

Research Paper

Performance of Ruzi Grass Combined with Woven Limited Life Geotextiles (LLGS) for Soil Erosion Control

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ABSTRACT

Natural fibers can be made into woven geotextile and combined with growing vegetation for slope protection. Thailand has highly abundant natural fibers and rural communities have been converting them into handicrafts. The water hyacinth yarns were fabricated to woven geotextile called limited life geotextiles (LLGs) to help stabilize the slope and improved the growth of vegetation for erosion control in geotechnical application. The study was aimed to assess the effectiveness of the LLGs new material for geotextile made from water hyacinth combined with Ruzi grass to control soil erosion in a representative slope. 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 geotextiles made from water hyacinth LLGs combined with Ruzi grass can reduce the flow rate of runoff and amount of soil loss.

1. 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). Vegetation growth on a slope is occasionally met with problems such as absence of initial binding material in the soil, washing away by runoff, etc. In such conditions, geotextiles serve the purpose of protecting the soil and the seeds in the initial stage of vegetative growth (Lekha, 2004).

Natural fiber can be modified to woven geotextile called "Limited Life Geotextiles (LLGs)" that are only required to perform short term applications (Sarsby, 2005). The geotextiles reduce runoff, retain soil particles and protect bare ground from the sun, rain and wind. Within two or three growing seasons (2–3 years) vegetation establishes itself within the apertures of the geotextile. This vegetation covers the ground surface

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and its roots anchor the soil so the geotextile is no longer needed to prevent erosion. This form of erosion control can equally be applied to riverbanks and coastlines to provide stable banks (Sarsby, 2007). There are many kinds of natural fibers which produce geosynthetics for erosion control function such as coir, jute, sugarcane, palm, etc. Geotextile of Coir are used to stabilize erodible steep slope because coir geotextile has a high tensile strength due to its high lignin content (Vishnudas et al., 2006). Dinu and Saska (2007) studied the sugarcane bagasse fibers which is a local, readily available material with properties that make it suitable for erosion control products. Choudhury et al. (2009) investigated geotextiles made of natural jute yarns, helps reduce the velocity of overland flow and entrapping the dissociated soil particles while fostering growth of vegetation for soil erosion control and slope stabilization in India. Smets and Poesen (2009) investigated the impact of soil pre-treatment on the effectiveness of biological geotextiles in increasing infiltration and reducing runoff and erosion rates on steep slope gradient which included five biological geotextiles composed of Borassus, Buriti, bamboo, rice straw, and maize stalk. Bhattacharyya et al. (2010) studied soil erosion by rain drops under field conditions for sandy sand and medium slope lands in the UK. The investigation of palm-mat geotextiles with Borassus palm and Buriti palm were studied on the effect of these mats on splash height and splash erosion. Bhattarai et al. (2011) investigated the effectiveness of three different types of biodegradable erosion control blankets- fine compost, mulch, and 50-50 mixture of compost and mulch, for soil erosion control under field and laboratory-scale experiments. Ayuba and Olorunnaiye (2014) has reviewed that geotextiles are highly effective in controlling soil erosion due to their salient properties (e.g. percent cover, geotextile-induced roughness, water holding capacity) which mimic that of vegetation in terms of its erosion-control ability (e.g. percent cover of soil, water retention, roughness imparted to flow).

These aforementioned applications have led to intensive studies of the characteristics of natural fiber woven LLGs especially erosion control application. 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.

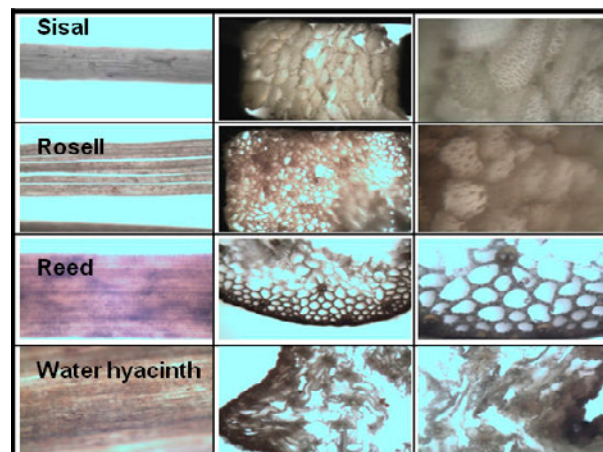


Fig. 1. Optical micrographs of surface (1st column) and cross-section (4x, 2nd column and 40x, 3rd column) morphology of the studied natural fibers.

