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Soil Mass Loss Reduction during Rainfalls by Reinforcing the Slopes with the Surficial Confinement

Ramli Nazir, Hossein Moayedi

Abstract**—**Soil confinement systems serve as effective solutions to any erosion control project. Various confinements systems, namely triangular, circular and rectangular with the size of 50, 100, and 150 mm, and with a depth of 10 mm, were embedded in soil samples at slope angle of 60°. The observed soil mass losses for the confined soil systems were much smaller than those from unconfined system. As a result, the size of confinement and rainfall intensity have a direct effect on the soil mass loss. The triangular and rectangular confinement systems showed the lowest and highest soil loss masses, respectively. The slopes also failed much faster in the unconfined system than in the confined slope.

Keywords**—**Erosion control, Soil confinement, Soil erosion, Slope stability.

I. Introduction

THERE are many ways to manage stormwater runoff. A variety of hard armor and soft armor resources are available to repair deteriorating drainage channels. An ideal method to prevent soil erosion is by using the natural vegetation of the channel bed. Aside from protecting the soil surface from the impact of raindrops, it shields the soil from the scouring effect of overland flow and decreases the erosive capacity of the flowing water by reducing its velocity [1]. Merrill [2] investigated the use of gabions in stormwater management and erosion control. The gabions can be used as hard armor to control erosion in soil-retention and hydraulic applications. Geosynthetics as engineered solutions to erosion control are proving their worth in several projects. Tice [3] also explored the use of geosynthetic materials for erosion control. He introduced several successful case histories of using geosynthetics as erosion-control systems in the USA [3].

Soil confinement systems serve as effective solutions to any erosion control project. They stabilize the slopes, slow the velocity of rainfall and/or stormwater, and prevent soil erosion along the slope, particularly in high-rainfall seasons in tropical areas [4]-[8]. Aird [9] investigated channel linings and erosion control systems extensively. He highlighted challenges to slope stabilization such as problems with blankets, soil nails, mesh, and cellular confinement systems. Then, from another research paper published in the same journal, *Erosion Control*, he designed an erosion-control system called "Open-Cell ACB" to slow down the velocity of water and retain the soil simultaneously [10]. In heavy rainfall, confinement systems can help dissipate some of the energy in the water flow through the voids between the individual confined cells [2]. The main objective of the present research is to monitor the effect of rainfall intensity on the soil erosion rate for slopes with confined and unconfined systems.

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II. Material and Methods

A schematic set-up of the test model is presented in Fig. 1. The customized set-up consisted of a 300-gallon water tank, a water pump, a collection tank and a measuring container. The collection tanks were 1.20m in length, 0.75m in width and 1.05m in depth. This capacity was selected not only to accommodate the test specimens but also to ensure that all the water sprayed on the specimens had the same hydraulic pressure. The function of the water pump was to provide a constant pressure of 1 bar (14.5 pounds per square inch) throughout the test. The soil selected for the experimental programmed had moisture content of 40.1%, bulk density of 1.703 Mg/m^3 and dry density of 1.252 Mg/m^3. Moisture content was kept at 40.1% throughout the test. Therefore, the weight of oven-dried soil and water required for test sample preparation was 54.70 kg and 21.94 kg respectively. The coefficient of permeability (k) ranged between $2.81x10^{-7}$ and $5.37x10^{-10}$ m/sec. three types of confinements in the experimental test programmed: circular (CF or Series 1), triangular (TF or Series 2), and rectangular (SF or Series 3). The specimens were set at various specified test angles.

