PERFORMANCE ASSESSMENT OF GREENING TECHNIQUES ON SLOPES

GEO REPORT No. 183

B.L.S. Lui & Y.K. Shiu

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

PERFORMANCE ASSESSMENT OF GREENING TECHNIQUES ON SLOPES

GEO REPORT No. 183

B.L.S. Lui & Y.K. Shiu

This report was originally produced in July 2004 as GEO Special Projects Report No. SPR 6/2004

Table of Contents
Table of Contents
Table of Contents
Table of Contents

First published, May 2006

Prepared by:

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

Table of Contents
Table of Contents
Table of Contents
Table of Contents

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
May 2006

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Table of Contents

Table of Contents
Table of Contents
Table of Contents

FOREWORD

As one of the initiatives to enhance the aesthetics of man-made slopes, different greening techniques have been tried out on slopes. A study has been carried out to review the performance of these techniques. The study includes assessment of the growth condition of vegetation on slopes where the greening techniques have been applied, and evaluation of the engineering performance of the techniques.

This report describes the details and results of the study. It also provides recommendations for improvements of the greening techniques.

The study was carried out by Ms Becky L S Lui and Mr Y K Shiu. Dr Billy C H Hau of the University of Hong Kong assessed the growth condition of vegetation on slopes. The study was overseen by a Working Group comprising representatives from various Government departments. Their contributions are gratefully acknowledged.

(W K Pun)
Chief Geotechnical Engineer/Standards & Testing

Table of Contents
Table of Contents
Table of Contents
Table of Contents

ABSTRACT

A study has been carried out to assess the performance of various greening techniques applied on 100 slopes.

Growth condition of vegetation on the slopes and engineering performance of the greening techniques were assessed in the study. Factors considered in the vegetation growth assessment included sustainability, health condition, coverage and diversity of the vegetation on the slopes. In the engineering performance assessment, factors considered included structural integrity of the planting stratum and effectiveness of erosion control of the greening techniques.

Inspections of the slopes and survey of the vegetation growth were carried out between September 2002 and November 2003. In addition, a review of case histories of previous studies on different techniques was also conducted.

Results of the study show that the performance of the products used in different techniques varied. Among the same type of technique, some products performed better than others. Many of the techniques have been used only for a few years in Hong Kong, their ability to sustain vegetation growth in the long term cannot be fully established.

Recommendations on improvements to different areas on the application of the greening techniques are provided.

CONTENTS

Table of Contents
Table of Contents
Table of Contents

Page No.

Table of Contents
Table of Contents
Table of Contents

Table of Contents
Table of Contents
Table of Contents

1. INTRODUCTION

As part of the recent initiatives to enhance the aesthetics of man-made slopes, the Geotechnical Engineering Office (GEO) of the Civil Engineering and Development Department and other slope maintenance departments have been applying different greening techniques on slopes. A study has been undertaken to review the performance of these techniques.

This study includes assessment of the growth condition of vegetation on slopes where the greening techniques have been applied, and evaluation of the engineering performance of the techniques. Dr Billy C H Hau of the University of Hong Kong has been engaged by the GEO to assess the growth condition of vegetation.

To oversee the study, a working group with representatives from the GEO and nine other government departments was established in September 2002. The membership of the working group is given in Appendix A.

This report describes the details and findings of the study, together with recommendations for improvements. It should not be construed as endorsement or rejection of any techniques or products.

2. DATABASE FOR GREENING TECHNIQUES

A common database called “Greening Methods on Slopes” has been established since July 2002. It contains information on the use of various proprietary greening techniques. It does not include the use of erosion control mats because they have already been widely used. The aim of the database is to share information and experience among government departments on the use of the greening techniques.

The database is updated and disseminated to relevant government departments at quarterly intervals. Up to the end of March 2004, the database contained information on about 350 slope features treated with 27 different greening products. A typical sample of the database is given in Table 1.

3. OTHER RELATED STUDIES

Reviews of various trials and methods of applying vegetation on slopes were reported by Li et al (2000) and Halcrow (2001). In addition, a consultant to Highways Department (HyD), Urbis Limited, conducted a review on the interim performance of various soft landscape treatments applied on HyD’s shotcreted slopes. The findings are presented in Urbis (2003).

Relevant information and results of these reviews have been taken into account in this study.

Table of Contents
Table of Contents
Table of Contents
Table of Contents

4. GREENING TECHNIQUES STUDIED

4.1 General

Twenty-four proprietary products for slope greening were reviewed in this study and they are listed in Table 2. The products reviewed are broadly classified into the following two groups of techniques:

(a) Group 1 Techniques: Products that are applied on slopes with a hard surface cover,

(b) Group 2 Techniques: Products that are used directly on exposed soil slope surface.

4.2 Group 1 Techniques

4.2.1 General

A total of 16 proprietary products have been used under the Group 1 techniques. They are broadly classified into the following four techniques according to their general characteristics:

(a) mulching system

(b) cellular system

(c) reinforced soil

(d) bio-engineering method

4.2.2 Mulching System

The following eight proprietary products are classified under the technique of mulching system:

- Biocrete
- Hong Kong Mulching
- NFY Hydro-Mulching
- "On" Method
- Rocksgrass
- CMS-ML Green System
- Soil Panel
- Toyo-Mulching

This technique generally involves applying one or more layers of soil mix or mulch hydraulically or by hand on slope surface. The finished surface of the soil mix/mulch is protected with a layer of erosion control mat. The soil mix in a few products is reinforced by a wire mesh. Two of the products involve the use of multiple layers of soil mix

Table of Contents Table of Contents Table of Contents Table of Contents

interbedded with erosion control mats. Figures 1 to 8 illustrate the typical details and construction methods of the eight greening products. Record photographs of slopes with the products applied are also shown in the Figures.

4.2.3 Cellular System

The following six proprietary products are classified under the technique of cellular system:

- Eco-link
- Instant Evergreen System
- NFY Eco-MP System
- NFY Hydro Planter
- NFY Mulching Panel
- Terra Cell

The above products contain compartments of soil mix or mulch installed on the slope surface. Figures 9 to 14 illustrate the details and construction methods of the products as well as views of slopes with the products applied.

4.2.4 Reinforced Soil

The proprietary product, Geofiber, is classified under the technique of reinforced soil. This product uses synthetic fiber to strengthen the soil mix. Figure 15 illustrates the details and construction methods of the product.

4.2.5 Bio-engineering Method

One single proprietary product, GW-Biodrains System, is classified under the technique of bio-engineering method. This product uses the deep geotropic rooting characteristics of selected *Vetiveria zizanioides* (Vetiver Grass, 香根草) to strengthen the slope. Figure 16 illustrates the typical details and construction methods of the product.

4.3 Group 2 Techniques

4.3.1 General

Group 2 techniques include erosion control mats that are used directly on exposed soil slope surface. The products are normally applied together with hydroseeding.

In Hong Kong, it is a common practice to classify erosion control products into two types, which are biodegradable and non-biodegradable. Indeed, some products are made of geosynthetics that are non-biodegradable but photodegradable. Similar to the biodegradable products, photodegradable products have short longevity. In this study, a better and more accurate classification proposed by the Erosion Control Technology Council (ECTC) has been

Table of Contents
Table of Contents
Table of Contents
Table of Contents

adopted. In this classification, erosion control products are divided into two main categories: temporary degradable products and long-term non-degradable products (ECTC, 2003).

The products under Group 2 techniques are divided into the following three types according to their general characteristics:

(a) temporary degradable erosion control mat,

(b) long-term non-degradable erosion control mat, and

(c) long-term non-degradable erosion control mat in conjunction with steel wire mesh.

4.3.2 Temporary Degradable Erosion Control Mat

The following three proprietary products are classified under the technique of temporary degradable erosion control mats:

- Soil Guard
- Coir
- Soil Saver.

In the product of "Soil Guard", material including wooden fiber and seeds are applied hydraulically on exposed soil slope surface to form an erosion control mat-like cover. Figure 17 illustrates the details and construction methods of this product. The material is degradable organically.

The other two products, Coir and Soil Saver, are rolled erosion control mats made of coconut fiber and jute fiber respectively. Both products are degradable organically. Hydroseeding is used in conjunction with these mats on slopes. Figures 18 and 19 illustrate the anchorage details of these products as well as views of slopes treated with the products.

4.3.3 Long-term Non-degradable Erosion Control Mat

The following five proprietary products are classified under the technique of long-term non-degradable erosion control mats:

- Enkamat
- Kangaroo Mat
- Miramat TM8
- Multimat
- Tensarmat/EM4.

The products are made of geosynthetic materials. Hydroseeding is applied in conjunction with these mats on slopes, except Kangaroo Mat for which fertilizer and seeds are prefabricated onto the mat and no hydroseeding is needed. Figures 20 to 24 illustrate the anchorage details of these products as well as views of slopes on which the products are used.

Table of Contents
Table of Contents
Table of Contents
Table of Contents

4.3.4 Long-term Non-degradable Erosion Control Mat in Conjunction with Steel Wire Mesh

Some slopes in the study are installed with the following long-term non-degradable erosion control mats in conjunction with steel wire mesh:

- Enkamat
- Miramat TM8
- Multimat
- Tensarmat/EM4.

Figures 25 to 28 illustrate the anchorage details of the steel wire mesh and the erosion control mats. Views of slopes applied with this assembly are shown on the Figures.

5. ASSESSMENT APPROACH

5.1 Aspects to be Assessed

The performance of the greening techniques is assessed based on the following two aspects:

(a) Growth of vegetation - the growth performance and sustainability of the vegetation planted on slopes on which the techniques have been applied. The growth performance includes health condition, coverage, dominance and diversity of vegetation.

(b) Engineering performance - structural integrity and effectiveness of erosion control of the greening techniques.

5.2 Selection of Slopes

As the first inspection of slopes for the vegetation assessment of the study commenced in September 2002 as discussed in Section 6.1 below, the man-made slopes selected for the study are those which were completed with application works of the greening products in or before September 2002, except two slopes completed in December 2002 and January 2003 respectively in view of the small number of slopes applied with those products. Slopes with application works of greening products completed after this date are not covered in the study.

A total number of 100 slopes have been examined for this study. Seventy-nine slopes using Group 1 techniques and one slope using Group 2 technique have been selected from the database of “Greening Methods on Slopes” for assessment. Another 20 slopes treated with Group 2 techniques have been selected for assessment from the Slope Information System database of the GEO. Details of the slopes are given in Tables B1 to B5 in Appendix B.

Some of the greening products have been applied on many slopes whilst the other only on a few slopes. If a product has been applied on three or less slopes, all the slopes were selected. For the products that have been used on four or more slopes, the following factors were considered in the selection:

Table of Contents
Table of Contents
Table of Contents
Table of Contents

(a) slope gradients,

(b) slope orientations,

(c) degree of isolation of the slope from natural terrain or large woodland,

(d) date of application of greening technique, and

(e) access to the site.

The slope selection was carried out in such a way that slopes with different gradients, orientations, degree of isolation and date of application were chosen. The objective of this is to determine whether any of the factors have significant influence on the performance of the greening techniques. Also slopes with difficult access for detailed investigation (e.g. those along highway where parking or slowing down of vehicles is not allowed) were not selected.

6. METHODOLOGIES FOR ASSESSMENT OF GREENING TECHNIQUES

6.1 Methodology for Assessing Vegetation Growth

A team led by Dr Billy Hau of the University of Hong Kong assisted the GEO in assessing the growth performance and sustainability of the vegetation on the slopes. The assessment process included:

(a) review of the information on the individual products obtained from the suppliers,

(b) inspection of slopes on which the products have been used, and

(c) statistical analysis of field data collected from the inspections.

In order to evaluate the growth condition of the vegetation under different climatic conditions and the ability of the vegetation to regenerate, the slope inspections were performed in the following time periods:

First Inspection	September to December 2002
Second Inspection	April to June 2003
Third Inspection	October to November 2003

Out of the 100 slopes selected, 84 slopes were inspected twice. Thirteen slopes were inspected three times to re-confirm the findings of the two previous inspections. The remaining three slopes were inspected once because maintenance works were being carried out on one slope at the time of inspection whereas another two slopes were found to have been re-hydroseeded after the first inspection, thus making the interpretation of the data impossible.The inspections comprised the following activities:

Table of Contents
Table of Contents
Table of Contents
Table of Contents

(a) identification of vegetation type and species,

(b) assessment of vegetation dominance (percentage cover), maturity and general health condition,

(c) recording signs of natural regeneration, and

(d) collection of site and environmental data including,

   (i) gradient and orientation of the slopes,

   (ii) signs of seepage,

   (iii) direction and distance of the slopes from structures (such as tall buildings) and natural forest that would possibly shade the slope face,

   (iv) degree of isolation of the slopes from natural or semi-natural vegetation,

   (v) degree of exposure of the slopes to road traffic, and

   (vi) presence of natural stream courses on or adjacent to the slope.

Details of the methodology for the inspections are given in Hau and Leung (2004a). For ease of reference, they are reproduced in Appendix C.

In this study, species richness (S) is used to represent the total number of woody native or exotic plant species that are believed to have established naturally rather than planted on each of the slopes inspected since the application of the greening product. The naturally-occurring woody exotic species counted in arriving at "S" are the non-invasive species only. Furthermore, the Shannon diversity index (H), which is a common quantitative index of species diversity, has been used to describe the composition of the plant communities that have been established naturally on the slopes. The index "H" is calculated on the basis of "S" by the following equation (Begon et al, 1996):

$$H = -\sum_{i=1}^{S} P_i \ln P_i$$

where P_i = the number of plants of the ith species in the sample / the total number of plants in the sample

A higher value of H indicates that the plant community has more diverse species. An example of how to calculate H is given in Appendix D.

Based on the data collected from the field inspections, parameters including percentage of slope area with vegetation cover, species richness and Shannon diversity index are derived for each slope studied. Details are given in Hau and Leung (2004a).

Table of Contents
Table of Contents
Table of Contents
Table of Contents

6.2 Methodology for Assessing Engineering Performance

The process of engineering performance assessment of the greening techniques included:

(a) desk study of the installation details of the greening techniques,

(b) review of previous relevant assessments, and

(c) inspections of the slopes to check for signs of distress.

In the assessment, at least two slopes were inspected for each greening product, except for those products which had been applied on only one slope. The selection of slopes for the engineering performance assessment was conducted after the first inspection of the 100 slopes for the vegetation assessment had been carried out. For products used on more than two slopes, at least one slope with higher vegetation cover and at least one with lower vegetation cover were selected for the engineering performance assessment. This is to ensure that the engineering structures of products on slopes with good and poor vegetation cover can be inspected. A total of 47 slopes were inspected during the period from May 2003 to March 2004.

The engineering performance of the greening products are assessed on the basis of the following two criteria:

(a) Structural Integrity
- stability of mulch/soil mix
- stability of the anchorage of the product to slope surface

(b) Erosion
- Effectiveness of erosion control

7. ASSESSMENT

7.1 General

Details of the assessment of vegetation growth are presented in Hau and Leung (2004a). Tables 3 to 9 summarize the results. More details are given in Appendices E and F for Group 1 and 2 techniques respectively.

Tables 10 to 15 summarize the results of engineering performance assessments of slopes applied with the greening products. Table 16 summarizes the types of wire meshes and erosion control mats provided for products categorized under the techniques of mulching system, cellular system and reinforced soil. Plates 1 to 28 illustrate the engineering condition of the products during the inspections. More details are given in Appendices E and F for Group 1 and 2 techniques respectively.

Table of Contents
Table of Contents
Table of Contents
Table of Contents

7.2 Group 1 Techniques - Mulching System

7.2.1 General

The technique of the mulching system is more commonly used than the other techniques. Over 60% of the slopes in the “Greening Methods on Slopes” database (Section 2) are treated with this technique. The popularity of the technique is mainly because of its quick and easy installation. Most products can be applied easily on uneven slope profiles to form smooth finished surfaces. They can provide a rapid and dramatic improvement in visual quality (Martin et al, 2001).

Except the “On” Method which was trialled in Hong Kong as early as 1984 (Lee et al, 1999), all the other products under the mulching system have only been used in Hong Kong for several years.

The products like Biocrete, Hong Kong Mulching, NFY Hydro-Mulching, “On” Method and Toyo-mulching have essentially been evolved from the general technique of hydro-mulching. According to Hyperdictionary (2003), hydro-mulching is defined as “seeding of grasses, mixed with fertilizer, a wood pulp mulch, and a tackifier to stick the mix to the ground, applied by a machine blower in a wet condition to exposed, denuded slopes or embankments. (If no mulch is used, it is called hydro-seeding.)”. Hydro-mulching was developed in 1960s in other countries as an improved method of hydro-seeding and conventional dry mulching techniques. The use of hydro-mulching has been generally limited to gentle slopes with low water flow because the mulches have short life span and very low tensile and shear strength (Lancaster & Austin, 1994 and Allen, 1996).

If mulches are applied on soil surface, they can have many advantages such as reducing soil erosion on slopes, conserving moisture in the soil, reducing extreme fluctuations of soil surface temperature, adding organic matter to the soil, and preventing weed growth (Rickerson, 1995 and Rose & Smith, 2004). The mulching products examined under this study are applied on the hard cover of slopes and so they do not offer these advantages to the soil of the slopes. They mainly serve as a medium for planting of vegetation. Although the products are developed and modified from the conventional hydro-mulching; many ingredients have been incorporated (such as steel mesh, soil, cement and erosion control mat) for improving the properties and strength of the mulch/soil mix.

7.2.2 Case Histories of Previous Studies

Halcrow (2001) carried out a review on some landscape treatments on slopes in Hong Kong. Toyo-mulching and “On” method were described in the review. Halcrow (2001) commented that whilst Toyo-mulching may provide a useful means of grassing steep rock slopes or shotcreted slopes, the long-term establishment of the grass may be problematic. For “On” method, the review pointed out that with the cement binding agent, this technique was liable to crack and lose its integrity.

Urbis (2003) carried out a review for the Highways Department (HyD) on the use of 15 proprietary soft landscape treatment under trial on 166 HyD’s slopes. Results of the review indicated that Toyo-mulching was one of the treatments that had the most consistent results in terms of vegetation coverage and health. For treatments such as Soil Panel,

Table of Contents
Table of Contents
Table of Contents
Table of Contents

modifications to the treatments are required before they are to be included in any future trials. The modifications include measures to prevent soil washout and reduce the visibility of the supporting system.

Urroz & Israelsen (1995) reported results of flume tests performed on eleven different hydromulches and eight different erosion control mats. The purpose of the test was to compare the performance of the hydromulches and erosion control mats in terms of soil loss reduction and vegetation growth under simulated rainfall and sunlight conditions. In the test, the hydromulches and mats were applied onto soil surface. According to the test results, the vegetation with erosion control mats generally performed better than the plants in hydromulches, in terms of plant characteristics and germination rate.

7.2.3 Results of the Present Study

From the results of vegetation assessment made during the three inspections (Table E1 in Appendix E), most of the slopes applied with Toyo-mulching or Rocksgrass had consistently high percentage of healthy vegetation cover, above 80% for over half of the slopes studied. For Hong Kong Mulching, the two slopes studied were also noted to have healthy vegetation cover of more than or around 70% in the first and second inspections. Owing to the small sample size of the product, it is difficult to determine its performance with certainty.

Healthy vegetation cover recorded on slopes treated with Soil Panel, CMS-ML Green System, Biocrete and “On” Method were relatively low, typically ranged from 0% to 54%, except values from a slope with “On” Method of 84% and another with Soil Panel of 78%. The products, Toyo-mulching and Rocksgrass, are therefore considered to have better vegetation cover under the technique of mulching system.

In all the products, the soil/mulch mix layers are thin (normally less than 100 mm thick) and so they cannot support large plants. From an engineering point of view, the soil/mulch mixes of the mulching systems studied are generally weak in strength. They rely on the steel meshes or geosynthetic mats to hold them in place. In some products, cement or other bonding agents are added to increase the strength.

Signs of deterioration, commonly surface cracks associated with desiccation and down slope movement of the mulch/soil mixes, were observed on many slopes (Plates 1, 4 and 6). Other problem included bulges of the mixes at the lower parts of the slopes (Plate 8). They highlight the need for more structural support to the products, especially Biocrete, NFY Hydro-Mulching and “On” Method. For Soil Panel, stronger panels should be provided for the mulch/soil mix to improve the system integrity.

Some products, namely NFY Hydro-Mulching and Toyo-mulching, use temporary degradable mat for erosion protection irrespective of the gradients of the slope. The cracked mulch/soil mix can be washed away after the mat has decomposed, especially on steep slopes and at areas of high flow concentration. The use of long-term non-degradable mats helps address this problem. Edges of some greening products were found to be eroded, especially for those adjacent to stepped channels.

Table of Contents
Table of Contents
Table of Contents
Table of Contents

The engineering performance of Toyo-mulching, Rocksgrass and CMS-ML Green System was found to be better than the other mulching products.

7.3 Group 1 Techniques - Cellular System

7.3.1 Case Histories of Previous Studies

Results of the previous review carried out by Urbis (2003) indicated that, for treatments such as Eco-link, NFY Hydro Planter, NFY Mulching Panel and Instant Evergreen System, modifications to the treatments are required. The modifications include measures to prevent soil washout, to improve movement of water and nutrients between cells and to reduce the visibility of the supporting system.

7.3.2 Results of the Present Study

From the results of the vegetation assessment (Table E2), the percentages of healthy vegetation cover recorded on the slopes applied with Eco-link, NFY Eco-MP System and Terra Cell were either consistently satisfactory in all the inspections or improving between the inspections. Only minor signs of deterioration were observed on these products. However, owing to the small sample size of these products, it is difficult to conclude the performance and sustainability of these products with certainty.

The products of Instant Evergreen System allow vegetation to establish at nursery areas before the panels of soil mix are installed on the slope face. They provide instant greening effect to the slope. However, the growth performance of the planted herb *Sedum tetractinum* (四芒景天) on the product was found to be variable.

For both the Instant Evergreen System and NFY Mulching Panel, the small isolated panels of soil mix tend to dry up quickly and result in unhealthy plant growth with time. Vegetation growing on the individual panels is therefore more susceptible to desiccation during dry season. The large exposed surface areas of the panels may lead to a high rate of surface evaporation. In some cases, the weak soil mix in the panels disintegrated as a result of desiccation (Plate 13a). Thus, if *Wedelia trilobata* (三裂葉蟛蜞菊) or other ground covering plants are able to establish and maintain a dense coverage, they may help retain soil moisture. Without a dense vegetation cover, the wire mesh forming the gabions for the product are very visible and may not be visually pleasing. Drought tolerant species may have a higher chance of healthy growth in a longer term. In addition, surface erosion was noted locally on the mulch/soil mix of NFY Mulching Panel (Plate 13c).

NFY Hydro Planter has been used on one slope. The performance of the technique is unsatisfactory in terms of vegetation growth and cover.

7.4 Group 1 Techniques - Reinforced Soil

7.4.1 Case Histories of Previous Studies

According to the review carried out by Urbis (2003), slopes treated with Geofiber

Table of Contents
Table of Contents
Table of Contents
Table of Contents

showed successful results in terms of vegetation coverage and health.

7.4.2 Results of the Present Study

Results of the vegetation assessment (Table E3) show that the slopes applied with the technique Geofiber generally had satisfactory performance of healthy vegetation cover, especially with the planting of *Wedelia trilobata*. On one of the slopes inspected, a number of cracks were identified on the mulch layer of the product (Plate 15).

7.5 Group 1 Techniques - Bio-engineering Method

7.5.1 Case Histories of Previous Studies

Results of the review carried out by Urbis (2003) indicated that the Biodrains was one of the treatments that had the most consistent results in terms of vegetation coverage and health.

7.5.2 Results of the Present Study

Results of the vegetation assessment (Table E4) show that the healthy vegetation covers recorded on all slopes applied with the product GW-Biodrains System were consistently satisfactory in both inspections or improving between the inspections. According to the local agent's recommendation (GreenWalls, 2003), old flowering stalks or tillers of the Vetiver grass should be cropped twice a year in order to provide space for the new ones. If cropping is carried out regularly, this product is considered to be self-sustainable in terms of vegetation cover. However, the cropping would involve substantial amount of work. Besides, the concrete slope cover will be exposed after cropping, leading to temporary visual impact. The local agent advised that the product GW-Biodrains System had subsequently been improved in such a way that the frequency of croppings could be reduced from twice a year to almost once every two years. The improved product has not been reviewed in the present study. Slope maintenance parties may programme their slope inspection and routine maintenance work to be carried out during the cropping period. A drawback of the product is the monotonous appearance of using the single species of Vetiver grass which is not a native species (Maunsell, 2003).

7.6 Group 2 Techniques

7.6.1 General

The proprietary products under Group 2 techniques are erosion control products. Soil Guard is a product that is hydraulically applied on to slope surface together with grass seed. The other products are mats manufactured or fabricated into rolls. They are used with hydroseeding. Four of the rolled products, Enkamat, Miramat TM8, Multimat and Tensarmat/EM4, have also been used in conjunction with steel wire mesh on a few slopes. Classification of rolled erosion control mats is provided in Appendix G.

Table of Contents
Table of Contents
Table of Contents
Table of Contents

As all the products are specially designed for controlling rain-induced erosion, an understanding of such erosion mechanism would be useful for assessing the performance of the products. A discussion on the rain-induced erosion is given in Appendix G.

7.6.2 Case Histories of Previous Local Studies on the Performance of Erosion Control Mats

Forth (1987) reported the result of performance assessment of Tensarmat which was applied on a 45 m high decomposed granite cut slope with slope angle of about 45°. Areas covered with Tensarmat were found to have higher grass cover and less surface erosion than areas without Tensarmat.

Li et al (2000) reported a study on the performance of four erosion control mats, namely Tensarmat, Enkamat, Miramat TM8 and Erolan. In the study, the four products were used at a steep cut slope formed in completely decomposed granite in 1992 and their performance was monitored till 2000. Monitoring results showed that the erosion control mats were ineffective if not securely fixed to slope surface. Among the four products studied, Tensarmat was reported to have provided better erosion control.

Li et al (2000) gave a brief account of a trial in using Soil Saver on a steep soil cut slope with angle up to 50°. Soil Saver degraded within about 2 years. The product was found to be useful in providing temporary surface protection and enhancing the establishment of vegetation.

Halcrow (2001) carried out a general review of the use of synthetic erosion control mats with hydroseeding or planting on slopes. Result of the review indicated that the mats were relatively successful in controlling erosion even though minor problems including wash-out and difficulty of plant establishment still occurred. It was pointed out in the review that owing to the decomposition of the degradable erosion control mats within a few years, the mats could not be used as a substitute for synthetic mats where there are potential long-term erosion problems.

7.6.3 Case Histories of Overseas Studies on the Performance of Erosion Control Mats

Comparative experiments have been carried out in other parts of the world to quantify the effect of various erosion control products. Rickson (1995) reported results of experiments performed to study the effect of a number of erosion control products on soil detachment by raindrop impact without runoff. Some of the products tested are also covered under the present study (e.g. Geojute, Enkamat and Tensarmat). Measurements of soil loss resulting from rainfall intensities of 35 mm/h and 115 mm/h were presented. Result obtained from each product tested was bench-marked against exposed soil. Figure 30 shows the results of the experiments performed on sandy loam soil. There were variations in the performance of the various products tested and the performance was dependent on the intensity of the rainfall. The products were generally more effective in reducing raindrop impact under high intensity rainfall than low intensity rainfall. One of the findings of the tests was the poor performance of buried products (i.e. mats with backfilled soil) in controlling soil detachment by raindrop impact. According to Rickson (1995), in some cases the buried products gave higher detachment rates than those observed for the unprotected control soil. This was due to the

Table of Contents
Table of Contents
Table of Contents
Table of Contents

reason that the backfilled soil was loose and highly erodible.

Rustom and Weggel (1993) presented results of comparative tests performed on various erosion control products obtained using a rainfall/runoff/infiltration system. The products were evaluated on their performance in the absence of vegetation, unfilled with soil, fastened to bare soil of a slope. Surface runoff and sediment yield resulting from rainfall intensities of 50, 125 and 200 mm/hr on the slope (1 vertical on 2.5 horizontal) were measured. Results obtained for each erosion control system were compared with results measured on unprotected soil. Figure 31 shows the test results which indicate that each product provided a different degree of soil protection. Some products were more successful in reducing raindrop impact and soil detachment while others were successful in slowing the rate of overland flow. For products that were relatively stiff and did not conform closely to ground surface, cavities were observed beneath the mats. In discussing the test results, Rustom and Weggel (1993) stated that because of the high capacity of Geojute fibers to absorb and hold water, the Geojute's heavy weight once saturated kept it from moving and allowed it to hold to the soil surface underneath. The soil was subject to little erosion. With regard to Enkamat and Miramat TM8 products tested, they provided less protection against detachment by rainfall impact because they had a relatively large open structure.

Similar observations were made by Gazzufi et al (1994) from laboratory tests performed with a rainfall simulator. Natural fibre products (such as Geojute) have the characteristics of high water absorption capacity and good soil contact when wetted and such characteristics help reduce erosion of soil. For products that do not have the capacity of absorption nor adherence to the ground, they do not reduce flow velocity.

It should be noted that different erosion control products are designed to achieve different objectives. For example, some products are intended for use with vegetation and to provide interlocking for plant root system. A true assessment of their performance would require testing under the conditions they are intended.

7.6.4 Results of the Present Study

7.6.4.1 General

Results of the vegetation growth assessment showed that there was no significant difference in vegetation cover between slopes treated with different products, and that the products performed more or less the same both in sustaining slope vegetation cover and in supporting the diversity of naturally occurring plant species.

Surface erosions below tree canopies were observed on a number of exposed slopes, see Plate 26. They are believed to be caused by significant impact energy from high concentration of large water drops falling from the canopies, as discussed in Appendix G.

7.6.4.2 Temporary Degradable Erosion Control Mat

From the slope inspections conducted in this study, the temporary degradable erosion control mats in some cases had decomposed before the vegetation was established to such a state that it could effectively protect the soil. This emphasises that the temporary mat must

Table of Contents
Table of Contents
Table of Contents
Table of Contents

have service life sufficiently long to allow vegetation to establish and sustain.

On fill slope no. 11NW-D/FR 40 where Coir erosion control mat was used, vegetation did not grow along the strips where two layers of the mat overlapped. Erosion gullies were found under the mat along the overlaps. This indicates that the thick layers of the mat at the overlaps had suppressed plant growth. The condition of the slope at the time of inspection is shown in Plate 17.

7.6.4.3 Long-term Non-degradable Erosion Control Mat

On cut slope no. 7SE-C/C42, Multimat was laid on the slope surface and the mat was backfilled with soil. At the time of inspection, a lot of the backfilled material had been washed away. The mat has a large open structure. This makes it less effective in protecting the erodible backfill material (Plate 21).

Erosions of different degree of seriousness were apparent on some slopes with non-degradable erosion control mats. Common problem was that the mats were not pegged securely onto the slope surface and water got under the mats and caused soil erosion. For high and steep slopes, surface erosions were still found, indicating that erosion cannot be completely eliminated in such cases.

7.6.4.4 Long-term Non-degradable Erosion Control Mat in Conjunction with Steel Wire Mesh

Use of steel wire mesh in conjunction with non-degradable erosion control mat provides a more effective means of controlling surface erosion. The steel mesh is usually stretched slightly and anchored securely onto concrete nail heads. This helps ensure that the erosion control mat is in good contact with the slope surface.

Minor erosion was apparent on steep slopes. However, the eroded soil was trapped by the erosion control mat and the steel mesh. The trapped material acted like a protective layer to minimize further erosion.

Similar method was also used in other countries. Rüegger et al (2001) described the use of high-tensile wire mesh in combination with soil nails for preventing local instabilities. The method makes use of the high tensile capacity of the wire mesh to retain the soil between soil nails. The mesh is fixed to the soil nail heads. The force required to support the soil is transmitted to the soil nails through the connections of the mesh and the nail heads. Figure 32 shows the mechanics.

8. DISCUSSION

8.1 Sustainability

8.1.1 Group 1 Techniques

For almost 70% of the slopes inspected, the greening products have only been applied for less than three years. Furthermore, some products have been used on a few slopes only. As such the long-term performance of the products, in terms of the their engineering performance and their ability to sustain vegetation, is still uncertain. However, a few products have been identified to have consistently satisfactory vegetation cover in the study period. The products, namely Toyo-mulching, Rocksgrass and Geofiber, are considered to be able to sustain grass and ground cover plants, but their performance in sustaining woody species like shrubs needs to be further assessed. The product, NFY Eco-MP System, that allows vegetation to have direct contact with soil underneath the concrete cover is considered to be able to sustain vegetation including small woody species. For the same reason, GW-Biodrains System is considered to be a self-sustainable product in terms of vegetation cover provided that cropping is carried out regularly.

From the vegetation assessment results (Tables E1 to E4 of Appendix E) on Group 1 techniques, the "H" and "S" values of most slopes are low, indicating that there is little diversity in plant species. Another problem added to the situation is that as vegetation is not included under the 5-year warranty commonly provided by the suppliers for their products, it is only maintained by the suppliers within the 1-year establishment period after completion of the installation works for the greening products (except that the 5-year warranty provided by the supplier of GW-Biodrains System will cover the survivability and growth of Vetiver Grass). A way to achieve sustainable vegetation cover for Group 1 techniques is to diversify the vegetation species on these slopes. As man-made slopes are usually relatively steep, the use of native species which are adaptable to such condition is recommended. Some suitable native species are recommended in Section 10 below.

8.1.2 Group 2 Techniques

From the engineering performance assessment results (Appendix F) on slopes with Group 2 techniques, some temporary degradable erosion control mats decomposed in less than two years' time. On the other hand, the long-term non-degradable products are much more durable.

Table E5 shows the vegetation assessment recorded on slopes with Group 2 techniques. Much higher "H" and "S" values were obtained for slopes with Group 2 techniques than those with Group 1. This indicates that the techniques which are applied on soil surface can support more diversified vegetation cover. Group 2 techniques tend to have higher sustainability on the vegetation cover over Group 1 techniques because the vegetation planted can have direct contact with the soil. Hence, planting directly on the soil surface of slopes is preferred provided that there is no stability concern of the slopes.

For slopes treated with erosion control mats and steel wire mesh, sufficient hole sizes would need to be provided in the wire mesh for existing trees. Maintenance work which involves removing locally the wire mesh would also be necessary for accommodating trees that are established naturally on the slopes.

8.2 Environmental Factors

A number of environmental factors including slope gradient and orientation, degree of

Table of Contents
Table of Contents
Table of Contents
Table of Contents

isolation of the slopes from natural vegetation and degree of exposure of slopes to traffic, etc., were collected during the field surveys. The effect of these environmental factors on the vegetation growth has been analyzed statistically and the results are presented in Hau and Leung (2004a).

Among the various environmental factors, only the exposure to road traffic and the age of vegetation planted are found significant on the percentage of the total and exposed vegetation cover. The vegetation cover is found to decrease with increasing number of lanes on road next to which the slopes are located.

The diversity index of naturally occurring plant species, “H”, is found significantly higher on slopes shaded by tall trees and with increasing age of planting. All the other environmental factors have no statistical significance in respect of the vegetation cover and the diversity index.

8.3 Plant Species

From the field surveys carried out by Hau and Leung (2004a), the most common ground covering vegetation on the slopes are grasses including *Cynodon dactylon* (狗牙根) and/or *Paspalum notatum* (百喜草) as well as creepers and/or climbers mainly including *Wedelia trilobata* (三裂葉蟛蜞菊) and less commonly *Parthenocissus dalziellii* (異葉爬牆虎). Woody shrubs and trees are planted only on a few slopes.

W. trilobata is planted together with grass species on some slopes. It generally grows better than the planted grass species in most cases irrespective of the types of greening techniques. However, *W. trilobata* tends to dominate the slope cover due to its invasive characteristic and this often gives rise to monotonous appearance of the slope cover. Planting *W. trilobata* in agricultural areas and along wetland marshes, streams, canals, mangrove edges and coastal areas should be avoided, as it is known to be particularly invasive in such habitat types.

Observations made during slope inspections indicated that grasses and *W. trilobata* failed to establish on shaded areas. Heavily shaded slopes are therefore not ideal for these plants. Shade tolerant species should be planted.

The results of this study also show that the planted species on slopes, especially the grasses, are gradually replaced by the naturally established native and exotic plant species. According to Hau and Leung (2004a), natural succession is better on slopes with exposed slope surface treated with erosion control mats as they would lead to a more diverse and sustainable vegetation cover. The reason for this is that the vegetation is not cut off from the soil by a concrete cover. In fact, slopes treated with Group 1 techniques tend to support much less naturally established woody species than slopes treated with erosion control mats. It is because most of the products in Group 1 techniques generally have thin layers of organic matter, i.e. growth medium, which is only sufficient for planting ground covers such as grasses, creepers, climbers or smaller creeping herbs.

A total of 196 naturally occurring species, including 126 woody species and 70 non-woody species (herbs, grasses, ferns, etc.) have been recorded on the 100 slopes

Table of Contents
Table of Contents
Table of Contents
Table of Contents

inspected. Among these 196 species, 41 are exotic. According to Hau and Leung (2004a), the high diversity of woody plants especially trees recorded on the slopes has significant implications. Most of the products have only shallow depths of soil mixes (100 mm or less) which are adhered to the surface of sprayed concrete. The thin growing medium is not able to support tree growth. Hence, the establishment of tree seedlings from natural sources could give rise to maintenance problems. Trees growing on thin layers of mulch/soil mixes can fall over easily, causing damages to the greening products and posing threats to the public.

For the naturally occurring exotic plant species, 3 out of the 41 were first found in the second inspection and 2 were first found in the third inspection. For some species, the abundance and the number of slopes that they occurred were found much higher in the second inspection than in the first one. This indicates that these exotic species can adapt well to the environment of steep man-made slopes. They may spread quickly and smother or overgrow other plants, creating maintenance problems. For trees, any fast growing exotic species including *Lophostemon confertus* (紅膠木), *Eucalyptus* spp. (桉屬) and *Acacia* spp. (金合歡屬), etc. may cause maintenance problems. For invasive species, species of concern include *Mikania micrantha* (薇甘菊), *Ipomoea cairica* (五爪金龍), and *Leucaena leucocephala* (銀合歡), etc.

8.4 Cost of Application

Table 2 gives information on the order of costs per unit area for both Group 1 and Group 2 techniques. The unit costs for the Group 1 techniques range from $450 to $1,700 whereas those for the Group 2 techniques generally range from $30 to around $280. Apart from cost, other factors such as long-term performance of the products, special characteristics of the slope, surrounding environment and future maintenance should be considered in selecting which products or techniques to be used.

8.5 Specifications for Erosion Control Mats

The current particular specifications (PS) for LPM works require that the erosion control mats shall conform to a number of index properties such as minimum weight, thickness, tensile strength, and material types. These index properties may not be related to the performance of the products. As such, mats that meet the requirements for the index properties do not mean that they can perform well in respect of erosion control. The PS for erosion control mats is given in Appendix H.

Yeo (1999) comments that it would not be appropriate to specify the minimum weight as requirement because with the advancement of manufacturing technique, higher grade of synthetic material can now be produced with less unit weight. In a recent review, Martin (2001) states that "commonly-specified index properties, such as tensile strength and weight per unit area, are of doubtful relevance…but tend to be used by default". He goes on to state that "generic performance-based specifications need to be developed for erosion products on steep slopes".

The problem of lacking a performance-based specification is not unique to Hong Kong. Product user and specifier in other parts of the world also face the same challenge. As

Table of Contents
Table of Contents
Table of Contents
Table of Contents

pointed out by Sutherland (1998), specifiers are inundated with a variety of products which claim that they are most effective but such claims are unsubstantiated, and it is hard to compare different products on the basis of test results because the approaches and test conditions are not standardised.

According to Allen (1996) and Sutherland (1998), the erosion control industry has been facing the following problems:

(a) a wide variety of product types and materials make test standards difficult,

(b) specifiers often rely solely on index properties to determine which products to use but the relationship between these properties and actual performance is unknown,

(c) users lack the knowledge about the differences in quality between products and how best to define quality, and

(d) there is absence of standardised performance test procedures.

The Erosion Control Technology Council (ECTC) has been developing recommendations for index test methods for characterising a variety of rolled erosion control products. The ECTC has recently produced a manual called "Technical Guidance Manual: Terminology and Index Testing Procedures for Rolled Erosion Control Products". The Manual provides standard terminology and uniform testing standards for determining index physical and mechanical properties of the rolled erosion control products.

In addition, the ECTC has also produced a set of standard specification for the use of different types of the products in slope and channel applications. The standard specification is given in Appendix I. For temporary degradable products, the specification divides the products into four types, with subdivisions in each type. This reflects the large number of different products available in the market. If the products are to be used on slopes, the specification only specifies the maximum required values of "C" Factor and the minimum required tensile strength of products. There is no longer any requirement for index properties. The "C" Factor, which is a performance based test value, is the ratio of soil loss from rolled erosion control mat protected slope to ratio of soil loss from unprotected (control) plot in large-scale testing. The "C" Factor would allow the estimation of soil loss using the Universal Soil Loss Equation (Wischmwier & Smith, 1978). The standard specification also provides guidance on what types of product to be used for slopes of different gradients.

The standard specification proposed by ECTC for the long-term rolled erosion control mats (which are called Permanent Turf reinforcement Mats in the standard specification) is also given in Appendix I. Because these products are used on steep slopes and channels, performance test values for shear stress are also specified in the specification.

The latest version of the Standard Specifications for Construction of Roads and Bridges on Federal Highway Projects (FHWA, 2003) adopts the standard specifications recommended by ECTC. Its earlier version (FHWA,1996) relied heavily on index

Table of Contents
Table of Contents
Table of Contents
Table of Contents

properties.

The ECTC's standard specification has a number of advantages over the PS currently used in LPM works:

(a) it is performance based, avoiding confusion created by comparisons of index properties among products,

(b) it provides a systematic classification to group the broad range of products,

(c) it stipulates the types and standards of tests,

(d) it uses standardised terminology.

With suitable modifications to suit the condition in Hong Kong, the ECTC's standard specifications may be applicable to local slope works. The feasibility of this should be reviewed.

9. CONCLUSIONS

Based on the consideration of vegetation growth, there is a wide variation in the performance of different techniques and products. However, the overall performance of slopes treated with the different greening techniques was in general quite satisfactory during the study period. Tables 17 and 18 summarize the merits and limitations of different proprietary products categorized under Group 1 and 2 techniques respectively.

