

**GEO Technical Guidance Note No. 20 (TGN 20)
Updating of GEO Publication No. 1/2000 - Technical Guidelines on
Landscape Treatment and Bio-engineering for Man-made Slopes and
Retaining Walls**

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1. **SCOPE**

- 1.1 This Technical Guidance Note (TGN) supplements the guidelines given in GEO Publication No. 1/2000 - Technical Guidelines on Landscape Treatment and Bio-engineering for Man-made Slopes and Retaining Walls (GEO, 2000) in respect of the use of new greening techniques and selection of suitable vegetation species for use on man-made slopes as well as cost-effectiveness of landscape treatment.
- 1.2 Any feedback on this TGN should be referred to Chief Geotechnical Engineer/Standards and Testing of the GEO.

2. **TECHNICAL POLICY**

- 2.1 The technical recommendations promulgated in this TGN were agreed by GEO's Geotechnical Control Conference (GCC) on 29th July 2004.

3. **RELATED DOCUMENTS**

- 3.1 *CEDD Standard Drawings No. C2511/1B and C2511/2C.* Civil Engineering and Development Department, Hong Kong.
- 3.2 Choi, K.C. & Chau, R.Y.H. (2004). *Identification of Suitable Vegetation Species for Use on Man-made Slopes (GEO Special Project Report No. SPR 7/2004).* Geotechnical Engineering Office, Hong Kong, 108 p.
- 3.3 GEO (2000). *Technical Guidelines on Landscape Treatment and Bio-engineering for Man-made Slopes and Retaining Walls (GEO Publication No. 1/2000).* Geotechnical Engineering Office, Hong Kong, 146 p.
- 3.4 Lui, B.L.S. & Shiu, Y.K. (2006). *Performance Assessment of Greening Techniques on Slopes (GEO Report No. 183).* Geotechnical Engineering Office, Hong Kong, 201 p.

4. **BACKGROUND**

- 4.1 The guidelines contained in this TGN are based on the findings of a study entitled "Performance Assessment of Greening Techniques and Vegetation Species on Slopes" and the results of a planting trial at Yuen Tun in Tai Lam Country Park (Lui & Shiu, 2006; Choi & Chau, 2004), as well as experience of the LPM Branch on measures to achieve cost-effectiveness of landscape treatment.

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5. **TECHNICAL RECOMMENDATIONS**

5.1 **Classification of Greening Techniques**

5.1.1 A number of new greening techniques have been used or tried on man-made slopes since the late 1990s. These techniques cover a wide variety of proprietary products. The techniques can be broadly classified into the following two groups:

- (a) Group 1 Techniques: Products that are applied on slopes with a hard surface cover, and
- (b) Group 2 Techniques: Products that are used directly on an exposed soil slope surface.

5.1.2 Proprietary products under the Group 1 Techniques can further be sub-divided into four types according to their general characteristics:

- (a) Mulching System. The proprietary products generally involve applying one or more layers of mulch or soil mix onto the slope surface. The mulch/soil mixes vary in type, composition and additives among different products. They generally have little tensile, compressive and shear strength. Some products use a layer of steel wire mesh and/or one or more layers of erosion control mats to strengthen the mulch/soil mixes.
- (b) Cellular System. The proprietary products generally contain compartments or panels of soil mix or mulch installed on the slope face. In some products, the soil mix/mulch are embedded into the slope, exposing the top surface for planting purposes.
- (c) Reinforced Soil. The proprietary product involves spraying soil mix on slope face and applying continuous synthetic fiber to the soil mix at the same time. The soil mix is reinforced by the fiber.
- (d) Bio-engineering Method. The method involves direct planting of vegetation, e.g. *Vetiveria zizanioides* (Vetiver Grass, 香根草), in closely spaced planter holes formed on the hard slope cover.

5.1.3 Products under the Group 2 Techniques can be sub-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.

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5.2 Group 1 Greening Techniques

- 5.2.1 Different proprietary products use different material and methods of construction. Some products perform relatively better than others under certain circumstances. In selecting which products or techniques to be used, factors such as cost-effectiveness, long-term performance of the products, special characteristics of the slope, the surrounding environment and the future maintenance requirement should be considered.
- 5.2.2 **Mulching System** - Most of the products can be applied on uneven slope profiles to form smooth finished surfaces. They are therefore particularly suitable for slopes with an irregular surface, e.g. a cut slope with many exposed corestones. In some products, the soil mixes/mulches are weak in strength and liable to cracking. They rely on steel mesh or erosion control mats to hold them in place. Surface cracks associated with desiccation and downslope movement of the mulch/soil mixes has been observed on some slopes.
- 5.2.3 **Cellular System** - Some products allow vegetation to be established at nursery areas before the panels of soil mix are installed on the slope face. They can therefore provide an instant greening effect to the slopes. However, the small isolated panels of soil mix may dry up and result in unhealthy plant growth with time. Without a dense vegetation cover, the wire mesh forming the gabions for the product are visible and can be unsightly. The panel thickness may limit their use on slopes with limited space in front of the slopes.
- 5.2.4 **Reinforced Soil** - The use of soil reinforcement permits a thicker layer of soil mix to be constructed on steep slopes. The thicker planting medium can support the growth of woody vegetation such as shrubs and small trees more successfully. This, however, may limit their use on slopes with limited space in front of the slopes.
- 5.2.5 If products of the above three types of techniques (mulching system, cellular system and reinforced soil) are used, the following measures are recommended to enhance the stability of the planting medium:
- (a) For products of the mulching system, support in the form of a layer of PVC coated steel wire mesh should be provided to the surface of the mulch/soil mix. The mesh should be slightly stretched to ensure close contact with the surface of soil/mulch. For slopes with an uneven profile and where installation of the wire mesh is difficult, vertical and horizontal bracing in the form of small diameter steel bars should be provided to increase the overall strength of the mulch/soil mix.
 - (b) For products without erosion control mats to protect the mulch/soil mix, suitable type of erosion control mat should be provided. Long-term non-degradable mats should be used for longer-term protection.