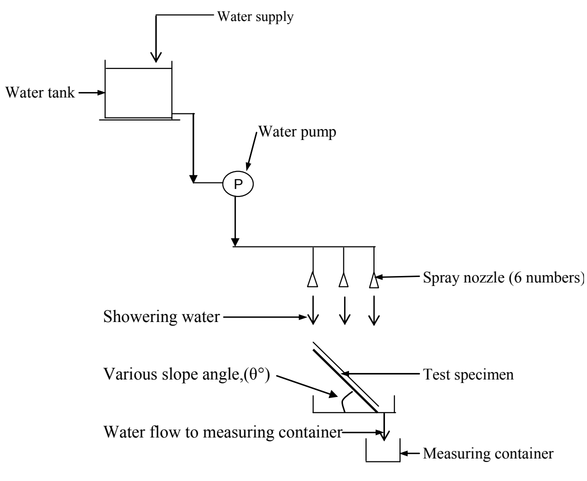

Fig. 1 Schematic setting up of model test

III. Results and Discussion

Figs. 2 to 11 show the variation of soil mass loss from both unconfined and confined slopes with different rainfall intensities and durations. Accordingly, rainfall intensity ranging from 20 to 75 mm/hour with rainfall durations of 60 minutes was considered. Broadly speaking, the soil mass loss increases with increments of rainfall intensity at various slope angles. Besides, the steeper the slope (higher slope angle), the more soil mass loss occurred in the experiments.

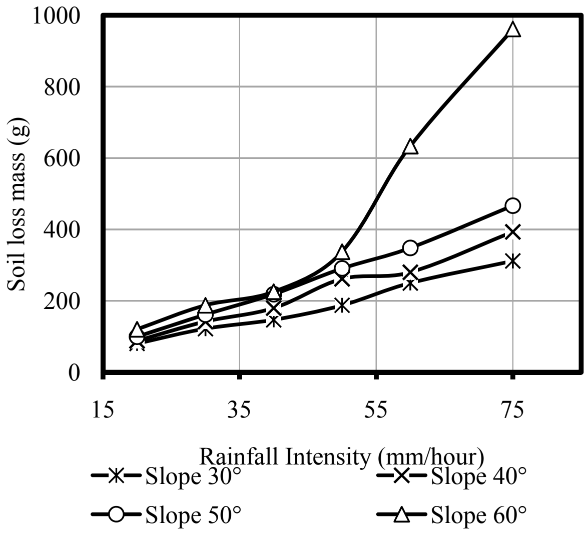

Fig. 2 Variation of soil loss mass in Non-confinements with various rainfall intensity and rainfall duration of 60 minutes

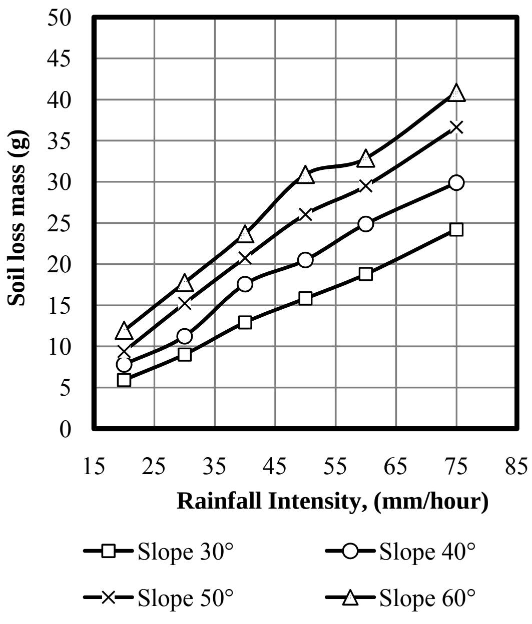

Fig. 3 Effect of rainfall intensity on soil loss mass in triangular confinement system of 50mm height for the duration of 60 minutes

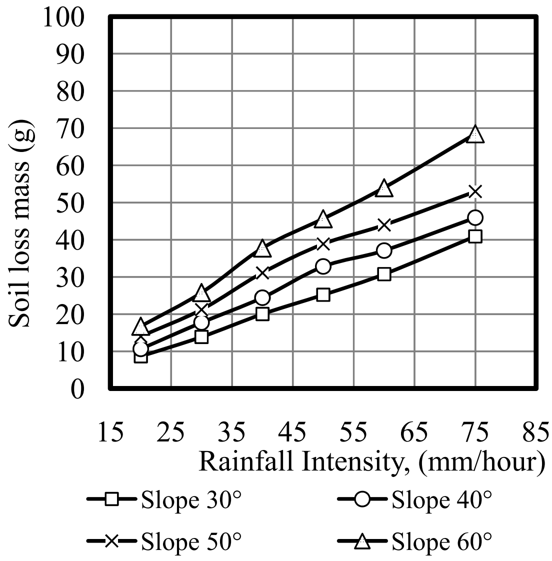

Fig. 4 Effect of rainfall intensity on soil loss mass in triangular confinement system of 100mm height for the duration of 60 minutes

