LABORATORY SCALE EXPERIMENTS TO MEASURE SEDIMENT YIELD IN COCO-FIBER REINFORCED SLOPES

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Abstract: This study was done to evaluate the performance of coco fiber geotextiles (cocomat) and their suitability with the slope of the soil when used for soil erosion control. Three cocomat designs were used – stitched fiber cocomat (SFC) and two woven S400 and S700, each with different mesh sizes. Samples of the three designs were tested to determine their technical properties. Prior to the laboratory rainfall simulation, soil specimen was made to pass through a 4-mm sieve to achieve a uniform aggregate size distribution. Soil specimen was then placed in the study plot and treated to be representative of field conditions. The cocomat-reinforced soil plots and bare soil plots were tested using two different soil slopes. Effectivity against soil erosion was measured based on rill occurrence, sediment concentration, and sediment yield. Comparison of the performance of cocomat-reinforced plots and bare plots showed that all cocomat designs are effective in reducing soil erosion at 30º while, at 40º, S400 cocomat failed to surpass the threshold value. The experiment procedure was also outlined for easy replicability by other cocomat suppliers in testing the performance of their products.

Key words: coco-fiber, erosion control, cocomats

1 INTRODUCTION

1.1 Background

Soil erosion occurs naturally in the environment due to elements like wind, water, and gravity. However, due to rapid expansion of human activities like grazing, cutting down of trees, land conversion, etc., soil erosion could occur at a much faster rate. Impacts of soil erosion could translate to substantial environmental and economic losses. As such, it is seen as a problem that should be provided with efficient and cost-effective solutions.

One common method is the use of geotextiles. Geotextiles are permeable fabrics, synthetic or natural, that has the ability to reinforce slopes and control soil erosion. To effectively control soil erosion, geotextiles must be able to protect the soil from eroding elements like rainfall, runoff, and wind. It must also be able to trap suspended sediments in the water without hindering the water to pass through. The selection of geotextile to be used is dependent not only on its effectiveness. According to Gray and Sotir (1996), the reasons for the widespread use of the geotextiles include availability, ease of installation, familiarity, advertising and promotion, existence of standards, and acceptance of specifiers. Usual practice is to use the most suitable and economically-efficient material. Also, with the addition to environmental degradation as an aftermath of the processes done to produce synthetic materials, focus is shifted on the research and utilization of natural materials for sustained development. Natural materials can be as efficient as other synthetic materials, with less negative impacts on the environment. Natural fibers are also biodegradable and a good moisture retainer and soil enhancer. Being so, the fibers can be applied in combination with plants with good soil-retaining capability, thereby, adding to slope stability and enhancing aesthetics.

Among the natural materials used as a geotextile is coconut fiber. It is produced from coconut husks (*Cocus Nucifera*) which are waste materials in the coconut industry. The process of extracting fiber from coconut husk is called retting, wherein husks are submerged in water storage tanks for a period of time. In the process, water interacts with the fiber matrix to remove impurities (Vishnudas et al, 2006).

Coco fiber has the highest tensile strength among fibers and retains much of its tensile strength when wet. Because of its high tensile and wet strength, cocomat can be used in very high flow velocity conditions. Fibers also have high durability and slow biodegradation. These properties are attributed to its high lignin content (Vishnudas et al, 2006).

Cocomat can be woven or nonwoven. Woven mats can be of different mesh sizes. In nonwoven mats, loose fibers are arranged randomly and then mechanically entangled by needle punching. Physically, woven and nonwoven mats differ in that more open area means more loose mesh and, therefore, lower density. Nonwoven mats are normally denser than woven mats.

1.2 Objectives of the Study

This study primarily aimed to evaluate the effectiveness of cocomat in reducing soil erosion and determine the suitability of the design with the slope of the soil to be reinforced. Furthermore, this aimed to identify the technical properties of cocomat relevant for use in soil erosion control and the test methods to determine these properties. The experiment procedure was also outlined which can be used by other cocomat supplier to test the performance of their products.