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- (c) Edges of mulch/soil mix should be separated from any stepped channel by a distance of at least 500mm to reduce the likelihood of erosion by splashing of water from the channel. In addition, edges of mulch/soil mix should be fully protected from surface erosion by erosion control mats wrapped around them.
- (d) Concrete kerb or planter wall should be provided as far as practicable to support the toe of the mulch/soil mix layers and to avoid downslope movement of the mulch/soil mix.

5.2.6 Bio-engineering Method - This technique allows direct planting of vegetation into the soil underneath the hard slope cover. Depending on the condition of the soil, more water and nutrients can be available for the vegetation than the other products which are applied on top of the slope cover. Vegetation with long roots may help to enhance the stability condition of the surface soil but this beneficial effect is difficult to quantify. Some vegetation species, e.g. *Vetiveria zizanioides*, require regular cropping in order to provide space for new growth. This needs to be considered in the maintenance operation of the slope. The hard slope cover will be exposed after each cropping, leading to temporary visual impact.

5.3 **Group 2 Greening Techniques**

5.3.1 Temporary degradable erosion control mats are usually made of natural material. They are intended to hold the soil and seeds until vegetation becomes established before the mats biodegrade or photodegrade. The use of such products should generally be limited to moderate slopes (slope angle less than 35°) with relatively low surface water flow velocities, where vegetation alone can provide long-term erosion control.

5.3.2 Long-term non-degradable erosion mats are usually made of synthetic material designed to provide long-term erosion protection. They are generally manufactured in three-dimensional matrices that help retain and entangle soil and plant roots together to form a “living” layer. Such products are particularly suitable for use on steep slopes (slope angle greater than 35°) where vegetation alone cannot provide sufficient erosion protection.

5.3.3 For both degradable and non-degradable erosion mats, the manufacturer’s recommended installation practice should be followed. To prevent water from flowing below the mat and causing surface erosion, the mats should be securely fastened to ensure close contact with the soil surface.

5.3.4 Use of non-degradable erosion control mats in conjunction with steel wire mesh provides a more effective means of controlling surface erosion. If erosion occurs, the debris is trapped between the wire mesh and the slope surface. This acts as a protective layer to prevent further erosion from happening. Construction details for erosion control mat and steel wire mesh are given in CEDD Standard Drawings No. C2511/1B and C2511/2C.

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- 5.3.5 The Group 2 Techniques allow planting of vegetation directly on the soil surface of a slope. Compared with the Group 1 Techniques, they can support the sustained growth of a greater 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 about the slope.
- 5.4 **Suitable Vegetation Species for Use on Slopes**
- 5.4.1 For Group 1 Techniques, most of the products only have a thin layer of planting medium (less than 100 mm) and so they cannot support large woody vegetation (such as trees and large shrubs) in terms of supply of water and nutrients and anchorage of roots. Smaller plants, such as small shrubs, climbers, ferns, and other herbaceous plants in addition to grass, are preferred in the products of Group 1 Techniques.
- 5.4.2 For soil slopes other than those using Group 1 Techniques, the plant roots can have direct contact with the soil of the slopes which provides a thicker planting medium for better supply of water and nutrients and stronger root anchorage. Both large woody vegetation and small herbaceous plants are suitable for use, depending on the gradient of the slope concerned. Generally, planting of trees on slopes with gradient greater than 45° is not recommended for safety reasons.
- 5.4.3 Certain exotic tree species can quickly develop into plantations, forming dense canopies over the slopes. Although these exotic species are generally more effective than the native species in providing an initial vegetation cover, their ecological value and sustainability are of great concern because they cannot reproduce naturally in Hong Kong and their dense canopies inhibit the growth of native species and hence natural succession of the slope vegetation covers. There is also a risk of wholesale loss of slope vegetation cover as the trees in the plantations comprising only these few exotic species may reach maturity and hence die in the same period. In view of these drawbacks, the extensive use of these exotic tree species should be adopted with care.
- 5.4.4 For ecological enhancement, more self-regenerating species, in particular the native species of strong pioneer character, should be introduced into the vegetation mixes. Native species can provide habitats for birds and insects. They can also enhance biodiversity, natural succession, and sustainability of slope vegetation covers. For soil slopes other than those using Group 1 Techniques, planting of the native species listed in Annex TGN 20 A1 can be considered. These species, which have been proven to be successful and reliable as planned vegetation and are generally easy to produce in nurseries in large quantities, are suitable for general use in greening slopes, preferably by means of pit planting directly on soil slope surfaces. In addition, as most of them provide fleshy fruit resources for seed dispersers, they can be particularly used on slopes where there are no existing mature, native trees to attract seed dispersers for increasing seed input for natural regeneration of slope vegetation or where the slopes are highly isolated from natural seed sources. The species in Annex TGN 20 A1