The results of this study show that four Group 1 greening products, namely, Toyo-mulching, Rocksgrass, Geofiber and GW-Biodrains System were relatively better than the other products in the same group in terms of supporting consistently high vegetation coverage. The engineering performance of the former three products was also satisfactory. Despite this, relevant improvements and points as discussed in Section 10 should be considered.

The above findings were based on the review of the performance of the products in the slopes inspected. Improved products may be introduced by the suppliers from time to time. Designers are advised to consult suppliers on new product development as needed.

For almost 70% of the slopes inspected, the Group 1 greening products have only been applied for less than three years and as such the long-term performance of the techniques is uncertain.

The results of this study also show that there is no significant difference in vegetation covers between slopes treated with different Group 2 techniques. The products performed more or less the same both in sustaining slope vegetation cover and in supporting the diversity of naturally occurring plant species.

Compared with the Group 1 techniques, the Group 2 techniques can sustain a greater

Table of Contents
Table of Contents
Table of Contents
Table of Contents

diversity of species, thus enhancing the ecological value of slopes. As such, planting directly on the soil surface of a slope is preferred to those techniques used on shotcrete cover provided that there is no stability concern of the slope. In addition, slopes where steel meshes are used in conjunction with non-degradable erosion control mats are more effective in controlling surface erosion.

10. RECOMMENDED IMPROVEMENTS

10.1 General

Based on the results of this study, the following improvements including recommendations on plant species and good practices on the design and construction of the various proprietary greening products are recommended.

10.2 Plant Species

The following six native fern and herbaceous species are naturally occurring species that have been found very common on the 100 slopes studied in this project and also on the 20 vegetated man-made slopes in another project (Hau and Leung, 2004b). Photographs of these species are shown on Plate 27. They will therefore provide good covers and increase biodiversity and ecological value of slopes on which Group 1 and Group 2 techniques are applied. All except *Dicranopteris pedata* (芒萁) are shade tolerant. These species may not be commercially available at this time. However, once a market has been created, commercial nurseries in Hong Kong or Guangdong should be able to produce some of these species:

- *Blechnum orientale* (烏毛蕨)
- *Cyclosorus parasiticus* (華南毛蕨)
- *Dicranopteris pedata* (芒萁)
- *Pityrogramma calomelanos* (粉葉蕨)
- *Pteris semipinnata* (半邊旗)
- *Pteris vittata* (蜈蚣草)

In addition to grass hydroseeding with standard seed mixes, the following shade tolerant species with photographs shown on Plate 28 are recommended to be planted as ground cover on heavily shaded slopes using both Groups 1 or 2 techniques:

- *Selaginella uncinata* (翠雲草)
- *Alocasia macrorrhiza* (海芋)
- *Ardisia crenata* (硃砂根)
- *Ficus hirta* (粗葉榕)

All the above four species are native to Hong Kong and are evergreen. *Selaginella uncinata* is a common fern which is particularly good as ground cover. *Alocasia macrorrhiza* is very common in disturbed forest or waste land in Hong Kong. It grows well on sunny place as well as in shade. The last two species are very small shrubs that also

Table of Contents
Table of Contents
Table of Contents
Table of Contents

survive well in shade.

The following list of native shrub species is recommended for planting on slopes with Group 2 techniques. Photographs of these species are shown on Plate 29.

- *Litsea rotundifolia* var. *oblongifolia* (豺皮樟)
- *Ardisia crenata* (硃砂根)
- *Rhodomyrtus tomentosa* (桃金娘)
- *Melastoma sanguineum* (毛棯)

The above four species have been proved viable on steep man-made slopes at previous trials (Hau and Leung, 2004b). They are all small in size and are not likely to cause safety concern on slopes. Most of these shrub species are commercially available.

10.3 Detailing

The following proposed improvement measures are applicable to all Group 1 techniques except the bio-engineering technique:

(a) For the products under the mulching system, additional support in the form of a PVC coated steel mesh to the surface of the mulch/soil mix is recommended. The mesh should be slightly stretched to ensure close contact with the surface of soil/mulch mix. Proposed details are shown in Figure 33. For slopes with uneven profile and where installation of the wire mesh is difficult, vertical and horizontal bracing (in the form of small diameter steel bars) may be provided to increase the overall strength of the soil/much mix.

(b) For those products that do not have erosion control mats to protect the soil/mulch mix, use of suitable mats is recommended.

(c) Long-term non-degradable erosion control mats instead of temporary degradable erosion control mats should be used for a longer-term protection.

(d) Some products under the cellular system are more vulnerable to desiccation, planting of drought tolerant species is recommended.

(e) Edges of soil/mulch mix adjacent to stepped channel are recommended to be separated from the channel by a distance of at least 500 mm to avoid erosion by the splashing of water in the channel. In addition, the edges of soil/mulch mix should be fully protected from surface erosion by wrapping erosion control mats around the edges.

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Plate 30 shows a view of a properly protected edge.

(f) Sufficient channels should be provided at slope crest and berms to drain surface runoff, and prevent the soil/mulch mix of the greening products from surface erosion.

(g) Concrete kerb or planter wall should be provided as far as practicable in order to support the toe of the soil/mulch layers and to avoid downslope movement of the soil/mulch. Plate 31 shows an example of such support.

(h) It is recommended that openings should be formed in the existing concrete cover to enable direct contact between the soil/mulch and the soil underneath the concrete through the openings. This would allow more moisture and nutrients to be obtained from the soil.

The following measures are recommended on the use of Group 2 techniques:

(a) To allow sufficient time for the growth and establishment of vegetation on slopes, temporary degradable erosion control mats should have longevity of at least 12 months.

(b) The use of thick temporary degradable mats should be avoided.

(c) Manufacturer's recommended practice in respect of overlapping the edges of adjacent mats should be followed. Some products may not recommend an overlap.

(d) Erosion control mats should be securely anchored to ensure close contact with the soil surface.

(e) For steep nailed cut slopes, long-term non-degradable erosion control mats should be used in conjunction with a layer of wire mesh, with details as recommended in Civil Engineering and Development Department (CEDD) Standard Drawings No. C2511/1 and C2511/2A which can be assessed and downloaded at the website of the CEDD (www.cedd.gov.hk).

At areas below tree canopies, the following measures are recommended for reducing surface erosions due to impact of large water drops from the leaves irrespective of the techniques used:

(a) Use shade-tolerant species as recommended in Section 10.1.

(b) Use long-term non-degradable erosion control mats.

Table of Contents
Table of Contents
Table of Contents
Table of Contents

10.4 Specification for Erosion Control Mats

It is recommended to change the current particular specification for erosion control mats to a performance-based specification. This can be done by making suitable modifications to the standard specification proposed by the ECTC (see Appendix I).

11. REFERENCES

Alen, S.R. (1996). Evaluation and Standardization of Rolled Erosion Control Products. Geotextiles and Geomembranes, Vol. 14, Nos 3/4, March/April, pp 207-221.

Begon, M., Harper, J.L. and Townsend, C.R. (1996). Ecology: Individuals, Populations and Communities. (Third Edition), Blackwell Science, Oxford, U.K.

Cazzuffi, D., Monferino, F., Monti, R. & Rimoldi, P. (1994). Experimental Evaluation of the Erosion on Bare and Geosynthetically Protected Slopes. Conserving Soil Resources, European Perspectives, Selected papers from the First International Congress of the European Society for Soil Conservation, (edited by R.J. Rickson), pp 413-421.

Department of Transport (1994). Design Manual for Roads and Bridges: Design Methods for the Reinforcement of Highway Slopes by Reinforced Soil and Soil Nailing Techniques, HA 68/94, Department of Transport, UK.

ECTC (2003). Facts on Web Site (www.ectc.org) of Erosion Control Technology Council, USA.

FHWA (2003). Standard Specifications for Construction of Roads and Bridges on Federal Highway Projects (FP-03), Publication No. FHWA-FLH-03-002, U.S. Department of Transportation, Federal Highway Administration,

Forth, R.A. (1987). The use of Tensarmat on a slope at Wong Nai Chung Road (Technical Note No. TN10/87), Geotechnical Engineering Office, Hong Kong, 16 p.

GreenWalls Bioengineering Ltd. (2003). Slope Aesthetic Greening Enhancement ("SAGE") Treatment Program

Halcrow China Ltd. (2001). Review of Effective Methods of Integrating Man-made Slopes and Retaining Walls (Particularly for Roadside Slopes) into their Surroundings. (GEO Report No. 116) Geotechnical Engineering Office, Civil Engineering Department.

Hau, B.C.H. and Leung, G.P.C. (2004a). Performance Assessment of Greening Techniques and Vegetation Species on Slopes. Task 1. Final Summary Report. Report to Geotechnical Engineering Office, Civil Engineering and Development Department (In preparation).

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Hau, B.C.H. and Leung, G.P.C. (2004b). Performance Assessment of Greening Techniques and Vegetation Species on Slopes. Task 2. Final Summary Report. Report to Geotechnical Engineering Office, Civil Engineering and Development Department.

Hyperdictionary (2003). www.hyperdictionary.com/dictionary

Lancaster, T. and Austin, D.N. (1994). Classifying rolled erosion-control products: a current perspective. Geotechnical Fabric Report, October/November, pp 16-24.

Li, A.C.O., Hung, H.F. and Ho, Y.K. (2000). A Review of Use of Vegetation on LPM Slopes. (Technical Note No. TN 4/2000) Geotechnical Engineering Office, Civil Engineering Department, 33p.

Li, C.O., Watkins, A.T. & Ho, Y.K. (1999). Use of vegetation as surface protection for steep slopes in Hong Kong. Proceedings of 1st Asia-Pacific Conference on Ground and Water Bio-engineering for Erosion Control and Slope Stabilisation, Manila, pp 477-484.

Martin, R.P. (2001). Panelist Report - Landscaping and bio-engineering of slopes in Hong Kong. Proceedings of the Fourteenth Southeast Asian Geotechnical Conference, Hong Kong, (Eds Ho & Li), 10-14 December, pp 661-670.

Martin, R.P., Li, C.O. and Pryor, M.R. (2001). Bio-engineering and landscape treatment of slopes and retaining walls in Hong Kong's Landslip Preventive Measures Programme. Proceedings of the Fourteenth Southeast Asian Geotechnical Conference, Hong Kong, (Eds Ho & Li), 10-14 December, pp 863-868.

Maunsell Geotechnical Services Ltd. (2003). Agreement No. CE80/2002(GE) Bio-engineering Repair Works on Selected Natural Terrain Landslide Sites - Design and Construction. Final Review Report. Report to Geotechnical Engineering Office, Civil Engineering Department.

Morgan, R.P.C. and Rickson, R.J. (1995). Water Erosion Control. Slope Stabilization and Erosion Control: A Bio-engineering Approach. (Edited by P.P.C. Morgan and R.J. Rickson), Published by E & FN Spon, pp 133-190.

Rickson, R.J. (1995). Simulated Vegetation and Geotextiles. Slope Stabilization and Erosion Control: A Bio-engineering Approach. (Edited by P.P.C. Morgan and R.J. Rickson), Published by E & FN Spon, pp 95-131.

Rose, M.A. and Smith, E. (2004). Mulching Landscape Plants. Ohio State University Extension Fact Sheet, Horticulture and Crop Science http://ohioline.osu.edu/hyg-fact/1000/1083.html (Jan., 2004)

Rüegger, R., Flum, D. & Haller, B. (2001). Slope stabilization with high-performance steel wire mesh in combinations with nails and anchors. Proceedings of International Conference on Landslides - Causes, Impacts and Countermeasures, 17-21 June, Davos, Switzerland, pp 597-606.

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Rustom, R.N. and Weggel, J.R. (1993). A Study of Erosion Control Systems: Experimental Results. Proceedings of the XXIV Annual Conference of the IECA, Indianapolis, Ind., February, pp 255-275.

Styczen, M.E. and Morgan, R.P.C. (1995). Engineering Properties of Vegetation. Slope Stabilization and Erosion Control: A Bio-engineering Approach. (Edited by P.P.C. Morgan and R.J. Rickson), Published by E & FN Spon, pp 5-58.

Sutherland, R.A. (1998). A critical assessment of the research conducted at the hydraulics and erosion control laboratory - a focus on rolled erosion systems applied to hillslopes. Geotextiles and Geomembranes, Vol. 20, No 2, April, pp 135-146.

Urbis (2003). Review of Interim Performance of Various Proprietary Soft Landscape Treatment under Trial on HyD Slopes. Final report submitted to the Highways Department under Consultancy Agreement No. HKR 1/2002.

Urroz, G.E. and Israelsen, C.E. (1995). Effectiveness of Selected Materials under Simulated Rain and Sunlight. A Compilation of Papers and Articles from IECA Conference Proceedings, Erosion Control Journal and the IECA Report, 1997, pp 361-370.

Wischmeier, W.H. and Smith, D.D. (1978). Predicting rainfall erosion losses. USDA Agr. Res. Serv. Handbook 537.

Yan, A.T.F. (2000). Vegetative Slope Engineering and Its Application in Hong Kong. M.Sc Dissertation, Imperial College of Science, Technology and Medicine, University of London (Unpublished).

Yeo, K.C. (1999). The application of geosynthetics in Hong Kong. Proceedings of the 11th Asian Regional Conference on Soil Mechanics and Geotechnical Engineering, Seoul, Korea, August 1999, pp 37-42.

Table of Contents
Table of Contents
Table of Contents
Table of Contents

LIST OF TABLES

Table of Contents
Table of Contents
Table of Contents

Table 1 - Typical Sample of the “Greening Methods on Slopes” Database

Slope No	Location	Maintenance Department	Type of Slope / Wall	Slope Height (m)	Slope Gradient (deg)	Soil Type/ Slope Forming Materials	Slope Suface Cover Before Work	Works Contract No	Works Completion Date	Name of Proprietary Product if used	Plant Type	Plant Species	Vegetation Base :	Area Treated	Cost per sq m	Maintenance Requirement	Date of Last Slope Inspection	Signs of Erosion	Condition of Vegetation (Grass)	Condition of Vegetation (Shrubs)	Condition of Vegetation (Tree)	Condition of Other Vegetation (pit planting & creeper)	Incident After Work	Remarks	Submitted By
nnXX-X/TTnnn (11NE-B/CR1234)	(Attach location plan and photographs for newly reported case)	AFCD, ArchSD, DSD, HD, HyD, LandsD, WSD	cut, fill, retaining wall, others	in metre	degree	Soil, Rock, Soil/ Rock	Shotcrete, Chunam, Bare, Soil, Rock, Vegetated, Other		DD/MM/YY	1 Name of Proprietary Product	Tree, Shrub, Grass, Creeper, N.A.	Material on which vegetation is planted (e.g.Soil, Rock, Shotcrete, Others)	Sq. m	$/Sq. m	Maintenance Requirement	DD/MM/YY	Severe, Fair, Minor, None	Good, Fair, Poor, N.A.	Good, Fair, Poor, N.A.	Good, Fair, Poor, N.A.	Good, Fair, Poor, N.A.	(Yes or No)			
3NE-C/C 159	Luk Keng Chan Uk, North	LandsD	Cut	9	55	Soil	Vegetated	4/LANDS/00	21/11/2001	Kangaroo Net II				150	300			None	Good						LandsD
3NE-C/C 161	Luk Keng Chan Uk, North	LandsD	Cut	13	50	Soil	Vegetated	4/LANDS/00	04/01/2002	Kangaroo Net II				400	300			None	Good						LandsD
3NE-C/C 175	Kai Kuk Shue Ha	LandsD	Cut	9	75	Soil	Vegetated	4/LANDS/00		Kangaroo Net				600	300	Routine Maintenance	13/01/2003	None	N.A.	N.A.	N.A.	N.A.	No		LandsD
3NE-D/C 104	Bride's Pool Road, North	HyD	Cut	4.5	60	Soil	Shotcrete	10/HY/2000	31/10/2001	Biocrete			Shotcrete	520	688		24/01/2003	Minor	Poor						HyD
3NE-D/C 107	Bride's Pool Road, North	HyD	Cut	13	57	Soil	Shotcrete	10/HY/2000	24/11/2002	Vetiver Grass	Grass			1150	996.86			None	Satisfactory						HyD
3SE-A/C 6	Nam Chung Road, North	HyD	Cut	9	50	Soil	Shotcrete	10/HY/2000	09/05/2002	CMS-ML Green System			Shotcrete	544	612				Satisfactory						HyD
3SE-B/C 64	Ting Kok Road	HyD	Cut	8.3	60		Shotcrete	10/HY/2000	20/04/2002	CMS-ML Green System	Grass			350	612		2002/5/31	Yes	Healthy						HyD
3SE-B/C 91	Bride's Pool Road, North	HyD	Cut	14	50	Soil	Shotcrete	10/HY/2000	10/04/2003	Vetiver Grass	Grass			1700	997	None									HyD
3SE-B/C 152	Bride's Pool Road, Tai Po	HyD	Cut	5	50	Soil/ Rock	Shotcrete	15/HY/1998	02/12/2000	Rocksgrass	Grass		Shotcrete	350	640		28/10/2002	None	Good						HyD
3SE-D/C 31	Bride's Pool Road, Tai Po	HyD	Cut	14	50	Soil	Shotcrete	10/HY/2000	26/11/2002	Vetiver Grass	Grass			700	997			None	Satisfactory						HyD
3SE-D/C 64	Ting Kok Road	HyD	Cut	7.9	65	Soil	Shotcrete	10/HY/2000	20/04/2002	CMS-ML Green System	Grass			350	688		11/11/2002	Yes	Not Satisfactory						HyD
3SE-D/C 77	Bride's Pool Road, Tai Po	HyD	Cut	14.5	50	Soil	Shotcrete	10/HY/2000	30/04/2003	Vetiver Grass	Grass			800	997	None		None							HyD
3SE-D/C 80	Bride's Pool Road, Tai Po	HyD	Cut	15.5	55	Soil	Shotcrete	10/HY/2000	30/04/2003	Vetiver Grass	Grass			700	997	None		None							HyD
3SE-D/C 93	Mei Wu Road, Tai Mei Tuk	WSD	Cut	4	65	Soil	Shotcrete	GE/2000/02	15/1/2002	NFY Hydro Mulching	Grass		Shotcrete	108	875	Maintenance Free	24/06/2003	None	Fair	N.A.	N.A.	N.A.	No	GEO has repaired the hydro-mulching	CGE/D & WSD
3SW-B/C 17	Lau Shui Heung Road	HyD	Cut	3	40	Soil	Chunam	10/HY/2000	23/12/2001	NFY Hydro Mulching				120	612				Satisfactory						HyD
3SW-B/C 292	Hok Tau Road, North	HyD	Cut	5.5	60	Soil	Shotcrete	15/HY/1998	24/03/2001	Rocksgrass			Shotcrete	550	640		05/11/2001		Not Satisfactory						HyD
5SE-C/C 45	Lung Mun Road, TM	HyD	Cut	14	50		Shotcrete	14/HY/1998	13/04/2002	NFY Hydro Mulching				875	650	Cut grass when required	24/06/2003	None	Poor						HyD
5SE-D/C 15	Lun Mun Road, TM	HyD	Cut	10	50		Shotcrete	SLA's contract 02/HY/20012		Planting															HyD
5SE-D/C 18	Lun Mun Road, TM	HyD	Cut	10	50		Shotcrete	SLA's contract 02/HY/20012		Planting															HyD
5SE-D/C 162	Lun Mun Road, TM	HyD	Cut	7	50		Shotcrete	SLA's contract 02/HY/20012		Planting															HyD

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Table 2 - List of Proprietary Products Reviewed

Groups	Types of Greening Techniques	Names of Proprietary Products	Estimated Installation Cost (Notes) (per m^2)
Group 1 - Techniques applied on slopes with hard cover	Mulching	Biocrete Hong Kong Mulching NFY Hydro-Mulching "On" Method Rocksgrass CMS-ML Green System Soil Panel Toyo-Mulching	\$650-\$750 \$800-\$900 \$600-\$1,000 \$680-\$880 \$600-\$750 \$600-\$750 \$1,000-\$1,150 \$800-\$1,700
	Cellular System	Eco-link Instant Evergreen System NFY Eco-MP System NFY Hydro Planter NFY Mulching Panel Terra Cell	\$660-\$1,250 \$450-\$750 \$600 \$600-\$700 \$600-\$1,000 \$200
	Reinforced Soil	Geofiber	\$800-\$1,200
	Bio-engineering	GW-Biodrains System	\$600-\$1,000
Group 2 - Techniques applied directly on exposed soil slope surface	Temporary Degradable Erosion Control Mat	Soil Guard Coir Soil Saver	\$70-\$100 \$30-\$58 \$48-\$94
	Rolled Long-term Non-degradable Erosion Control Mat	Enkamat Kangaroo Mat Miramat TM8 Multimat Tensarmat/EM4	\$80-\$111 \$200-\$350 \$75-\$106 \$75-\$106 \$80-\$111
	Rolled Long-term Non-degradable Erosion Control Mat in conjunction with Steel Wire Mesh	Enkamat Miramat TM8 Multimat Tensarmat/EM4	\$206-\$278 \$201-\$273 \$201-\$273 \$206-\$278

Notes:
(1) Estimated costs are based on information provided by government departments in the database of greening methods on slopes in the period of 2000 to 2003 and rates of LPM works contracts in the period of 2002 to 2003.
(2) The cost includes the cost of material, workmanship for installation and planting, as well as the establishment works of vegetation.

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Table 3 - Summary of Results of Vegetation Growth Assessment for Slopes under Category of Mulching System (Sheet 1 of 2)

Greening Products	Construction Details in Figure No.	Slopes inspected	Observations during inspection	Relevant Section of Appendix E
Biocrete	1	3NE-D/C104 6NE-D/C55	• Both slopes planted with grasses. • Total healthy vegetation cover of the two slopes varied greatly: figure on slope C104 dropped from 26% to 19% between the two inspections whereas that on slope C55 increased from 11% to 47%. • Low values of H (≈1) and S (=3) were recorded for both slopes in the two inspections. • The results show that the vegetation on this product, whether planted or natural, did not seem to do very well.	E.2.2.1
Hong Kong Mulching	2	8SW-B/C46 8SW-B/C95	• Both slopes planted with creepers and grasses. • Both slopes had ≥ 70% total healthy vegetation cover in both inspections. • Both H and S equaled 0 for slope C46 in the two inspections. • Low values of H (between 1.3 and 1.6) and medium values of S (between 4 and 5) were recorded for slope C95 in the two inspections.	E.2.3.1
NFY Hydro-mulching	3	3SE-D/C93 6SE-B/C256 10NE-B/C123 11NW-B/C19 11NW-B/C266 11NW-B/C39 11NW-D/C90 11SE-C/C19 11SE-C/C32 11SE-C/C33 11SW-A/C293A 11SW-A/CR28 11SW-B/C214 11SW-D/C105 11SW-D/C1642 11SW-D/FR39	• All slopes planted with grasses. 11 of them also planted with creepers and/or climbers. • Performance of this product was variable among the 16 slopes. • 8 slopes had ≥70% total healthy vegetation cover in the latest inspection. The other slopes had healthy vegetation cover ranging from 5% to >50%. • % cover of planted species on more than half of the slopes decreased in the 2nd inspection, while for others it was found to increase slightly or about the same. • H for 5 slopes equaled to zero, while the others had low values of H (between 1 and 2). The S values for these 5 slopes were consistently low (e.g. between 0 and 2). • S values for another 8 slopes were found decreasing from high to low values throughout the various inspections. Only 2 slopes were recorded to have increasing S values	E.2.4.1
On Method	4	11NE-A/C357 11NW-A/C123 11NW-A/C441 11NW-B/C64 11NW-B/F41	• All slopes planted with grasses and 3 of them also planted with creepers and/or climbers. • % cover of exposed planted grass species decreased on all slopes except slope C64 in the latest inspection. These exposed cover were largely unhealthy. • Total healthy vegetation cover were low in 3 slopes out of 5. • Slope C123, which had abundant large remnant trees on the slope surface, was recorded with high values of S (between 7 and 12) despite rather low values of H (between 0.5 to 1.6). Slope 64 has both high H (2.0) and S (11). • On the other 3 slopes, H recorded were low (between 0 and 0.95). • S were low (between 0 and 3) on 2 slopes and high (between 5 and 6) on a slope. Assessment results suggested the product is largely unable to sustain good vegetation covers.	E.2.5.1

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Table 3 - Summary of Results of Vegetation Growth Assessment for Slopes under Category of Mulching System (Sheet 2 of 2)

Greening Products	Construction Details in Figure No.	Slopes inspected	Observations during inspection	Relevant Section of Appendix E
Rocksgrass	5	3SW-B/C292 11NE-C/C62 11NW-D/C130 11NW-D/C52 11SE-C/C753 11SW-A/C142 11SW-C/C385 11SW-D/C111	• All slopes were planted with grasses and creepers and/ or climbers. • Overall vegetation cover of the slopes ranged from 66% to 100%. No significant difference in vegetation cover between the 1st and 2nd inspections. • In the 2nd inspection, two slopes reached 100% of total exposed vegetation cover and the remainder ranged from 66% to 93%. • Overall percentage cover of vegetation on slopes treated with this product was very good. • On slope C62, both H and S were recorded as zero whereas on slope C753, H were recorded to be marginally high (between 1.89 to 2) and S were high (between 12 and 13). • H recorded on the other slopes were low (between 0.42 to 1.9) whereas S were low to high (between 4 and 11). • This product may be able to support small shrubs owing to their ability to maintain soil moisture.	E.2.6.1
CMS-ML Green System	6	3SE-A/C6	• The slope was only planted with grasses. • Total exposed vegetation cover was high (around 90%) in both inspections but % of healthy vegetation cover remained low (around 10%). • Low values of H(=0) and S (=1) were recorded for both inspections.	E.2.7.1
Soil Panel	7	11SE-A/C487 11SW-A/C331 11SW-D/C117	• All slopes were planted with grasses and creepers. • Except slope C487 which had satisfactory total exposed vegetation cover (about 90 %), vegetation cover of the other slopes was quite low (< 50 % for exposed and around 20 % for healthy). • Low values of H(=0) and S(=1) were recorded for both inspections for slope C487 • The other two slopes had low H (between 1.72 and 1.88) but high S (between 9 and 22) values in both inspections	E.2.8.1
Toyo-Mulching	8	7SW-D/CR538 7SW-D/C547 7SW-D/CR553 11NE-D/C815A 11NW-B/C82 11NW-D/C330 11NW-D/C548 11SE-A/C123 11SE-C/C166 11SE-C/C679 11SE-C/C684 11SE-C/C694 11SW-A/C135 11SW-A/C138 11SW-A/F75 11SW-C/C322 11SW-D/C110 12NW-C/C92 12SW-A/C125 15NW-B/C176	• A slope planted with grasses only; 7 planted with creepers *Wedelia trilobata* only; and the remaining 12 planted with both grasses and *W. trilobata.* • Overall vegetation cover of slopes treated with this technique was generally good: 18 out of 20 slopes were recorded to have 60% to 100% total healthy vegetation cover in the latest inspection, including 4 slopes with 100% and 6 slopes with >90% healthy vegetation cover. • For most slopes planted with both grasses and *Wedelia*, % cover of *Wedelia* was generally much higher than the planted grasses, showing that *Wedelia* is more adaptable to steep man-made slopes than grass. • H and S values recorded on the slopes were extreme. • 4 slopes were recorded to have zero H and S in all inspections and 8 slopes recorded to have low H (between 0 and 0.9) and low S (between 1 and 4). • The remaining 8 slopes had low to marginally high H (between 1.18 and 1.94) and high S (between 5 and 15). • The product appears to be well in sustaining ground cover vegetation, especially *W. trilobata*.	E.2.9.1

Notes: (1) Range of H: - Low (<2)
- High (≥2)
(2) Range of S: - Low (< Mean of S of Group 1 products, i.e. 4.36)
- High (≥ Mean of S of Group 1 products, i.e. 4.36)

Table of Contents Table of Contents Table of Contents Table of Contents

Table 4 - Summary of Results of Vegetation Growth Assessment for Slopes under Category of Cellular System (Sheet 1 of 2)

Greening Products	Construction Details in Figure No.	Slopes inspected	Observations during inspection	Relevant Section of Appendix E
Eco-link	9	15NE-B/C232 15NE-C/C3	• Both slopes were planted with grasses with some creepers. • Total vegetation cover, exposed and healthy, of planted grass increased in the 2nd inspection on both slopes. • In the 2nd inspection, nearly 100% healthy vegetation cover recorded on slope C232 whereas 85% on slope C3, but that on slope C3 decreased to 43% in the 3rd inspection. • H and S for slope C232 dropped to low values (H from 1.46 to 0.69 and S from 5 to 2) from the 1st to 2nd inspection. • Both low values of H (ranged from 0.45 to 1.08) and S (between 2 to 4) were recorded for another slope.	E.3.2.1
Instant Evergreen System	10	11NE-A/F167 11NE-D/C366 11SE-B/C5	• All slopes were planted with the herb *Sedum tetractinum* as the main ground cover. • Performance of this product was variable among the 3 slopes. • Healthy vegetation cover of slope C366 in 2nd and 3rd inspections: 6% and 38%. But % of planted herb was just 17% at the 3rd inspection. • Healthy cover of planted herb on slopes F167 and C5 were extreme in the latest inspections: 6% and about 80% respectively. • Low values of H (between 0 and 1) and S (between 0 and 4) were recorded for all slopes in all inspections. • The ability for this product to sustain the planted herb is extreme, but the panel seem not to be able to support other naturally occurring woody species though invasive weeds may be possible to establish.	E.3.3.1
NFY Eco-MP System	11	7SW-C/C41	• The slope was planted with grasses, creepers and climbers. • Total healthy vegetation cover in both inspections > 78% • Similar % cover recorded in the two inspections suggested that this product was able to support a healthy vegetation cover on slopes. • Low values of H (=0) and S (=1) were recorded in both inspections. • As the planting holes of this product are connected to the soil under the shotcrete, it should be able to sustain vegetation, especially woody species.	E.3.4.1
NFY Hydro Planter	12	15NW-B/C343	• Only 23 out of 230 planting holes of this technique were found with grasses or climbers in the 1st inspection, 24 in the 2nd inspection. • This product is found to be not as successful as other products in terms of maintaining green vegetation cover on slope surface.	E.3.5.1

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Table 4 - Summary of Results of Vegetation Growth Assessment for Slopes under Category of Cellular System (Sheet 2 of 2)

Greening Products	Construction Details in Figure No.	Slopes inspected	Observations during inspection	Relevant Section of Appendix E
NFY Mulching Panel	13	7SW-C/C55 11SW-A/C61 11SW-A/C139 11SW-A/C293B 11SW-B/C206 11SW-D/C1090 11SW-D/CR1993	• All slopes were planted with grasses and creepers except one planted with creeper only. • The total exposed vegetation cover was generally high for all slopes (ranging from 57 % to 100 %) but the total healthy cover of only three slopes (C55, C61 and C206) were high in the second inspection. • A general reduction in total exposed vegetation cover in 5 slopes between the two inspections indicating vegetation died off in the dry season. • Slopes C139, C293B and C206 were recorded to have low H (between 0.96 and 1.97) but high S values (between 5 to 14). • The other 4 slopes were recorded to have both low H (between 0 and 0.95) and S (between 0 and 3) values. • The vegetation on this product seemed to experience problems in getting soil moisture in dry season. The large surface areas of the panels might have a high rate of surface evaporation.	E.3.6.1
Terra Cell	14	11NE-D/C815B	• The slope was only planted with grasses. • Total healthy vegetation cover increased dramatically in the 2nd inspection, mainly involving climbers and herbs taking over the slope. • Low H values (< 0.4) and S (ranging from 1 to 2) were recorded for both inspections.	E.3.7.1

Notes: (1) Range of H: - Low (<2)
- High (≥2)

(2) Range of S: - Low (< Mean of S of Group 1 products, i.e. 4.36)
- High (≥ Mean of S of Group 1 products, i.e. 4.36)

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Table 5 - Summary of Results of Vegetation Growth Assessment for Slopes under Category of Reinforced Soil System

Greening Products	Construction Details in Figure No.	Slopes Inspected	Observations during Inspection	Relevant Section of Appendix E
Geofiber	15	11SW-B/C24 11SW-D/C601 11SW-B/F74 A slope in Lam Tei Quarry	• One slope was planted with grasses, creepers and some woody plants, one with grass and woody plants, one planted creepers only and the last one with grasses only. • Slope C601, which was planted only with creeper *Wedelia trilobata*, was recorded to have 100% total healthy vegetation cover in both inspections. This suggests that *W. trilbata* is a better species than the commonly planted grass species in terms of maintaining a healthy ground cover using Geofiber. • Slope F74 was recorded to have % exposed and healthy vegetation cover of 120%. • Performance on slopes C24 and the slope in Lam Tei were variable with the % healthy vegetation cover ranging from 35% to 64%. • Low H values (between 0.69 and 0.99) but high S values (between 7 and 10) were recorded for slope C24. • Low H values (between 0 and 0.9) and S values (between 0 and 3) were recorded for slope F74. • H and S both equalled 0 for other slopes in both inspections. • The product is able to sustain *W. trilbata* on small slopes.	E.4.1

Notes: (1) Range of H: - Low (<2)
- High (≥2)
(2) Range of S: - Low (< Mean of S of Group 1 products, i.e. 4.36)
- High (≥ Mean of S of Group 1 products, i.e. 4.36)

Table 6 - Summary of Results of Vegetation Growth Assessment for Slopes under Category of Bio-engineering Method

Greening Products	Construction Details in Figure No.	Slopes Inspected	Observations during Inspection	Relevant Section of Appendix E
GW-Biodrains System	16	6SE-B/C167 7SW-C/C47 7SW-D/C1	• All slopes were planted with the Vetiver grass. • Performance of this product is very good in terms of vegetation cover. • 2 slopes C167 and C47 have 100 % healthy vegetation cover in the second inspection. The other slope also has >80 % healthy vegetation cover. • Low values of H (between 0.64 and 1.32) and low values of S (between 2 and 4) were obtained for slope C47. • Both H and S values for the other 2 slopes were recorded as zero. • This product is considered to be a self-sustainable product in terms of vegetation cover as the Vetiver grass is not isolated from the ground.	E.5.1

Notes: (1) Range of H: - Low (<2)
- High (≥2)
(2) Range of S: - Low (< Mean of S of Group 1 products, i.e. 4.36)
- High (≥ Mean of S of Group 1 products, i.e. 4.36)

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Table 7 - Summary of Results of Vegetation Growth Assessment for Slopes using Temporary Degradable Erosion Control Mats

Greening Products	Construction Details in Figure No.	Slopes Inspected	Observations during Inspections	Relevant Section of Appendix F
Soil Guard	17	11NW-D/C403	• The slope was planted with grass species. • Percentage of main ground vegetation cover formed by planted grasses was very low (<15%) in the 2nd inspection. Most of the slope surface was bare Miramat TM8 additionally specified on the slope. The value increased to >30% in the 3rd inspection. • Low values of H (between 1.35 and 1.8) and S (between 7 and 11) were recorded.	F.2.2.1
Coir	18	11NW-D/FR40	• The slope was planted with grass species. • % cover of healthy planted species and total healthy vegetation cover generally increased in the 2nd inspection. This shows that the overall vegetation on the slope grows better in spring. Both the overall exposed and healthy vegetation cover were very satisfactory in the 2nd inspection (>90%). • Species richness S did not change much in the second inspection except that the diversity index H is doubled, but low values of H (between 0.46 and 1.02) and S (between 3 and 4) were recorded.	F.2.3.1
Soil Saver	19	6SE-D/C212	• The slope was planted with both grass and the creeper *Wedelia trilobata*. • % cover of healthy planted species and total healthy vegetation cover generally increased in the 2nd inspection. This shows that the overall vegetation on the slope grows better in spring. The overall exposed and healthy vegetation cover in the 2nd inspection were 75% and 57% respectively. • Both H and S remained more or less the same at low values in the 2 inspections, i.e. H between 1.55 and 1.7 whereas S between 5 and 6.	F.2.4.1

Notes: (1) Range of H: - Low (<2)
- High (≥2)

(2) Range of S: - Low (< Mean of S of Group 2 products, i.e. 12.37)
- High (≥ Mean of S of Group 2 products, i.e. 12.37)

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Table 8 - Summary of Results of Vegetation Growth Assessment for Slopes using Long-term Non-degradable Erosion Control Mats (Sheet 1 of 2)

Greening Products	Construction Details in Figure No.	Slopes Inspected	Observations during Inspections	Relevant Section of Appendix F
Enkamat	20	11NW-D/FR50	• The slope was planted with grass species. • % of total exposed vegetation cover was the same in both inspections (94%), and the total healthy vegetation cover increased two times in the 2nd inspection, showing that the vegetation had regenerated in the spring season. • Species diversity increased a little bit in the second inspection, further suggesting that the vegetation was recovering from the winter dry season. But low values of H (between 0.69 and 1.04) and S (between 2 and 3) were recorded.	F.3.2.1
Kangaroo Mat	21	3NE-C/C159 11NW-A/C159	• Both slopes were planted with grass species. • % cover of planted grasses in both inspections were low (only about 6% and 1% on the slopes respectively). • Overall vegetation cover of the two slopes is not bad, ranging from 60% to 75% and showing that both slopes were dominated by naturally established ground covering species. • High values of H (between 2.66 and 2.7) and S (between 21 and 22) of slope 3NE-C/C159 were recorded because the slope is connected to a wood with natural vegetation. • But low values of H (between 0.56 and 1.01) and S (between 2 and 3) were recorded on the other slope which is isolated from natural vegetation.	F.3.3.1
Miramat TM8	22	7SW-C/C180 7SW-C/C181 7SW-D/C22 11NW-B/C90	• All slopes were planted with grasses and slope C22 was also planted with climber. • All slopes showed satisfactory healthy vegetation cover (>62%) in the second inspection except slope C90 (41%). • Species diversity indices at all slopes did not change much between the two inspections, suggesting that the vegetation of the slopes was rather stable. • Slope C180 was recorded to have high values of H (between 2.15 and 2.19) and marginally low S (between 11 and 12) in the 2 inspections. Slopes C181 and C22 had relatively low values of H (between 1.3 and 1.51) and S (between 5 and 6). • However, both H (between 0 and 0.5) and S (between 1 and 2) of slope C90 are rather low probably because the slope is isolated to natural seed source by a few large shotcrete slopes.	F.3.4.1
Multimat	23	7SE-C/C42	• The slope was planted with grass. • Overall vegetation cover was very good. Both the planted and total vegetation cover increased significantly in the second inspection. • % cover of healthy planted grass in the second inspection>85%, largely contributed by the healthy planted grass species. • Both H (=0.64) and S (=3) were low probably owing to the young age of the slope.	F.3.5.1

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Table 8 - Summary of Results of Vegetation Growth Assessment for Slopes using Long-term Non-degradable Erosion Control Mats (Sheet 2 of 2)

Greening Products	Construction Details in Figure No.	Slopes Inspected	Observations during Inspections	Relevant Section of Appendix F
Tensarmat/ EM4	24	7SE-D/C13 7SE-D/C53	• Both slopes were planted with grass species and creepers and/or climbers. • % cover of planted creepers/climbers increased in the 2nd inspection while that of the planted grass was almost zero, showing that creepers/climbers started to overgrow the planted grass species. • Both H (ranging from 2.47 to 3.16) and S (ranging from 35 to 43) recorded on the 2 slopes were very high probably owing to the older age of the slopes and their connection to a natural hillside. The vegetation communities of the two slopes are very diverse. Those planted species on the slopes will be eventually displaced by the increasingly dense and diverse native plants.	F.3.6.1

Notes: (1) Range of H: - Low (<2)
- High (≥2)
(2) Range of S: - Low (< Mean of S of Group 2 products, i.e. 12.37)
- High (≥ Mean of S of Group 2 products, i.e. 12.37)

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Table 9 - Summary of Results of Vegetation Growth Assessment for Slopes using Long-term Non-degradable Erosion Control Mats with Steel Wire Mesh

Greening Products	Construction Details in Figure No.	Slopes Inspected	Observations during Inspections	Relevant Section of Appendix F
Enkamat	25	3SE-D/C74 3SE-D/C75	• Both slopes were planted with grass species. • Slope C74 had to be dropped from the study as re-planting work had been carried out after the 1st inspection. • % cover of exposed planted grass and total vegetation of slope C75 decreased in the 2nd inspection. Likewise, the healthy vegetation cover also decreased. These show that the vegetation of this slope has become less good after the winter season. • Species diversity of slope C75 is almost the same in the two inspections. High values for H (ranging from 2.11 to 2.15) but low values for S (ranging from 9 to 11) were recorded.	F.4.2.1
Miramat TM8	26	3SW-D/C118	• The slope was planted with grass and climber. • The % cover of both exposed planted species and the overall exposed vegetation were rather low, i.e. (<30%) and (<40%) respectively. • Results had deteriorated at the 2nd inspection. Figures for % cover of both exposed planted species and the overall exposed vegetation were 23% and 30% respectively. • But high values of the H (ranging from 2.04 to 2.18) and S (ranging from 14 to 17) were recorded.	F.4.3.1
Multimat	27	6SE-C/C28	• The slope was planted with grass. • % cover of healthy planted species and total healthy vegetation cover generally increased in the 2nd inspection, indicating that the overall vegetation on the slope grew better in spring. • % cover of exposed planted grass decreased in the second inspection, whereas the total exposed vegetation cover increased, implying that the planted grass is being taken over by the naturally established vegetation. • Despite marginally low H values (between 1.84 and 1.97) were recorded, high S values (between 23 and 24) were obtained and they remained more or less the same in the two inspections.	F.4.4.1
Tensarmat/ EM4	28	7NW-B/C13 8SW-B/C74 11SW-C/C82 11SW-C/C98	• All slopes were planted with grass species. Slopes C82 and C98 were also planted with creepers and/or climbers. • % cover of exposed vegetation increased or remained more or less the same in the second inspection while that of the planted grass generally decreased, showing that the planted grass species were gradually replaced by the naturally established vegetation. • Both H and S values recorded on 3 slopes C74, C82 and C98 were found to have increased between the 2 inspections, suggesting that the planted species on the slopes will be eventually displaced by the increasingly dense and diverse native plants naturally established • High H (between 2.44 and 2.69) and S (between 21 and 23) values were recorded on slope C74. Relatively low values of H (between 1.04 and 1.46) and S (between 9 and 14) were recorded on slopes C82 and C98. • Low values of H(=0) and S(=1) were recorded on slope C13.	F.4.5.1

