Evaluation of Laterite Soil Stabilized using Waste Paper Sludge

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***Abstract*— A method of improving the properties of soil by blending and mixing it with other materials is known as Soil stabilization. In this paper an attempt is made to use waste paper sludge (WPS) as stabilizing agent in rural road construction in combination with lateritic soil (LS) and also intended to find the properties such as Compaction, Shear properties, California Bearing Ratio (CBR) and Durability, when lateritic soil is replaced with waste paper sludge at different mix proportions (2%, 4%, 6%, 8% and 10%). The result has shown that the mix proportions of waste paper sludge at 6% gives good strength.**

***Keywords*—Laterite soil, Compaction, CBR and UCC**

I. INTRODUCTION

Soil stabilization means a method of changing the properties of soil by mixing the soil with other materials or stabilizers using different methods like mechanical, alternative and chemical methods. Soil stabilization process is applied on the situations where sub soils are not suitable for construction and construction of highways, bridges, dams, runways; buildings etc.

Stabilization improves the properties of construction materials and considerable proportion of their strength is retained after saturation with water. Stabilization sometimes may cause thermal and shrinkage cracks which can allow water to enter the pavement and Strength of layer can decrease due to the reversible stabilization reaction by the attack of CO_2 to the material.

Utilization of locally available materials for construction projects will helps to save construction cost, transportation charges and protects environment. At present economic and environmental situation, more pressures are put on engineers to find out suitable methods to re-use any waste materials which are locally available so that project cost will be less and the impact of waste on the environment can be minimized. Waste materials acts as alternative materials to use as stabilizer in soil stabilization process. They showed good potential for improving strength and stability of weak soil. In this work, the possibility of using waste paper sludge as an additive to stabilize locally available laterite soil is studied.

II. SCOPE OF THE STUDY

The proposed study is conducted to examine the effect on the strength, stability and durability of laterite soil with the replacement of different proportions of WPS. Geotechnical properties of laterite soil were changed due to the replacement of Waste Paper Sludge in different proportions. In this study the application of WPS can be investigated by conducting different laboratory tests. The study will reveal the effect of waste paper sludge on stabilized soils.

III. OBJECTIVE OF THE STUDY

- To study the geotechnical properties of Laterite Soil (LS) used in the study.
- To investigate the geotechnical properties of Waste Paper Sludge (WPS) mixture with Laterite Soil.
- To determine the optimum moisture content (OMC) and maximum dry density (MDD) for the various mixtures.
- To determine the change in California Bearing Ratio (CBR), Shear strength with addition of different percentages of WPS.

IV. NEED FOR THE STUDY

Every year a large quantity of Waste Paper Sludge is getting generated and accumulated. There are no proper methods for optimum utilization of these wastes. At present paper sludge is being used as fertilizers, fuel and in landfill, but not even 10% of WPS are reutilized. If these wastes are not reutilized then they may become hazardous for environment, therefore there is a growing need for the study of best utilization of WPS. There are many attempts have been made by the researchers towards the study of reutilization of these wastes and have shown to be effective in protecting environment and protecting natural resources.

V. REVIEW OF LITERATURE

Surya et al. (2016) conducted a study on stabilized high swelling soil with 2%, 4%, 6%, 8%, 10%, 11% and 14% of WPS. Liquid limit (LL), plastic limit (PL), plasticity index (PI), Free Swelling and Compaction tests were conducted. LL, PL, PI and differential swelling index has been decreased to 34.3%, 22.48% 11.82% and 91% respectively and concluded that by adding WPS, high swelling soil properties were improved.

Usha (2016) made a study to improve the soil property by the addition of Lime and Hypo sludge in different proportions like 0%, 2%, 4%, 6%, 8% and 10%. Atterberg limits,

compaction and CBR value tests were conducted. Results shows that there will be decrease in LL, PL and PI, increase in OMC, decreases in MDD with the addition of hypo sludge in different proportion and the value of CBR is optimum at 8% addition of hypo sludge and concluded that hypo sludge and lime are the economical waste management solution.

Santosh (2016) investigated on the clayey soil by adding 2%, 4%, 5%, 6%, 7% and 10% WPS as stabilizing agent and evaluated the strength and moisture content. M.D.D decreased and O.M.C was increased by the addition of WPS. The UCS for soil increased to better strength with WPS addition of upto 5% it was the optimum value for strength to soil.

