INVESTIGATION OF WATER HYACINTH WOVEN LIMITED LIFE GEOTEXTILES (LLGS) AND APPLICATIONS

S. Artidteang[1], D.T. Bergado[2], S. Chaiyaput[3] and J. Saowapakpiboon[4]
[1]Doctoral Candidate, School of Engineering and Technology, Asian Institute of Technology, Thailand;
Tel: +66-2 524 5523; Email: kwangce@gmail.com,
[2]Professor, School of Engineering and Technology, Asian Institute of Technology, Thailand;
Tel: +66-2 524 5512; Email: bergado@ait.ac.th
[3]Research Assistant, School of Engineering and Technology, Asian Institute of Technology, Thailand;
Tel: +66-2 524 5523; Email: salisa.fern@gmail.com
[4]Civil Engineer, Bureau of Standards and Evaluation, Department of Highways, Thailand;
Tel: +66-2 524 5523; Email: jtrsnum@gmail.com

ABSTRACT

Natural fiber can be modified to woven geotextile which is an innovative method of growing vegetation and is designed for slope protection. Thailand has highly abundant natural fibers and rural communities capable of converting them into handicrafts. The water hyacinth yarns were fabricated to woven geotextile called limited life geotextiles to help stabilize the slope and improved the growth of vegetation for erosion control in geotechnical application. The study was aimed to access the effectiveness of the new material for geotextile made from water hyacinth to control soil erosion in a representative slope at different plots of tests. The erosion control test was performed by using the artificial rainfall. The flow rates of water runoff and amount of soil loss were investigated. Consequently, the limited life geosynthetics made from water hyacinth LLGs combined with Ruzi grass can reduce the flow rate of runoff and amount of soil loss. This study confirms that the water hyacinth LLGs can be used for erosion control in geotechnical applications.

Keywords: Geosynthetics, geotextile, erosion, natural fiber

INTRODUCTION

In the recent years, the intensity of torrential rainfall and its subsequent destructive influencing on human community has become severe and unpredictable due to climate change including global warming. Soil erosion is a worldwide problem that washes away fertile farmlands, slopes of roadway cuts and embankments, produces undesirable deposits in rivers and reservoirs, and at a larger scale result to landslides (Kothyari, 1996 and Thakur, 1996).

In tropical countries like Thailand, precipitation is high and erosion by water is the dominant driving force based reported cases. Protection of soil surfaces especially of slopes is needed. To protect the soil surface from erosion, it should be protected from direct contact with erosive forces. Plant cover helps protect the soil surface and provide supplemental soil stability (Morgan, 2005).

Natural fiber can be modified to woven geotextile which is an innovative method of growing vegetation and is designed for slope protection. Thailand has highly abundant natural fibers and rural communities capable of converting them into handicrafts. Water hyacinth is a free floating aquatic weed originated in the Amazon in South America. Due to its fast growth and the robustness of its seed, the water hyacinth has since then caused major problems in the whole area. It can also cause practical problems for marine transportation, fishing, hydropower generation and irrigation.

Methacanon et al., 2010 have investigated the possibility of developing good performance woven geotextiles made of the studied natural fibers; sisal, roselle, reed, or water hyacinth. Tensile strength of dry sisal, roselle was significantly higher than that of reed and water hyacinth, while elongation of all studied fibers with exception of water hyacinth was not significantly different (see Fig. 1).

Moreover, it is interesting to note that when the fibers are wet, their tensile strength and elongation increase. Their moisture absorption and thermal property were also investigated as shown in Figs. 2 and 3, respectively. Water hyacinth, it is worth to study ability, lower cost and higher water absorption.

Artidteang et al. 2011 have been investigated the tensile strength of water hyacinth woven LLGs. The plain pattern had the highest tensile strength, followed by hexagonal and knot-plain, respectively, as shown in Fig. 4. In this study, the water hyacinth yarn was selected due to their availability and economically in Thailand. The water hyacinth yarns were fabricated to woven geotextile called limited life geotextiles to help stabilize the slope and improved the growth of vegetation for erosion control in geotechnical application. The study was aimed to access the effectiveness of the new material for geotextile made from water hyacinth to control soil erosion in a representative slope at different plots of tests.

