Innovative Soil Stabilization: Harnessing Waste Materials for Sustainable Development

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Abstract— In a well-organized environment, disposal of waste poses a great threat as regards where and how to effectively dispose of the waste material without any harmful effect to society. In recent times, utilization of solid waste materials in soil stabilization has gained eminence as an effective means to manage waste generated from various industries. Soil stabilization is a crucial process in civil engineering aimed at enhancing the physical and mechanical properties of soil. This research investigates the effectiveness of various waste materials in stabilizing soil. The study explores the utilization of industrial by-products such as Wastepaper Sludge, Sawdust Ashes, and Crushed Glass Waste. The findings indicate that these waste materials significantly improve soil strength, reduce permeability, and provide an eco-friendly alternative to traditional soil stabilization methods.

In this paper, a comparative study has been performed to examine the influence of waste materials over the traditional methods on the properties of the soil sample.

Keywords— soft soil, stabilization, stabilizer, waste, environment

Introduction:

Soil Stabilization is the process of enhancing the engineering properties of soil to improve its strength, durability, and load-bearing capacity. This is typically achieved by adding various materials to the soil, to alter its physical and mechanical characteristics.

This review paper delves into the innovative paradigm of utilizing waste materials for soil stabilization, a promising avenue towards sustainable development in construction projects. By repurposing waste materials that would otherwise end up in landfills or pollute the environment, this approach not only addresses the challenge of waste management but also offers a cost-effective and eco-friendly alternative to conventional soil stabilization techniques.

The traditional methods of soil stabilization typically involve the use of cement, lime, or chemical additives, which not only contribute to carbon emissions but also entail high production costs and energy consumption. Moreover, the extraction and processing of these materials often result in ecological disturbances and habitat degradation.
This paper aims to provide a comprehensive review of recent advancements and methodologies in soil stabilization using waste materials. It explores the diverse range of waste materials, including industrial by-products, agricultural residues, and recycled materials, that have demonstrated potential for enhancing soil properties and promoting long-term stability. Additionally, the paper

examines the technical feasibility, performance characteristics, and environmental implications of utilizing these waste materials in soil stabilization applications.

Literature Review:

Nidhi Singh, Shruti Singh Bisen et al (2021) have added 2 %, 4 %, 6 %, 8 % and 10 % Waste Paper Sludge to the soil and conducted for analysis of strength properties of soil. Laboratory experiments results showed that 6 % is the optimum percentage of Waste Paper Sludge (WPS) which is mixed in the soil for higher strength. OMC and MDD values decreased with the addition of WPS up to 10%.

Kalpana P. Patel, Champaneria Harshiv, Dadhaniya Priyal, Dhodiya Deep, Hunny Modi, Khatri Nishith[2] et al (2020) investigate the different percentages of waste paper sludge i.e. 2%, 4%, and 6% were used to stabilize the black cotton soil. The soil was evaluated using physical and strength performance tests such as Specific gravity, Plasticity index, Compaction; free swell index, California Bearing Ratio (CBR) and unconfined compressive strength (UCS). They observed that at the optimum percentage of 6% WPS showed an improvement in unconfined compressive strength from 0.227 kg/cm2 to 0.4079 kg/cm2. Furthermore, California Bearing Ratio values improved from 17.08% to 4.53%. In general, it was found that WPS is a suitable waste material for stabilizing Black Cotton Soil.

