

GUIDELINES ON THE USE OF PRESCRIPTIVE MEASURES FOR ROCK CUT SLOPES

GEO REPORT No. 161

Y.F. Yu, C.K. Siu & W.K. Pun

**GEOTECHNICAL ENGINEERING OFFICE
CIVIL ENGINEERING AND DEVELOPMENT DEPARTMENT
THE GOVERNMENT OF THE HONG KONG
SPECIAL ADMINISTRATIVE REGION**

GUIDELINES ON THE USE OF PRESCRIPTIVE MEASURES FOR ROCK CUT SLOPES

GEO REPORT No. 161

Y.F. Yu, C.K. Siu & W.K. Pun

**This report was originally produced in May 2003
as GEO Special Project Report No. SPR 3/2003**

© The Government of the Hong Kong Special Administrative Region

First published, January 2005

Prepared by:

Geotechnical Engineering Office,
Civil Engineering and Development Department,
Civil Engineering and Development Building,
101 Princess Margaret Road,
Homantin, Kowloon,
Hong Kong.

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. The GEO Reports can be downloaded from the website of the Civil Engineering and Development Department (<http://www.cedd.gov.hk>) on the Internet. Printed copies are also available for some GEO Reports. For printed copies, a charge is made to cover the cost of printing.

The Geotechnical Engineering Office also produces documents specifically for publication. These include guidance documents and results of comprehensive reviews. These publications and the printed 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
January 2005

FOREWORD

Since the publication of GEO Report No. 56 “Application of Prescriptive Measures to Soil Cut Slopes” in October 1996, there have been continuous development to improve the guidelines and to extend the scope of application of prescriptive measures. This Report presents guidelines on the use of different items of prescriptive measures for rock slopes.

This Report was prepared by Dr Y. F. Yu and Mr C. K. Siu under my direction and supervision. The guidelines presented in this Report are based on the findings of Atkins China Limited’s consultancy study on prescriptive measures design methods for rock cut slopes, which was overseen by Mr Y. K. Shiu and Mr H. C. Chan. Colleagues in the GEO and slope maintenance departments reviewed the draft Report and offered valuable comments and suggestions. All contributions are gratefully acknowledged.



W K Pun
Chief Geotechnical Engineer/Special Projects

ABSTRACT

Prescriptive measures have been widely used in rock slope stabilisation works in Hong Kong for many years. The guidelines given in this report aim at rationalising the current practice and achieving consistency in the designs between different designers.

Prescriptive measures for use in rock cut slopes can be classified into four types according to their design objectives and can be applied for preventive maintenance, urgent repair and upgrading of existing slopes. The qualifying criteria for applying prescriptive measure item of rock dowels as upgrading works for treating potentially unstable blocks are given in this Report. There are no qualifying criteria for the application of other items of prescriptive measures to rock cut slopes.

This Report presents a recommended standard of good practice for applying prescriptive measures to rock cut slopes.

CONTENTS

	Page No.
Title Page	1
PREFACE	3
FOREWORD	4
ABSTRACT	5
CONTENTS	6
1. GENERAL	8
2. SCOPE OF APPLICATION	8
3. SPECIFICATIONS	9
4. TYPES AND DETAILS FOR PRESCRIPTIVE MEASURES	9
5. TYPE 1 PRESCRIPTIVE MEASURES - SURFACE PROTECTION, LOCAL TRIMMING AND SURFACE DRAINAGE	9
5.1 Wire Mesh/Face Netting	9
5.2 Local Trimming and Removal	10
5.3 Dentition	10
5.4 Surface Drainage	10
6. TYPE 2 PRESCRIPTIVE MEASURES - SUBSURFACE DRAINAGE	11
6.1 Relief Drains	11
7. TYPE 3 PRESCRIPTIVE MEASURES - STRUCTURAL SUPPORT	11
7.1 Rock Dowels	11
7.2 Concrete Buttress	12
8. TYPE 4 PRESCRIPTIVE MEASURES - PROTECTION ZONE	12
8.1 Rock Trap Ditch	12
9. STATUS OF THE SLOPE AFTER IMPLEMENTATION OF PRESCRITPIVE MEASURES	12

	Page No.
10. GUIDANCE FOR APPLICATION	13
10.1 General	13
10.2 Step 1 - Desk Study	13
10.3 Step 2 - Discontinuity Data Collection	14
10.4 Step 3 - Assessment	14
10.5 Step 4 - Selection of Prescriptive Measures	14
10.6 Step 5 - Complete Part A of Record Sheet	15
10.7 Step 6 - Construction Review	15
10.8 Step 7 - Complete Part B of Record Sheet	15
11. PERSONNEL	15
12. REFERENCES	15
LIST OF TABLES	17
LIST OF FIGURES	20

1. GENERAL

Prescriptive measures for rock cut slopes is not a new concept and has been widely applied in local practice for many years (e.g. Brand, 1983; Dubin et al, 1986). These Guidelines rationalise the current practice and provide technical guidance on the functions and use of different items of prescriptive measures (Figure 1) recommended for rock cut slopes.

Useful advice on the design of rock cut slopes can be found in the TGN 10 - Enhancement of Rock Slope Engineering Practice Based on Findings of Landslide Studies (GEO, 2002).

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.

2. SCOPE OF APPLICATION

Prescriptive measures for use in rock cut slopes can be classified into four types according to their design objectives, i.e. Types 1, 2, 3 and 4 (refer to Section 4 for details), and can be applied for preventive maintenance, urgent repair and upgrading of existing slopes. There are no qualifying criteria for the application of the recommended measures, except when rock dowels (Item 3.1, Table 1) are used as upgrading works. For the treatment of rock blocks with a potential for sliding instability using the prescriptive measure item of rock dowels (Item 3.1, Table 1), the following qualifying criteria should be met:

- (a) the rock type is granitic or volcanic and of decomposition grades I to III and with no clay- or silt-infilled joints,
- (b) the volume of the rock block is not more than 5 m³ and the rock block is not supporting any foundations of structures or other surcharge, and
- (c) the angle between the slope at the rock face and the potential sliding surface should be equal to or greater than 10°; the dip angle of the rock block basal sliding surface should be smaller than 60°.

Items of Type 1 and 2 prescriptive measures should be considered in all cases for improving slope stability. Where structural support is needed for stabilising unstable rock blocks, rock dowels and/or concrete buttresses (i.e. Type 3 prescriptive measures) can be used as appropriate. Since rock trap ditch (Type 4 prescriptive measure) is very effective in retaining rockfalls, it may be adopted to reduce rockfall hazard if there is sufficient room at the toe of the slope to accommodate the ditch. The designer should adopt appropriate measures, generally a combination of items, based on a consideration of the nature and extent of the potential instability problem, the likely scale of failure, the consequence of failure, site constraints, cost and aesthetics.

3. SPECIFICATIONS

The works should comply with the General Specification for Civil Engineering Works Hong Kong Government (1992). Where necessary, Particular Specification clauses should be included in the contract under which the works are to be carried out.

4. TYPES AND DETAILS FOR PRESCRIPTIVE MEASURES

- (a) Type 1 - surface protection, local trimming and surface drainage,
- (b) Type 2 - subsurface drainage,
- (c) Type 3 - structural support, and
- (d) Type 4 - protection zone.

Nine items of prescriptive measures, including five items for Type 1, one item for Type 2, two items for Type 3 and one item for Type 4 are recommended (Table 1). Typical details of the items for prescriptive measures are given in Figures 2 to 9.

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

5.1 Wire Mesh/Face Netting

Wire mesh (or called face netting) (Item 1.1, Table 1) may be fixed to the rock face to prevent rock from falling, or hung loosely over a slope to guide rocks to a rock trap ditch (Item 4.1, Table 1) at the slope toe. When there is no rock trap ditch at the slope toe, the lower end of the mesh should be no more than about 0.6 m above the toe to prevent rocks from falling and bouncing onto the road or facility at the slope toe. These methods are generally effective for retaining rock fragments of dimensions up to about 0.6 - 1 m.

Two critical factors govern the choice of mesh:

- (a) The likely volume/extent of material to be retained.
- (b) The minimum typical block size of the rock face.

In general the material to be retained will comprise a blocky, moderately to highly fractured rock mass. More particulate, weathered materials are not well suited to this approach.

Twisted wire PVC covered netting or 200 mm opening cable nets are suitable on steep faces for controlling rockfalls with dimensions less than about 0.6 m, and woven wire rope may be suitable for rock blocks with dimensions up to about 1 m. For larger blocks, ring nets (200 mm opening gauge and smaller gauge twisted wire PVC covered netting) can be utilised. In all cases, the upper edge of the mesh should be placed close to the potential

source of the rockfall so that the blocks will have little momentum when they strike the mesh. The mesh should be anchored at intermediate points by U-hooks at a spacing of about 3 m. This spacing permits rocks to work their way down to the toe rather than accumulating behind the mesh. For the same reason of avoiding accumulation of debris, the mesh is not usually used on slopes flatter than $\frac{3}{4}:1$ (37°). At the bottom of the slope, U-hooks with an extension connector are recommended at the lowest row so that they can be loosened and removed from the anchored end and the mesh can be lifted for removal of fallen loose rock blocks.