Notes: (1) Range of H: - Low (<2)
- High (≥2)

(2) Range of S: - Low (< Mean of S of Group 2 products, i.e. 12.37)
- High (≥ Mean of S of Group 2 products, i.e. 12.37)

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Table 10 - Summary of Results of Engineering Assessment for Slopes under Category of Mulching System (Sheet 1 of 2)

Greening Products	Construction Details in Figure No.	Slopes Inspected	Observations(Note) during Inspections	Relevant Plate(s) No.	Relevant Section of Appendix E
Biocrete	1	3NE-D/C104 6NE-D/C55	• Surface cracks (width of about 10 mm) noted on the mulch/soil mix on both slopes, particularly extensive on slope C104. • Mulch/soil mix dried up, disintegrated and hardened, probably owing to addition of cement in the mulch/soil mix. • Mulch/soil mix detached locally on both slopes, exposing the PVC mesh which was embedded in the soil mix of the system.	1	E.2.2.2
Hong Kong Mulching	2	8SW-B/C46 8SW-B/C95	• Mulch/soil mix up to about 1.5 m high along the slope toe disintegrated and partly fell off, exposing the steel mesh. System integrity above this level noted to be satisfactory.	2 & 3	E.2.3.2
NFY Hydro-mulching	3	6SE-B/C256 11NW-D/C90 11SE-C/C33 11SW-D/C105	• Moderately narrow surface cracks were found locally on surface of mulch/soil mix on slopes C256, C33 and C90. Narrow cracks were widespread on surface of slope C105 • On slope C90, the system over-hanged along the toe of 2nd batter of slope C90 for a length of about 5 m to 10 m. • Temporary degradable erosion control mat almost completely degraded on all slopes • Local surface erosions of mulch/soil mix on slopes C90 and C105, especially under the tree canopies. • Edges of mulch/soil mix exposed and subject to surface erosion on slope C90.	4 & 5	E.2.4.2
On Method	4	11NE-A/C357 11NW-A/C123	• Soil mix on slope C357 was so hard to be broken up by a hammer, probably owing to addition of cement in the mulch/soil mix. • Narrow surface cracks found locally on the surface of the mulch/soil mix of slope C123. • Soil mix fell off locally on slope C357 but it was quite extensive on slope C123. • Long-term non-degradable erosion control mats used on slope C357 but no mat was used on slope C123. • Erosion along slope toe noted at a few locations on slope C123.	6	E.2.5.2
Rocksgrass	5	11NW-D/C130 11SW-D/C111	• 10 mm diameter mild steel bars noted on surface of the soil mix horizontally across slope C130 at a vertical spacing of 1.5 m. Minor bulges of soil mix noted but confined between horizontal bars. • Horizontal rows of PVC pipes were found on slope surface within the soil mix as support. • No sign of surface cracking or detachment of soil mix on the slopes. • No signs of weakening of the long-term non-degradable erosion control mats on the product surface. • Edges of system well-protected. • No sign of surface erosion.	7	E.2.6.2

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Table 10 - Summary of Results of Engineering Assessment for Slopes under Category of Mulching System (Sheet 2 of 2)

Greening Products	Construction Details in Figure No.	Slopes Inspected	Observations(Note) during Inspections	Relevant Plate(s) No.	Relevant Section of Appendix E
CMS-ML Green System	6	3SE-A/C6	• Composite layer of the soil mix and the erosion control mats was satisfactorily intact. • No signs of surface cracking, weakening of the erosion control mats or surface erosion.	N/A	E.2.7.2
Soil Panel	7	11SE-A/C487 11SW-D/C117	• Bulges of the soil mix noted at a few locations above the concrete kerb at the toe of both slopes • Temporary degradable erosion control mat completely decomposed on slope C478 and partially decomposed on slope C117 • Signs of erosion noted at a few locations near crest of slope C487. • No sign of erosion on slope C117	8 & 9	E.2.8.2
Toyo-Mulching	8	11SE-C/C166 11SW-A/C138	• No apparent signs of distress of mulch/soil mix on both slopes • Temporary degradable erosion control mat in good condition on slope C166, but partially decomposed on slope C138. • Anchorage of the mat found to be inadequate at the edge of the mulch/soil mix on slope C166. • Signs of erosion and cracking were noted locally at the toe of slope C138.	10	E.2.9.2

Notes:
(1) Description of Crack Width on Mulch/Soil Mix:
- Narrow (<5 mm)
- Moderately Narrow (5-10 mm)
- Wide (>10 mm)

(2) Extent of Observations:
- Locally (< 30% of total slope surface area)
- Extensive (between 30% and 70% of total slope surface area)
- Widespread (> 70% of total slope surface area)

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Table 11 - Summary of Results of Engineering Assessment for Slopes under Category of Cellular System

Greening Products	Construction Details in Figure No.	Slopes Inspected	Observations(Note) during Inspections	Relevant Plate(s) No.	Relevant Section of Appendix E
Eco-link	9	15NE-B/C232 15NE-C/C3	• Mulch/soil mix confined within the cells, minimizing the possibility of downward movement of the mulch/soil mix • No sign of weakening of the long-term non-degradable erosion control mats. • Vertical edges of the mulch/soil mix of slope C3 were not fully protected by the erosion control mat. • System at slope C232 over-hanged and was unsupported.	11	E.3.2.2
Instant Evergreen System	10	11NE-A/F167 11NE-D/C366	• Each panel individually anchored on slope. • No apparent sign of detachment of panels from the slope surface. • No apparent sign of detachment of mulch/soil mix from the panels. • No apparent sign of surface erosion on mulch/soil mix in the panel lined with geotextile.	12	E.3.3.2
NFY Eco-MP System	11	7SW-C/C41	• Engineering condition of the system was satisfactory as the gabions containing mulch block are embedded in the slope. • No erosion control measure used on the product but no significant erosion was noted.	N/A	E.3.4.2
NFY Hydro Planter	12	15NW-B/C343	• No apparent sign of distress on PVC pipes and the associated bolts. • No erosion protection measure was used. • Most of the pipes were empty, indicating that the mulch/soil mix inside had been washed away.	N/A	E.3.5.2
NFY Mulching Panel	13	11SW-D/C1090 11SW-A/C139	• Each panel individually anchored onto slope. • No apparent sign of detachment of panels from the slope surface. • Locally on slope C139 mulching blocks were noted to have dried up with narrow cracks and disintegrated. • No erosion control measure was used to protect the exposed surface of the mulching panels. Surface erosion was noted locally on a number of mulching blocks on slope C139.	13	E.3.6.2
Terra Cell	14	11NE-D/C815B	• The cellular structure was not fully supported at slope toe, rendering it vulnerable to down slope movement. • No erosion control mat was provided on the finished surface and local erosion of the soil mix in the cell was observed.	14	E.3.7.2

Notes: (1) Description of Crack Width on Mulch/Soil Mix:
- Narrow (<5 mm)
- Moderately Narrow (5-10 mm)
- Wide (>10 mm)

(2) Extent of Observations:
- Locally (< 30% of total slope surface area)
- Extensive (between 30% and 70% of total slope surface area)
- Widespread (> 70% of total slope surface area)

Table of Contents Table of Contents Table of Contents Table of Contents

Table 12 - Summary of Results of Engineering Assessment for Slopes under Category of Reinforced Soil System

Greening Products	Construction Details in Figure No.	Slopes inspected	Observations(Note) during inspections	Relevant Plate(s) No.	Relevant section of Appendix E
Geofiber	15	11SW-D/C601 11SW-B/C24	• Overall engineering condition of the system was generally satisfactory on slope C601. • Moderately narrow cracks were found on the surface mulch on slope C24 and the mulch had detached at some locations, exposing the wire mesh and the continuous fiber underneath. • The fiber-reinforced soil under the surface mulch was intact, without any sign of deterioration. • No erosion control mats were used. No sign of erosion was observed on slope C601 but local surface erosions were noted on slope C24.	15	E.4.2

Notes: (1) Description of Crack Width on Mulch/Soil Mix:
- Narrow (<5 mm)
- Moderately Narrow (5-10 mm)
- Wide (>10 mm)

(2) Extent of Observations:
- Locally (< 30% of total slope surface area)
- Extensive (between 30% and 70% of total slope surface area)
- Widespread (> 70% of total slope surface area)

Table 13 - Summary of Results of Engineering Assessment for Slopes using Temporary Degradable Erosion Control Mats

Greening Products	Construction Details in Figure No.	Slopes Inspected	Observations(Note) during Inspections	Relevant Plate(s) No.	Relevant Section of Appendix F
Soil Guard	17	11NW-D/C403 11NW-B/C504	• On slope C403, the Soil Guard was covered by a layer of rolled erosion control mat which obstructed detailed inspection of the product. • On slope C504, localized areas of erosion, particularly near crest were noted.	16	F.2.2.2
Coir	18	11NW-D/FR40	• Mat partially degraded at 1st inspection in May 2003. • On slope FR40, erosion gullies were found along areas where two layers of the mat overlapped during inspection in May 2003. Further erosion at the gullies was not apparent at inspection in October 2003.	17	F.2.3.2
Soil Saver	19	6SE-D/C212	• Mat almost completely degraded. • Minor erosion was noted locally.	18	F.2.4.2

Note: Extent of Observations:
- Locally (< 30% of total slope surface area)
- Extensive (between 30% and 70% of total slope surface area)
- Widespread (> 70% of total slope surface area)

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Table 14 - Summary of Results of Engineering Assessment for Slopes using Long-term Non-degradable Erosion Control Mats

Greening Products	Construction Details in Figure No.	Slopes Inspected	Observations(Note) during Inspections	Relevant Plate(s) No.	Relevant Section of Appendix F
Enkamat	20	11NW-D/FR50	• No sign of weakening of the mats • The mat generally conformed to the soil surface. • No sign of erosion.	N/A	F.3.2.2
Kangaroo Mat	21	3NE-C/C159 11NW-A/C159	• Material inside the soil factor and fertilizer strips of the mats of both slopes decomposed, leaving the PVC erosion control mat alone. • No apparent sign of erosion on both slopes • For slope 11NW-A/C159, overlaps of two mats were not anchored securely on the slope surface	19	F.3.3.2
Miramat TM8	22	7SW-C/C180 7SW-C/C181 7SW-D/C22	• No sign of weakening in strength of the mats on all slopes. • No sign of erosion on all slopes. • On slope C180, the mat was not installed to conform to the undulating slope profile	20	F.3.4.2
Multimat	23	7SE-C/C42	• No sign of weakening in strength of the mats was noted on the slope. • Extensive surface erosions were noted on the slope. The eroded materials were partly derived from the insitu soil of the slope and partly from the granular soil fill placed after mat installation • Erosion may be attributed to the large hole size of the mat.	21	F.3.5.2
Tensarmat/ EM4	24	7SE-D/C13 7SE-D/C53	• No sign of weakening in the strength of the mats on the two slopes. • The mats on both slopes were in close contact with the soil surface and were securely pegged. • Erosion occurred locally on both slopes, but in a larger extent on slope C53.	22	F.3.6.2

Note: Extent of Observations:
- Locally (< 30% of total slope surface area)
- Extensive (between 30% and 70% of total slope surface area)
- Widespread (> 70% of total slope surface area)

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Table 15 - Summary of Results of Engineering Assessment for Slopes using Long-term Non-degradable Erosion Control Mats and Steel Wire Mesh

Greening Products	Construction Details in Figure No.	Slopes Inspected	Observations(Note) during Inspections	Relevant Plate(s) No.	Relevant Section of Appendix F
Enkamat	25	3SE-D/C74 3SE-D/C75	• No sign of weakening in strength of the mats noted on the slopes. • On slope C74, minor erosion was noted locally. Eroded material trapped by wire mesh. The trapped material acted like a protective layer to minimize further erosion. • The wire mesh and the mats generally conformed to soil surface.	23	F.4.2.2
Miramat TM8	26	3SE-D/C118	• No sign of weakening in strength of the mats. • The wire mesh and the mats were securely anchored on the slope and in close contact with the soil surface. • No sign of erosion.	N/A	F.4.3.2
Multimat	27	6SE-C/C28	• No sign of weakening in strength of the mats. • No signs of erosion noted. • The steel wire mesh and mat were anchored securely on the slope and in close contact with the soil surface, except at the slope toe locally.	24	F.4.4.2
Tensarmat/ EM4	28	8SW-B/C74 11SW-C/C82	• The mat on slope C74 lost strength and became brittle; no sign of weakening in strength of the mat on slope C82. • On slope C74, minor erosion was noted locally. Eroded material was trapped by wire mesh. • No apparent sign of surface erosion noted on slope C82. • The mats conformed to soil surface and securely pegged on both slopes.	25	F.4.5.2

Note: Extent of Observations:
- Locally (< 30% of total slope surface area)
- Extensive (between 30% and 70% of total slope surface area)
- Widespread (> 70% of total slope surface area)

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Table 16 - Types of Wire Meshes and Erosion Control Mats Provided for Group 1 Techniques under Categories of Mulching System, Cellular System and Reinforced Soil

Types of Techniques	Products	Wire Mesh Used	Erosion Control Mat Used
Mulching System	Biocrete	• Not used	• No reinforcing element is specified in the supplier's brochure, but a layer of PVC mesh was found embedding within the mulch/soil mix.
	Hong Kong Mulching	• 3-D, PVC coated	• 1 layer of Coir mat (Temporary degradable) as specified in the supplier's brochure, but it was noted on the two slopes inspected that the mat is long-term non-degradable type.
	NFY Hydro-Mulching	• 3-D, PVC coated	• 1 layer of Soil Saver (Temporary degradable)
	"On" Method	• 1-D	• 1 layer of Soil Saver (Temporary degradable) as specified in the supplier's brochure, but it was noted on a slope inspected that the mat was Miramat TM8 (Long-term Non-degradable) whereas there was no mat on another slope inspected.
	Rocksgrass	• Not used	• 2 layers of temporary degradable mats, brand not specified • 3 layers of long-term non-degradable mats (2 of them are Enkamat, the other of unknown brand)
	CMS-ML Green System	• Not used	• 4 layers of Secumats (Long-term Non-degradable)
	Soil Panel	• 1 layer of PVC coated steel grids with bar diameter of 5.8 mm behind mulch/soil mix. • 1 layer of PVC coated steel wire mesh for the system with wire diameter of 3.2 mm	• 1 layer of Coir mat (Temporary degradable)
	Toyo-Mulching	• 3-D, PVC coated	• 1 layer of Coir mat (Temporary degradable)
Cellular System	Eco-link	• No wire mesh is specified in the supplier's brochure, but a layer of wire mesh was found within the product on the two slopes inspected.	• 1 layer of Tensarmat (Long-term Non-degradable)
	Instant Evergreen System	• 1-D PVC coated wire mesh forming the gabion for the mulching panel	• 1 layer of PVC mat (Long-term Non-degradable), brand not quoted
	NFY Eco-MP System	• 1-D PVC coated as gabion	• Not used
	NFY Hydro Planter	• 1-D covering the planters	• Not used
	NFY Mulching Panel	• 1-D PVC coated wire mesh forming the gabion for the mulching panel	• Not used
	Terra Cell	• Not used	• Not used
Reinforced Soil	Geofiber	• 1-D, PVC coated	• Not used

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Table 17 - Summary of Merits and Limitations of Different Proprietary Products of Group 1 Techniques (Sheet 1 of 3)

Techniques	Products	Merits	Limitations
Mulching	Biocrete	• Able to form smooth finished surface on uneven slope profile • Quick installation	• Low vegetation cover • Mulch/soil mix with extensive cracks and detachment due to desiccation • Mulch/soil mix too hard for roots to develop due to presence of cement additives • Mulch/soil mix layer thin and unable to support small woody species
	Hong Kong Mulching	• Medium to high vegetation cover • Quick installation • Able to form smooth finished surface on uneven slope profile • Satisfactory engineering performance except local detachment of mulch/soil mix	• Mulch/soil mix liable to crack due to desiccation • Mulch/soil mix layer thin and unable to support small woody species
	NFY Hydro-Mulching	• Able to form smooth finished surface on uneven slope profile • Quick installation	• Variable vegetation cover on different slopes • Mulch/soil mix with cracks and detachment due to desiccation • Mulch/soil mix layer thin and unable to support small woody species
	“On” Method	• Able to form smooth finished surface on uneven slope profile • Quick installation	• Variable vegetation cover on different slopes • Mulch/soil mix with cracks and detachment due to desiccation • Mulch/soil mix too hard for roots to develop due to presence of cement additives • Mulch/soil mix layer thin and unable to support small woody species
	Rocksgrass	• High vegetation cover • Quick installation • Able to support small shrubs owing to the ability to maintain soil moisture • Able to form smooth finished surface on uneven slope profile • Good engineering performance	• Monotonous appearance of planting *Wedelia trilobata*
	CMS-ML Green System	• Able to form smooth finished surface on uneven slope profile • Quick installation • Good engineering performance	• Low vegetation cover
	Soil Panel	• Quick installation • Able to support small shrubs owing to the thicker layer of mulch/soil mix	• Variable vegetation cover on different slopes • Engineering performance of system to be improved (e.g. bulging of mulch/soil mix) • More space required to accommodate the mulch/soil mix

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Table 17 - Summary of Merits and Limitations of Different Proprietary Products of Group 1 Techniques (Sheet 2 of 3)

Techniques	Products	Merits	Limitations
	Toyo-Mulching	• High vegetation cover • Quick installation • Able to form smooth finished surface on uneven slope profile • Satisfactory engineering performance except local detachment of mulch/soil mix	• Mulch/soil mix layer thin and unable to support small woody species
Cellular System	Eco-link	• High vegetation cover • Quick installation • Satisfactory engineering performance except local erosion of mulch/soil mix	• Volume of mulch/soil mix confined by the cell size and too small to support small woody species
	Instant Evergreen System	• Instant greening effect • Quick installation • Nurturing of plant in controlled environment (e.g. at nursery area)	• Variable vegetation cover on different slopes • Lack of species diversity as a single species of herb *Sedum tetractinum* as the main cover • High desiccation rate resulting from large exposed surface area • Highly rugged profile on uneven slope surface • Prefabricated gabions highly visible if without a dense vegetation cover
	NFY Eco-MP System	• High vegetation cover • Quick installation • Vegetation able to obtain moisture from soil under the shotcrete through planting holes • Good engineering performance as gabions with mulch/soil mix concealed in the slope	• Need to form large holes through the concrete cover to accommodate the gabions • Part of the existing shotcrete cover exposed
	NFY Hydro Planter	• Quick installation	• Very low vegetation cover • Large pipes and exposed concrete surface cover highly visible and not visually pleasing • Erosion of soil in the pipes leaving behind empty pipes
	NFY Mulching Panel	• Quick installation	• Variable vegetation cover on different slopes • High desiccation rate resulting from large exposed surface area of panels • Unreinforced Mulch/soil mix with cracks and detachment due to desiccation • Highly rugged profile on uneven slope surface • Prefabricated gabions highly visible if without a dense vegetation cover
	Terra Cell	• High vegetation cover • Quick installation	• Detachment of soil mix from the cells on steep slope • Liable to surface erosion (no erosion control mat)

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Table 17 - Summary of Merits and Limitations of Different Proprietary Products of Group 1 Techniques (Sheet 3 of 3)

Techniques	Products	Merits	Limitations
Reinforced Soil	Geofiber	• High vegetation cover • Able to form smooth finished surface on uneven slope profile • Good engineering performance except local cracking of surface mulch and erosion • Able to support small shrubs owing to the thicker layer of planting medium	• More space required to accommodate the thick planting medium
Bio-engineering	GW-Biodrains System	• High vegetation cover • Quick installation • Vegetation able to obtain moisture from soil under the shotcrete through planting holes	• Monotonous appearance owing to lack of species diversity • Regular cropping of Vetiver Grass required • Vetiver grass not being a native species • No natural invasion of other plants allowed • Need to form holes through the concrete cover for planting

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Table 18 - Summary of Merits and Limitations of Different Proprietary Products of Group 2 Techniques (Sheet 1 of 2)

<table>
<tr><th>Techniques</th><th>Products</th><th>Merits</th><th>Limitations</th></tr>
<tr><td rowspan="3">Temporary Degradable Erosion Control Mat</td><td>Soil Guard</td><td>• Degradable organically
• Quick installation</td><td>• Low Vegetation Cover</td></tr>
<tr><td>Coir</td><td rowspan="2">• Medium to high vegetation cover
• Degradable
• Flexible
• Quick installation
• Capable of holding up moisture and nutrient for plant growth
• Effective in erosion control on gentle slopes
• Enhancement of natural succession of vegetation</td><td rowspan="2">• Not suitable for steep slopes or slopes with concentrated surface runoff
• Not durable</td></tr>
<tr><td>Soil Saver</td></tr>
<tr><td rowspan="3">Rolled Long-term Non-degradable Erosion Control Mat</td><td>Kangaroo Mat</td><td>• High vegetation cover
• Flexible
• Quick installation
• Durable, strong, capable of withstanding high shear stress
• No hydroseeding required as the non-woven fabric contains seeds
• With long-lasting fertilizer bag to provide plants with fertilizers
• Enhancement of natural succession of vegetation</td><td rowspan="2">• Large aperture size easily leading to erosion
• Restriction of growth of woody plants</td></tr>
<tr><td>Multimat</td><td>• High vegetation cover
• Flexible
• Quick installation
• Durable, strong, capable of withstanding high shear stress
• 3-D matrix for entangling plant roots and soils to form a continuous composite living mat
• Ultra-violet stabilized
• Enhancement of natural succession of vegetation</td></tr>
<tr><td>Enkamat</td><td rowspan="3">• Medium to high vegetation cover
• Flexible
• Quick installation
• Durable, strong, capable of withstanding high shear stress
• 3-D matrix for entangling plant roots and soils to form a continuous composite living mat
• Ultra-violet stabilized
• Effective in erosion control on steep slopes
• Enhancement of natural succession of vegetation</td><td>• Restriction of growth of woody plants</td></tr>
<tr><td rowspan="2"></td><td>Miramat TM8</td><td rowspan="2">•</td></tr>
<tr><td>Tensarmat/EM4</td></tr>
</table>

Table of Contents
Table of Contents
Table of Contents
Table of Contents

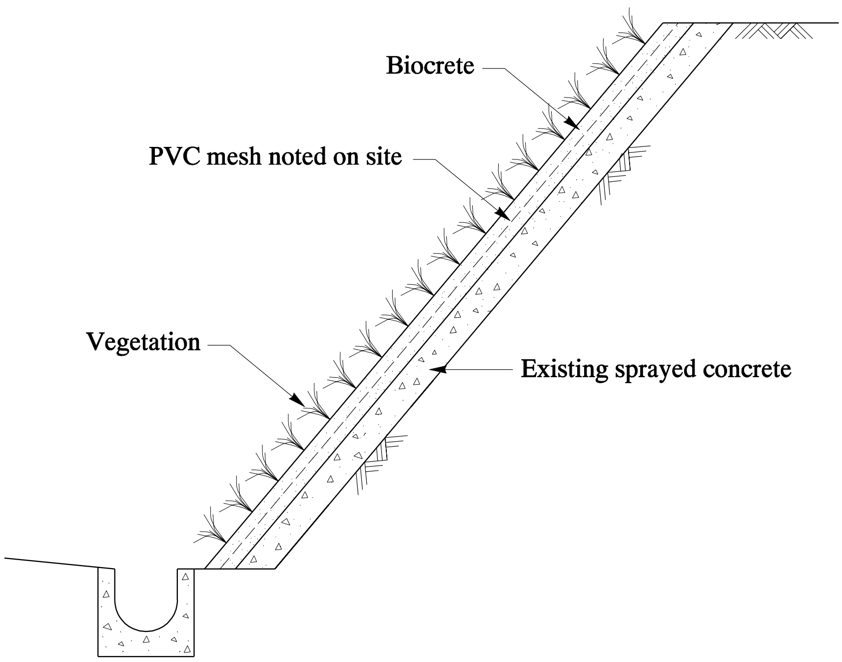
Table 18 - Summary of Merits and Limitations of Different Proprietary Products of Group 2 Techniques (Sheet 2 of 2)

<table>
<tr><th>Techniques</th><th>Products</th><th>Merits</th><th>Limitations</th></tr>
<tr><td rowspan="4">Rolled Long-term Non-degradable Erosion Control Mat with Steel Wire Mesh</td><td>Multimat</td><td>• High vegetation cover
• Flexible
• Quick installation
• Durable, strong, capable of withstanding high shear stress
• 3-D matrix for entangling plant roots and soils to form a continuous composite living mat
• Ultra-violet stabilized
• Enhancement of natural succession of vegetation
• Able to prevent local instability between soil nail heads</td><td>• Large aperture size easily leading to erosion
• Restriction of growth of woody plants by steel wire mesh</td></tr>
<tr><td>Enkamat</td><td rowspan="2">• Flexible
• Quick installation
• Durable, strong, capable of withstanding high shear stress
• 3-D matrix for entangling plant roots and soils to form a continuous composite living mat
• Ultra-violet stabilized
• Effective in erosion control on steep slopes
• Enhancement of natural succession of vegetation
• Able to prevent local instability between soil nail heads</td><td rowspan="2">• Low to medium vegetation cover
• Restriction of growth of woody plants by steel wire mesh</td></tr>
<tr><td>Miramat TM8</td></tr>
<tr><td>Tensarmat/EM4</td><td>• Medium to high vegetation cover except one slope with low vegetation cover
• Flexible
• Quick installation
• Durable, strong, capable of withstanding high shear stress
• 3-D matrix for entangling plant roots and soils to form a continuous composite living mat
• Ultra-violet stabilized
• Effective in erosion control on steep slopes
• Enhancement of natural succession of vegetation
• Able to prevent local instability between soil nail heads</td><td>• Restriction of growth of woody plants by steel wire mesh</td></tr>
</table>

Table of Contents
Table of Contents
Table of Contents
Table of Contents

LIST OF FIGURES

Table of Contents
Table of Contents
Table of Contents



Typical details based on supplier's information
(not to scale)

Overall view of slope treated with Biocrete

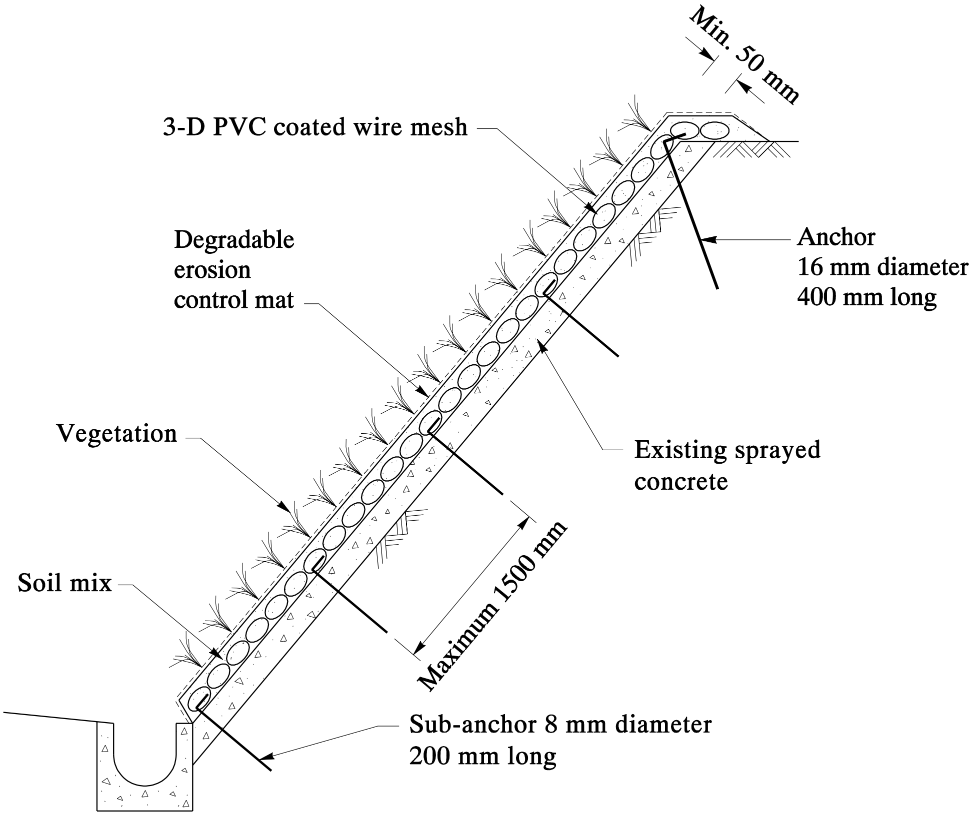
Close-up view

Construction method (based on information provided by the product supplier):

- A mixture of soil, concrete and organic fibre is sprayed onto the slope surface (Thickness not mentioned in supplier's brochure). Soil and fertilizer are embedded in the mixture in the form of "bio-capsules".
- A layer of PVC mesh, which has not been mentioned in supplier's brochure, was noted on site embedded in the soil mixture.
- Though not mentioned in the supplier's brochure, the usual landscaping treatment is hydroseeding grass seeds.

Figure 1 - Details of Biocrete

Table of Contents
Table of Contents
Table of Contents
Table of Contents



Typical details based on supplier's information
(not to scale)

Overall view of slope treated with
Hong Kong Mulching

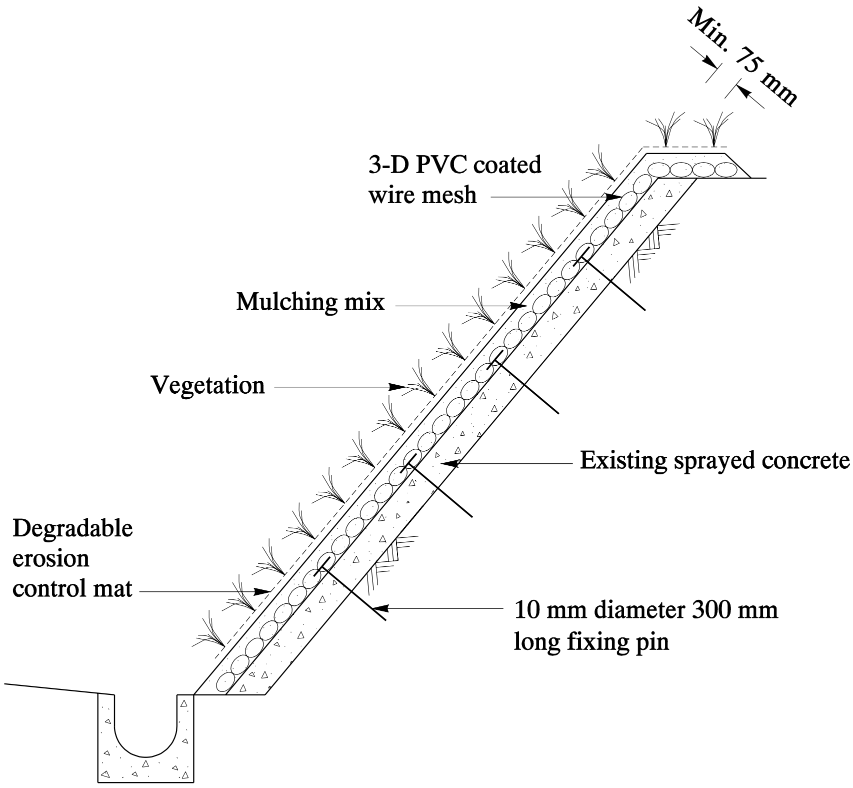
Close-up view

Construction method (based on information provided by the product supplier):

- A layer of 3-D PVC coated wire mesh is fixed on slope surface by a row of steel anchors along slope crest at 1.2 m c/c spacing and by sub-anchors on every 100 m^2 of slope face.
- Soil mix containing soil, binding agent and seeds is sprayed on the wire mesh and slope surface to a minimum thickness of 50 mm.
- The finished slope surface is covered by a layer of degradable erosion control mat, usually coir mesh, which is fixed with U-pins on soil mix surface (Not shown in section for clarity).

Figure 2 - Details of Hong Kong Mulching

Table of Contents
Table of Contents
Table of Contents
Table of Contents



Typical details based on supplier's information
(not to scale)

Overall view of slope treated with NFY Hydro-Mulching

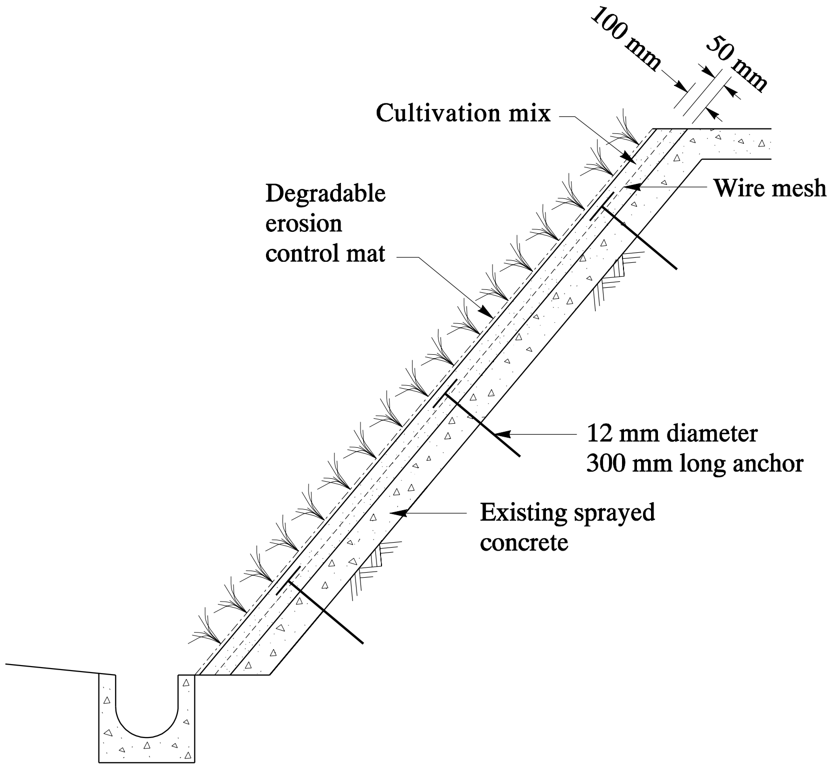
Close-up view

Construction method (based on information provided by the product supplier):

- A layer of 3-D PVC coated wire mesh is anchored on to slope surface by fixing pins at 2 m c/c spacing.
- Mulching mix consisting of fertilizer and moisture retaining agent with a minimum thickness of 75 mm is then sprayed on the wire mesh and slope surface. The final face is covered with a degradable erosion control mat, which is fixed by plastic strips (not shown in section for clarity).
- The usual landscape treatments are hydroseeding grass seeds and/or planting creepers.

Figure 3 - Details of NFY Hydro-Mulching

Table of Contents
Table of Contents
Table of Contents
Table of Contents



Typical details based on supplier’s information
(not to scale)

Overall view of slope treated with
“On” Method

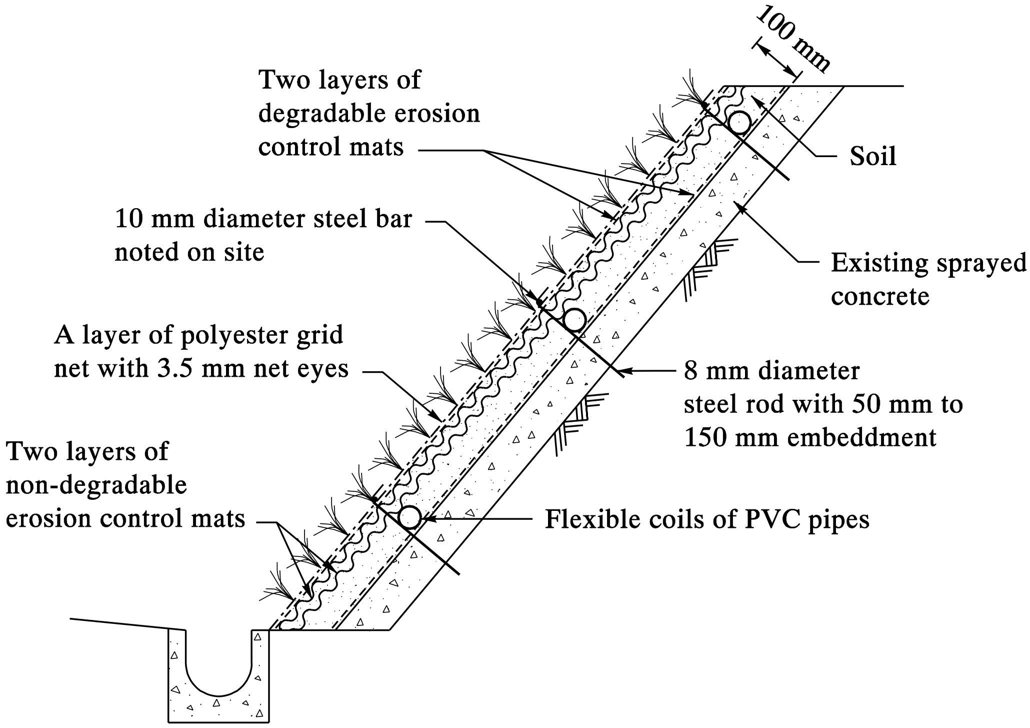
Close-up view

Construction method (based on information provided by the product supplier):

- A layer of wire mesh is anchored on the slope surface.
- Cultivation mix in a thickness of 100 mm containing a mixture of urea-formaldehyde resins, peat moss, bark compost, organic substances, fertilizers and cement, is sprayed on the slope surface.
- The finished slope surface is covered by a layer of degradable erosion control mat, normally soil saver, and then hydroseeded.

Figure 4 - Details of “On” Method

Table of Contents
Table of Contents
Table of Contents
Table of Contents



Typical details based on supplier's information
(not to scale)

Overall view of slope treated with Rocksgrass

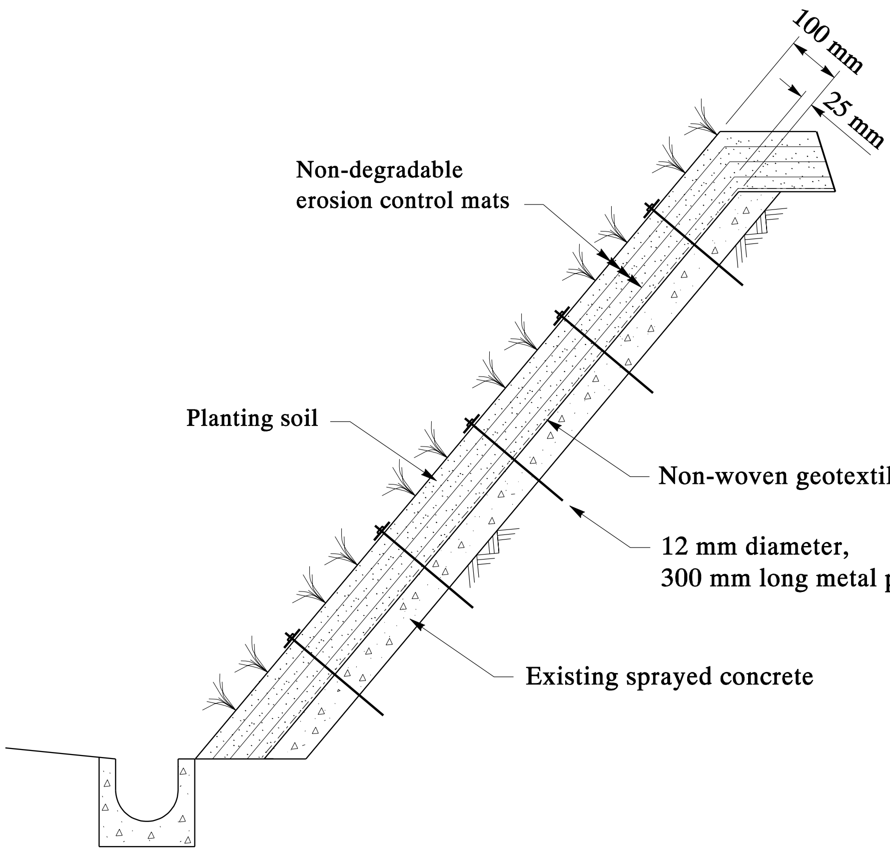
Close-up view

Construction method (based on information provided by the product supplier):

- An 100 mm-thick composite layer, interbedded with soil and 5 layers of mats, is applied onto slope surface by hand. Horizontal rows of flexible coils of PVC pipes are also provided in the composite layer.
- The composite layer is anchored on the slope with steel rods.
- Mild steel bars, which have not been mentioned in supplier's brochure, were noted to be fixed onto the surface of the composite layer horizontally at vertical spacing of about 1.5 m. The finished slope surface is hydroseeded and planted with creepers.

Figure 5 - Details of Rocksgrass

Table of Contents
Table of Contents
Table of Contents
Table of Contents



Typical details based on supplier's information
(not to scale)

Overall view of slope treated with
CMS-ML Green System

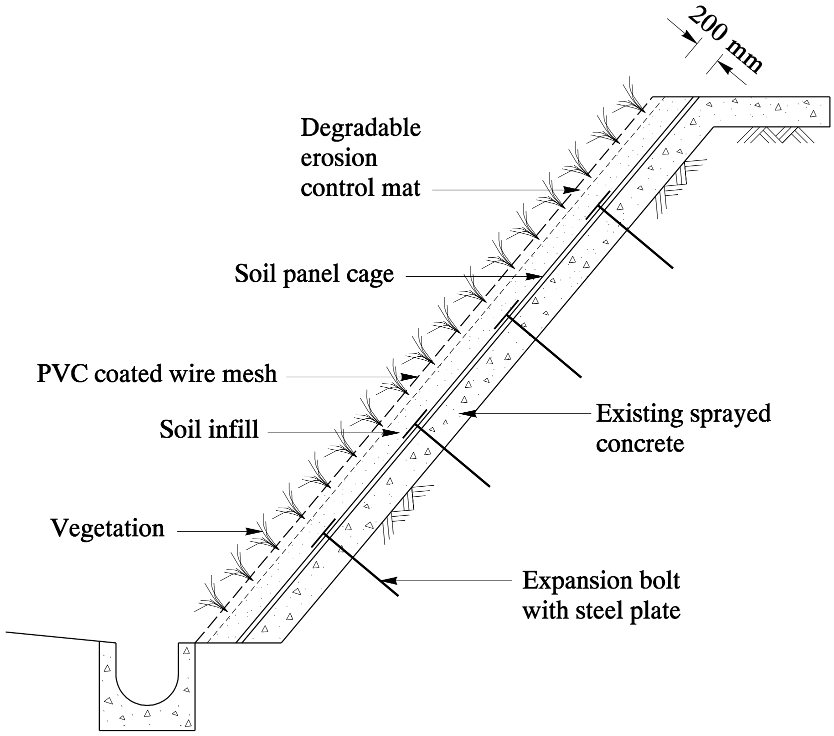
Close-up view

Construction method (based on information provided by the product supplier):

- An 100 mm-thick composite interbedded with planting soil and 5 layers of erosion control mats (a base layer of non-woven geotextile and 4 layers of non-degradable erosion control mats) is applied on the slope.
- The composite layer is fixed on the slope with anchors at 1 m c/c spacing.
- The finished slope is hydroseeded.