The above literature reviews not only helped in identification of the gap in the present body of knowledge but has also enabled to establish relationship of the present study with what already exist. Many studies and investigations were made by many scholars on distinct types of soil by adding different stabilizers in different proportions. By adding the stabilizers there was an improvement in the property, strength and stability of distinct type of soil.

VI. Materials Used

A. Laterite Soil

Laterite soil used in this study was collected at the depth of 1m from Balladka region which is at a distance of 5km from Sullia located in Dakshina Kannada district. Wet sieve analysis, dry sieve analysis, Atterber's limit, specific gravity and moisture content tests are conducted for the collected soil samples.

B. Waste Paper Sludge

The paper sludge for the study was collected from a recycled paper manufacturing company the South Indian Paper Mill, Nanjangud.

Figure 1. Waste Paper Sludge Sample

Figure 2 shows the methodology which is followed to achieve the objective of the study. Physical and geotechnical properties of the collected laterite soil sample and soil with the replacement of proportion 2%, 4%, 6%, 8% and 10% of WPS is determined. By the replacement of WPS to the laterite soil properties of soil will get modified. Stabilized soil specimens are tested for different curing days of 0, 7, 14, 28 and 60.

VII. Methodology

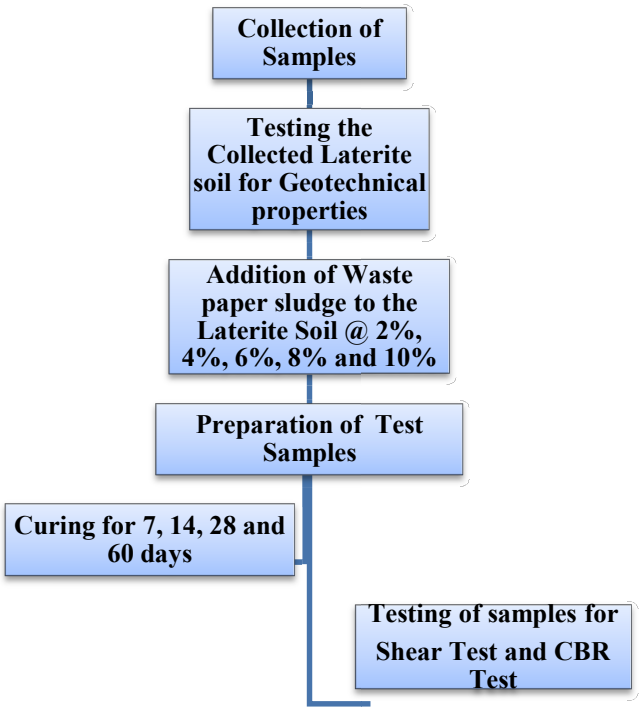

Figure 2. Methodology followed in the present study

VIII. Experimental Investigations

Many experimental works were conducted to study the strength of laterite soil and laterite soil with various proportions of waste paper sludge. The index property and engineering properties have been studied. The experiments performed were Atterberg's Limit, compaction, unconfined compression, and CBR and Durability tests. The results of different tests were noted and studied. Tests conducted to modify the property of the soil as well as soil replaced with WPS are as follows.

IX. Results and Discussions

In this study various experimental works was conducted to determine the strength of laterite soil and Laterite soil with different proportions of WPS. The engineering properties and index properties have been studied and results were compared and discussed.

A. Specific Gravity

The Specific gravity test was carried out on laterite soil and soil replaced with 2, 4, 6, 8 and 10 percent WPS by weight. From Figure 3, it was observed that the replacement of WPS in soil with varying proportions decreases the specific gravity.