1.3 Scope and Limitations

This study primarily focused on the performance of cocomat for soil erosion control. However, due to equipment limitations and time constraints, it was limited to two soil slopes and three cocomat designs. Wind effects were not considered in the analysis since experiment was done in an indoor laboratory. Also, since the soil specimen was transported from the field to the laboratory, it is assumed that treatment of the specimen was enough to be representative of field conditions. Test results are suited only to the materials that were acquired from the source and not to those by other manufacturers.

It was assumed further that the cocomat will be complemented by vegetation so that erosion will be continuously mitigated by the time the cocomat has degraded.

2 METHODOLOGY

2.1 Materials

Three designs of cocomat were used for the experiment: stitched fiber cocomat (SFC) and two woven S400 and S700. The cocomat used were manufactured by the Soriano Multi-Purpose Fiber Corporation. The summary of the technical properties of cocomat used is listed in Table 1. The experiment was done at the Hydraulics Laboratory of the Flood Control and Sabo Engineering Center of the Department of Public Works and Highways in Pasig City, Metro Manila. The rainfall apparatus used is a fixed-type simulator manufactured by Maruto Testing Machine Co., Ltd. Freesia Macros conventional oven was used to dry sediments to determine moisture content. The soil plot has an effective size of 1.5m x 1.0m (length x width). Runoff was collected in plastic containers and filtered to separate sediments through a filter cloth.

Table 1 Technical Properties of Cocomat Used

Property	**S400**	**S700**	**SFC**
Color	Brown	Brown	Brown
Mass per Unit Area (g/m²)	400	700	1790
Thickness, mm	8.17	8.08	17.81
Machine Direction	534	388	57
Cross- Machine Direction	366	427	30

2.2 Experimental Set-up

Each soil plot condition was replicated five times for every slope, giving a total of 40 experiments. Each experiment consisted of four phases. A phase of the experiment starts from collecting soil specimen up to post-rainfall simulation activities. Phase 1 involved application of simulated rainfall on bare study plot. Phase 2 involved the study plot reinforced with SFC, Phase 3 with S400, and Phase 4 S700. Each phase is further divided into two sub-phases. Sub-phase 1 was done with study plot slope of 30º and sub-phase 2 with study plot slope of 40º. The cocomat and soil specimen used for one run were replaced with another cocomat and specimen for the subsequent run. Soil morphology was observed before the soil specimen is excavated from the soil plot.

The soil plot was properly bounded by a frame made of wood with height of approximately 50cm. The runoff on the study plot was conveyed to containers through a collecting trough installed at the outlet.

2.2.1 Soil Specimen Preparation

Soil specimen must be erodible enough to favor runoff generation and rill occurrence. The specimen used was classified as ML under the Unified Soils Classification System (USCS). It has a natural optimum moisture content of 0.32 and a maximum dry density of 1.382 g/cm³.

Prior to the rainfall simulation, the soil specimen was made to pass through a 4-mm sieve. This was done to achieve uniform aggregate size distribution. The sieved soil was filled to the study plot to a height of 30cm. Soil was filled at every 10cm. and compacted using a 100N force to achieve a bulk density of 1.35 ± .05 g/cm³. To reduce variability in compacting, the soil plots were pre-wetted by spraying approximately 5 liters of water over the plot area and then left to equilibrate overnight. Soil samples from the soil plot were oven-dried for 12 hours to determine the initial moisture content.

2.2.2 Installation Methods

The soil plots were also treated so that the top surface was even. Cocomat were carefully laid to the top surface, gently stretched and pressed to come in close contact with the soil. Aluminum rods were used to secure the contact between the two. The plots were then placed on the stand configured to the desired slopes.