The use of netting systems requires the use of specialised retainer units commonly termed cable anchors. These comprise a looped cable grouted into a borehole that provides an eye at the rock surface. The eye is used to secure main hawsers (horizontal, vertical or diagonal) to which the cable netting and twisted wire netting systems are securely attached (refer to Figure 2).

5.2 Local Trimming and Removal

Local areas may be trimmed (Item 1.2, Table 1) in order to avoid local instability from developing. In particular, failure of a portion of a rock slope may form an overhang on the face which may be a hazard if it were to fail.

Loose rock can also be removed by hand-held scaling bars. However, removal should only be used where it is certain that the new face will be stable and there is no risk of undermining the upper part of the rock slope. The designer should re-examine and re-assess the stability of the rock face following local trimming and scaling of specified loose rock. Removal of loose rock on the face of a slope is not effective when the rock is highly fragmented. Other measures such as wire mesh may be considered in such case.

5.3 Dentition

Dentition (Item 1.3, Table 1) can be used to backfill slots resulting from trimming of bands of soft materials or to support an overhang formed in the rock face.

Typical details of dentition works are shown in Figure 3. A grout pipe may be provided for subsequent grouting to ensure good contact between the overhang and the supporting concrete.

5.4 Surface Drainage

U-channels (Item 1.4, Table 1) can be provided to drain away any water coming out of the weepholes in the rock slope surface. Upstands can be provided to crest channels (Item 1.5, Table 1) to minimise possible spillage of surface water onto the slope.

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. Catchpits should be provided at the junctions of channels.

Typical details of U-channels and crest channels with upstands are given in Figures 4 and 5 respectively. Excavation in rock for the construction of drainage channels may be difficult. An alternative typical details of crest channel is shown in Figure 5. Half-round channels may be used on berms to minimise excavation in rock.

For steeply inclined rock face, the size of catchment on the rock face itself is generally small. If the amount of surface runoff on the rock slope face is not large, berm channel which requires excavation in rock may be omitted. However, the berm should still be paved by concrete to avoid infiltration of water into rock joints from the berm.

The use of stepped channels on steep rock slopes may result in spillage of water. Site-specific designed downpipes are alternatives to stepped channels for transferring water down to the slope toe.

6. TYPE 2 PRESCRIPTIVE MEASURES - SUBSURFACE DRAINAGE

6.1 Relief Drains

Where there are signs of potential seepage sources (e.g. rock joints with signs of seepage) behind an existing shotcreted rock slope face or a concrete cover, relief drains should be provided (Item 2.1, Table 1) as shown in Figure 6. Relief drains should likewise be provided at the locations of water seepage for newly shotcreted slopes. It is important to avoid sliding instability at the interface between the rock and the geosynthetic material by providing proper anchorage by the use of nails or plaster (Figure 6). The drainage material should be covered by an impermeable fabric with a hole cut through to insert a PVC flange and pipe for drainage.

7. TYPE 3 PRESCRIPTIVE MEASURES - STRUCTURAL SUPPORT

7.1 Rock Dowels

Loosening and failure of small blocks of rock on the slope face can be prevented by the installation of passive rock dowels (Item 3.1, Table 1) which are composed of lengths of reinforcing steel grouted into holes drilled in the underlying stable rock. The typical arrangement of a rock dowel is illustrated in Figure 7.

From the review of previous cases of LPM works, rock dowels used to stabilise sliding blocks/wedges typically have a length of between 3 m to 6 m. The slope angle typically varies from 50 to 80 degrees and the volume of loose rock blocks is generally less than or equal to 5 m³.

Based on the findings of the study by Atkins (2002), standard rock dowel design is presented in Table 2 for prescriptive application. The rock block sliding angle and rock block volume should be estimated prior to using the design table to determine the number of dowels required. By reading off from the design table with the appropriate rock block volume sizes, the required number of dowels can be estimated.

7.2 Concrete Buttress

When a rockfall has occurred that forms a cavity in the slope face, it may be necessary to construct a concrete buttress (Item 3.2, Table 1) in the cavity to prevent further rock falls. The buttress serves two functions, viz. to retain and protect areas of weak rock and to support the overhang. It may also be used to prevent local toppling failure of the rock face. Rock dowels are commonly used in conjunction with buttresses to stabilise and tie the rocks together (Figure 8).

The size of a concrete buttress is generally governed by geometrical considerations such that it is large enough to provide physical support to a rock block. The stability of its foundation should be considered. It should be founded on a level, clean and sound rock surface. If this surface is not at right angles to the direction of resultant force acting on the buttress, the buttress should be anchored to a solid base using dowels to prevent sliding. In addition, the top of the buttress should be set at a higher elevation than the top of the overhang to ensure good contact (Figure 8).

8. TYPE 4 PRESCRIPTIVE MEASURES - PROTECTION ZONE

8.1 Rock Trap Ditch

A rock trap ditch (Item 4.1, Table 1) at the toe of a rock slope can keep rockfalls from reaching the roadway, residential area or other facilities in front of the slope.

The proposed prescriptive dimensions of the rock trap ditch (Figure 9) are based on the study carried out by Ritchie (1963). Where the rock slope surface is irregular with protrusions on the face or where the slope is higher than 16m, the ditch dimensions should be assigned based on full engineering design to account for less predictable bounces by falling rocks. It is recommended that the base of the ditch should be covered by a layer of gravel not less than 0.3 m to absorb the impact energy of the falling rocks.

9. STATUS OF THE SLOPE AFTER IMPLEMENTATION OF PRESCRIPTIVE MEASURES

In addition to the failure modes to be treated by the prescriptive measures recommended in this guideline, the designer should assess other modes of instability including:

- (a) potential for global instability (e.g. the presence of extensive unfavourably orientated and persistent discontinuities and/or adverse groundwater conditions), and
- (b) rock mass failure mechanisms not treated by the prescriptive measures given in this document, such as toppling.

A rock slope can be considered as upgraded only when all potential failure mechanisms have been adequately dealt with using the prescriptive measures items recommended in this document and by the implementation of additional designed engineering

measures as needed, which are designed using the analytical approach.

10. GUIDANCE FOR APPLICATION

10.1 General

Designers should aim at achieving a safe and cost-effective design in selecting the appropriate items of prescriptive measures to be used, and take due account of the type and level of improvement required, the nature of the rock slope, the geological and groundwater conditions of the site, the nature and locations of adjacent utilities and water-carrying services, surface water pathways, the performance history of the slope, the consequence of failure and site constraints.

Designers should review the overall stability of their slopes before concentrating on securing small blocks of unstable rock by prescriptive measures. Desk study, collection of relevant rock joint data and assessment of the stability of the existing rock slope through visual inspection in the field should be carried out as needed.

For unprotected steep rock faces of Consequence-to-life Category 1 in accordance with Works Bureau Technical Circular No. 13/99 “Geotechnical Manual for Slopes - Guidance to Interpretation and Updating” and Section 4.2 of Highway Slope Manual (GEO, 2000), the provision of wire mesh (Item 1.1, Table 1) is strongly recommended for protection against minor rockfall. Nevertheless, judgement should be exercised to identify cases where wire mesh is not warranted, e.g. presence of massive, very tightly- and not adversely jointed rock where there is no credible minor rockfall potential, near the tapering ends of big rock cuts where reduced height and setback from the carriageway would prevent any minor falls from reaching the road, mixed rock/soil slopes where mesh is only warranted on the ‘hard-rock’ part with credible rockfall potential.

The recommended procedures for application of prescriptive measures are described in the following Sections.

10.2 Step 1 - Desk Study

A desk study is for collecting relevant data and information to form a preliminary ground model of the slope. It should cover the regional and local geology, the extent and details of existing stabilisation measures, records of slope maintenance, history of past instability, and existing relevant site investigation data.

The data collected should be reviewed by the designer. If the desk study reveals that the slope has undergone stabilisation previously, then the designer should assess whether the existing measures are adequate and appropriate; and whether stabilisation measures are required for other parts of the slope. The designer should conduct a field inspection for the purpose of this assessment.

10.3 Step 2 - Discontinuity Data Collection

Stability in rock is controlled principally by discontinuities in the rock mass. The role of discontinuity data collection is primarily to aid identifying the possible modes of failure. Rock outcrop mapping is the best field way to obtain discontinuity data. Geoguide 2 - Guide to Site Investigation (GEO, 1993) and Geoguide 3 - Guide to Rock and Soil Descriptions (GEO, 1994) describe the requirements for rock discontinuity mapping for rocks in Hong Kong; Section 26 of Geoguide 2 and Section 2.3 of Geoguide 3 are particularly relevant.

Rock joint discontinuity data should be recorded in a proforma similar to Figure 1 of Geoguide 3.

