Field performance of vegetated flapped soil-bag retaining structure along a stream bank

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ABSTRACT

A flapped soil-bag have been designed such that the connection between adjacent bags is enhanced by the friction force imposed on its flaps due to the surcharge weight from overlying and adjacent bags. This paper investigated the performance of flapped soil bags with gabion and geotextile toe walls used to stabilize a stream bank (5m high and 45° gradient) in Lablae district, Uttaradit province of Northern Thailand. By horizontally placing live stakes of various species along connections between adjacent soil bags, the riveting effects of the soil bag would improve with time as live stake rooted deep down and provided anchoring effect. Survival rate of the installed live stake was satisfactory when placed horizontally between the soil bags. The movement vector also showed that the bags with gabion toe wall moved the least, as compared to geotextile toe wall, and appeared to be mainly in vertical direction suggesting that it was perhaps due to only settlement of the fill during the first year and less of the horizontal translation of the wall.

Keywords: flapped soil-bags; stream bank erosion; bio-slope engineering

1 INTRODUCTION

Various bio-engineering techniques have been developed and used in practice to prevent erosion and slope stability for geotechnical structures, embankment, stream bank, etc (Gray and Sotir, 1996). These methods normally combine different vegetation's covers, such as vetiver grass, live stakes, erosion control blanket, with some forms of retaining structures, namely gabion wall, geotextile bag or soil bags. This approach has recently received a considerable attention amongst researchers and practitioners owing to its relatively low-cost, environmental and ecological values, sustainability and aesthetics.

To improve the friction resistance between the soil bag interfaces, a flapped soil-bag have been developed in Thailand (PTTGC, 2007). The connection between adjacent bags is enhanced by the friction force imposed on its flaps due to the surcharge weight from overlying and adjacent bags. Made of high density polyethylene (HDPE) material with UV resistant additives, the bag material was expected to be of 15 years design life. Jotisankasa et al., (2017) conducted full-scale pullout friction tests on the flapped soil bags filled with uniform sand, finding the friction angle of the flapped soilbags to be 57.4 degree, almost three times the value of non-flapped soilbags.

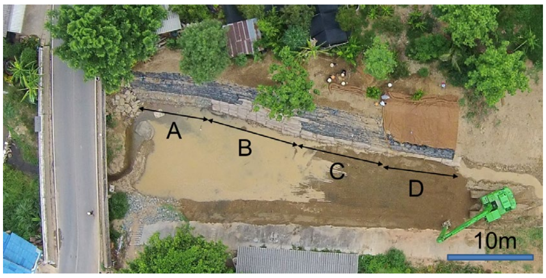

Fig. 1. Bird's-eye view of the test bio-engineered stream bank (after construction in 2015)

In the current study, various kinds of bio-engineering techniques, including flapped soil-bags, gabion and geotextile toe walls, and soil-erosion control blanket, were constructed along a stream bank (5m high and 45° gradient) in Lablae district, Uttaradit province of Northern Thailand. Four plots (A, B, C and D), each of about 10 m long, were constructed in 2015 (Fig. 1) and the monitoring of crest movement, live stake survival rate, and root growth with time over 1.5 years have been carried out and reported in this paper to shed some lights on the performance of these bio-engineering techniques for stream bank stabilization.