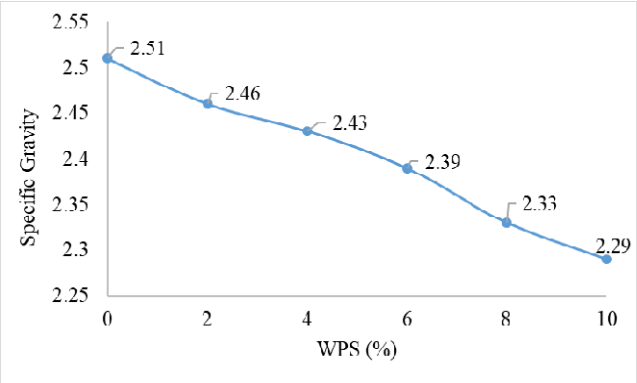

FIGURE 3. VARIATION OF SPECIFIC GRAVITY WITH VARYING PERCENTAGE OF WPS

Decrease in specific gravity from 2.51 to 2.29 of about 8.76% was observed when WPS varied from 0% to 10%. Paper sludge is a material which has lower specific gravity (1.56) than the laterite soil (2.51). Hence increase in the percentage of WPS in soil decreases the specific gravity of the soil

B. Atterberg's Limit

Atterberg's limits like LL, PL and PI tests are conducted to determine critical water content of a soil and soil with replacement of different proportion of WPS content. Results are presented in Figure 4.

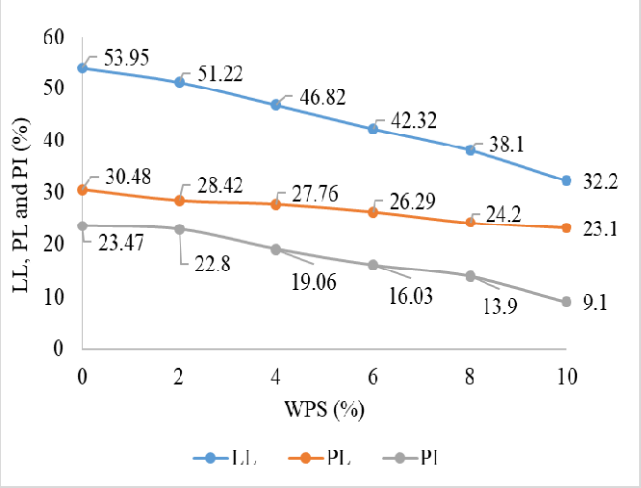

FIGURE 4. VARIATION OF ATTERBERG'S LIMIT WITH VARYING PERCENTAGE OF WPS

It is observed that the addition of WPS with varying proportions decreases the LL, PL and PI upto 40.31%, 24.21% and 61.22% respectively. This decrease in the PL, LL and PI indicates improvement in soil. Here the PI value is greater than 17% therefore the soil is highly plastic. According to the IS soil classification based on the result of LL and PI of laterite soil, laterite soil is classified as inorganic clay of high plasticity (CH).

C. Compaction Test

The compaction test was carried out on laterite soil and soil replaced with 2, 4, 6, 8 and 10 percent WPS by weight to study the behaviour of compaction. Heavy compaction tests were conducted in the present study and the results are as shown in Figure 5.

1) Effect of Compaction Effort on Water Content

Based on modified proctor test results the effect of compaction effort on water content of laterite soil with 0, 2, 4, 6, 8 and 10% replacement of WPS were determined. From graphical representation of Figure 5, it is clear that replacement of different proportion of WPS increased the OMC in heavy compactions. The increase in OMC 13.33 % to 18.35% is about 5.02% by the increase in the replacement of WPS to laterite soil, which decreases the content of clay and create coarser materials that requires lot of water to compact the mixture of laterite soil and WPS.

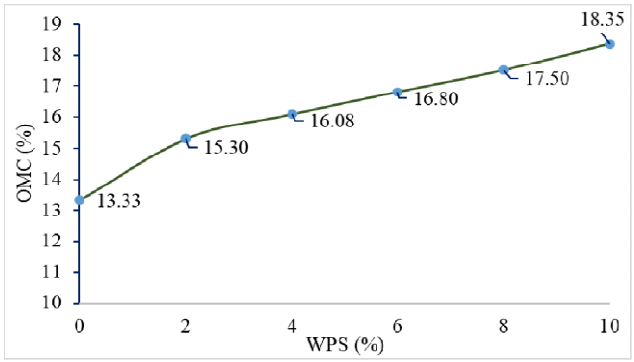

FIGURE 5. VARIATION OF OMC WITH VARYING PERCENTAGE OF WPS

2) Effect of Compaction Effort on Density of Soil

Based on modified proctor test results the effect of compaction effort on density of laterite soil with 0, 2, 4, 6, 8 and 10% WPS were determined. From graphical representation of Figure 6 it is clear that MDD increases with the increase in percentage of paper sludge up to 6%. It was noticed that beyond 8% replacement of paper sludge MDD decreases.