The degree of rock exposure is usually the controlling factor in determining the accuracy of the data collected. In the event that the rock slope face is fully exposed, all data is usable. If little or no exposure is available on the slope, knowledge of the local geology may permit extrapolation from outside the slope. The key to this lies in the recognition of discontinuity patterns. Where extrapolation is necessary, the designer should determine whether the rock mass and discontinuity pattern in the area of data collection is akin to those of the rock slope by consideration of the local geological conditions. Where there is doubt on this, discontinuity data should be collected from the covered rock slope direct. Techniques for investigating partially and fully covered surfaces include surface cover stripping, window opening, coring and drillhole inspection. Where stripping is used, a scanline survey may be undertaken as opposed to stripping the whole slope.

10.4 Step 3 - Assessment

A qualitative assessment is required to determine the potential instability problem and the likely scale of failure. If local zones of instability are observed, the prescriptive measure items given in this guideline can be applied. However, if there are potential global instability or large zones of potentially unstable rock block with a volume greater than 5 m³, the use of these prescriptive measure items alone is not considered adequate, and provision of measures based on analytical design should be undertaken.

During the assessment, kinematic analysis could be used to facilitate judgement to be made on the stability of the slope. Where stereoplots are used, their limitations should be recognised (Hoek & Bray, 1981; Hencher, 1985). It is important that engineers exercise care when interpreting stereoplots and that correct judgement is applied. It should also be noted that assessment of discontinuity data only provides a reference to the designer. The stability of an existing rock slope, particularly local stability of individual rock block, should always be assessed based on field inspection. Indeed, the step of discontinuity data collection may be omitted if the rock face to be treated is fully exposed, such that detailed examination of the rock face is carried out to identify all instability problems.

10.5 Step 4 - Selection of Prescriptive Measures

Where local instability problems are observed, the designer should adopt appropriate

prescriptive measures items to address the problems. Referring to the typical details of the relevant items of prescriptive measures (Table 1), one can specify the key dimensions for each item and the extent of application to the rock slope to suit the actual site conditions.

10.6 Step 5 - Complete Part A of Record Sheet

The designer should document the rationale for application of rock slope prescriptive measures and the details of the measures, e.g. sizes and dimensions of rock blocks and the number, length and spacing of dowels.

Part A of the Record Sheet to be completed is presented in Figure 10.

10.7 Step 6 - Construction Review

Rock slope stabilisation works for dealing with potential local instability problems are commonly prescribed in the construction stage when safe access for inspection is made available. Where prescriptive measures are specified without a close inspection of all the rock blocks to be treated, the actual rock block size and the measures needed should be reviewed once the conditions and dimensions of the block can be examined on site more accurately during the construction phase. The review during construction should also determine whether other parts of the rock slope face need to be stabilised.

10.8 Step 7 - Complete Part B of Record Sheet

Part B of the Record Sheet to be completed is presented in Figure 11.

11. PERSONNEL

The prescriptive measures should be specified by a professionally qualified geotechnical engineer (such as Registered Professional Engineer (Geotechnical)) or engineering geologist (such as Chartered Geologist) with experience in rock slope stabilisation works.

12. REFERENCES

- Atkins China Ltd (2002). Prescriptive Design Manual for Rock Slope Stabilization. Geotechnical Control Office, Civil Engineering Services Department, Hong Kong Government, 114 p.
- Brand, E.W., Hencher, S.R. & Youdan, D.G. (1983). Rock Slope Engineering in Hong Kong. Proceedings of the Fifth International Rock Mechanics Congress, Melbourne, Vol. 1, pp C17-C24. (Discussion, vol. 3, G126)
- Civil Engineering Department (2001). CED Standard Drawings. Hong Kong Government.

- Dubin, B.I., Watkins, A.T. & Chang, D.C.H. (1986a). Stabilization of Existing Rock Faces in Urban Areas of Hong Kong. Proceedings of the Conference on Rock Engineering and Excavation in an Urban Environment, Hong Kong, pp 155-171.
- Geotechnical Engineering Office (1993). Guide to Site Investigation (Geoguide 2). Geotechnical Engineering Office, Hong Kong, 368 p.
- Geotechnical Engineering Office (1994). Guide to Rock and Soil Descriptions (Geoguide 3). Geotechnical Control Office, Hong Kong, 195 p.
- Geotechnical Engineering Office (1999). Guide to Slope Maintenance (Geoguide 5) (Second edition). Geotechnical Engineering Office, Hong Kong, 91 p.
- Geotechnical Engineering Office (2000). Highway Slope Manual. Geotechnical Engineering Office, Hong Kong, 114 p.
- Geotechnical Engineering Office (2002). Enhancement of Rock Slope Engineering Practice Based on Findings of Landslide Studies. GEO Technical Note No. 10, Geotechnical Engineering Office, Hong Kong, 8 p.
- Hencher, S.R. (1985). Limitations of Stereo-graphic Projections for Rock Slope Stability Analysis. Hong Kong Engineer, Vol. 13, No. 7, pp. 37-41.
- Hoek, E. & Bray, J. (1981). Rock Slope Engineering (Revised Third Edition). Institution of Mining and Metallurgy, London, 358 p.
- Hong Kong Government (1992). General Specification for Civil Engineering Works. Hong Kong Government, 3 volumes plus 1 volume of Guidance Notes.
- Ritchie A. M. (1963). Evaluation of Rockfall and Its Control. Highways Research Record, 17, pp13-28.

LIST OF TABLES

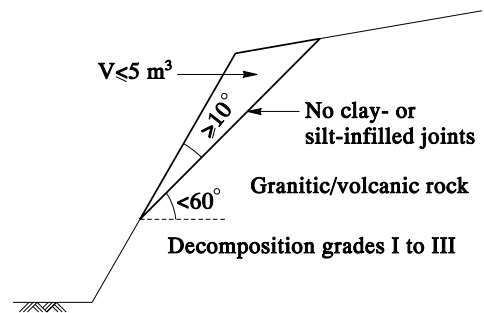
Table No.		Page No.
1	Prescriptive Measures for Rock Slopes	18
2	Prescriptive Design for Rock Dowel	19

Table 1 - Prescriptive Measures for Rock Slopes

Type	Prescriptive Measures	Primary Design Objectives	Item No. and Description of Works	Details
1	Surface protection	– Improve surface protection	1.1 Fix wire mesh/netting to rock face	Figure 2
	Local trimming	– Remove local instability	1.2 Carry out local trimming and removal of loose blocks	
			1.3 Apply dentition to rock face	Figure 3
	Surface drainage	– Improve surface drainage	1.4 Provide toe or berm channel	Figure 4
			1.5 Provide crest channel with upstand	Figure 5
2	Subsurface drainage	– Improve subsurface drainage	2.1 Provide relief drains	Figure 6
3	Structural support	– Provide support to improve local or overall slope stability	3.1 Provide rock dowels	Figure 7
			3.2 Provide concrete buttress	Figure 8
4	Protection zone	– Provide protection zone	4.1 Provide rock trap ditch	Figure 9

Table 2 - Prescriptive Design for Rock Dowel

Volume of Potentially Unstable Rock Block, V (m^3)	$V \leq 1$	$1 < V \leq 2$	$2 < V \leq 3$	$3 < V \leq 4$	$4 < V \leq 5$
Number of Rock Dowels Required	1	2	3	4	5
<p>Notes: (1) The following qualifying criteria should be satisfied in using the above prescriptive design:</p> <p>(a) the rock type is granitic or volcanic and of decomposition grades I to III and with no daylighting clay- or silt-infilled joints,</p> <p>(b) the volume of the rock block is not more than $5 m^3$ and the rock block is not supporting any foundations of structures or surcharge, and</p> <p>(c) angle between the slope at the rock face and the potential sliding surface should be equal to or greater than 10°; angle of the rock block basal sliding surface should be smaller than 60°.</p> <p>(2) Dowel bars shall be 32 mm diameter, hot dip galvanised type 2 high yield steel bars to be used.</p> <p>(3) Angle of dowels to be approximately perpendicular to potential sliding surface of the rock block.</p> <p>(4) Dowel length = 3 x thickness of potentially unstable rock block subject to a minimum length of 3 m and a maximum length of 6 m.</p> <p>(5) The layout of the rock dowels applied to a sliding rock block/wedge to be at least 0.3 m from the identified periphery of the rock block/wedge to provide effective stabilisation.</p> <p>(6) The vertical/horizontal spacing of the rock dowels to be from a minimum of 0.3 m to an effective spacing evenly distributed to cover the sliding area of the block.</p>					



LIST OF FIGURES

Figure No.		Page No.
1	Typical Prescriptive Measures for Rock Slopes	21
2	Fixing of Wire Mesh to Rock Face	22
3	Typical Rock Face Dentition	23
4	U-channel on Berm	24
5	Crest Channel with Upstand	25
6	Relief Drain Details	26
7	Typical Arrangement of Rock Dowel	27
8	Typical Details of Concrete Buttress	28
9	Rock Trap Ditch	29
10	Indicative Record Sheets for Prescriptive Measures Application to Rock Slopes (Sheet 1 of 2)	30
11	Indicative Record Sheets for Prescriptive Measures Application to Rock Slopes (Sheet 2 of 2)	31

