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Erosion control for sustainable highway and urban constructions in Southeast Asia

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ABSTRACT: Southeast Asia is a region with tropical natural beauty. Its unique climate, eco-diversity and the rapidly developing economy have been attracting steady development and investment in industries, agriculture and property development. The direct consequences of these rapid developments are the population growth, rapid urban development and increased traffic flow. To cater for these increases in urbanization and traffic flow, the federal government & privatize concessionaires in Malaysia have undertaken to build new roadways and widen existing roads. In Singapore, the construction of modern highways into new regional centres, as well as increased density of urban construction within the developed housing estates forced the engineers to build nearer to the existing slopes and green areas. Erosion control of such urban construction has become an important design and construction consideration in this part of the world. Soil erosion is difficult to control in the tropics due to complexity in climatic and geologic conditions. The problem is exacerbated with high rainfall and hilly terrain. Malaysian and Singaporean top soils typically consist of very erodible residual soils, laterite soils or highly-weathered rocks. Construction practices often results in steep "cuts & fill" embankments, striping of localize vegetation-shrubs and heavy earth movements with total disregards to environmental considerations. This paper presents modern erosion control products coupled with geosynthetics reinforced bioengineering technique to "heal scarped" slopes or roadside cuts for sustainable development in tropical urban environment. Three case histories on slope rehabilitation & vegetation at various locations in Malaysia and Singapore were presented, and exemplifying sustainable construction best management practices can be achieved via these geosynthetics reinforced bioengineering techniques. This paper also presents a large scale physical model study on the efficiency of erosion control measures. The results seem to imply that the relationship between the "soil lost" over rainfall duration (T) is not linear, and suitable Erosion Control Mattress ECM may be used to effectively limit the "soil lost".

1 INTRODUCTION

Erosion control for Highway and Urban Construction activities has much in common with most development activities in the tropics. This paper describes the various principles affecting the erosion problem in this region, and discusses a number of case histories using biotechnical stabilization coupled with modern geosynthetics reinforcement products. The ultimate aim is to rehabilitate slopes for sustainable vegetation and development.

Figure 1 shows examples of some urban and road side construction with serious erosion and sediment concerns. The principle elements of erosion and sediment problem in tropical areas can be characterized as follows (Fifield, 2004):

1. Environmental Factor: High humidity and high temperature (15-30°C) affecting vegetation growth. Vegetation and shrub canopy is quintessential to sustainable slope stability.
2. Climate Factors: Hydrologic Cycle of the highlands pertaining to rainfall, runoff, storage and evaporation are critical to erosion. Being in the equatorial rain forest belt, precipitation of 2200 to 3800 mm per annum characterizes by high intensity and short duration resulting in high peak flow impacting slopes, and thus causing downstream flooding, especially during the monsoon period.
3. Soil and Geological Factors: The top soils in this region consist of typically residual soil of sedimentary and granitic rock origin with high

percentage of clay contents. These soils are very susceptible to erosion process. Roads and highway developments typically call for very steep "cut and fill" embankments altering the already steep natural topography and thereby contributing to extreme eroded rills and gullies resulting in localized failures during construction.

Figure 1. Examples of urban road side construction with serious erosion and sediment concerns

In Malaysia and Singapore, the typical solutions for the stabilization of steep slope embankments include "soil nailing & rock anchors" with "cement grouting and rubble pitching" for surface treatment against erosion and water infiltration. This paper presents a "green" solution using the combination of bioengineering erosion control measures coupled with geosynthetics soil reinforcement techniques to stabilize steep slope embankments and re-vegetation for sustainable solutions. Case histories are presented. This paper also presents a large scale physical model study on the efficiency of erosion control of various Erosion Control Mattress.

2 CASE STUDIES

2.1 *Case study 1: Cameron Highlands, Malaysia*

This is a highway widening project by Public Roads Department, Malaysia, from Brinchang to Tringkep, Cameron Highlands. The total length of the project is about 15km long. This project location is situated within a prime bird and wildlife's habitats, with many indigenous flora and fauna, watershed and drainage basins, tea plantations, and "Orang Asli" settlements. It was therefore critical to maintain "green" environment not only during the construction stage but also for long term sustainability against erosion and soil lose.

Hydro-seeding the slopes to establish vegetation as an erosion control measure failed as the seeds were generally "washed-off slopes" during the rain. Alternative solution of using jute netting together with hydro-seeding was tried. However the wider apertures on the netting provided little seed and nutrient retention during heavy downpours. It was also noted that germination did not survive sufficiently long for the growth and establishment of root system.

