attention should be given to providing adequate protection of the ground immediately upslope of a cut slope against significant ingress of surface water (Item 1.1.4, Table 2). Potential locations of water ponding in the upslope area should be dealt with. Localised shallow depressions should be filled with shotcrete to achieve a smooth fall to the slope crest drains. If the potential for ponding could not be effectively reduced by shotcreting alone, consideration should be given to providing additional surface channels to bring the water from the upslope area to the slope toe.

A.4.2 Surface Drainage

Poor surface drainage provisions, such as inadequate number of drainage channels, undersized drainage channels and poor channel layout and detailing, are important causes of slope failure. Where the existing provisions are deficient, additional surface drainage channels with an adequate layout and proper detailing should be prescribed to improve the hydraulic capacity of the drainage system and minimise the risk of blockage.

Consideration should be given to providing an upstand for the slope crest channel (Item 1.2.2, Table 2) to minimise possible spillage of surface water, and increasing the channel gradient and size (Item 1.2.1, Table 2). However, the possibility of local ponding behind the upstand at the slope crest channel should be considered. It is recommended that, where an upstand is provided, the gradient along the alignment of the channel should exceed 1 in 10.

Special attention should be given to the layout and detailing of the surface drainage system to ensure adequate flow capacity and containment of flow within the channels and adequate discharge capacity at the downstream side. For instance, abrupt changes in the direction of flow should be avoided; catchpits should be provided at junctions of channels, and where this cannot be arranged, baffle walls should be provided to minimise spilling or overflow. Environmental factors, such as potential sources of concentrated flow of surface water, which may adversely affect slope stability, should be dealt with. Further discussion on the role of environmental factors is given in Au & Suen (1991a, 1991b & 1996).

A.5 TYPE 2 PRESCRIPTIVE MEASURES - SUBSURFACE DRAINAGE

A.5.1 Drainage behind Impermeable Slope Surface Cover

Inadequate drainage behind an impermeable slope surface cover (e.g. shotcrete) can be a contributory cause of failure in slopes with subsurface seepage flow. Geosynthetic composite drainage material can be installed behind the impermeable slope surface cover (Item 2.1, Table 2), with the provision of a no-fines concrete toe (Figure A4) or relief drains (Figure A5), to minimise the build up of water pressure. This is particularly important at locations where preferential flow paths, such as soil pipes, erosion channels or holes left behind by rotted tree roots or burrowing animals, exist in the ground behind the impermeable cover.

It is important to avoid sliding instability at the interface between the soil and the geosynthetic composite drainage material by providing proper anchorage, and to ensure that there are no significant gaps at the interface which may result in erosion. The spacings of the geosynthetic composite drainage material shown in Figures A4 and A5 may be adjusted on site to suit the locations of seepage and preferential flow path, provided that the overall area of the surface covered by the drainage material is within about one-third of the area of the impermeable slope surface.

It should be noted that geosynthetic composite drainage material has a limited drainage capacity and is suitable for relieving water pressures in the soil close to the impermeable cover. Where a larger drainage capacity is required, the use of a no-fines concrete cover (Item 2.2, Table 2) should be considered.

Installation of geosynthetic composite drainage material may be difficult if the slope surface is irregular, e.g. at a landslide scar. In such case, using no-fines concrete may be more convenient.

A.5.2 No-fines Concrete Cover

No-fines concrete has good drainage capability and its dead weight offers some stabilisation effects. It can conveniently be built against irregular ground profile to give a uniform surface, and if used properly in combination with a geotextile filter or geosynthetic composite drainage material, it is effective in controlling slope surface instability and erosion. It may be used locally (Item 1.1.3, Table 2) or over a larger area of the slope face (Item 2.2, Table 2) to provide drainage of water from the soil close to the slope face.

Loose material on the slope surface should be removed (Item 1.1.2, Table 2) before placing the no-fines concrete. Care should be exercised during placement of no-fines concrete to avoid damaging and blocking the geotextile filter or geosynthetic composite drainage material, which is required to prevent internal soil erosion. If necessary, an additional protective layer of geotextile filter or sand bags may be placed over the geotextile filter or geosynthetic composite drainage material for protecting it from damage during casting of the no-fines concrete.

The no-fines concrete cover should be founded on firm ground to ensure stability. Benching of the concrete into the slope should be considered to improve the stability, especially on steep slopes. Galvanised steel dowel bars may also be used to tie the no-fines concrete block and geotextile filter or geosynthetic composite drainage material to the slope.

Where the build-up of water pressures is likely to be so rapid that drainage from the slope surface alone may not be adequate to avoid failure, the use of additional subsurface drainage provisions (e.g. Item 2.3, Table 2) or alternative Type 2 measures (e.g. Items 2.4 and 2.5, Table 2) should be considered.

A.5.3 Raking Drains

Raking drains are effective in lowering the groundwater level and relieving the groundwater pressures at depths. Three types of prescriptive application are proposed, which include:

(a) at the upper part of the slope (Item 2.3(a), Table 2) - this aims to control the development of a perched water table in a permeable stratum of soil at the upper part of the slope,

(b) at the lower part of the slope (Item 2.3(b), Table 2) - this aims to control the rise of the main groundwater level affecting the slope,

(c) at specific seepage or potential seepage areas (Item 2.3(c), Table 2) - this aims to facilitate drainage and relieve water pressures at specific locations where persistent seepage or preferential flow path are present.

Raking drains may also be prescribed as contingency measures to cater for uncertainties in groundwater conditions behind a slope and possible adverse effects of subsurface seepage, e.g. from leaking services, on slope stability.

Further technical guidance on the construction, maintenance and performance of raking drains can be found in GCO (1984), Lam et al (1989) and Martin et al (1995).

A.5.4 Counterfort Drains

For slopes which are liable to a rapid build up of water pressures, such as development of a perched water table in a layer of loose colluvium overlying weathered rock (e.g. Pun & Li (1993); Wong & Ho (1995a)), using raking drains alone may not provide sufficient drainage capacity to quickly relieve the groundwater pressures to avoid slope failure. In such cases, counterfort drains (Item 2.4, Table 2) could be used, either on their own or in combination with raking drains, to tackle the problem.

Counterfort drains should be extended into the underlying less permeable ground to be more effective. If this cannot be achieved, then raking drains should be provided to intercept any groundwater flow underneath the counterfort drain. Particular care should be taken to ensure that the watertightness of the impermeable membrane forming the base of the drain is achieved in construction.

For construction safety reasons, the use of counterfort drains exceeding 2.5 m deep is not recommended. It is advisable that, before commencement of the works, some trial pits be excavated over the crest of the slope to confirm the subsoil conditions and the suitability of using these items of prescriptive measures.

A.5.5 Toe Drains

For slopes affected by high groundwater level, construction of toe drains (Item 2.5, Table 2) provides an effective means of lowering the water level in the ground close to the lower part of the slope face. They may also be used in combination with other measures (e.g. Items 2.1, 2.2(b) & 2.3(b), Table 2) to facilitate subsurface drainage or as contingency provisions.

A.6 TYPE 3 PRESCRIPTIVE MEASURES - STRUCTURAL SUPPORT

Soil nails (Table 1, Item 3.1 of Table 2 and Table A1) provide an effective means of offering substantive support and they has been successfully used in upgrading old soil cut slopes in Hong Kong. A total of about 300 soil nailed cut slopes designed analytically by the GEO and consultants under the LPM Programme and by other consultants for private developments has been reviewed. Based on the findings of the review, eleven standard soil nail layouts (Table A2) are derived to facilitate prescriptive applications.

Prescriptive design of soil nails can be carried out by following the steps below:

(a) Determine the required range of increase in factor of safety (ΔFOS) for the slope, viz:

- Range A for a large ΔFOS ($0.3 < \Delta FOS \leq 0.5$),
- Range B for a medium ΔFOS ($0.1 < \Delta FOS \leq 0.3$), and
- Range C for a small ΔFOS ($0 < \Delta FOS \leq 0.1$).

(b) Determine the standard soil nail layout from Table A2, based on the required range of ΔFOS and the maximum effective height of the slope, H_e.

The required range of ΔFOS should be determined by the designer based on professional judgement. Some guidance on this is given in Table A3.

The maximum effective height H_e is given by the following equation (Wong & Ho, 1995b):

$$H_e = H * (1 + 0.35 \tan \beta) + q / 20 \quad \text{(A1)}$$

where H = maximum height from the toe to the crest of the slope (m)
β = average gradient of the ground above the crest of the slope
q = surcharge loading expressed as equivalent uniform pressure (kPa)

The soil nail layout derived from prescriptive design based on a consideration of the maximum effective slope height may be applied to the whole slope. Alternatively, the slope may be split into different sections, with the soil nail layout for each section designed by the use of the maximum effective slope height for the respective section.

If the required ΔFOS is over 0.5, the slope is outside the bounds of previous experience and is hence beyond the scope of application.

A.7 REFERENCES

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LIST OF TABLES

Table A1 - Grouping of Facilities

Group No.	Facilities
1	(a) Buildings - any residential building, commercial office, store and shop, hotel, factory, school, power station, ambulance depot, market, hospital/polyclinic/clinic, welfare centre
	(b) Others - bus shelter, railway platform and other sheltered public waiting area - cottage, licensed and squatter area - dangerous goods storage site (e.g. petrol station) - road with very heavy vehicular or pedestrian traffic density
2	(a) Buildings - built-up area (e.g. indoor car park, building within barracks, abattoir, incinerator, indoor games' sport hall, sewage treatment plant, refuse transfer station, church, temple, monastery, civic centre, manned substation)
	(b) Others - road with heavy vehicular or pedestrian traffic density - major infrastructure facility (e.g. railway, tramway, flyover, subway, tunnel portal, service reservoir) - construction sites (if future use not certain)(1)
3	- densely-used open space and public waiting area (e.g. densely used playground, open car park, densely-used sitting out area, horticulture garden) - quarry - road with moderate vehicular or pedestrian traffic density
4	- lightly-used open-aired recreation area (e.g. district open space, lightly-used playground, cemetery, columbarium) - non-dangerous goods storage site - road with low vehicular or pedestrian traffic density
5	- remote area (e.g. country park, undeveloped green belt, abandoned quarry) - road with very low vehicular or pedestrian traffic density

Notes:
(1) If the intended future use is known, the Facility Group should be based on the facility which corresponds to the intended future use of the site.
(2) For roads, the Facility Group should be based on Figure A13 taking into account the actual Annual Average Daily Traffic and the number of road lanes. For footpaths alongside roads, it may be assumed that footpaths are within the same group as the adjoining roads, except for Expressway (EX), Urban Trunk Roads (UT) and Rural Trunk Road (RT). Footpaths alongside EX, UT and RT roads may be taken, by default, as a Group 5 facility, unless dictated otherwise by site-specific conditions.

Table A2 - Standard Soil Nail Layout

Standard Soil Nail Layout	H_e (m)	ϕ_r (mm)	ϕ_h (mm)	A			B			C		
				N	L(m)	S_h(m)	N	L(m)	S_h(m)	N	L(m)	S_h(m)
(a)	3.0	25	100	2	3.5	1.5	2	3.5	1.5	2	3.5	1.5
(b)	4.0	25	100	2	4.5	1.5	2	4.5	1.5	2	4.5	1.5
(c)	5.0	25	100	3	6.0	1.5	3	6.0	1.5	3	6.0	2.0
(d)	7.5	25	100	4	9.0	1.5	3	8.5	1.5	3	7.5	1.5
(e)	10.0	25	100	6	10.0	1.5	4	9.5	1.5	4	8.5	1.5
(f)	12.5	32	100	6	11.0	1.5	5	10.0	1.5	5	10.0	2.0
(g)	15.0	32	100	7	12.0	1.5	6	11.0	1.5	6	11.0	2.0
(h)	17.5	32	100	8	13.0	1.5	8	11.5	2.0	7	11.5	2.0
(i)	20.0	32	100	10	13.5	2.0	9	12.0	2.0	8	12.0	2.0
(j)	22.5	32	100	11	14.0	2.0	9	12.0	2.0	8	12.0	2.0
(k)	25.0	32	100	12	14.5	2.0	10	12.0	2.0	8	12.0	2.0

Notes:

(1) H_e is the maximum effective slope height, ϕ_r the nail diameter, ϕ_h the hole diameter S_h the horizontal spacing of nails, and N & L the number of rows and length of the soil nails respectively.

