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Investigation Of Agricultural And Industrial Waste For Laterite Soil Stabilization

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Abstract
The amount of waste in a developing city has significantly reduced land dumping and heightened the public health risks in nearby areas. To alleviate these challenges, exploring disposal alternatives beyond landfills becomes imperative. The primary goal is to investigate the potential enhancement of laterite soil stabilization in road embankments by incorporating various percentage of waste material into the mix. While waste material proves less costly than soil in road embankments, the main objective is to replace as much as soil as feasible to both save costs and diminish disposal waste. However, care should be taken that not to add excessive waste material in the soil stabilization. The collected waste material underwent careful separation for subsequent utilization as a partial substitute in road embankments. Various tests were then conducted on soil samples to ascertain their index Properties following IS specification. Geotechnical tests were systematically executed to understand the index properties, specifically focusing on laterite soil and black cotton soil. This study not only addresses waste management challenges but also underscores the importance of sustainable practices, paving the way for environmentally conscious waste solutions in urban development.
Keywords: - *Waste material, Landfill, Soil Stabilization, Road Embankment, Index Properties and Laterite Soil.*

INTRODUCTION

Solid waste must be disposed which are the result of various human activities which include industrial, building, medical and agricultural waste. The building waste is the waste due to demolition, rehabilitation, repair and removal of existing structures and installations. The commonly found waste in garbage include sand, glass, stone, gravel, tiles, ceramic, marble, wood, paints, pipes, electric parts, asbestos, steel etc. The Nashik municipal corporation daily collects 300- 350 tons of municipal solid waste (MSW). As per the report the 37.8% consist of easily compostable materials, 19.50% contains hard lignite's and other material that biodegrade slowly. The 16.20 % consists of non-food items such as textiles, plastics, rubber which are non-biodegradable, which is a big concern for disposal. To solve this disposal problem new techniques should be considered to achieve a long term solution of landfill management. The use of waste material in road embankment can reduced the cost of construction of road by 10 to 20%. The fly ash is the waste product of coal which is available in at electricity power plant. The transportation cost of waste material and laying cost of waste material need to be considered when considering it as a fill material. Laterite soil is week in stabilization due to its less molecular attraction between the soil particles.

LITERATURE REVIEW

Road deformation, erosion, settlement, dam leakage, slope instability and other geotechnical problems are all associated with laterite soils.
Olufuwobi et. al. 2014 [1] conducted california bearing ratio (CBR) test and direct shear tests on clay soil with varying proportions of glass powder, along with cement by the weight of the soil, both with and without powdered glass. Renu et al. 2018 [2] overviewed the various solid waste materials used to stabilize soft soils. Sajja et al. 2014 [3] studied that the service life of pavement is often shortened on weaker clayey sub soils due to their high plasticity and compressibility. Tiwari et al. 2014 [4] studied the engineering and index properties of soil with the influence of fly ash, waste crushed glass, coconut coir in varying percentages alongside black cotton soil. Ikeagwuani et al. 2019 [5] three types of concerns were highlighted regarding the appropriate

implementation of emerging trends in soil stabilization expansion: geo-environmental, standardization and optimization issues. Chauhan et al. 2015 [6] employed waste plastic and crushed glass in various proportion for soil stabilization, aiming to increasing soil strength parameters. Subash et al. 2016 [7] examined that the construction of highways and other civil engineering structures over large soils is problematic due to its high compressibility, poor shear strength and high permeability. Blayai et al. 2020 [8] waste glass was crushed and mixed with the soil sample in various proportions: 2.5%, 5%, 10%, 15% and 25%, respectively, based on the dry weight of the soil. Ali et al. 2016 [9] studied the fiberglass- Portland cement as replacement to improve the structural and index properties of sandy soils in duzce, turkey. Hanifi et al. 2016 [10] investigated the effect of scrap aluminium beverage can strips on lean clay strength and swelling properties. Baloochi et al. 2020 [11] utilized waste paper fly ash as a soil stabilizing binder. Mosa et al. 2017 [12] investigated how waste glass bottles could be used to improve the qualities of poor subsoil soils. Aravind et al. 2012 [13] suggested that material could be utilized in highway construction to reduce disposal and Pollution problems. Vijayakumar 2019 [14] reviewed a quick overview of soil stabilization using waste materials such as agricultural waste, construction waste, and industrial waste. Kumar et al. 2016 [15] focused on stabilization using solid wastes to enhance engineering properties. Dr. Zainab et al. 2012 [16] evaluate the improvement of embankment of road using fibre glass treatment. Kalidas 2014 [17] aimed to assess improvement in the properties of black cotton soil with varying percentage of fly ash. Kassa et al. 2020 [18] plastic waste was cut in strip and added by weight in 3 different aspect ratios (5mm 7.5mm, 10mm 15 mm, 15mm 20 mm) and 3 different mixing ratios (0.5%, 1%, 2%). Choudhary et al. [19] utilize the industrial waste in geotechnical applications to increase the soil properties. Ikara et al. 2015 [20] explored the use of waste glass and cement for black cotton soil as backfill, road and embankment material. Thangavel et al. 2021 [21] this research on geotechnical rehabilitation of problem soils with bagasse ash and banana fibre revealed significant changes in compressive strength of expanded soil. Rawat et al. 2019 [22] study of municipal solid waste in road embankment. Shivaprasad et al. 2022 [23] geotechnical laboratory evaluation of construction demolition recycled material for road embankment. Soganci 2024 [24] the use of waste material i.e. red mud and bottom ash as road embankment fill.

