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Relation between Storage Volume and Erosion Control Performance of Woven Geomesh

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Abstract: **Soil management techniques using vegetation and geomesh can mitigate runoff soil erosion. In this paper, the erosion control performance of different grade commercial coir and jute geomeshes were studied at different angle of soil slope using ASTM D 7101 standards, in a bench-sale setup with some modifications. The erosion control performance of geomeshes were correlated with the calculated storage volume of geomeshes and it was observed that the coir geomesh have better correlation with R^2 value of 0.858. Whereas, jute geomesh have a moderate correlation with R^2 value of 0.640, due to additional influence of high drapability, which facilitates better contact with soil surface and results in better performance than the calculated storage volume.**

Index Terms- **Runoff soil erosion, geomesh, storage volume, erosion control performance**

I. INTRODUCTION

Removal of top layer of soil by wind, water and other human activities is called as soil erosion [1], [2]. Among various forms of erosion, erosion induced by runoff of water, down the slopes known as 'runoff soil erosion' is most common. Heavy rainfall accelerates such erosion and results in the problems of loss of soil structure, soil acidity and loss of organic matter in the soil. Also it induces some devastating problems like landslide, flood, desertification, chocking down the bridges and reservoirs [3] – [5]. These problems of runoff soil erosion can be controlled by proper soil management techniques using geomesh and natural vegetation [6]. When compared to nonwoven geomeshes, woven geomeshes have additional advantage of higher strength and larger mesh opening size, which facilitates easy growth of vegetation [7] – [10]. Also, the geomeshes made from natural fibres can provide better microclimate for the growth of vegetation, due to higher moisture regain [11] – [13]. Hence woven biodegradable geomeshes made of natural fibres like coir, jute, etc are highly preferable for runoff erosion control.

During onsite installation, woven geomeshes are rolled down the soil slope with weft yarns laid against the direction of slope. The impact of rain water on the soil surface is controlled by the canopy action of geomesh cover, while the velocity of runoff rain water is controlled by the micro-barriers created by the weft yarns lying against the direction of slope. Runoff erosion control would be effective if water flow velocity is controlled, which is highly dependent on the weft yarn diameter and its density (Weft yarns/meter). In most of the cases geomeshes are being used on their mass per unit area and none of the studies in literature uses such considerations except recent studies by the authors [10], [14], [16]. So, detailed study on the influence of weft yarn density and diameter on the erosion control performance of geomeshes is needed.

In 2006 & 2013 Sanyal proposed a geometrical model to calculate the storage volume of open weave geomesh with an assumption of weft yarn is circular in cross section, and it hinders the overland flow (runoff water) to form triangular cross-section storage [15], [16]. Based on the model he modifies the commercial jute geomesh and evaluates its erosion control performance at onsite conditions. It was observed that modified geoemeshes show better erosion control performance. But the performance of geomeshes of different weft yarn density and diameter laid at different soil slope (slope angle) was not studied. In this study coir and jute geomeshes of different weft yarn density and diameter are studied for the erosion control performance at different soil slopes in laboratory conditions, and the performance is evaluated on the basis of storage model proposed by Sanyal.

II. THEORETICAL BACKGROUND

By considering weft yarn as circular cross section with diameter 'd' and angle of soil slope as 'β' (Fig. 1), a

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Vol 1, Issue 6, June 2016

geometrical model was proposed by Sanyal (2006 & 2013) to calculate the water storage volume of geomesh in one square meter area (Equation 1) [15], [16]. The transportation of detached soil which is a factor of infiltration, grain size and plasticity of soil is not considered in the design. It is also considered that the function of warp yarn is only to hold the weft yarn in its position for the dimensional stability against runoff water and other extraneous forces.