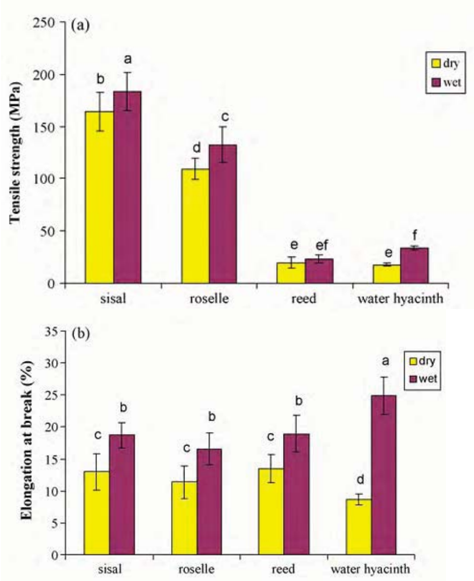

Fig. 1 Mechanical properties of the studied natural fibers: (a) tensile strength, and(b) elongation at break.

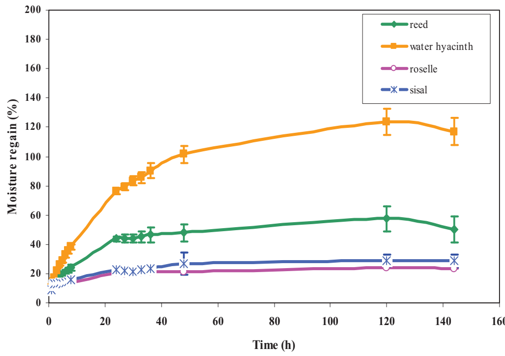

Fig. 2 Moisture absorption of the natural fibers at 95%RH, 23ºC

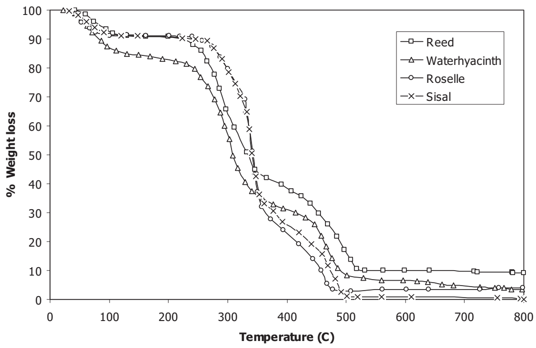

Fig. 3 TGA thermograms of the four studied natural fibers.

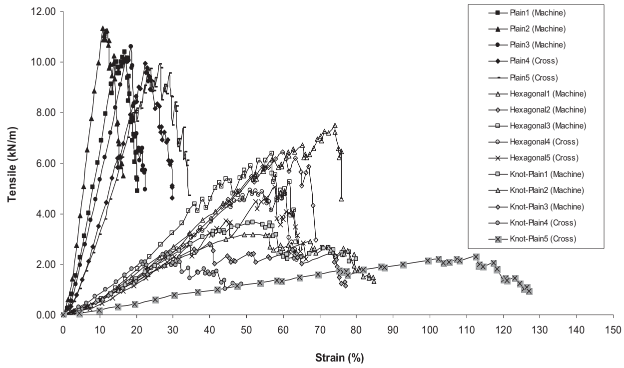

Fig. 4 Comparison of tensile strength of water hyacinth for all patterns.

MATERIALS AND METHODS

Study Area

The experiment was conducted on the test embankment which was constructed at the northern part of the campus of the Asian Institute of Technology (AIT) in Klong Luang, Pathumthani, Thailand in February, 2011. The height of embankment is four meters. The embankment was constructed by using silty sand backfill until 3 m height with six layers of plain pattern of kenaf LLGs. The vertical spacing is 0.5 m to reinforce the embankment, and weather crust of soft Bangkok clay 1 m height was covered the silty sand backfill embankment. Moreover, the side slope consisted of 1 vertical to 1.5 horizontal and back slope consisted of 1 vertical to 1 horizontal. The experiments were conducted at slope 1 vertical to 1.5 horizontal at the east and west side of embankment. The embankment for monitoring is shown in Fig. 4.