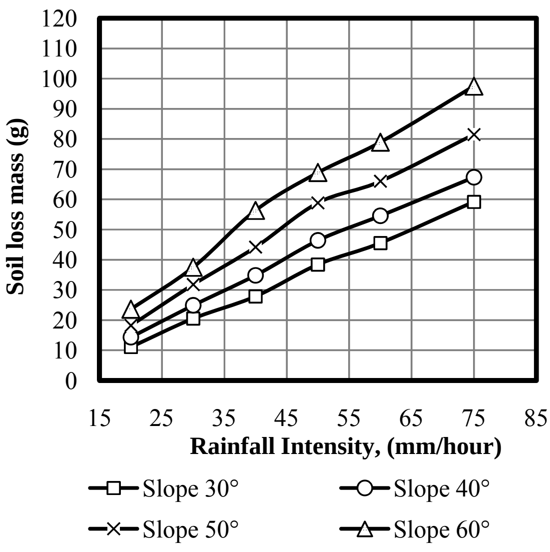

Fig. 5 Effect of rainfall intensity on soil loss mass in triangular confinement system of 150mm height for the duration of 60 minutes

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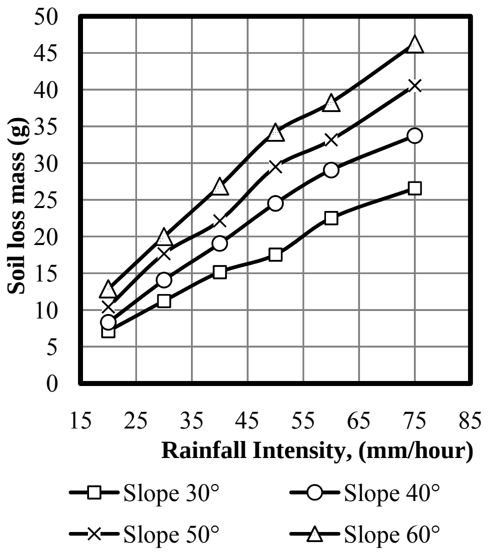

Fig. 6 Effect of rainfall intensity on soil loss mass in circular confinement system and 50mm height for the duration of 60 minutes

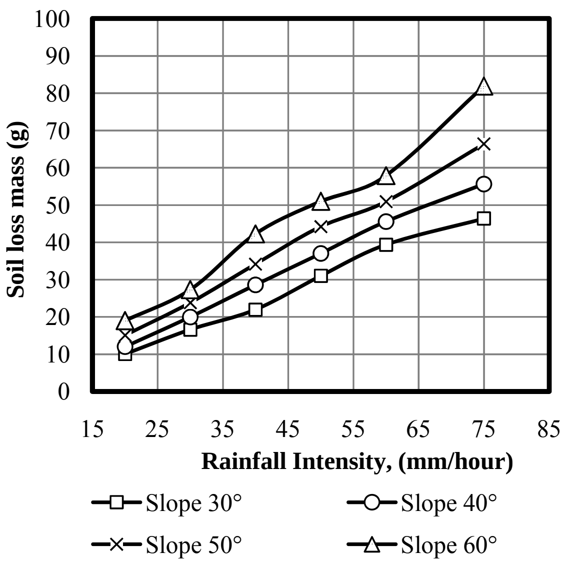

Fig. 7 Effect of rainfall intensity on soil loss mass in circular confinement system and 100mm height for the duration of 60 minutes