2.2.3 Rainfall Simulation

The rainfall apparatus has an effective rainfall area of 10.0m x 5.0m and effective rainfall height of 8.0m. The control box was adjusted to give a discharge of 5.0 ± 0.05 m^3/s corresponding to a rainfall intensity of 125.0 ± 5.0 mm/hr. Each simulation lasted for 50.0 minutes, with the runoff collected at 10-minute intervals. To verify the adjusted intensity, four rain gauges were stationed near the four corners of the soil box. Rainfall gauge measurements were taken after every 10.0 minutes.

2.2.4 Post-Rainfall Simulation Activities

Soil morphology is observed after every rainfall simulation. Used cocomat were discarded while the used soil is sun-dried for one day. Due to the limited volume of soil specimen, the sun-dried soil was used for subsequent rainfall simulation.

Runoff was collected in a plastic container. Samples and container weights were recorded. Then filter cloths were used to separate the collected sediments from the water. The filtered sediments were air-dried overnight and then weighed.

2.3. Contractors' Survey

On the usability of the cocomats against soil erosion, three Contractors were interviewed about their experience in the use of cocomats.

3 RESULTS AND DISCUSSION

3.1 Calculations

The data obtained from the experiment were runoff generation, rill occurrence, sediment concentration, sediment yield, and effectivity against erosion. Runoff generation was measured by subtracting the total weight of the containers used from the total weight of the collected runoff. Rill occurrence was visually observed after every rainfall simulation. Sediment concentration (in grams/liter) was computed for each interval of collection by dividing the mass of the air-dried sediment (in grams) by the volume of water (in liters). Sediment yield (in grams/(square meter*hour) was obtained by dividing the mass of the air-dried sediment by the surface area of the soil plot (in square meters) and time (in hours).

From the sediment yield, the effectivity against erosion was computed by dividing the difference of bare plot sediment yield and cocomat sediment yield by the bare plot sediment yield, and then multiplying by 100%.

3.2 Rill Occurrence

For the two soil plot slopes, rill occurrence was only visible on the bare plots. For the bare plots, rain dropped directly on the soil, causing soil particles to be detached and thrown into the air over a few centimeters. These detached particles were more prone to be eroded downslope. The infiltration capacity of the soil was also easily reached which consequently caused reduction in the infiltration rate. Due to this, more water moved downslope as runoff. Along its path to the outlet, runoff collected sediments. Note that the detached particles were easily dislodged by the runoff. As runoff increased and became more concentrated, it gradually formed channels that further developed into rills. For the soil plots reinforced with cocomat, direct throughfall was partially prevented. This resulted to the decrease in the transfer of the momentum from the raindrop to the soil particles which mean that less energy is available to dislodge the particles. After removing the cocomat, it was observed that the soil beneath it followed its pattern. More particles were eroded from the soil in between the ropes as compared to the soil directly under them.

3.3 Sediment Concentration and Sediment Yield

The summary of the mean sediment concentration and mean sediment yield for the 30- and 40-degree slopes are presented in Tables 2 and 3, respectively. The data is graphically represented in Figures 1 and 2.

Table 2 Mean Sediment Concentration(g/L) from Soil Plots at 30º

Time (min)	**0**	**10**	**20**	**30**	**40**	**50**	**Overall**
Bare Plot	0.00	63.74	34.01	35.59	31.95	31.09	35.67
Plot w/ 400	0.00	12.13	4.22	4.96	4.22	5.06	5.47
Plot w/ 700	0.00	11.46	2.14	2.40	1.75	1.68	3.71