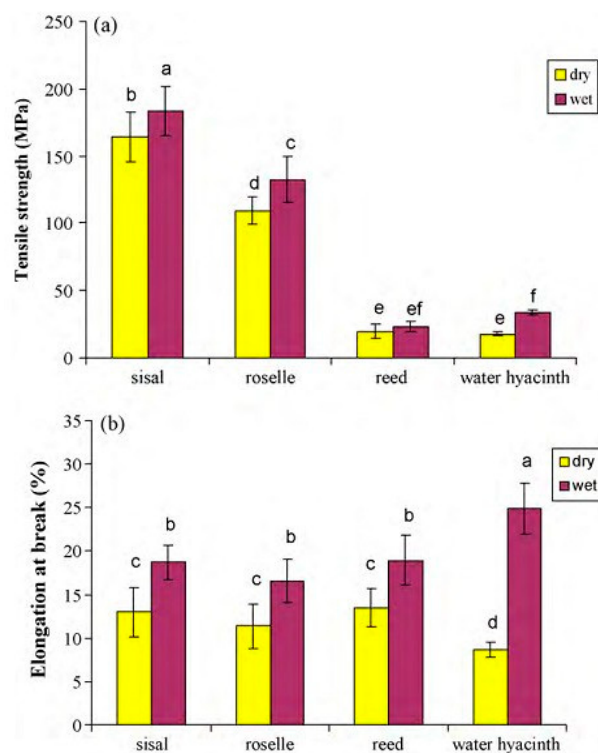


Fig. 2. Mechanical properties of the studied natural fibers: (a) tensile strength, and (b) elongation at break

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. Morphology and fiber length of the fibers were determined using optical microscope as shown in Fig. 1. 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. 2).

The results showed that there was a positive correlation between tensile strength and fiber length; the

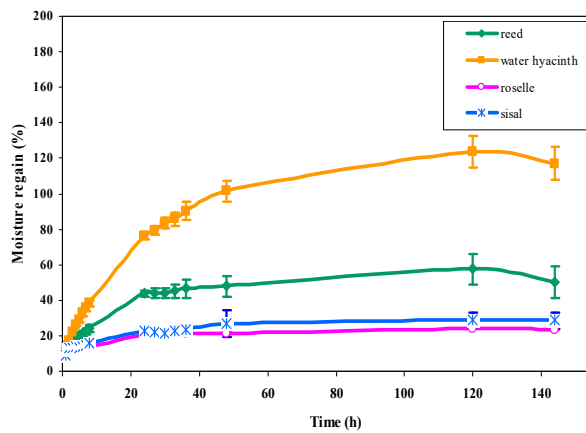


Fig. 3. Moisture absorption of the natural fibers at 95%RH, 23°C

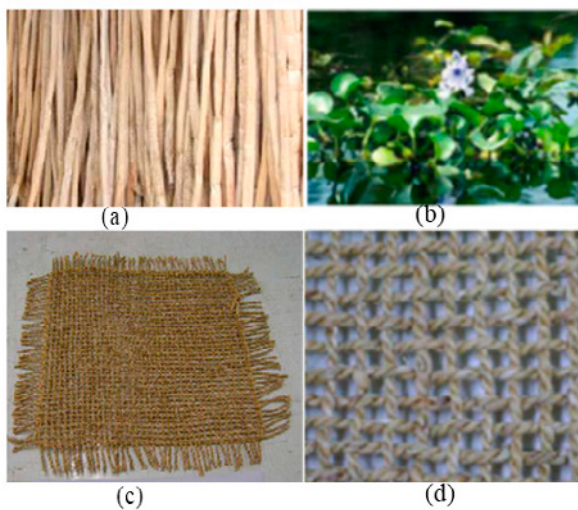


Fig. 4. Water hyacinth natural fiber Limited Life Geotextiles (LLGs): (a) Original fiber of water hyacinth, (b) Water hyacinth in reservoir, (c) Woven water hyacinth in plain pattern, and (d) Opening of woven water hyacinth

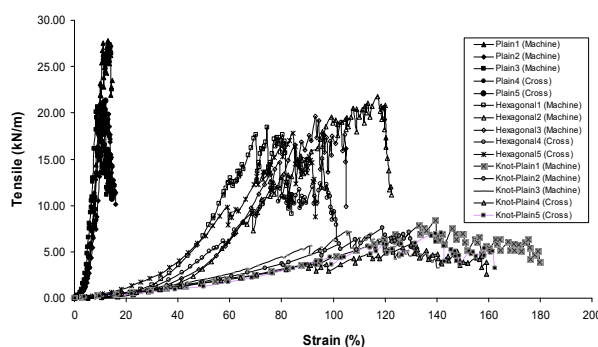


Fig. 5. Comparison of tensile strength of water hyacinth for all patterns

longer fiber length, the higher tensile strength. Moreover, it is interesting to note that when the fibers are wet, their tensile strength and elongation increase. Their moisture absorption was also investigated as shown in Fig. 3. Water hyacinth, it is worth to study ability, due to its lower cost and higher water absorption (Fig. 4).