(2) For H_e between any of the two consecutive values, the soil nail layout corresponding to the higher H_e value should be adopted.

(3) Soil nails should be evenly spaced over the slope face.

(4) N is the number of soil nails per vertical column required at the critical section, i.e. the section with the maximum effective height, H_e. At other parts of the slope, soil nails should be provided at vertical and horizontal spacings similar to that at the critical section. Alternatively, different soil nail layouts according to the maximum H_e of that part of the slope may be adopted.

(5) 'A', 'B' and 'C' refer to a large factor of safety increase ($0.3 < \Delta FOS \leq 0.5$), a medium factor of safety increase ($0.1 < \Delta FOS \leq 0.3$) and a small factor of safety increase ($0 < \Delta FOS \leq 0.1$) respectively.

(6) If in the process of drilling rock is encountered such that part of the soil nails will be installed in rock (e.g. installation through a PW50/90 zone or better, see Geoguide 3), the designer may exercise professional judgement to reduce the nail length L. In the absence of site-specific ground investigation, sound engineering judgement is required to ensure that the nails are not prematurely terminated in corestone boulders.

(7) The designer should check the land status to see whether the nails encroach into adjoining land and if so whether this is acceptable to the land owner.

Table A3 - Guidance on Ranges of Factor of Safety Increase for Prescriptive Application of Soil Nails to Soil Cut Slopes

Consequence-to-life Category[1]	1						2						3					
Is it an 'existing slope'[2]?	No			Yes			No			Yes			No			Yes		
Observed or Recorded Past Instability[3]	Ma	Mi	No	Ma	Mi	No	Ma	Mi	No	Ma	Mi	No	Ma	Mi	No	Ma	Mi	No
Range of FOS Increase for Prescriptive Application of Soil Nailing	A^+	A	A	A	B	B	A	B	B	B	B	C	B	B	C	B	C	C

Notes:

(1) 1 = high risk-to-life, 2 = low risk-to-life and 3 = negligible risk-to-life as defined in GCO (1984). In determining the consequence-to-life category of a slope, reference should be made to GCO (1984), Appendix A of WBTC No. 13/99 and Table A1.

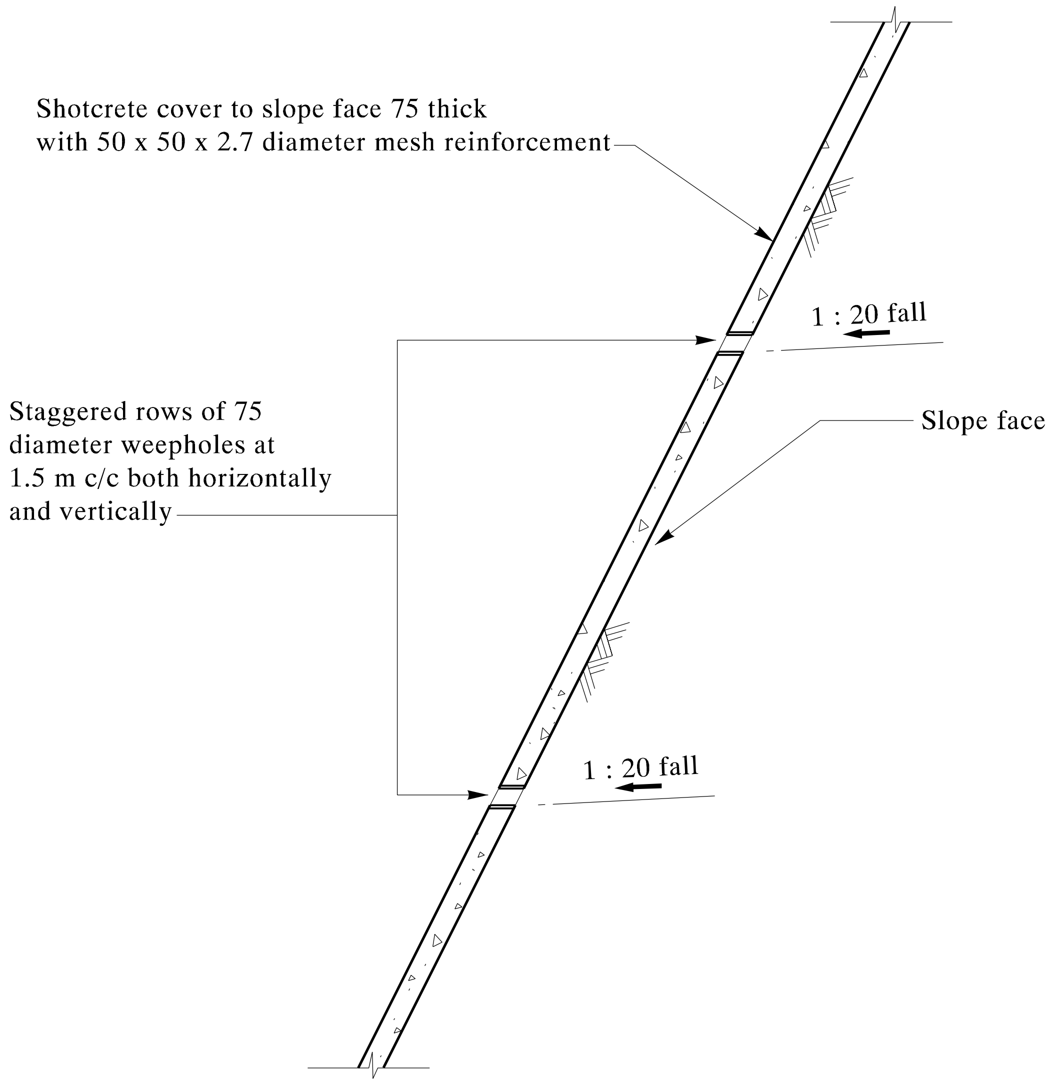
(2) 'Existing slope' refers to one which satisfies the conditions stipulated in Section 7.3.3 of the Geotechnical Manual for Slopes (GCO, 1984).

(3) Past instability includes both recorded and observed failures. 'Ma', 'Mi' and 'No' refer to slopes with major (i.e. failure volume ≥ 50 m^3), minor and no past instability respectively.

(4) 'A', 'B', and 'C' refer to factor of safety increase in the ranges 0.3 to 0.5, 0.1 to less than 0.3, and less than 0.1 respectively. 'A^+' is similar to 'A' except that Type 2 prescriptive measures (e.g. raking drains) must be adopted as contingency provisions.

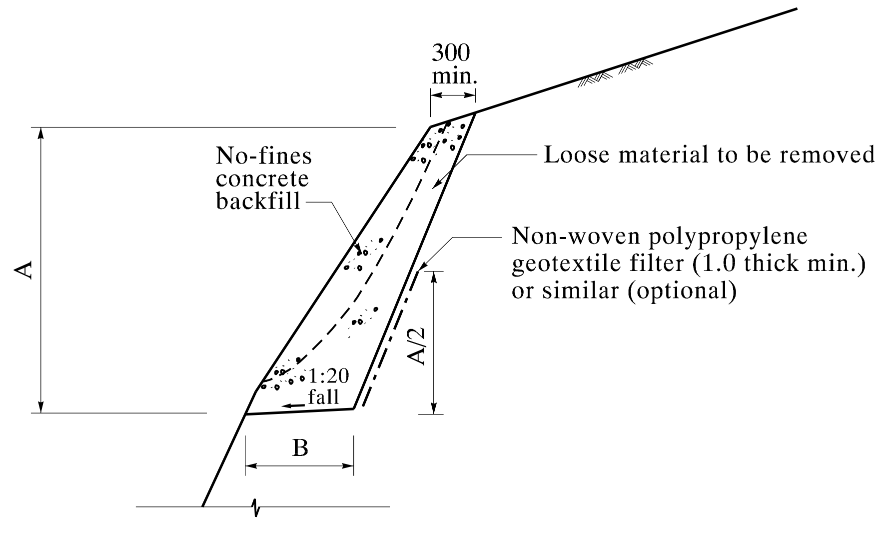
(5) Slopes that require a factor of safety increase of over 0.5 are beyond the scope of application.

LIST OF FIGURES

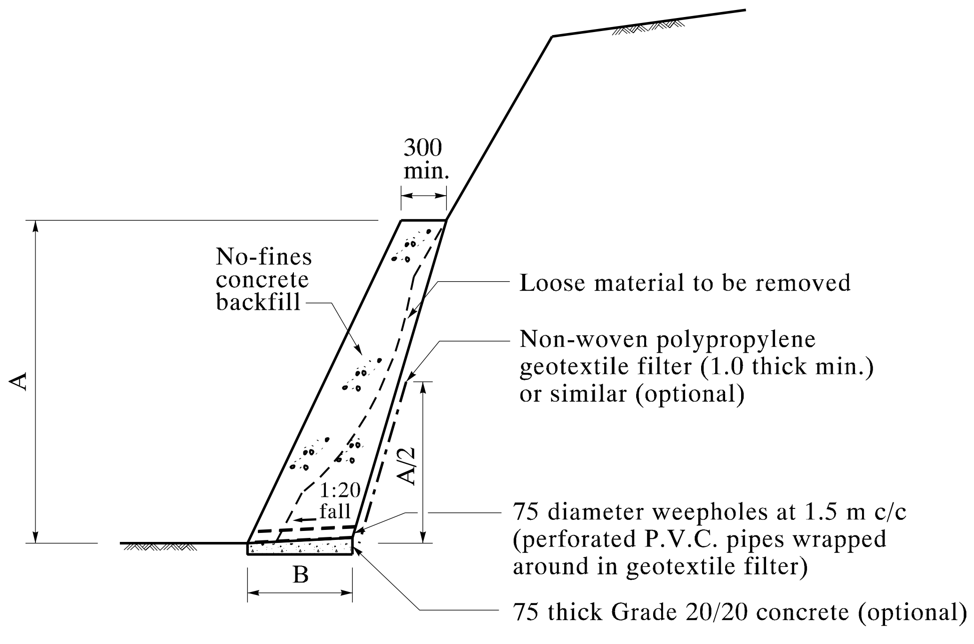


Note: Dimensions in mm unless stated otherwise.