Plot w/ SFC	0.00	0.02	0.00	0.02	0.09	0.07	0.04

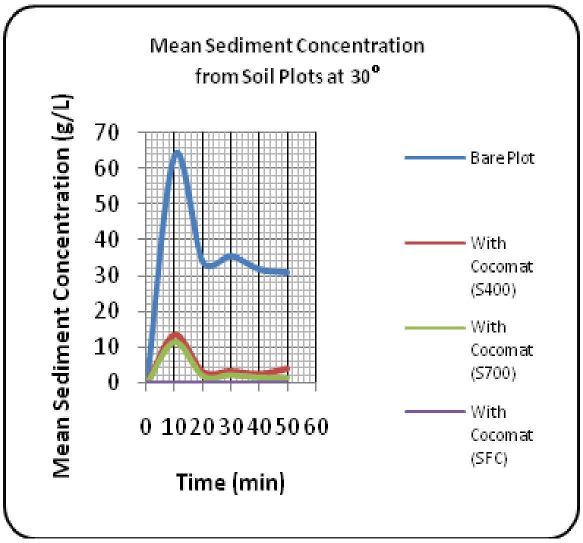

Figure 1 Sediment Concentration at 30°

Table 3 Mean Sediment Concentration(g/L) from Soil Plots at 40°

Time (min)	0	10	20	30	40	50	Overall
Bare Plot	0.00	69.42	36.62	28.46	25.00	24.80	32.54
Plot w/S400	0.00	22.49	12.73	9.41	10.41	9.90	11.36
Plot w/S700	0.00	7.01	1.50	1.31	1.57	1.94	2.31
Plot w/SFC	0.00	1.39	0.29	0.15	0.45	0.23	0.55

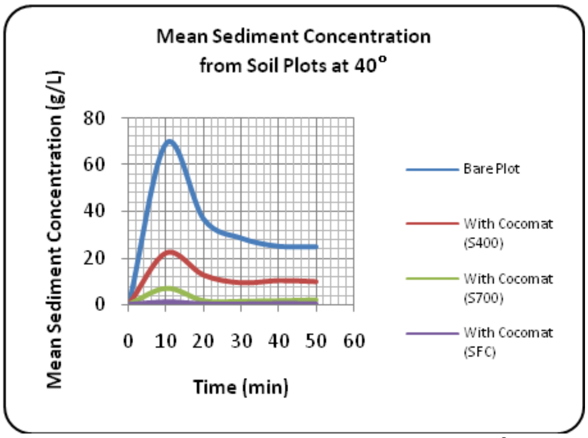

Figure 2 Sediment Concentration at 40°

From the graphs, it is evident that the cocomats were effective in decreasing the amount of sediments that flowed with the run-off. Using the bare plot as the control group, we can compare the amount of reduction of sediment yield for the different types of coco mats. The more mass of cocofiber per unit area, the more that it can hold sediments in place. For the 30^0 slope, the difference in the behavior between the SF400 and SF700 is not so marked. For the 40°, the graph shows a marked reduction when using SF700 compared to SF400. For both slopes, the stitched type (SFC) is highly effective in holding sediments, thus preventing erosion.

3.4. Contractors' Survey

The result of the surveys showed that the following contractors previously used cocomat for soil erosion control projects:

- ME Sicat Construction, Inc
- Leighton Contractors Asia
- First Worldwide Marketing Corporation

From their perspective, the advantages of cocomats over other conventional methods are

a. cheaper cost of materials;
b. materials are readily available since many suppliers are engaged in the industry; and
c. it is very good for landscaping.

However, there are also some problems – cocomats are highly combustible, inconsistency in the quality of material, lacking in skilled workers for proper installation – that they encountered.

4 CONCLUSION

The study was able to demonstrate that the cocomats were effective in preventing soil erosion based on the laboratory experiments that were used. Of the three types, the stitched or the non-woven type has the least amount of sediment yield during a run-off. The study also outlined the experimental set-up and conditions that can be used in testing the effectivity of geotextiles against erosion.

It was recommended by the contractors that workers should be trained on proper installation techniques and cocomats should be tested in accordance to specifications to prevent soil erosion for higher embankment.

ACKNOWLEDGEMENT

The authors are grateful for the support of the Soriano Multi-Purpose Fiber Corporation. Likewise, we acknowledge the assistance by the Department of Public Works and Highways for letting us use their rainfall simulator and providing the researchers with technical advice.

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