Case Study: The use of geo-materials for erosion and sediment control

In Malaysia, early research on bio-engineering involved studies on plant selection for the re-vegetation of cut slopes along highways. Research in 2000–01 involved gully erosion control and vegetation establishment on degraded slopes. These techniques have incorporated the coppicing abilities of cut stems and the soil-binding properties of roots into civil designs, to strengthen the ground and to control erosion. Bio-engineering designs have great potential and application in Malaysia because in deforested upland sites landslides are common, particularly during the wetter months between November and January. Post-landslide restoration works involving conventional civil designs are costly and sometimes not practical at remote sites. Due to cost constraints, the remoteness of the sites and low risk to lives and property, bio-engineering was the option taken for erosion control, slope stabilisation and vegetation establishment.

⇨

The study took place at Fraser's Hill, in the state of Pahang, Malaysia. The area receives 20–410 millimetres of rainfall each month. The temperature is moderate, ranging from 18 to 22 °C annually, with high humidity, ranging from 85 to 95 per cent every month. The surrounding vegetation is lower montane forest.

Two study plots were chosen, and a control plot. Initial works involved soil nailing, using 300 live stakes of *angsana* tree branches and 200 cut stems of *ubi kayu*. Subsequently, major groundworks involved the installation of **geo-structures** (structures constructed from **geo-materials** such as bamboo and brush bundles, coir rolls and straw wattles). The volume of sediment trapped by the geo-structures was measured every two weeks, while plant species that were established on the retained sediments and on geo-materials were identified. The number of live stakes that produced shoots and roots was also recorded. Ten 1 metre-tall saplings of *Toona sinensis*, a fast-growing tree species, were planted at the toe of the slope for long-term stability.

The first slope failure was caused by seepage of drainage water into the cut slope of the access road. The total area affected by the landslide was about 0.25 hectare. Two large trees, 4–5 metres tall, were uprooted and ground vegetation and debris were washed downhill, preventing road access. The second and more extensive failure was located uphill and was a rotational failure. It covered an area of about 0.75 hectare. The landslide was probably triggered by seepage of water from a badly damaged toe drain beside the road.

Bio-engineering design: After six months

The bio-engineering designs involved the installation of 11 bamboo bundles ('faschines') and 16 brush bundles along rills and gullies. At suitable sites along contours, 10 coir rolls and 5 straw wattles were installed, using live stakes and steel wiring. Lighter geo-materials such as straw wattles and brush faschines were positioned on the upper slope face, while heavier geo-materials such as coir rolls were positioned lower down.

At the end of six months, the situation at each study site was assessed (Table 9.17).

Table 9.17 Selected geo-materials and total volume of sediment retained over six months at the two study sites

Geo-materials	Total sediment retained m^3	Total number of migrant species
Bamboo faschine	1.7	14
Brush faschine	1.0	17
Coir roll	2.2	20
Straw wattle	0.2	26
Total sediment retained by different geo-materials	**5.1**	–
Total number of migrant species	–	**77**

Live stakes and *Toona sinensis* saplings

At the end of six months, the live stakes had become living trees. A high percentage of *angsana* stakes (93 per cent) sprouted shoots and roots after a month, and 75 per cent of *ubi kayu* stems sprouted leaves within a week. Thus, live stakes were effective in stabilising unstable slopes.

Vegetation cover on slopes helped reduce soil erosion because shoots helped reduce the intensity of raindrops falling on the exposed soil. Furthermore, root-reinforced soils functioned like micro-soil nails to increase the shear strength of surface soils.

Slope stability

The indicator poles at both study sites moved less than 8°, unlike the indicator poles from the control plot, which moved about 20°. Without erosion-control measures, there was aggressive soil erosion during heavy downpours, which caused scouring of the steep slope below the tarred road and resulted in an overhang of the road shoulder.

Trapped sediments and vegetation establishment

A total of 57 geo-structures retained 5.1 m^3 of sediment after six months. The retained sediments and decomposing geo-materials also trapped moisture and provided ideal conditions for the germination of incoming seeds. After six months, it was found that 77 plant species were established.

After one year

A year after the study was first implemented, about 75 per cent of one study site was covered by vegetation, while 90 per cent of the second plot was re-vegetated. There was no more incidence of landslide at these two plots. However, at the control plot there was further soil erosion, which resulted in further undercutting of the slope face.

At the control plot, after one year, only seven plant species were present. These were weeds. The poor vegetation cover was probably due to unstable soil conditions caused by frequent soil erosion and minor landslides. It is believed that vegetation cover can provide a layer of roots beneath the soil layer and this contributes additional shear strength to the soil and slope stability.

The geo-structures were installed at a cost of about US$3078, which was cheaper than restoration works using conventional civil structures such as rock gabions, which cost about US$20 000. As the site is quite remote, higher transportation and labour costs would have contributed to the higher cost of constructing a rock gabion at this site. On the other hand, the geo-materials that are abundantly available locally are relatively cheap to make or purchase, and this contributed to the low project cost. The geo-structures were non-polluting, required minimal post-installation maintenance, were visually attractive and could support greater biodiversity within the restored habitats. The geo-materials used in this project, such as faschines, coir rolls and straw wattles, biodegrade after about a year and become organic fertilisers for the newly established vegetation.

After 18 months, the restored cut slopes were almost covered by vegetation, and there was no further incident of landslides. The geo-structures installed on site were cost-effective and visually attractive. The restored cut slopes were more stable and supported higher biological diversity.

Assessment of costs

The geo-structures cost approximately $3000 to install. In contrast, a rock gabion would have cost about $20 000 to install (as the area is remote, transport costs would increase, and there would be increased emissions of greenhouse gases). Moreover, the geo-structures were visually attractive, could support biodiversity, were locally available, and took just two weeks to install. In terms of a cost-benefit analysis, therefore, the geo-structure has a great deal to offer.