Figure A1 - Shotcrete Cover to Slope Face



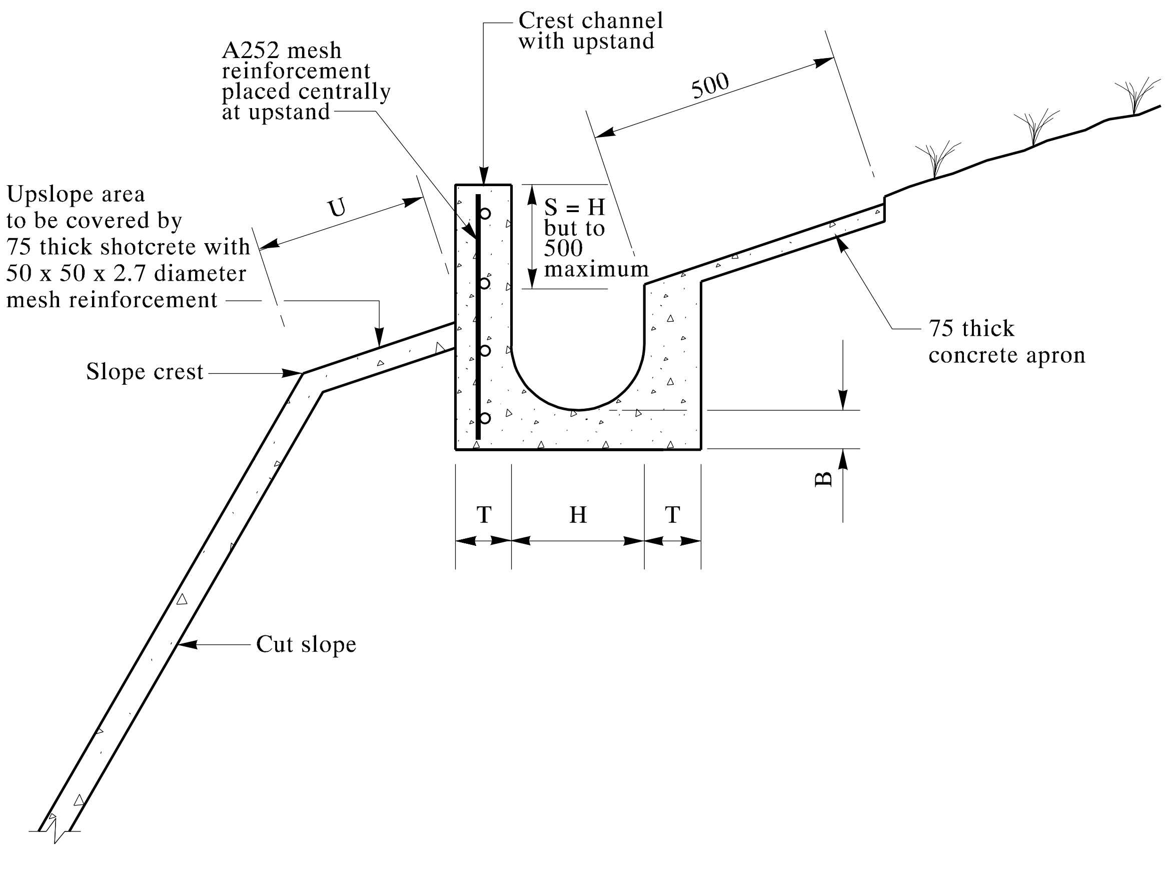
(a) At Upper Part of Slope



(b) At Lower Part of Slope or on Berm

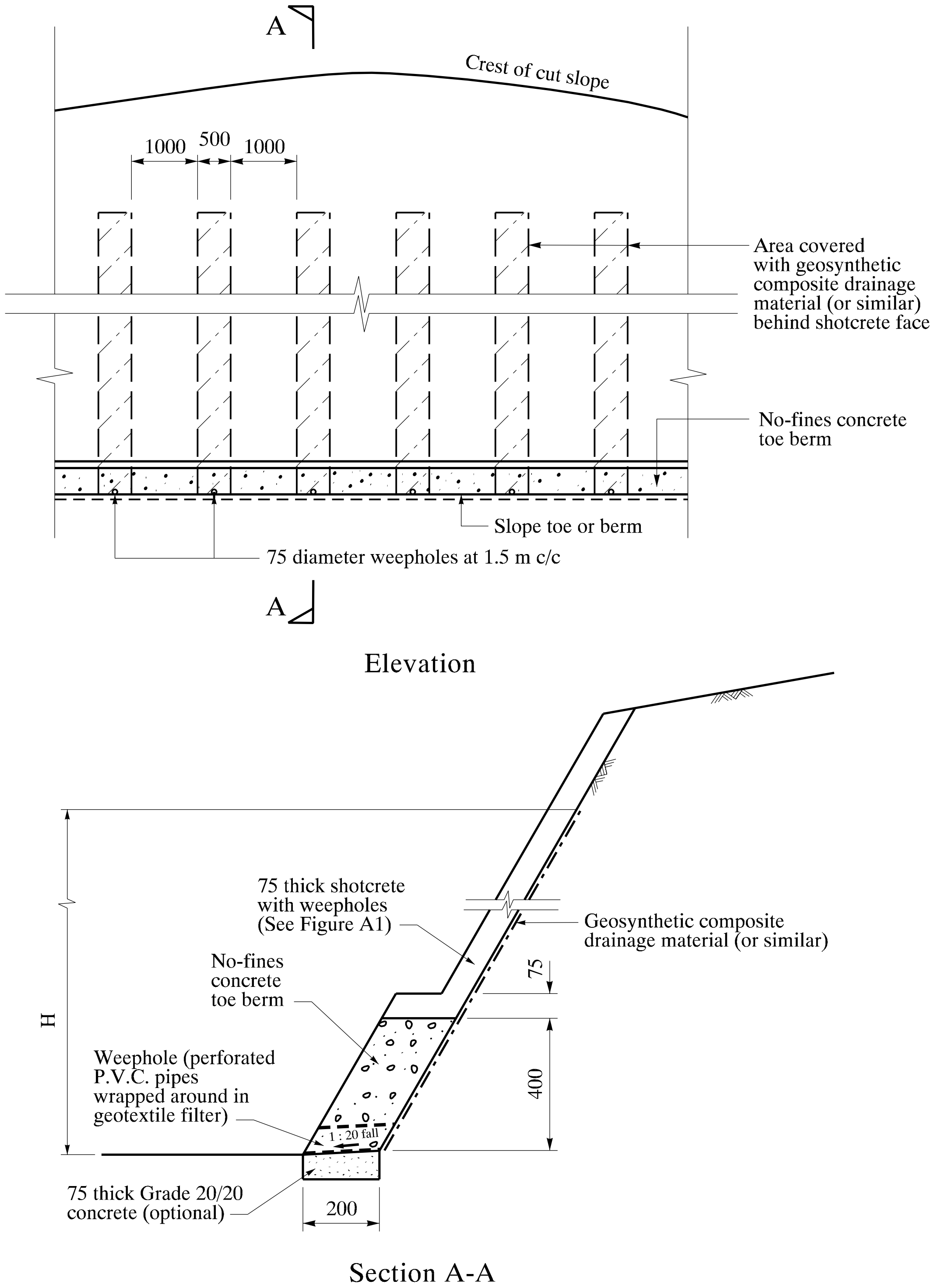
Notes:
(1) Dimensions in mm unless stated otherwise.
(2) For A<1.5 m , B=0.3 m minimum. For A⩾1.5 m, B=0.5 m minimum.
(3) The geotextile filter behind the no-fines concrete block may be extended further upslope to cover seepage/potential seepage areas as specified by the designer.
(4) Where necessary to improve the stability of the no-fines concrete block, hot dip galvanised high yield deformed bars, typically 2 m long, 25 mm in diameter grouted in 50 mm diameter holes at spacings not exceeding 2 m in both the vertical and horizontal directions, may be provided to tie the no-fines concrete block to the slope.

Figure A2 - No-fines Concrete Backfill to Local Areas



Notes:
(1) Dimensions in mm unless stated otherwise.
(2) For dimensions of channels (i.e. H, T & B), see CED Drawing No. C2409 B.
(3) Dimension U to be determined by the designer to suit site conditions, typically about one-fourth of the height of the soil cut slope or 3 m, whichever is greater.
(4) Tree rings should be provided where required within the upslope area U. For details of tree rings, refer to CED Drawing No. C2104A.
(5) The slope crest channel with upstand should have a minimum gradient of 1 : 10.
(6) Concrete channel should be cast against insitu ground to avoid the use of external formwork.

Figure A3 - Shotcrete to Upslope Area and Crest Channel with Upstand



Notes:

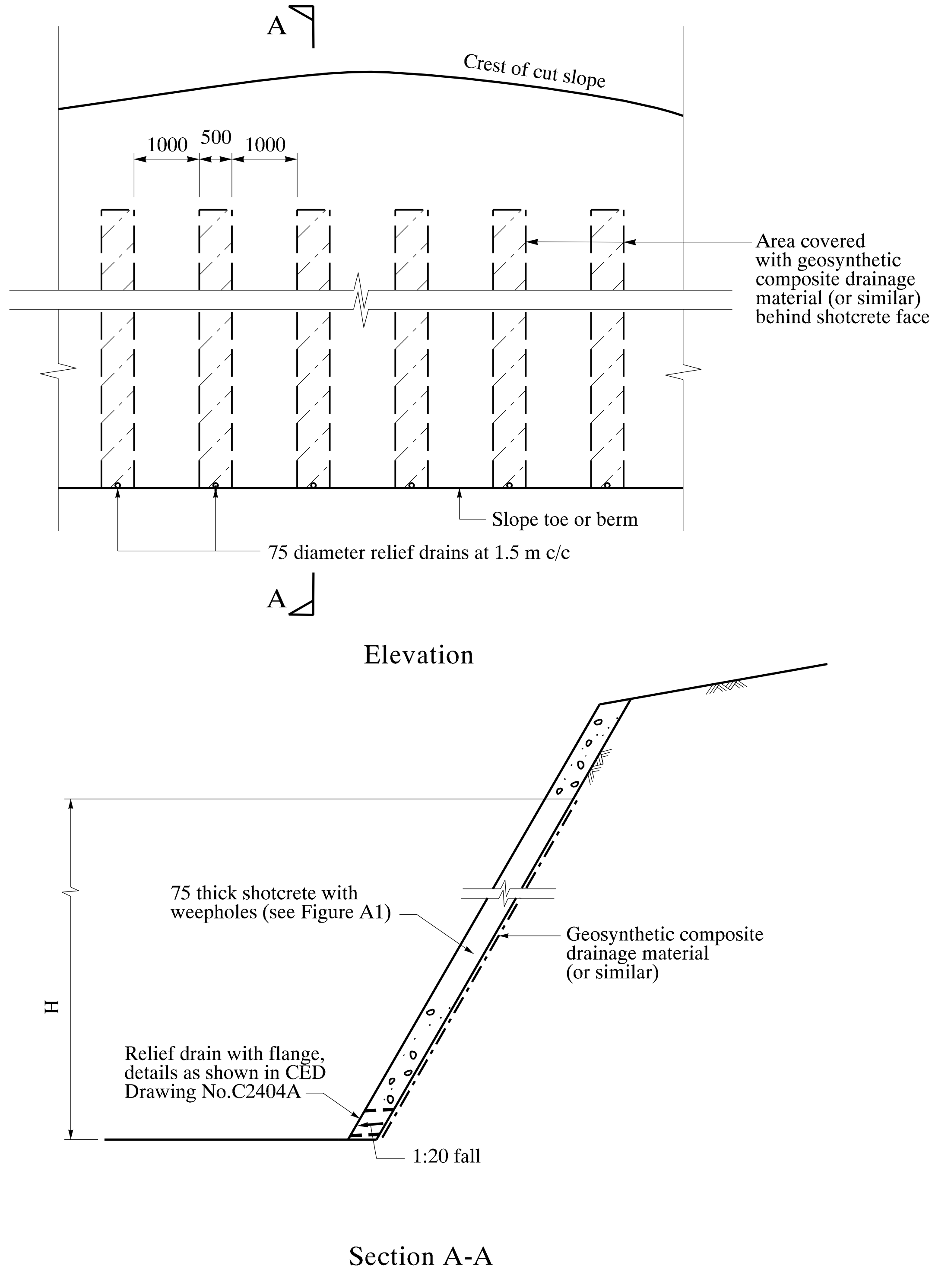
(1) Dimensions in mm unless stated otherwise.

(2) Width and spacings of the geosynthetic composite drainage material (or similar) may be varied to suit site conditions, e.g. closer spacings in areas of observed seepage.

(3) The height of the geosynthetic composite drainage material (or similar), H , to be specified by the designer.

