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Feasibility Study On Enhancement of Erosion Resistance of River Bank Soil using Lignosulfonate

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Abstract - *River bank erosion is one of the major challenges face by geotechnical engineers and geologists. It affects the socio-economic condition of society along the river bank at regular interval. River bank erosion usually takes place by two mechanisms, surface erosion and mass failure. The surface erosion is caused by the hydrological action of running water. The dynamic force of water exerted shear stress on the soil surface. Whenever the exerted shear stress is greater than binding force between soil particle, soil start to erode. This paper discusses improvement of erosion resistance of river bank soil by adding lignin (2%,4%,6%,8% and 10%). Lignin is a nontoxic material obtained as the bi product from paper industries. Erosion parameters of soil; critical shear velocity and erodibility constant are determined by Erosion Measurement Device designed and constructed in college laboratory. Direct shear test also determined to support the erosion resistance enhancement of soil. The result shows the addition of pozzolanic lignin material improves the binding forces between the particle and eventually increases erosion resistance of soil.*

Key Words: **Erosion Resistance, Critical Shear Velocity, Erodibility Constant, Erosion Measurement Device. Lignosulfonate.**

1.INTRODUCTION

The anthropogenesis and development of human race are located along the banks of rivers. Living things in the planet earth cannot be live without water Most of the past and present human settlements in the planet are located in the vicinity of rivers. One of the major sources of usable water is rivers. The rivers are the pumping vessel of a country. India is one of the country which is blessed with good number of rivers and tributaries. These rivers and tributaries are helpful in the field of agricultural and inland transport system of the country.

Soil erosion is a process of wearing away of the topsoil by the action of some physical agencies; water, wind, snow etc. The hydraulic surface erosion of river bank soil involves the loosening of the soil particles, blowing or washing away of the soil particles, and either ends up in the valley and faraway lands or washed away to the oceans by rivers and streams. Soil erosion is a natural process which has increasingly been enhanced by human activities; agriculture and deforestation. Farming area also significantly contribute to soil erosion. The flow of rivers and its tributaries causes erosion of river bed and river bank. River bank erosion would cause the riverbed to degrade, and dump sediments into receiving water body. Dumping of these sediment block the flow & which ultimately leads to the change of course of river. If erositivity of water system is high the cross section of channel become V-shape. The rate of river erosion seems maximum at headwaters zone when compared to transfer zone and depositional zone. River bank erosion had a bad effect on social, economic, health, education and sometimes political. Main areas affected by river bank erosion are loss of Arable Land, water Pollution and Clogging of Waterways, health of local communities, threat to aquatic life, destruction of infrastructures and desertification.

1.1 Mechanism of Hydraulic Surface Erosion of Soil

Bank soil erosion can be explain by two process; fluvial erosion and mass failure. Bank scour or fluvial erosion is the direct removal of soil particles by flowing water is known as fluvial erosion. It occurs when the shear force exerted by the flowing water greater than binding force between the soil particle, it may cohesion or electrochemical forces based on the type of soil material. The rate of fluvial erosion is depending on both force of the flowing water (more velocity means more shear force) and the resistance of the bank material to erosion (e.g. clay is generally more resistant to erosion than sand).

Mass failure occurs when the weight of a saturated bank is greater than the strength of the soil, causing the bank to collapse. Actually mass failure is the after effect of fluvial erosion at the bottom of the bank. Fluvial erosion creates a steeper bank angle or overhanging soil blocks. These are more unstable and likely to collapse when get saturated

1.2 Theoretical Background

Briaud et al. (2001) has been built a new apparatus called the EMD (Erosion measurement device) to measure the erosion rate of fine grained soils. Water flows through the pipe and erodes protrudes soil sample (1 mm above the bottom of the pipe). The rate at which the sample erodes is measured, and the shear stress imposed by the water on the soil is calculated. The plot of erosion rate versus shear stress is the result of an EMD test. The Intercept taken as critical shear stress and slope of trend line taken as erodibility constant.

Hanson (2001) The assessment of the erodibility of soil materials is essential. There are wide variety of test method present. The selection of particular erosion test depends upon the area of application. The designed and construct a jet erosion test. Jest erosion test is simple and transferable apparatus. The main advantage of jet erosion test is it measure in situ erosion characteristics of soil.

Vinod et al. (2010) studied internal erosional behavior of a lignosulfonate-treated dispersive soil after designing and constructing apparatus at University of Wollongong. The effectiveness of lignosulfonate-treated dispersive clay on its erosion resistance has been investigated and its advantages over traditional admixtures (cement) have been presented. Lignosulfonate is a non-toxic admixture that can stabilize certain erodible and dispersive soils effectively. It did not cause any adverse environmental impact on the ground. Test results show that the erosional parameters such as critical shear stress and coefficient of soil erosion are improved with the increase in the amount of lignosulfonate.

