Investigation Into the Role of Soil Parameters onthe Erodibility of Soils

Athulya G S[1,(A)] ;Kannan K[2,(B)], Soorya S R[3,(C)]
[1]PG Student, Department of Civil Engineering, Marian Engineering College
[2]Assistant Professor, Department of Civil Engineering, Marian Engineering College
[3]Assistant Professor, Department of Civil Engineering, Marian Engineering College

***Abstract*: Soil erosion is a process that impacts bridge scour, meander migration, levee overtopping, internal erosion of earth dams, highway embankments surface erosion, cliff retreat, beach erosion, and more. These problems often lead to costly repairs and sometimes even loss of life. This article explores the key factors on which erodibility of soil depend upon and tries to establish a functional correlation between key parameters. Erosion function apparatus (EFA) tests from literatures are made use of to evaluate the resistance to erosion of soils. The EFA is a laboratory device used to measure the erosion function of a soil, which depends on soil erosion rate and the velocity of water. Regression analysis was performed on soil samples to establish a linear relation between the erosion rate and shear stress and to determine the slope and erosion rate axis intercept of the linear relation. Thus, the relationship derived from this study is conducive to effectively predicting the erosion rate of soil without performing hydraulic experiment set up, such asa flume test.**

Keywords: Soil erosion,Erosion function apparatus, Regression analysis

1. INTRODUCTION

Erosion is the process of removal of soil particles by water flowing over them. It impacts bridge scour, meander migration, levee overtopping, internal erosion of earth dams, highway embankments' surface erosion, cliff retreat, beach erosion, and more. These problems often lead to costly repairs and sometimes to loss of life. Solutions to arrest, or at least minimize, erosion have been proposed. The erosion countermeasures are typically classified into three categories: rigid armoring, such as concrete facing, flexible armoring such as rip rap, and soft armoring such as vegetation. The results of various tests such as wet sieve analysis and hydrometer analysis, EFA test are being collected from literature. These results are analyzed and compared to arrive at a conclusion and scope for future work.

2. MATERIALS AND METHODS

Soil used in this study: Datas based on soil samples were collected mainly from literature of Journal of Geotechnical and Geoenvironmental Engineering. The soil samples used in the reference journal (Shafii et al.,2019) are collected from three distinct regions. As per the reference journal (Shafiiet al.,2019) the sand used was fine sand that passed through U.S Standard Sieve No. 40. The silt and clay were collected from the UMR Geotechnical Laboratory. Both silt and clay are soil passing through U. S. Standard Sieve No. 200.The dry sand, silt, and clay were mixed thoroughly to get a uniform mixture, then water was added, first using a sprinkler and then by pouring. The soil mixture prepared was then compacted in Shelby tubes of 76.2 mm diameter using an ASTM compactor. The samples with 34% water content were compacted by placing equal amount of the well mixed soil composition in each layer. Four layers of about 1.5 inch thickness were compacted in each Shelby tube to obtain approximately 6 inch long samples. Extreme care wastaken during the compaction process to ensure that the sampleswere uniformly compacted. The three different soil types prepared for this study were named Soil A, Soil B and Soil C. The samples in the literature were collected according to the ASTM (D 1587 - 00) standard practice for thin walled tube sampling. The Shelby tube was driven perpendicular to the streambank to the entire tube length using the Shelby tube Header shown in Figure 1.

Fig 1. Shelby tube header

*Collection of test results :*The test results of Wet Sieve analysis (ASTM D 2217-85) and Hydrometer Analysis (ASTM D 422- 63) were made used from literature(Preetha Veeraraghavan et al.,2007) in order to get the percentage composition of sand, siltand clay of the soil samples A,B,C and also Erosion function apparatus test results were made used from literature (Shafii et al.,2019) to evaluate the resistance to erosion of soils and to establish a functional correlation between key parameters. Erosion function apparatus test (Fig 1) was originally developed by Briaud and his co-workers in

1990 (Briaud et al. 1999). Soil samples were taken using ASTM standard Shelby tubes with an outside diameter of 76.2 mm. Water, as the eroding fluid, was driven using a pump into a 1.2-m-long rectangular cross section 101.6 × 50.8 mm conduit, as shown in Figure 2. . The water flow can be adjusted using a valve, and the average water velocity is measured by a flowmeter in line with the flow. The top end of the Shelby tube is placed through the bottom of the conduit and the bottom end is connected to apiston. The piston is designed to push the sample up at a rate $\dot{z}$ so that the soil surface remains flush with the bottom surface of the rectangular cross section conduit. The rate $\dot{z}$ is the soil erosion rate.