(4) Non-woven polypropylene geotextile filter (1.0 mm thick min.) should be provided between the no-fines concrete toe berm and the soil at seepage/potential seepage areas.

Figure A4 - Drainage behind Impermeable Slope Surface Cover (with No-fines Concrete Toe)



Notes:

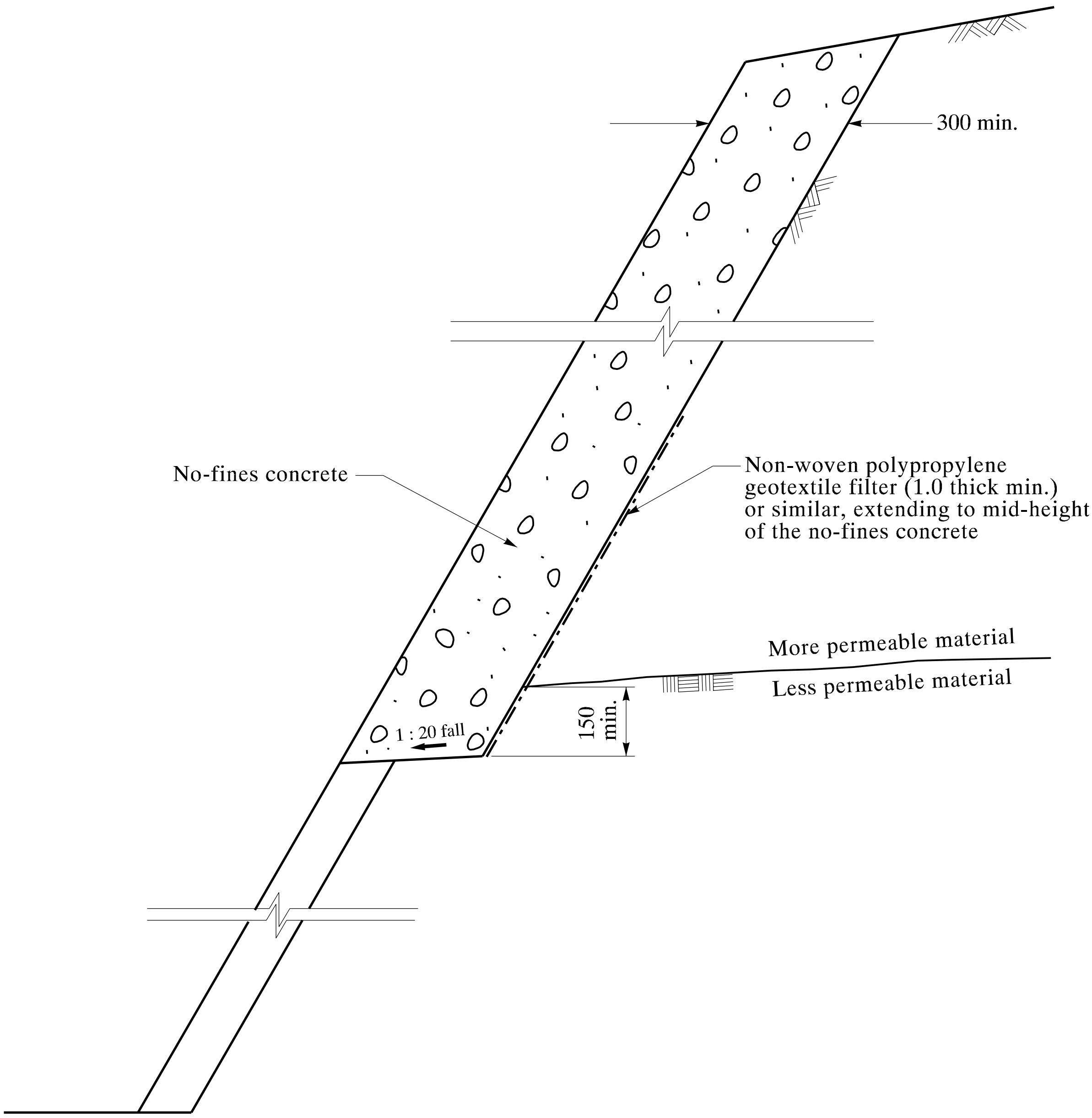
(1) Dimensions in mm unless stated otherwise.

(2) Width and spacings of the geosynthetic composite drainage material (or similar) may be varied to suit site conditions, e.g. closer spacings in areas of observed or potential seepage.

(3) The height of the geosynthetic composite drainage material (or similar), H , to be specified by the designer.

(4) If H > 5 m, relief drains should also be provided at mid-height of the geosynthetic composite drainage material (or similar).

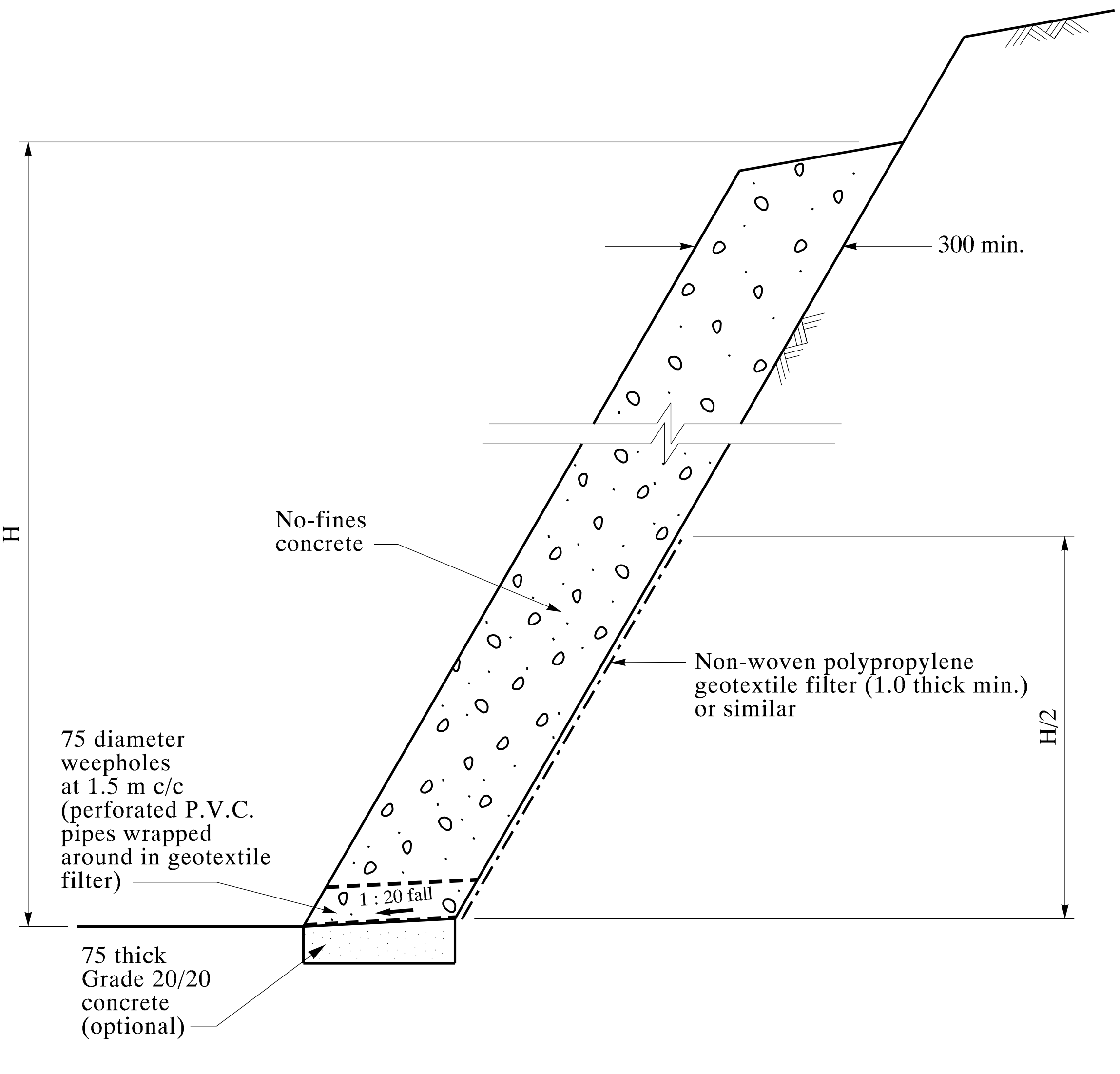
Figure A5 - Drainage behind Impermeable Slope Surface Cover (with Relief Drains)



Notes: (1) Dimensions in mm unless stated otherwise.

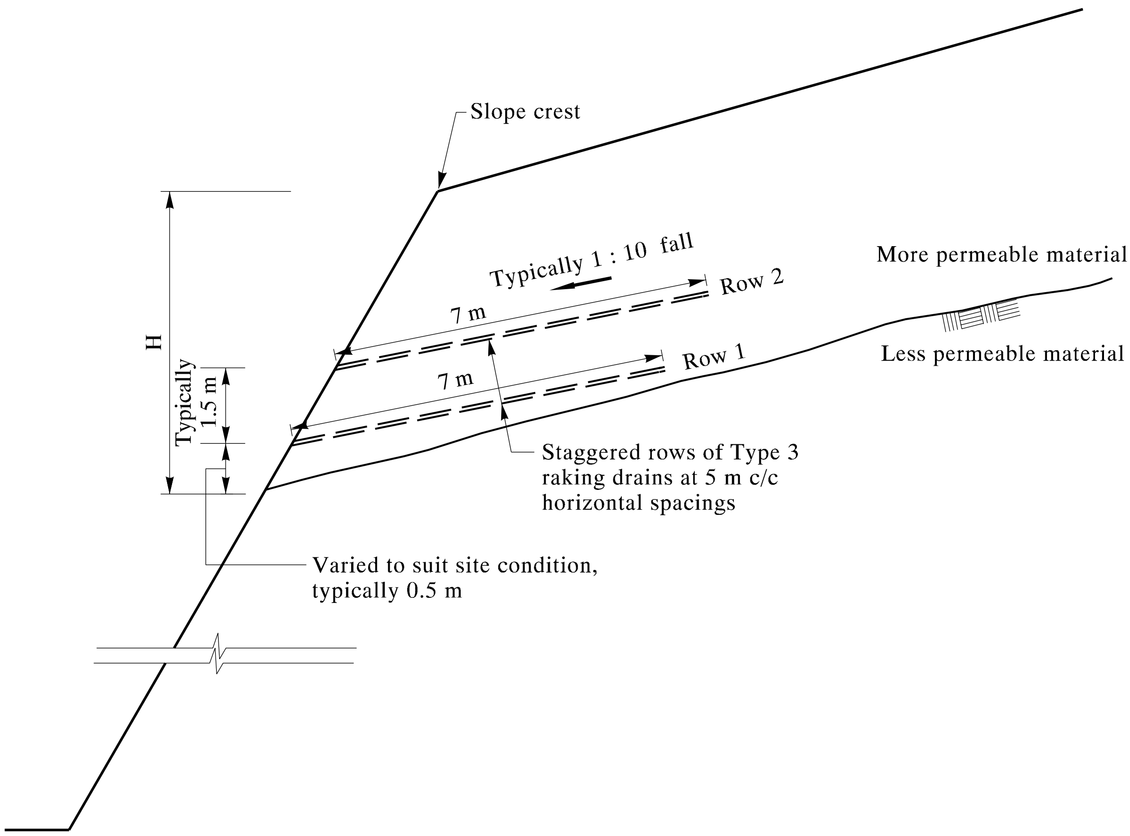
(2) Where necessary to improve the stability of the no-fines concrete block, hot dip galvanised high yield deformed bars, typically 2 m long, 25 mm in diameter grouted in 50 mm diameter holes at spacings not exceeding 2 m in both the vertical and horizontal directions, may be provided to tie the no-fines concrete cover to the slope.