Hussein Karim, Makki Al-Recaby, and Maha Nsaif et al (2018) uses mixture of sawdust ashes with soft clay soils improves most other physical and mechanical properties of the soil, as expressed by a general reduction in specific gravity and maximum dry density (MDD), as well as a reduction in the compression coefficients (Cc and Cr) with an increase in SDA content. While increasing the optimum moisture content (OMC) and the undrained shear strength (cu) with the increase in SDA content. The stabilized soils (with 4 and 10% ash content) resulted in low CBR values (1.6-1.2%) which can be used as a sub-base. The SDA can be considered **as a cheap and acceptable stabilizing agent in road construction for improving most of the geotechnical properties of the soft clayey soils, as under examination.**

Nilesh S. Pawar, Tejas N. Rasal, Sourabh B. Shinde, Supriya S. Gavade, Mrunali M. Kagwade, Neha A. Wadkar et al (2021) has studied and concluded that crushed glass and wastage can be used to increase the CBR value of a soil considerably. In this study we can see that the maximum CBR value can be achieved when 5% and 10% amounts of crushed glass are added to the soil. The load carrying of the soil mixture with crushed glass is relatively more than the soil sample by itself.

Materials and Methodology:

Soil Sample

The soil sample was taken from locally available soil near the university premises and underwent a series of tests.

Wastepaper Sludge

Wastepaper sludge, a residue from paper recycling processes, presents challenges but also opportunities for sustainable utilization. It shows promise as a soil stabilizer due to its organic composition and moisture retention properties. When mixed with soil, it enhances cohesion and improves soil structure, thereby increasing stability and reducing erosion.

Additionally, its biodegradability and nutrient content can contribute to soil health and fertility over time. However, careful consideration of its composition, application rates, and potential environmental impacts is necessary for effective and sustainable use as a soil stabilizer.

Figure 1: Wastepaper Sludge at paper mill

Sawdust

Sawdust, a byproduct of woodworking, holds multifaceted utility across various industries. Sawdust offers potential as a soil stabilizer due to its ability to improve soil structure and moisture retention. When mixed with soil, sawdust enhances stability, reduces compaction, and promotes aeration, making it particularly beneficial for enhancing soil fertility and preventing erosion in agricultural and landscaping applications. However, considerations regarding decomposition rate, nutrient release, and potential impacts on soil pH should be addressed for its effective and sustainable use as a soil stabilizer.

Figure 2: Sawdust powder

Crushed Glass Waste

Crushed glass waste, a byproduct of glass recycling efforts, presents a valuable opportunity for sustainable resource management. Crushed glass can enhance soil stabilization when mixed with soil, providing improved drainage, reduced compaction, and increased permeability, thus offering a promising solution for eco-friendly construction practices.

Figure 3: Crushed Glass Waste

Plastic Limit

The plastic limit is conducted when the soil possesses much water content and loses shape called as plastic limit of soil. This test is performed until the rolling out fine grained soil reaches 3mm (about 0.12 in) by diameter, then water content is measured as it breaks down on reaching the diameter. Other methodology includes

- Standard Proctor Compaction Test
- Unconfined compression test
- California bearing ratio
- Volume shrinkage behavior of soil.

Liquid Limit

It is the water content at which the soil loses its strength, and it behaves as viscous material. The channel is made in the soil and then it is closed in 25 blows in liquid limit device which is shown in Figure For better results accuracy, test is carried out many times and the number of blows is listed.

Unconfined Compression Strength

Unconfined Compressive Strength (UCS) stands for the maximum axial compressive stress that a cohesive soil specimen can bear under zero confining stress. Unconfined compression test is one of the fastest and cheapest methods of measuring shear strength of clayey soil.

Results:

Table1: Engineering Properties of soil sample

S. No.	PROPERTIES OF SOIL	VALUES
1	Dry Density	16.89 kN/m^3
2	Optimum Moisture Content	18%
3	Liquid Limit	37.8%
4	Plastic Limit	28%
5	Plasticity Index	9.8%
6	Unconfined Compression Strength	201 kPa
7	Frictional Angle	17.5°
8	Cohesion	73.323

Table 2: Variation of engineering properties of soil sample with addition of lime