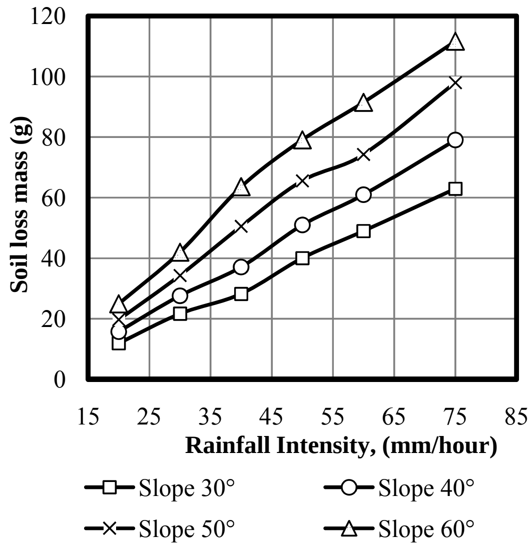

Fig. 8 Effect of rainfall intensity on soil loss mass in circular confinement system and 150mm height for the duration of 60 minutes

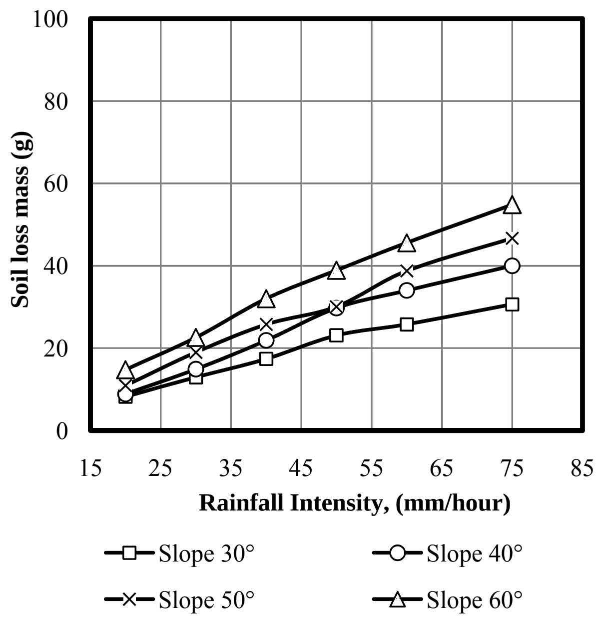

Fig. 9 Effect of rainfall intensity on soil loss mass in rectangular confinement system and 50mm height for the duration of 60 minutes

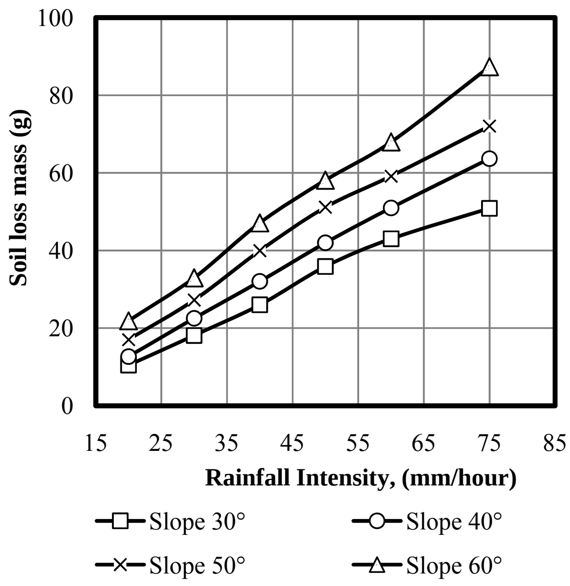

Fig. 10 Effect of rainfall intensity on soil loss mass in rectangular confinement system and 100mm height for the duration of 60 minutes