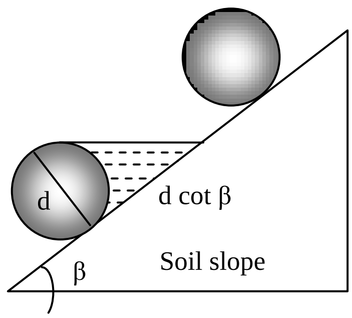


Fig. 1: Geometrical model to calculate the storage volume of geomesh

Storage volume per square meter of open weave geomesh is given by equation (1).

$$S = \frac{Nd^2}{8}(4\cot\beta - \pi)\ 10^{-3}\ \text{litres/m}^2 \qquad (1)$$

Where,

S- Storage volume/ m^2 of open weave geomesh (litres/m^2)

N- Weft yarn density (number of wefts/meter)

d- Weft yarn diameter (mm)

β- Angle of soil slope (degree)

III.MATERIALS AND METHODS

Table 1 show the specifications of different grade commercial coir and jute geomeshes which were used in the study.

Table 1: Specification of geomeshes

Specifications		Coir geomesh grades			Jute geomesh grades	
		400 grade	700 grade	900 grade	500 grade	700 grade
% cover		21	33	25	23	25
Warp	Yarns/ meter	53	57	56	74	74
	Linear density (Tex)	7614	6765	7614	2961	4773
	Diameter (mm)	6.5	5.0	6.5	2.5	3.9
Weft	Yarns/ meter	40	58	48	52	80
	Linear density (Tex)	4794	4794	6765	4773	4773
	Diameter (mm)	4.0	4.0	5.0	3.9	3.9

Note: Tex is used to represent the linear density of yarns and is defined as the mass of 1000 meters of yarn in grams.

A. Erosion control performance

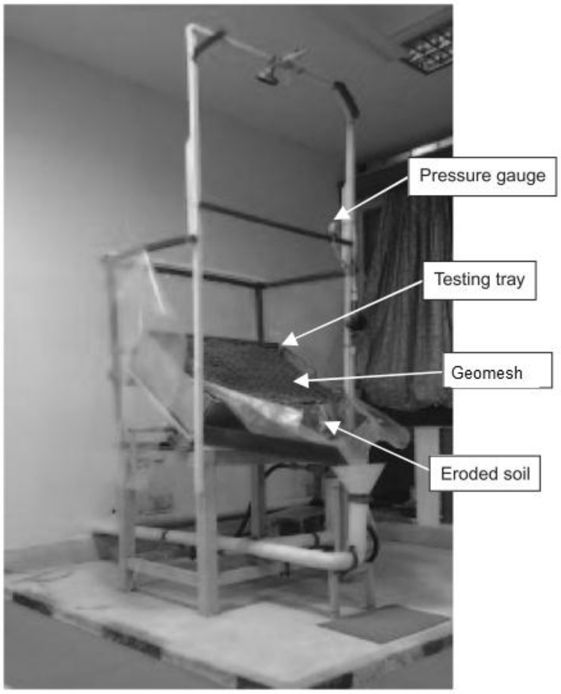


***Fig. 2: Bench scale setup to perform erosion control test*.**

The erosion control performance of coir and jute geomeshes was tested based on ASTM D 7101 using a bench-sale setup with some modifications as shown in Fig. 2 [17]. Since the geomeshes studied are open woven structures with larger mesh opening size of 17-21 mm, the test core of 20 cm diameter specified in ASTM D7101 were replaced by a test tray 75 cm in length, 50 cm in width, and 25 cm in depth [18]. The test trays were filled with 2 cm of sand at the bottom and with 20 cm of soil to be tested (Shiwalik soil) at the top [10]. Testing was carried out at three different angles of soil slope 15°, 30°, and 45°. The testing trays which contain settled soil were placed at the required angle of slope and covered with and without geomeshes. Rain splash of 100 mm/hr was simulated on the trays using standard rainfall simulators, and the eroded soil was collected for 2 minutes. The percentage difference of eroded soil from the trays with and without geomesh was calculated to know the erosion control percentage of geomesh (2).

$$\text{Erosion control \%} = \frac{(E-C)}{E} \times 100 \qquad (2)$$

Where,
E - Eroded soil without geomesh (gms)
C - Eroded soil with geomesh (gms)