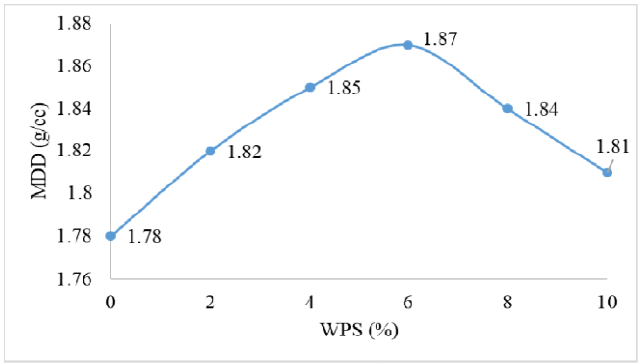

FIGURE 6. VARIATION OF MDD WITH VARYING PERCENTAGE OF WPS

D. The increase in MDD from 1.78 to 1.87g/cc are about 5.05%. The value of MDD increases because the soil voids are filled by paper sludge hence density increases so the MDD also increases. After addition of more than 8% paper sludge there was increase of void ratio due to separation of soil grains caused by paper sludge. As a result, MDD decreases.

E. Unconfined Compressive Strength Test

The variation in the UCC of the laterite soil with the replacement of varying proportion of WPS for the curing period of 0, 7, 14, 28 and 60 days were calculated and presented.

Figure 7 shows variation in UCC values of the soil sample prepared by using OMC and MDD values of Heavy compaction. This result shows that the UCC values get increases from 320.42 to 500.52 kN/m2 about 56.20%, 340.12 to 545.63 kN/m2 about 60.42%, 360.82 to 609.85 kN/m2 about 69.01%, 380.12 to 660.82 kN/m2 about 73.84% and 399.20 to 712.54 kN/m2 about 78.49% for 0, 7, 14, 28 and 60 days respectively upto 6% and after it get decreases.

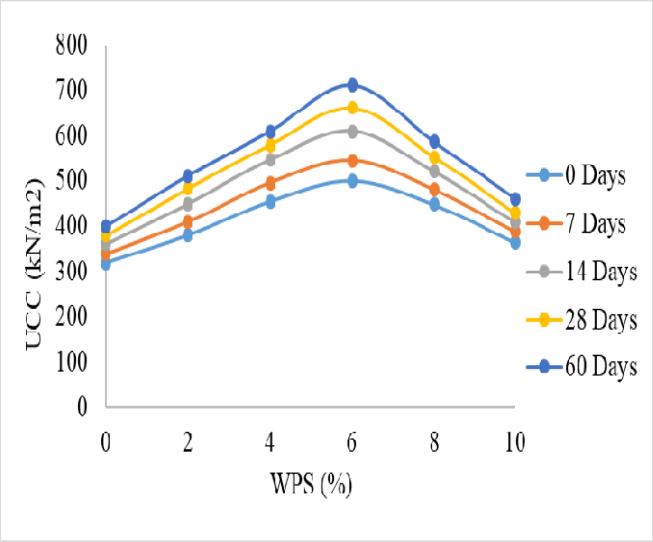

FIGURE 7. VARIATION OF UCC WITH VARYING PERCENTAGE OF WPS

Strength and stiffness of soil increases with the increase in the replacement of WPS and at the same time the loss of ductile or cohesive nature of the soil will occur. As the axial strain decreases soil become more brittle with increase in the replacement of WPS contents. Hence After 6% addition of WPS UCC values considerably get decreases.

F. California Bearing Ratio Test

The soil loses its strength in the presence of water in it. Hence it is necessary to know the strength of soil under worst condition. To know the behaviour of soil under worst condition CBR test was conducted in soaked condition. The variation in the CBR in soaked condition of the laterite soil with the replacement of varying proportion of WPS for the curing period of 0, 7, 14, 28 and 60 days were calculated.