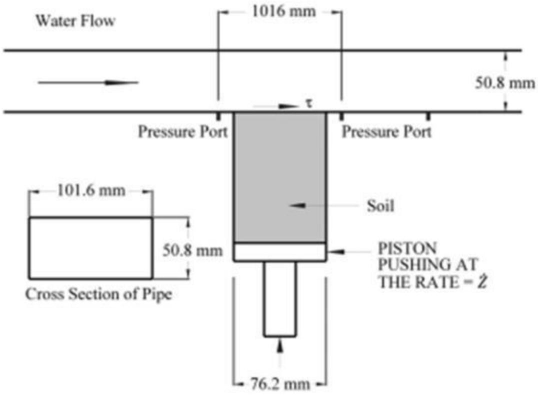

Fig 2. Schematic diagram of the EFA device

The test procedure is as follows (Briaud et al. 2001):
1. Fill the rectangular pipe with water and wait for 1 h.
2. Initiate the flow with a small flow velocity, typically 0.2 m/s.
3. Start recording time. Hold the sample surface flush with the bottom of the rectangular pipe by actuating the piston as the sample is being eroded by the water flow. Continue this until 50 mm of soil is eroded or 30 min have passed. Record the movement of the piston and thus the sample length eroded.
4. Repeat Steps 2 and 3 for a new and higher flow velocity (i.e., 0.2, 0.6, 1, 1.5, 2, 3, 4.5, and 6 m/s). The scour rate versus flow velocity is plotted. The shear stress on the eroded surface of the soil is calculated by using Moody chart (Moody 1944)

$$\tau = \frac{1}{8} f \rho v^2 \quad (1)$$

- τ = Shear stress (Pa)
- ρ = Density of water (1,000 kg/m^3)
- v = Flow velocity (m/s)
- f = Friction factor obtained using Moody chart.

Briaud (2013) developed an erosion category chart (Fig 3) to make it easier to identify the erodibility of soils. In that chart (Fig 3), the erosion categories are bound by lines in the erosion rate (mm/h) versus shear stress (Pa) plots. These charts were based on many years of EFA testing at Texas A&M University.

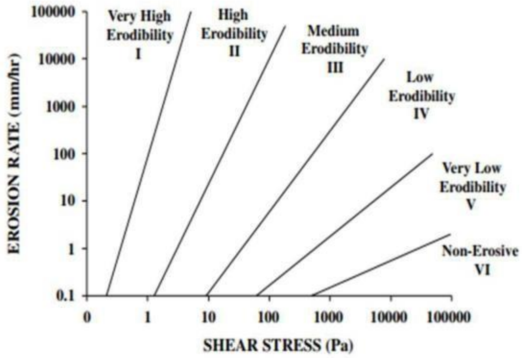

Fig 3 . Erosion category for soils and rocks based on shearstress

Soil classification: The United States Department of Agriculture defines twelve major soil texture classifications (sand, loamy sand, sandy loam, loam, silt loam, silt, sandy clay loam, clay loam, silty clay loam, sandy clay, silty clay, and clay). Soil textures areclassified by the fractions of sand, silt, and clay in a soil. Classifications are typically named for the primary constituent particle size or a combination of the most abundant particles sizes (e.g. sandy clay, silty clay). Loams are soils having roughly equal proportions of sand, silt, and/or clay in a soil sample. Texture affects many soil properties, such as infiltration, structure, porosity, water holding capacity, and chemistry. The soil texture triangle is based on grain size, that is the distribution of sand, silt, and clay in a soil. The texture triangle is shown in figure 5. The relationship to hydrologic soil group, which is used in stormwater applications, is illustrated in this image. The percentage composition obtained from literature were analyzed based on the USDA Soil Triangle Group B: silt loam or loam. It has a moderate infiltration rate when thoroughly wetted and consists chiefly of or moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures.