Artidteang et al. 2011 has 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 5.

In this study, the water hyacinth yarn was selected due to their economy and availability in Thailand. The water hyacinth yarns were fabricated to woven geotextile called limited life geotextiles (LLGs) to help stabilize the slope and improved the growth of vegetation for erosion control in geotechnical application. The study was aimed to assess the effectiveness of the LLGs made from water hyacinth to control soil erosion combined with Ruzi grass in representative slope and test plots.

2. Materials

2.1 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 plan view of test embankment is shown in Fig. 6. 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. Figure 7 shows the embankment construction.

2.2 Water Hayacinth woven LLGs

Water Hayacinth (*Eichhornia crassipes*) woven LLGs are made from 100% water hyacinth fiber twine woven into the pattern. The woven water hyacinth LLGs with two different opening sizes dimension of 8 mm by 8 mm and 12 mm by 12 mm were selected to investigate the performance which are including coated and non-coated with polyurethane. The polyurethane can be decreased water absorption and, thereby prolong the life of LLGs.

The properties of woven water hyacinth LLGs are tabulated in Table 1. The woven water hyacinth LLGs (Fig. 4c) 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 12 mm of woven water hyacinth LLGs was used at east side

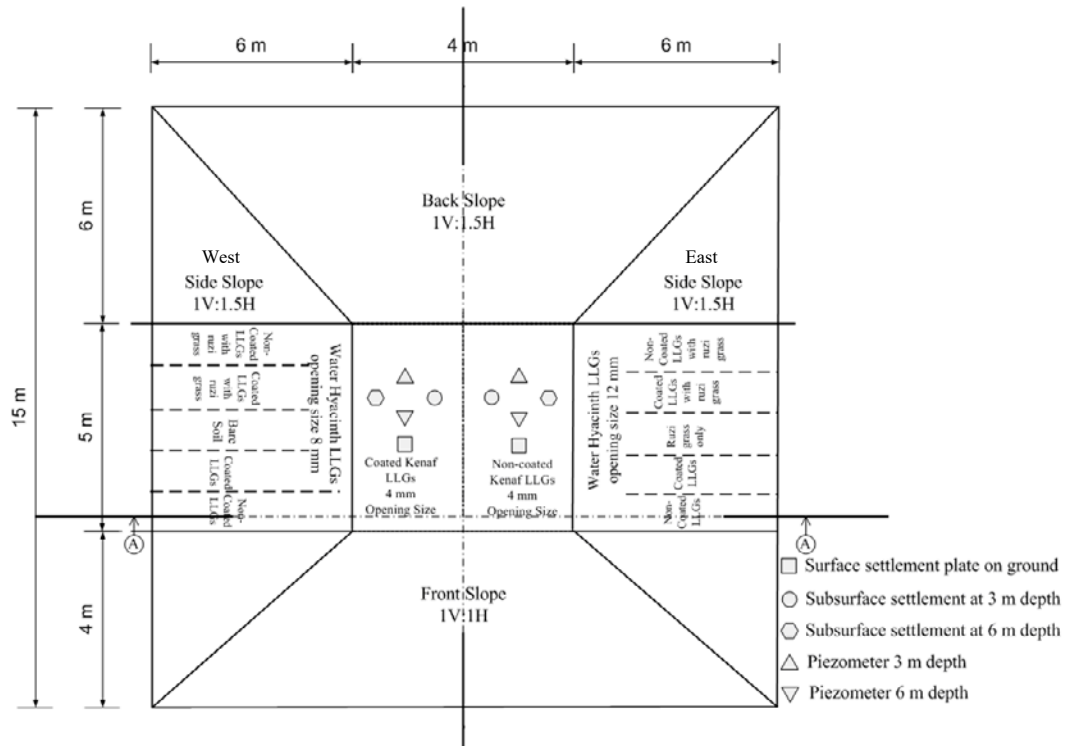


Fig. 6. Plan view of test embankment



Fig. 7 The construction of embankment slope (1V:1.5H) for monitoring

and the opening size of 8 mm of woven water hyacinth LLGs was used at west side of the embankment.