2 BIOENGINEERED RETAINING WALL

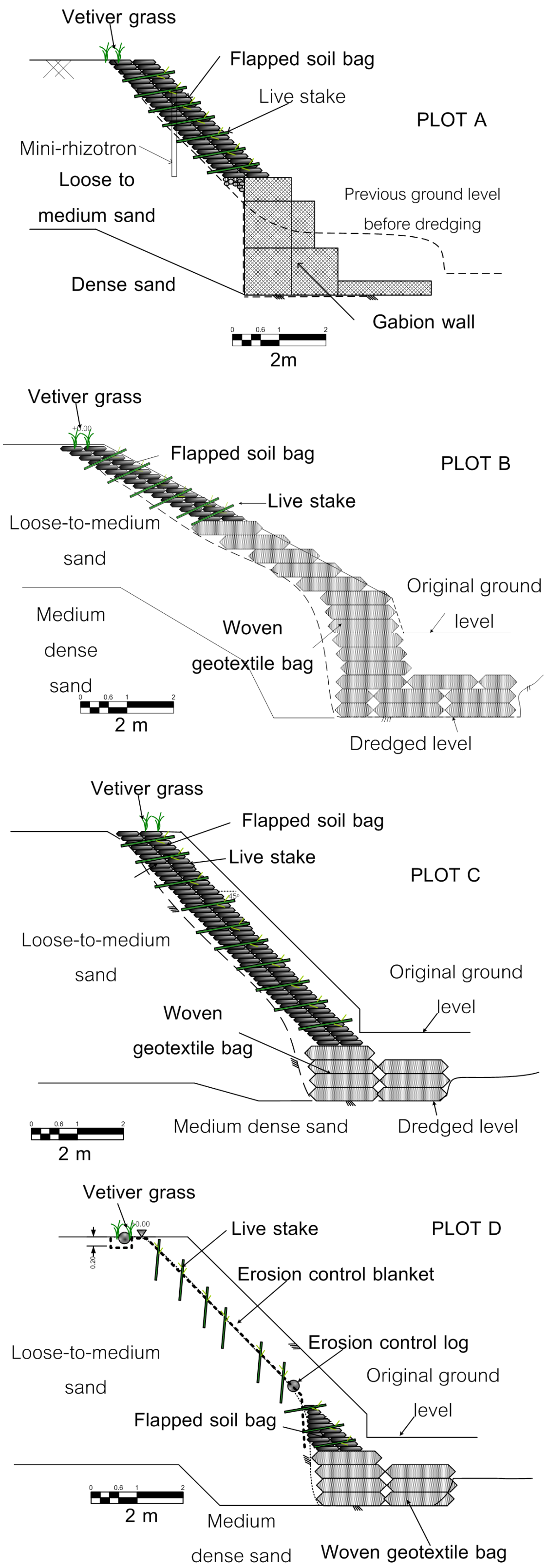

Fig. 2. Schematic cross-sections of the bio-stabilization test plots

2.1 Test plots

The test plots are located on the stream bank near the Chang-moob bridge pier in Mae-poon sub-district, Laplae district, Uttaradit province in Northern Thailand. Prior to the stabilization work, the stream suffered from sediment problem caused by landslide and debris flow event in 2006 (Jotisankasa and Tapparnich, 2010) as well as bank erosion in the following years. In order to demonstrate an environmentally friendly solution to stream bank stabilization and dredging work in the area, the Chaipattana Foundation, PTTGC and various organizations have supported the bio-stabilization works along the selected part of the stream bank. Four test plots (each of 10 m length) were designed and constructed as shown in Figure 2.

The soil profile was shown in Figure 2 as characterized using the light-weight dynamic cone penetration test, or so-called Kunzelstab Penetration test (KPT) at the crest and base of each plot. This test involves dropping a 10 kg weight, with a falling height of 0.5 m, on a 25mm diameter 60º cone attached to 20 mm diameter rod. The number of KPT blow counts was recorded for each 20cm penetration. The loose-to-medium sand layer was characterized as those with KPT counts between 6 to 55, while the dense layer was with KPT greater than 55 counts. Table 1 summarizes the sand properties. The sand sediment in the stream was dredged using back-hoe excavator down to this medium dense layer which was also selected as the foundation level of the wall. The dredged sand was used to fill the soil bags used to stabilize the stream bank to provide a sustainable solution to disposal of the dredged material.