Figure 6 - Details of CMS-ML Green System

Table of Contents
Table of Contents
Table of Contents
Table of Contents



Typical details based on supplier's information
(not to scale)

Overall view of slope treated with Soil Panel

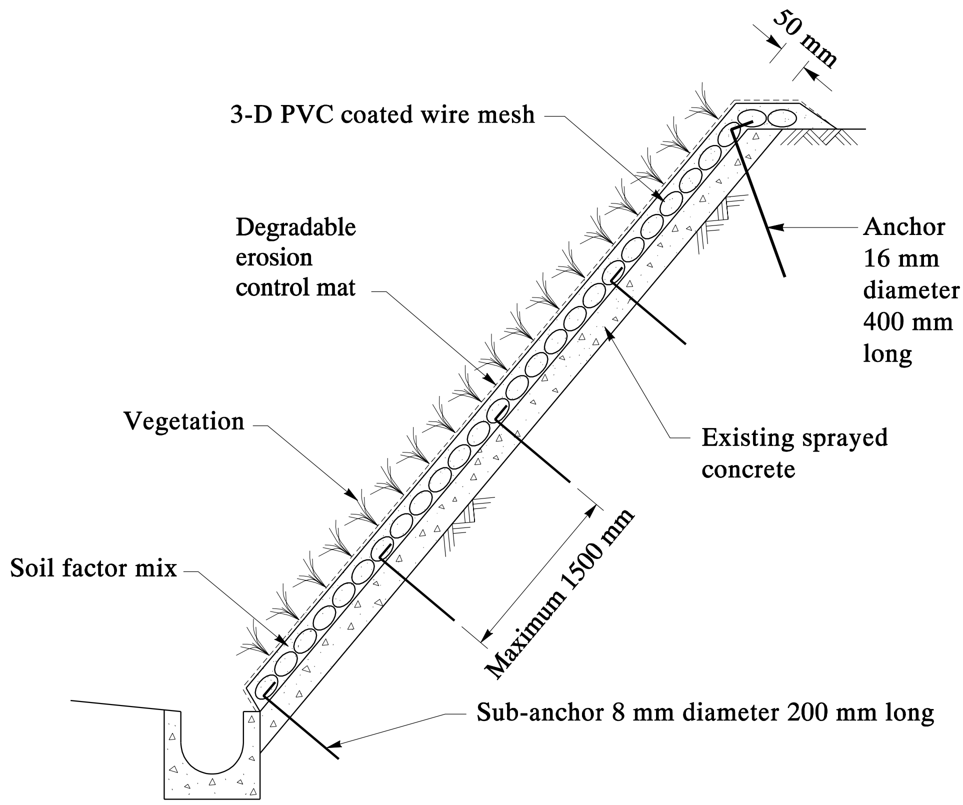
Close-up view

Construction method (based on information provided by the product supplier):

- Prefabricated panel made of a layer of steel gird at the rear and a layer of steel wire mesh at the front connected by steel diaphragm is assembled and bolted on the slope surface to form a cage like structure.
- The inside of front wire mesh is lined with a layer of degradable erosion control mat, usually coir mesh.
- Soil is placed inside the panels from the top.
- The usual landscape treatment is hydroseeding grass seeds and/or planting ground cover.

Figure 7 - Details of Soil Panel

Table of Contents
Table of Contents
Table of Contents
Table of Contents



Typical details based on supplier's information
(not to scale)

Overall view of slope treated with Toyo-Mulching

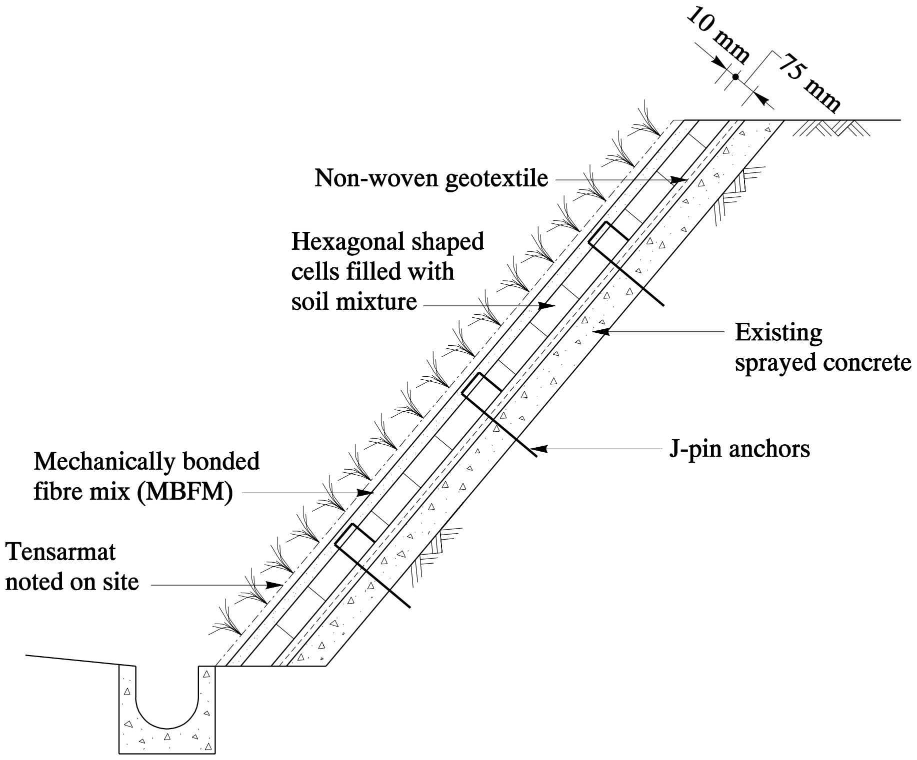
Close-up view

Construction method (based on information provided by the product supplier):

- A layer of 3-D PVC coated wire mesh is fixed on slope surface by a row of steel anchors along slope crest at 1.2 m c/c spacing and by sub-anchors on every 100 m^2 of slope face.
- Grass seeds and fiber soil (containing moisture retaining agent, fertilizer and binding agent) are sprayed on the wire mesh to a thickness of 50 mm. For slopes steeper than 45°, fertilizer strips will be installed on the wire mesh before spraying.
- The finished surface is covered by a layer of degradable erosion control mat, which is fixed with U-pins on soil factor surface (U-pins not shown in section for clarity). Climbers are sometimes planted in planter holes through sprayed cover layer.

Figure 8 - Details of Toyo-Mulching

Table of Contents
Table of Contents
Table of Contents
Table of Contents



Typical details based on supplier's information
(not to scale)

Overall view of slope treated with Eco-link

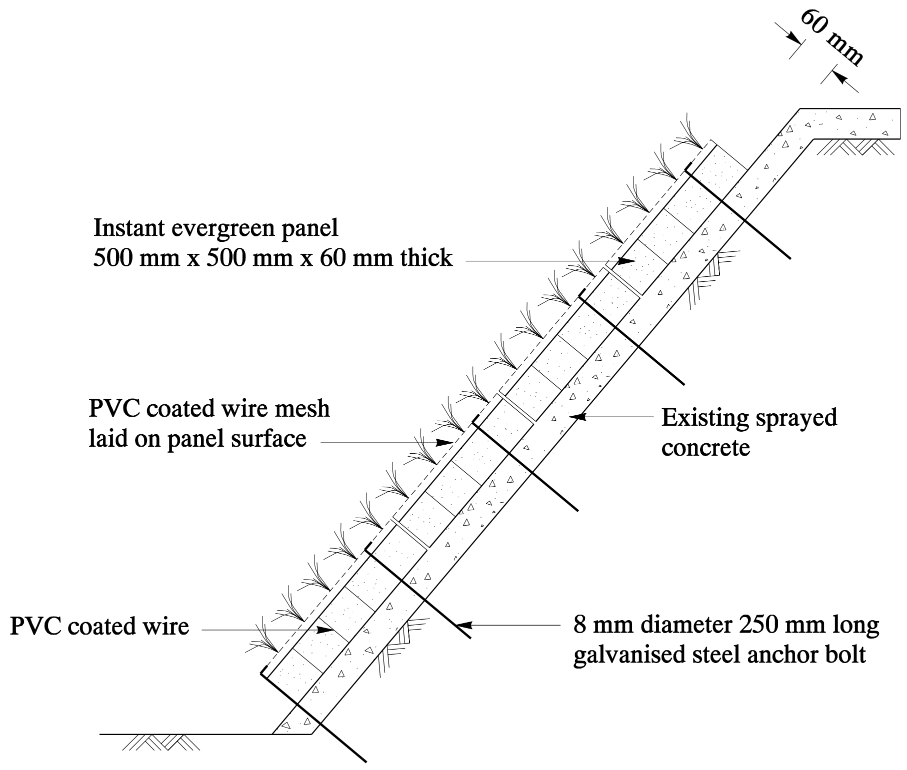
Close-up view

Construction method (based on information provided by the product supplier):

- A layer of non-woren geotextile and a layer of 75 mm-thick Cellular Soil Confinement System (a mat-like material made of polyethylene with hexagonal shaped cells) are anchored by pins on the slope surface. The cells are then filled with a mixture named as Hydro-compost consisting of soil, organic substances and nutrients.
- A layer of mulch named Mechanical Bonded Fiber Matrix containing wood fiber, paper pulp, organic substances, water and green dye, mixed together with seeds and fertilizer, is applied to form the final face.
- Though not mentioned in the supplier's brochure, a layer of tensarmat was noted on site covering the finished slope surface.

Figure 9 - Details of Eco-link

Table of Contents
Table of Contents
Table of Contents
Table of Contents



Typical details based on supplier's information
(not to scale)

Overall view of slope treated with
Instant Evergreen System

Close-up view

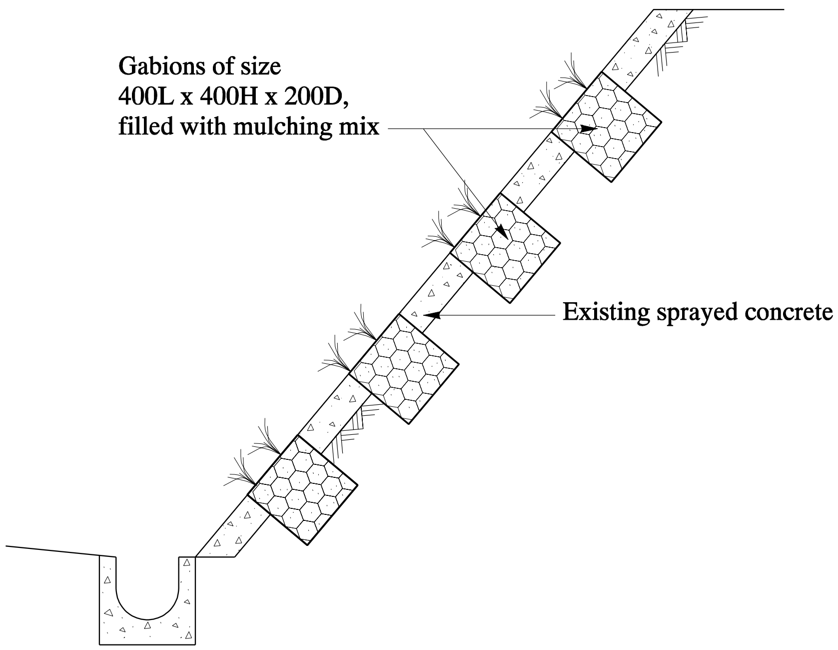
Construction method (based on information provided by the product supplier):

- Prefabricated panels of mulch mix encaged in PVC coated galvanized wire mesh are mounted on slope surface by anchor bolts. The size of each panel is 500 mm x 500 mm x 60 mm thick.
- The panels contain mulch composed of peat moss and loam which are lined with a layer of geotextile in the panel.
- A layer of PVC coated wire mesh is used for covering the panels.

Note: Before the panels are fixed onto slope, they are cultivated in nursery areas till vegetation is established.

Figure 10 - Details of Instant Evergreen System

Table of Contents
Table of Contents
Table of Contents
Table of Contents



Typical details based on supplier's information
(not to scale)

Overall view of slope treated with
NFY Eco-MP System

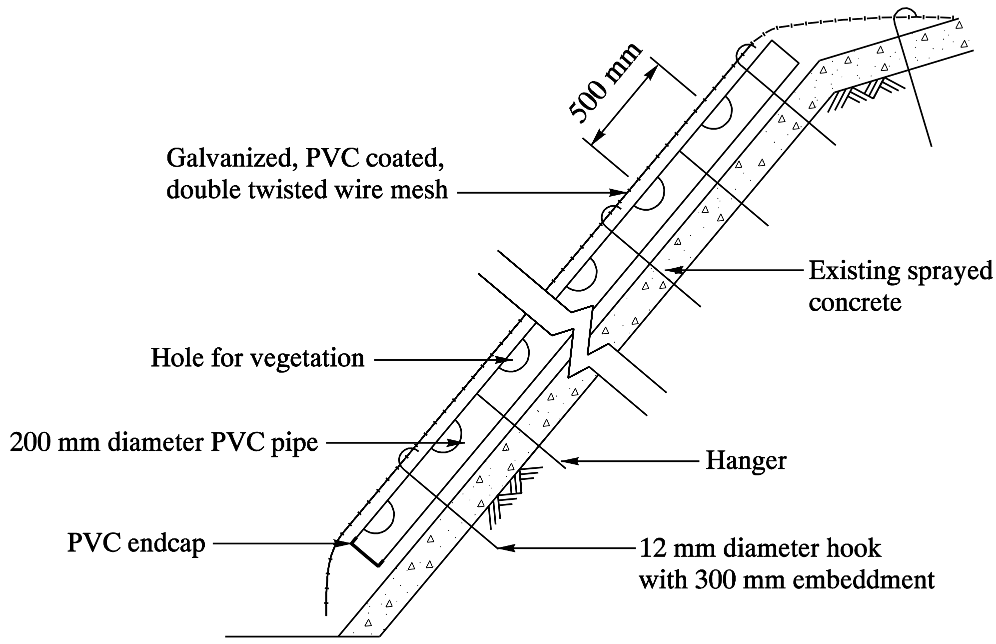
Close-up view

Construction method (based on information provided by the product supplier):

- Rectangular holes usually spaced at 1.5 m c/c are excavated on the slope surface with a dimension of about 200 mm deep, 400 mm wide and 800 mm long.
- Prefabricated PVC coated gabion cages filled with mulching mix consisting of fertilizer and moisture retaining agent and with vegetation planted on are fitted in each hole.

Figure 11 - Details of NFY Eco-MP System

Table of Contents
Table of Contents
Table of Contents
Table of Contents



Typical details based on supplier's information
(not to scale)

Overall view of slope treated with NFY Hydro Planter

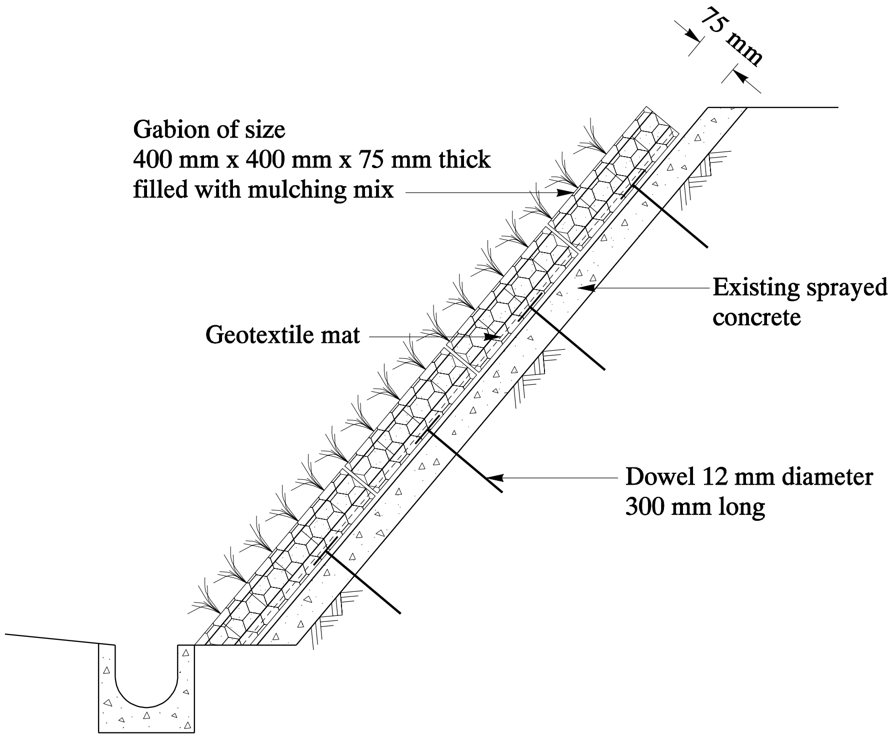
Close-up view

Construction method (based on information provided by the product supplier):

- 200 mm-diameter PVC pipes with circular holes spaced at 500 mm along the pipe are anchored on the slope at 2.5 m c/c spacing.
- The pipes are filled with soil mix. Seedlings are planted in the holes of the pipes.
- A layer of PVC coated wire mesh is used for covering the pipes and the slope surface.

Figure 12 - Details of NFY Hydro Planter

Table of Contents
Table of Contents
Table of Contents
Table of Contents



Typical details based on supplier's information
(not to scale)

Overall view of slope treated with
NFY Mulching Panel

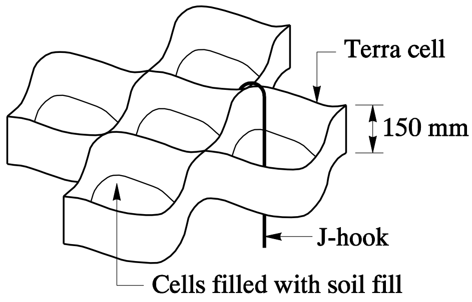
Close-up view

Construction method (based on information provided by the product supplier):

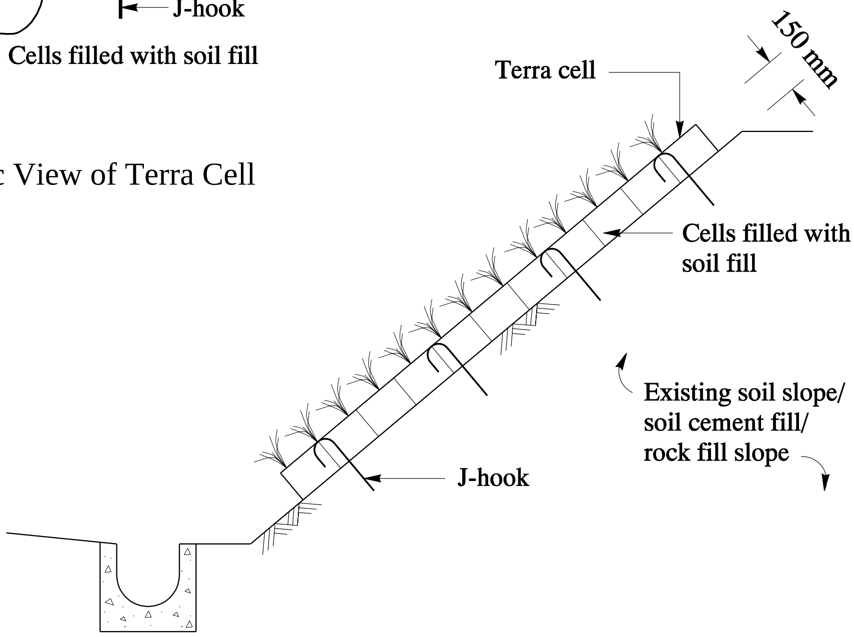
- Prefabricated gabions of size 400 mm x 400 mm x 75 mm thick containing mulching mix are mounted onto slope surface by dowels.
- The usual landscape treatment is hydroseeding grass seeds on the finished slope surface with the panels.

Figure 13 - Details of NFY Mulching Panel

Table of Contents
Table of Contents
Table of Contents
Table of Contents



Isometric View of Terra Cell



Typical details based on supplier’s information
(not to scale)

Overall view of slope treated with Terra Cell

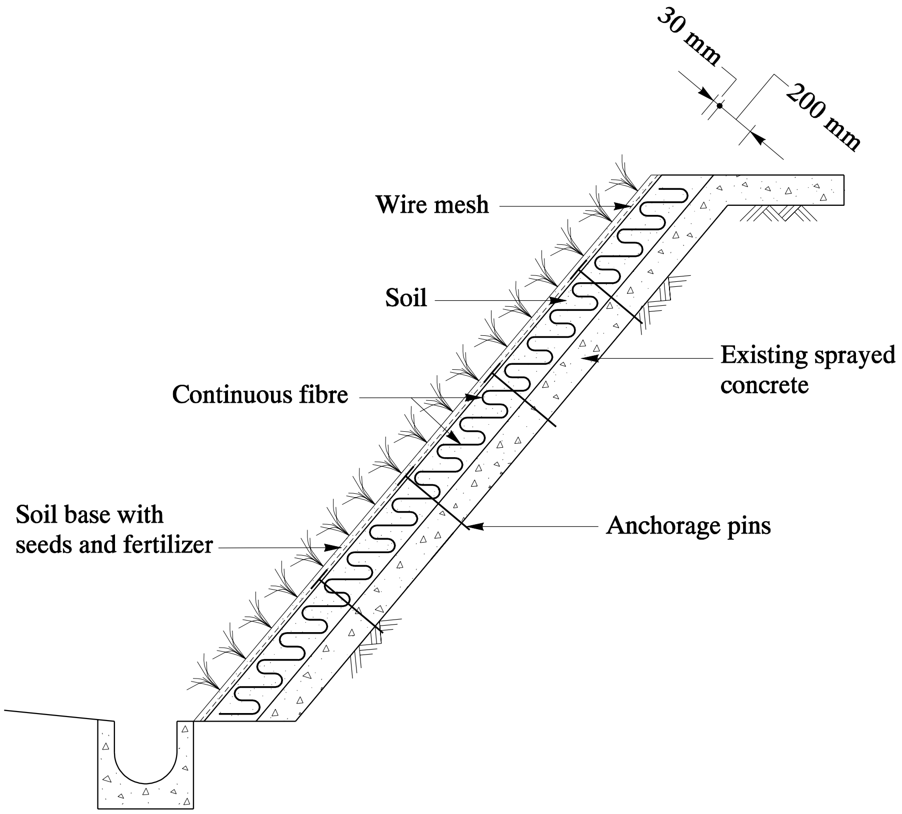
Close-up view

Construction method (based on information provided by the product supplier):

- A mat-like material with diamond shaped cells in a thickness of about 150 mm is anchored by pins on the slope surface. The cells are then filled with soil fill.
- The usual landscape treatment, though not mentioned in the supplier’s brochure, is to hydroseed the finished surface.

Figure 14 - Details of Terra Cell

Table of Contents
Table of Contents
Table of Contents
Table of Contents



Typical details based on supplier's information
(not to scale)

Overall view of slope treated with Geofiber

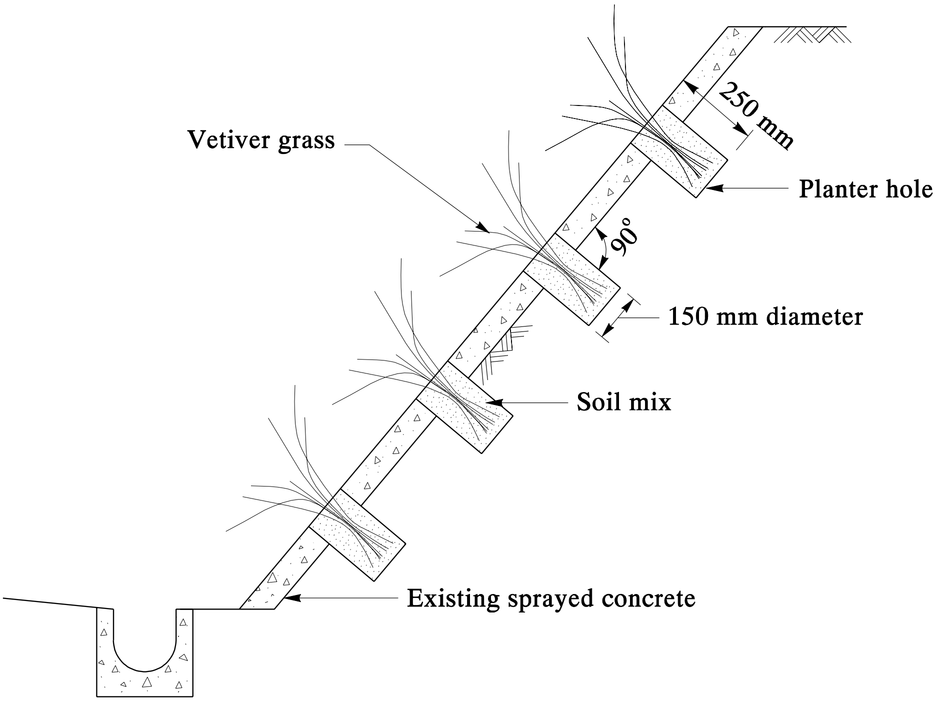
Close-up view

Construction method (based on information provided by the product supplier):

- Soil and continuous fiber (polyester) are sprayed onto slope surface to form a layer of "reinforced" soil about 200 mm thick.
- A layer of wire mesh is placed on top of the geofiber body by anchorage pins at 1.5 m spacing, followed by a layer of 30 mm-thick soil base mixed with seeds and fertilizer on the surface.

Figure 15 - Details of Geofiber

Table of Contents
Table of Contents
Table of Contents
Table of Contents



Typical details based on supplier's information
(not to scale)

Overall view of slope treated with GW-Biodrains System

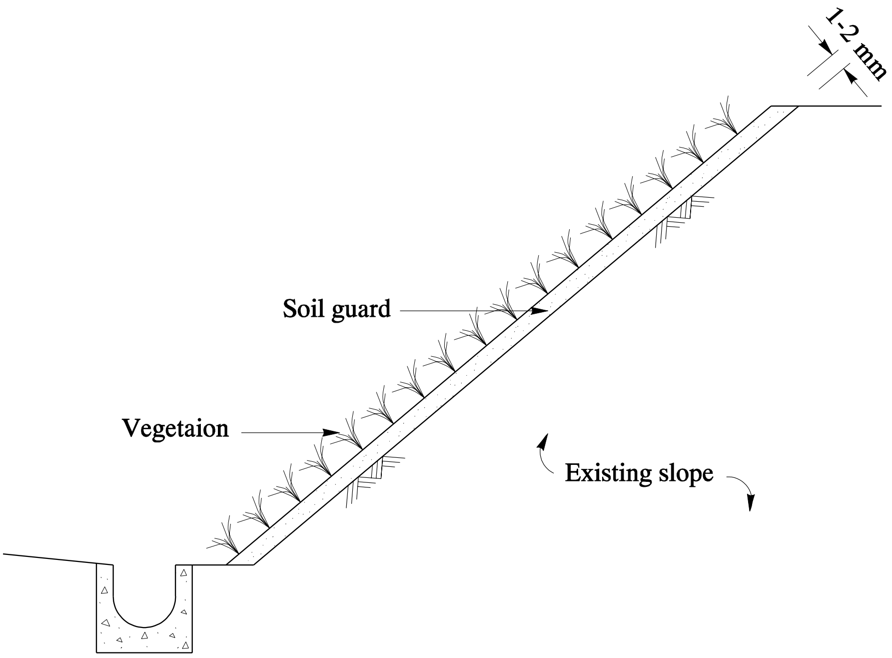
Close-up view

Construction method (based on information provided by the product supplier):

- Planter holes of 150 mm-diameter 250 mm-deep are excavated on the slope surface at 750 mm horizontal spacing and 1 m vertical spacing. Vetiver grass is planted in each planter hole and the hole is backfilled with special soil mix containing CDG and soil conditioner by volume of 3:1.

Figure 16 - Details of GW-Biodrains System

Table of Contents
Table of Contents
Table of Contents
Table of Contents



Typical details based on supplier's information
(not to scale)

Overall view of slope treated with Soil Guard

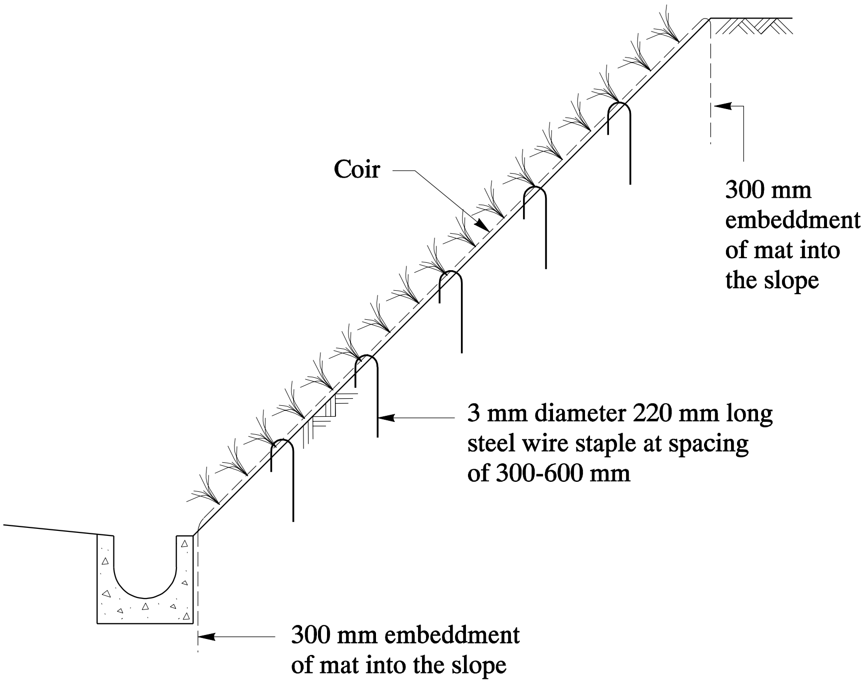
Close-up view

Construction method (based on information provided by the product supplier):

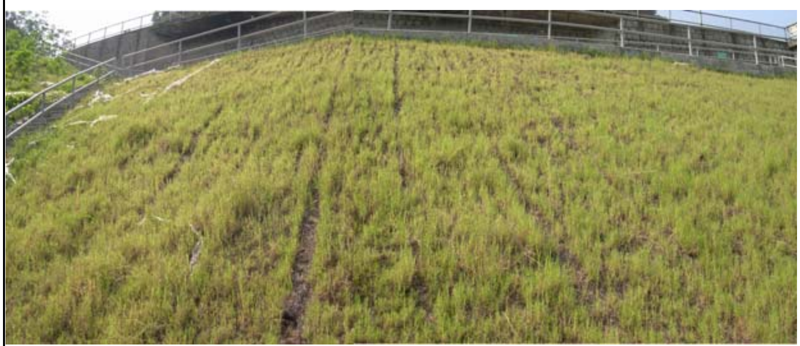
- A mulch in a thickness of 1 to 2 mm composed of wood fibers, natural binding agents, a mixture of organic and mineral activator and vegetation seeds is sprayed on slope surface.
- The system is designed to be used on steep soil slope surface and rocky slopes with high soil contents.

Figure 17 - Details of Soil Guard

Table of Contents
Table of Contents
Table of Contents
Table of Contents



Typical details of anchorage based on supplier's information
(not to scale)



Overall view of slope applied with Coir

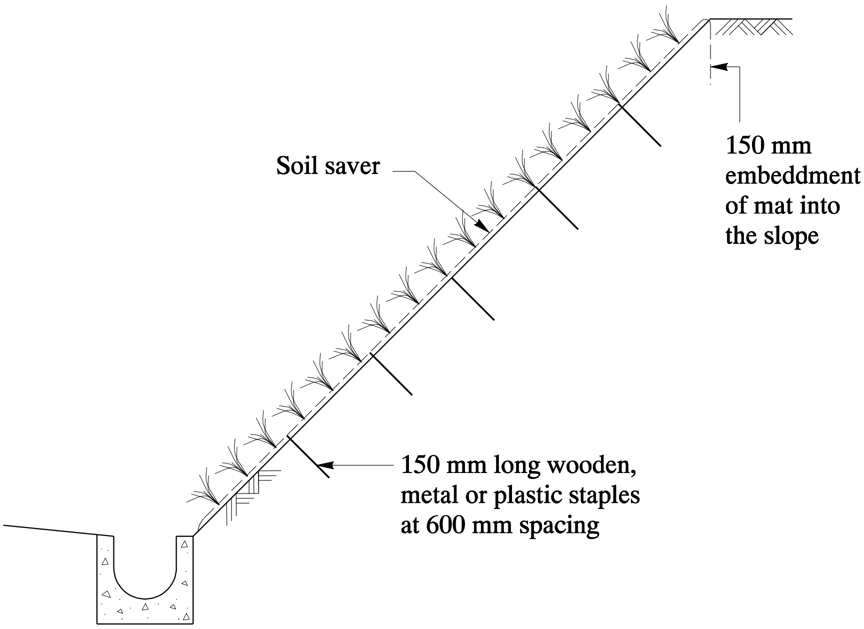
Close-up view

Details of Coir (based on information provided by the product supplier):

- Made up of coconut fibre.
- Degradable organically.
- Densities ranging from 400 to 1,400 g/m^2.
- Provide support on slopes for about 5 years.
- Seeding the slope twice, before and after the mat is laid, is suggested.

Figure 18 - Details of Coir

Table of Contents
Table of Contents
Table of Contents
Table of Contents



Typical details of anchorage based on supplier's information (not to scale)

Overall view of slope applied with Soil Saver

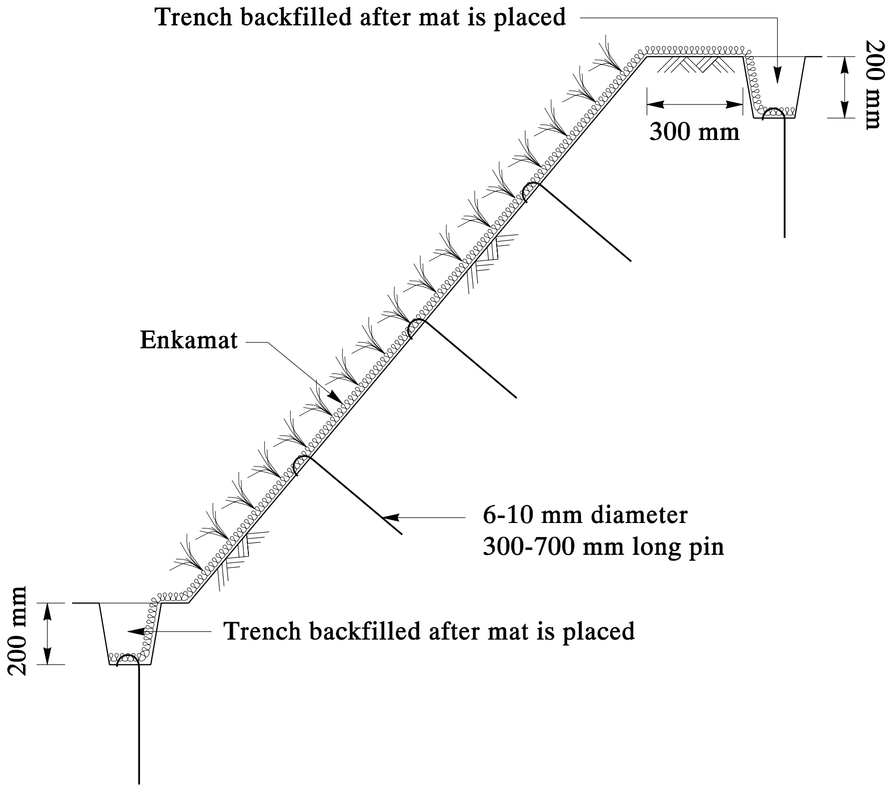
Close-up view

Details of Soil Saver (based on information provided by the product supplier):

- Made up of jute fibre.
- Degradable organically.
- Common densities available: 500, 750 and 1,000 g/m^2.
- Thickness ranging from 5 to 7 mm.
- Duration: 2 years.
- Hydroseeding after the mat is laid on slope.

Figure 19 - Details of Soil Saver

Table of Contents
Table of Contents
Table of Contents
Table of Contents



Typical details of anchorage based on supplier's information
(not to scale)

Overall view of slope applied with Enkamat

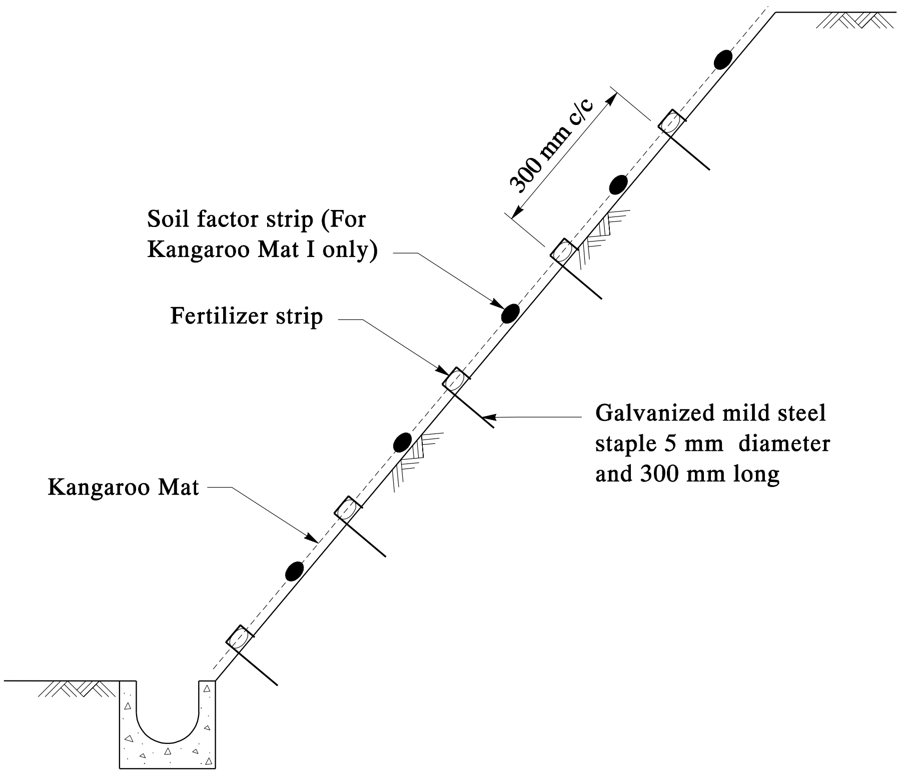
Close-up view

Details of Enkamat (based on information provided by the product supplier):

- 3-D mat made up of polyamide.
- Long-term non-degradable.
- Soil is suggested to fill the whole thickness of mat, followed by hydroseeding.

Figure 20 - Details of Enkamat

Table of Contents
Table of Contents
Table of Contents
Table of Contents



Typical details of anchorage based on supplier's information
(not to scale)

Overall view of slope treated with Kangaroo Mat

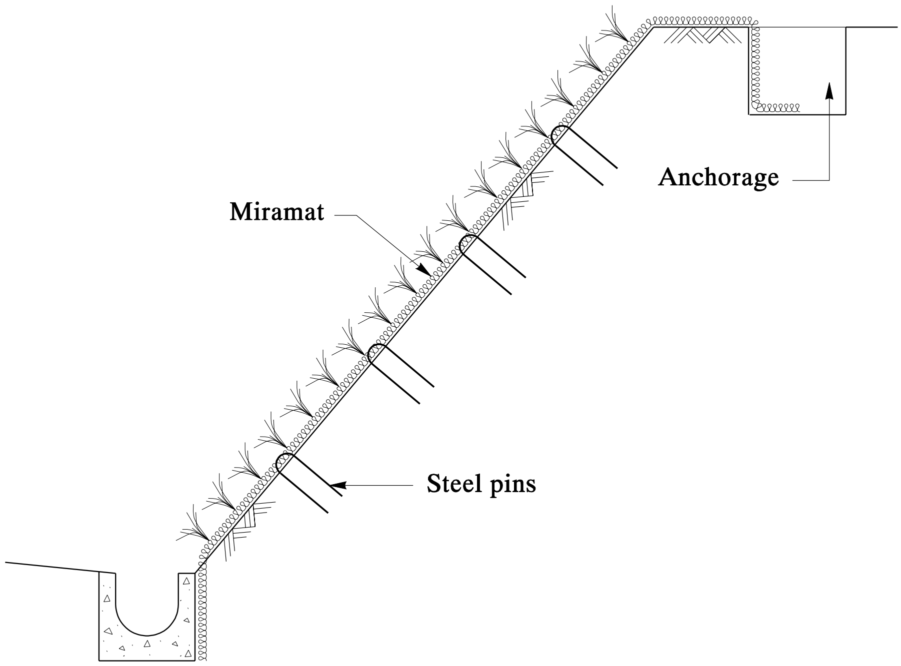
Close-up view

Details of Kangaroo Mat (based on information provided by the product supplier):

- Kangaroo Mat I is a double-layer composite made up with a PVC erosion control mat and a degradable non woven fabric filled with vegetation seeds, fertilizer and water retaining agents. Strips of fertilizer and soil factor are fixed on the composite mat at 150 c/c alternately.
- Kangaroo Mat II is the basically same as Mat I but without the soil factor strip.
- Kangaroo Mat is fixed on to slope surface by steel staples. The Mats are usually used on soil slope surface, sometimes on concrete nail head face.