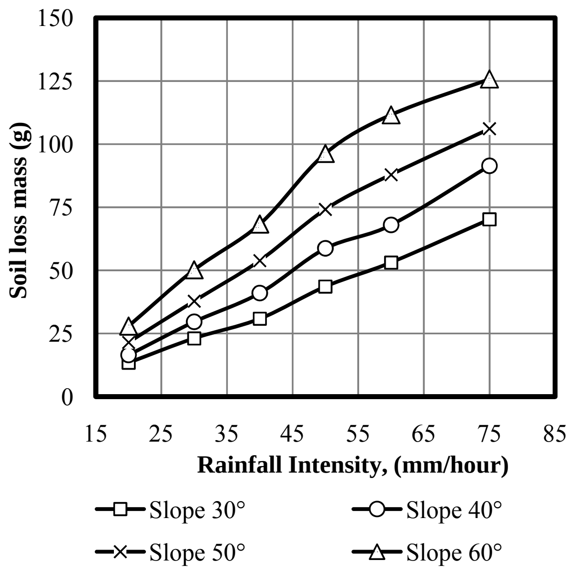

Fig. 11 Effect of rainfall intensity on soil loss mass in rectangular confinement system and 150mm height for the duration of 60 minutes

The observed results for the soil mass loss exhibited that the triangular confinement system is more efficient than both the circular and/or rectangular confinement systems. For instance, with a slope angle of 60°, confinement size of 100 mm, rainfall intensity of 75 mm/hour, and rainfall duration of 60 minutes, the soil mass losses for the triangular, circular, and rectangular confinement systems were 68.48, 81.89, 87.35 g, respectively (Figs. 3, 7, and 10). It can be seen that less soil mass loss occurs with the circular confinement system than with the rectangular one.

IV. Conclusions

The experimental tests consisted of an entire series of unconfined and confined systems measuring 50, 100, and 150 mm with different values of rainfall intensity and slope angle. Three types of confinement systems, namely circular, triangular, and rectangular, were tested. According to the observed results from the different confinement systems it can be concluded that the triangular confinement system has less soil mass loss than both the circular and rectangular confinement systems. Also, the soil mass loss obtained from the circular confinement system is less than that from the rectangular confinement system. The slopes in the unconfined system failed much faster than the confined slopes.

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References

[1] S. Goldberg, "Channel protection measures," *Erosion Control*, vol. 16, no. 1, pp. 22-29, 2009.
[2] L. Merrill, "Multitalented and versatile: Gabions in stormwater management and erosion control," *Erosion Control*, vol. 11, no. 3, pp. 42-45, 2004.
[3] B. Tice, "Synthetic strength: Geosynthetics for erosion control," *Erosion Control*, vol. 13, no. 1, pp. 46-59, 2006.
[4] P.K. Thakur, J.S. Vinod, B. Indraratna, "Effect of confining pressure and frequency on the deformation of ballast," *Geotechnique*, vol. 63, no. 9, pp. 786-790, 2013.
[5] B. Leshchinsky, H. Ling, "Effects of geocell confinement on strength and deformation behavior of gravel," *Journal of Geotechnical and Geoenvironmental Engineering*, vol. 139, no. 2, pp. 340-352, 2013.
[6] Q.H. Truong, C. Lee, Y.U. Kim, J.S. Lee, "Small strain stiffness of salt-cemented granular media under low confinement," *Geotechnique*, vol. 62, no. 10, pp. 949-953, 2012.
[7] J.B. Belflower, J.K. Bernard, D.K. Gattie, D.W. Hancock, L.M. Risse, C. Alan Rotz, "A case study of the potential environmental impacts of different dairy production systems in Georgia," *Agricultural Systems*, vol. 108, no., pp. 84-93, 2012.
[8] K. Mohamed, M. Abouzakhm, M. Elias, "Applications and performance of geosynthetic-reinforced soil abutments on soft subsurface soil conditions," 74-81, 2011.
[9] J. Aird, "Challenges in slope stabilization: Solving problems with blankets, mesh, soil nails, and cellular confinement systems," *Erosion Control*, vol. 17, no. 1, pp. 18-25, 2010.
[10] J. Aird, "Channel linings," *Erosion Control*, vol. 17, no. 2, pp. 34-41, 2010.