A Study on the Erodibility of Lateritic Soil due to Flooding

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Abstract. Soil erosion is a process of detachment and transportation of soil materials from its original place by the action of various erosive forces. Erodibility of soils is referred to as the vulnerability of the soils to get eroded. Laterite soil is one of the major types of soil found in Kerala, which is rich in iron and aluminium content. So, the present study aims at identifying the key parameters affecting the erodibility of lateritic soils during floods as well as studying its effects on lateritic slopes. Also, the study focuses on the measurement of quantum of erosion by developing a suitable test set- up. The flood parameters are considered as the key parameters for the erodibility study. The test set-up consists of a tank with a lateritic slope inside, an inlet tank (storage tank) and a sediment collecting tank. Water is allowed to flow from the inlet tank towards the lateritic slope and the water along with eroded soil is collected in the sedimentation tank after passing through a strainer. Tests are carried out under various flood parameters such as the velocity of flood water, the height of flood water and duration of water flow at a slope of 2.5:1 maintaining a bulk density of 18 kN/m³. The quantum of erosion is measured in terms of the total weight of the eroded material. The variation in the erosion rate under varying flood parameters are studied**.**

Keywords: · Erodibilty · Lateritic Soil · Flood Parameters · Geometric Parameter.

1 Introduction

Soil erosion is a process of detachment and transportation of soil materials from its original place by the action of various erosive forces. Erodibility of soils is referred to as the vulnerability of the soils to get eroded. Erosion of soil is due to the movement of various water bodies, winds, deforestation, etc. Soil erosion affects agriculture, damages infrastructure, desertifies arid & semi-arid areas, etc. Laterite soil is one of the major types of soil found in Kerala, which is rich in iron and aluminium content. Lateritic soils are abundant in Kerala and during the 2018 floods in Kerala, lateritic slopes were subjected to drastic failure.Kerala was affected by severe floods from 8 August 2018 due to unusually high rainfall during the monsoon season. The flood resulted in over 483 deaths and 14 missing. The floods also had adverse impacts on properties and structures.

2 Literature Review

Shaikh et al. (1988) created empirical equations to gauge the disintegration rate of compacted unsaturated montmorillonite clay. These empirical equations are a function of the sodium adsorption ratio and tractive stress. Wan and Fell (2004) introduced an empirical equation to measure the erosion by presenting the term erosion rate index, which estimates the rate of erosion, with the assistance of tests like Slot erosion test and Hole erosion tests, developed by the authors. It was also shown that the rate of erosion is dependent on the soil fines and clay-sized content, plasticity, and dispersivity, compaction water content, density, degree of saturation, clay mineralogy, and possibly the presence of cementing materials such as iron oxides. Indraratna et al. (2008) conducted erosion tests by utilizing a “Process Simulation Apparatus for Internal Crack Erosion” (PSAICE). To ceaselessly gauge the erosion rate, an in-line process turbidity meter with an overall range of 0-3500 NTU was fixed near the downstream side of the soil example to constantly screen the effluent turbidity at the time of erosion test. The turbidity values were then used with the relationship between the concentration of solids (kg/m^3) and turbidity (NTU) to calculate the erosion rate. The effluent was weighed with an electronic balance for continuous flow rate measurement. An empirical equation was then established to evaluate the erosion rate of chemically stabilized soils. As indicated by Indraratna et al. (2013), the expression for the rate of erosion of silty sand is based on the principle of conservation of energy. The authors inferred that the rate of erosion can be found out if the packing arrangement of soil particles in compacted samples, shear characteristics, mean flow velocity, mean particle size, and the specific gravity of the soil are known.

3 Methodology

The proposed methodology for the present study is shown in Fig. 1.

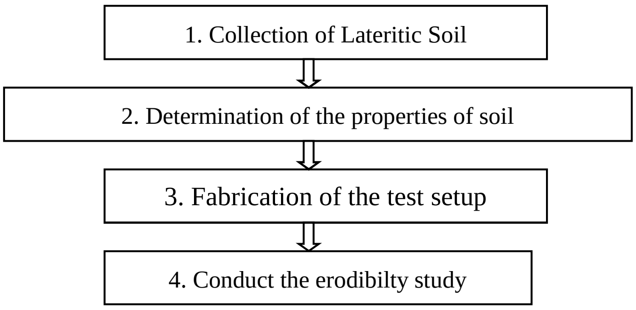

Fig. 1. Proposed Methodology

3.1 Test Soil

Laterite soil is one of the major types of soil found in Kerala and most of the slopes and embankments consist of this soil. Moreover, lateritic slopes and embankments were severely affected during the 2018 Kerala floods. So, the type of soil considered for the erodibility study is the laterite soil and it is collected from Balaramapuram in Trivandrum district, Kerala.Laterite soil is rich in aluminium and iron content. Due to the presence of high iron oxide content, almost all the laterites are red in color. Table 1 shows the properties of the laterite soil collected for the study. It is observed that the soil has no gravel-sized particles and the plasticity of the soil is low. The optimum moisture content and maximum dry density were found to be 18% and 16.75 kN/m^3 respectively.