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supplement the suggested vegetation species mixes and the lists of vegetation species given in Appendices G and H of GEO Publication No. 1/2000 respectively.

- 5.4.5 The herbaceous species, *Wedelia trilobata* (Wedelia, 三裂葉蟛蜞菊), is a hardy climber species. It tends to dominate the slope vegetation cover due to its invasive characteristic, which often results in monotonous appearance of the vegetation cover. While this species is effective in greening slopes and thus can be used on slopes with a harsh environment where other vegetation species generally do not perform well, its use in agricultural areas and along wetland marshes, streams, canals, mangrove edges and coastal areas should be avoided, because it is known to be particularly invasive in such habitats.

5.5 Cost Effectiveness of Landscape Treatment on Slopes

- 5.5.1 In addition to the design considerations discussed in Section 3.2 of GEO Publication No. 1/2000, cost effectiveness of landscape treatment should be considered when preparing landscape designs on slope works. The following recommendations should be noted:

- (a) The use of proprietary greening products should be carefully considered with reference to the need and the factors as suggested in Section 5.2.1 above.
- (b) Masonry facing should not be used indiscriminately as it may not bring about visual enhancement, especially where its use is incompatible with the scale involved or the landscape character of the surroundings. Moreover, it should be noted that masonry facings on walls may also have the potential problem of detachment owing to trapping of water behind the facings. Alternatives such as patterned concrete finish on walls and pigmented shotcrete on slopes with hard surface may be considered.
- (c) Toe planters should not be provided as a routine. Consideration should be given to their cost-effectiveness in enhancing visual amenity of the areas concerned. For example, in situations where the slopes are obscured by structures and hence not visually sensitive, toe planters may be omitted.

6. ANNEX

- 6.1 TGN 20 A1 - Proposed Native Vegetation Species for Use in Greening Slopes.

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Proposed Native Vegetation Species for Use in Greening Slopes¹

Botanical Name	Common Name	Chinese Name	Growth Habit ⁶
<i>Ardisia crenata</i> ^{2,4,5}	Hilo Holly	硃砂根	Shrub
<i>Bridelia tomentosa</i> ^{3,4}	Pop-gun Seed	土蜜樹	Shrub or small tree
<i>Gordonia axillaries</i> ^{2,3,4}	Hong Kong Gordonia	大頭茶	Shrub or small tree
<i>Litsea rotundifolia</i> var. <i>oblongifolia</i> ^{2,4}	Oblong-leaved Litsea	豺皮樟	Shrub
<i>Mallotus paniculatus</i> ^{3,4}	Turn-in-the-wind	白楸	Medium tree
<i>Melastoma sanguineum</i> ^{3,4}	Blood-red Melastoma	毛椴	Shrub
<i>Melicope pteleifolia</i> ^{2,4}	Thin Evodia	三椴苦	Shrub or small tree
<i>Microcos nervosa</i> ⁴	Microcos	破布葉	Medium tree
<i>Psychotria asiatica</i> ^{2,3,4,5}	Wild Coffee	九節	Shrub or small tree
<i>Raphiolepis indica</i> ^{2,3,4}	Hong Kong Hawthorn	車輪梅	Shrub or small tree
<i>Rhodomyrtus tomentosa</i> ^{3,4}	Rose Myrtle	桃金娘	Shrub
<i>Schefflera heptaphylla</i> ^{2,3,4}	Ivy Tree	鴨腳木	Shrub or small tree
<i>Sterculia lanceolata</i> ^{3,4}	Scarlet Sterculia	假蘋婆	Large tree
<i>Zanthoxylum avicennae</i> ^{2,4}	Prickly Ash	籐欖	Shrub or small tree

Notes:

1. Planting of medium or large tree species on slopes with gradient greater than 45° is not recommended for safety reason.
2. Species planted in the planting trial at Yuen Tun, Tai Lam Country Park.
3. Species commonly planted in natural hillside afforestation projects.
4. Species bearing flowers, fruits, and/or seeds that are attractive to wildlife.
5. Shade-tolerant species that can be used particularly on heavily-shaded slopes.
6. Tree species are classified for convenience into the following groups according to their normal sizes in the wild -
Large tree = Tree with a normal height greater than 10 m and with a large crown.
Medium tree = Tree with a normal height much greater than 3 m but with a small crown.
Small tree = Tree with a normal height around 3 m.

**Geotechnical Engineering Office, Civil Engineering and Development Department
The Government of the Hong Kong Special Administrative Region**

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