Fig. 4 The construction of embankment slope (1V:1.5H) for monitoring

Water Hayacinth Woven LLGs

Water Hayacinth (Eichhornia crassipes) woven LLGs are made from 100% water hyacinth fiber twine woven into the pattern. In this study, The woven water hyacinth LLGs with two different opening sizes dimension of 8 mm by 8mm and 12 mm by 12mm were selected to investigate the performance which are including coated and non-coated with polyurethane. The properties of woven water hyacinth LLGs are tabulated in Table 1. The woven water hyacinth LLGs (Fig. 5) were spread on weather crust of soft Bangkok clay at slope 1 vertical to 1.5 horizontal side of embankment. The water hyacinth LLGs dimension is 1 meter width and 5 meters length. The spacing of 12mm of woven water hyacinth LLGs was used at East side and the opening size of 8mm of woven water hyacinth LLGs was used at West side of the embankment.

Table 1 Properties of woven water hyacinth LLGs

Item	Test method	8 mm	12 mm
Thickness (mm)	ASTM D5199	6.96	6.94
Mass per unit area (g/m^2)	ASTM D5261	854	648
Wide width tensile strength (kN/m)	ASTM D4595	10	3.8
Elongation at break (%)	ASTM D4595	20	18

Fig. 5 Woven water hyacinth LLGs

Ruzi Grass

Ruzi grass is called in scientific name “Brachiaria ruziziensis”. Ruzi grass has been promoted as a good grass for improving pastures for cattle in the tropics. The seed can easily be planted in high rainfall area. Ruzi grass is extensively used in Thailand, its acceptance by farmers depends on the availability of a cheap and high quality seed supply as shown in Fig. 6. The seed of Ruzi grass was spread on the soil 60 g/m2 before installed woven water hyacinth LLGs.

Fig. 6 The seed of Ruzi grass

Rainfall Simulation

In this study, the erosion control test was performed by using the artificial rainfall to assess the effectiveness of water hyacinth woven LLGs in erosion control and water run-off. The rainfall simulator is capable of creating uniform rain drops and intensities over the entire area of the specimen. In this study, the rainfall intensity of 120mm/h which normal occurs in Thailand with return period ranging from 2 to 200 years during 90 minute duration of rainfall was obtained to investigate the runoff effect. The artificial rainfall was installed by using pump and sprinkler as shown in Fig. 7. The water motor pump was used to connect with the reservoir near the test embankment. The water delivery system of water supply using PVC pipe line connected ½ inch PVC pipes and it is scaled down to ¾ inch diameter and controlled by two points of pressure control. The nine sprinklers were installed in both side of the embankment at the height of 1.0 m along the edge and middle.

The rain gauge made from PVC pipe with 4 inches diameter and 32 cm long. The 100 ml cylinder were put inside and 15mm diameter of cone was put on top the PVC pipe to measure the rainfall intensity and the standard size of the rainfall is recorded continuously. The rainfall at the first minute was collected to measure the intensity by pouring the cylinder to read the volume and the volumes were calculated by a formula to determine the intensity of rainfall. The required rainfall intensities in this study were 120 mm/hr per two hours. The windshields were used to protect the wind at the both side of embankment.

Fig. 7 Set up artificial rainfall

Experimental Set Up

The field apparatus for both side of test embankment consists of five plots, divided by pinewood sheets to prevent water running on to them from up slope and contamination from the surrounding plots. Before the field site facilities could be set up, the funnels and dividers had to be installed. To remedy this situation, relief trenches were dug into the downhill side of the bucket holes to an approximate depth of 700 mm. The seed of ruzi grass was spread on the soil 60 g/m^2 at grassed control plots before installed woven water hyacinth LLGs. The opening size of 12 mm of woven water hyacinth was performed at the east of embankment with 5 plots including polyurethane coated water hyacinth LLGs with ruzi grass, non polyurethane coated water hyacinth LLGs with ruzi grass, ruzi grass only, polyurethane coated water hyacinth LLGs without ruzi grass and polyurethane coated water hyacinth LLGs without ruzi grass. The opening size of 8 mm of woven water hyacinth was performed at the west of embankment with 5 plots including polyurethane coated water hyacinth LLGs with ruzi grass, non polyurethane coated water hyacinth LLGs with ruzi grass, bare soil, polyurethane coated water hyacinth LLGs without ruzi grass and polyurethane coated water hyacinth LLGs without ruzi grass. Experimental set up at the test embankment is shown in Figs. 8 and 9.