Table 1. Properties of Test Soil

Specific Gravity	2.41
Percentage of Gravel (%)	0
Percentage of Sand (%)	59
Percentage of Silt (%)	22
Percentage of Clay (%)	19
Liquid Limit (%)	34
Plastic Limit (%)	26
Plasticity Index (%)	8
O. M. C. (%)	18
Maximum Dry Density (kN/m^3)	16.75

3.2 Test Setup

A test setup is fabricated for conducting the erodibility study of lateritic soils. The test setup consists of three primary parts, 1. An inlet tank to store water at a head, 2. A test tank where erosion of the lateritic slope takes place and 3. A collecting tank with a sieve to collect the eroded soil. The primary parts of the test setup are shown in Fig. 2, Fig. 3 and Fig. 4.

Fig. 2. Inlet Tank

Fig. 3. Test Tank

Fig. 4. Collecting Tank

A 0.3 m^3 PVC water tank is used as the inlet tank to store the water required for conducting the test. This tank is placed on a movable scaffolding, which enables to conduct the test at different velocities by varying the head difference between water levels in the inlet tank and test tank. A plastic hose connected to tap is used for filling water in the inlet tank. A test tank is made using acrylic glass of dimensions 0.8 m x 0.5 m x 0.6 m. The test tank has three inlet PVC pipes of 25.4 mm diameter and an outlet PVC pipe of 50.8 mm diameter. The test tank and the inlet tank is connected using 25.4 mm diameter PVC pipes.

The collecting tank has a dimension of 2.44 m x 1.55 m x 0.62 m. It was made of MS steel sheet and was welded together. The collecting tank has a 25.4 mm valve at its one bottom corner. There are two sieves, one inside and the other outside the collecting tank. The sieve inside the tank is placed inside a plastic bucket. On top of the sieve a polyester cloth is placed, this is to collect the soil but allows the water to pass. If the eroded soil does not get collected by the sieve inside the tank due to the overflowing of the bucket, it will be get collected in the sieve placed outside the tank.

3.3 Test Procedure

The properties of the test soil were determined including the specific gravity, particle size distribution, consistency limits, optimum moisture content, etc. The test soil was filled in the test tank with a slope 2.5:1 maintaining a bulk density of 18 kN/m³. After filling and compacting the soil in the test tank, experiments were conducted to study the effects of the flood parameters on the quantity of erosion. The flood parameters considered are the duration of the flood, the height of flood and velocity of the flood. Tests are conducted by keeping two parameters as constant while the third parameter is varied. After each experiment the total weight of eroded soil was measured. Using this the rate of erosion was computed.

4 Results & Discussion

The various height of the flood, duration of flood and velocity of flood considered for the study are shown in Table 2.

Table 2. Flood Parameters

Height of Flood (m)	h/3 = 0.08	2h/3 = 0.16	h = 0.24
Duration Of Flood (minutes)	5	10	15
Velocity of Flood (m/s)	0.42	0.45	0.47

Each experiment is repeated three times and the mean of the three rate of erosion was calculated.

4.1 Height of Flood

Here, the duration and the velocity of the flood were kept constant and the height of flood is varied. The duration of the flood was 5 minutes and the velocity of the flood was 0.42 m/s. Tests are conducted at three different heights, h/3 (0.08 m), 2h/3 (0.16 m) and h (0.24 m). The variation in the rate of erosion with the height of flood is shown in Fig. 5.

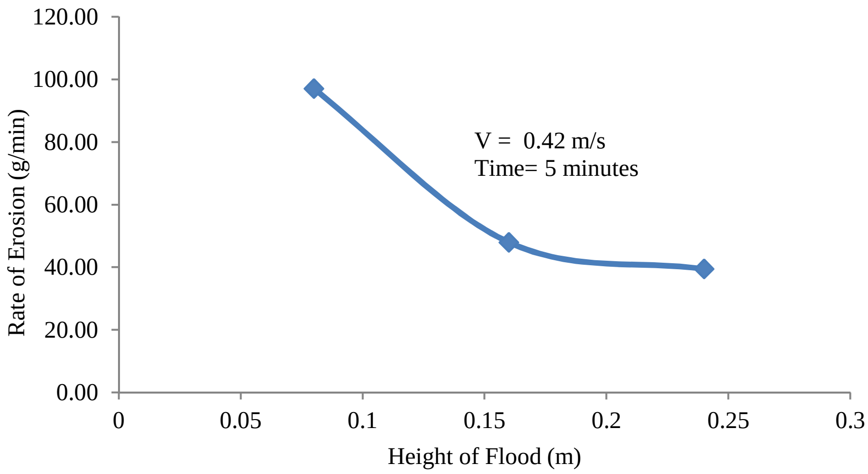

Fig. 5. Variation in the rate of erosion with height of flood

The trend shows a non-linear decrease. This is because the Toe failure is predominant at low heights of flood.

