A Study on Erosion of Soil in Slopes Using Laboratory Slope Model

Lingala Rishipal Reddy, Arumairaj. P. D, S.Janaki Raman, Nancy Debora S

Abstract—Soil in hilly areas is mostly eroded due to rainfall and wind. There are different types of erosion that takes place in Slopes that are splash erosion Rill erosion, sheet erosion, gully erosion. The severity of erosion is depends on the inclination of slope, intensity of rainfall, duration of rainfall. Mostly Sand and silt will get eroded due to its cohesionless nature. This soil erosion in hilly areas causes severe damage to the vegetation and embankments. So many studies and researches are carried on to control the soil erosion. In this study a laboratory slope model is designed and fabricated for the soil erosion studies and the erosion studies has done on the siruvani hills of whestren ghat soil.

Keywords—Soil Erosion, Rainfall intensity, Silty sand

1. INTRODUCTION

In India soil erosion is the main cause of soil loss in hilly areas due to rainfall and wind. Silty Sand will get eroded easily due to its cohesionless nature of soil.When the raindrop hits the soil surface the soil particle will detach and transport to the lower position of the surface. In India soil Erosion is cause of loosing top soil. According to the estimation by the Indian Council of Agricultural Research, Soil eroded due to rain water is 53.34 million hectares annually. A working group set up by the Ministry of Home Affairs in 1971, estimated that there are 39.75 lakh hectare ravines spread in 18 states, out of which 27.65 lakh hectares (or 69.55 per cent) are in the states of Uttar Pradesh, Madhya Pradesh, Rajasthan and Gujarat. Erosion is basically the displacement of soil from one area to another. On steep slopes and embankments erosion is caused primarily by water, especially by heavy rainfall. Rain that falls onto the exposed ground dislodges soil particles which are then carried away down the slope by the flowing water. Cohesionless particles of soil will get easily detached from soil and get transported to the lower portion of the slope. The type of erosion that is going to takes place on a particular type of soil is depends on the intensity of rain and angle of inclination of the soil profile. Rill erosion and gully erosion occur for medium rainfall intensity and sheet erosion occur for heavy rainfall intensity and there are other type of erosions that takes place along with this type of erosions. Naturally this type of erosions are controlled by the roots of the trees that which it resists the soil particles from detaching. Major soil erosion will takes places on the heavily inclined slopes.

Researchers are being made various attempts to study the erosion of soil in slopes. K.R. Lekha (2004) has done a field instrumentation and monitoring of soil erosion in hilly areas stabilized by coir geotextile aided vegetative turfing, Coir in the form of nettings has proved to be advantageous for controlling soil erosion in hill slopes since it protects the seeds in the initial stage of plant growth. Raghuvanshi Ram and J.P. Shukla (2009) presented the use of sisal geotextiles in erosion control, this sisal geotextile is good in reducing the runoff volume and soil loss compared with jute and coir.Jesus Alvarez-Mozos and Eguzki Abad (2014)did a study on performance of erosion control geotextiles on steep slopes(45^0 and 60^0) with natural conditions. M.V.S Sreedhar and C.Prashanth Kumar (2017) has done a research on Laboratory evaluation of erosion control using Coir Geoproducts, in this study they have designed a bench scale laboratory model and has been performed on embankment slopes prepared in a test tank, results clearly established that, for a given rainfall intensity and duration, higher the slope angle, higher was the soil erosion, the use of coir geosynthetics showed a definite improvement in control of erosion. In the study, it is aimed to study the characteristics of soil in Western Ghats of Sirivani Hills near Coimbatore and Kerala border. Laboratory Slope model is designed and Fabricated for Erosion studies. Erosion test has been conducted by varying the parameters such as Rainfall intensity, Rainfall duration, Inclination of slope. The details of Fabricated Slope model and Soil properties of the Slope area are discussed.