Table 1. Basic properties of the sand

Properties	Value
% sand particles	88 %
% silt particles	8 %
% clay particles	4 %
pH	7.2 (Neutral)
%Organic content	0.11% (very low)
Phosphorus, P	15 mg/g (medium)
Potassium, K	25 mg/g (very low)
Calcium, Ca	665 mg/g (High)
Magnesium, Mg	120 mg/g (High)
Salinity, ECe	0.38 dS/m (non-saline)

Plot A involved gabion wall at the toe, overlain by flapped soil bags. The flapped soil bag's dimension is shown in Figure 3. The connection between bags is enhanced by the friction force imposed on its flaps due to the surcharge weight from overlying and adjacent bags. In this study, live stake (0.8 to 1m long and 18-25cm in diameter) of various species were placed horizontally between each flapped soil bag at spacing of about 0.5 m as shown in Figure 4. The species of live stakes used at the test slope included *Bougainvillea, Erythrina subumbrans*, *Salix tetrasperma*, *Spondias pinnata*. The lower end of the live stake was cut sharply and laid down to touch the soil behind the soil bags so that root could grow out of the live stake end and act as living soil nails.

Plots B and C involved sand-filled woven geotextile bags (GB400m type with 1.4m×2.5m size) at the toe, overlain by vegetated flapped soil bags to rivet the slope surface. The only difference between the two plots was that Plot B's geotextile toe wall was of a greater height than Plot C (Fig. 2). Plot D was of the smallest toe wall consisting of geotextile bags and flapped soil bag. The slope surface of Plot D was covered with erosion control blanket (ECB) made of HDPE net with coconut and palm fibers. Ruzi grass (*Brachiaria ruziziensis*) was planted by sprinkling its seeds underneath the ECB. Live stakes were also installed as pins to fix the ECB in place with about 0.5m spacing.

Several instruments were installed on the slopes to monitor the behaviour in the long term, including transparent mini-rhizotron tubes, standpipe, and settlement plate near the slope crest.

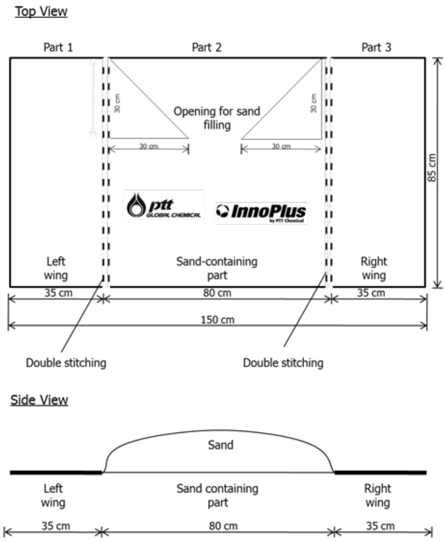

Fig. 3. Flapped plastic sack used in this study

Fig. 4. Placement of flapped soil bag with live stake

2.2 Plant and root growth observation

The survival rate of the live stakes species was monitored for the first two months after installation as shown in Figure 5. The survival rate was calculated as the number of live stake which showed a sign of growth (i.e. budding leaves) divided by the total number of live stake of that particular species. Generally, about 20 to 30% of the live stake installed survived for Plots A, B and C and it took about one month for the live stake to fully show the sign of growth. Interestingly, significantly less percentage of live stakes installed with the ECB in Plot D didn't survive. This could be due to several reasons. Firstly, species of live stakes used for each plot were not exactly the same and direct comparison of survival rate between plots may not be unbiased. Yet, importantly, the live stakes were installed in Plot D at a later stage than in other plots (A, B and C) and thus the growing quality of live stakes became poor as the stakes may have lost the growing ability with time. Also, the stake was tamped into slope in Plot D, as opposed to gentle placement in between the bags as in other plots, and hence the tamping action could have damaged the stakes.