Figure A6 - No-fines Concrete Cover at Upper Part of Slope



Notes:
(1) Dimensions in mm unless stated otherwise.
(2) Where necessary to improve the stability of the no-fines concrete block, hot dip galvanised high yield deformed bars, typically 2 m long, 25 mm in diameter grouted in 50 mm diameter holes at spacings not exceeding 2 m in both the vertical and horizontal directions, may be provided to tie the no-fines concrete cover to the slope.

Figure A7 - No-fines Concrete Cover at Lower Part of Slope or on Berm

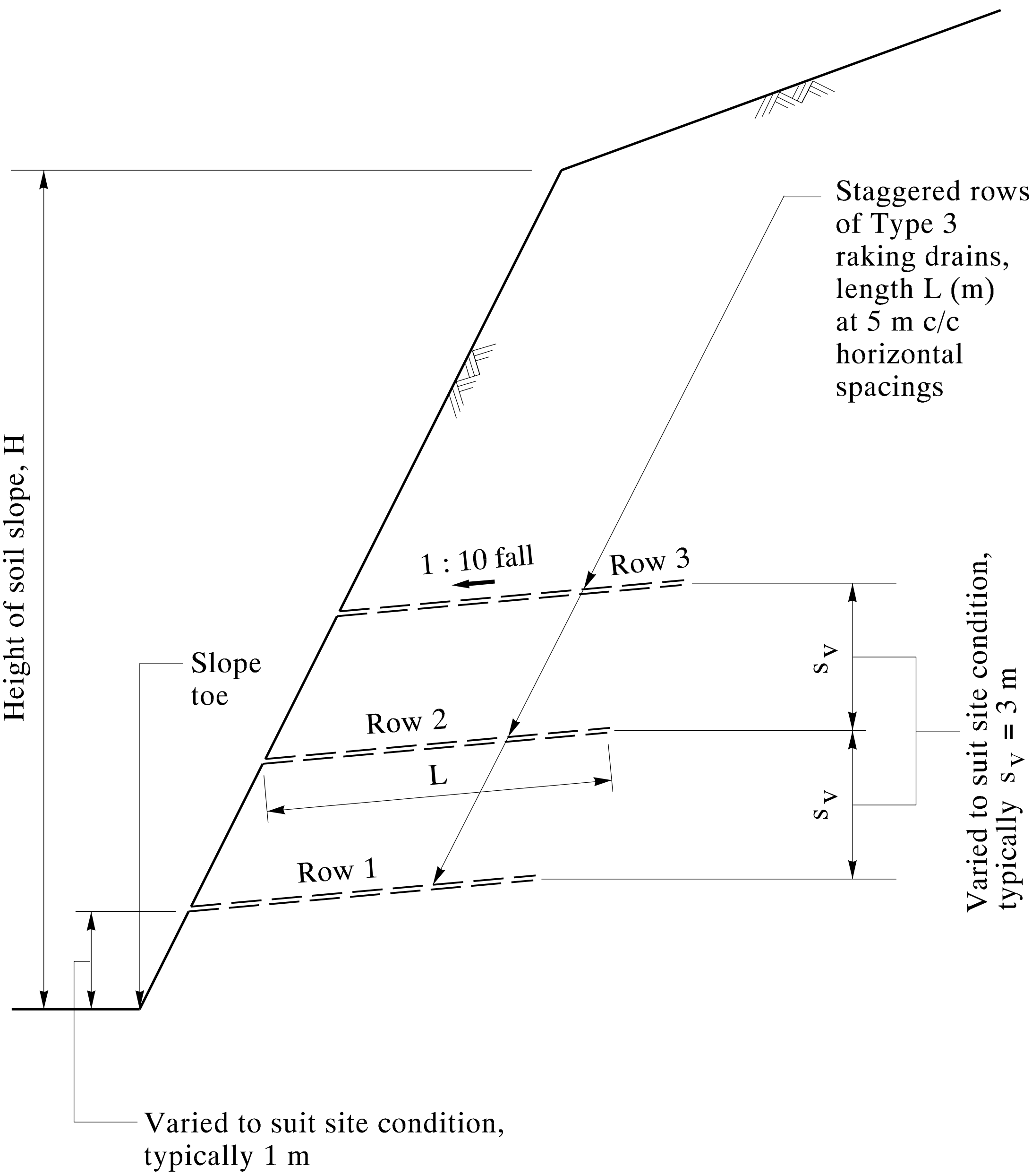


H (m)	≲ 3	> 3
No. of Rows Required	Row 1	Rows 1 & 2

Notes: (1) For details of raking drains, see CED Drawing No. C2403.

(2) The spacings of the raking drains are nominal and may be varied to suit the site condition as determined by the designer.

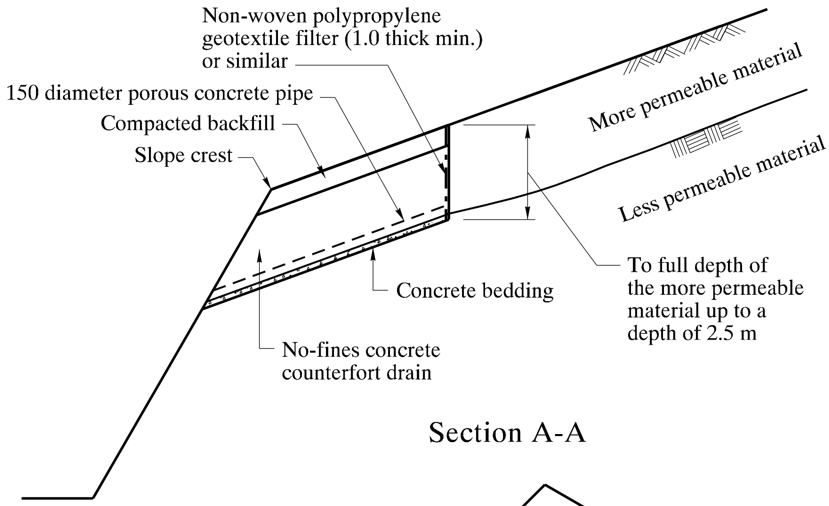
Figure A8 - Raking Drains at Upper Part of Slope



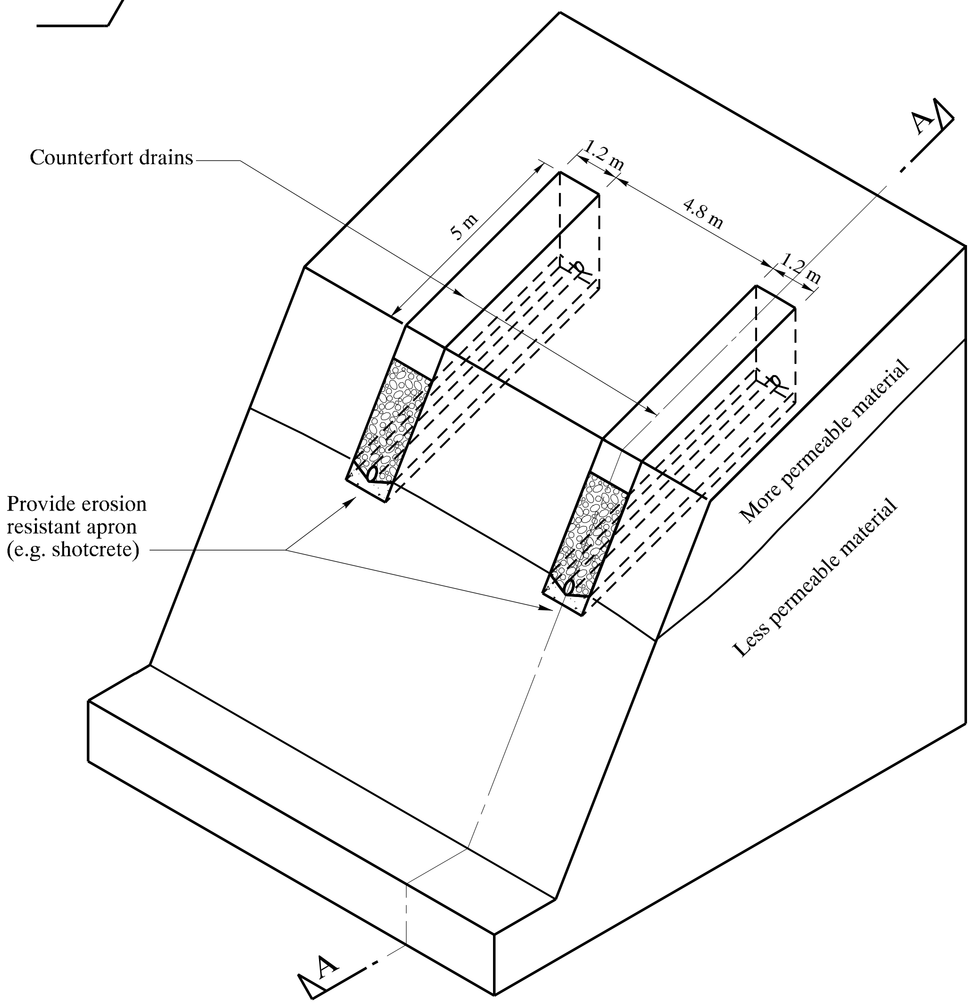
H (m)	≤ 7	7 - 15	> 15
No. of Rows Required	Row 1	Rows 1 & 2	Rows 1, 2 & 3
L (m)	5	7	10

Notes:
(1) For details of raking drains, see CED Drawing No. C2403.
(2) The spacings of the raking drains are nominal and may be varied to suit the site condition as determined by the designer.

Figure A9 - Raking Drains at Lower Part of Slope



Section A-A



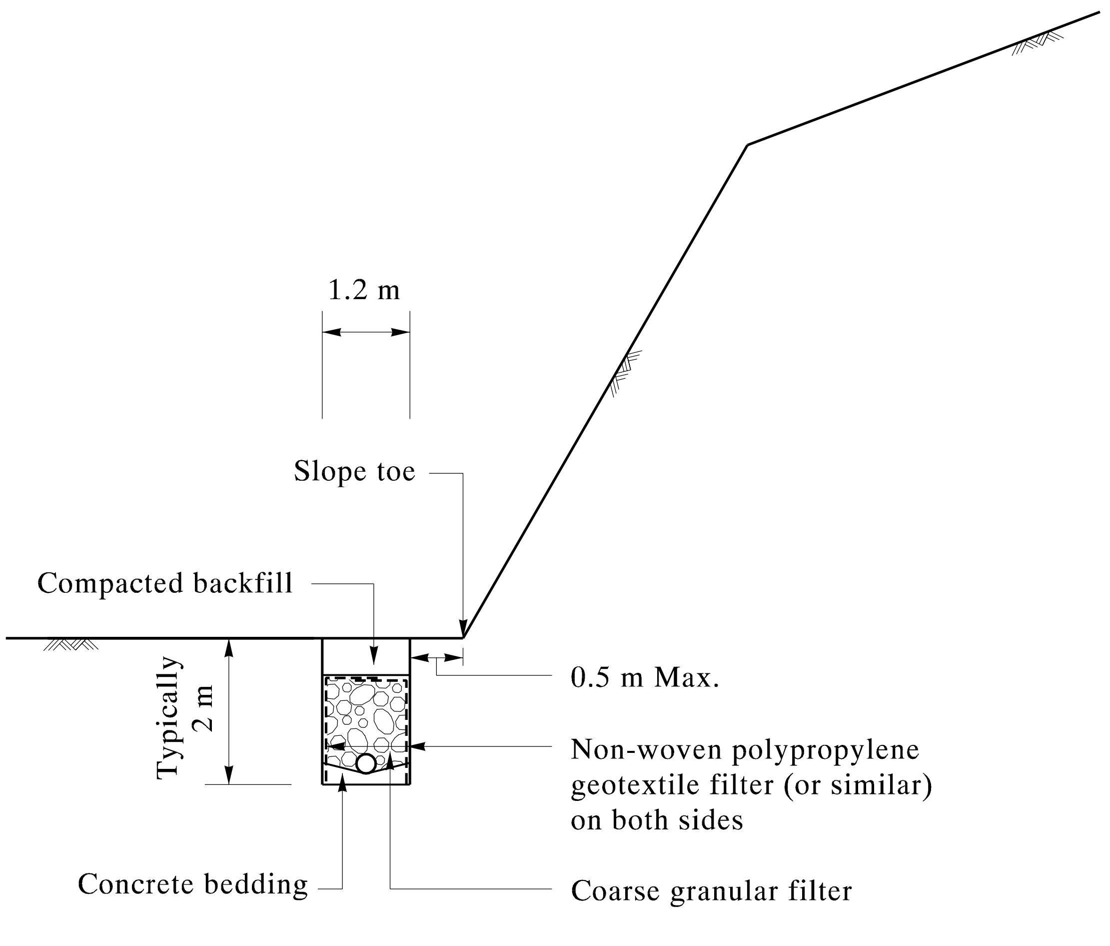
Isometric View

Notes:

(1) Details of counterfort drain should be similar to cut-off drain shown in CED Drawing No. C2401A except that the coarse granular filter material is replaced by no-fines concrete, and the non-woven polypropylene geotextile filter should be placed against both side walls of the trench.