- Group C: sandy clay loam. They have low infiltration rates when thoroughly wetted and consist chiefly of soils with a layer that impedes downward movement of water and soils with moderately fine to fine structure.
- Group D: clay loam, silty clay loam, sandy clay, silty clay or clay. This HSG has the highest runoff potential. They have very low infiltration rates when thoroughly wetted and consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface and shallow soils over nearly impervious material.

classification. Soils are classified by the Natural Resource Conservation Service into four Hydrologic Soil Groups (HSG) based on the soil's runoff potential. The four Hydrologic Soils Groups are A, B, C and D where A's generally have the smallest runoff potentialand D's the greatest.

- Group A: sand, loamy sand or sandy loam types of soils. It has low runoff potential and high infiltration rates even when thoroughly wetted. They consist chiefly of deep, well to excessively drained sands or gravels and have a high rate of water transmission.

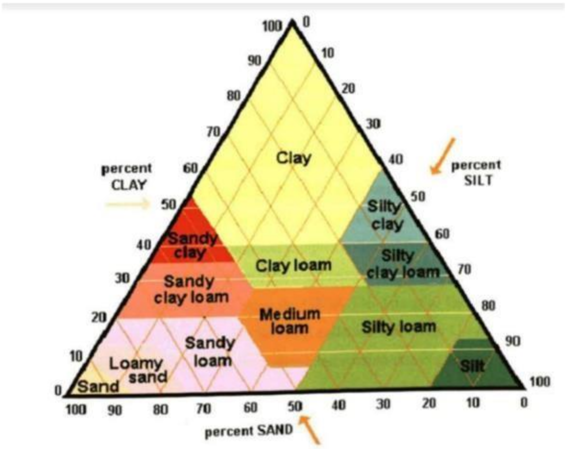

Fig 4. USDA Soil Textural Triangle

3. RESULTS AND DISCUSSION

Analysis of test results from literature: Wet sieve analysis and hydrometer analysis results of soil A,B and C collected from the literature are tabulated(Table 1) and analysed. According to the percentage composition of soil samples obtained from the literature, the samples collected were classified based on the USDA textural classification and found out that soil samples are silty loam which comes under group B of hydrologic soil groups. Erosion function apparatus test results from literaturewere also tabulated in Table 2.

By analysing the erosion function apparatus test results, a graph was plotted with erosion rate in y axis and shear stress in x axis (Fig 5) and found out that most of the points lies between 0.05 and 0.2. By comparing with the erosion category chart it was found that the soil samples A,B and C comes under medium erodibility category

Regression Analysis: Polynomial, linear, logistic regression fits were tried for the data sets. The linear fit was found to be the best for all data sets. The regression analysis was performed using MS Excel software to obtain the best fit for the data points. Figure 6 shows the linear fit for the soil sample. From the graph, the linear relationship obtained between theshear stress and erosion rate is given by

$$E = 10.389\ \tau\ - 0.324 \qquad (2)$$

Here, 10.389 is the slope of the line and 0.324 iserosion rate axis intercept

$$R^2 = 0.8042 \qquad (3)$$

where E is the erosion rate in in/hr and τ is the shear stress applied in psf. The R squared value obtained was 0.80, which indicates good correlation of the data points. From the regression analysis, it is clear that the major soil parameters that control the erosion of soil are shear stress and velocity of flow. As we obtain a linear regression equation ,the erosion rate of that soil can be estimated for any shear stress value.

TABLE 1. Percentage of composition (Shafii et al.,2019)

Soil	% Sand	% Silt	% Clay
A	32	54	14
B	9	71	20
C	11	71	18

TABLE 2. Result of EFA test (Preetha Veeraraghavan et al.,2007)

Velocity(ft/S)	Shear Stress(psf)	Erosion Rate(in/hr)
2.18	0.03	0.01
5.35	0.14	1.57
3.70	0.07	0.40
8.91	0.35	4.02
2.85	0.05	0.06
3.22	0.06	0.03
4.44	0.10	1.16
6.47	0.20	2.54
2.93	0.03	0.00
4.10	0.09	0.00
4.60	0.11	1.44
9.90	0.43	3.39
6.49	0.20	0.82
5.03	0.13	0.34
6.73	0.21	2.59
5.53	0.15	0.86