Figure 21 - Details of Kangaroo Mat

Table of Contents
Table of Contents
Table of Contents
Table of Contents



Typical details of anchorage based on supplier's information
(not to scale)

Overall view of slope applied with Miramat TM8

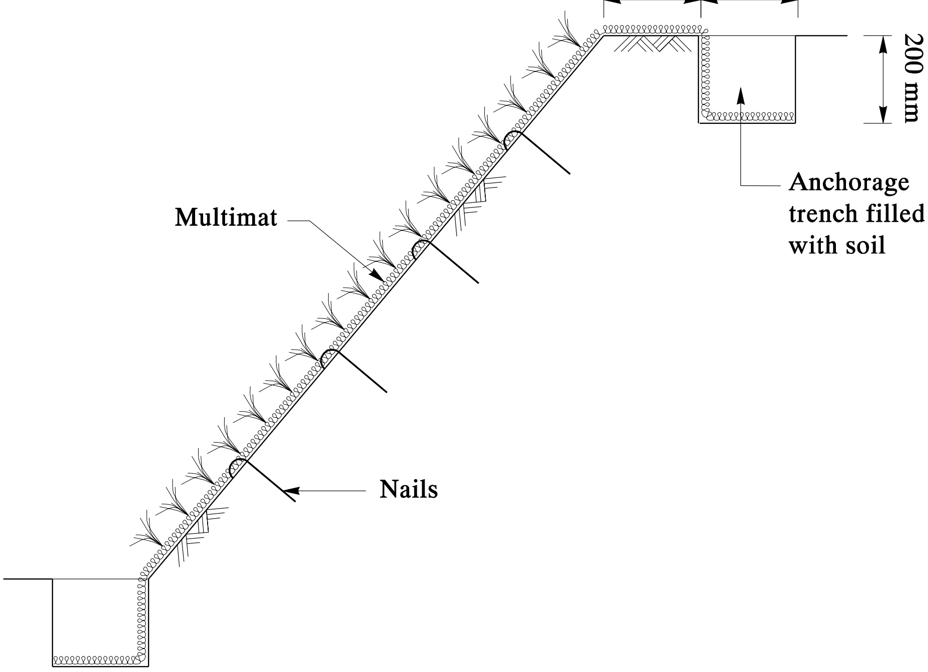
Close-up view

Details of Miramat TM8 (based on information provided by the product supplier):

- 3-D geosynthetic mat.
- Density: 431g/m^2.
- Long-term non-degradable.

Figure 22 - Details of Miramat TM8

Table of Contents
Table of Contents
Table of Contents
Table of Contents



Typical details of anchorage based on supplier's information
(not to scale)

Overall view of slope applied with Multimat

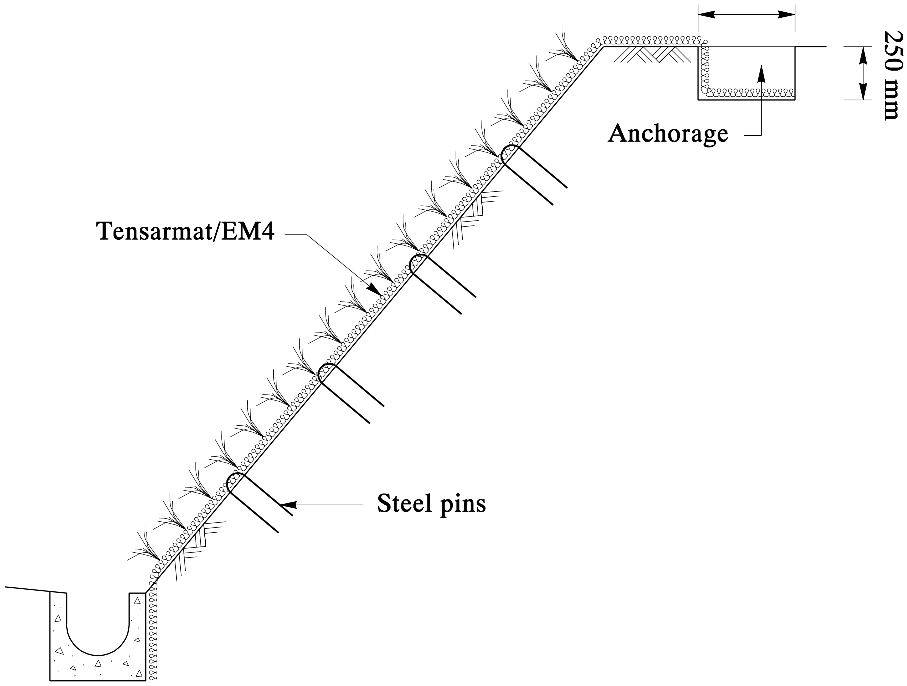
Close-up view

Details of Multimat (based on information provided by the product supplier):

- 3-D mat made up of three layers of polypropylene meshes woven together.
- Long-term non-degradable.
- Mats with different weight per unit area available: 175, 180, 320 and 430 g/m^2.

Figure 23 - Details of Multimat

Table of Contents
Table of Contents
Table of Contents
Table of Contents



Typical details of anchorage based on supplier's information
(not to scale)

Overall view of slope applied with Tensarmat/EM4

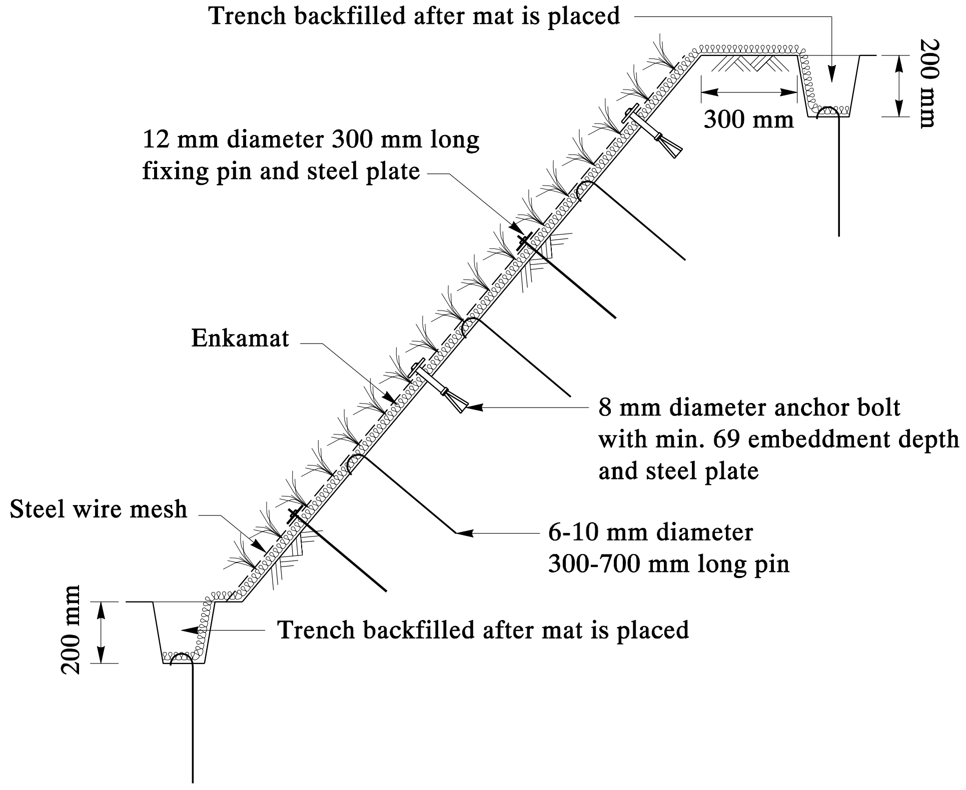
Close-up view

Details of Tensarmat/EM4 (based on information provided by the product supplier):

- 3-D mat made of polyethylene.
- Long-term non-degradable.
- Tensarmat and EM4 have the same material properties except EM4 is available in both black and dark green colour while Tensarmat is only available in black.

Figure 24 - Details of Tensarmat/EM4

Table of Contents
Table of Contents
Table of Contents
Table of Contents



Typical details of anchorage
(not to scale)

Overall view of slope applied with Enkamat and Steel Wire Mesh

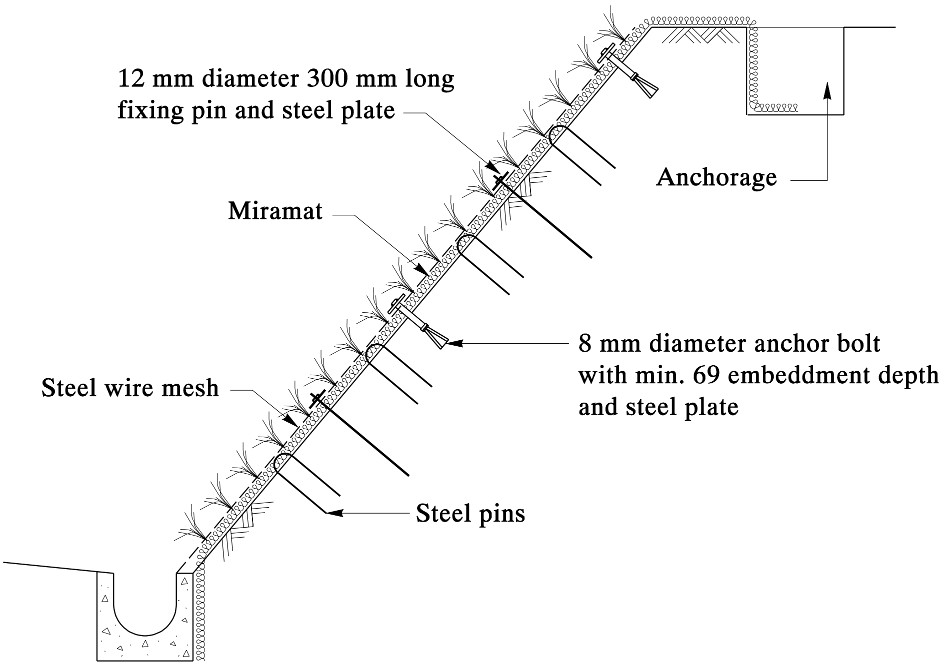
Close-up view

Details of the system:

- Refer to Figure 20 for details of Enkamat.
- The steel wire mesh is galvanized and PVC coated.
- Anchor bolts are installed at soil nail head location.

Figure 25 - Details of Enkamat with Steel Wire Mesh

Table of Contents
Table of Contents
Table of Contents
Table of Contents



Typical details of anchorage
(not to scale)

Overall view of slope applied with
Miramat TM8 and Steel Wire Mesh

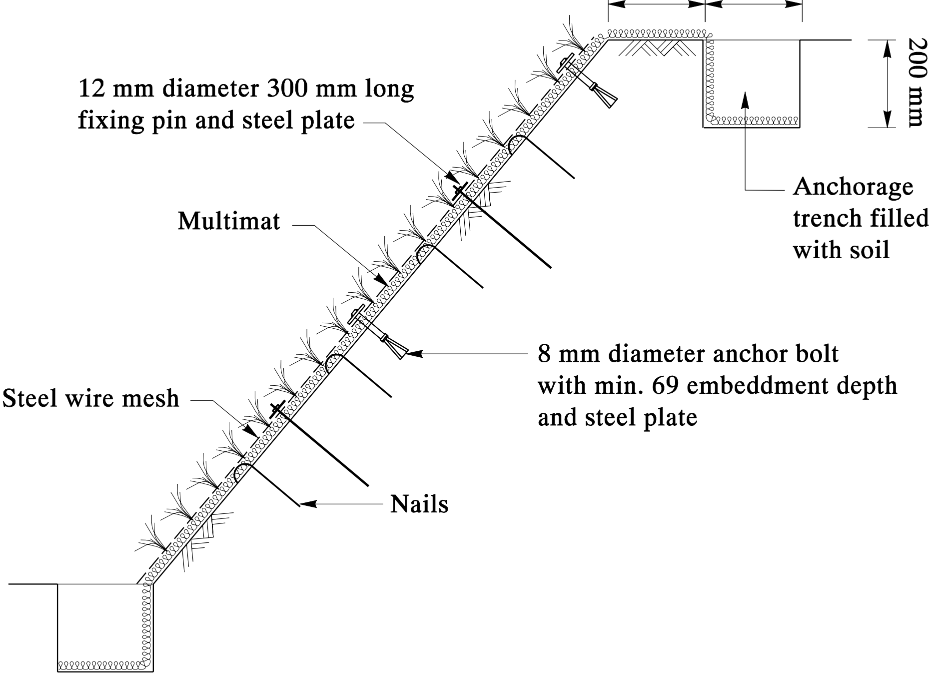
Close-up view

Details of the system:

- Refer to Figure 22 for details of Miramat TM8.
- The steel wire mesh is galvanized and PVC coated.
- Anchor bolts are installed at soil nail head location.

Figure 26 - Details of Miramat TM8 with Steel Wire Mesh

Table of Contents
Table of Contents
Table of Contents
Table of Contents



Typical details of anchorage
(not to scale)

Overall view of slope applied with
Multimat and Steel Wire Mesh

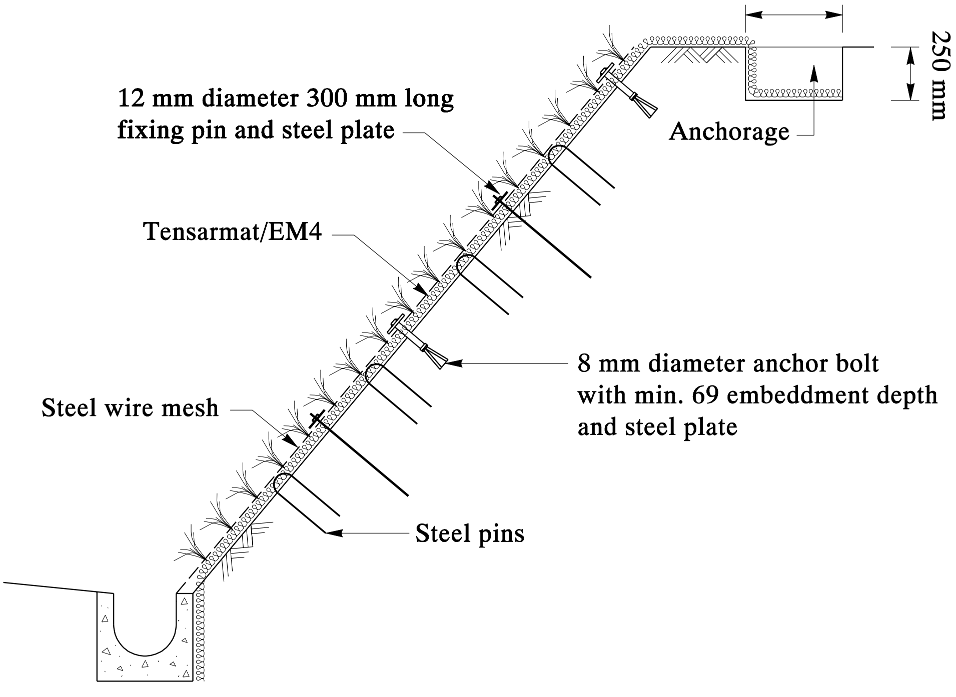
Close-up view

Details of the system:

- Refer to Figure 23 for details of Multimat.
- The steel wire mesh is galvanized and PVC coated.
- Anchor bolts are installed at soil nail head location.

Figure 27 - Details of Multimat with Steel Wire Mesh

Table of Contents
Table of Contents
Table of Contents
Table of Contents



Typical details of anchorage
(not to scale)

Overall view of slope applied with
Tensarmat/EM4 and Steel Wire Mesh

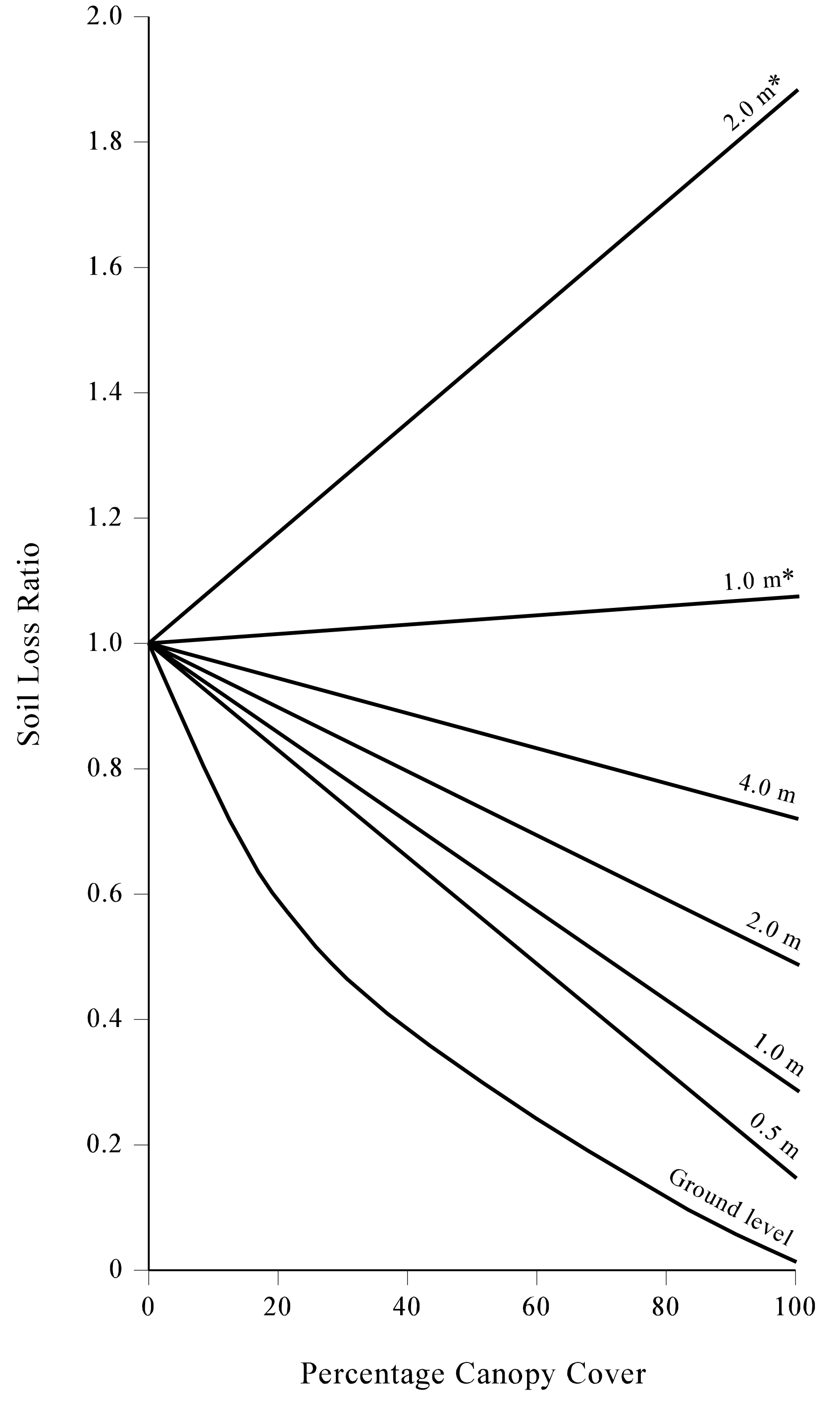
Close-up view

Details of the system:

- Refer to Figure 24 for details of Tensarmat/EM4.
- The steel wire mesh is galvanized and PVC coated.
- Anchor bolts are installed at soil nail head location.

Figure 28 - Details of Tensarmat/EM4 with Steel Wire Mesh

Table of Contents
Table of Contents
Table of Contents
Table of Contents



Legend:

* Relationships allowing for effect of leaf drainage

Figure 29 - Relationship between Soil Loss Ratio and Percentage Vegetation Cover Taking Account of the Effect of Soil Detachment by Raindrop Impact (after Rickson and Morgan, 1995)

Table of Contents
Table of Contents
Table of Contents
Table of Contents

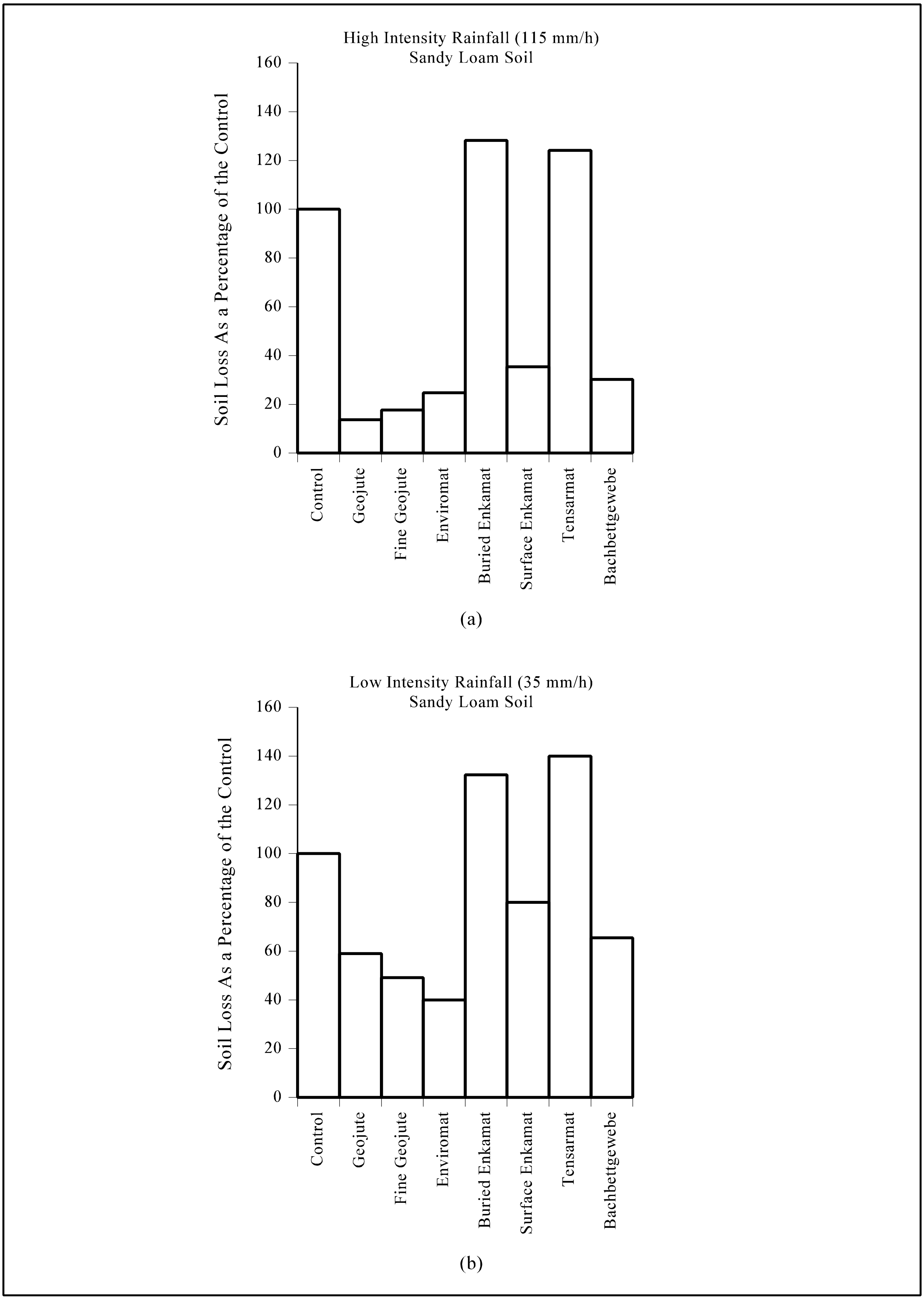


Figure 30 - Results of Geotextile Performance under Simulated Rainsplash Erosion (after Rickson, 1995)

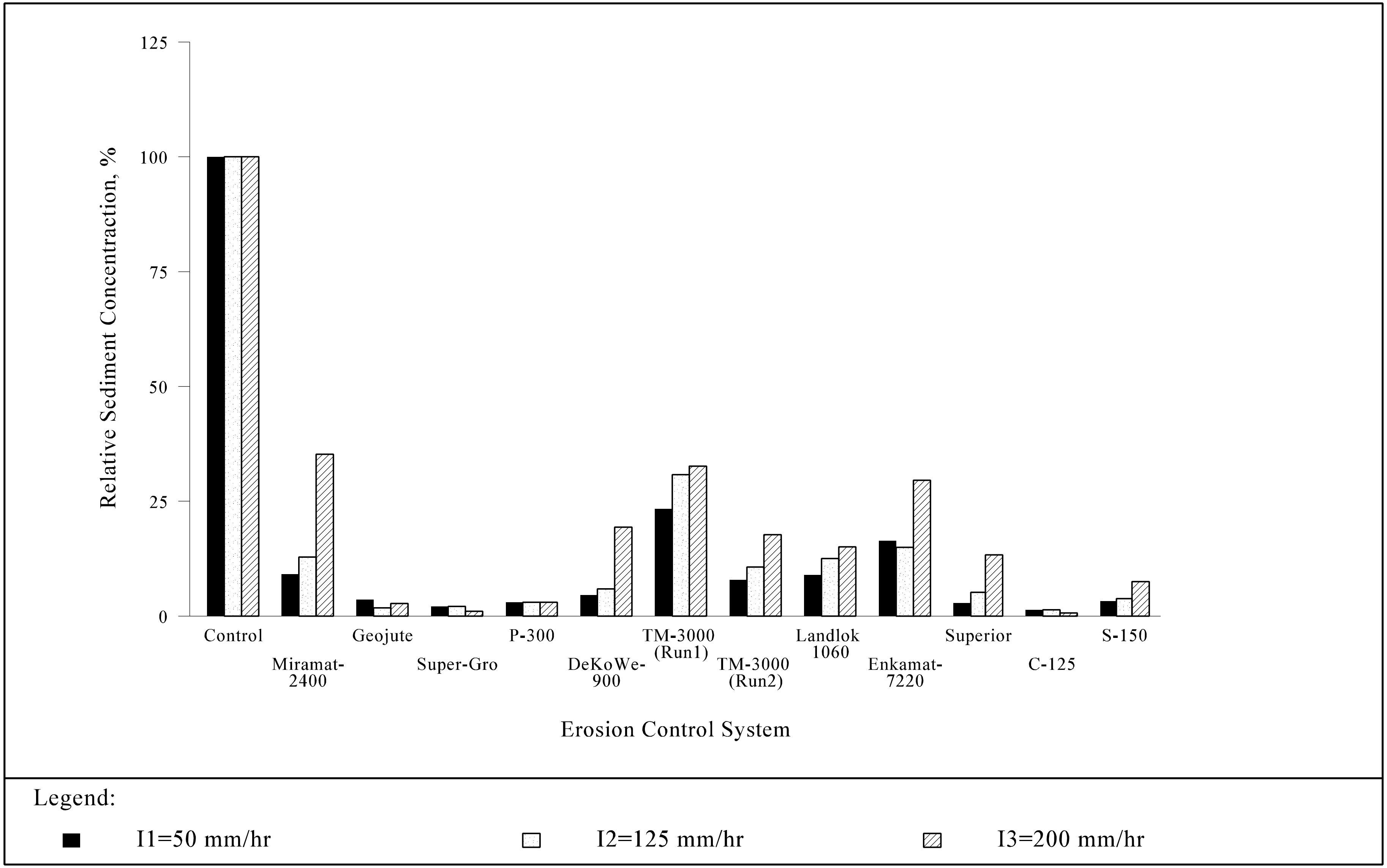


Figure 31 - Relative Cumulative Sediment Concentration at Rainfall Intensities of 50, 125 and 200 mm/hr (after Rustorm & Weggel, 1993)

Table of Contents
Table of Contents
Table of Contents
Table of Contents

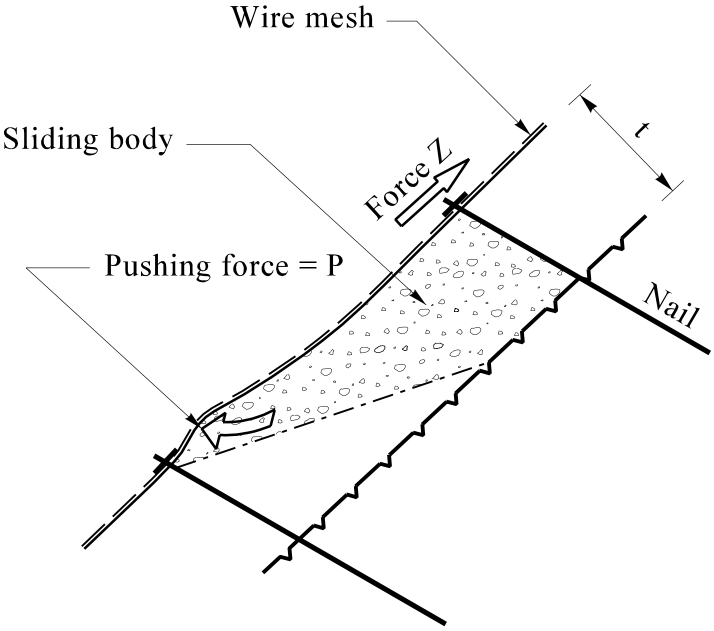


Figure 32 - Pushing Force P and Tensile Force Z (after Rüegger et al, 2001)

Table of Contents
Table of Contents
Table of Contents
Table of Contents

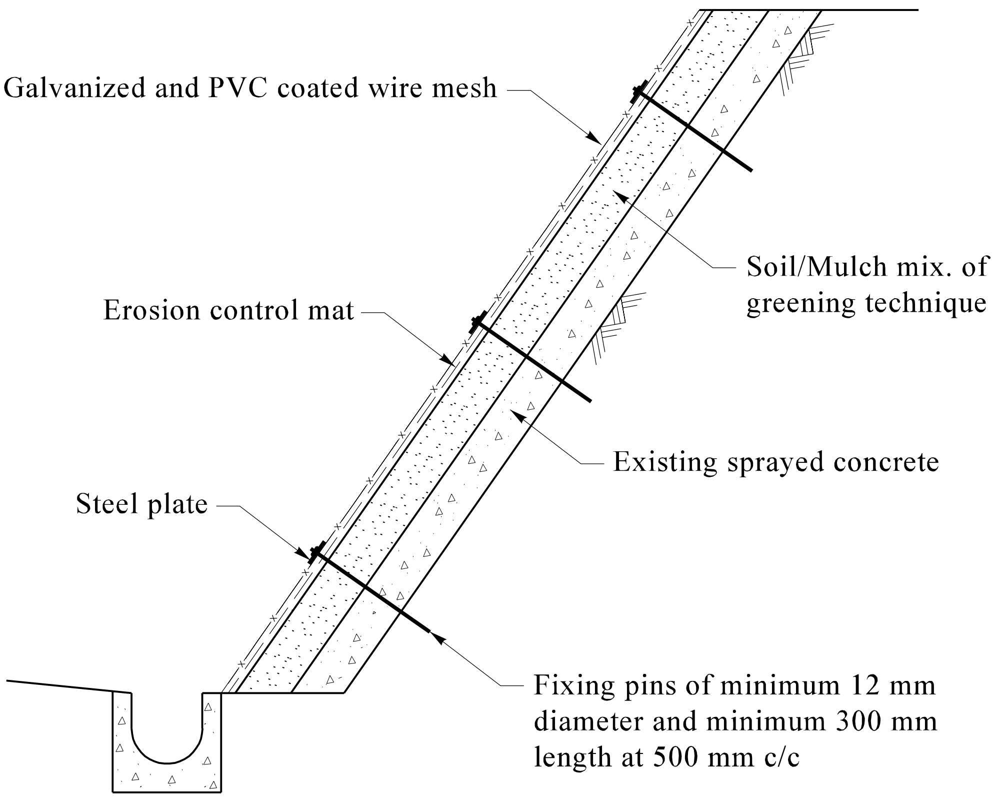


Figure 33 - Fixing Details of Erosion Control Mat with Wire Mesh

Table of Contents
Table of Contents
Table of Contents
Table of Contents

LIST OF PLATES

Table of Contents
Table of Contents
Table of Contents

Table of Contents
Table of Contents
Table of Contents

Plate 1a

Observations:	Cracks and drying up of mulch/soil mix
Slope No.:	6NE-D/C55
Location:	Route Twisk
Date of Inspection:	22 May 2003

Plate 1b

Observations:	Widespread cracks on mulch/soil mix
Slope No.:	3NE-D/C104
Location:	Bride’s Pool Road
Date of Inspection:	7 January 2004

Plate 1 - Signs of Distress Observed on Slopes with Biocrete (Sheet 1 of 2)

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Plate 1c

Observations:	Widespread cracks on mulch/soil mix
Slope No.:	3NE-D/C104
Location:	Bride's Pool Road
Date of Inspection:	7 January 2004

Plate 1d

Observations:	Detachment of mulch/soil mix, exposing the erosion control mat which is embedded in the mulch/soil mix
Slope No.:	3NE-D/C104
Location:	Bride's Pool Road
Date of Inspection:	7 January 2004

Plate 1 - Signs of Distress Observed on Slopes with Biocrete (Sheet 2 of 2)

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Plate 2a

Observations:	Detachment of mulch/soil mix
Slope No.:	8SW-B/C95
Location:	Tai Mong Tsai, Sai Kung
Date of Inspection:	2 May 2003

Plate 2b

Observations:	Detachment of mulch/soil mix, exposing the wire mesh
Slope No.:	8SW-B/C46
Location:	Yan Yee Road, Sai Kung
Date of Inspection:	7 January 2004

Plate 2 - Signs of Distress Observed on Slopes with Hong Kong Mulching

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Plate 3a

Observations: Difference in vegetation coverage on upper and lower parts of slope
Slope No.: 8SW-B/C95
Location: Tai Mong Tsai, Sai Kung
Date of Inspection: 2 May 2003

Plate 3b

Observations: Difference in vegetation coverage on upper and lower parts of slope
Slope No.: 8SW-B/C46
Location: Yan Yee Road, Sai Kung
Date of Inspection: 7 January 2004

Plate 3 - Difference in Vegetation Coverage on Different Levels of Slopes with Hong Kong Mulching

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Plate 4a

Observations: Surface cracking
Slope No.: 6SE-B/C256
Location: Route Twisk
Date of Inspection: 22 May 2003

Plate 4b

Observations: Surface cracking
Slope No.: 11SE-C/C33
Location: Wong Nai Chung Gap Road
Date of Inspection: 25 October 2003

Plate 4 - Signs of Distress Observed on Slopes with NFY Hydro-Mulching (Sheet 1 of 2)

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Plate 4c

Observations:	Cracks on mulch/soil mix, exposing the wire mesh
Slope No.:	11SW-D/C105
Location:	Deep Water Bay Road
Date of Inspection:	17 December 2003

Plate 4d

Observations:	Unsupported at toe
Slope No.:	11NW-D/C90
Location:	Homantin
Date of Inspection:	7 May 2003

Plate 4 - Signs of Distress Observed on Slopes with NFY Hydro-Mulching (Sheet 2 of 2)

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Plate 5a

Observations:	Surface erosion
Slope No.:	11NW-D/C90
Location:	Homantin
Date of Inspection:	7 May 2003

Plate 5b

Observations:	Surface erosion
Slope No.:	11NW-D/C90
Location:	Homantin
Date of Inspection:	7 May 2003

Plate 5 - Signs of Erosion Observed on Slopes with NFY Hydro-Mulching (Sheet 1 of 2)

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Plate 5c

Observations:	Edge of system subject to surface erosion
Slope No.:	11NW-D/C90
Location:	Homantin
Date of Inspection:	7 May 2003

Plate 5d

Observations:	Edge of system near stepped channel subject to surface erosion
Slope No.:	11NW-D/C90
Location:	Homantin
Date of Inspection:	7 May 2003

Plate 5e

Observations:	Surface erosion on mulch/soil mix (view from berm on slope face)
Slope No.:	11SW-D/C105
Location:	Deep Water Bay Road
Date of Inspection:	17 December 2003

Plate 5 - Signs of Erosion Observed on Slopes with NFY Hydro-Mulching (Sheet 2 of 2)

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Plate 6a

Observations:	Bare surface on hard soil mix
Slope No.:	11NE-A/C357
Location:	Jat's Incline
Date of Inspection:	27 May 2003

Plate 6b

Observations:	Detachment of soil mix
Slope No.:	11NE-A/C357
Location:	Jat's Incline
Date of Inspection:	27 May 2003

Plate 6c

Observations:	Detachment of mulch/soil mix, exposing the wire mesh
Slope No.:	11NW-A/C123
Location:	Caldecott Road
Date of Inspection:	16 December 2003

Plate 6 - Signs of Distress Observed on Slopes with "On" Method (Sheet 1 of 2)

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Plate 6d

Observations:	Inadequate anchorage of erosion control mat
Slope No.:	11NE-A/C357
Location:	Jat's Incline
Date of Inspection:	27 May 2003

Plate 6e

Observations:	Erosion and detachment of mulch/soil mix, exposing wire mesh
Slope No.:	11NW-A/C123
Location:	Caldecott Road
Date of Inspection:	16 December 2003

Plate 6 - Signs of Distress Observed on Slopes with "On" Method (Sheet 2 of 2)

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Plate 7a

Observations:	Horizontal bracing in the form of steel bars on system surface
Slope No.:	11NW-D/C130
Location:	Chung Hau Street, Homantin
Date of Inspection:	7 May 2003

Plate 7b

Observations:	Horizontal support within the soil mix in the form of PVC pipes
Slope No.:	11NW-D/C131
Location:	Chung Hau Street, Homantin
Date of Inspection:	14 October 2003

Plate 7 - Horizontal Support of Rocksgrass

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Plate 8a

Observations: Bulging of soil mix
Slope No.: 11SE-A/C487
Location: Mount Parker Road
Date of Inspection: 24 May 2003

Plate 8b

Observations: Minor bulging of soil mix above concrete kerb
Slope No.: 11SW-D/C117
Location: Nam Fung Road
Date of Inspection: 17 December 2003

Plate 8 - Signs of Distress Observed on Slopes with Soil Panel

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Observations: Surface erosion
Slope No.: 11SE-A/C487
Location: Mount Parker Road
Date of Inspection: 24 May 2003

Plate 9 - Protection of Erosion at Crest of Slopes with Soil Panel

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Plate 10a

Observations: Steeply inclined slope profile
Slope No.: 11SE-C/C166
Location: Mount Butler
Date of Inspection: 23 May 2003

Plate 10b

Observations: Inadequate anchorage of erosion control mat at edge of system
Slope No.: 11SE-C/C166
Location: Mount Butler
Date of Inspection: 23 May 2003

Plate 10 - Signs of Distress Observed on Slopes with Toyo-Mulching (Sheet 1 of 2)

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Plate 10c

Observations: Erosion along slope toe
Slope No.: 11SW-A/C138
Location: Pokfulam Road
Date of Inspection: 27 December 2003

Plate 10 - Signs of Distress Observed on Slopes with Toyo-Mulching (Sheet 2 of 2)

Table of Contents Table of Contents Table of Contents Table of Contents

Plate 11a

Observations:	Edge of system subject to surface erosion
Slope No.:	15NE-C/C3
Location:	Stanley
Date of Inspection:	24 May 2003

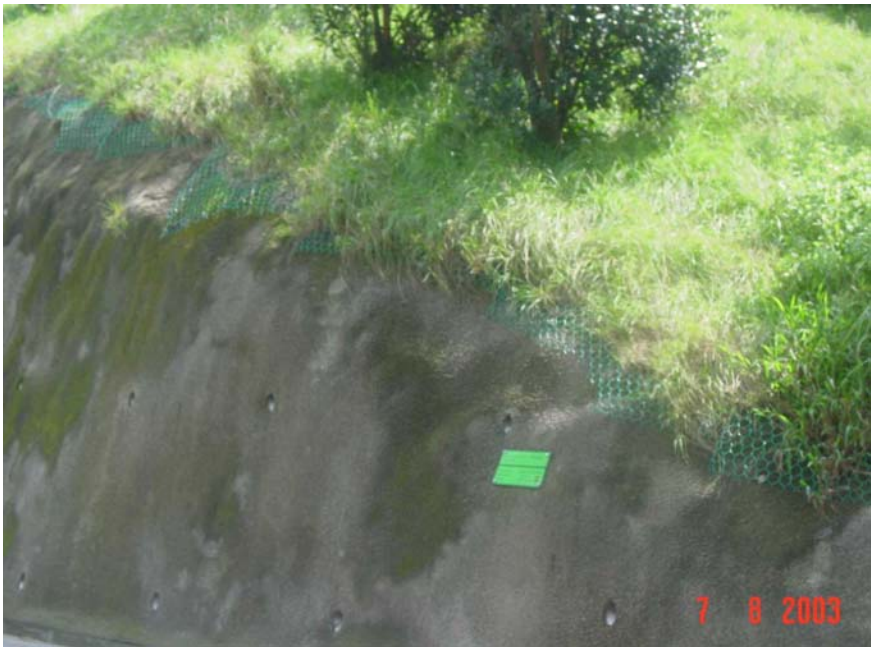


Plate 11b

Observations:	System Over-hanging
Slope No.:	15NE-B/C232
Location:	Shek O
Date of Inspection:	7 August 2003

Plate 11 - Signs of Distress Observed on Slopes with Eco-link

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Slope No.: 11NE-D/C366
Location: Lam Tin
Date of Inspection: 27 May 2003

Plate 12 - Lining of Geotextiles for Panels on a Slope with Instant Evergreen System

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Plate 13a

Observations:	Cracks and disintegration of the mulching blocks
Slope No.:	11SW-A/C139
Location:	Pokfulam Road
Date of Inspection:	27 December 2003

Plate 13b

Observations:	Erosion of mulch/soil mix out of the gabion
Slope No.:	11SW-A/C139
Location:	Pokfulam Road
Date of Inspection:	27 December 2003

Plate 13c

Observations:	Erosion of mulch/soil mix out of the gabion at the edge of system
Slope No.:	11SW-A/C139
Location:	Pokfulam Road
Date of Inspection:	27 December 2003

Plate 13 - Sign of Distress Observed on Slopes with NFY Mulching Panel

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Plate 14a

Observations: Unsupported system of Terra Cell
Slope No.: 11NE-D/C815
Location: Tiu Keng Leng
Date of Inspection: 17 July 2003

Plate 14b

Observations: Erosion on slope with Terra Cell
Slope No.: 11NE-D/C815
Location: Tiu Keng Leng
Date of Inspection: 17 July 2003

Plate 14 - Signs of Distress on a Slope with Terra Cell

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Plate 15a

Observations:	Detachment of surface mulch, exposing the wire mesh and the fiber underneath
Slope No.:	11SW-B/C24
Location:	Stubbs Road
Date of Inspection:	28 Feb 2004

Plate 15b

Observations:	Detachment of surface mulch in a large extent
Slope No.:	11SW-B/C24
Location:	Stubbs Road
Date of Inspection:	28 Feb 2004

Plate 15 - Signs of Distress Observed on a Slope with Geofiber

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Plate 16a

Observations:	Erosion control mat covering slope with Soil Guard
Slope No.:	11NW-D/C403
Location:	Homantin
Date of Inspection:	7 May 2003

Plate 16b

Observations:	Erosion on slope with Soil Guard
Slope No.:	11NW-B/C504
Location:	Beacon Hill
Date of Inspection:	17 July 2003

Plate 16c

Observations:	Erosion at crest of slope with Soil Guard
Slope No.:	11NW-B/C504
Location:	Beacon Hill
Date of Inspection:	17 July 2003

Plate 16 - Slopes Applied with Soil Guard

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Plate 17a

Observations: Erosion gullies formed along the lapping of two mats
Slope No.: 11NW-D/FR40
Location: Homantin
Date of Inspection: 21 May 2003

Plate 17b

Observations: Vegetation established on the lapping paths of two mats
Slope No.: 11NW-D/FR40
Location: Homantin
Date of Inspection: 16 October 2003

Plate 17 - Erosion Gullies Formed along the Lapping of Two Mats on a Slope with Coir

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Slope No.: 6SE-D/C212
Location: Route Twisk
Date of Inspection: 22 May 2003

Plate 18 - Degradation of Soil Saver on a Slope

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Slope No.: 11NW-A/C159
Location: Kwai Tai Road, Kwai Chung
Date of Inspection: 13 May 2003

Plate 19 - Inadequate Anchorage of Kangaroo Mat on a Slope

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Plate 20a

Observations: Miramat TM8 on slope with grillage beams
Slope No.: 7SW-D/C22
Location: Lower Shnig Mun Road
Date of Inspection: 21 May 2003

Plate 20b

Observations: Miramat TM8 not conforming to surface profile
Slope No.: 7SW-C/C180
Location: Shek Lei Estate
Date of Inspection: 13 May 2003

Plate 20 - Slopes Applied with Miramat TM8

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Plate 21a

Observations:	Filling material on Multimat
Slope No.:	7SE-C/C42
Location:	Fei Ngo Shan Road
Date of Inspection:	27 May 2003

Plate 21b

Observations:	Filling material on Multimat eroded away
Slope No.:	7SE-C/C42
Location:	Fei Ngo Shan Road
Date of Inspection:	27 May 2003

Plate 21 - Fill Material on Multimat

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Plate 22a

Observations:	Minor erosion on slope surface
Slope No.:	7SE-D/C13
Location:	Hiram's Highway
Date of Inspection:	2 March 2003

Plate 22b

Observations:	Erosion on slope surface
Slope No.:	7SE-D/C53
Location:	Hiram's Highway
Date of Inspection:	2 March 2003

Plate 22 - Erosion on Slopes Applied with Tensarmat/EM4

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Plate 23a

Observations: Erosion at slope applied with Enkamat
Slope No.: 3SE-D/C74
Location: Bride’s Pool Road
Date of Inspection: 29 May 2003

Plate 23b

Observations: Eroded material at slope applied with Enkamat trapped by wire mesh
Slope No.: 3SE-D/C74
Location: Bride’s Pool Road
Date of Inspection: 29 May 2003

Plate 23 - Erosion on a Slope with Enkamat with Steel Wire Mesh

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Slope No.:	6SE-C/C28
Location:	Tsing Lung Tau
Date of Inspection:	8 March 2004

Plate 24 - Steel Wire Mesh and Multimat not Securely Anchored at Slope Toe

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Plate 25a

Observations: Eroded material at slope applied with Tensarmat/EM4 trapped by wire mesh
Slope No.: 8SW-B/C74
Location: Tai Mong Tsai, Sai Kung
Date of Inspection: 2 May 2003

Plate 25b

Observations: No sign of erosion apparent
Slope No.: 11SW-C/C82
Location: Pokfulam Road
Date of Inspection: 15 May 2003

Plate 25 - Slopes Applied with Tensarmat/EM4 with Steel Wire Mesh

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Plate 26a

Slope No.:	11NW-D/C90
Location:	Homantin
Date of Inspection:	7 May 2003

Plate 26b

Slope No.:	6SE-B/C256
Location:	Route Twisk
Date of Inspection:	22 May 2003

Plate 26c

Slope No.:	6SE-B/C256
Location:	Route Twisk
Date of Inspection:	22 May 2003

Plate 26 - Surface Erosions below Tree Canopies

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Plate 27a - *Blechnum orientale* (烏毛蕨)

Plate 27b - *Cyclosorus parasiticus* (華南毛蕨)

Plate 27 - Photographs of Native Fern and Herbaceous Species (Sheet 1 of 3)

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Plate 27c - *Dicranopteris pedata* (芒萁)

Plate 27d - *Pityrogramma calomelanos* (粉葉蕨)

Plate 27 - Photographs of Native Fern and Herbaceous Species (Sheet 2 of 3)

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Plate 27e - *Pteris semipinnata* (半邊旗)

Plate 27f - *Pteris vittata* (蜈蚣草)

Plate 27 - Photographs of Native Fern and Herbaceous Species (Sheet 3 of 3)

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Plate 28a - *Selaginella uncinata* (翠雲草)

Plate 28b - *Alocasia macrorrhiza* (海芋)

Plate 28 - Photographs of Shade Tolerant Species (Sheet 1 of 2)

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Plate 28c - *Ardisia crenata* (硃砂根)

Plate 28d - *Ficus hirta* (粗葉榕)

Plate 28 - Photographs of Shade Tolerant Species (Sheet 2 of 2)

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Plate 29a - *Litsea rotundifolia* var. o*blongifolia* (豺皮樟)

Plate 29b - *Ardisia crenata* (硃砂根)

Plate 29 - Photographs of Native Shrub Species (Sheet 1 of 2)

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Plate 29c - *Rhodomyrtus tomentosa* (桃金娘)

Plate 29d - *Melastoma sanguineum* (毛棯)

Plate 29 - Photographs of Native Shrub Species (Sheet 2 of 2)

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Slope No.: 11SE-A/C487
Location: Mount Parker
Date of Inspection: 24 May 2003

Plate 30 - Protection at the Edge of Soil Panel

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Slope No.: 11NW-D/C130
Location: Homantin
Date of Inspection: 7 May 2003

Plate 31 - Concrete Kerb As Toe Support for Greening System

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Table of Contents

Table of Contents

APPENDIX A

MEMBERSHIP OF THE WORKING GROUP

Table of Contents

Table of Contents

A working group was established in September 2002 to oversee the study on the performance of the greening techniques. The members of the working group are listed below.