S. No.	**PROPERTIES OF SOIL**	**2%**	**4%**	**6%**	**8%**
1	Dry Density	17.05 kN/m^3	17.4 kN/m^3	17.3 kN/m^3	16.9 kN/m^3
2	Optimum Moisture Content	17.5 %	17.1 %	17.2 %	17.7 %
3	Liquid Limit	35.7%	34.8%	32.5 %	31.9%
4	Plastic Limit	26.77 %	26.2 %	25.7 %	24.8 %
5	Plasticity Index	9 %	8.6 %	6.8 %	6.5 %
6	d Compression Strength	212.2 kPa	220 kPa	218 kPa	205 kPa
7	Frictional Angle	22°	23.8°	24.6°	25.1°
8	Cohesion	75.2	78.1	76.3	74.7

Table 3: Variation of properties of soil with addition of Crushed Glass Waste

S. No.	**PROPERTIES OF SOIL**	**2%**	**4%**	**6%**	**8%**
1	Dry Density	17.5 kN/m^3	17.89 kN/m^3	18.2 kN/m^3	18.1 kN/m^3
2	Optimum Moisture Content	16.9 %	16.46 %	16.3 %	16.6 %
3	Liquid Limit	34.2%	33.90%	31.48%	29.70
4	Plastic Limit	23.9%	21.50%	18.30%	16.20%
5	Plasticity Index	10.3%	12.40%	13.18%	13.50%
6	d Compression Strength	230 kPa	250 kPa	264 kPa	258.6 kPa
7	Frictional Angle	24.8°	25°	26.2°	27°
8	Cohesion	72.04	75.7	77.10	74.35

Table 4: Variation of properties of soil with addition of sawdust

S. No.	PROPERTIES OF SOIL	2%	4%	6%	8%
1	Dry Density	16.52 kN/m^3	16.2 kN/m^3	16.35 kN/m^3	16.42 kN/m^3
2	Optimum Moisture Content	19.2%	20.10 %	21.5 %	22.30 %
3	Liquid Limit	38.5%	39%	40%	42.2%
4	Plastic Limit	31.1%	33.5%	35.8%	39.4%
5	Plasticity Index	7.4%	5.5%	4.2%	2.8%
6	d Compression Strength	205 kPa	211 kPa	220 kPa	208 kPa
7	Frictional Angle	24.8°	25°	26.2°	27°
8	Cohesion	74.20	76.10	73.05	70.50

Table 5: Variation of properties of soil with addition of Wastepaper Sludge

S. No.	PROPERTIES OF SOIL	2%	4%	6%	8%
1	Dry Density	16.2 kN/m^3	15.80 kN/m^3	15.95 kN/m^3	15.92 kN/m^3
2	Optimum Moisture Content	21.30%	22.8 %	24.20 %	25.5 %
3	Liquid Limit	37.0 %	36.20 %	34.50 %	32.70 %
4	Plastic Limit	29.10 %	30.40 %	30.80 %	31.20 %
5	Plasticity Index	7.90 %	5.80 %	3.70 %	1.50 %
6	Unconfined Compression Strength	195 kPa	202 kPa	210 kPa	204 kPa
7	Frictional Angle	24.8°	25°	26.2°	27°
8	Cohesion	76.50	77.10	79	73.70