Kimiaghalama et al. (2015) investigate the relationship between erosion resistance and engineering properties of soil. Cohesion was the only property had strong relation with erosion parameters. But all other properties shows a specific trend with erosion parameters and not a fixed relation.

2. METHODOLOGY

Experiments are conducted in the college laboratory to study the effectiveness of enhancement of erosion resistance of river bank soil after mixing with lignosulfonate. Direct shear test, compaction test, permeability tests are conducted. The erosion characters of material are find out after design and constructing EMD (Erosion Measurement Device).

2.1 Alluvial soil

The soil material collected from bank of Mahe River, which is the border of Puducherry and Kerala. The point of collection was at the mouth of river. Sampling station experiences tremendous erosion throughout the year. Massive bank erosion is due to the presences of loose soil particle in the surface. Deterioration of soil particle is caused by the presence of salt content. It takes place when return flow of water from sea during high tide and low tide. Eventually the presence of salt water destructs the binding force between the particles. Hence soil will have eroded with very low velocity when normal flow took place.

2.2 Lignosulfonate

Lignosulfonate are lignin-based organic polymers obtained from the wood and paper-processing as a waste by-product. The main advantages of lignosulfonate over traditional stabilizers; cement, lime, slags etc. are non-toxicity, non-corrosiveness, environmental friendly, supports surface vegetation and durable binding mechanism. The amount required for the stabilization are very less, hence the problem of polluting ground water source are negligible. Lignosulfonate are planning to add 0.2%, 0.4%, 0.6% ,0.8% by weight of soil. Lignosulfonate develops a soil macrostructure that provides an excellent reinforcing effect to the soil matrix for withstanding wind and water erosion of desiccated sandy soils, thereby ensuring relatively long-term stability. (Vinod et.al 2010)

2.3 Erosion Test and EMD

Erosion from riverbank can be a related to erodibility coefficient of soil. Erodibility of a soil depend upon the erosion resistance of soil and channel profile. Erosion resistance can be expressed as functions different factors consisting of physical, geochemical and biological properties. Physical properties that affect erodibility are size of soil particle, size distribution among the soil particle, density, shear strength, water content, temperature and hydrodynamics of flowing water.

The hydraulic surface erosion can be express in terms of erosion rate of the soil and the hydraulic shear stress **τ**. The rate of erosion is proportional to the effective shear stress in excess of the critical shear stress and is written as

$$E = K_d (\tau_e - \tau_c)$$

k_d = the erodibility or detachment coefficient (m^3/Ns)
τ_e = the effective hydraulic stress (Pa)
τ_c = the critical stress (Pa)

Erosion of soil particles by flowing water may occur under the influence of both drag and lift forces. It is thus mainly hydraulic shear stress which controls the incipient motion of particles in flowing water. Before particles begin to move, a critical value of shear stress must be exceeded. This threshold value of shear stress known as critical shear stress. This critical value of shear stress can be considered as a measure of soil resistance to erosion by flowing water. Critical shear stress of soil can be easily connected to velocity of water.

$$\tau = 0.125 f \rho v^2$$

f= Friction factor obtained from the Moody chart
ρ= Mass density of water
v= Mean flow velocity
From equation we can understand the only factor depend on shear stress is velocity since rest all are constant.
Besides critical shear stress, another important parameter that characterizes soil behavior during erosion is the erodibility coefficient. It is the slope of the erosion rate versus shear stress line which can be used for calculation of erosion rates under different velocities. The erosion rate is

defined as the volume of soil eroded per unit time per unit surface area.

A laboratory apparatus was constructed according to Briaud et al. (2001) for measuring the erosion characteristics of soil.

Fig-1: constructed EMD

The procedure for the EMD test is as follows

1. Pure soil/Soil mix is filled in mould with a density of 95% of maximum dry density.
2. The prepared samples were wrapped in moisture proof bag and cured for 7 days. Insert the sample in to EMD.
3. Sample kept saturated for 30min.
4. Push the sample 0.5cm towards the flow.
5. Set the initial velocity.
6. Collect the soil (g) eroded in 15 min.
7. The collected soil, air dried and weighed.
8. Smoothen the sample surface and repeat tests for varying velocities.
9. Plot graph between soil eroded (g/min) vs velocity.
10. Draw trend line for each curve.
11. X intercept taken as Critical velocity.
12. Slope of line taken as erodibility constant.