Post	Representative	Affiliation
Chairman	Mr W K Pun	Civil Engineering and Development Department
Members	Mr Y K Shiu	Civil Engineering and Development Department
	Ms Rebecca Y H Chau	Civil Engineering and Development Department
	Mr K M Poon	Architectural Services Department
	Mr K K Yung	Drainage Services Department
	Mr Andy H C Lam	Water Supplies Department
	Mr Norman Woods	Lands Department
	Mr Eddy Leung	Housing Department
	Mr C P Choi	Highways Department
	Mr Peter C Y Yung	Highways Department
	Mr C K Chan	Agriculture, Fisheries & Conservation Department
	Mr S P Ng	Civil Engineering and Development Department (the-then Territory Development Department)
	Dr. Billy Hau	University of Hong Kong
Secretary	Ms Becky L S Lui	Civil Engineering and Development Department

Table of Contents
Table of Contents
Table of Contents
Table of Contents

APPENDIX B

DETAILS OF SLOPES INCLUDED IN THE STUDY

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Table B1 - Details of Slopes Using Group 1 Techniques under the Technique of Mulching System (Sheet 1 of 3)

Group 1 Techniques used	Slope No.	Location	Slope Angle	Orientation	Maintenance Dept.	Completion Date	Facilities at Crest	Facilities at Toe
Biocrete	3NE-D/C104	Bride's Pool Road	60º	NE	HyD	31 Oct 2001	Natural Terrain	Road
	6NE-D/C55	Route Twisk	50º	NW	HyD	2 Feb 2002	Natural Terrain	Road
Hong Kong Mulching	8SW-B/C46	Yan Yee Road, Sai Kung	85º	NE	HyD	14 Mar 2002	Natural Terrain	Road
	8SW-B/C95	Tai Mong Tsai Road	50º	S	HyD	16 Mar 2002	Natural Terrain	Road
NFY Hydro-Mulching	3SE-D/C93	Tai Mei Tuk, Tai Po	56º	NW	WSD	15 Jan 2002	Platform	Building
	6SE-B/C256	Route Twisk, Tsuen Wan	55º	SE	HyD	3 Aug 2001	Natural Terrain	Road
	10NE-B/C123	Tsing Yi Heung Sze Wui Road	60º	N to NE	HyD	7 Jan 2002	Building	Road
	11NW-B/C19	Ching Cheung Road	55º	S	HyD	13 Jan 2002	Building	Road
	11NW-B/C266	Cornwall Street, Kowloon Tong	60º	SE	HyD	18 Dec 2001	Natural Terrain	Road
	11NW-B/C39	Woh Chai Street, Shek Kip Mei	48º	N	HyD	8 Apr 2002	Natural Terrain	Road
	11NW-D/C90	Hau Man Street, Homantin	60º	SW	HyD	2 Apr 2002	Service Reservoir	Road
	11SE-C/C19	Deep Water Bay Road	60º	SW	HyD	25 Aug 2001	Natural Terrain	Road
	11SE-C/C32	Wong Nai Chung Gap Road	50º	NE	HyD	9 Apr 2002	Natural Terrain	Road
	11SE-C/C33	Wong Nai Chung Gap Road	65º	SE to E	HyD	28 Feb 2002	Natural Terrain	Road
	11SW-A/C293A	Victoria Road	60º	W	HyD	28 Mar 2002	Natural Terrain	Road
	11SW-A/CR28	Glenealy	40º	E	HyD	16 Dec 2001	Road	Road
	11SW-B/C214	Bowen Rd	50º	NW to NE	LandsD	31 Oct 2001	Natural Terrain	Building
	11SW-D/C105	Deep Water Bay Road	50º	SE	HyD	9 Apr 2002	Natural Terrain	Road
	11SW-D/C1642	Peak Road	70º	N	HyD	25 Sep 2001	Road	Road
	11SW-D/FR39	May Road	30º	N	HyD	15 Aug 2001	Road	Slope

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Table B1 - Details of Slopes Using Group 1 Techniques under the Technique of Mulching System (Sheet 2 of 3)

Group 1 Techniques used	Slope No.	Location	Slope Angle	Orientation	Maintenance Dept.	Completion Date	Facilities at Crest	Facilities at Toe
On Method	11NE-A/C357	Jat's Incline	60º-65º	NW to W	HyD	3 Jul 2001	Natural Terrain	Road
	11NW-A/C123	Caldecott Road	65º	SE to S	HyD	15 Mar 2001	Building	Road
	11NW-A/C441	Ching Cheung Road	55º	SE	HyD	6 Apr 2001	Natural Terrain	Road
	11NW-B/C64	Tai Po Road	65º	NE	HyD	11 Mar 2001	Natural Terrain	Road
	11NW-B/F41	Cheung Fat Street, So Uk Estate	35º	SW	HyD	2 Nov 2001	Road	Bus Terminal
Rocksgrass	3SW-B/C292	Hok Tau Road, North	60º	E to S	HyD	24 Mar 2001	Natural Terrain	Road
	11NE-C/C62	Hong Ning Road, Kwun Tong	60º	SE	HyD	10 May 2001	Natural Terrain	Road
	11NW-D/C130	Chung Hau Street, Homantin	54º	SE	HyD	4 May 2002	Natural Terrain	Road
	11NW-D/C52	Sheung Shing Street, Homantin		NW	HyD	16 Feb 2002	Natural Terrain	Road
	11SE-C/C753	Deep Water Bay Road	50º	S	HyD	13 Jan 2001	Road	Road
	11SW-A/C142	Pok Fu Lam Road	40º-55º	NW	HyD	17 Mar 2001	Natural Terrain	Road
	11SW-C/C385	Sai Wan Drive, Pokfulam	45º	SW	HyD	16 Feb 2001	Natural Terrain	Road
	11SW-D/C111	Nam Fung Road	50º	S	HyD	28 Feb 2001	Natural Terrain	Road
CMS-ML Green System	3SE-A/C6	Nam Chung, Luk Keng	50º	SE	HyD	9 May 2002	Natural Terrain	Road
Soil Panel	11SE-A/C487	Mount Parker Road	65º	E	HyD	9 May 2001	Natural Terrain	Road
	11SW-A/C331	Pok Fu Lam Road	60º	NW	HyD	12 May 2001	Natural Terrain	Road
	11SW-D/C117	Nam Fung Road	60º	SE	HyD	30 Jul 2001	Natural Terrain	Road

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Table B1 - Details of Slopes Using Group 1 Techniques under the Technique of Mulching System (Sheet 3 of 3)

Group 1 Techniques used	Slope No.	Location	Slope Angle	Orientation	Maintenance Dept.	Completion Date	Facilities at Crest	Facilities at Toe
Toyo-mulching	7SW-D/CR538	Beacon Hill Catchwater	60º	NE	WSD	Sep 2000	Natural Terrain	Road
	7SW-D/C547	Beacon Hill Catchwater	76º	W to SW	WSD	Nov 2000	Natural Terrain	Road
	7SW-D/CR553	Beacon Hill Catchwater	57º	NW to NE	WSD	Oct 2000	Natural Terrain	Road
	11NE-D/C815A	Tiu Keng Leng Cottage Area	60º	W	HD	Mar 2002	Natural Terrain	Road
	11NW-B/C82	Tai Po Road	60º	SW	HyD	Apr 1999	Natural Terrain	Road
	11NW-D/C330	Chung Hau St, Homantin	55º	NE	WSD	11 Nov 2000	Service Reservoir	Slope
	11NW-D/C548	Chung Hau St, Homantin	55º	NE	WSD	11 Nov 2000	Slope	Road
	11SE-A/C123	Tai Hang Road	55º-68º	SW	HyD	23 Mar 2001	Building	Road
	11SE-C/C166	Price Road, Mt Butler	40º	W	HyD	19 Mar 2001	Natural Terrain	Road
	11SE-C/C679	Mount Parker Road	65º-70º	E	WSD	4 Dec 2000	Natural Terrain	Road
	11SE-C/C684	Mount Parker Road	70º	E	WSD	4 Dec 2000	Natural Terrain	Road
	11SE-C/C694	Tai Tam Reservoir Road	65º	NW to W	WSD	16 Sep 2000	Natural Terrain	Road
	11SW-A/C135	Pok Fu Lam Road	60º	NW	HyD	7 Apr 2001	Natural Terrain	Road
	11SW-A/C138	Pok Fu Lam Road	50º	NW	HyD	7 Apr 2001	Natural Terrain	Road
	11SW-A/F75	Victoria Road	30º	W	HyD	5 Mar 2001	Road	Natural Terrain
	11SW-C/C322	Pokfulam Reservoir Road	65º	N	WSD	20 Jan 2001	Natural Terrain	Road
	11SW-D/C110	Nam Fung Road	60º	SW	HyD	22 Dec 2000	Natural Terrain	Road
	12NW-C/C92	Clear Water Bay Road	45º-65º	NE	HyD	Sep 2000	Natural Terrain	Road
	12SW-A/C125	Tai Au Mun Road	63º	SE	HyD	Dec 2000	Natural Terrain	Road
	15NW-B/C176	Nam Long Shan Road	70º-80º	W to SE	HyD	22 Feb 2001	Natural Terrain	Road

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Table B2 - Details of Slopes using Group 1 Techniques under the Technique of Cellular System

Group 1 Techniques used	Slope No.	Location	Slope Angle	Orientation	Maintenance Dept.	Completion Date	Facilities at Crest	Facilities at Toe
Eco-Link	15NE-B/C232	Shek O Road	40º	W	HyD	27 Mar 2001	Natural Terrain	Road
	15NE-C/C3	Tung Tau Wan Road	65º	NE	HyD	24 Apr 2001	Building	Road
Instant Evergreen System	11NE-A/F167	Wing Tai Sin Road	45º		HyD	8 Sep 2002	Slope	Road
	11NE-D/C366	Sin Fat Road, Lam Tin	45º	W	HyD	1 Jul 2002	Platform	Road
	11SE-B/C5	Pik Wan Road, Lam Tin	45º	SE	HyD	1 Jul 2002	Natural Terrain	Road
NFY Eco-MP System	7SW-C/C41	Kwai Shing Circuit	55º	W	HD, HyD & WSD	3 Dec 2001	Natural Terrain	Road
NFY Hydro Planter	15NW-B/C343	Shum Wan Road	60º	W	HyD	24 Mar 2001	Slope	Road
NFY Mulching Panel	7SW-C/C55	Kwai Shing Salt Water Reservoir	50º	NW	WSD	Nov 2000	Service Reservoir	Road
	11SW-A/C61	Robinson Road	60º	N	HyD	26 Aug 2002	Platform & Building	Road
	11SW-A/C139	Pok Fu Lam Road	50º	NW	HyD	10 Apr 2002	Building	Road
	11SW-A/C293B	Victoria Road	60º	W	HyD	28 Mar 2002	Natural Terrain	Road
	11SW-B/C206	Kennedy Road	60º	N to NE	HyD	22 Aug 2002	Natural Terrain	Road
	11SW-D/C1090	Bowen Road	55º	W	HyD	22 Aug 2002	Natural Terrain	Road
	11SW-D/CR1993	Stubbs Road	70º	E	HyD	31 Mar 2002	Natural Terrain	Building
Terra Cell	11NE-D/C815B	Tiu Keng Leng Cottage Area	60º	W	HD	March 2002	Natural Terrain	Road

Table B3 - Details of Slopes using Group 1 Techniques under the Technique of Reinforced Soil

Group 1 Techniques used	Slope No.	Location	Slope Angle	Orientation	Maintenance Dept.	Completion Date	Facilities at Crest	Facilities at Toe
Geofiber	11SW-B/C24	Stubbs Road	60º	E to SE	HyD	31 Jan 2002	Building	Road
	11SW-D/C601	Coombe Road	50º	E	HyD	11 Feb 2002	Vegetated slope	Road
	11SW-B/F74	Hong Kong Park	33º	E	ArchSD	Jan 2003	Road	Park
	Slope no. not assigned	Lam Tei Quarry	50º	SE	CED	12 Nov 2001		

Table B4 - Details of Slopes using Group 1 Techniques under the Technique of Bio-engineering Method

Group 1 Techniques used	Slope No.	Location	Slope Angle	Orientation	Maintenance Dept.	Completion Date	Facilities at Crest	Facilities at Toe
GW-Biodrains System	6SE-B/C167	Route Twisk	60º	SE to SW	HyD	16 Sep 2002	Natural Terrain	Slope
	7SW-C/C47	Kwai Shing Circuit	60º	N	HyD	Jan 2001	Natural Terrain	Road
	7SW-D/C1	Lion Rock Tunnel Road.	60º	NW	HyD	17 May 2002	Natural Terrain	Road

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Table B5 - Details of Slopes using Group 2 Techniques (Sheet 1 of 2)

Group 2 Techniques used	Slope No.	Location	Slope Angle	Orientation	Maintenance Dept.	Completion Date	Facilities at Crest	Facilities at Toe
Soil Guard	11NW-D/C403	Sheung Lok Street, Homantin	60º	SW to W	ArchSD & WSD	Dec 2002	Service Reservoir	Road
Coir	11NW-D/FR40	Chung Hau Street, Homantin	35º	SE	HyD	26 Feb 2002	Road	Natural Terrain
Soil Saver	6SE-D/C212	Route Twisk	50º	NE to E	LandsD	12 Nov 2001	Natural Terrain	Building
Enkamat	11NW-D/FR50	Chung Hau Street, Homantin	30º	S	WSD	25 Jan 2002	Reservoir	Road
Kangaroo Mat I	11NW-A/C159	Kwai Tai Road	30º	NW	HyD	5 Jan 2001	Slope	Road
Kangaroo Mat II	3NE-C/C159	Luk Keng Chan Uk	55º	E	LandsD	21 Nov 2001	Natural Terrain	Road
Miramat TM8	7SW-D/C22	Lower Shing Mun Road	55º	NE	ArchSD	Feb 1999	Natural Terrain	Road
	7SW-D/C180	Lei Pui Street, Shek Lei Estate	57º-70º	NW	HyD	31 May 2001	Natural Terrain	Road
	7SW-D/C181	Lei Pui Street, Shek Lei Estate	53º-75º	NW	HD & HyD	31 May 2001	Natural Terrain	Road
	11NW-B/C90	Shek Kip Mei Estate	35º	SE	HD	30 Dec 2000	Slope	Platform
Multimat	7SE-C/C42	Fei Ngo Shan Road	-	S	ArchSD & HyD	1 Oct 2002	Natural Terrain	Road
Tensarmat/EM4	7SE-D/C13	Hiram's Highway, Sai Kung	60º	E	HyD	29 Jul 2000	Natural Terrain	Road
	7SE-D/C53	Hiram's Highway, Sai Kung	45º	SE to S	HyD	20 Mar 2000	Natural Terrain	Road
Enkamat with steel wire mesh	3SE-D/C74	Tai Mei Tuk, Tai Po	63º	E to S	Arch SD	8 Dec 2001	Platform	Road
	3SE-D/C75	Tai Mei Tuk, Tai Po	53º	SE to SW	Arch SD	25 Jan 2002	Platform	Road

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Table B5 - Details of Slopes using Group 2 Techniques (Sheet 2 of 2)

Group 2 Techniques used	Slope No.	Location	Slope Angle	Orientation	Maintenance Dept.	Completion Date	Facilities at Crest	Facilities at Toe
Miramat TM8 with steel wire mesh	3SE-D/C118	Tai Mei Tuk, Tai Po	45º	SW	WSD	30 Nov 2001	Natural Terrain	Road
Multimat with steel wire mesh	6SE-C/C28	Tsing Lung Tau Village	55º	SW to W	Arch SD	27 Mar 2002	Natural Terrain	Building
Tensarmat/EM4 with steel wire mesh	7NW-B/C13	Tai Po Road	50º	NE	HyD	10 Apr 2002	Natural Terrain	Road
	8SW-B/C74	Tai Mong Tsai Rd, Sai Kung	60º	SW	HyD	Dec 2000	Natural Terrain	Road
	11SW-C/C82	122 Pokfulam Road	50º	SW to NW	ArchSD	19 Nov 2001	Natural Terrain	Building
	11SW-C/C98	Pokfulam Road	60º	E	HyD	Jul 2002	Platform	Road

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Table of Contents

Table of Contents

APPENDIX C

DETAILS OF METHODOLOGY FOR SLOPE INSPECTION BY DR BILLY HAU

Table of Contents

Table of Contents

CONTENTS

Table of Contents
Table of Contents
Table of Contents

C.1 GENERAL

The team responsible for carrying out the vegetation assessment includes Dr Billy Hau, the Primary Investigator, and a few research assistants of the University of Hong Kong.

All slopes except 15NW-B/C343 (NFY Hydro Planter) were surveyed using the method described below. Because of the special nature of the NFY Hydro Planter technique, a different assessment method was used in which the condition of plant growth in each planting hole along the PVC tubes was assessed.

All vascular plants on all of the selected slopes were covered in the field survey. To avoid double counting and/or missing any vascular plants on the slopes, longitudinal transects were set from right to left on all batters of all slopes as far as was practicable. In each batter, the first transact was set at 5 m from the bottom right corner, subsequent transects were also set at 5 m intervals. Each batter was partitioned into quadrates of 5 m wide and about 7.5 m tall (Figure C1). The last quadrant in each batter was between 5 to 10 m in width. All vascular plants in each quadrat were surveyed. Certain selected slopes were too tall and steep for working on the surface. At such slopes, the plants were identified by using binoculars and height estimated instead of measured.

C.2 VEGETATION TYPE AND SPECIES IDENTIFICATION

The surface area of each vegetation type including grass, creeper, fern, shrub and tree, and other surface types including exposed soil, erosion control material, shotcrete, wall and rock in each quadrat were measured or estimated if the surface was too steep for direct measurement. The determination of vegetation type was based on the characteristics of the plant species present. Plant species were identified on site. Specimen was collected for unknown and doubtful species for herbarium checking. The total surface area of each vegetation type and other surface types were calculated by adding up the surface area in each quadrat.

For each vegetation type and other surface types, the area in each quadrat that was directly exposed to the open sky i.e. the top layer, was determined separately. It was then used to calculate the total percentage cover of the exposed surface type on the slope. The percentage cover of different exposed surface types were then added up to 100%. The dominant exposed vegetation type on a given slope will be the one with the highest percentage cover at the top layer.

In some cases, the total surface area of the cover type on a slope was used. This includes those cover types not even exposed to the open sky on a slope, e.g. area under the shade or canopy of a taller tree. The total percentage cover of different surface types on the slope in this calculation would be greater than 100%.

C.3 CONDITION OF VEGETATION

For shrubs and tree seedlings (< 1.5 m in height), the height was measured or estimated. For trees (> 1.5 m in height), the stem diameter at breast height (dbh) was

Table of Contents
Table of Contents
Table of Contents
Table of Contents

measured or estimated, the height and spread were estimated. For each tree and shrub, the health condition was recorded as “Healthy”, “Dying” or “Dead”. Since it was not practical to examine individual plants of grass, creeper or fern species, the health assessment was based on surface area. As such, the surface area of grass, creeper or fern cover was classified as “Healthy”, “Dying”, “Dead” or “Regenerating” and the respective surface area measured.

C.4 NATURAL REGENERATION

In each quadrat, those individuals that were found flowering and/or fruiting were recorded. Based on the information on local flora, the general plant list in the commercial landscaping field and the structure, especially the spatial patterns of each species, of the vegetation on the slope, any individual plant was planted or occurred naturally on the slope can be determined.

C.5 ENVIRONMENTAL DATA

Environmental data of each slope was collected or determined in the field inspection as follows (see Appendix A, Hau & Leung 2004a):

- The slope gradient and the slope orientation were determined;

- Seepage on the slope, if any, was noted;

- The direction and distance of features such as tall building and natural forest from the slope that would possibly shade the slope face were noted;

- Exposure to strong wind was estimated subjectively as “Exposed”; “Partially Sheltered” or “Sheltered”.

- The degree of isolation of the slope from natural or semi-natural vegetation was determined subjectively as “0” = directly connected to natural vegetation such as hillside grassland, shrubland and forest; “1” = connected to natural vegetation though corridors such as parks and gardens; “2” = connected to well vegetated parks and gardens larger than 1 ha; or “3” = completely isolated.

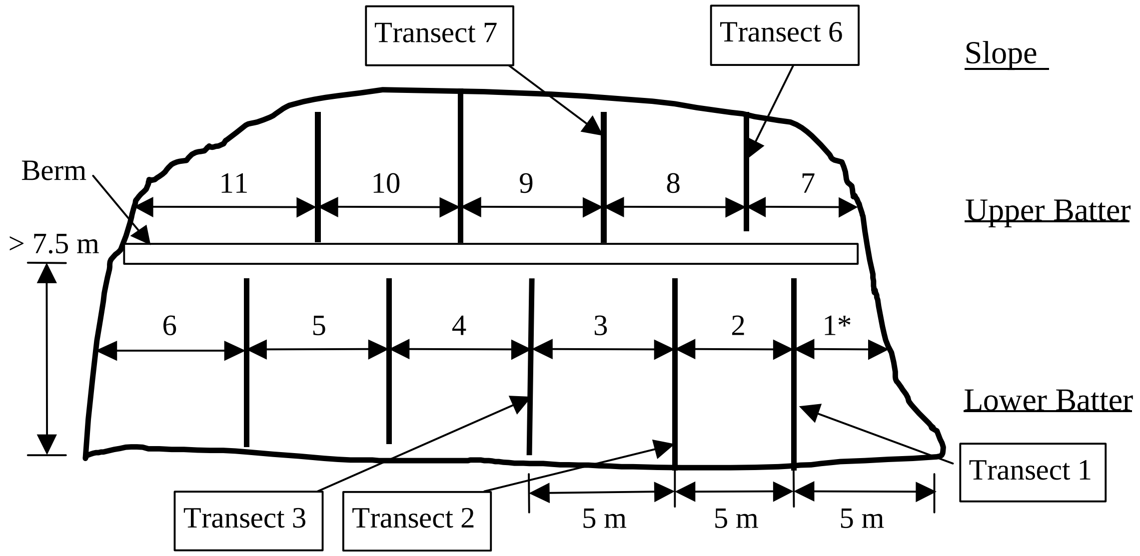
- The degree of exposure of slopes to road traffic was determined subjectively as “0” = not exposed to road traffic (not next to any vehicle road); “1” = low exposure to road traffic (next to single lane low use road such as those inside Country Park); “3” = high exposure (next to highway).

- The presence of natural stream courses on or adjacent to the slope was noted.

Table of Contents
Table of Contents
Table of Contents
Table of Contents

LIST OF FIGURES

Table of Contents
Table of Contents
Table of Contents



Legend:

* Quadrat number: 1-11

Figure C1 - Survey Layout on a Slope

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Table of Contents

Table of Contents

APPENDIX D

EXAMPLE SHOWING CALCULATION OF SHANNON DIVERSITY INDEX

Table of Contents

Table of Contents

In this study, species richness (S) is used to represent the total number of woody native or exotic plant species that are believed to have established on each of the slope inspected since the completion of the of greening technique. Furthermore, the Shannon diversity index (**H**), which is a common quantitative index of species diversity, is used for describing the composition of the plant communities that have been established naturally on the slopes. The index **H** is calculated on the basis of S and is the sum of the proportion of individuals that each species contributes to the total in the sample, i.e. the proportion of Pi for the ith species by (Begon et al, 1996):

$$H = -\sum_{i=1}^{S} P_1 I_n P_i$$

where P_i = the number of plants of the ith species in the sample / the total number of plants in the sample

An example below shows the calculation of **H** for a hypothetical slope with 5 species:

Species:	1	2	3	4	5	**Total**
Abundance:	50	60	50	70	90	**320**
Pi =	50/320 = 0.16	60/320 = 0.19	50/320 = 0.16	70/320 = 0.22	90/320 = 0.28	
Pi x lnPi =	-0.29	-0.31	-0.29	-0.33	-0.36	

H = -[(-0.29) + (-0.31) + (-0.29) + (-0.33) + (-0.36)] = 1.58

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Table of Contents

Table of Contents

APPENDIX E

SUMMARY OF SITE INSPECTIONS AND ASSESSMENTS OF GROUP 1 GREENING TECHNIQUES

Table of Contents

Table of Contents

CONTENTS

Table of Contents
Table of Contents
Table of Contents

E.1 GENERAL

Details of the assessment of vegetation growth of the various greening techniques are presented in Hau and Leung (2004a). Results of the vegetation assessment along with those of the engineering assessment of the group 1 greening techniques are briefly discussed in the following sections.

E.2 MULCHING SYSTEM

E.2.1 General

All the eight products under this technique have been applied on the concrete cover of slopes. They involve applying one or more layers of mulch or soil mix onto the slope surface. The mulches/soil mixes vary in type, composition and additives and have little strength. Some products use a layer of wire mesh in conjunction with one or more layers of erosion control mats to strengthen the mulches/soil mixes. The meshes and mats form the major engineering components of the mulching system and they are fixed on to the sprayed concrete cover by steel pins or anchors. The erosion control mats are either temporary degradable or long-term non-degradable. A summary of the types of wire meshes and erosion control mats used in the various mulching techniques is given in Table 16.

E.2.2 Biocrete

In this product, a mixture of soil and organic fibre, reinforced by cement, is applied on slope surface to serve as a growing stratum for vegetation. Typical details of the product are shown in Figure 1.

E.2.2.1 Vegetation Assessment

Vegetation growth conditions on the two slopes (3NE-D/C104 and 6NE-D/C55) treated with the product were surveyed twice. Both slopes were planted with grasses. The performance of the product in terms of sustaining vegetation cover on the two slopes vary greatly but both are considered not good. Slope C104 had only about 30% of total exposed vegetation cover in both first and second inspections (Table E1). The percentage cover of the planted grasses was also found decreased in the second inspection. For the other slope C55, the performance is better than the previous one but for the 80% total vegetation cover-exposed recorded in the second inspection, only about half was recorded as “healthy”. In addition, most of this cover was made up by the planted grasses. On the other hand, few naturally established woody species were recorded on these two slopes as seen by the rather low values of H and S. The results show that the vegetation on these two slopes, whether planted or natural, does not seem to be very well. However, in view of the fact that only two slopes are studied, the results should be treated with care.

E.2.2.2 Engineering Assessment

Bare patches with surface cracks of maximum width of about 10 mm were observed on

Table of Contents
Table of Contents
Table of Contents
Table of Contents

the mulch/soil mix on the two slopes inspected (Plates 1a to 1c). The cracked surface on slope C104 was extensive, covering more than 30% of the slope surface area. The mulch/soil mix layer was hard and dry, and had disintegrated at local areas, probably owing to the addition of cement additives. No reinforcing element is specified in the manufacturer's brochure. However, a layer of PVC mesh was found embedding within the mulch/soil mix. It probably serves to reinforce the mulch/soil mix. The mesh was however weak and brittle. On both slopes, the soil mix had detached locally, exposing the PVC mesh (Plate 1d). No erosion control mat was provided to the surface of the mulch/soil mix.

E.2.3 Hong Kong Mulching

In this technique, a layer of PVC coated wire mesh which is fixed onto slope surface is used for providing strength of the mulch. Typical details of the product are shown in Figure 2.

E.2.3.1 Vegetation Assessment

The condition of vegetation growth conditions on two slopes no. 8SW-B/C46 and 8SW-B/C95 treated with this product were assessed twice. Both slopes were found planted with creepers (*Wedelia trilobata*) and grasses (*Cynodon dactylon* and *Paspalum notatum*). The overall coverage of the vegetation on the two slopes is quite satisfactory. Both slopes had about 70% or more healthy vegetation coverage in both inspections (Table E1). Slope C46 was dominated by the planted *Wedelia trilobata* (61% healthy cover), and slope C95 was dominated by the naturally occurring creepers and herbs. The percentage cover of planted creepers on slope C46 was found much increased in the second inspection but the percentage cover of planted grasses was decreased. The same trend was not observed on slope C95.

Zero values of the Shannon diversity index H and the species richness S were recorded for slope C46 in both inspections. For slope C95, a few naturally established woody species were found but the H values between the two inspections are similar.

E.2.3.2 Engineering Assessment

The two slopes were inspected for engineering assessment. Degradable erosion control mat was specified in the manufacturer's brochure for use in the system. However, a layer of non-degradable mat was noted on site. Detachments of mulch/soil mix and the erosion control mat were noted along the toes of the slopes up to a height of about 1.5 m above slope toe, exposing the steel mesh which was originally covered under the mulch (Plate 2). The condition of the system above this level was satisfactory. As the two sites are located in remote area, the system detachment may be caused by cows when they eat the vegetation as judged by the contrast between the dense vegetation coverage at higher level of the slopes and the poor condition at toe levels of the two slopes (Plate 3).

E.2.4 NFY Hydro-Mulching

Similar to the Hong Kong Mulching technique, a layer of wire mesh is provided to

Table of Contents
Table of Contents
Table of Contents
Table of Contents

strengthen the mulch/soil mix of NFY Hydro-Mulching. Figure 3 shows the typical details.

E.2.4.1 Vegetation Assessment

Vegetation growth conditions on 16 slopes were surveyed. All slopes were planted with grasses and 11 of them were also planted with creepers and/or climbers. Six of the 16 slopes were surveyed in all the three inspections owing to remarkable differences in vegetation covers between the first two inspections. The performance of this product is variable amongst the 16 slopes surveyed. Half of the slopes had more than 70% total exposed vegetation cover in the latest inspection which were considered healthy whereas the figures for the other slopes ranged from 5% to more than 50%. The percentage cover of planted species on more than half of the slopes was found to decrease in different degrees, while for others it was found to increase slightly or about the same in the second inspections.

For the species diversity and richness of naturally established woody species, five slopes had H equalled to zero, while the others were recorded to have low values of H (e.g. between 1 and 2). S values for five slopes were consistently low (e.g. between 0 and 2). For another eight slopes, S were found decreasing from high to low values throughout the various inspections. Only two slopes were recorded to have increasing S values. This shows that slopes treated with NFY Hydro-Mulching are not particularly good in supporting naturally established woody plant species.

E.2.4.2 Engineering Assessment

Four slopes were inspected for assessing the engineering aspects of this product. Moderately narrow (width of about 5-20 mm) surface cracks were found locally on the surface of the mulch/soil mix (Plate 4a) on slopes no. 6SE-B/C256, 11SE-C/C33 and 11NW-D/C90. Narrow (width less than 5 mm) cracks were widespread on surface of mulch/soil mix on slope 11SW-D/C105. Drying up of the mix was probably the reason for the crack formation. On slopes C33 and C105, local parts of the mulch/soil mix had detached, exposing the steel mesh underneath (Plates 4b and 4c). On slope C90, the mulch/soil mix over-hanged along the second batter of the slope for a length of about 5 m to 10 m. Parts of the soil mix had completely dislodged from the slope (Plate 4d). For the mulch/soil mix remaining on the slope, some continuous horizontal cracks were formed, probably due to the downward pulling force from the self-weight of the soil mix.

The surface of the soil mix is protected with a layer of temporary degradable erosion control mat. During the site inspections, the mats on all the slopes had almost completely decomposed. Surface erosion was observed on slope C90 at various locations (Plates 5a and 5b). The vertical edges of the system on this slope were noted to be exposed (Plate 5c) and subject to surface erosion, especially those adjacent to stepped channel (Plate 5d). Surface erosion was also noted locally on slope C105 (Plate 5e), covering less than 10% of the total slope surface. Serious surface erosions were observed at areas directly under the canopies of existing trees at slopes C90 and C256 (Plate 26).

Table of Contents
Table of Contents
Table of Contents
Table of Contents

E.2.5 <u>"On" Method</u>

In this product, the soil mix is applied on a layer of wire mesh which is attached to slope surface by anchors as shown in Figure 4.

E.2.5.1 <u>Vegetation Assessment</u>

Growth conditions of vegetation on five slopes were surveyed. One slope (Slope No. 11NW-A/C123) was inspected in all the three inspections and one slope (Slope No. 11NW-B/C64) was inspected once. The remaining three slopes were surveyed twice. All the slopes were planted with grasses and three of them were also planted with creepers and/or climbers. For all slopes except slope 11NW-B/C64, the percentage covers of exposed planted grass species showed a decline between the field inspections. These covers were largely unhealthy (Table E1). This indicates that this product is unable to sustain planted grass species. The percentage planted creepers were also low on the three slopes planted with creepers. In summary, the percentage total covers of healthy and exposed vegetation were low in three out of five slopes.

For naturally occurring woody plant species, all slopes except slopes 11NW-A/C123 and 11NW-B/C64 were found to have rather low values of H and S. The high H and S on slope C123 during the third inspection were attributable to the abundant trees seedlings newly recruited on the slope surface in the summer. However, the sustainability of the tree seedlings on this slope is in doubt as they are isolated from the ground by a layer of concrete. In fact, the drop in H of 11NW-A/C123 during the second inspection appeared to be due to mortality of the seedlings during the winter preceding the second inspection.

The results of this assessment seem to suggest that On Method is largely unable to sustain good vegetation covers (whether planted or naturally established).

E.2.5.2 <u>Engineering Assessment</u>

Two slopes no. 11NE-A/C357 and 11NW-A/C123 were inspected for assessing the engineering aspects of this product. At some areas of slope C357, the soil mix was so hard that it could not easily be broken up by a hammer. No vegetation cover was found at these areas, see Plate 6a. This may be due to the use of cement additive in the soil mix. Narrow surface cracks with width of about 5 mm were found locally on the surface of the mulch/soil mix of slope C123. Detachment of soil mix was locally noted on slope C357. It was, however, quite extensive on slope C123; and as a result, the wire mesh beneath the soil mix and the existing concrete slope cover were exposed in places (Plates 6b and 6c).

It was specified in the manufacturer's brochure that a layer of soil saver will be installed on the slope surface as part of this greening product. The surface of the soil mix of slope C357 was, however, protected with a layer of long-term non-degradable erosion control mat. The mat was however not securely anchored with good contact with the surface of the soil mix (Plate 6d). No erosion control mat was noted on the surface of the slope C123. Erosion occurred at a few locations of the slope toe (Plate 6e).

Table of Contents
Table of Contents
Table of Contents
Table of Contents

E.2.6 Rocksgrass

The mulch/soil mix in this system is alternately interbedded with three layers of non-biodegradable mat and two layers of biodegradable mat. Typical details of the system are shown in Figure 5.

E.2.6.1 Vegetation Assessment

Growth conditions of vegetation on eight slopes were surveyed. All the slopes were planted with grasses and creepers and/ or climbers. All slopes were inspected twice except that slope 11SW-D/C111 was inspected three times. The overall percentage cover of slopes treated with this product is very good. Six out of eight slopes were recorded to have more than 80% total exposed and healthy vegetation cover (Table E1). In addition, four of these six slopes have the planted grass and *Wedelia trilobata* as the main ground vegetation cover. For the other two slopes, slope 11SE-C/C753 was dominated by the remnant trees as the main vegetation cover on the slope. The main vegetation cover of the remaining slope (11SW-C/C385) was formed both by planted species and existing trees on slopes. In the second inspection, except two slopes that reached 100% of total exposed vegetation cover, the total exposed vegetation cover of the remaining slopes was only found decreased slightly in the second inspection. However, both the percentage total exposed and healthy vegetation cover of slope C111 had recovered to a satisfactory level of more than 83% at the third inspection after the drop in the second inspection. This suggests that this technique may be able to retain soil moisture better during the winter dry season.

The species diversity and richness of naturally occurring woody plant species vary greatly amongst the slopes. However, the difference in most slopes between the two inspections is not large (Table E1). This product may be able to support small shrubs owing to its apparent ability to maintain soil moisture in the winter dry season and a thicker plant growth medium.

E.2.6.2 Engineering Assessment

Two slopes no. 11NW-D/C130 and 11SW-D/C111 were inspected for engineering assessment of this product. On slope C130, mild steel bars of 10 mm diameter are fixed on to the surface of the soil mix horizontally across the slope at a vertical spacing of about 1.5 m (Plate 7a). These horizontal bars act as bracing to provide additional support to the soil mix. Minor bulges of the mulch/soil mix were noted and they were confined by the horizontal steel bars. There were no apparent signs of surface cracking or detachment of soil mix. A layer of long-term non-degradable erosion control mat was provided on the surface of the two slopes. No sign of weakening was noted on these mats at the time of inspection and they were securely anchored on the slopes with tension. Edges of the system were noted to be well-protected by mats pinned on the slope.