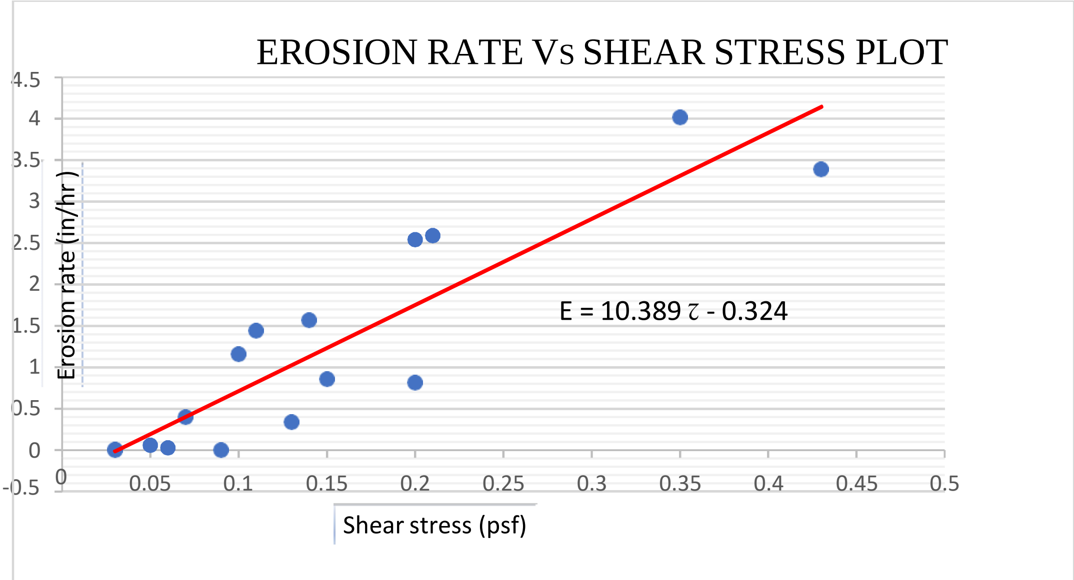

Fig 5. linear fit for soil samples

4. CONCLUSION

In the present study, the key factors on which erodibility of soil depend upon were studied and a functional correlation was established. According to results, the following outcomes are summarized:

- Soil analysis shows that the shear stress and the velocity of water are two major parameters in predicting soil erosion rates.
- Regression analysis were performed on the EFA test results to obtain the linearrelationship between the shear stress and the erosion rates of these soils

  $$E = 10.389\,\tau - 0.324$$

  where E is the erosion rate in in/hr and τ is the shear stress applied in psf.

  The R squared value obtained was 0.80, which indicates good correlation of the data points
- Once this linear regression equation is obtainedfor a soil type, the erosion rate of that soil can be estimated for any shear stress value.

The results from the present paper are based on results obtained from literature for three specific soils of same type and as such, require further cooraborative laboratory studies to ensure validity. Also, the results of the study may be extended to more soil types to further increase the applicabilityof the findings of other soils as well.

REFERENCES

[1] Andreas Becker., Christos Vrettos., "Study on erosion stability enhancement of sands using enzymes", *Environmental Geotechnics* , Pp 301–308(2014).

[2] Becker, A., and C. Vrettos.,"Study on erosion stability enhancement of sands using enzymes." Environ. Geotech. 2 (5): 301– 308(2015).

[3] Bergmann, R..,"Soil stabilizers on universally accessible trails" Washington, DC:USDA Forest Service, San Dimas Technology and Development Center (2000).

[4] Briaud, J.-L., M. Bernhardt, and M. Leclair.., "The pocket erodometer test: Development and preliminary results." Geotech. Test. J. 35(2): 342–352.(2012).

[5] Briaud, JL., A. V. Govindasamy, and I. Shafii.,"Erosion charts for selected geomaterials." J. Geotech. Geoenviron. Eng. 143 (10) .(2017).

[6] Shafii., Anna Shidlovskaya.,Jean-Louis Briaud.,."Investigation into the Effect of Enzymes on the Erodibility of a Low-Plasticity Silt and a Silty Sand by EFA Testing", *Journal of Geotechnical and Geoenvironmental Engineering* (2019).

[7] Moody, L. F., "Friction factors for pipeflow." Trans. ASCE 66 (8): 671–684 (1944).

[8] Preetha Veeraraghavan.,"Analysis Of Soil Erosion Based On Soil Properties" *universityof missouri-rolla.*(2007).