4.2 Duration of Flood

Here, the velocity and height of the flood were kept constant and the duration of flood is varied. The flood velocity was 0.42 m/s and the height of flood was 2h/3 = 0.16 m. The tests are conducted at three different durations, 5, 10 & 15 minutes. The variation in the rate of erosion with the duration of flood is shown in Fig. 6.

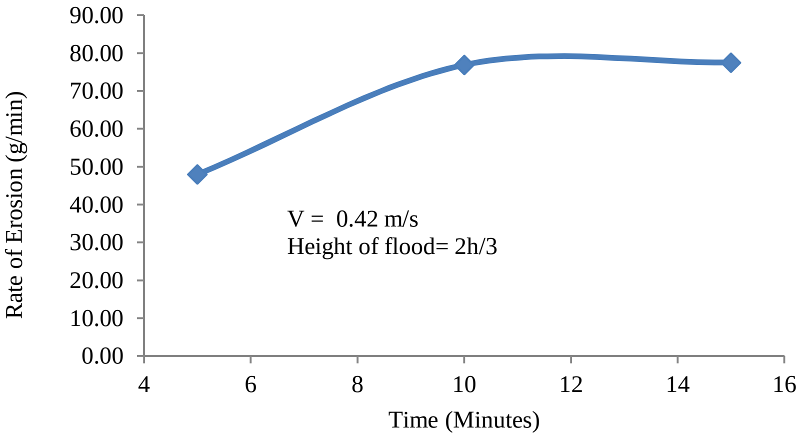

Fig. 6. Variation in the rate of erosion with duration of flood

The trend shows a non-linear increase. This is because as the duration of flood increases, the amount of eroded soil increases hence the rate of erosion increases.

4.3 Velocity of Flood

Here, the duration and height of the flood were kept constant and the velocity of the flood is varied. The duration of the flood was 5 minutes & the height of flood was 2h/3 = 0.16 m. The tests are conducted at different velocities, 0.42 m/s, 0.45 m/s and 0.47 m/s. The variation in the rate of erosion with velocity of flood is shown in Fig. 7.

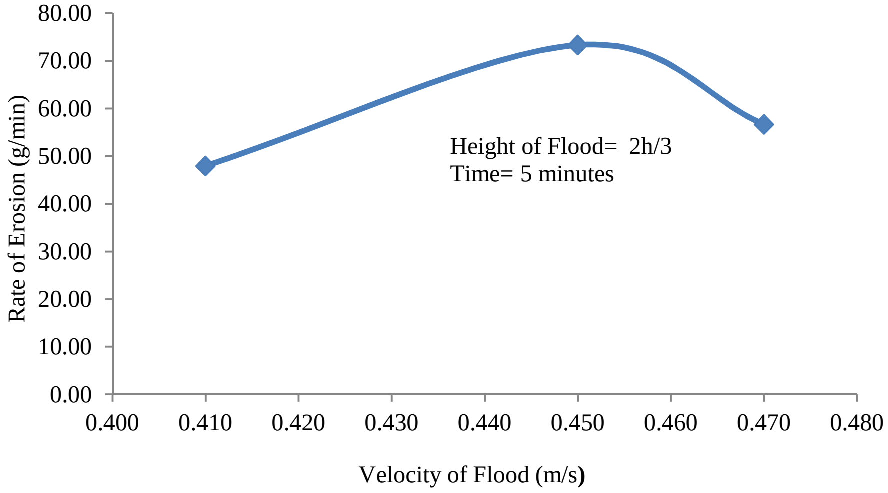

Fig. 7. Variation in the rate of erosion with velocity of flood

The rate of erosion first increases and then decreases with increase in velocity.

5 Conclusion

Laterite soil is one of the major types of soil found in Kerala and most of the slopes and embankments consist of this soil. Moreover, lateritic slopes and embankments were severely affected during the 2018 Kerala floods. So, the type of soil considered for the erodibility study is the laterite soil and it is collected from Balaramapuram in Trivandrum district, Kerala. Experiments were conducted to study the effects of the flood parameters on the quantity of erosion.The flood parameters considered for the experiments are the duration of flood (5, 10 & 15 minutes) height of flood (h/3 = 0.08 m, 2h/3 = 0.16 m and h = 0.24 m) & velocity of flood (0.42 m/s, 0.45 m/s & 0.47 m/s). Two parameters are kept constant while the third parameter is varied. After each experiment the total weight of eroded soil was taken after each experiment. Then the rate of erosion was computed.

The following conclusions were inferred-

1. The Flood parameters affecting erodibility of lateritic slopes during floods were identified namely- Height of flood, Duration of flood & Velcoity of flood.
2. Rate of erosion decreased by 59.34 % when height of flood increased from 0.08 m to 0.24 m.
3. Rate of erosion increased by 61.62 % when duration of flood increased from 300 seconds to 900 seconds.
4. Rate of erosion increased by 52.93 % when velocity of flood increased from 0.42 m/s to 0.45 m/s.
5. Rate of erosion decreased by 22.73 % when velocity of flood increased from 0.45 m/s to 0.47 m/s.

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