2.3 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. The seed of Ruzi grass was spread on the soil 60 g/m² before installed woven water hyacinth LLGs. Fig. 8(a, b) shows the Ruzi grass growing through the 8

Table 1. Properties of woven water hyacinth LLGs

Items	Test method	Opening Size	
		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

mm and 12 mm opening size of water hyacinth LLGs.

3. 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. 9. 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.



(a)



(b)

Fig. 8. Ruzi grass grow up through sample (a) 8 mm

The rain gauge made from PVC pipe with 4 inches diameter and 32 cm long. The 100 ml cylinder were put inside and 15 mm 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 geosynthetic nets were used to protect against the wind at the both sides of embankment.

4. Experimental Set Up

The field apparatus for both side of test embankment consists of five plots, divided by plywood sheets to prevent running water on to them from up slope and contamination to the surrounding plots. Before the field site facilities could be set up, the funnels and dividers



Fig. 9. Set up artificial rainfall

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 seeds of Ruzi grass were spread on the soil of 60 g/m² in the grassed control plots before the installation of woven water hyacinth LLGs. The opening size of 12 mm of woven water hyacinth was installed 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 installed at the west side of the 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 Fig. 10 and Fig. 11.

5. 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 in each plots. Runoff samples were taken by using plastic containers (Fig. 12) after the flow rates were constant. Runoff samples were kept in the laboratory until the soil particles were settled by gravity.

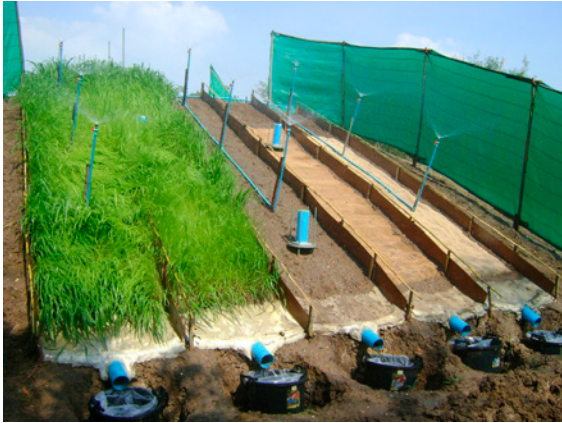


Fig. 10. The embankment at west side



Fig. 11. The embankment at east side



Fig. 12. Collection of runoff samples

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 soil particles 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.

6. Test Results

6.1 Runoff rate

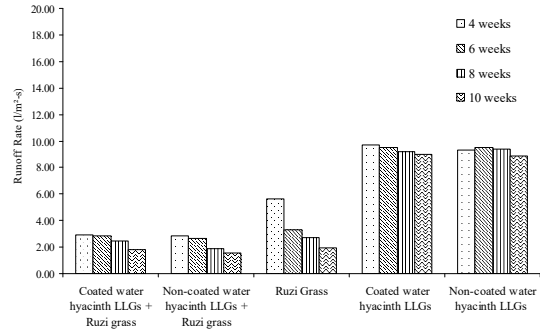


Fig. 13. Runoff rate at east side of embankment (12 mm opening size)

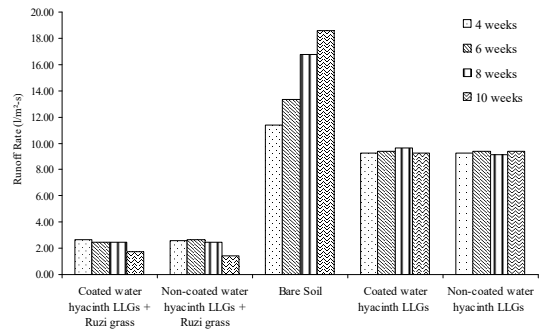


Fig. 14. Runoff rate at west side of embankment (8 mm opening size)

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. 13.