Fig. 8 The embankment at West side

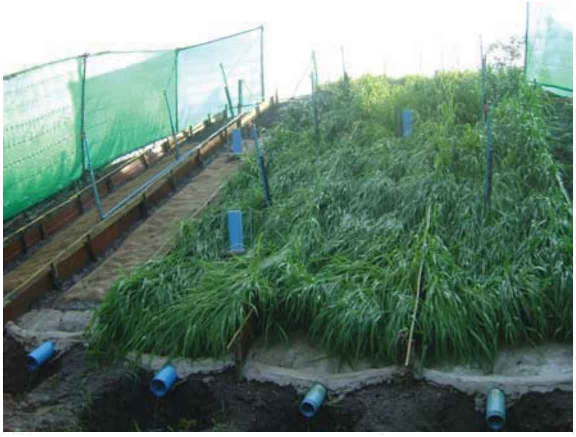

Fig. 9 The embankment at East side

Procedure for Monitoring Data

Simulated rainfall erosion tests were performed with rainfall intensity of 120 mm/hr on the both side of the embankment slope (1V:1.5H) after growing period of grass 4 weeks. The rain gauges were used to collected and measure the intensity by pouring the cylinder to read the volume. The flow rates of water runoff that can pass on the test slope from each test plots were recorded by flow of surface water through quantity of flow measured versus time each plots. Runoff samples were taken by using plastic containers (Fig. 10) after the flow rates were constant. Runoff samples were kept in the laboratory until sediments were deposited by gravity. Thereafter, the clear water was removed and the sludge was dried by using an oven at 105°C. After that, dried soil in each samples were weighed, then the eroded sediment and runoff volume were calculated. The following procedure was observed for the collection of field site data after growing period of grass 4, 6, 8 and 10 weeks.

Fig. 10 Collection of runoff samples

TEST RESULTS AND DISCUSSIONS

Runoff Rate

The effect of the new material for geotextile made from water hyacinth to control soil erosion in a representative slope (1V:1.5H) at different plots of tests at the growing periods of ruzi grass of 4, 6, 8, and 10 weeks. For the opening size of 12 mm of woven water hyacinth LLGs was used at the East side of embankment, the results show that the polyurethane coated and non-coated woven water hyacinth LLGs have higher amount of runoff rate followed by ruzi grass only, polyurethane coated and non-coated woven water hyacinth LLGs with ruzi grass, respectively, as shown in Fig. 11.

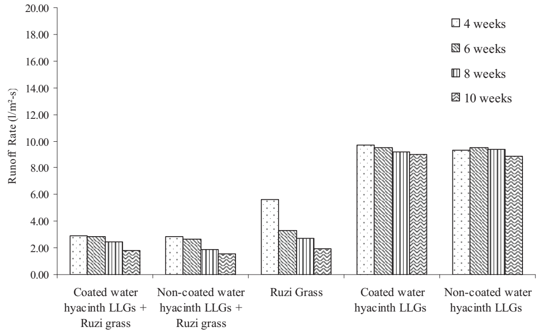

Fig. 11 Runoff rate at east side of embankment (12 mm opening size)

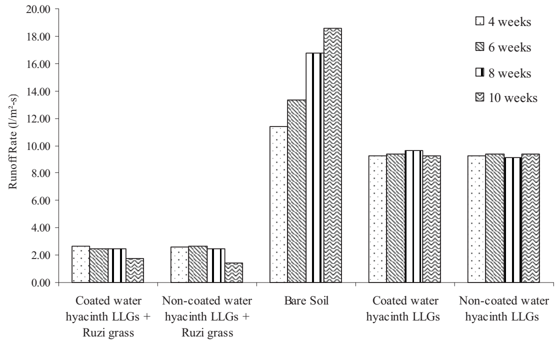

Fig. 12 Runoff rate at west side of embankment (8 mm opening size)

Figure 12 shows the results of woven water hyacinth LLGs 8 mm opening size at the West side of embankment, the total soil loss on bare soil was much higher than polyurethane coated and non-coated woven water hyacinth LLGs and the runoff tend to increase with time. Conversely, the runoff decreased with increasing growing period of ruzi grass. The runoff rates were significantly reduced with woven water hyacinth LLGs and ruzi grass covers. There was not much statistical difference in runoff between coated and non-coated woven water hyacinth LLGs.

From the results, it can be seen that combination of water hyacinth LLGs with ruzi grass reduced the amount of runoff from the rainfall. The cover of the LLGs can be reduced the impact of raindrops on the surface of the soil, and the barrier between the rain and the soil delayed the development of runoff. Runoff rate has 50 percent decreased by using water hyacinth LLGs covered soil surface.