After reviewing we can then use wide variety of recycled materials in geotechnical and transportation applications and categorizing them based on variables such as usability, applicability, environmental impact and cost.

METHODOLOGY

The main goal of this research study is to determine the amount of waste material to be used as the soil stabilizer in subgrade of road embankment. The waste collected from various building waste after demolition of building, empty glass containers, plastic bottle, and agriculture waste of rice husk, baggase husk is used in the subgrade. The waste material are crushed into small particle similar to small gravel and sand. The crushed particle is mixed with subgrade and the effect of recycled crushed material on embankment strength is observed. The problem of landfill can be solved and the material will act as the subgrade for the road embankment. This paper highlight on investigation of waste material to be used as filler in the subgrade which gives economical road embankment. The Indian Standard testing method are used for testing of soil i.e. IS 2720. Laterite soil is used in the investigation with 5%, 10%,15% and 20% fly ash as cementing agent along with 0%, 3%, 5% ,7% and 9% waste glass, plastic waste, rice husk, and baggase husk ash respectively by that much percent of soil sample.

RESULT AND DISCUSSION

The index properties of the soil were determined, following the guidelines of I.S. code 2720. From the experimental results obtain the properties of the soil can be classified as CH (In organic clays of high plasticity), according to Casagrande's A line chart. The Modified proctor tests and the California bearing ratio test (CBR) were performed to determine the soil's maximum dry density (MDD), optimum moisture content (OMC), and bearing capacity.

Table No. 1 Universal Soil Classification

Sr.No.	Test	IS Codes	Laterite Soil
1	**Specific Gravity**	IS:2720 Part 2-1964	2.4
2	**Moisture Content**	IS:2720 Part 1	11.17%
3	**Particle Size Distribution**	IS:2720 Part 4-1985	Silt -74.15% Clay- 25.87%
4	**Atterbergs Limit** **Liquid Limit** **Plastic Limit** **Plasticity Index**	IS : 2720 Part 5-1985	54.96% 24.43% 34.53%
5	**Modified Proctor Test** **MDD** **OMC**	IS : 2720 Part 7-1965	1.195 gm/cc 18.12%
6	**CBR** **Unsoaked** **Soaked**	IS : 2720 Part 5-1979	8.50% 4.18%
7	**Direct Shear Test** **Internal Friction Angle**	IS : 2720 Part 13-1965	22^0
8	**Co Efficient of Permeability**	IS: 2720 Part 36-1986	9.66×10^{-3}cm/s
9	**Universal Soil Classification**		CH

Additionally the shear parameters i.e. angle of friction and cohesion were evaluated to assess the soil's shear strength. The coefficient of permeability was also analyzed with varying proportions to determine the presence of voids within the soil.

Table No. 2 Standard Proctor Test and Coefficient of Permeability of Laterite soil

Sr. No.	% of Waste material and % of Fly ash	MDD (gm/cc)	OMC (%)	Value of Coefficient of Permeability (cm/s)
1	3%, 5%, 7% & 9% of waste material with 5% of fly ash	1.46	20.81	6.12×10^{-3}
2	3%, 5%, 7% & 9% of waste material with 10% of fly ash	1.73	21.81	$3.58 \text{ X } 10^{-3}$
3	3%, 5%, 7% & 9% of waste material with 15% of fly ash	1.83	22.41	$3.07 \text{ X } 10^{-3}$
4	3%, 5%, 7% & 9% of waste material with 20% of fly ash	1.79	23.68	$2.6 \text{ X } 10^{-3}$