3. EXPERIMENTAL PROGRAME

Basic engineering test are conducted according to the IS standard and dispersivity of soil determined by double hydrometer and crump test. The erosion tests are carried out using Erosion measurement device constructed in geology laboratory. The grain size distribution of soil is given in chart-1. The properties of soil were represented in table 1

Table -1: Properties of soil

S.NO	PROPERTIES	VALUES
1	Specific gravity	2.16
2	Gravel(%)	20.5
3	Sand(%)	77.3
4	Silt & clay (%)	2.2
5	MDD	1.755
6	OMC	17.18
7	Cohesion(saturated)	0
8	Friction angle(saturated)	25

According IS classification the soil designated as as SW (Well graded sands). Dispersivity of soil determined by double hydrometer test and crump test and both test result shows soil as intermediate disperse soil

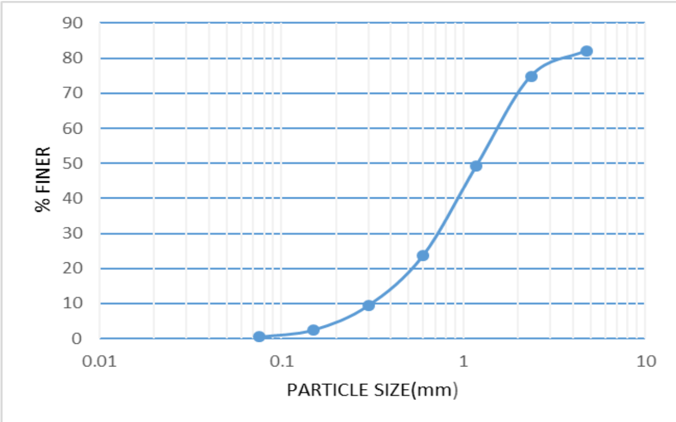


Chart -1: Particle size distribution curve

shear strength of soil measured using direct shear test. The soil /blended soil is filled in the shear box at a 0.95 of MDD in saturated condition.

Table-2: Direct shear test

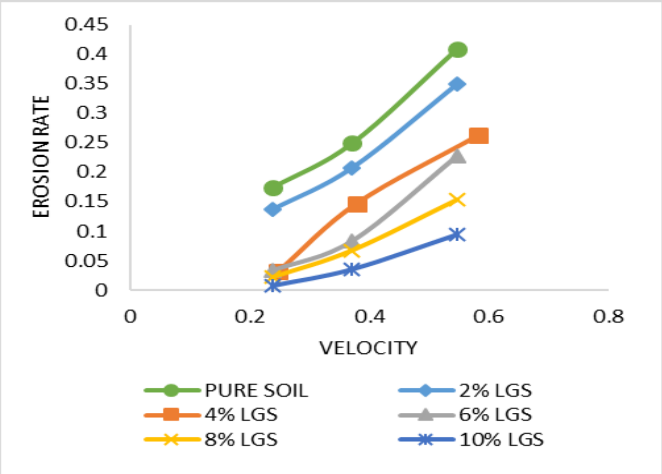
% LGS	C (kPa)	Θ^0	SHEAR STRENGTH(kPa)
0	0	25	12.9
2	3.7	18	12.7
4	3.3	22.98	15.04
6	4.9	26.1	18.47
8	3.8	28.8	16.05
10	13.73	12	19.61

(LGS)- Lignosulfonate

Erosion characteristic of soil expressed as critical velocity and erodibility constant.

Table-2: Erosion test data

% LGS	ERODIBILITY CONSTANT	CRITICAL VELOCITY(m/s)
0	0.766	0.03
2	0.697	0.06
4	0.678	0.17
6	0.644	0.2
8	0.433	0.22
10	0.283	0.24



3.DISCUSSIONS

The result from the tests shows that erosion resistance of soil improved with addition of lignosulfonate. The shear strength of pure soil is 12.9kpa enhanced to 19.61kpa. Almost 53% improvement on shear strength can be seems in soil after addition of lignosulfonate. Lignosulfonate is a pozzolanic material which provides a strong binding force between the soil particle. Hence shear strength increases.
For a good erosion resistant soil, the erosion curve should fall away from origin with low slope. The X intercept of each curve shifted to left side, which means critical shear velocity of soil increase as the increases of lignosulfonate. It can also be interpreted as shear stress exerted by the water on the soil for initiation of erosion increases as the percentage of lignosulfonate. All the curve of blended soil was fall on left side of pure soil with less slope. Slope goes on decreasing means amount of soil eroded per unit time decreasing. The pozzolanic action and filling of voids present in the soil may be reason of increases of erosion resistance of soil.

3. CONCLUSIONS

It was found that mixing of soil with lignosulfonate is best practice as compared to conventional admixtures like cement, lime and slags based on in-toxicity, ecofriendly, durability and erosion tests. Erosion test and shear strength gives positive results on the erosion resistance enhancement of soil. At 10% lignosulfonate shear strength value yield as 19.61kpa, erodibility constant decreased to 0.283and critical velocity increases tremendously.

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