(2) If required the compacted backfill to the drains may be replaced by concrete or shotcrete to blend in with the surrounding hard surfaces.

Figure A10 - Counterfort Drains at Upper Part of Slope

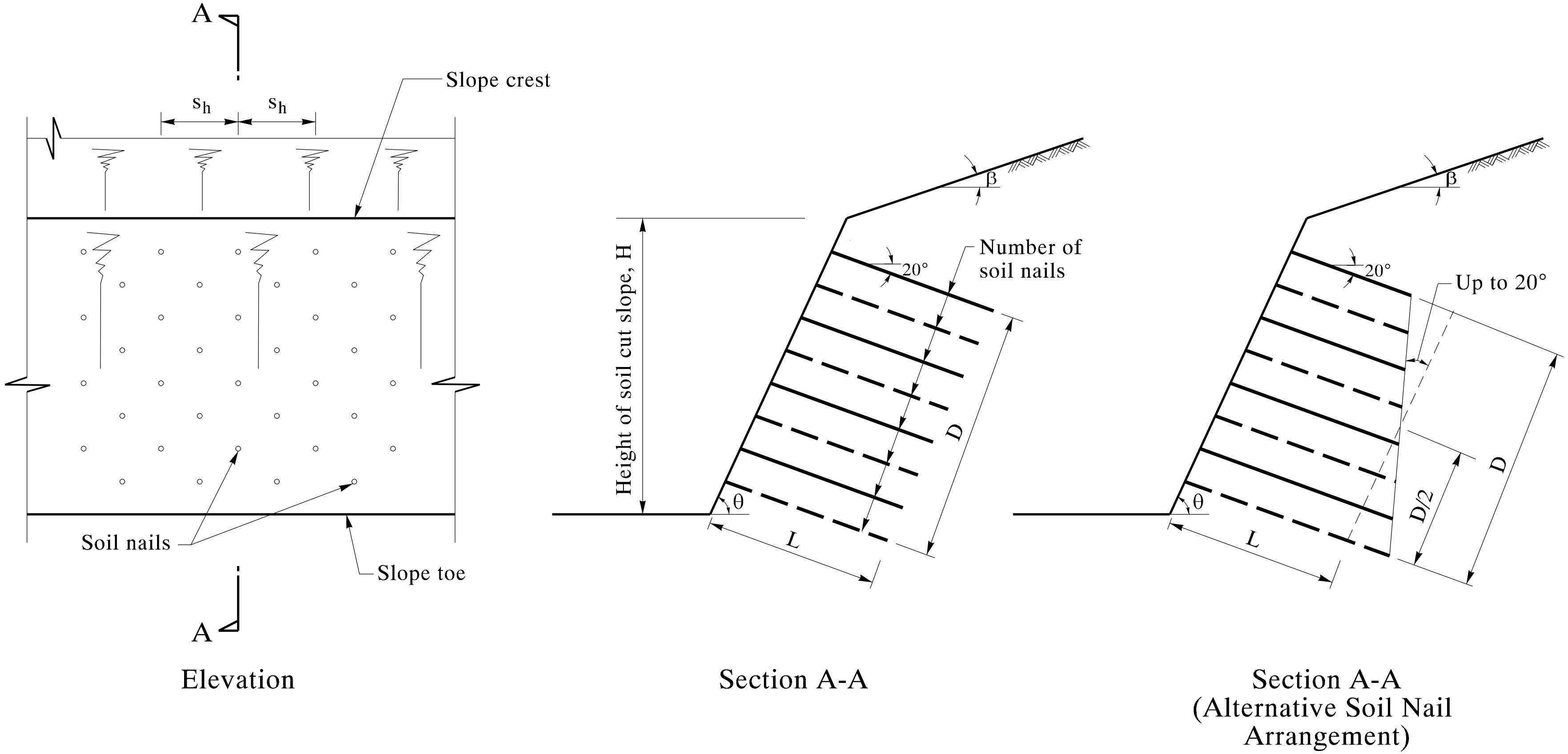


Notes:

(1) Toe drain details should be similar to those of cut-off drain given in CED Drawing No. C2401A except that non-woven polypropylene geotextile filter should be placed against both side walls of the trench.

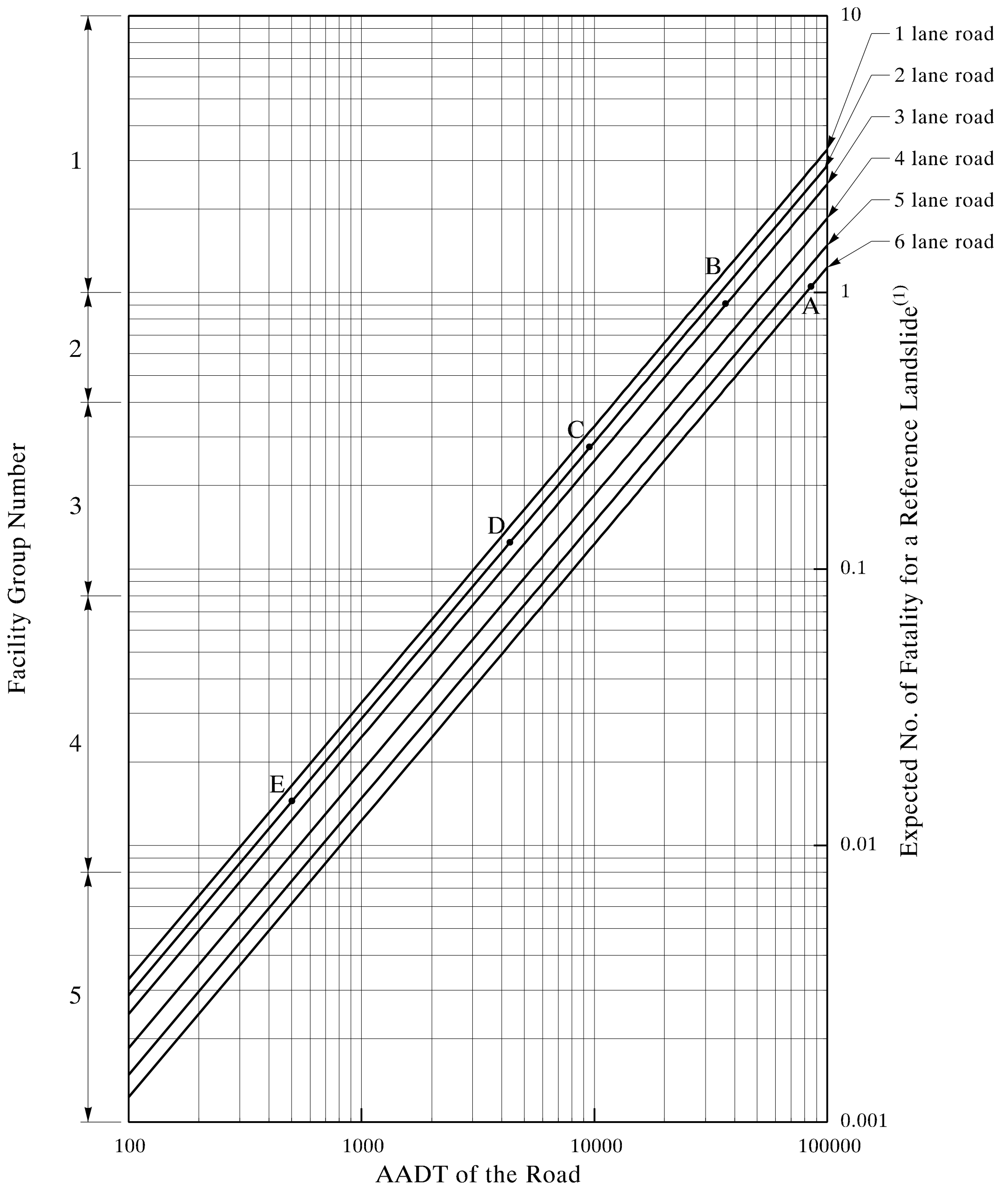
(2) If required the compacted backfill to the drains may be replaced by concrete or shotcrete to blend in with the surrounding hard surfaces.

Figure A11 - Toe Drain



Notes:
(1) N, L, s_h and other dimensions for the soil nails are given in Table A2 based on the type of soil nail layout specified by the designer.
(2) See CED Drawing Nos. C2106/1D, 2B & 3C for details of soil nails.
(3) The alternative soil nail arrangement may be adopted as appropriate to suit site conditions.
(4) This Figure shows the arrangement of soil nails staggered at alternative rows. Alternatively, soil nails staggered at alternative columns may be adopted by the designer as appropriate to suit site conditions.

Figure A12 - Soil Nailing to Cut Slope



Legend:

AADT	Annual Average Daily Traffic
A	Princess Margaret Road (from Wylie Road to Pui Ching Road)
B	Pokfulam Road (from Pokfield Road to Mount Davies Road)
C	Castle Peak Road (from Sham Tseng to Siu Lam)
D	Borrett Road
E	Shouson Hill Road West

Notes:

(1) Reference landslide is defined as a 10-m wide failure of 50 m^3 in volume (Wong et al, 1997).
(2) Information on actual AADT is given in the Annual Traffic Census and Statistics published by the Transport Department. Design AADT values are given in the Transport Planning and Design Manual (Transport Department, 1984).
(3) The design AADT, the expected AADT or the actual AADT whichever is the highest, should be considered. The AADT used should be documented in Maintenance Manuals to facilitate review in future Engineer Inspections for Maintenance.

Figure A13 - Relationship between Facility Group Number, Actual AADT and Number of Lanes

APPENDIX B

GUIDELINES ON PRESCRIPTIVE DESIGN OF SKIN WALLS FOR UPGRADING MASONRY RETAINING WALLS

CONTENTS

B.1 PRESCRIPTIVE DESIGN OF SKIN WALLS

Construction of concrete skin walls with or without soil nails is the most common method of upgrading masonry retaining walls. The design of thirty-two reinforced concrete skin walls used for upgrading masonry retaining walls under the LPM Programme has been reviewed. Based on the findings of the review, prescriptive design line was derived (Figure B1). Theoretical analyses using a range of design parameters have been carried out to provide supportive indications that the prescriptive design line is adequately safe.