Figure 14 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 reduce the impact of raindrops on the surface of the soil, and the barrier between the rain and the

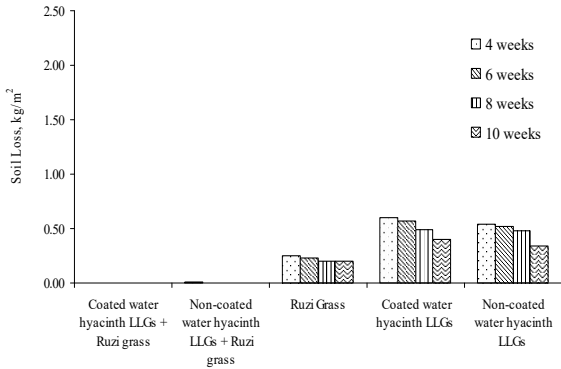


Fig. 15. Soil loss at east side of embankment (12 mm opening size)

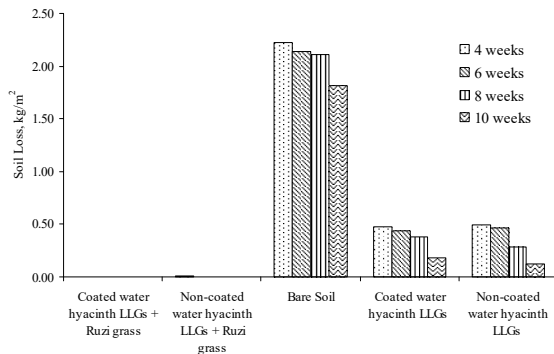


Fig. 16. Soil loss at west side of embankment (8 mm opening size)

soil delayed the development of runoff. By covering the soil surface with water hyacinth LLGs, the runoff rate was decreased by 50 percent.

The opening size insignificantly affected runoff rate with the results of woven water hyacinth LLGs 8 mm opening size had better erosion control performance than 12 mm opening size. The smaller opening size can reduce the impact of raindrops and increasing coverage on soil that act as soil barriers and, thus, reduced the velocity of surface runoff. Regarding the effect of polyurethane coating, the coating of LLGs were not effective for any performance of the combination system because the polyurethane coating is for water absorption resistance and to increase its lifetime only.

6.2 Soil Loss

The eroded soil particles were collected from the field tested embankment and dried by using an oven in the laboratory. Figure 15 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 it can be shown 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/m^2) plot is less than the amount of soil loss

from covered soil surface by water hyacinth LLGs only by about 50 percent. The amount of soil loss tends to decrease with increasing time.

In the west of embankment by 8 mm opening size of water hyacinth LLGs was installed. Figure 16 shows that the bare soil plot was highest amount of soil loss about 2.2 kg/m^2 . The polyurethane coated and non-coated water hyacinth LLGs can reduce the amount of soil loss by about 70 percent of bare soil. Moreover, very low amount of soil loss has been found from the polyurethane coated and non-coated water hyacinth LLGs combined with Ruzi grass plots because the increasing coverage to the soil and the short roots of Ruzi grass can help control surface soil erosion (Teerawattanasuk et al., 2014). In addition, the root system facilitates infiltration of water by improving the porosity of the soil (Ranganathan, 1994; Ahn et al., 2002).

Consequently, 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 utilized 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. The smaller apertures size of the woven water hyacinth can entrapped the soil particles and prevented from being transported by runoff water.

7. Conclusions

The water hyacinth natural fibers were fabricated into woven limited life geosynthetics (LLGs) with 8 mm and 12 mm opening sizes and combined with growing vegetation of Ruzi grass of 4, 6, 8 and 10 weeks for erosion control on a representative slope using artificial rainfall. Several combinations were investigated including bare soil polyurethane coated and non-coated LLGs, as well as polyurethane coated and non-coated LLGs combined with Ruzi grass. The flow rates of water runoff and amount of soil loss were investigated in the field at the side slope of the embankment.

The combination of soil with water hyacinth woven LLGs reduced the amount of runoff from the rainfall. The high coverage of the water hyacinth woven LLGs reduced the impact of raindrops on the surface of the soil, and served as barrier between the rain and the soil, thus, delayed the development of runoff and reduced the soil loss by 70%. From the results of runoff and soil loss, covering the soil with 8 mm opening size of water hyacinth woven LLGs has significantly reduced the amount of surface runoff compared to covering the soil

with water hyacinth woven LLGs with 12 mm opening size because the smaller opening size can entrapped the soil particles and prevented from being transported by runoff water. Moreover, the effect of polyurethane coating on water hyacinth woven LLGS were not effective for reducing soil erosion. The polyurethane coating was only applicable for water absorption resistance and increase its lifetime only.

The better results of soil loss were found when growing Ruzi grass combined with woven water hyacinth LLGs. The soil loss was greatly reduced for 4, 6, 8 and 10 weeks growing periods. Ruzi grass reduced the amount of soil loss because of increasing coverage of vegetation. The roots system of Ruzi grass can also help control surface soil erosion. Consequently, the limited life geotextile made from water hyacinth LLGs combined with Ruzi grass can reduce the flow rate of runoff and amount of soil loss.

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