Inspection was also made on slope no. 11NW-D/C131 during the application of Rocksgrass on the slope face. Horizontal rows of flexible coils of PVC pipes fixed on the slope surface were provided within the soil mix as support element (Plate 7b).

Table of Contents
Table of Contents
Table of Contents
Table of Contents

E.2.7 CMS-ML Green System

This system, similar to the Rocksgrass system, is also a composite involving soil mix interbedded with five layers of geosythetic mats fixed onto slope surface by pins (CMS). Figure 6 illustrates the typical details.

E.2.7.1 Vegetation Assessment

There is only one slope 3SE-A/C6 treated with this product in this study. The growth conditions of vegetation on this slope were surveyed twice. The slope was only planted with grasses. The overall percentage cover of both planted and total vegetation cover did not change much in both inspections (Table E1). The total exposed vegetation cover is quite high (around 90%) in both inspections but the percentage of healthy vegetation cover remained low (around 10%). From this perspective, the grass species is unable to persist on this product.

Zero value of H was recorded in both inspections and only one naturally occurring woody plant species was recorded.

E.2.7.2 Engineering Assessment

Slope 3SE-A/C6 was inspected for engineering assessment. The condition of the composite layer of the soil mix and the erosion control mats was satisfactorily intact at the time of inspection. There was no sign of cracking or detachment of the soil mix and no sign of weakening in strength of the erosion control mat.

E.2.8 Soil Panel

In this product, soil mix is placed between a layer of steel grid and another layer of steel mesh as a growing medium for the vegetation (Figure 7).

E.2.8.1 Vegetation Assessment

Vegetation growth conditions on the three slopes were surveyed twice. All the slopes were planted with both grasses and creepers which formed the main vegetation cover of the slopes (Table E1). Except slope 11SE-A/C487 which has satisfactory total exposed vegetation cover (about 90%) which is considered healthy, the vegetation cover of the other two slopes was quite low (less than 50% for exposed and around 20% for healthy).

For naturally occurring woody plant species, species diversity H and richness S are very low for slope C487 despite the best vegetation cover amongst the three slopes. On the contrary, the other two slopes have quite high species diversity H and richness S in both inspections. A high number of seedlings (of 20 different species) were recorded for slope 11SW-A/C331.

The overall percentage vegetation cover and species diversity recorded in both inspections are rather stable, showing that the slope vegetation has not changed much between

Table of Contents
Table of Contents
Table of Contents
Table of Contents

the two inspections. However, the performance of this product is not consistent amongst the three slopes. It is difficult to make a fair judgement on the success of this product based on the result of this study.

E.2.8.2 Engineering Assessment

Two slopes no. 11SE-A/C487 and 11SW-D/C117 were inspected for engineering assessment. Minor problems common to both slopes included bulging of the soil mix at or near the toe of the slopes (Plate 8). This is indicative of downward movements of the soil mix.

The temporary degradable erosion control mat used on slope C487 had almost degraded completely. Signs of erosion were locally noted at three to four locations near the crest of the slope. Plastic sheets were used at the crest of slope C487 to cover the top part of the greening system to prevent erosion into the soil mix (Plate 9). The erosion control mat on slope C117 had partly degraded. No sign of erosion was noted on the slope.

E.2.9 Toyo-Mulching

Similar to Hong Kong Mulching, a layer of wire mesh, which is fixed onto slope surface, is used for providing strength of the mulch as shown in the typical details in Figure 8.

E.2.9.1 Vegetation Assessment

Vegetation growth conditions on 20 slopes treated with Toyo-mulching were surveyed. All slopes were surveyed twice except that two slopes no. 7SW-D/C547 and 11NE-D/C815A were surveyed three times. Amongst the 20 slopes, one was planted with grasses only, seven were planted with the creeper *Wedelia trilobata* only, and the remaining 12 slopes were planted with both grasses and *Wedelia* (Table E1). The overall vegetation cover of slopes treated with this technique is generally good. Eighteen out of 20 slopes were recorded to have over 60% to 100% total exposed vegetation cover in the latest inspection which was considered healthy, including four slopes with 100% exposed and healthy vegetation cover and six slopes with more than 90% exposed and healthy vegetation cover. All but one slope planted only with *Wedelia* had very good total cover of *Wedelia* which also formed the main total exposed vegetation cover of the slopes. For most slopes planted with both grasses and *Wedelia*, the percentage cover of *Wedelia* was found generally much higher than the planted grasses, again showing that *Wedelia* is better ground cover species than commonly planted grass species in terms of maintaining a healthy and stable vegetation cover on steep man-made slopes.

For naturally occurring woody plant species, the pattern on Toyo-mulching is not that consistent. The species diversity H and richness S are variable amongst the slopes. Four slopes (15NW-B/C176; 7SW-D/C547, 11SW-A/F75 and 11SW-C/C322) had relatively higher H and S amongst the studied slopes.

In summary, Toyo-mulching appears to be quite well in sustaining the ground covering vegetation, especially *Wedelia* whilst the ability to support naturally occurring woody plant species is variable.

Table of Contents
Table of Contents
Table of Contents
Table of Contents

E.2.9.2 Engineering Assessment

Two slopes no. 11SE-C/C166 and 11SW-A/C138 were inspected for engineering assessment. The overall condition of the greening system on slope C166 was generally satisfactory with no apparent signs of distress. Vegetation at local areas of the slope toe was not able to establish (Plate 10b), probably owing to the steep gradient.

Temporary degradable erosion control mat was used on both slopes. On slope C136, the mat was in good condition. At the edge of the system (Plate 10a), however, anchorage of the erosion control mat was found to be inadequate. The mulch and wire mesh were exposed, rendering the system susceptible to surface erosion from this location. On slope C138, the mat had partly degraded. The mulch locally at the slope toe was found to have detached, exposing the wire mesh which was supposed to be embedded in the mulch (Plate 10c).

E.3 CELLULAR SYSTEM

E.3.1 General

All the techniques under this category except Terra Cell have been applied on slopes with sprayed concrete cover. A summary of the types of wire meshes and mats provided for the techniques in this category is given in Table 16.

E.3.2 Eco-link

This greening system involves the use of a three-dimensional (3-D) mat of hexagonal shaped geosynthetic cells. The 3-D mat is anchored on the slope surface and the cells of the mat are filled with soil mix (Figure 9).

E.3.2.1 Vegetation Assessment

Vegetation growth conditions on two slopes treated with Eco-Link System were surveyed. One slope was surveyed twice whereas the other was surveyed three times. Both slopes were mainly planted with grasses although some planted creepers were recorded. The total vegetation cover, exposed and healthy, of planted grass were found increased in the second inspection on both slopes. The performance of Eco-Link System on these two slopes is rather good. Nearly 100% total exposed vegetation cover was recorded in the second inspection for slope 15NE-B/C232, and almost all of this cover was recorded as “healthy” (Table E2). Slope 15NE-C/C3 was also found to have about 85% of the total exposed vegetation cover and almost all of this cover was recorded as “healthy” in the second inspection despite a rather low coverage in the first inspection. However, the total exposed and healthy vegetation cover decreased to 66% and 43% in the third inspection. For both slopes, large proportion of the vegetation cover was contributed by planted grasses, especially grasses which looked green and healthy in the second inspection.

The relative low values of H and S also suggest that few woody species have naturally established on these two slopes. Since only two slopes using this product were studied, one should be careful in interpreting the survey results.

Table of Contents
Table of Contents
Table of Contents
Table of Contents

E.3.2.2 Engineering Assessment

Slopes 15NE-B/C232 and 15NE-C/C3 treated with this product were inspected. The cells of the mat as shown in the close-up view in Figure 8 confined the soil mix within the cells, minimizing the possibility of downward movement of the soil mix. Apart from few minor cracking on the soil mix surface, the slopes were in satisfactory condition.

No wire mesh is specified in the manufacturer's brochure for use in the product. However, a layer of wire mesh was found embedding within the product on the two slopes. It probably serves to reinforce the mulch/soil mix. The face of the soil mix was protected with a layer of non-degradable erosion control mat and no sign of weakening of the mat was noted. Vertical edges of the mulch/soil mix of slope C3 were not fully covered by the erosion control mat (Plate 11a). On the other slope C232, the greening product was actually applied on the upper portion of the slope. The system was terminated at a location where the slope changes gradient and just over-hanged, exposing the wire mesh (Plate 11b).

E.3.3 Instant Evergreen System

In this product, prefabricated panels filled with soil mix inside are installed on the slope surface as shown in details in Figure 10.

E.3.3.1 Vegetation Assessment

Vegetation growth conditions on three slopes with this product were surveyed. Two slopes were surveyed twice and one was surveyed three times. All of them were planted with the herb *Sedum tetractinum* as the main ground cover. Slope 11NE-D/C366 was recorded to have a few *Paspalum notatum* grasses growing on the slope surface in the second inspection. The total healthy vegetation cover on slope C366 was low as 6% in the second inspection but increased to 38% in the third inspection, but the percentage healthy cover of the planted herb was just 17%. The performance of the planted herb was also poor on another slope 11NE-A/F167 where the healthy cover was just 6%. On the other slope 11SE-B/C5, it was recorded to have more than 80% for healthy *Sedum tetractinum* cover respectively (Table E2). Low values of both H and S were recorded on all slopes in all inspections. There was no naturally established woody species found on all three slopes, showing that this product may not be able to support woody species but only grasses or herbs.

The results seem to suggest that the ability of this product to sustain the planted herb *Sedum tetractinum* is extreme. It appears to be difficult for other naturally occurring woody species to grow on this product though invasive weeds may be possible to establish.

E.3.3.2 Engineering Assessment

Two slopes no. 11NE-D/C366 and 11NE-A/F167 were inspected for engineering assessment. The panels were individually anchored on both slopes by bolts. No apparent sign of detachment of the panels from the surface of the two slopes was observed. Also no apparent sign of detachment of the mulch/soil mix from the panels was noted.

Table of Contents
Table of Contents
Table of Contents
Table of Contents

The panels were lined with layers of geotextiles (Plate 12). The soil mix layers inside the panels were in satisfactory condition with no apparent signs of surface erosion.

E.3.4 NFY Eco-MP System

In this system, gabions containing soil/mulch blocks are embedded in holes excavated in shotcreted slopes as shown in Figure 11. This system has only been trialled on one slope.

E.3.4.1 Vegetation Assessment

Slope no. 7SW-C/C41 was treated with NFY Eco-MP System in this study. The growth conditions of vegetation on this slope were surveyed twice. This slope was found planted with the creeper (*Wedelia trilobata*), the grass species (*Cynodon dactylon* and *Paspalum notatum*) and the climber (*Parthenocissus dalziellii*). However, they only form a small proportion of the ground covering vegetation on this slope. The main vegetation cover of this slope was formed by various planted woody species (*Bougainvillea spectabilis, Lantana mita*, *Bauhinia glauca* and *Lantana montevidensis*).

The total exposed and healthy vegetation cover are quite satisfactory on this slope. More than 85% total exposed vegetation was recorded in the second inspection and most of it was recorded as "healthy". The percentage covers recorded in the two inspections were similar, suggesting that this product is able to support a stable green and healthy vegetation cover on slopes. However, there was only one woody species found naturally established on the slope in both inspections (Table E2). This shows that the rather "diverse" vegetation community on this slope was only contributed by planted species. However, as the planting holes of this product are connected to the soil under the shotcrete, it should be able to sustain vegetation, especially woody species.

E.3.4.2 Engineering Assessment

As the gabions containing the mulch block are embedded in the slope, there is not much concern about the stability problem of the mulch/soil mix for this product since the mulch/soil mix is not exposed on the slope surface. The engineering condition of the system was satisfactory during the inspection. No erosion control measures were provided on the exposed surface of the gabions placed on the slope. Despite this, no significant erosion was noted on this system.

E.3.5 NFY Hydro Planter

PVC pipes filled with soil mix inside constitute this greening system. The pipes are anchored on the slope by hangers (Figure 12).

E.3.5.1 Vegetation Assessment

There is only one slope (15NW-B/C343) treated with NFY Hydro Planter. Because

Table of Contents
Table of Contents
Table of Contents
Table of Contents

of the special nature of this product, a different assessment method was used in which plant growth condition in each planting hole along the PVC tubes was assessed.

The growth conditions of vegetation on this slope were surveyed twice. This product is found to be not as successful as other products in terms of maintaining green vegetation cover on slope surface. Only 23 out of the 230 planting holes on the PVC pipes were found covered with plants (climbers or grasses) in the first inspection; and one more hole was found covered with plants in the second inspection. Most of the holes without plants were empty.

E.3.5.2 Engineering Assessment

The PVC pipes and the associated bolts are the engineering components of this product. The conditions of these components were in general satisfactory without apparent signs of distress.

No erosion control measure was noted for the system. Most of the pipes were empty, indicating that the soil mix had been washed away. The close-up view of the system in Figure 12 illustrates this.

E.3.6 NFY Mulching Panel

This product involves installation of prefabricated panels of soil mix on the slope surface as shown in Figure 13.

E.3.6.1 Vegetation Assessment

Vegetation growth conditions on seven slopes with this product were surveyed. All slopes were surveyed twice except that slope 11SW-D/CR1993 was surveyed three times. All slopes were planted with both grasses and *Wedelia trilobata* whereas one slope 7SW-C/C55 was only planted with the creeper *W. trilobata*. Whilst the percentage covers of the grasses are low in all six slopes, the percentage cover of *W. trilobata* are variable (Table E2). The total percentage cover of planted *W. trilobata* on slope C55 was rather high (~73%) and all of the recorded cover was healthy. On slope 11SW-B/C206, the percentage cover of *W. trilobata* almost doubled in the second inspection, which also constituted the main vegetation cover of this slope. However, on the other five slopes, the percentage covers of *W. trilobata* were generally very low. Comparing the percentage total exposed vegetation cover and the percentage planted species cover in the latest inspection, naturally occurring vegetation has rather significant coverage in all seven slopes. The total exposed vegetation cover is generally high for all seven slopes (from 57% to 100%) but only the percentage total healthy cover of three slopes (11SW-A/C61, 7SW-C/C55, 11SW-B/C 206) are high in the second inspection. In addition, there is a general reduction in percentage total exposed vegetation cover in five of the seven slopes between the two inspections indicating that vegetation gradually died off in the winter dry season.

For naturally occurring woody plant species, species richness is low for all slopes except 11SW-A/C139 but its H value is low (<1). This shows that NFY Mulching Panel is

Table of Contents Table of Contents Table of Contents Table of Contents

not very good for the establishment of naturally occurring woody plant species. In fact, dead native tree seedlings were seen on some of these seven slopes, which were appeared to be due to desiccation.

In summary, the common planted grass species do not grow well on this product. The planted *W. trilobata* was growing well on certain slopes. This product supports low diversity of naturally occurring woody plant species but there are some naturally occurring ground covering vegetation. The vegetation on this product seemed to experience some problems in getting soil moisture in dry season. The large surface areas of the panels may lead to a high rate of surface evaporation. Thus, if *W. trilobata* is able to establish and maintain a dense coverage, it may help to retain soil moisture better such that a green vegetation cover can be maintained even in dry season. A good example can be found at Kennedy Road (11SW-B/C206). Without a dense vegetation cover, the wire mesh forming the gabions for the panel are very visible and may not be visually pleasing.

E.3.6.2 Engineering Assessment

Two slopes no. 11SW-D/C1090 and 11SW-A/C139 were inspected for engineering assessment. Each panel was found individually anchored on the slope by dowels. No apparent signs of detachment of the panels from the surface of the two slopes were observed. On slope C139, many of the mulching blocks were noted to have dried up with narrow cracks on the surface (Plate 13a). Some of the blocks had disintegrated.

No erosion control measure was noted on the exposed surface of the mulching panels mounted on the slope. Surface erosion was noted locally on a number of mulching blocks on slope C139 (Plate 13b). At the edge of the system on slope C139 (Plate 13c), half of a mulching block was found to be eroded out of the gabion containing the mulching block.

E.3.7 Terra Cell

This product makes use of a 3-dimensional mat with diamond shaped cells fabricated from synthetic materials. The mat is anchored on to the slope surface. The cells are filled with soil mix and hydroseeding is applied (Figure 14).

E.3.7.1 Vegetation Assessment

There is only one slope (11NE-D/C815B) in this study treated with Terra Cell. The growth conditions of vegetation on this slope were surveyed twice. Only grasses were found planted on this slope. Both exposed and healthy percentage covers of the planted grasses were found to have increased slightly in the second inspection. For the total vegetation cover, both the exposed and healthy cover were found to have increased dramatically in the second inspection. This shows that naturally occurring ground covering vegetation (mainly climbers and herbs) is taking over this slope. For the woody species composition, the diversity index H and the species richness S in the two inspections are also very low, indicating that there were few woody species establishing on this slope.

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Since there is only one slope treated with the product in the study, it is not possible to draw any conclusion on this product. Inspection results of the single slope show that the total exposed and healthy vegetation cover is more than 90% and 80% respectively.

E.3.7.2 Engineering Assessment

The Terra Cell at the slope toe (Plate 14) was not fully supported, rendering it vulnerable to down slope movement. No erosion control mat was provided on the finished surface and erosion of the soil mix was observed. Some cells were found only partly filled with the soil mix (Plate 14), indicating that part of the soil mix had been washed away.

E.4 REINFORCED SOIL SYSTEM

Geofiber is the single product classified under the technique of reinforced soil. A summary of the types of wire meshes and mats provided for the techniques under this category is given in Table 16. This product involves spraying of soil mix reinforced with continuous fibre on the slope surface. A vegetation base is then installed by spraying a thin layer of mulch on the reinforced soil (Figure 15).

E.4.1 Vegetation Assessment

Four slopes in this study were treated with Geofiber. All slopes were surveyed twice. One slope was planted with grasses, creepers and some woody plant seedlings; another planted with grass and woody plant seedlings. The other two slopes were only planted with creepers and grass respectively. The total exposed vegetation cover of all four slopes is very good (> 90%) but only the vegetation of the slope planted with *Wedelia trilobata* was wholly recorded as “healthy” (Table E3) in the two inspections. The healthy total vegetation cover of slope 11SW-B/C24 had almost doubled in the second inspection (from 38% to 64%) despite after the dry season. On the other hand, the healthy total vegetation cover of the slope in Lam Tei Quarry had dropped by a half between two inspections.

Slope 11SW-B/F74 was not inspected in the first inspection because construction work was in progress. The total healthy vegetation cover recorded in the second inspection on this slope was only 40% and the value was found to increase to 120% in the third inspection. This suggests that the vegetation was developing well between the two inspections.

For the naturally established woody plants, one slope was found to have low values of the Shannon diversity index H and species richness S and the other three slopes had zero H and S (Table E3). This indicates that the number woody plants established naturally on these four slopes were low.

It is worth noting that the 16-month old slope 11SW-D/C601 planted with the creeper *Wedelia trilobata* has achieved 100% total healthy vegetation cover in both inspections (Table E3). This suggests that *W. trilobata* is a better species than the commonly planted grass species (i.e. *Cynodon dactylon* and *Paspalum notatum*) in terms of maintaining a healthy ground cover using Geofiber. The same phenomenon is seen in some other

Table of Contents
Table of Contents
Table of Contents
Table of Contents

proprietary products. Although four slopes using Geofiber were studied, it is still difficult to make any generalization. It is because the vegetation planted on these slopes is rather different, making comparison and interpretation of the results difficult. Nevertheless, the assessment results suggest that Geofiber is able to sustain *W. trilobata* on small slopes.

E.4.2 Engineering Assessment

Slopes 11SW-D/C601 and 11SW-B/C24 were inspected for the engineering assessment. The overall condition of the slope with the greening system on slope C601 at the time of inspection was generally satisfactory with no apparent signs of distress. However, the surface mulch on slope C24 was found to have cracked and detached at about five locations, exposing the wire mesh and even the continuous fiber underneath (Plate 15a). Width of the cracks ranged from 5 to 10 mm. At a few locations, the area of detachment was more than 3 m^2 (Plate 15b). The fiber-reinforced soil under the surface mulch, however, was still intact, without any sign of deterioration.

No erosion control mat was provided on the surface of the mulch. No sign of erosion was observed on slope C604 but local surface erosions were noted on slope C24.

E.5 BIO-ENGINEERING METHOD

GW-Biodrains System is the single product classified under the technique of bio-engineering method. In the system, Vetiver grass is planted in small openings excavated on shotcreted slope surface. Details of the product are shown in Figure 16.

E.5.1 Vegetation Assessment

There are three slopes in this study treated with Vetiver Biodrains and all were planted with the grass Vetiver which was also the sole vegetation cover on the slopes. The performance of Vetiver Biodrains is very good in terms of vegetation cover. Two slopes (6SE-B/C167 and 7SW-C/C47) had 100% healthy vegetation cover recorded in the second inspection (Table E4). The remaining slope (7SW-D/C1) also had over 80% healthy vegetation cover. As this product involved planting of Vetiver grass in circular planting holes on shotcrete surface, other species could hardly establish in the planting holes. Thus, except slope 7SW-C/C47 which had a small H, the values of H for the other two slopes were zero (Table E4). This product is considered to be a self-sustainable product in terms of vegetation cover as the Vetiver grass is not isolated from the ground.

E.5.2 Engineering Assessment

Since this greening technique does not involve any engineering elements, no engineering assessment has been conducted.

Table of Contents

Table of Contents

Table of Contents

Table of Contents

LIST OF TABLES

Table of Contents
Table of Contents
Table of Contents

Table E1 - Vegetation Coverage of Slopes under the Category of Mulching System in the Inspections (after Hau and Leung, 2004a) (Sheet 1 of 4)

Product/ technique used	Slope number	% planted grass cover						% planted creepers/ climbers/ herbs cover						% total vegetation cover						Shannon diversity index, H			Species richness, S		
		Exposed			Healthy			Exposed			Healthy			Exposed			Healthy								
		1st Inspection	2nd Inspection	3rd Inspection	1st Inspection	2nd Inspection	3rd Inspection	1st Inspection	2nd Inspection	3rd Inspection	1st Inspection	2nd Inspection	3rd Inspection	1st Inspection	2nd Inspection	3rd Inspection	1st Inspection	2nd Inspection	3rd Inspection	1st Inspection	2nd Inspection	3rd Inspection	1st Inspection	2nd Inspection	3rd Inspection
BioCrete	3NE-D/C104	18.07%	16.35%		11.57%	9.11%								32.30%	29.76%		25.79%	19.18%		1.0986	1.0397		3	3	
	6NE-D/C55	90.32%	82.78%		8.38%	44.05%								93.02%	85.28%		11.09%	46.56%		0.8676	1.0397		3	3	
Hong Kong Mulching	8SW-B/C46	27.53%	10.20%		27.04%	9.00%		1.43%	47.30%		1.43%	60.55%		73.93%	77.98%		73.44%	90.90%		0.0000	0.0000		0	0	
	8SW-B/C95	22.72%	17.16%		20.03%	16.49%		35.20%	13.67%		35.20%	14.60%		73.12%	68.56%		70.44%	69.38%		1.3297	1.5596		4	5	
NFY Hydro-Mulching	11SW-A/C293A	50.99%	49.86%		4.54%	30.71%		34.82%	35.63%		36.28%	35.91%		88.25%	87.94%		43.27%	69.06%		0.0000	0.0000		0	0	
	6SE-B/C256	27.42%	10.83%	0.86%	11.82%	3.55%	0.25%	0.00%	2.08%	7.62%	0.00%	2.08%	7.62%	96.16%	71.14%	95.43%	82.31%	63.43%	97.88%	2.1370	1.4594	0.8979	11	6	3
	10NE-B/C123	34.99%	2.63%		23.45%	2.27%		48.41%	83.32%		46.61%	82.16%		84.37%	85.94%		70.42%	84.43%		0.6931	0.0000		2	1	
	11NW-B/C19	87.72%	49.26%	59.85%	5.03%	8.96%	9.39%							97.67%	52.65%	77.29%	11.80%	12.35%	24.19%	1.6770	1.6770	1.3322	6	6	4
	11NW-B/C266	31.73%	7.21%	30.00%	20.48%	7.21%	0.00%	12.64%	0.69%	0.38%	10.51%	0.69%	0.30%	71.88%	10.79%	34.81%	58.49%	10.79%	4.73%	1.8026	1.0889	0.7586	9	4	4
	11NW-B/C39	80.70%	94.65%		14.69%	33.02%								98.21%	97.83%		32.20%	36.20%		0.0000	0.0000		0	1	
	11NW-D/C90	69.54%	78.61%	67.12%	47.11%	7.96%	26.57%							98.61%	79.13%	83.14%	75.38%	8.48%	36.38%	1.3160	1.3582	1.9227	7	6	10
	11SE-C/C19	19.73%	8.39%	46.76%	5.78%	3.12%	11.91%	21.44%	16.24%	26.07%	19.16%	16.29%	26.61%	65.66%	39.57%	87.16%	49.55%	32.68%	52.84%	1.5230	1.5230	1.0397	5	5	3
	11SE-C/C32	65.77%	99.24%		7.27%	86.52%		0.60%	0.04%		0.60%	0.04%		100.00%	99.82%		40.72%	87.11%		1.6957	1.4942		6	5	
	11SE-C/C33	57.34%	76.74%		13.41%	21.89%		1.22%	0.74%		0.81%	0.45%		89.98%	86.03%		42.09%	30.37%		0.6931	0.0000		2	1	
	11SW-A/CR28	23.01%	21.31%		90.77%	90.77%		0.22%	0.11%		0.22%	0.11%		99.83%	100.00%		167.75%	169.58%		0.4506	0.0000		2	1	
	11SW-D/C105	56.10%	5.12%	61.64%	5.64%	1.30%	5.49%	1.03%	0.10%	0.63%	1.03%	0.10%	0.49%	89.03%	5.23%	64.42%	30.20%	1.40%	8.12%	1.2876	1.0986	1.3863	5	3	4
	11SW-D/C1642	1.72%	1.52%		0.95%	1.52%		51.62%	72.32%		39.52%	72.32%		55.44%	76.07%		42.20%	76.07%		1.5607	1.5194		5	6	
	11SW-D/FR39	47.45%	33.28%		48.50%	33.28%								94.73%	96.31%		97.93%	96.31%		1.1027	1.1542		7	6	

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Table E1 - Vegetation Coverage of Slopes under the Category of Mulching System in the Inspections (after Hau and Leung, 2004a) (Sheet 2 of 4)

Product/ technique used	Slope number	% planted grass cover						% planted creepers/ climbers/ herbs cover						% total vegetation cover						Shannon diversity index, H			Species richness, S		
		Exposed			Healthy			Exposed			Healthy			Exposed			Healthy								
		1st Inspection	2nd Inspection	3rd Inspection	1st Inspection	2nd Inspection	3rd Inspection	1st Inspection	2nd Inspection	3rd Inspection	1st Inspection	2nd Inspection	3rd Inspection	1st Inspection	2nd Inspection	3rd Inspection	1st Inspection	2nd Inspection	3rd Inspection	1st Inspection	2nd Inspection	3rd Inspection	1st Inspection	2nd Inspection	3rd Inspection
NFY Hydro-Mulching	3SE-D/C93	37.12%			3.61%			4.44%			3.18%			41.89%			7.11%			1.0114			3		
	11SW-B/C214	0.35%	0.00%		0.35%	0.00%								88.12%	91.29%		88.12%	91.29%		2.1899	1.6770		14	6	
"On" Method	11NE-A/C357	59.31%	24.14%		24.59%	18.53%								86.15%	89.61%		45.31%	84.00%		0.9503	0.5623		3	2	
	11NW-A/C123	91.67%	32.78%	24.53%	3.94%	0.82%	0.00%	0.59%	0.80%	0.75%	0.59%	0.80%	0.75%	96.48%	38.92%	33.68%	7.94%	6.97%	7.65%	1.6222	0.4994	1.4051	12	8	7
	11NW-A/C441	53.16%	49.00%		0.29%	12.87%								53.16%	49.00%		0.29%	12.87%		0.0000	0.0000		0	1	
	11NW-B/C64		34.69%			1.51%			0.54%			0.54%			70.45%			34.85%			1.9992			11	
	11NW-B/F41		56.16%	42.13%		56.84%	23.20%		15.88%	24.40%		16.32%	17.69%		87.18%	80.98%		88.55%	54.11%		0.8959	0.6045		6	5
Rocksgrass	3SW-B/C292	46.90%	46.51%		17.90%	2.36%		27.20%	18.52%		27.20%	12.57%		76.85%	65.86%		47.84%	15.77%		1.9062	1.7479		7	6	
	11NE-C/C62	53.94%	3.17%		5.79%	1.80%		27.29%	73.57%		27.29%	73.57%		88.92%	83.27%		40.42%	81.90%		0.0000	0.0000		0	0	
	11NW-D/C130	30.54%	14.62%		21.83%	10.17%		61.52%	76.28%		62.40%	76.28%		94.56%	91.34%		86.74%	86.89%		1.3297	1.2407		4	4	
	11NW-D/C52	3.91%	4.22%		1.94%	0.54%		95.44%	89.47%		95.44%	89.47%		99.35%	93.69%		97.38%	90.01%		0.9976	1.2770		5	4	
	11SE-C/C753	0.00%	0.00%		0.74%	0.49%		0.00%	0.00%		67.77%	27.72%		100.00%	100.00%		171.54%	130.96%		1.8065	0.9904		8	8	
	11SW-A/C142	14.58%	11.97%		11.33%	10.76%		10.05%	25.85%		16.85%	43.23%		97.78%	100.00%		124.16%	129.41%		1.8923	1.9984		13	12	
	11SW-C/C385	17.60%	4.99%		1.78%	5.51%		11.76%	22.05%		20.61%	42.27%		94.25%	88.99%		95.30%	113.44%		0.7160	0.4249		8	8	
	11SW-D/C111	57.42%	48.05%	12.94%	18.48%	7.97%	10.85%	34.31%	26.68%	71.27%	34.31%	14.73%	71.27%	92.76%	75.73%	85.14%	53.81%	23.58%	83.06%	1.4366	1.3054	0.9821	11	10	5
CMS-ML Green System	3SE-A/C6	89.32%	86.68%		6.61%	8.80%								92.36%	89.20%		9.65%	11.18%		0.0000	0.0000		1	1	
Soil Panel	11SE-A/C487	69.32%	62.80%		23.48%	51.72%		3.09%	2.75%		3.09%	2.75%		85.79%	88.89%		39.95%	78.39%		0.0000	0.0000		1	1	
	11SW-A/C331	2.88%	13.26%		2.88%	0.43%		15.04%	19.77%		15.04%	14.54%		37.24%	43.88%		37.24%	22.71%		1.8820	1.7285		22	20	

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Table E1 - Vegetation Coverage of Slopes under the Category of Mulching System in the Inspections (after Hau and Leung, 2004a) (Sheet 3 of 4)

Product/ technique used	Slope number	% planted grass cover						% planted creepers/ climbers/ herbs cover						% total vegetation cover						Shannon diversity index, H			Species richness, S		
		Exposed			Healthy			Exposed			Healthy			Exposed			Healthy								
		1st Inspection	2nd Inspection	3rd Inspection	1st Inspection	2nd Inspection	3rd Inspection	1st Inspection	2nd Inspection	3rd Inspection	1st Inspection	2nd Inspection	3rd Inspection	1st Inspection	2nd Inspection	3rd Inspection	1st Inspection	2nd Inspection	3rd Inspection	1st Inspection	2nd Inspection	3rd Inspection	1st Inspection	2nd Inspection	3rd Inspection
Soil Panel	11SW-D/C117	32.52%	24.70%		32.52%	3.01%		10.97%	16.53%		10.97%	16.53%		44.53%	42.27%		44.53%	20.58%		1.7438	1.7299		9	9	
Toyo-mulching	7SW-D/CR538	4.79%	0.82%		0.76%	0.60%		0.00%	0.55%		0.00%	0.55%		5.22%	8.59%		1.20%	8.36%		0.5623	0.5623		2	2	
	15NW-B/C176							86.80%	87.94%		86.80%	88.08%		88.58%	90.42%		88.58%	90.66%		1.5366	1.5366		15	15	
	7SW-D/C547	2.00%	0.00%	0.00%	2.00%	0.00%	0.00%	95.00%	70.00%	50.00%	95.00%	70.00%	45.00%	97.00%	70.00%	50.00%	97.00%	70.00%	45.00%	1.9062	1.9062	1.4452	8	8	5
	7SW-D/CR553	2.15%	8.12%		2.15%	0.00%		92.62%	62.10%		92.62%	62.10%		96.20%	70.22%		96.20%	62.10%		0.6365	0.6365		2	2	
	11NE-D/C815A	0.00%	0.89%	0.00%	0.00%	0.89%	0.00%	0.09%	0.89%	3.13%	0.09%	0.89%	3.13%	92.77%	67.41%	68.13%	63.04%	67.41%	66.79%	0.0000	0.0000	0.0000	0	0	0
	11NW-B/C82	44.95%	33.61%		25.26%	3.99%								87.52%	88.05%		67.91%	58.51%		0.5623	1.0986		2	3	
	11NW-D/C330	32.04%	27.12%		18.68%	29.41%		2.09%	9.17%		2.09%	9.17%		91.05%	89.95%		81.26%	100.54%		0.0000	0.0000		0	0	
	11NW-D/C548	21.35%	6.62%		5.16%	0.86%		4.84%	10.54%		12.44%	10.54%		83.65%	76.86%		87.75%	71.10%		0.9186	1.1681		5	6	
	11SE-A/C123	5.71%	17.40%		5.71%	1.36%		90.58%	73.12%		90.58%	73.12%		100.00%	97.66%		100.00%	82.27%		0.6931	0.6931		2	2	
	11SE-C/C166							82.50%	86.50%		82.50%	86.50%		100.00%	97.60%		100.00%	97.60%		0.0000	0.0000		1	1	
	11SE-C/C679							1.07%	0.00%		1.07%	0.00%		100.00%	100.00%		100.00%	100.00%		0.0000	0.0000		0	0	
	11SE-C/C684							97.76%	95.78%		97.76%	97.68%		99.84%	99.84%		99.84%	101.74%		1.3297	1.3297		4	4	
	11SE-C/C694	1.25%	1.14%		0.74%	0.68%		31.70%	67.42%		40.43%	67.42%		98.77%	98.40%		108.21%	97.95%		0.6931	0.6931		2	2	
	11SW-A/C135							80.44%	75.00%		80.44%	75.00%		80.44%	76.32%		80.44%	76.32%		1.4942	1.3297		5	4	
	11SW-A/C138	2.54%	1.27%		2.54%	1.27%		66.68%	64.15%		66.68%	64.15%		69.52%	68.66%		69.52%	68.66%		0.5010	0.5010		3	3	
	11SW-A/F75	2.74%	0.68%		3.64%	2.67%		60.69%	62.75%		79.67%	84.34%		100.00%	100.00%		123.29%	127.40%		1.9152	1.9354		10	10	
	11SW-C/C322							99.44%	98.14%		99.44%	98.14%		99.44%	98.14%		99.44%	98.14%		1.7242	1.7440		7	7	

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Table E1 - Vegetation Coverage of Slopes under the Category of Mulching System in the Inspections (after Hau and Leung, 2004a) (Sheet 4 of 4)

Product/ technique used	Slope number	% planted grass cover						% planted creepers/ climbers/ herbs cover						% total vegetation cover						Shannon diversity index, H			Species richness, S		
		Exposed			Healthy			Exposed			Healthy			Exposed			Healthy								
		1st Inspection	2nd Inspection	3rd Inspection	1st Inspection	2nd Inspection	3rd Inspection	1st Inspection	2nd Inspection	3rd Inspection	1st Inspection	2nd Inspection	3rd Inspection	1st Inspection	2nd Inspection	3rd Inspection	1st Inspection	2nd Inspection	3rd Inspection	1st Inspection	2nd Inspection	3rd Inspection	1st Inspection	2nd Inspection	3rd Inspection
Toyo-mulching	11SW-D/C110							99.75%	100.00%		99.75%	100.00%		99.75%	100.00%		99.75%	100.00%		1.6094	1.6094		5	5	
	12NW-C/C92	2.00%	0.00%		2.00%	0.00%		95.00%	100.00%		95.00%	100.00%		97.00%	100.00%		97.00%	100.00%		0.0000	0.0000		0	0	
	12SW-A/C125	54.02%	4.00%		30.00%	4.00%		5.17%	83.33%		5.17%	87.01%		86.03%	99.67%		62.01%	103.34%		0.8953	0.8953		4	4	

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Table E2 - Vegetation Coverage of Slopes under the Category of Cellular System in the Inspections (after Hau and Leung, 2004a)

Product/ technique used	Slope number	% planted grass cover						% planted creepers/ climbers/ herbs cover						% total vegetation cover						Shannon diversity index, H			Species richness, S		
		Exposed			Healthy			Exposed			Healthy			Exposed			Healthy								
		1st Inspection	2nd Inspection	3rd Inspection	1st Inspection	2nd Inspection	3rd Inspection	1st Inspection	2nd Inspection	3rd Inspection	1st Inspection	2nd Inspection	3rd Inspection	1st Inspection	2nd Inspection	3rd Inspection	1st Inspection	2nd Inspection	3rd Inspection	1st Inspection	2nd Inspection	3rd Inspection	1st Inspection	2nd Inspection	3rd Inspection
Eco-Link System	15NE-B/C232	74.13%	82.36%		48.41%	85.13%		0.00%	0.24%		0.00%	0.24%		98.59%	99.36%		75.70%	102.13%		1.4648	0.6931		5	2	
	15NE-C/C3	10.32%	62.95%	47.95%	2.30%	63.55%	25.40%	2.15%	0.00%	0.73%	2.15%	0.00%	0.73%	19.85%	84.10%	65.80%	11.83%	85.34%	43.25%	0.4506	1.0776	0.8305	2	4	3
Instant Evergreen System	11NE-A/F167								82.71%	6.02%		88.31%	6.02%		90.33%	86.59%		95.92%	86.59%		0.0000	0.9306		1	4
	11NE-D/C366	0.00%	0.08%	0.00%	0.00%	0.08%	0.00%	56.11%	2.34%	18.29%	56.24%	0.24%	17.71%	65.41%	8.24%	39.43%	65.53%	6.15%	38.35%	0.0000	0.0000	0.2403	1	1	2
	11SE-B/C5							65.58%	60.42%		80.40%	79.34%		88.63%	83.47%		103.45%	102.39%		0.0000	0.0000		0	0	
NFY Eco-MP System	7SW-C/C41	17.25%	6.34%		10.35%	1.31%		6.80%	7.98%		6.96%	7.98%		91.29%	87.57%		83.65%	78.11%		0.0000	0.0000		1	1	
NFY Mulching Panel	11SW-A/C61	6.40%	4.08%		5.75%	3.78%		0.00%	3.48%		1.26%	28.78%		98.84%	100.00%		102.01%	126.74%		0.0000	0.0000		1	0	
	11SW-A/C139	33.19%	61.39%		4.64%	0.00%		0.53%	2.71%		0.53%	2.71%		93.75%	80.68%		67.57%	19.42%		0.9569	0.9699		14	13	
	7SW-C/C55							69.39%	73.80%		70.23%	73.80%		98.15%	92.45%		98.12%	80.95%		0.0000	0.0000		1	1	
	11SW-D/CR1993	5.00%	40.00%	50.00%	0.00%	20.00%	0.00%	80.00%	10.00%	5.00%	60.00%	10.00%	0.00%	92.00%	57.00%	55.00%	67.00%	37.00%	0.00%	0.6365	0.0000	0.0000	2	1	0
	11SW-A/C293B	61.96%	32.82%		9.45%	4.60%		0.00%	2.47%		0.00%	2.47%		85.43%	79.38%		36.63%	56.71%		1.3374	1.9753		5	10	
	11SW-B/C206	34.91%	0.00%		20.40%	0.00%		38.75%	72.92%		39.28%	92.98%		99.28%	99.68%		86.02%	120.18%		1.1685	1.5654		4	6	
	11SW-D/C1090	4.13%	37.19%		4.13%	3.92%		0.00%	1.73%		0.00%	1.73%		14.95%	61.70%		14.95%	28.43%		0.5623	0.9503		2	3	
Terra Cell	11NE-D/C815B	44.26%	46.71%		21.82%	37.95%								64.51%	92.24%		41.74%	81.85%		0.3768	0.0000		2	1	

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Table E3 - Vegetation Coverage of Slopes under the Category of Reinforced Soil in the Inspections (after Hau and Leung, 2004a)

Product/ technique used	Slope number	% planted grass cover						% planted creepers/ climbers/ herbs cover						% total vegetation cover						Shannon diversity index, H			Species richness, S		
		Exposed			Healthy			Exposed			Healthy			Exposed			Healthy								
		1st Inspection	2nd Inspection	3rd Inspection	1st Inspection	2nd Inspection	3rd Inspection	1st Inspection	2nd Inspection	3rd Inspection	1st Inspection	2nd Inspection	3rd Inspection	1st Inspection	2nd Inspection	3rd Inspection	1st Inspection	2nd Inspection	3rd Inspection	1st Inspection	2nd Inspection	3rd Inspection	1st Inspection	2nd Inspection	3rd Inspection
Geofiber	11SW-B/C24	48.19%	38.22%		11.59%	17.56%		37.13%	38.72%		14.11%	24.42%		97.89%	98.62%		38.02%	64.06%		0.9898	0.6928		10	7	
	11SW-D/C601							100.00%	100.00%		100.00%	100.00%		100.00%	100.00%		100.00%	100.00%		0.0000	0.0000		0	0	
	11SW-B/F74		68.00%	68.00%		10.00%	85.00%			0.00%			5.00%		98.00%	98.00%		40.00%	120.00 %		0.0000	0.8975		0	3
	Lam Tei Quarry (slope no. not assigned)	94.32%	94.32%		75.04%	35.03%								94.32%	94.32%		75.04%	35.03%		0.0000	0.0000		0	0	

Table E4 - Vegetation Coverage of Slopes under the Category of Bio-engineering Method in the Inspections (after Hau and Leung, 2004a)

Product/ technique used	Slope number	% planted grass cover						% planted creepers/ climbers/ herbs cover						% total vegetation cover						Shannon diversity index, H			Species richness, S		
		Exposed			Healthy			Exposed			Healthy			Exposed			Healthy								
		1st Inspection	2nd Inspection	3rd Inspection	1st Inspection	2nd Inspection	3rd Inspection	1st Inspection	2nd Inspection	3rd Inspection	1st Inspection	2nd Inspection	3rd Inspection	1st Inspection	2nd Inspection	3rd Inspection	1st Inspection	2nd Inspection	3rd Inspection	1st Inspection	2nd Inspection	3rd Inspection	1st Inspection	2nd Inspection	3rd Inspection
GW-Biodrains System	6SE-B/C167	20.00%	100.00%		20.00%	100.00%								20.00%	100.00%		20.00%	100.00%		0.0000	0.0000		0	0	
	7SW-C/C47	100.00%	100.00%		100.00%	100.00%								100.00%	100.00%		100.00%	100.00%		0.6365	1.3297		2	4	
	7SW-D/C1	83.44%	83.44%		83.44%	83.44%								83.44%	83.44%		83.44%	83.44%		0.0000	0.0000		0	0	

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Table of Contents

Table of Contents

APPENDIX F

SUMMARY OF SITE INSPECTIONS AND ASSESSMENTS OF GROUP 2 GREENING TECHNIQUES

Table of Contents

Table of Contents

CONTENTS

F.1 GENERAL

Details of the assessment of vegetation growth of the various greening techniques are presented in Hau and Leung (2004a). Results of the vegetation assessment along with those of the engineering assessment of group 2 greening techniques are briefly discussed in the following sections.