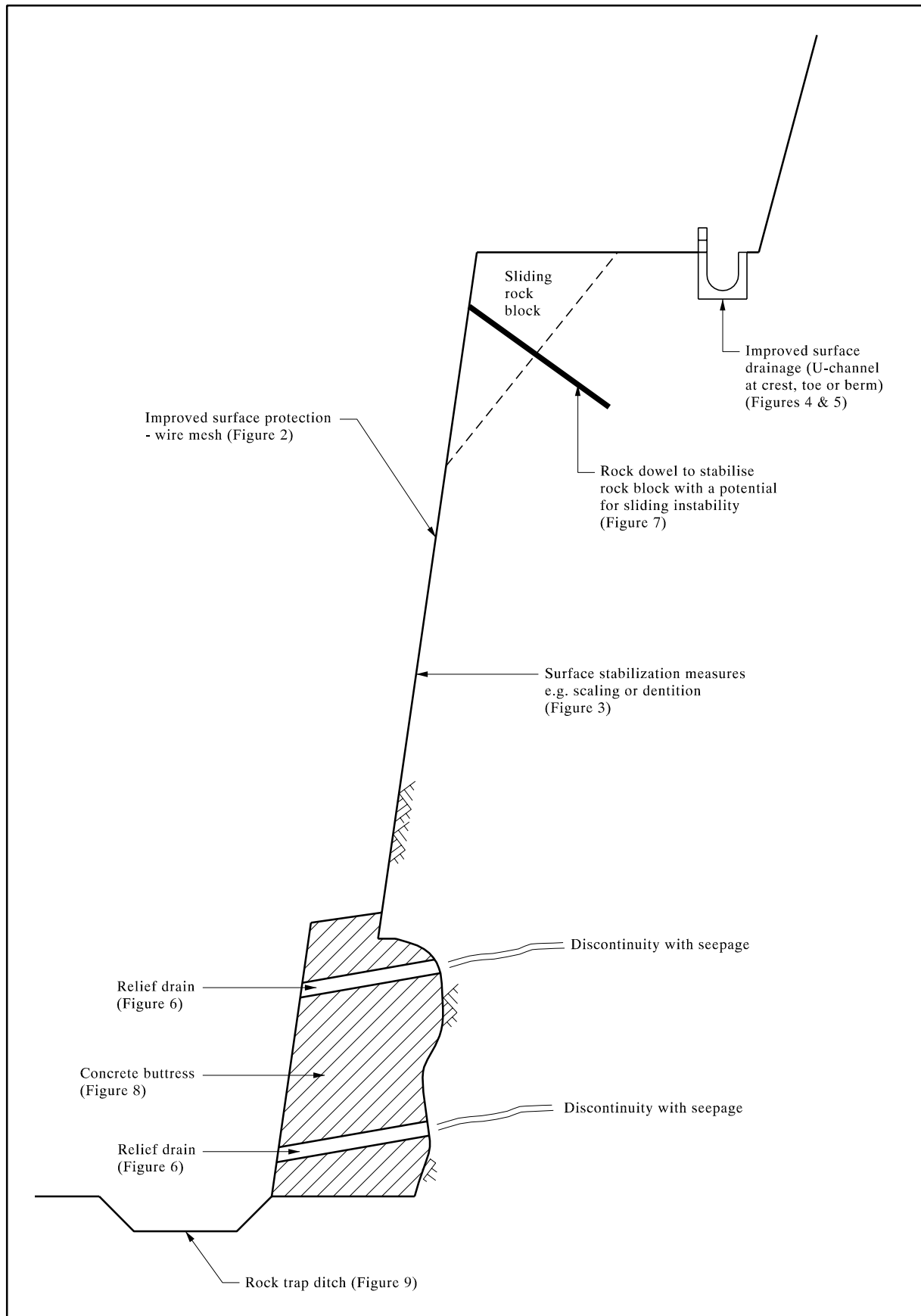


Figure 1 - Typical Prescriptive Measures for Rock Slopes

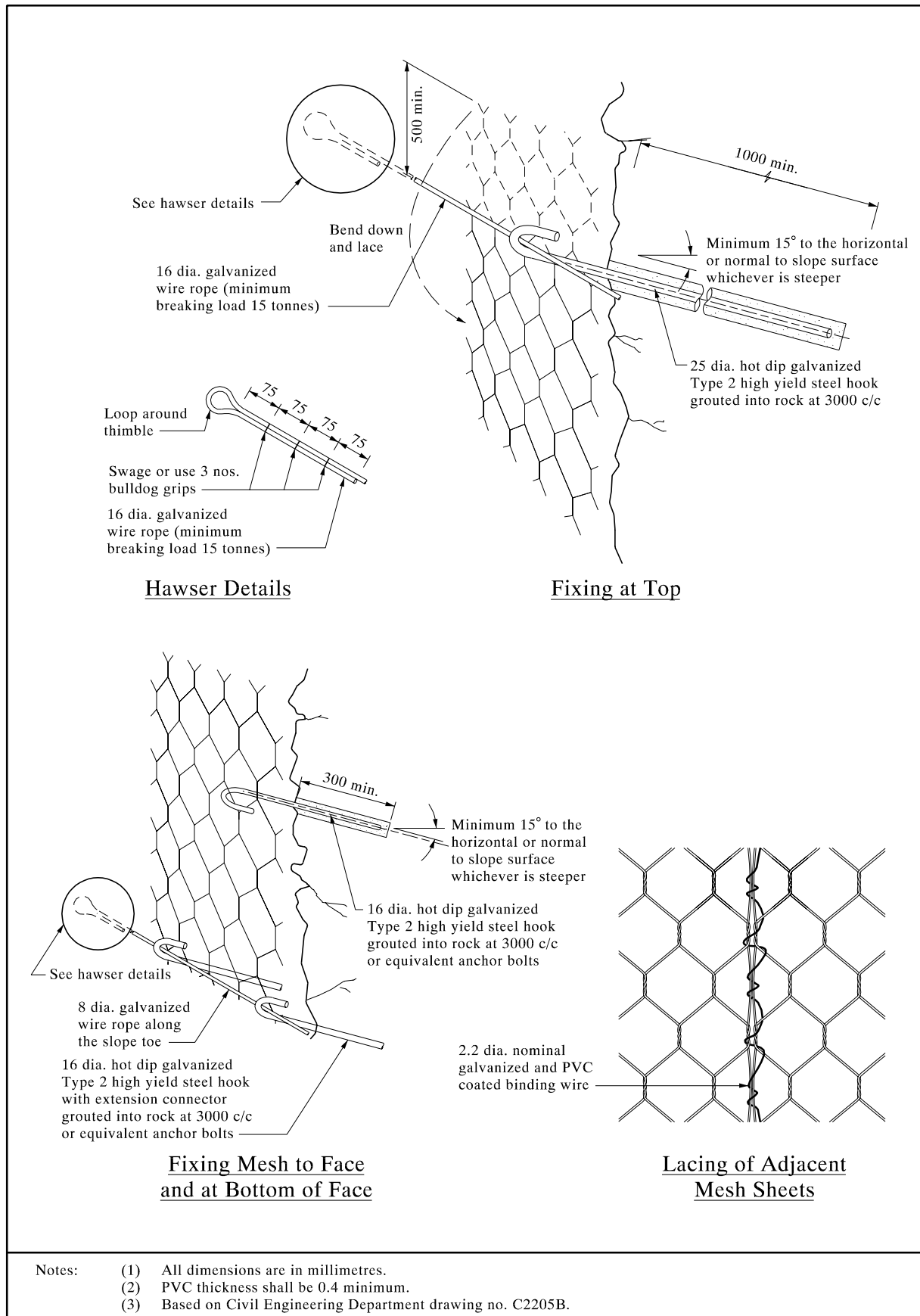


Figure 2 - Fixing of Wire Mesh to Rock Face

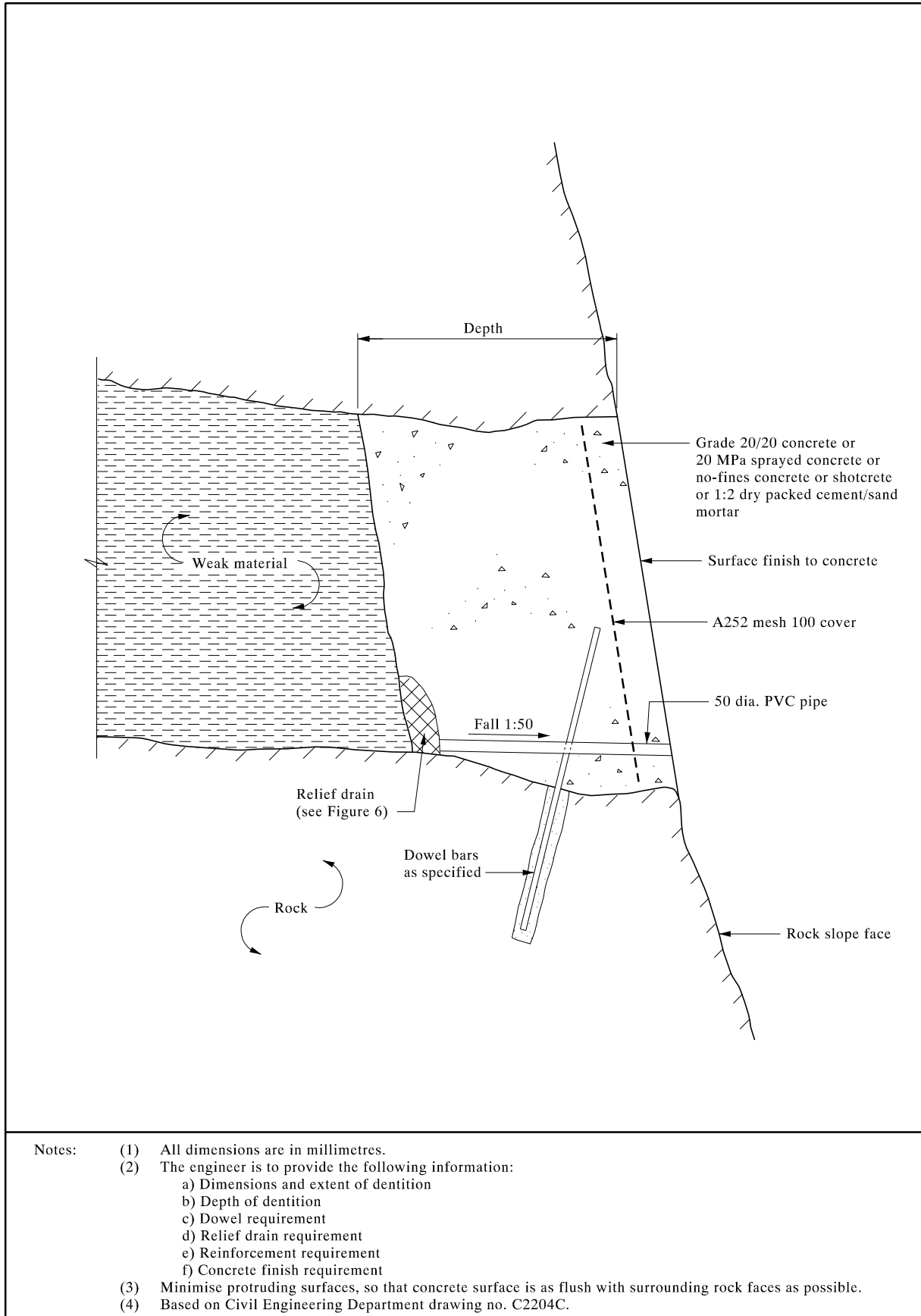
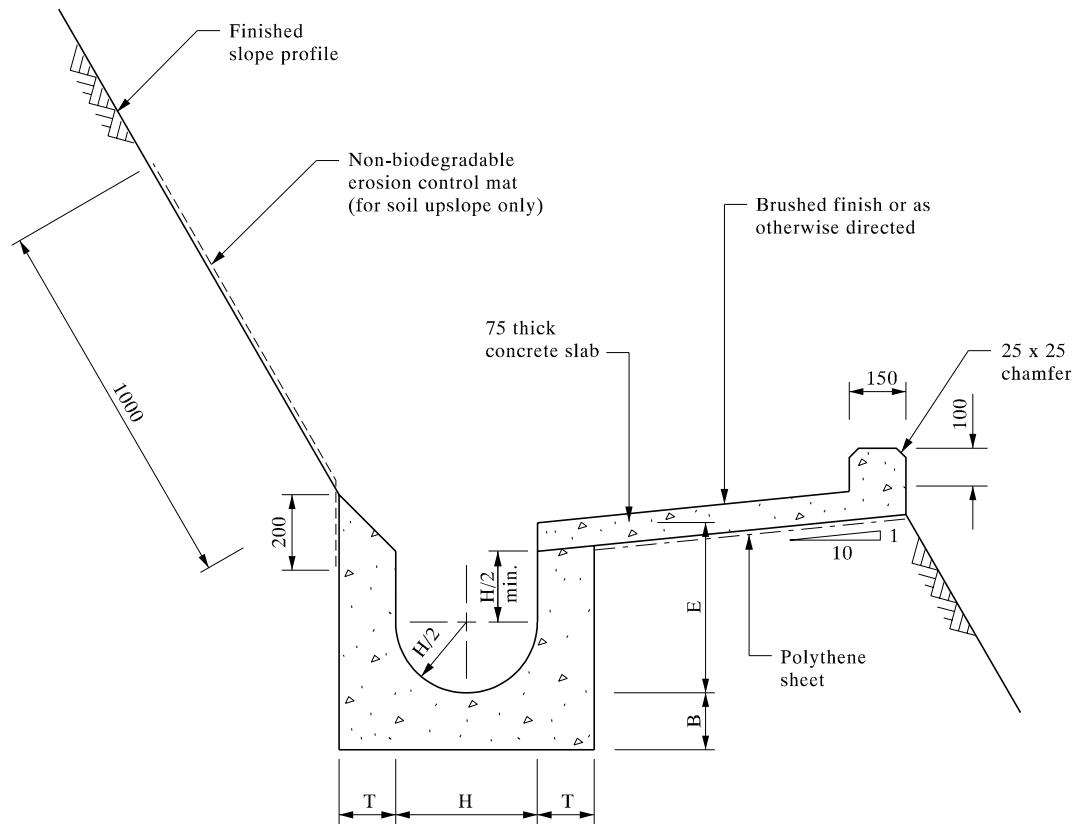


Figure 3 - Typical Rock Face Dentition



Nominal Size H	T	B	Reinforcement
300	100	100	A252 mesh placed centrally when E>750
375 - 675	150	150	
750 - 900	175	175	A252 mesh placed centrally

- Notes:
- (1) All dimensions are in millimetres.
 - (2) All concrete to be grade 20/20.
 - (3) Concrete surface finish shall be Class U2, F2 or brushed finish as directed.
 - (4) Spacing of expansion joint in channels, berm slabs and aprons to be 10 m maximum, see CED drawing no. C2413C for details.
 - (5) Joints for channels, berm slabs, aprons and walls, etc. to be on the same alignment.
 - (6) Half-round channels may be used on berms to minimise excavation into rock.
 - (7) Geotextile to be fixed in accordance with manufacturer's instructions.
 - (8) Based on Civil Engineering Department drawing no. C2410E.