2. CHARACTERIZATION OF MATERIALS

A. Soil

The soil in western ghats siruvani hills is identified as Silty sand with greater than 90% of fine sand and less than 10% of fine grained soil.The soil is poorly graded soil. The soil of silty sand(SM).As in steep slopes the soil get eroded due to rainfall mostly and type of soil getting eroded is silt and sand because this type soils are cohesion less.So this soils are easily detachable and transportable to other location by the rain water and wind.

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Table 1: Description of soil

S.No	Description of soil	Percentage
1.	Gravel	0.2
2.	Coarse sand	0.9
3.	Medium sand	29.2
4.	Fine sand	66.3
5.	Silt and Clay	3.4

Density of soil is determined by using UCC mould of size 7.5*3.5cm.UCC mould is pushed into the soil in the field and is collected by trimming the UCC mould.

Density (γ) = 1.4274 gm/cm

Dry density (γd)=1.304 gm/cm3

Moisture content is determined by using oven dry method that is 9.4% or 0.094

B. Slope model set up

The model setup that is fabricated and used in this study is shown in the Fig 1.The slope model that was designed to study the erosion rate was a geometrically distorted. As the slant length of the slope is predominant and it influences the erosion, it is given maximum prominence. The scale of length and breadth was taken as 2:1. Soil erosion is a surface phenomenon and hence the depth of the model soil profile is taken as 0..015m.The size and dimensions of the soil slope model was decided by calculating the work done due to rain drop, rainfall intensity calculations, rainfall simulator size and the load coming upon the slope model, Height of rainfall, diameter of the raindrop, Angle of inclination. In this model height, depth, length is fixed only angle can be changed. The slope angle can be varied as 10^0,20^0,30^0,40^0,50^0,60^0,$70^0$and 80^0. The change in inclination of slope is designed by using bolted connection. The output of the designed rainfall simulator is similar to the natural rainfall. Rainfall simulator is designed by using constant head method. The intensity of rainfall can be changed by maintaining the different total heads in the tank. The erosion tests were conducted using a rainfall simulator with a tank of size 1m× 0.5m× 0.2m. The discharge required for different intensities are calculated. Based on the discharge the water tank was designed to have 1.2mm diameter holes with 5 cm spacing between the holes. The bottom plate of the tank is drilled with 132 holes of 1.2mm diameter. The hole will be passed by water to form beads of rain which intended to obtain the desired rainfall intensities. The rainfall intensity is simulated by maintaining a particular head of water in the tank for an hour. The intensity is obtained by filling water tank up to a certain height, where height is intended to provide different pressures resulting intensity variation. The rainfall simulator designed by this method is called as rainfall simulator with the constant head method.

Fig 1: Slope model

Test Procedure:

- Soil is to be weighed and mixed with the water to get the field density.
- Soil is to be placed in soil box by compacting as per the density value.
- Then the Soil box is fixed in a particular angle as according to the requirement.
- Then the water is to be filled in the tank and when the particular height reached as per the intensity value then the time duration is to be noted.
- The eroded soil is to be collected at the lower portion of the soil profile by using tray.
- The soil is to be air dried and then woven dried.
- Note the weight of the dried soil that is eroded.
- By using the weight of the eroded soil erosion rate is to be calculated.

$$\textbf{Erosion rate} = \frac{\textbf{Total weight of eroded soil}}{\textbf{Area of rainfall} \times \textbf{Duration of rainfall}} \ \text{gm/m}^2\text{/hr}$$

3. EXPERIMENTAL STUDIES

A. Scheme of experiments

The tests were performed on slopes making 20º, 30º, 40º with horizontal under a rainfall intensity of 100 mm/hr (which is relatively higher intensity) over a duration of 1 hour for each test.

Test 1:

At an angle of 20^0 the soil box has been placed.The amount of soil required to fill the soil box is calculated using the field density value and volume of the soil box.

Amount of soil =89.3967 kg

Amount of water = 8.403L

Duration of rainfall = 1hr

Intensity= 90mm/hr

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Fig 2: Soil erosion test with 20^0 inclination

Test 2:

At an angle of 30^0 the soil box has been placed by using bolts. Other all parameters are similar to the test 1.Angle of inclination with 30^0 is shown in the Fig 3.