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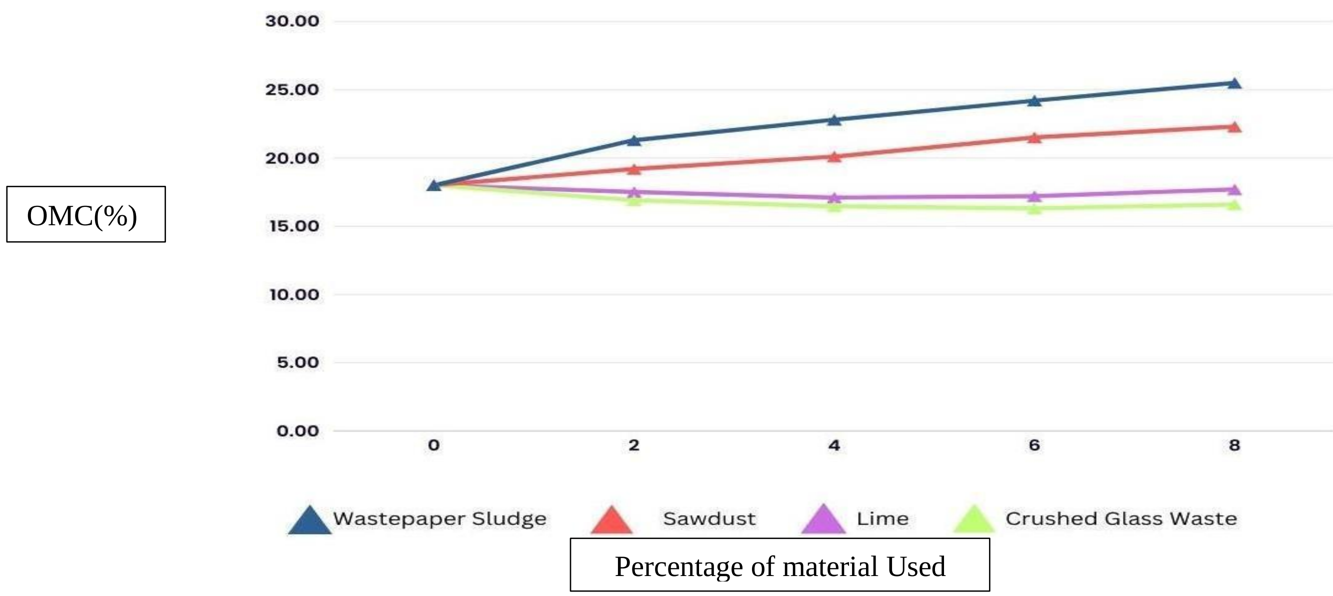

Figure 4: Comparison of Optimum Moisture Content with addition of various materials