IV. RESULT AND DISCUSSION

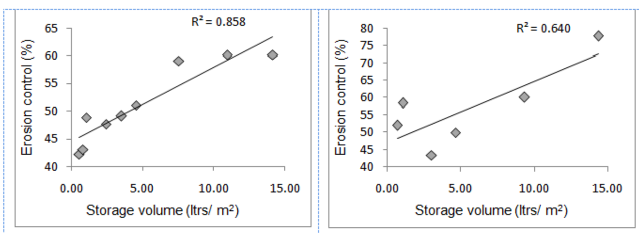
Equation (1) and (2) were used to calculate the storage volume and erosion control % of the geomeshes at different angles of soil slope (Table 2).

Table 2: Calculated storage volume and erosion control % of geomeshes

Storage volume/ Erosion control %		Coir geomesh grades			Jute geomesh grades	
		400 grade	700 grade	900 grade	500 grade	700 grade
Calculated storage volume (ltrs/m^2)	15° soil slope	7.54	10.94	14.15	9.32	14.34
	30° soil slope	2.42	3.52	4.55	3.00	4.61
	45° soil slope	0.55	0.80	1.03	0.68	1.05
Erosion control %	15° soil slope	59.1	60.2	60.2	60.1	77.7
	30° soil slope	47.6	49.1	51.1	43.4	49.8
	45° soil slope	42.2	43.1	48.8	51.9	58.4

Among different geomeshes, 700 grade jute geomesh has highest storage volume at all the angles. It is due to the highest number of weft yarns per meter in the geomesh. It was followed by the 900 grade coir geomesh which shows higher storage volume due to the larger weft yarn diameter. When compared to jute geomeshes, 400 grade coir geomesh had larger weft yarn diameter, but it has lowest storage volume due to the least number of wefts per meter.

All geomesh had better control on erosion at the lower angle of slope due to the lower overland flow and water velocity. But at higher angle of soil slope water velocity would be higher with more volume; hence the performance of geomeshes reduces at higher angle of slopes. Among different geomeshes erosion control percentage of 700 grade jute and 900 grade coir geomesh were observed to be higher at all angle of slope. It is due to its higher storage capability when compared to the other geomeshes. Further it was observed that overall performance of jute geomesh was comparatively better than the coir geomesh, due to the better drapability of jute geomesh [19], [20]. This influence is observed to be predominant at higher angle of soil slope, where the contour formation is deeper. Jute geomesh with less flexural rigidity can drape easily into the deep contours and have better contact with soil surface; it results in better control on soil erosion. Therefore at 45° soil slope, erosion control performance of 400 grade jute geomesh was observed to be higher than the 900 grade coir geomesh, even though its storage volume is higher.



(a) (b)

Fig. 3: Correlation between storage volume and erosion control %, (a) Coir geomesh; (b) Jute geomesh.

Overall, calculated storage volume was observed to have better correlation with the erosion control performance of geomeshes. Among coir and jute geomeshes, coir geomeshes were observed to have a better correlation with R^2 value of 0.858 (Fig. 3a), whereas the jute geomeshes have the R^2 value of 0.640 (Fig. 3b). It is due to the higher drapability of jute geomeshes. Because of it, even at lower calculated storage volume at higher angle of slope jute geomeshes have better performance due to better contact with soil surface. Since the jute geomeshes perform better than the calculated storage volume, the correlation between calculated storage volume and erosion control % was observed to be less. But, the stiffer coir geomesh with lower flexural rigidity have less contact with soil surface and has the only influence of storage effect to control soil erosion.

V. CONCLUSION

Erosion control performance of different commercial coir and jute geomeshes was evaluated and its correlation with calculated storage volume was studied. It was observed that coir geomesh have better correlation than jute geomesh with R^2 value of 0.858, whereas in jute geomesh R^2 value is 0.640. It is due to the high drapability of jute geomeshes which facilitate better contact with soil and result in better performance than the calculated storage volume.

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