Fig 3: Soil erosion test with 30^0 inclination

Test 3:

At an angle of 40^0 the soil box has been placed by using bolts. Other all parameters are similar to the test 1and 2. The experimental study with Angle of inclination 40^0 is shown in the fig 4.

Fig 4: Soil erosion test with 40^0 slope

4. RESULTS AND DISCUSSIONS

The test results for different inclinations have been used to calculate the erosion rate for each test. Fig 6 shows the erosion rate for 20^0 ,30^0 and 40^0 slope angle. Based on the test results, the following observations have been made.

- In all the test conditions higher the slope angle, higher the amount of soil eroded.
- The eroded soil for 20^0 and 30^0 slope angle is less while compared with the 40^0 slope angle as shown in the Fig 5.
- The erosion taken place for an angle upto 30^0 is rill erosion and gully erosion.
- The erosion takes place for an angle 40^0 is sheet erosion as shown in the Fig 4.
- Among the three inclinations erosion rate for 40^0 slope angle is very severe.

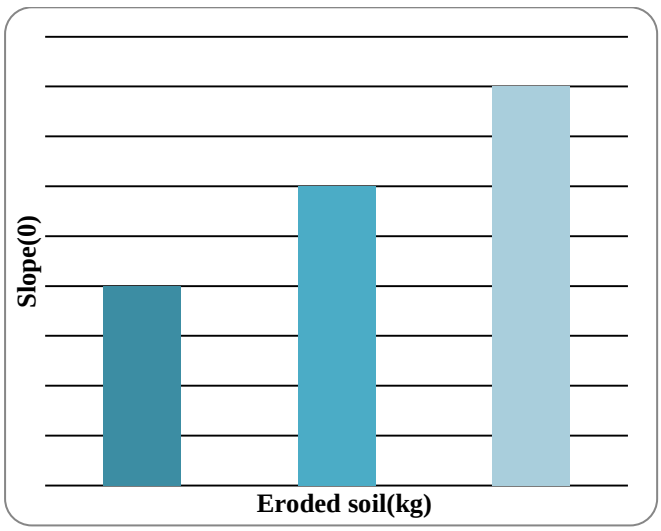

Fig 5: Eroded soil for varies inclinations

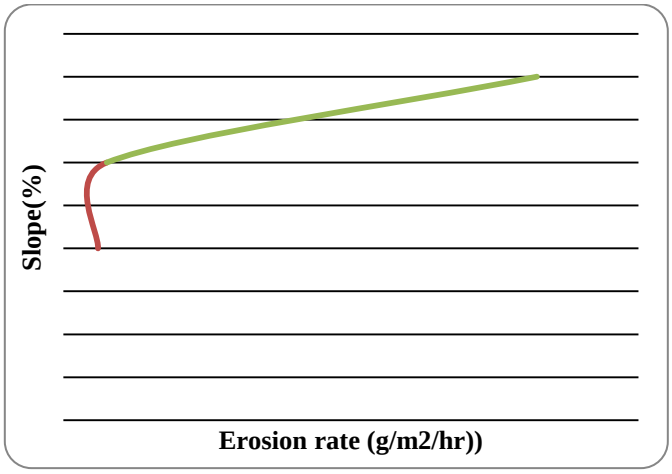

Fig 6: Erosion rate for 20^0,30^0 and 40^0 slope

5. CONCLUSION

In this paper the Experimental studies has done on the whestren ghat soil. The soil identified as Silty sand with greater than 90% of fine sand and less than 10% of fine grained soil. Erosion tests has been conducted on this soil with the field conditions by changing varies inclinations. There is a definite relationship between the angle of inclination and erosion rate, greater the slope angle higher the erosion rate. The erosion rate for 40^0 slope angle is very high compared with the 20^0 and 30^0 slope angle. So a greater protection is required to control the soil erosion for this angle.

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