In this study, erosion control mats directly placed on soil surface of slopes were assessed. The products are grouped into two primary categories in accordance with Erosion Control Technology Council (ECTC, 2003): temporary degradable and long-term non-degradable. A few kinds of long-term non-degradable erosion control mats were used in conjunction with steel wire mesh.

F.2 TEMPOROARY DEGRADABLE EROSION CONTROL MATS

F.2.1 General

Temporary degradable erosion control mats are designed to enhance the establishment of vegetation. These products are used where vegetation alone provides sufficient site protection after the temporary products have degraded (ECTC, 2003).

The erosion control mats of this type are often made of natural material and are usually hard and strong when they are new for use. They then decompose slowly within a few months' to a few years' time accompanied with decline in strength. They eventually disintegrate. The intention is that vegetation cover can be established on the slope and takes over the role of erosion control before the product starts degradation.

Three products fall within this category. Soil Guard is a mixture of mulch of wood fiber and seeds to be hydraulically sprayed on the slope. The other two rolled products, Coir and Soil Saver, are rolled mats to be laid on slope surface directly. These two products of mats usually come with a few densities ranging from 400 to 1220 g/m^2. A higher density means a tighter mesh and less open area in the netting.

Findings of the assessment of the three products in the temporary degradable category are discussed in the following sections.

F.2.2 Soil Guard

Soil Guard involves the spraying of a mulch of wood fiber and seeds onto soil slope surface directly as shown in Figure 17.

F.2.2.1 Vegetation Assessment

One slope (11NW-D/C403) in the study was treated with this product and it was inspected twice. The slope was not inspected in the first inspection owing to construction in progress. During the inspection, a layer of Miramat TM8 and a wire mesh were added on top of the surface of Soil Guard. The slope was found to be planted with grasses only. A

Table of Contents
Table of Contents
Table of Contents
Table of Contents

few remnant trees were found preserved on the first batter of the slope. The main ground vegetation cover was formed by the planted grasses. Both the total exposed and healthy percentage vegetation cover increased from a low value of 15% at the second inspection to more than 30% in the third inspection. Most of the slope surface was still bare Miramat TM8.

There were quite a number of small naturally occurring woody plant seedlings recorded on this slope. Therefore, the diversity index H and the species richness S are relatively high compared to other slopes in this study.

F.2.2.2 Engineering Assessment

Slope (11NW-D/C403) was inspected for the engineering assessment of the product. The layer of Miramat TM8 laid on the slope surface had masked the Soil Guard mulch (Plate 16a), preventing detailed inspection of the product. Another slope no. 11NW-B/C504 which was treated with Soil Guard and has recently been included in the Database "Greening Methods on Slopes" was selected for inspection. Vegetation cover on this slope is generally satisfactory except localized areas of erosion (Plate 16b), particularly near slope crest (Plate 16c). This demonstrates that Soil Guard alone may not be able to effectively control erosion.

F.2.3 Coir

Coir is made of coconut fiber which can degrade organically. Figure 18 shows the installation details of the mat.

F.2.3.1 Vegetation Assessment

One slope no. 11NW-D/FR40 was treated with Coir in this study and had grasses planted on them. When comparing the percentage cover recorded in the two inspections, it is found that the percentage cover of planted species recorded as "healthy" generally increases in the second inspection (Table F1). The total healthy vegetation cover also shows a similar trend. This shows that the overall vegetation on the slope grows better in spring (the time that the second inspection was carried out). The percentage cover – exposed of the planted grass is found decreased in the second inspection, whereas the total vegetation cover-exposed remained more or less the same. This simply implies that the planted grass is being taken over by the naturally established vegetation on the slopes.

The species richness does not change much in the second inspection except that the diversity index is doubled. The increase in the diversity index is due to the equality in the abundance of the plant species.

F.2.3.2 Engineering Assessment

Slope no. 11NW-D/FR40 which was protected with Coir was inspected in May and

Table of Contents
Table of Contents
Table of Contents
Table of Contents

October 2003 for the engineering assessment. According to records, upgrading works involving recompaction of fill was completed in early 2003. The slope stands at an average angle of about 35°. In the inspection carried out in May 2003, the erosion mat had partly decomposed and much of the slope was covered by vegetation. However, no vegetation was found growing at areas where two layers of the mat overlapped. Figure 18 shows an overall view of the slope with vegetation failed to establish along the strips where two layers of mat overlapped. Erosion gullies were found along most of these strips, under the mats, see Plate 17a. This suggests that thick layers of the mat had suppressed plant growth and establishment. In the subsequent inspection carried out in October 2003, most of the erosion mats had been decomposed completely and vegetation was found to have established on the slope surface including the erosion gullies identified in May 2003, see Plate 17b. Further erosion at the previous gully areas was not apparent, indicating that the vegetation established was able to control erosion.

F.2.4 Soil Saver

Soil Saver is made of jute fiber which can degrade organically. Figure 19 shows the installation details of the mat.

F.2.4.1 Vegetation Assessment

One slope no. 6SE-D/C212 was treated with Soil Saver in this study. The slope was planted with both grass and the creeper *Wedelia trilobata*. Similar to the condition on the slope using Coir, both the percentage cover of planted species recorded as “healthy” and the total healthy vegetation cover are found to increase in the second inspection (Table F1). This shows that the overall vegetation on the slope grows better in spring (the time that the second inspection was carried out). The percentage cover-exposed of the planted grass is found decreased in the second inspection, whereas the total vegetation cover-exposed has increased. This simply implies that the planted grass is being taken over by the naturally established vegetation on the slopes.

The species richness and diversity index do not change much in the second inspection. This means that the plant species on the slope is more or less the same in the two inspections.

The overall exposed vegetation cover of all two slopes treated with temporary degradable mat is quite satisfactory (> 70%). The result of the second inspection does not differ much from the first inspection. This shows that this kind of mat is quite good in supporting both the planted and naturally occurring species even after the winter season.

F.2.4.2 Engineering Assessment

Slope C212 was inspected in May 2003 for the engineering assessment. The slope stands at about 50°. The mat laying and hydroseeding works were completed in November 2001. The grade of the Soil Saver mat used on the slope was 500g/m^2 according to information provided by the Lands Department. During the inspection, i.e. one and a half year after installation, the layer of Soil Saver was found to be almost completely degraded,

Table of Contents
Table of Contents
Table of Contents
Table of Contents

see Plate 18. Minor sign of erosion was noticed at local areas.

F.3 LONG-TERM NON-DEGRADABLE EROSION CONTROL MATS

F.3.1 General

Long-term non-degradable erosion control products are normally made of synthetic materials designed to provide erosion protection, improve vegetation growth and extend the erosion control performance limits of vegetation (ECTC, 2003). All products in this category are mat-like material designed to be laid on slopes to provide long-term erosion control. They are also used at areas where vegetation alone is not able to furnish sufficient erosion control. Findings of the assessment on non-degradable erosion control products are discussed below.

F.3.2 Enkamat

This product is a 3-D mat made of polyamide. Figure 20 shows the installation details of the mat.

F.3.2.1 Vegetation Assessment

Three slopes in this study were treated with Enkamat. Slope no. 11NW-D/FR50 was only installed with Enkamat on its surface whereas the other two slopes, numbered 3SE-D/C74 and C75, were installed with Enkamat in conjunction with steel wire mesh as well. On slope FR50, the total exposed vegetation cover was the same in both inspections (i.e. 94%), and the total healthy vegetation cover was found to increase two times in the second inspection. This shows that the vegetation on this slope was able to regenerate in spring. The species diversity of slope FR50 has increased a little bit in the second inspection, further suggesting that the vegetation recovered from the winter dry season.

F.3.2.2 Engineering Assessment

The slope no. 11NW-D/FR50 on which Enkamat was only installed as erosion protection was inspected in March 2004 for engineering assessment. No sign of weakening in strength of the mats was noted. The mat was anchored securely on the slope and was also generally conformed to the soil slope surface. No apparent sign of erosion was noted on the slope.

F.3.3 Kangaroo Mat

It is a composite material consisting a layer of PVC erosion control mat and a degradable non-woven fabric. Figure 21 shows the installation details of the mat.

Table of Contents
Table of Contents
Table of Contents
Table of Contents

F.3.3.1 Vegetation Assessment

Slopes no. 3NE-C/C159 and 11NW-A/C159 in this study were treated with Kangaroo Mats. Both slopes were found to have a small cover of planted grasses in the first inspection, which was further reduced in the second inspection (only about 6% and 1% on the two slopes respectively). The total vegetation cover-exposed and healthy of both slopes were also found to decrease slightly. However the overall vegetation cover of the two slopes is not bad. Slope 11NW-A/C159 was recorded to have more than 75% total vegetation cover that is exposed and healthy. The other slope (3NE-C/C159) was recorded to have about 60% total vegetation cover that is exposed and healthy. These show that both slopes were dominated by naturally established ground covering species.

The high values of H and S of slope 3NE-C/C159 suggest that this product is able to support a diverse community of naturally established woody species. The other slope (11NW- A/C159) was found to have a much lower values of H and S. The large difference of the H and S values between the two slopes is probably due to the fact that slope 3NE-C/C159 is directly connected to natural vegetation (a *feng shui* wood behind the slope) where natural seed source is not limited. On the other hand, slope 11NW-A/C159 is much more isolated from natural vegetation.

F.3.3.2 Engineering Assessment

Both slopes no. 11NW-A/C159 and 3NE-C/C159 were also inspected for engineering assessment. The average slope angles of 11NW-A/C159 and 3NE-C/C159 are 35° and 60° respectively. The material inside the soil factor and fertilizer strips had decomposed, leaving the PVC erosion control mat alone. No apparent sign of erosion was observed on both slopes. For slope 11NW-A/C159, overlap of two mats was not pegged securely onto the slope surface (Plate 19).

F.3.4 Miramat TM8

It is a 3-D geosynthetic mat. Figure 22 shows the installation details of the mat.

F.3.4.1 Vegetation Assessment

Four slopes of this study, namely 7SW-C/C180, C181, 7SW-D/C22 and 11NW-B/C90, were treated with Miramat TM8 as their sole erosion protection measure on the slope surface. All slopes were planted with grasses and slope C22 was also planted with climber. In the second inspection, percentage cover of exposed total vegetation of slope C181 have increased whereas that of the other three slopes have decreased slightly. Three slopes C180, C181 and C22 show satisfactory healthy vegetation cover (>62%) in the second inspection whereas slope C90 was recorded with a low value (41%). The species diversity indices at all four slopes have not changed very much between the two inspections, thus suggesting that the vegetation of the four slopes is rather stable. However, both H (ranging from 0 to 0.5) and S (ranging from 1 to 2) of slope C90 are rather low. It is probably because the slope is isolated to natural seed source by a few large shotcrete slopes.

Table of Contents
Table of Contents
Table of Contents
Table of Contents

F.3.4.2 Engineering Assessment

Three cut slopes no. 7SW-D/C22, 7SW-C/C180 and C181 standing at about 55° to 60° were inspected for engineering assessment. Grillage concrete beams were constructed on Slope C22. The soil surface between the beams were protected with a layer of Miramat TM8 (Plate 20a). No sign of weakening in strength of the mats was noted. On slope C180, the erosion control mat did not follow closely the undulating slope profile (Plate 20b). This is probably because Miramat TM8 is relatively rigid and difficult to conform to uneven slope surface. At areas where the mat was not in contact with the soil surface, vegetation failed to establish on the soil surface. Moreover, no sign of erosion was found on the three slopes.

F.3.5 Multimat

It is a 3-D mat made up of three layers of polypropylene mesh. Figure 23 shows the installation details of the mat.

F.3.5.1 Vegetation Assessment

Only one slope (7SE-C/C42) in this study was treated with Multimat and planted with grasses as the ground cover. The overall vegetation cover of this slope is very good. Both the planted vegetation cover and total vegetation cover have increased significantly in the second inspection. The percentage cover of exposed planted grass was found greater than 85% in the second inspection and almost all of this grass cover was recorded as "healthy". The total vegetation cover of this slope is also largely contributed by the healthy planted grass species. However, it is hard to make a conclusion on the performance of Multimat as this is the only slope surveyed using this product. Besides, the slope was only two-month old when it was surveyed in the first inspection. The seeded grass might not have fully germinated at that time. In the second inspection six months later, the planted grass might have fully germinated and grow longer, forming a rather green and satisfactory vegetation cover. This may probably explain the significant difference between the vegetation cover recorded in the two inspections. On the other hand, since the slope is still too young, only few species have been naturally established on the slope. Therefore, both H and S are quite low.

F.3.5.2 Engineering Assessment

Slope C42 was inspected in May 2003 for the engineering assessment. The gradient of the slope is about 40°. There was no sign of weakening in strength of the mats. Surface erosions were noticed extensively on the slope of more than 30% of slope area. The eroded soil had been washed down and deposited at the slope toe and at berm levels (Plate 21a). The eroded materials were partly derived from the insitu soil of the slope and partly from the granular soil fill which was placed to fill into the mat. The holes sizes of the mat were big (approximately 12 mm by 18 mm), and as such the mat may not be effective in protecting the soil surface from the erosive forces of raindrop impact and surface runoff (Plate 21b).

Table of Contents
Table of Contents
Table of Contents
Table of Contents

F.3.6 Tensarmat/EM4

It is a 3-D mat made of polyethylene. Figure 24 shows the anchorage details of the mat.

F.3.6.1 Vegetation Assessment

Two slopes in this study, namely 7SE-D/C13 and C53, were treated with Tensarmat/EM4 as their sole erosion protection measure on the slope surface. Both slopes were planted with grass species and creepers and/or climbers (Table F1). The percentage cover of planted creepers/climbers was found to have increased in the second inspection while that of the planted grass was almost zero (Table F1). This shows that the creepers *Wedelia trilobata* and the climber *Parthenocissus dalziellii* have started to overgrow the planted grass species. Also these two slopes are quite old among all the surveyed slopes and the regeneration of the natural vegetation on the slopes proceeds very well.

The vegetation communities of these two slopes are very diverse as reflected by the high H and S values (Table F1). These naturally generated speceies consists of a large number of native species. This shows that if the conditions are favourable and time is allowed, native species can naturally establish on artificial slopes covered with erosion control mat. Those planted species on the slopes will be eventually displaced by the increasingly dense and diverse native plants.

F.3.6.2 Engineering Assessment

The two slopes C13 and C53 were inspected for engineering assessment. The average slope angles for the slopes are 60° and 50° respectively. There was no sign of weakening in the strength of the mats on the two slopes. The mats on both slopes were securely pegged and were in close contact with the soil surface in general. Minor erosion occurred locally at about two locations on Slope C13 (Plate 22a). On slope C53, erosion was noted, locally at about four locations, but each occurrence was noted to be in a larger extent than those on slope C13 (Plate 22b).

F.4 LONG-TERM NON-DEGRADABLE EROSION CONTROL MATS WITH STEEL WIRE MESH

F.4.1 General

A few kinds of long-term non-degradable erosion control mats were used in conjunction with steel wire mesh. They are normally used at steep slopes where the non-degradable erosion control mats and vegetation alone cannot provide sufficient erosion control. Findings of the assessment on the non-degradable erosion control mats with steel wire mesh are discussed below.

Table of Contents
Table of Contents
Table of Contents
Table of Contents

F.4.2 Enkamat and Steel Wire Mesh

Figure 25 shows the installation details of the mat with the wire mesh. It also shows the view of a slope installed with the system.

F.4.2.1 Vegetation Assessment

Two slopes, 3SE-D/C74 and C75, in the study use both Enkamat and steel wire mesh as erosion control measures. Vegetation on slope C74 was not surveyed in the second inspection because hydroseeding work was in progress. The data collected at first inspection on slope C74 should therefore be discarded as any further data collected cannot be interpreted due to the re-planting work between the surveys. Both the percentage cover of exposed planted grass and total vegetation of slope C75 decreased (Table F1). Likewise, the healthy vegetation cover was also found decreased in both cases. These show that the vegetation of this slope has become less good after the winter season. The species diversity of slope C75 is almost the same in the two inspections.

F.4.2.2 Engineering Assessment

Both slopes C74 and C75 standing at about 60° were inspected for engineering assessment. A steel wire mesh was installed on top of Enkamat. No sign of weakening in strength of the mats was noted on the 2 slopes. The wire mesh and the mats were generally conformed to soil surface. Minor surface erosion was found at various localized areas as indicated in Plate 23a. The eroded soil shown in Plate 23b was noted to be trapped by the erosion control mat and the wire mesh. The trapped material acted like a protective layer to minimize further erosion.

F.4.3 Miramat TM8 and Steel Wire Mesh

Figure 26 shows the installation details of the mat with the wire mesh.

F.4.3.1 Vegetation Assessment

A slope no 3SE-D/C118 in this study uses both Miramat TM8 and steel wire mesh as erosion control measures. The slope was planted with grass and climber. It had a rather low percentage cover in both exposed planted species (<30%) and overall exposed vegetation (<40%) in the first inspection. The percentage cover for healthy vegetation was even lower. The results were found to have deteriorated over the winter at the second inspection, with the percentage cover in both exposed planted species and the overall exposed vegetation recorded as only about 23% and 30% respectively. High values of the species richness and diversity index were recorded.

Table of Contents
Table of Contents
Table of Contents
Table of Contents

F.4.3.2 Engineering Assessment

Slope C118 was inspected in March 2004 for engineering assessment. No sign of weakening in strength of the mats was noted. The wire mesh and the mat were both anchored securely on the slope and were in close contact with the slope. No major sign of erosion was noted on the slope.

F.4.4 Multimat and Steel Wire Mesh

Figure 27 shows the installation details of the mat with the wire mesh.

F.4.4.1 Vegetation Assessment

There is one slope no. 6SE-C/C28 that uses both Multimat and steel wire mesh for erosion control purpose. The slope was planted with grass. Comparing the vegetation growth between the two inspections, the percentage cover of planted species recorded as "healthy" generally increased in the second inspection (Table F1). The total vegetation cover also shows a similar trend. This indicates that the overall vegetation on the slope looked more "green" and grew better in spring at the second inspection. The exposed percentage cover of the planted grass decreased in the second inspection, whereas the total exposed vegetation cover had increased. This simply implies that the planted grass is being taken over by the naturally established vegetation on the slopes.

The species richness and diversity index did not change much in the second inspection on the slope, suggesting that the plant species were more or less the same in the two inspections. Slope C28 was found to support a very high species diversity (Table F1).

F.4.4.2 Engineering Assessment

The slope C28 was inspected in March 2004 for engineering assessment. No sign of weakening in strength of the mats was noted. The steel wire mesh and mat were anchored securely on the slope and and were in good contact with the soil surface, except at local areas at the slope toe (Plate 24). No apparent sign of erosion was noted on the slope.

F.4.5 Tensarmat/EM4 and Steel Wire Mesh

Figure 28 shows the anchorage details of the mat and the wire mesh.

F.4.5.1 Vegetation Assessment

Four slopes in this study, namely no. 7NW-B/C13, 8SW-B/C74, 11SW-C/C82 and C98, were treated with both Tensarmat/EM4 and steel wire mesh for erosion control. They were all planted with grass species. Two of the slopes also had creepers and/or climbers planted on them (Table F1). The percentage cover of exposed vegetation was found increased or

Table of Contents
Table of Contents
Table of Contents
Table of Contents

remained more or less the same in the second inspection while that of the planted grass was found generally decreased. This shows that the planted grass species on these slopes have been gradually replaced by the naturally established vegetation. The vegetation communities on slope C74 are very diverse and consist of a large number of native species. This shows that if the conditions are favourable and time is allowed, native species can naturally establish on artificial slopes covered with erosion control mat. Those planted species on the slopes will be eventually displaced by the increasingly dense and diverse native plants.

The overall vegetation cover of slopes treated with Tensarmat/EM4 is satisfactory. Except one slope (11SW-C/C82) which has rather low total exposed vegetation cover (~50%), all the other three slopes have more than 61% total exposed vegetation cover. The species diversity of the slopes treated with Tensarmat/EM4 is also quite high (except slope 7NW- B/C13) when comparing with slopes treated with other types of erosion control products. These suggest that Tensarmat/EM4 is a rather good erosion control product and is able to support diverse naturally established plant communities. The natural vegetation established on these slopes can also achieve long-term sustainability as they are able to grow deep in the soil layer of the slope without the interception of a concrete surface.

F.4.5.2 Engineering Assessment

Two slopes no. 8SW-B/C74 and 11SW-C/C82 were inspected for engineering assessment. The average slope angles for slopes C74 and C82 are 60° and 50° respectively. The mat on slope C74 had lost strength and become brittle, illustrating that it might not be adequately ultra violet stabilized. Minor erosion occurred on Slope C74 and the eroded soil was trapped by the mat and the wire mesh (Plate 25a). There was no sign of weakening in the strength of the mats nor sign of erosion on the other slope (Plate 25b). The mats were noted to have conformed to the soil surface and securely pegged on both slopes.

Table of Contents
Table of Contents
Table of Contents
Table of Contents

LIST OF TABLES

Table of Contents
Table of Contents
Table of Contents

Table F1 - Vegetation Coverage of Slopes using Group 2 Techniques in the Inspections (after Leung and Hau, 2004a) (Sheet 1 of 2)

Group 2 Techniques used	Slope number	% planted grass cover						% planted creepers/ climbers/ herbs cover						% total vegetation cover						Shannon diversity index, H			Species richness, S		
		Exposed			Healthy			Exposed			Healthy			Exposed			Healthy								
		1st Inspection	2nd Inspection	3rd Inspection	1st Inspection	2nd Inspection	3rd Inspection	1st Inspection	2nd Inspection	3rd Inspection	1st Inspection	2nd Inspection	3rd Inspection	1st Inspection	2nd Inspection	3rd Inspection	1st Inspection	2nd Inspection	3rd Inspection	1st Inspection	2nd Inspection	3rd Inspection	1st Inspection	2nd Inspection	3rd Inspection
Soil Guard	11NW-D/C403		14.83%	22.92%		14.83%	18.34%								14.98%	36.589%		14.98%	32.00%		1.7987	1.3488		7	11
Coir	11NW-D/FR40	91.29%	88.69%		62.04%	89.11%								91.96%	91.28%		62.71%	91.70%		0.4634	1.0200		3	4	
Soil Saver	6SE-D/C212	53.14%	50.23%		12.76%	31.96%		11.68%	16.89%		11.68%	16.89%		69.52%	74.80%		29.14%	56.53%		1.6977	1.5508		6	5	
Enkamat	11NW-D/FR50	94.47%	74.42%		50.00%	81.97%								94.47%	94.47%		50.00%	102.02%		0.6931	1.0397		2	3	
Kangaroo Mat	3NE-C/C159	20.68%	6.43%		6.12%	5.17%								60.23%	56.68%		50.95%	59.64%		2.6607	2.7111		21	22	
	11NW-A/C159	1.82%	1.02%		1.82%	0.00%								85.54%	78.10%		84.76%	77.12%		1.0114	0.5623		3	2	
Miramat TM8	7SW-C/C180	73.96%	67.91%		73.11%	67.75%								73.96%	69.21%		73.11%	69.05%		2.1526	2.1974		11	12	
	7SW-C/C181	54.99%	57.38%		35.64%	47.01%								69.52%	72.59%		49.98%	62.21%		1.3624	1.5111		5	6	
	7SW-D/C22	3.74%	4.25%		3.46%	3.54%		41.22%	31.10%		41.22%	36.77%		63.32%	62.30%		62.76%	67.69%		1.2997	1.4515		5	6	
	11NW-B/C90	92.92%	78.64%		30.20%	27.25%								93.86%	92.91%		31.14%	41.52%		0.0000	0.5004		1	2	
Multimat	7SE-C/C42	73.12%	85.24%		14.16%	82.53%								73.12%	89.26%		14.16%	86.55%		0.6390	0.6390		3	3	
Tensarmat/EM4	7SE-D/C13	0.83%	0.00%		0.46%	0.00%		13.99%	25.35%		17.18%	43.42%		83.46%	94.32%		96.32%	124.24%		2.4819	2.4714		35	35	
	7SE-D/C53	3.43%	0.87%		1.35%	1.19%		26.11%	42.75%		32.02%	53.18%		77.29%	94.73%		84.89%	117.94%		3.1787	3.1619		43	42	
Enkamat with steel wire mesh	3SE-D/C74	15.07%	N.A.		3.43%	N.A.								18.61%	N.A.		6.97%	N.A.		2.1383	N.A.		9	N.A.	
	3SE-D/C75	60.68%	51.66%		24.33%	14.19%								67.75%	59.61%		31.18%	22.14%		2.1137	2.1501		11	11	
Miramat TM8 with steel wire mesh	3SE-D/C118	27.41%	23.34%		15.25%	12.88%		3.34%	1.20%		3.34%	1.20%		37.11%	30.58%		24.95%	20.12%		2.0385	2.1808		14	17	
Multimat with steel wire mesh	6SE-C/C28	33.35%	22.25%		15.38%	16.99%								85.85%	86.62%		67.74%	84.66%		1.8390	1.9738		24	23	

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Table F1 - Vegetation Coverage of Slopes using Group 2 Techniques in the Inspections (after Leung and Hau, 2004a) (Sheet 2 of 2)

Group 2 Techniques used	Slope number	% planted grass cover						% planted creepers/ climbers/ herbs cover						% total vegetation cover						Shannon diversity index, H			Species richness, S		
		Exposed			Healthy			Exposed			Healthy			Exposed			Healthy								
		1st Inspection	2nd Inspection	3rd Inspection	1st Inspection	2nd Inspection	3rd Inspection	1st Inspection	2nd Inspection	3rd Inspection	1st Inspection	2nd Inspection	3rd Inspection	1st Inspection	2nd Inspection	3rd Inspection	1st Inspection	2nd Inspection	3rd Inspection	1st Inspection	2nd Inspection	3rd Inspection	1st Inspection	2nd Inspection	3rd Inspection
Tensarmat/EM4 with steel wire mesh	7NW-B/C13	42.50%	68.58%		6.18%	68.35%								45.42%	71.65%		9.10%	71.42%		0.0000	0.0000		1	1	
	8SW-B/C74	85.27%	79.82%		47.67%	22.77%								85.75%	84.73%		48.15%	27.63%		2.4408	2.6929		21	23	
Tensarmat/EM4 with steel wire mesh	11SW-C/C82	27.06%	19.45%		12.62%	12.14%		0.00%	0.04%		0.00%	0.04%		63.93%	53.95%		44.02%	41.93%		1.2310	1.4596		12	14	
	11SW-C/C98	21.47%	4.89%		15.88%	1.90%		8.22%	6.95%		8.22%	7.53%		41.82%	61.32%		36.24%	58.83%		1.0393	1.1391		9	11	

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Table of Contents
Table of Contents
Table of Contents
Table of Contents

APPENDIX G

DISCUSSION ON RAIN-INDUCED EROSION AND CLASSIFICATION OF ROLLED EROSION CONTROL MATS

Rain-induced Erosion

Rainfall causes erosion of exposed soil in two ways. These are (a) soil detachment by impact of raindrops and waterdrops falling from vegetation, and (b) transportation of soil particles by runoff.

Soil detachment by raindrop impact is related to various properties of the rain such as sizes, momentum and kinetic energy of rain drops and intensity of rainstorm. If vegetation is present, vegetation canopy can change the mass of rainfall reaching the ground, its drop size distribution and its local intensity (Styczen & Morgan (1995), Yan (2000)).

When raindrops strike the vegetation, they are shattered into small droplets. Large drops are formed by coalescence of raindrops on the leaf before they fall to the ground. Concentration of water from leaf drip points can result in very high localised rainfall intensities, many times greater than the intensity received at the canopy. The large water drops pick up large momentum before they pound onto the ground. This translates into significant erosive power.

Many studies have shown that soil loss ratio relating to soil detachment by raindrop impact decreases with increasing percentage canopy cover. The soil loss ratio is the ratio of soil loss when vegetation is present to the amount loss on a bare soil. As the height of the canopy cover above the ground increases, the relationship becomes linear. Where large water drops are formed by combining raindrops on the leaves, and the canopy is 1 m or more above the ground, the soil loss ratios increase with increasing percentage cover (see Figure 29). This highlights an important point that in order to obtain maximum soil protection from vegetation, the vegetation canopy should be either close to or in contact with the soil surface (Styczen & Morgan (1995), Morgan & Rickson (1995)).

Surface runoff is generated when the amount of rainfall exceeds infiltration. Water flowing on a bare soil surface entrains and transports soil particles already detached and may also detach additional particles if the flow velocities are high. Flow transport capacity and detachment by flow are related to energy-spending processes within the flow at the interface between the flowing water and the soil (Styczen & Morgan, 1995). Surface roughness is an important parameter controlling the speed of the generated runoff.

Classification of Rolled Erosion Control Mats

Erosion control mats affect soil erosion processes through protection of soil and modifications in runoff volume and velocity. Some mats have a high surface cover to prevent the raindrops from impacting onto the soil. This simulates canopy interception and storage effect of vegetation. They also prevent the run-off water from gathering sufficient velocity to detach the soil particles and carry them away. Rolled erosion control mats can be classified into two primary categories (ECTC, 2003):

(a) temporary degradable, and

(b) long-term non-degradable.

Table of Contents
Table of Contents
Table of Contents
Table of Contents

The temporary erosion control products are intended to hold soil and seed until vegetation becomes established after which they biodegrade or photodegrade. The use of such products is generally limited on moderate slopes with relatively low flow velocities, where vegetation alone can provide long-term erosion control. The long-term erosion control products are intended to remain intact to control erosion even in the absence of vegetation. For these products, degradation of the mat materials constitutes failure of the product (Rustorm and Weggel, 1993). Such products are generally used on steep slopes where vegetation alone cannot provide erosion control. These mats are manufactured in 3-dimensonal matrices that help retain and entangle soils and plant roots together to form a unified 'living mat' which keeps erosion to a tolerable level (Lancaster and Austin (1994), Rickson (1995)).

In the present study, the proprietary products, Coir and Soil Saver, can be taken as temporary degradable erosion control mats. The other products including Enkamat, Kangaroo Mat, Miramat, Multimat and Tensarmat are long-term non-degradable mats.

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Table of Contents
Table of Contents
Table of Contents
Table of Contents

APPENDIX H

LPM PARTICULAR SPECIFICATIONS FOR EROSION CONTROL MATS (EXTRACTED FROM CONTRACT NO. GE/2002/01)

Non-biodegradable mats for erosion control

Non-biodegradable mats for erosion control shall be woven and ultraviolet stabilized mats with the following properties or products having equivalent functions or performance as approved by the Engineer:

Material Type	Tensile Strength (kN/m)	Minimum average mat thickness (mm)	Minimum average weight (g/sq. m.)
Polyamide	2.0 (DIN 53857)	20	410
Polyethylene	3.2 (BS6909, Part I)	18	430
Polypropylene	7.0 (ASTM D4595)	12.5	430
Composite Polypropylene or Polyethylene	2.0 (DIN EN ISO 10319)	20	600

The mats must be produced by proprietary manufacturers and specifically designed for the erosion control of sloping ground.

The colour of the mats shall be BS 5252F:1976 colour code 08B27 or 10B25 or other colour as directed or approved by the Engineer.

Biodegradable mats for erosion control

Biodegradable mats for erosion control be woven coir or jute mats complying with the following requirements or products having equivalent functions or performance as approved by the Engineer:

Material Type	Minimum average mat thickness (mm)	Minimum average weight (g/sq. m.)
Natural coir	5	400, 740 or 900
Natural jute fibre	5	500, 750 or 1000

The mats must be produced by proprietary manufacturers and specifically designed for the erosion control of sloping ground.

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Table of Contents

Table of Contents

APPENDIX I

STANDARD SPECIFICATIONS FOR
EROSION CONTROL MATS RECOMMENDED BY ECTC

Table of Contents

Table of Contents

Table I1 - ECTC Standard Specification For Temporary Rolled Erosion Control Products (ECTC, 2003)

For use where natural vegetation alone will provide permanent erosion protection

Type	Product Description	Material Composition	Slope Applications*		Channel Applications*	Minimum Tensile Strength[1]
ULTRA SHORT-TERM - Typical 3 month functional longevity						
Type	Product Description	Material Composition	Maximum Gradient	C Factor[2, 5]	Permissible Shear Stresss[3, 4, 6]	Minimum Tensile Strength[1]
1.A	Mulch Control Nets	A photodegradable synthetic mesh or woven biodegradable natural fiber netting.	5:1 (H:V)	≤ 0.10 @ 5:1	= 0.25 lbs/ft^2 (12 Pa)	5 lbs/ft (0.073 kN/m)
1.B	Netless Rolled Erosion Control Blankets	Natural and/or polymer fibers mechanically interlocked and/or chemically adhered together to form a RECP.	4:1 (H:V)	≤ 0.10 @ 4:1	= 0.5 lbs/ft^2 (24 Pa)	5 lbs/ft (0.073 kN/m)
1.C	Single-net Erosion Control Blankets & Open Weave Textiles	Processed degradable natural and/or polymer fibers mechanically bound together by a single rapidly degrading, synthetic or natural fiber netting or an open weave textile of processed rapidly degrading natural or polymer yarns or twines woven into a continuous matrix.	3:1 (H:V)	≤ 0.15 @ 3:1	= 1.5 lbs/ft^2 (72 Pa)	50 lbs/ft (0.73 kN/m)
1.D	Double-net Erosion Control Blankets	Processed degradable natural and/or polymer fibers mechanically bound together between two rapidly degrading, synthetic or natural fiber nettings.	2:1 (H:V)	≤ 0.20 @ 2:1	= 1.75 lbs/ft^2 (84 Pa)	75 lbs/ft (1.09 kN/m)
SHORT-TERM - Typical 12 month functional longevity						
Type	Product Description	Material Composition	Maximum Gradient	C Factor[2, 5]	Permissible Shear Stresss[3, 4, 6]	Minimum Tensile Strength[1]
2.A	Mulch Control Nets	A photodegradable synthetic mesh or woven biodegradable natural fiber netting.	5:1 (H:V)	≤ 0.10 @ 5:1	= 0.25 lbs/ft^2 (12 Pa)	5 lbs/ft (0.073 Kn/m)
2.B	Netless Rolled Erosion Control Blankets	Natural and/or polymer fibers mechanically interlocked and/or chemically adhered together to form a RECP.	4:1 (H:V)	≤ 0.10 @ 4:1	= 0.5 lbs/ft^2 (24 Pa)	5 lbs/ft (0.073 Kn/m)
2.C	Single-net Erosion Control Blankets & Open Weave Textiles	An erosion control blanket composed of processed degradable natural or polymer fibers mechanically bound together by a single degradable synthetic or natural fiber netting to form a continuous matrix or an open weave textile composed of processed degradable natural or polymer yarns or twines woven into a continuous matrix.	3:1 (H:V)	≤ 0.15 @ 3:1	= 1.5 lbs/ft^2 (72 Pa)	50 lbs/ft (0.73 Kn/m)
2.D	Double-net Erosion Control Blankets	Processed degradable natural and/or polymer fibers mechanically bound together between two degradable, synthetic or natural fiber nettings.	2:1 (H:V)	≤ 0.20 @ 2:1	= 1.75 lbs/ft^2 (84 Pa)	75 lbs/ft (1.09 Kn/m)
EXTENDED-TERM – Typical 24 month functional longevity						
Type	Product Description	Material Composition	Maximum Gradient	C Factor[2, 5]	Permissible Shear Stresss[3, 4, 6]	Minimum Tensile Strength[1]
3.A	Mulch Control Nets	A slow degrading synthetic mesh or woven natural fiber netting.	5:1 (H:V)	≤ 0.10 @ 5:1	= 0.25 lbs/ft^2 (12 Pa)	5 lbs/ft (0.073 Kn/m)
3.B	Erosion Control Blankets & Open Weave Textiles	An erosion control blanket composed of processed slow degrading natural or polymer fibers mechanically bound together between two slow degrading synthetic or natural fiber nettings to form a continuous matrix or an open weave textile composed of processed slow degrading natural or polymer yarns or twines woven into a continuous matrix.	1.5:1 (H:V)	≤ 0.25 @ 1.5:1	= 2.00 lbs/ft^2(96 Pa)	100 lbs/ft (1.45 Kn/m)
LONG-TERM – Typical 36 month functional longevity						
Type	Product Description	Material Composition	Maximum Gradient	C Factor[2, 5]	Permissible Shear Stresss[3, 4, 6]	Minimum Tensile Strength[1]
4	Erosion Control Blankets & Open Weave Textiles	An erosion control blanket composed of processed slow degrading natural or polymer fibers mechanically bound together between two slow degrading synthetic or natural fiber nettings to form a continuous matrix or an open weave textile composed of processed slow degrading natural or polymer yarns or twines woven into a continuous matrix.	1:1 (H:V)	≤ 0.25 @ 1:1	= 2.25 lbs/ft^2 (108 Pa)	125 lbs/ft (1.82 kN/m)

Notes:

(*) "C" factor and shear stress for Types 1.A., 2.A. and 3.A mulch control nettings must be obtained with netting used in conjunction with pre-applied mulch material.

(1) Minimum Average Roll Values when tested in the machine direction using ECTC Modified ASTM D 5035.

(2) "C" Factor calculated as ratio of soil loss from RECP protected slope (tested at specified or greater gradient, h:v) to ratio of soil loss from unprotected (control) plot in large-scale testing.These performance test values should be supported by periodic bench scale testing under similar test conditions using ECTC Test Method # 2.

(3) Minimumshear stress RECP(unvegetated) can sustain without physical damage or excess erosion [> 12.7 mm(0.5 in) soil loss] during a 30-minute flow event in large-scale testing. These performance test values should be supported by periodic bench scale testing under similar test conditions and failure criteria using ECTC Test Method #3.

(4) The permissible shear stress levels established for each performance category are based on historical experience with products characterized by Manning's roughness coeffecients in the range of 0.01 - 0.05.

(5) Acceptable large-scale test methods may include ASTM D6459 or other independent testing deemed acceptable by the engineer.

(6) Acceptable large-scale testing protocol may include ASTM D6460 or other independent testing deemed acceptable by the engineer.

Table of Contents Table of Contents Table of Contents Table of Contents

Table I2 - ECTC Standard Specification For Permanent Rolled Erosion Control Products (ECTC, 2003)

For applications in channels and on slopes not exceeding 0.5:1 (H:V) where vegetation alone will not sustain expected flow conditions and/or provide sufficient long-term erosion protection

Type[1]	Product Description	Material Composition	Minimum Tensile Strength[2,3]	Minimum Thickness (ASTM D 6525)	UV Stability (ASTM D 4355 @ 500 Hours)	Channel Applications Permissible Shear Stress[4, 5]
5.A	Turf Reinforcement Mat	Long term, non-degradable rolled erosion control product composed of UV stabilized, non-degradable, synthetic fibers, filaments, nettings and/or wire mesh processed into three dimensional reinforcement matrices designed for permanent and critical hydraulic applications where design discharges exert velocities and shear stresses that exceed the limits of mature, natural vegetation. Turf reinforcement mats provide sufficient thickness, strength and void space to permit soil filling and/or retention and the development of vegetation within the matrix.	125 lbs/ft (1.82 kN/m)	0.25 inches (6.35 mm)	80%	= 6.0 lbs/ft^2(288 Pa)
5.B	Turf Reinforcement Mat		150 lbs/ft (2.19 kN/m)	0.25 inches (6.35 mm)	80%	= 8.0 lbs/ft^2 (384 Pa)
5.C	Turf Reinforcement Mat		175 lbs/ft (2.55 kN/m)	0.25 inches (6.35 mm)	80%	= 10.0 lbs/ft^2 (480 Pa)

Notes:
(1) For TRMs containing degradable components, all property values must be obtained on the non-degradable portion of the matting alone.
(2) Minimum Average Roll Values, machine direction only for tensile strength determination using ASTM D6818 (Supercedes Mod. ASTM D5035 for RECPs)
(3) Field conditions with high loading and/or high survivability requirements may warrant the use of a TRM with a tensile strength of 44 kN/m (3,000 lb/ft) or greater.
(4) Shear stress that fully vegetated TRM can sustain without physical damage or excess erosion [> 12.7 mm (0.5 in.) soil loss] during a 30-minute flow event in large scale testing.
(5) Acceptable large-scale testing protocol may include ASTM D6460 or other independent testing deemed acceptable by the engineer.

Table of Contents
Table of Contents
Table of Contents
Table of Contents

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.

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。

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

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

<u>or</u>

- 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

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):

<u>書面訂購</u>
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

<u>或</u>

- 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，網址爲 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)

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

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

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

<u>For Geological Survey Sheet Reports and maps which are free of charge:</u>
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: jsewell@cedd.gov.hk

<u>For other publications which are free of charge</u>:
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

如欲索取地質調查報告、其他免費刊物及地質圖，請致函：

<u>地質調查報告及地質圖</u>:
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: jsewell@cedd.gov.hk

<u>其他免費刊物</u>:
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

Table of Contents
Table of Contents
Table of Contents
Table of Contents

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. 1/2000	Technical Guidelines on Landscape Treatment and Bio-engineering for Man-made Slopes and Retaining Walls (2000), 146 p.
GEO Publication No. 1/2006	Foundation Design and Construction (2006), 376 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

Table of Contents
Table of Contents
Table of Contents