Soil Loss

The eroded sediment was collect from the field tested embankment and it was dried by using an oven in the laboratory. Figure 13 shows the total soil loss with varying time from the East of embankment by using 12 mm opening size of water hyacinth LLGs. From the results show that very low soil loss were found in 4 to 10 weeks from polyurethane coated and non-coated water hyacinth LLGs combined with ruzi grass. The amount of soil loss from ruzi grass only (0.25 kg/m2) plot is less than the amount of soil loss from covered soil surface by water hyacinth LLGs only about 50 percent. The amount of soil loss tends to be decreased when increasing time.

For the West of embankment by using 8 mm opening size of water hyacinth LLGs, Fig. 14 shows that bare soil plot has highest amount of soil loss about 2.2 kg/m2. The polyurethane coated and non-coated water hyacinth LLGs can be reduced the amount of soil loss about 70 percent of bare soil. Moreover, very low amount of soil loss has found from the polyurethane coated and non-coated water hyacinth LLGs combined with ruzi grass plots due to the root of ruzi grass.

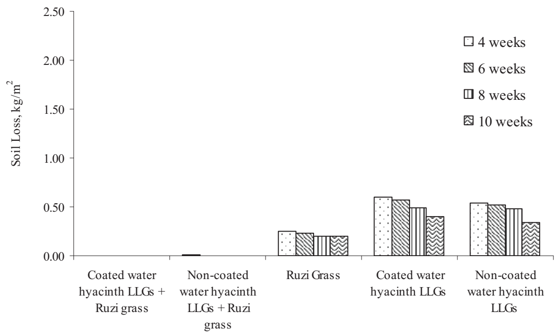

Fig. 13 Soil loss at east side of embankment (12 mm opening size)

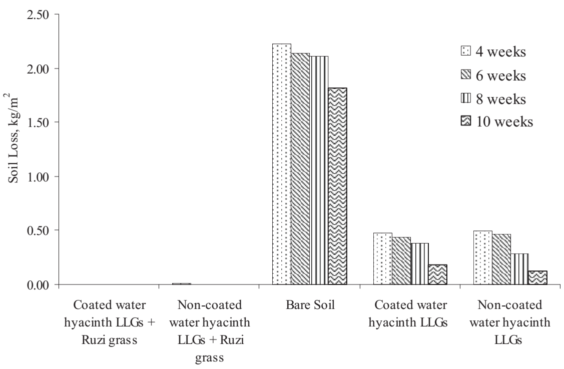

Fig. 14 Soil loss at west side of embankment (8 mm opening size)

It can be seen that the limited life geotextiles made from water hyacinth LLGs can reduce the amount of runoff. Two types of opening sizes (8 and 12 mm) were obtained in this study. The results indicated that soil cover with LLGs with 8 mm opening size has significantly reduced the amount of surface runoff rather than LLGs with 12 mm opening size.

CONCLUSIONS

From results of flow rate of the runoff and amount of soil loss, better results were found when growing Ruzi grass with woven water hyacinth LLGs. The 4, 6, 8 and 10 weeks growing period of Ruzi grasses reduced the amount of soil loss because of increasing coverage of vegetation. Woven water hyacinth LLGs can makes effectiveness to control soil erosion. Thus, plain pattern of water hyacinth can be applied for soil erosion control in geotechnical field.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the Royal Thai Government (RTG) for providing the funds for this research.

REFERENCES

Artidteang, S., Bergado, D.T., Methacaonon, P., and Prahsarn, C. (2011). Properties of limited life woven geotextiles (LLGs) for soil reinforcement and soil erosion control applications, Proc. Intl. Conf. on Soil Mechanics and Geotechnical Engineering, Hong Kong Polytechnic Univ. Hong Kong, China: 411.

Methacanon, P., Weerawatsophon, U., Sumransin, N., Prahsarn, C., and Bergado, D.T. (2010). Properties and potential application of the selected natural fibers as limited life geotextiles. Carbohydrate Polymers, 82(4): 1090–1096.

Morgan, R.P.C. (2005) Soil Erosion and Conservation, 3rd Ed. Blackwell Publishing, USA.

Kothyari, U.C. (1996). Erosion and sedimentation problems in India, Proc, Intl. Symp. on Erosion and Sediment Yield; Global and Regional Perspectives, U.K.,: 531-540.

Thakur, V.C. (1996) Landslide Hazard Management and Control in India. International Centre for Integrated Mountain Development. Kathmandu.