Figure 8 shows variation in CBR values of the soil sample prepared by using OMC & MDD values of heavy compaction.

This results show that the CBR values get increases with increase in replacement of WPS. With increase in replacement of different percentage of WPS the CBR value also get increases about 5.45%, 5.58%, 5.64%, 5.76% and 5.98% that is about 5 to 6 times the soil for 0, 7, 14, 28 and 60 days respectively upto 10%.

The increase in the CBR value is because of the pozzolanic reaction and the cementation process of WPS. Here not much increase in the CBR takes place. Replacement of WPS increases the CBR value so further study have to be made to know the bearing capacity of WPS stabilized soil with more replacement of WPS. By this particular study because of only 5% increase in CBR value, it can be concluded that the WPS stabilized soil can be used for foundation in Building construction.

G. Durability Test (Wetting Drying Method)

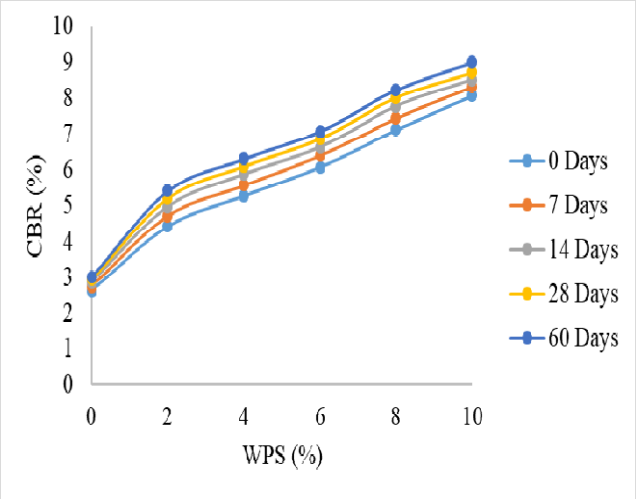

FIGURE 8. VARIATION OF UCC WITH VARYING PERCENTAGE OF WPS

The increase in the CBR value is due to the pozzolanic reaction and the cementation process of WPS.

No. of Cycles	Percentage Weight Loss with Respect to WPS Content											
	0%		2%		4%		6%		8%		10%	
	Wetting	Drying	Wetting	Drying	Wetting	Drying	Wetting	Drying	Wetting	Drying	Wetting	Drying
1	Collapse		-1.82	4.78	-1.76	4.77	-2.06	5.17	-2.48	5.40	-2.83	7.80
2			Collapse		Collapse		-1.33	5.38	-1.90	5.72	-2.90	10.62
3							Collapse		-2.80	7.60	-3.12	13.52
4									0.39	9.89	-1.85	14.52
5									Collapse		-1.62	16.22
6											0.79	20.82
7											Collapse	

The weight loss after each wetting & drying for each cycle was calculated separately. The specimens were weighed and measured after each cycle to obtain soil WPS, moisture changes and volume changes (swelling and shrinkage). The results indicate that Specimens with 8% and 10% replacement of WPS could survive up to 5 and 7 cycles respectively whereas specimens with 0, 2, 4 and 6% WPS replacement failed in earlier cycles.

X. CONCLUSIONS

In this study based on the experimental investigation, following conclusions were being made

- Increase in the replacement of different proportions of WPS decreases the LL, PL and PI
- Optimum moisture content increases significantly and Maximum dry density decreases for with the increase in the replacement of different proportions of Waste Paper Sludge to the laterite soil. Increase in OMC will decreases the clay content and forms coarser materials that needs more water to compact the mixture of laterite soil and WPS. MDD decreases with the increase in the replacement of WPS because of its lower specific gravity.
- Strength and stiffness of soil increases with the increase in the replacement of WPS and at the same time the loss of ductile or cohesive nature of the soil will occur. As the axial strain decreases soil become more brittle with increase in the replacement of WPS contents. Hence After 6% addition of WPS UCC values considerably get decreases.
- The increase in the CBR value is due to the pozzolanic reaction and the cementation process of WPS.
- The durability test results indicate that Specimens with 8% and 10% replacement of WPS could survive up to 5 and 7 cycles respectively
- Waste paper sludge is an advanced material which can be used as ground improvement material and this is an effective and efficient solution for waste management.

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