Prescriptive design can be carried out by following the steps below:

(a) Compare the measured retaining wall thickness with the minimum masonry retaining wall thickness for no works determined using Figure B1(b). If the measured retaining wall thickness is equal to or greater than the minimum thickness required, the wall can be considered as up to the geotechnical standards for 'existing walls' recommended in the Geotechnical Manual for Slopes (GCO, 1984) provided that the conditions for ‘existing walls’ are satisfied, and no upgrading works will be required.

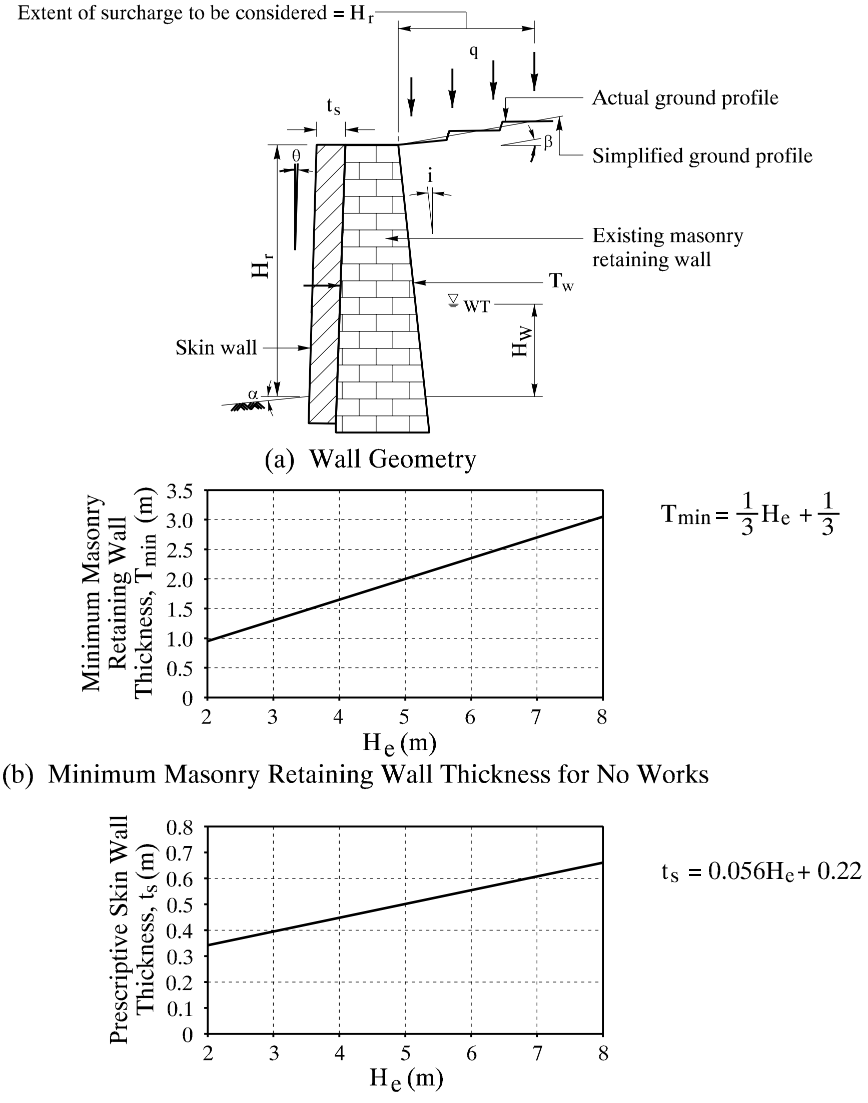
(b) Otherwise, determine the prescriptive skin wall thickness using the design chart given in Figure B1(c).

Typical skin wall details are given in Figure B2.

B.2 REFERENCES

GCO (1984). Geotechnical Manual for Slopes. (Second edition). Geotechnical Control Office, Hong Kong, 301 p.

LIST OF FIGURES



(a) Wall Geometry

(b) Minimum Masonry Retaining Wall Thickness for No Works

(c) Prescriptive Skin Wall Thickness

Legend :

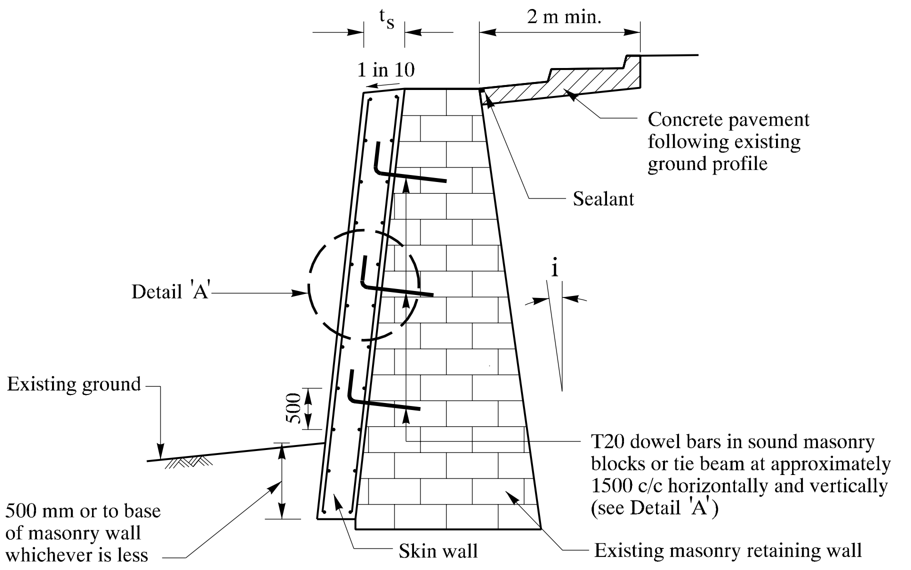
α	Gradient of ground in front of wall (over a horizontal distance of four times the masonry wall thickness)
q	Design surcharge
H_r	Height of retained ground
H_W	Height of design groundwater level behind the wall
T_W	Average thickness of masonry retaining wall
β	Gradient of retained ground
θ	Wall face angle
i	Wall back angle
∇ WT	Design water table
t_s	Prescriptive skin wall thickness
H_e	Effective height of masonry retaining wall $= H_r (1 + 0.35 \tan \beta) + q/\gamma$ (m)
γ	Unit weight of soil

Notes:

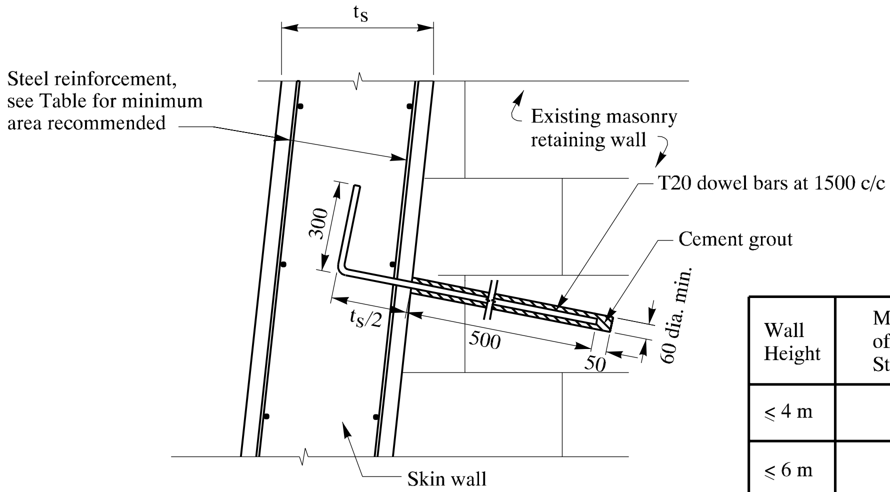
(1) This design chart is only applicable where 2 m $\leqslant H_e \leqslant$ 8 m, $0° \leqslant \theta \leqslant 10°$, $\alpha \leqslant 10°$, $\beta \leqslant 10°$, q $\leqslant$10 kPa, the wall is not subject to a total horizontal surcharge load (P) exceeding $0.2\ H_r^2$ (where P is in kN/m and H_r is in metres), the wall satisfies the conditions for 'existing walls' stipulated in Section 7.3.3 of the Geotechnical Manual for Slopes, its conditions are no worse than wall condition Class B in Tables 6 and 7, and there is no observable or recorded presence of weak materials or signs of water indicating a groundwater level higher than $\frac{1}{3}H_r$.

(2) Figure B1(b) is solely to be used for checking whether upgrading works are required for the existing masonry retaining wall. If upgrading works are required, then the prescriptive skin wall thickness should be determined from Figure B1(c).

Figure B1 - Design Charts for Prescriptive Design of Skin Walls



(a) Typical Layout of Skin Wall



(b) Detail 'A'

Wall Height	Minimum Area of High Yield Steel Bar (mm^2/m)
≤ 4 m	1000
≤ 6 m	1800
≤ 8 m	4000

Legend :

t_s Skin wall thickness to be provided (see Figure B1)

i Wall back angle

Notes:

(1) All dimensions are in mm.
(2) All concrete should be grade 30/20 D.
(3) Minimum concrete cover should be 50 mm.
(4) Horizontal weepholes of size 50 mm dia. minimum (normally 50 PVC pipe) at approximately 1.5 m horizontal x 1.5 m vertical spacing should be provided through the skin wall and masonry retaining wall. If there are existing weepholes at the masonry wall, it is important to ensure that the existing weepholes are extended through the skin wall. If not, new weepholes should be constructed to beyond the back of masonry wall. Drainage channels should be provided along the crest of the masonry wall. Prescriptive raking drains should also be provided where necessary to control transient rises in groundwater pressure.
(5) At any time, the maximum allowable length of excavation in front of the wall is 10 m or one third the wall length whichever is smaller.
(6) The trench excavated for the construction of the skin wall should be properly backfilled with concrete.

Figure B2 - Typical Details of Skin Wall

APPENDIX C

GUIDELINES ON PRESCRIPTIVE USE OF VEGETATION COVER FOR SOIL CUT SLOPES

CONTENTS

C.1 GENERAL

For the control of visual impact of new slopes, Works Branch Technical Circular No. 25/93 (Hong Kong Government, 1993) stipulates that the use of chunam or shotcrete on slopes should only be considered as a last resort and only after other techniques have been explored and found not practical. This policy should also be adopted for preventive maintenance and upgrading works to existing slopes.

C.2 RECOMMENDED MEASURES

Recommended measures for the prescriptive use of vegetation cover for existing soil cut slopes of different gradients are given in Table C1. Such measures are appropriate for existing soil cut slopes which have an inadequately developed vegetation cover or a defective chunam cover which no longer serves as an impermeable cover effectively. They should be used in conjunction with suitable items of prescriptive measures recommended in this Report (see Appendix A). Figure C1 shows the typical details of the prescriptive vegetation cover with other appropriate erosion protection works.

The recommended measures may also be prescribed to replace a relatively impermeable cover (e.g. a shotcrete cover) on an existing soil cut slope, but this should be done only when soil nailing works are to be carried out to upgrade the slope at the same time in accordance with the recommendations of this Report. For such cases, the upgrading works should be designed to give an increase in factor of safety for the slope to meet the standards for a new slope (Table A3). Also, a wire mesh structurally connected to the soil nail heads should be provided to the slope.

The above recommendation may not be applicable to the maintenance of soil cut slopes of consequence-to-life Category 3 (as defined in WBTC No. 13/99). In carrying out the assessment to decide on whether an impermeable slope cover can be replaced by a vegetation cover in slope maintenance, account should be taken of the average and local slope angles, the size of the upslope catchment and whether there is likely to be concentrated surface water flow onto the slope, signs of seepage from the slope surface, records of past failure of slopes of similar nature, the likelihood of casualty should a failure occur, etc. Consideration should also be made of the potential socio-economic impact should failure occur, in consultation with the owner.