Figure 4 - U-channel on Berm

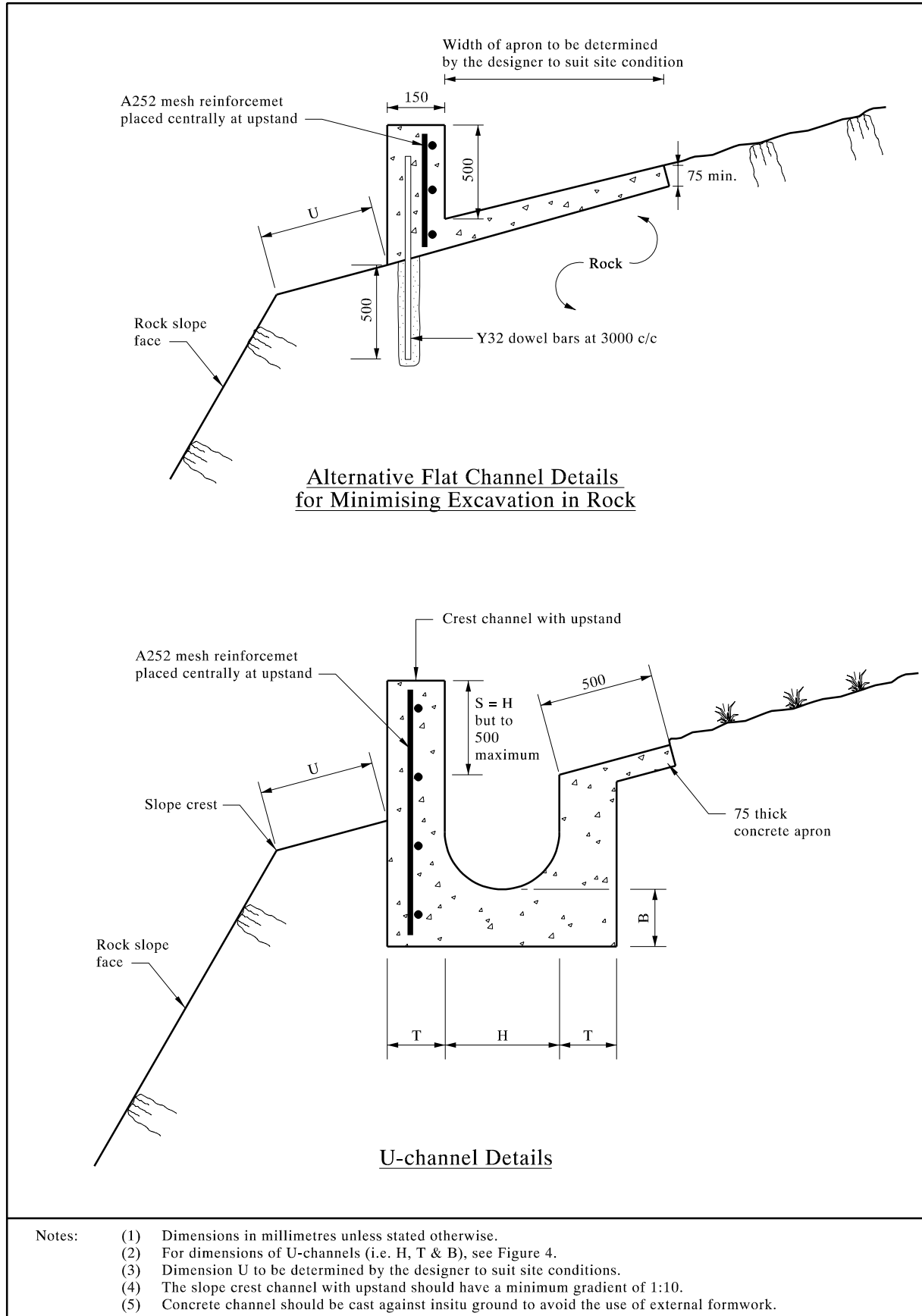


Figure 5 - Crest Channel with Upstand

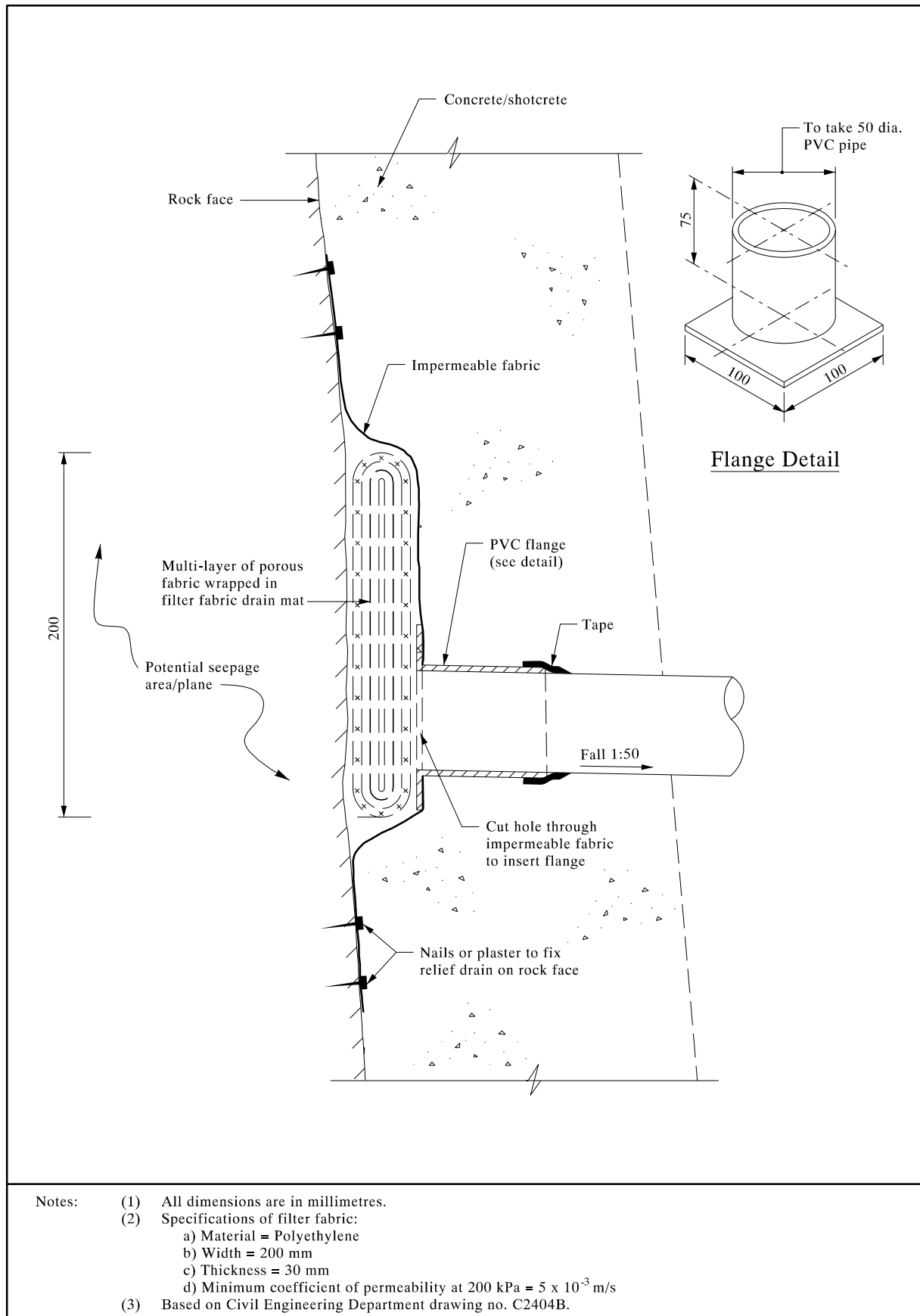


Figure 6 - Relief Drain Details

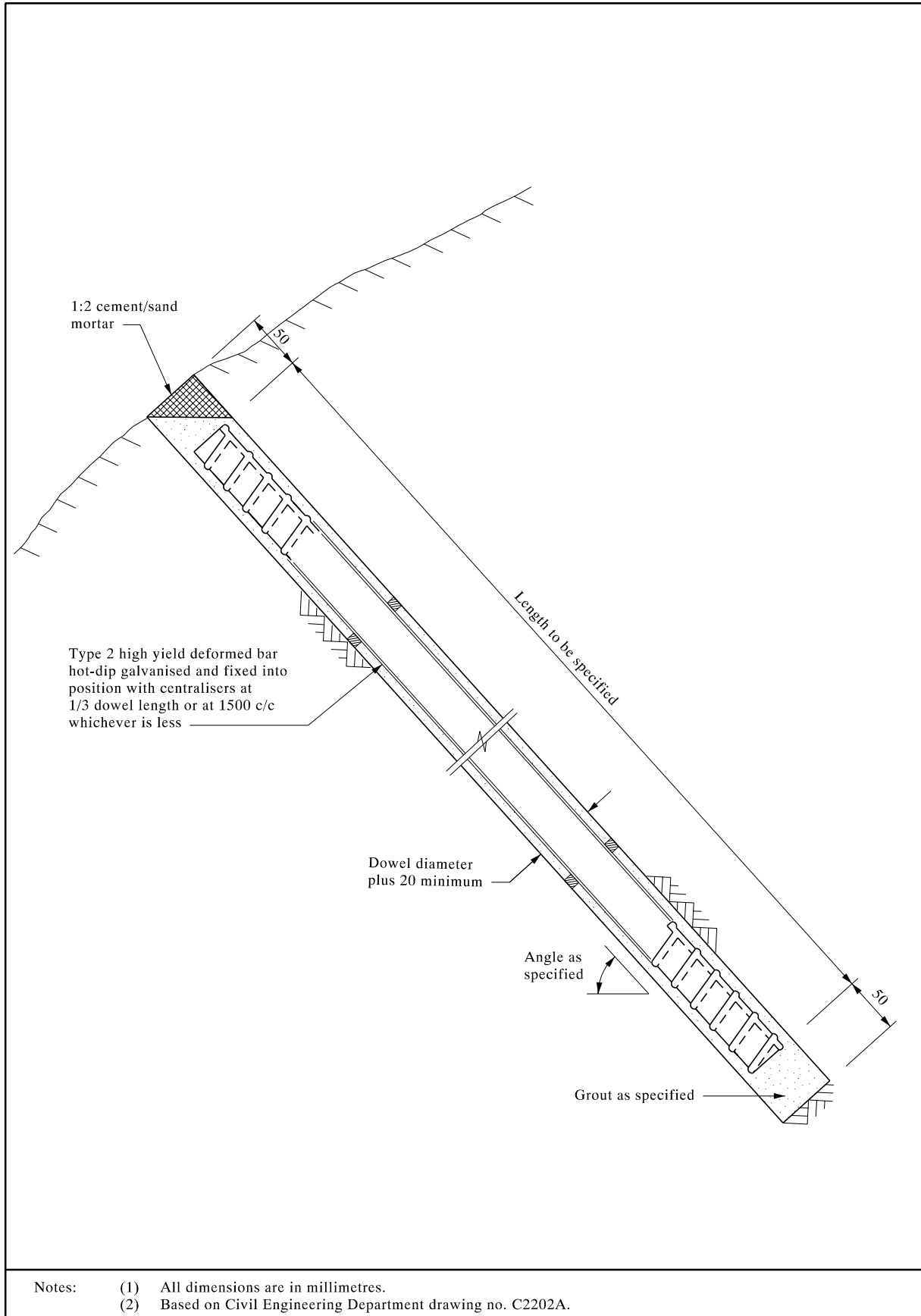


Figure 7 - Typical Arrangement of Rock Dowel

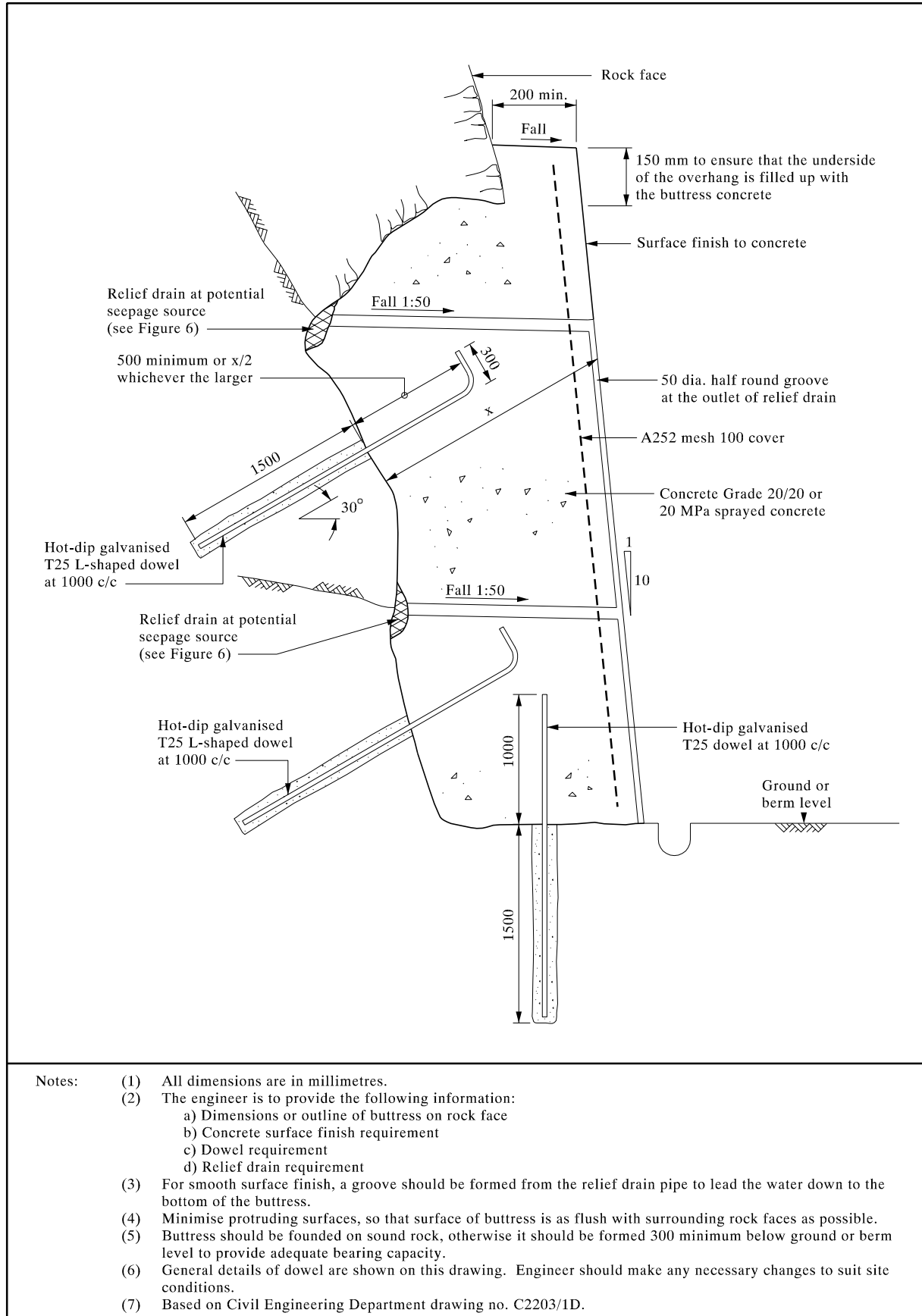
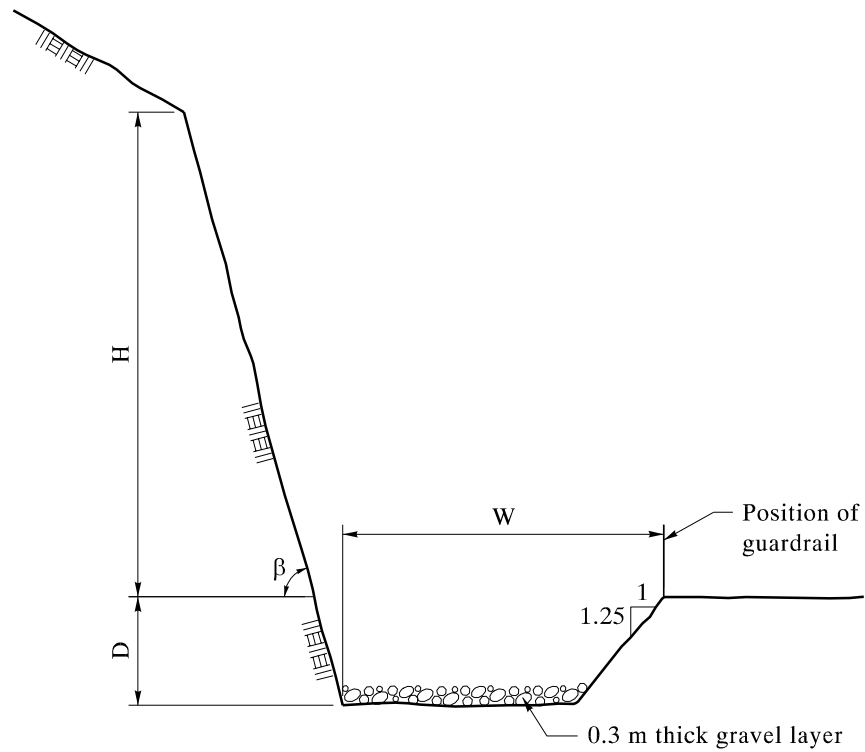


Figure 8 - Typical Details of Concrete Buttress



Rock Face Gradient (β)	H (m)	W (m)	D (m)
$\geq 0.3:1$ to near vertical	$>0 \ \& \ \leq 8$ $>8 \ \& \ \leq 16$	3 4.5	1 1.2
$>0.75:1 \ \& \ <0.3:1$	$>0 \ \& \ \leq 8$ $>8 \ \& \ \leq 16$	3 4.5	1.2 1.8
$>1:1 \ \& \ \leq 0.75:1$	$>0 \ \& \ \leq 8$ $>8 \ \& \ \leq 16$	3 4.5	1 1.6

- Notes:
- (1) Based on the guidelines of Ritchie (1963).
 - (2) Proper drainage measures should be provided to avoid flooding of the ditch.
 - (3) Where the rock slope surface is irregular with protrusions on the face or where the slope is higher than 16 m, the ditch dimensions should be assigned based on full engineering design to account for less predictable bounces by falling rocks.