A final workable solution involved the establishment of dense vegetative cover to reduce the eroding impact by hydro-seeding the slope with the aid of a layer of dense fibrous erosion control mattress (ECM). Several ECMs were investigated for its suitability using large scale physical testing facilities in National University of Singapore, and it was found that the ECM must have sufficient fiber density. This erosion control mattress (ECM) was designed to address the key technical needs on increased impact resistance to rain drop, increased abrasion resistance with high roughness thus reducing surface runoff flow velocity, improved moisture retention for better germination and growth, provide root reinforcement, and better filtration performance (Gray and Sotir, 1996).

A look at slope at several locations on this project after 2+ years into the service, as shown in Figure 2, clearly showed that the initial hydro-seeded grass has been replaced by local indigenous plant species and this vegetation is sustainable with a gradual establishment of vegetation canopy. This indicates that the bioengineering technique used has given the local slower growing indigenous plants a chance to establish on a steeper slopes.

Figure 2. The environmental friendliness of the slope 2 years later

2.2 *Case study 2: Sustainable "green" geotextile reinforced slope at Kedah*

At Kedah, a reinforced soil structure comprised of a 12.5m high slope with an inclination of 1H: 5V with vegetation facing was built as part of new North-South Highway development. The slope must be designed to blend with the surrounding greenery

(Figure 3 and 4). The nature of the residual soil with high clay content and heavy tropical rain prevalent in this area necessitated that the geosynthetic reinforcement used be capable of undertaking both the drainage and reinforcement function and have a high soil-fabric interface friction. The geotextile used is a composite of nonwoven geotextile and high tenacity polyester reinforcing yarns. Its high in-plane drainage property allows quick dissipation of pore water pressure during the lifetime of the structure and increases the structure stability (Fabian and Fourie, 1986; and Chew et al., 1998).

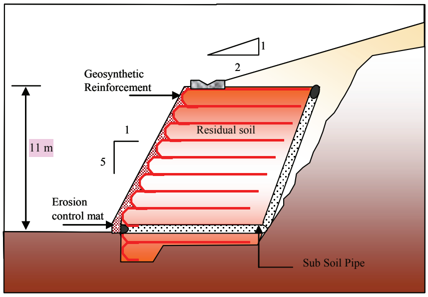

Figure 3. Cross section of reinforced soil slope, Kedah

The unique feature of this slope is that the slope facing, a geosynthetics wrap around system, was designed to incorporate an erosion control mat. Erosion control mat using coconut fibre of mass > 400 g/m^2 with soil munching was laid, overlapping the front part of geosynthetics reinforcement, during the construction of wrapping around facing with the aid of removable formwork. The performance of this slope was excellent with no sign of any significant movement and with no significant soil lost during monsoon period.

Figure 4. Wrap around reinforcement facing with coconut fibre ECM.

3 LARGE SCALE PHYSICAL MODEL

Physical model testing with rainfall simulators in the laboratory environment have been an essential tool in soil erosion research (Koerner et al., 1992). The objective of this part of research is to evaluate the efficiency of the proposed ECM. The specific measurements in this series of test are (1) the amount of soil loss under simulated rainfall of appropriate design intensities over design rainfall duration, and (2) the effectiveness of proposed ECM in terms of reducing "soil lost".

A large scale physical model testing facility was developed in the Hydraulics Engineering Laboratory of the National University of Singapore. The model setup, as shown in Figure 5, consists of the following three components:

(a) Rainfall Simulator - The rainfall simulator is a 2m long pipe consisting of 15 nozzles at every 100mm interval, attached to a beam with rollers, and connected to a water pump. This rainfall simulator can be moved over the entire surface of the slope at specific speed and cycle. Thus, the entire slope of 2m x 2.5m will be showered with simulated rainwater.

(b) Filter and Retention Facility - This is located about 4m away from the toe of the slope. The geotextile filter serves to retain the "lost soil" from the slope under designed rainfall configuration.