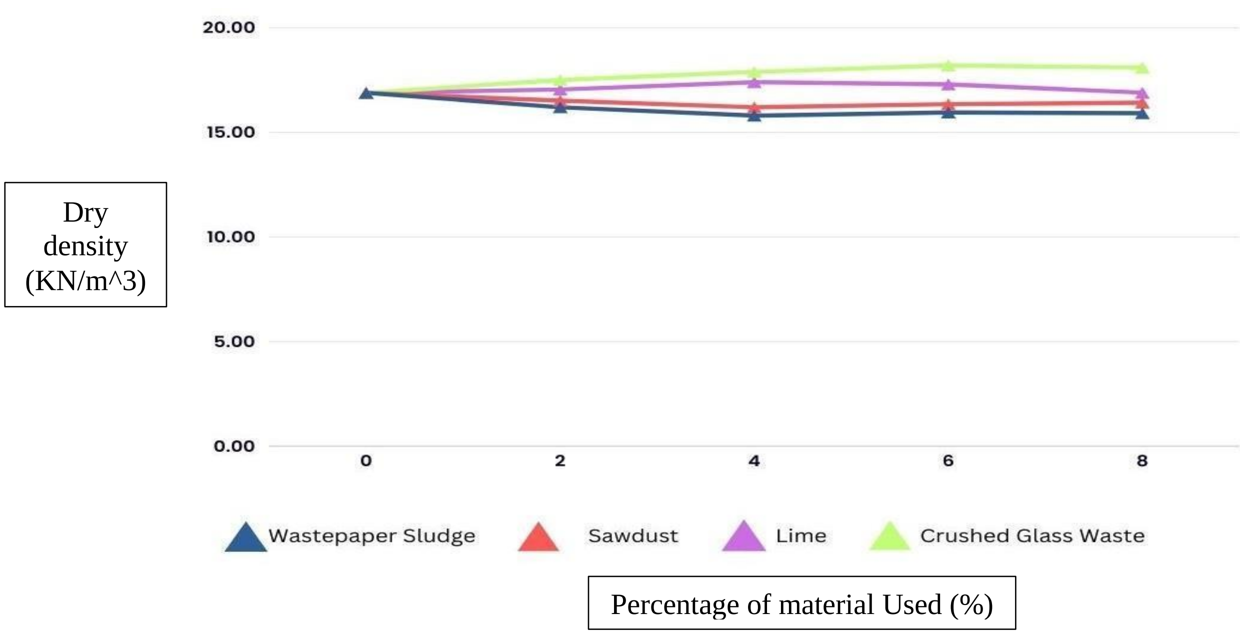

Figure 5 : Comparison of MDD with addition of various materials

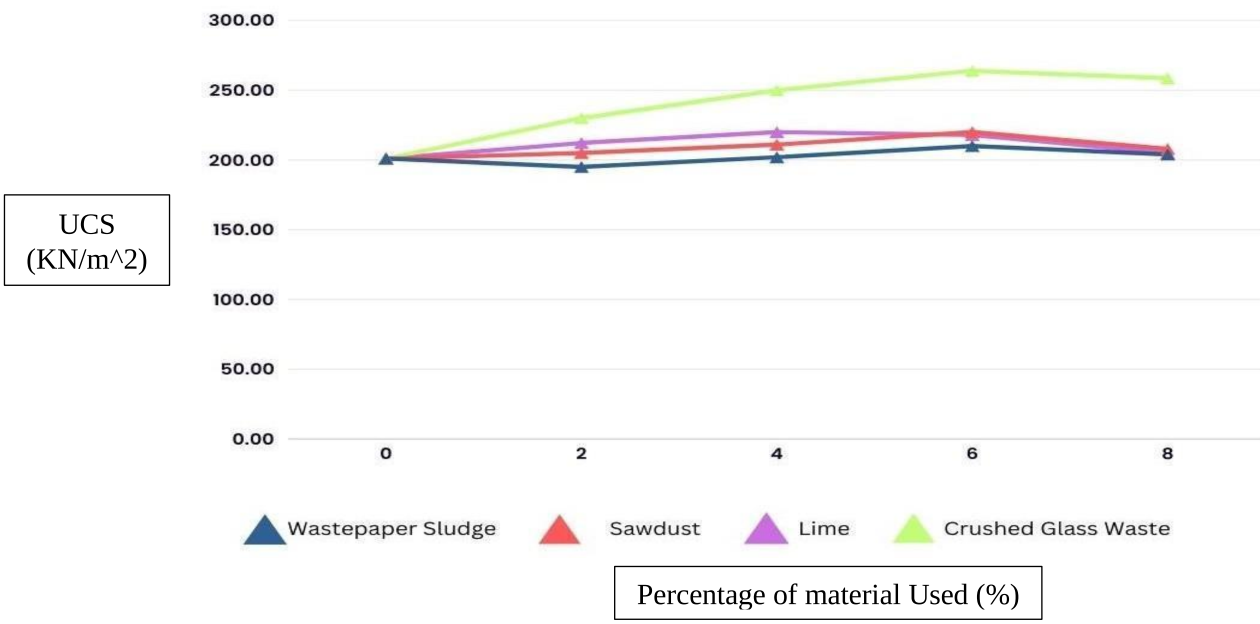

Figure 6: Comparison of Unconfined Compressive Strength with addition of various materials

Conclusion

The disposal of waste material has become a burdensome task; hence, it is crucial that these waste materials are utilized in some valuable tasks which could reduce the load on disposal sites, as well as attain the maximum potential of these waste materials**.**

There was a major difference in the values of standard proctor test and UCS when crushed glass waste was added in contrast to other materials. The dry density increased, and OMC decreased. There was a significant increase in the compression strength as well. Thus, crushed glass waste is one of the best replacements for traditional soil stabilizers. However, the use of crushed glass waste with soil is not ideal for the workers, hence, the conditions under which this task is done should be controlled.

Many studies have examined the use of waste materials for soil stabilization and have proven to be more advantageous than the conventional methods, however, the field is yet open for further research and advancements.

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