Figure 9 - Rock Trap Ditch

PART A - Prescriptive Measures for Rock Cut Slope

Slope Reference No.		Location	
Slope Geometry and Consequence Category Slope Gradient (degrees) Slope Height: (m) Facility Group of Facilities Affected: 1/2/3/4/5* Consequence-to-life Category: 1/2/3* Available Engineer Inspection Records: Yes/No* If yes, date of inspection HKGS Geology Map Sheet No.:		Qualifying Criteria (for Item 3.1 - rock dowels only) 1. Rock type granitic or volcanic <input type="checkbox"/> Yes 2. Rock decomposition grade I to III <input type="checkbox"/> Yes 3. Slope not supporting foundations or other surcharge <input type="checkbox"/> Yes 4. Max. volume of unstable blocks less than 5m ³ <input type="checkbox"/> Yes	
Records of Rock Fall			
Date of Failure	Failure Volume (m ³)	Mode of Failure	GEO Incident No.
1. _____	_____	_____	_____
2. _____	_____	_____	_____
3. _____	_____	_____	_____
Type of Improvement Works <input type="checkbox"/> Preventive Maintenance <input type="checkbox"/> Urgent Repair <input type="checkbox"/> Upgrading Works			
Design Objective	Prescriptive Measures Recommended	Figure No.	
<input type="checkbox"/> Improve surface protection	<input type="checkbox"/> 1.1 Fix wire mesh to rock face	2	
<input type="checkbox"/> Improve local stability	<input type="checkbox"/> 1.2 Carry out local trimming and removal	-	
	<input type="checkbox"/> 1.3 Apply dentition to rock face	3	
<input type="checkbox"/> Improve surface drainage	<input type="checkbox"/> 1.4 Provide toe or berm channel	4	
	<input type="checkbox"/> 1.5 Provide crest channel with upstand	5	
<input type="checkbox"/> Improve subsurface drainage	<input type="checkbox"/> 2.1 Provide relief drains	6	
<input type="checkbox"/> Provide support to improve local/overall slope stability	<input type="checkbox"/> 3.1 Provide rock dowels	7	
	<input type="checkbox"/> 3.2 Provide concrete buttress	8	
<input type="checkbox"/> Provide protection zone	<input type="checkbox"/> 4.1 Provide rock trap ditch	9	
<input type="checkbox"/> Others (please specify)	<input type="checkbox"/> Other measures (please specify)		
Attachments: <input type="checkbox"/> Site location plan <input type="checkbox"/> Photographs <input type="checkbox"/> Rock joint discontinuity data <input type="checkbox"/> Plans, sketches/drawings showing the potential unstable rock blocks (including volume, geometry, rock type, weathering, etc) and other potential instability problems <input type="checkbox"/> Plan, sketches/drawings showing locations/layout/key dimensions of the proposed prescriptive measures			
Designed by:	Signature:	Checked by:	Signature:
Post:	Date:	Date:	Date:

* Delete where appropriate

Figure 10 - Indicative Record Sheets for Prescriptive Measures Application to Rock Slopes (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 and post)	Initial (& Date)
<p>Post-construction Design Review Recommended: <input type="checkbox"/> Yes <input type="checkbox"/> No</p> <p>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)</p> <hr/>					
<p>Notes: (1) Sketches/drawings showing the design amendments should be attached.</p> <p>(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'.</p>					
Works commenced on	Works completed on	Works certified by (name and post)			

Figure 11 - Indicative Record Sheets for Prescriptive Measures Application to Rock Slopes (Sheet 2 of 2)

GEO PUBLICATIONS AND ORDERING INFORMATION

土力工程處刊物及訂購資料

A selected list of major GEO publications is given in the next page. An up-to-date full list of GEO publications can be found at the CEDD Website <http://www.cedd.gov.hk> on the Internet under "Publications". Abstracts for the documents can also be found at the same website. Technical Guidance Notes are published on the CEDD Website from time to time to provide updates to GEO publications prior to their next revision.

Copies of GEO publications (except maps and other publications which are free of charge) can be purchased either by:

writing to

Publications Sales Section,
Information Services Department,
Room 402, 4th Floor, Murray Building,
Garden Road, Central, Hong Kong.
Fax: (852) 2598 7482

or

- Calling the Publications Sales Section of Information Services Department (ISD) at (852) 2537 1910
- Visiting the online Government Bookstore at <http://bookstore.esdlife.com>
- Downloading the order form from the ISD website at <http://www.isd.gov.hk> and submit the order online or by fax to (852) 2523 7195
- Placing order with ISD by e-mail at puborder@isd.gov.hk

1:100 000, 1:20 000 and 1:5 000 maps can be purchased from:

Map Publications Centre/HK,
Survey & Mapping Office, Lands Department,
23th Floor, North Point Government Offices,
333 Java Road, North Point, Hong Kong.
Tel: 2231 3187
Fax: (852) 2116 0774

Requests for copies of Geological Survey Sheet Reports, publications and maps which are free of charge should be sent to:

For Geological Survey Sheet Reports and maps which are free of charge:

Chief Geotechnical Engineer/Planning,
(Attn: Hong Kong Geological Survey Section)
Geotechnical Engineering Office,
Civil Engineering and Development Department,
Civil Engineering and Development Building,
101 Princess Margaret Road,
Homantin, Kowloon, Hong Kong.
Tel: (852) 2762 5380
Fax: (852) 2714 0247
E-mail: sdccampbell@cedd.gov.hk

For other publications which are free of charge:

Chief Geotechnical Engineer/Standards and Testing,
Geotechnical Engineering Office,
Civil Engineering and Development Department,
Civil Engineering and Development Building,
101 Princess Margaret Road,
Homantin, Kowloon, Hong Kong.
Tel: (852) 2762 5345
Fax: (852) 2714 0275
E-mail: ykhui@cedd.gov.hk

部份土力工程處的主要刊物目錄刊載於下頁。而詳盡及最新的土力工程處刊物目錄，則登載於土木工程拓展署的互聯網網頁 <http://www.cedd.gov.hk> 的“刊物”版面之內。刊物的摘要及更新刊物內容的工程技術指引，亦可在這個網址找到。

讀者可採用以下方法購買土力工程處刊物(地質圖及免費刊物除外):

書面訂購

香港中環花園道
美利大廈4樓402室
政府新聞處
刊物銷售組
傳真: (852) 2598 7482

或

- 致電政府新聞處刊物銷售小組訂購 (電話: (852) 2537 1910)
- 進入網上「政府書店」選購，網址為 <http://bookstore.esdlife.com>
- 透過政府新聞處的網站 (<http://www.isd.gov.hk>) 於網上遞交訂購表格，或將表格傳真至刊物銷售小組 (傳真: (852) 2523 7195)
- 以電郵方式訂購 (電郵地址: puborder@isd.gov.hk)

讀者可於下列地點購買1:100 000, 1:20 000及1:5 000地質圖:

香港北角渣華道333號
北角政府合署23樓
地政總署測繪處
電話: 2231 3187
傳真: (852) 2116 0774

如欲索取地質調查報告、其他免費刊物及地質圖，請致函:

地質調查報告及地質圖:

香港九龍何文田公主道101號
土木工程拓展署大樓
土木工程拓展署
土力工程處
規劃部總土力工程師
(請交:香港地質調查組)
電話: (852) 2762 5380
傳真: (852) 2714 0247
電子郵件: sdccampbell@cedd.gov.hk

其他免費刊物:

香港九龍何文田公主道101號
土木工程拓展署大樓
土木工程拓展署
土力工程處
標準及測試部總土力工程師
電話: (852) 2762 5345
傳真: (852) 2714 0275
電子郵件: ykhui@cedd.gov.hk

MAJOR GEOTECHNICAL ENGINEERING OFFICE PUBLICATIONS

土力工程處之主要刊物

GEOTECHNICAL MANUALS

Geotechnical Manual for Slopes, 2nd Edition (1984), 300 p. (English Version), (Reprinted, 2000).

斜坡岩土工程手冊(1998)，308頁(1984年英文版的中文譯本)。

Highway Slope Manual (2000), 114 p.

GEOGUIDES

Geoguide 1 Guide to Retaining Wall Design, 2nd Edition (1993), 258 p. (Reprinted, 2000).

Geoguide 2 Guide to Site Investigation (1987), 359 p. (Reprinted, 2000).

Geoguide 3 Guide to Rock and Soil Descriptions (1988), 186 p. (Reprinted, 2000).

Geoguide 4 Guide to Cavern Engineering (1992), 148 p. (Reprinted, 1998).

Geoguide 5 Guide to Slope Maintenance, 3rd Edition (2003), 132 p. (English Version).

岩土指南第五冊 斜坡維修指南，第三版(2003)，120頁(中文版)。

Geoguide 6 Guide to Reinforced Fill Structure and Slope Design (2002), 236 p.

GEOSPECS

Geospec 1 Model Specification for Prestressed Ground Anchors, 2nd Edition (1989), 164 p. (Reprinted, 1997).

Geospec 2 Model Specification for Reinforced Fill Structures (1989), 135 p. (Reprinted, 1997).

Geospec 3 Model Specification for Soil Testing (2001), 340 p.

GEO PUBLICATIONS

GCO Publication No. 1/90 Review of Design Methods for Excavations (1990), 187 p. (Reprinted, 2002).

GEO Publication No. 1/93 Review of Granular and Geotextile Filters (1993), 141 p.

GEO Publication No. 1/96 Pile Design and Construction (1996), 348 p. (Reprinted, 2003).

GEO Publication No. 1/2000 Technical Guidelines on Landscape Treatment and Bio-engineering for Man-made Slopes and Retaining Walls (2000), 146 p.

GEOLOGICAL PUBLICATIONS

The Quaternary Geology of Hong Kong, by J.A. Fyfe, R. Shaw, S.D.G. Campbell, K.W. Lai & P.A. Kirk (2000), 210 p. plus 6 maps.

The Pre-Quaternary Geology of Hong Kong, by R.J. Sewell, S.D.G. Campbell, C.J.N. Fletcher, K.W. Lai & P.A. Kirk (2000), 181 p. plus 4 maps.

TECHNICAL GUIDANCE NOTES

TGN 1 Technical Guidance Documents