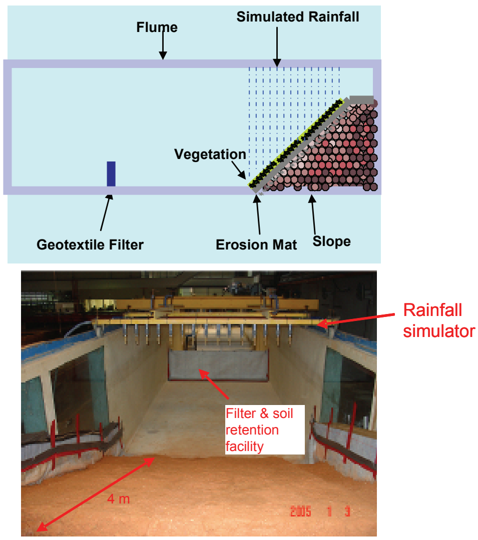

Figure 5. Large scale physical model for erosion control study in NUS

(c) Sloping Ground with or without ECM - The soil collected for the project site was compacted to the in-situ density to make up the model slope. The proposed ECM was laid on top of the slope with vegetation grown.

A series of test was carried out to determine the effect of erosion on the slope with and without erosion control measures. Figure 6 illustrates the "soil lost" for three products with different fiber density with the bare slope results as the benchmark at one particular designed rainfall (15 minutes duration and 500 mm/hr intensity). It can be seen that all three products seems to be very effective in reducing the "soil lost". The products 2, 3 and 4 are all the same ECMs with fiber density (mass of fibers per unit surface area) of 400 g/m^2, 270 g/m^2 and 320 g/m^2 respectively. It is observed that the amount of "soil lost" is proportional to the density of ECM products, if the same type of fiber was used.

The amount of "soil lost" can be converted into the suspended solid content of the runoff flow as shown in Table 1. It can be shown that only ECM with 400 g/m^2 will be able to reduce the solid content to about 50 ppm (part per million), which is the limit set by government authority for urban environment for long term sustainable development.

As shown in Table 1, the results seem to imply that the relationship between the "soil lost" over rainfall duration (T) is not linear. Also, the rate of soil loss after 15 minutes of rainfall was found to be slower than the rate of soil loss within the first 15 minutes. This decrease in the rate of soil loss over time could be due to that the surface loose soil may have eroded within the first few minutes.

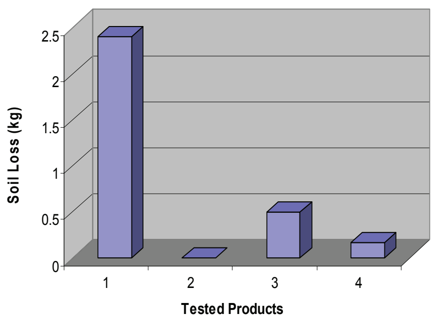

Figure 6. Comparison of the "soil lost" for various ECM tested.

Table 1. Result of soil loss in terms of ppm

T (min)	Intensity (mm/hr)	Soil Loss (ppm)			
		Bare Slope	ECM 1	ECM 2	ECM 3
Fiber Mass/area (g/m^2)			270	400	320
15	300	3048	610	-	-
	500	2743	571	80	183
30	300	2667	486	-	-
	500	2286	446	51	114

4 CONCLUSION

Soil erosion is difficult to control in the tropics due to complexity in climatic and geologic conditions. The problem is exacerbated with high rainfall and hilly terrain with very erodible residual soils or laterite soils as top soil. Highway development in Southeast Asia often results in steep "cuts & fill" embankments, striping of localize vegetation-shrubs and heavy earth movements with total disregards to environmental considerations. Modern erosion control products coupled with geosynthetics reinforced bioengineering technique can be used to provide good management practice for sustainable development in tropical urban environment. Laboratory physical model tests with rainfall simulation were conducted to verify the suitable of ECMs products under local conditions.

REFERENCES

Chew, S.H., Tan, S.A., Loke, K.H., Delmas, P. and Ho, C.T. (1998). "Large Scale Pullout Test of Geotextile in Poor Draining Soils", 6th International Conf. On Geosynthetics, Atlanta, USA, Vol. 2, 25- 29 March 1998, p. 821 – 824.

Fabian, K.J., and Fourie, A.B., (1986). "Clay-geotextile interaction in large retaining wall models". Geotextile and Geomembrane 7, p. 179 – 201.

Fifield, J.S. (2004), "Erosion, Sediment and Sedimentation", Designing for Effective Sediment and Erosion Control on Construction Sites, Forrester Press.

Gray, D.H., and R.B. Sotir (1996). Biotechnical and Soil Bioengineering Slope Stabilization. John Wiley & Sons.

Koerner, R.M., Weggel, J.R. and Rustom, R. (1992). "Soil Erosion by Rainfall and Runoff – State of the Art", Geosynthetics in Filtration, Drainage and Erosion Control, Elsevier Applied Science, London & New York. pp. 215-236.