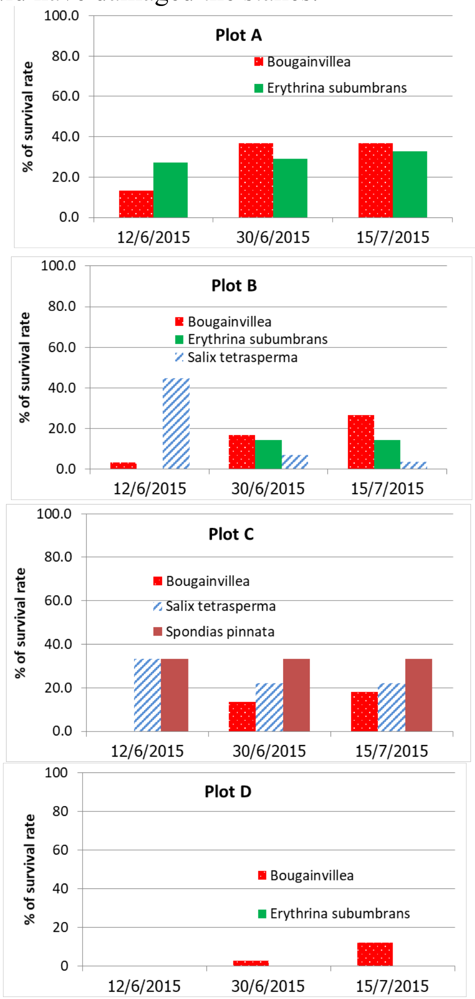

Fig. 5. Survival rates of live stake for each plot

Figure 6 shows the appearance of the test plots at different stages; i.e. before the construction (Jan 2015), immediately after construction (June 2016), 8 months (Feb 2016), 1 year and 4 months (Oct 2016) and 2 years and 5 months (Nov 2016). It can be seen that 8 months after the construction, the aesthetic value of bio-engineered wall was clearly improved and the flapped bags were almost fully covered by the vegetation which contribute to further protection of the bags from UV rays. After one year, vegetation on the flapped soil bag started to change into local species and bio-diversity was evident after two years (Nov 2016). In general, the ecological restoration of the stream bank was considered significantly improved in the long term.

Fig. 6. Appearance of the vegetation cover of the test plots over time

2.4 Crest movement

The surface movement of the plot crest was observed by means of total station survey. The benchmark stationery control points were located on the nearby bridge and the movement were measured relative to the bridge pier.

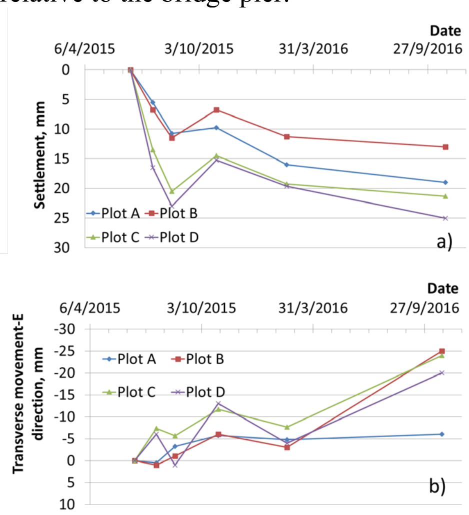

Fig. 7. Movement vector at the crest of four test plots

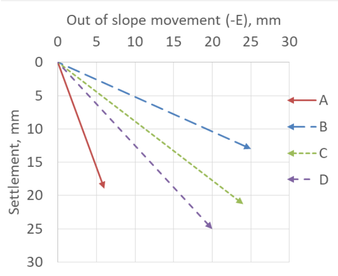

Fig. 8. Movement vector at the crest of four test plots

As shown in Figure 7, the settlements were largest during the first two months (June to August 2015) corresponding to the first wetting collapse of the fill after placement. The movement of Plot A during the 1.5 year was also the least amongst all plots especially in the lateral direction. The movement vector (Fig. 8) also showed that movement of Plot A was mainly in vertical direction suggesting that it was perhaps due to only settlement of the fill during the first year and less of the horizontal translation of the wall. This difference in movement between the plots is understandable and to be expected given the greater rigidity of the gabion toe wall as compared to other geotextile toe walls.

3 CONCLUSION

Live stakes have been used successfully together with flapped soil bags to provide the riveting effects of the soil bag which would improve with time. Survival rate of the installed live stake was satisfactory when placed horizontally between the soil bags. The movement of the bags over gabion wall was the least, as compared to geotextile toe wall.

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