It is essential to provide a bio-degradable protective fabric to a slope face after hydroseeding is completed, irrespective of slope gradient. The temporary fabric serves to reduce raindrop impact and erosion while the grass is establishing.

C.3 VEGETATION SPECIES AND PLANTING TECHNIQUE

General guidance on vegetation types (grass, shrubs and/or trees), species and planting techniques (e.g. hydroseeding mix) can be found in Sections 8.4.4, 8.4.5, 9.6.1 and 9.6.2 of the Geotechnical Manual for Slopes (GCO, 1984). Selection of vegetation type and species for area- or site-specific applications should be made in consultation with a landscape architect, the advice of whom could also be sought on visual and ecological aspects. The party responsible for maintenance of the slope and the horticulture should also be consulted, as appropriate.

Sufficient establishment period should be allowed to ensure that planting introduced is well established on a slope. Usually a 2-year establishment period is recommended for tree planting.

C.4 SPECIFICATIONS

Section 3 of the General Specification for Civil Engineering Works (Hong Kong Government, 1992) and the associated Guidance Notes, which have been used successfully in the past, provide specification clauses and guidance on landscape softworks and establishment works.

Suggested additional specification clauses for the recommended measures are given below:

(a) In general, the order for application of the various elements of works shall be geosynthetic erosion protection mat, wire mesh (where applicable), hydroseeding and bio-degradable protective fabric. Subject to the approval of the Engineer, the recommendations of the geosynthetic erosion protection mat manufacturers/specialist contractors shall be followed.

(b) The geosynthetic erosion protection mat shall be a proprietary product with proven application in Hong Kong. It shall be installed to follow the profile of the slope face. The profile of the slope shall be well trimmed to avoid large local protrusions due to the presence of boulders/corestones or local depressions due to erosion.

(c) Wire mesh shall comprise 2.2 mm mild steel wires, galvanised and PVC coated for corrosion protection and the mesh openings shall be 50-75 mm in size. It shall be stretched on site to give a slight tension when being fixed onto the slope. The PVC coating shall be dark green, dark brown, grey or black in colour.

(d) Openings of appropriate size shall be cut in the geosynthetic erosion protection mat and wire mesh for slopes with shrub or tree planting to allow for growth of the shrubs or trees. The wire shall be properly treated at the cut locations to prevent deterioration and harming maintenance staff due to sharp edges.

(e) Fixing pins shall be provided separately for the geosynthetic erosion protection mat and the wire mesh when both are used. The pins for the geosynthetic erosion protection mat shall be hot dip galvanised U-shaped steel bars of 4 mm minimum diameter, placed at not more than 1 m c/c on the slope face with a minimum penetration depth of 300 mm into the slope.

(f) Overlaps of the geosynthetic erosion protection mat shall be 500 mm minimum and the upslope mat shall cover the downslope mat. Fixing pins shall be provided at the overlaps to secure the mats onto the slope.

(g) For the wire mesh, fixing details onto the slope shall comply with the manufacturers' instructions where available. If no specific instructions are available, similar fixing details as for the geosynthetic erosion protection mat may be adopted but the depth of penetration of the fixing pins shall be longer, viz. 500 mm minimum. The wire mesh shall be a continuous one spanning across soil nail heads and shall be fixed to the soil nail heads structurally. It shall be sufficiently strong to retain the slope-forming materials should such materials between soil nail heads become detached from the slope.

C.5 OTHER CONSIDERATIONS

Designers should incorporate advice in the Slope Maintenance Manual on the maintenance of vegetation cover on the slope, as part of slope maintenance. Regular maintenance, including re-planting in bare areas, is essential to maintain the erosion protection functions of the vegetation cover. Trimming of overcrowded trees may be necessary to facilitate establishment of grass in bare areas.

Potential convergent surface water flow, if identified at the site during slope design, should be diverted away from the slope where possible, or it should be directed downslope, preferably with no change in the direction of flow, by means of drains of adequate capacity. In areas adjacent to the downslope drains for convergent surface water flow, consideration should be given to providing an impermeable, erosion-resistant surface protective cover, e.g. apron slabs.

Where berms are present on the slope, they should be hard paved, e.g. with a concrete slab or stone pitching. It is desirable to plant trees or shrubs within a short distance down the slope of the berms to act as screens. Where space is available on the berms, creepers may also be planted along the outer edge of the berms in planting beds.

Drainage channels with an upstand should be provided along the crest and along berms of the slope. Similar details may be adopted for the berm channels except that the height of the upstand may be reduced to 200 mm. Figure C1 shows the suggested details of crest and berm channels with upstands.

Unless herringbone drains are provided, downslope drains should preferably be spaced at horizontal distances not exceeding 15 m. Even with the provision of herringbone drains, an upper limit of about 30 m should be adopted where practicable, integrating with the locations of existing manholes, catchpits, etc.

C.6 REFERENCES

GCO (1984). Geotechnical Manual for Slopes. (Second edition). Geotechnical Control Office, Hong Kong, 306 p.

Hong Kong Government (1992). General Specification for Civil Engineering Works. Hong Kong Government, 3 volumes plus 1 volume of Guidance Notes.

Hong Kong Government (1993). Work Branch Technical Circular No. 25/93: Control of Visual Impact of Slopes. Works Branch, Hong Kong Government, 1 p. plus an appendix.

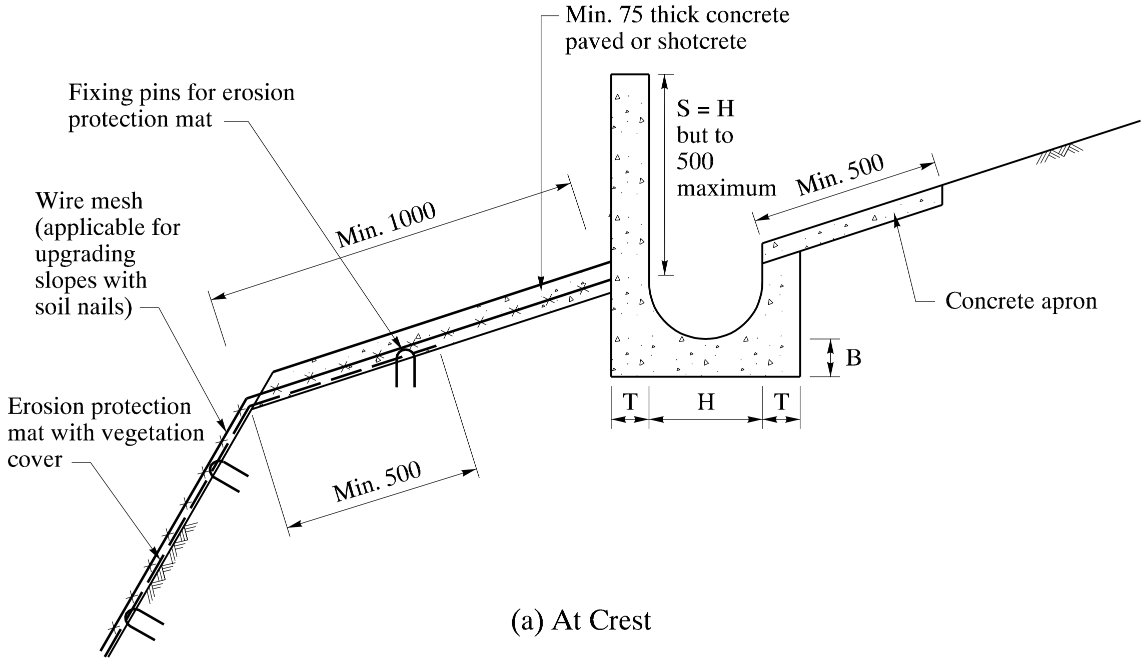
LIST OF TABLES

Table C1 - Prescriptive Use of Vegetation Cover for Soil Cut Slopes

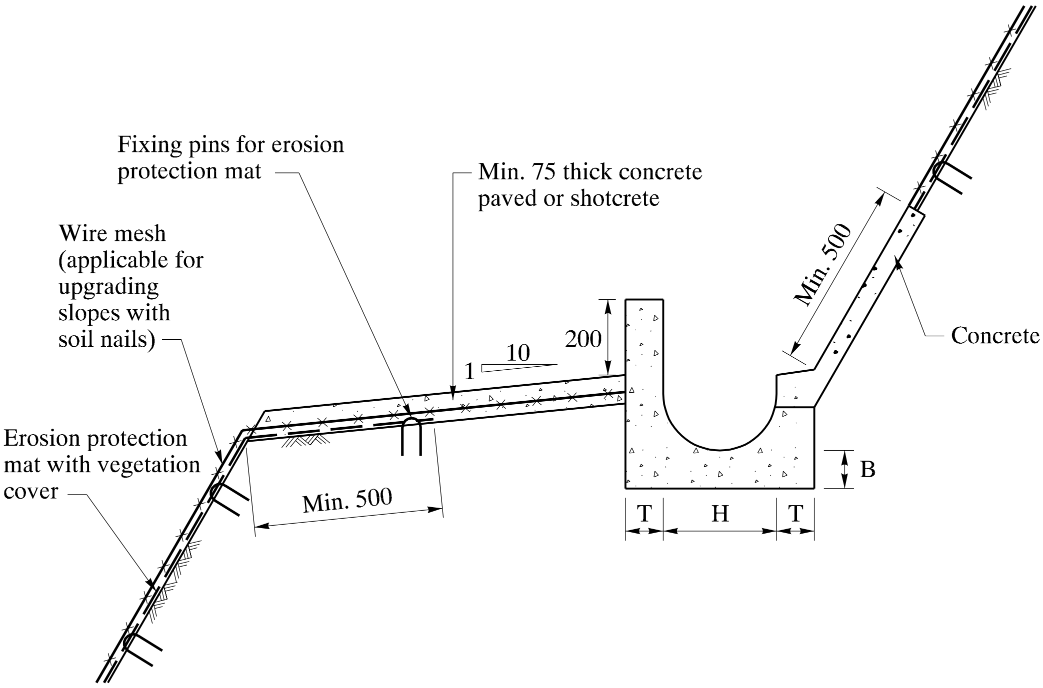
SLOPE GRADIENT	$\theta \leq 35°$	$35° < \theta \leq 45°$	$45° < \theta \leq 55°$[(3)]
EROSION PROTECTION MEASURES TO BE PROVIDED	Hydroseeding or turfing	Hydroseeding + geosynthetic erosion protection mat[(4)]	Hydroseeding + geosynthetic erosion protection mat[(4)]
PLANTING	Shrubs and/or trees	Shrubs and/or trees	Shrubs and/or creepers

Notes:
(1) This Table should be read in conjunction with the guidelines.
(2) The measures given in this Table are based on known successful experience. Other measures may be used if considered appropriate.
(3) For soil cut slopes steeper than 55°, there is no documented local experience on the successful use of vegetation cover. Designers may adopt vegetation cover on a trial basis but close monitoring of vegetation growth and its performance on erosion control during maintenance is recommended.
(4) Examples of geosynthetic erosion protection mat are Enkamat Type 7020, Tensar Mat (18 mm thick), Erolan (20 mm thick) and "Soil Saver" (1 pound per square yard). Other suitable mats may also be used.

LIST OF FIGURES



(a) At Crest



(b) At Berm (6)

Notes:
(1) Dimensions in millimetres unless specified otherwise.
(2) All concrete to be Grade 20/20.
(3) Overlaps of the erosion protection mat should be provided where necessary.
(4) Fixing pins for the erosion protection mat at not more than 1 m c/c. Fixing details for wire mesh (not shown) should comply with the manufacturer's instructions.
(5) Refer to CED Drawing C2410 for dimensions of channels.
(6) For berms, the drainage details shown in CED Drawing GC1001C may also be used as an alternative to that shown in (b) above.

Figure C1 - Details of Erosion Protection Works