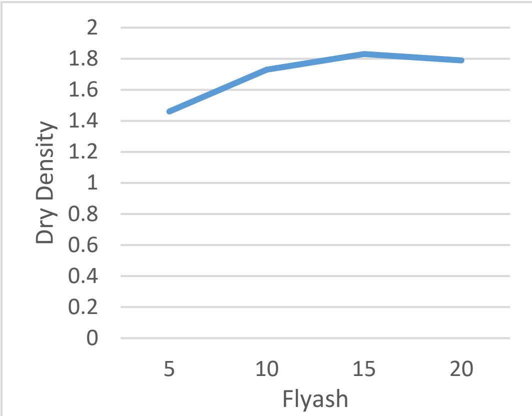

Figure. 1 Maximum Dry Density

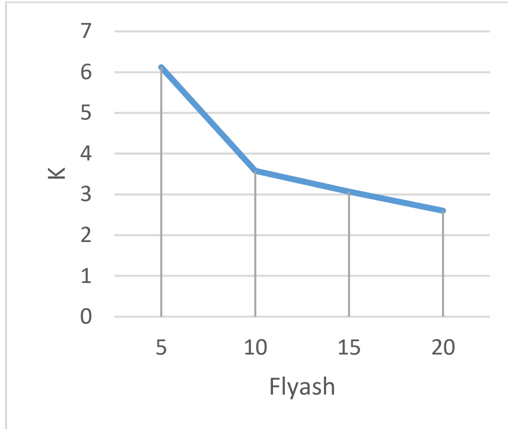

Figure. 2 Coefficient of Permeability

The findings depicted in Figure 1 reveal that the optimal percentages of waste material in the soil mass are 3%, 5%, 7% and 9% combined with varying fly ash percentage (5%, 10%, 15%, and 20%). For laterite soil, the highest maximum dry density (MDD) of 1.83 gm/cc is achieved with 15% fly ash and 7% admixture, representing a significant 65% improvement over conventional laterite soil. However, when using 7% admixture with 20% fly ash, the MDD decreases. As the fly ash content in the soil increases in combination with the waste material, there is a notable improvement in soil strength. Simultaneously, the optimum moisture content decreases by 6.88% and 14.17% for 15% and 20% fly ash, respectively, compared to soil with 5% admixture. Compaction of soil increase the soil density, which minimizes voids and permeability of the soil.

Table No.3 Direct Shear Test

Sr. No.	% of waste material and % of fly ash	Normal stress (kg/cm^2)	**ϕ**	Shear Strength S= C +**σ**tan**ϕ** (kg/cm^2)
1	7% of waste material with 5% of fly ash	15	26°	7.31
2	7% of waste material with 10% of fly ash	15	28°	7.97
3	7% of waste material with 15% of fly ash	15	38°	11.71
4	7% of waste material with 20% of fly ash	15	33°	9.73

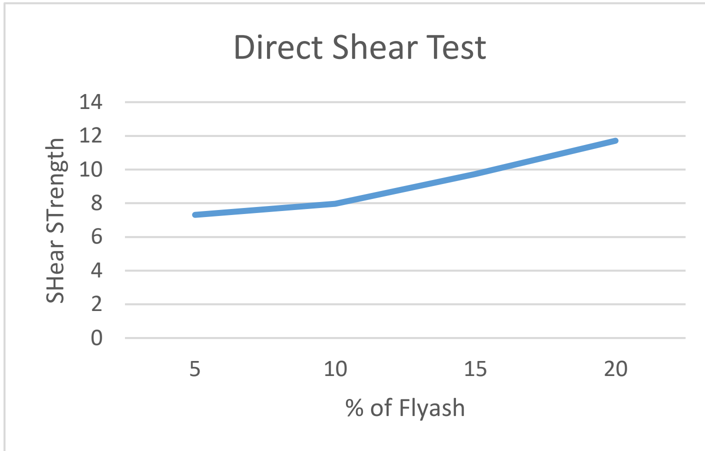

Figure No. 3 Direct Shear Stress

Figure 3 displays shear test conducted on soil sample containing 7% admixture with 5%, 10%, 15%, 20% fly ash which was greatest of all the outcomes of all tests of direct shear test. The results observed under a normal stress of 15kg/cm^2, the shear strength is 11.71kg/cm^2 for the corresponding normal stress. This observation implies that an increase in normal stress leads to a proportional increase in shear force. The shear strength parameters, namely the angle of friction (ø) and cohesion (c), are determined from the test data, serving as crucial indicators of the soil's shear strength. The calculated shear strength of the soil (S) is found to be 11.71 kg/cm^2. Consequently, there is a 60.91% increase in the shear strength compared to the material with 0% admixture to be 5.75 kg/cm^2.

Table No. 4 California Bearing Ratio for unsoaked and soaked Test

Sr. No.	% of waste material and % of fly ash with soil	Unsoaked 2.5 mm	Soaked 2.5 mm
1	100% Soil	8.5 %	4.18 %
2	7% of waste material with 5% of fly ash	8.55 %	4.21 %
3	7% of waste material with 10% of fly ash	9.92 %	6.35 %
4	7% of waste material with 15% of fly ash	11.43 %	8.35 %
5	7% of waste material with 20% of fly ash	14.81 %	8.61 %

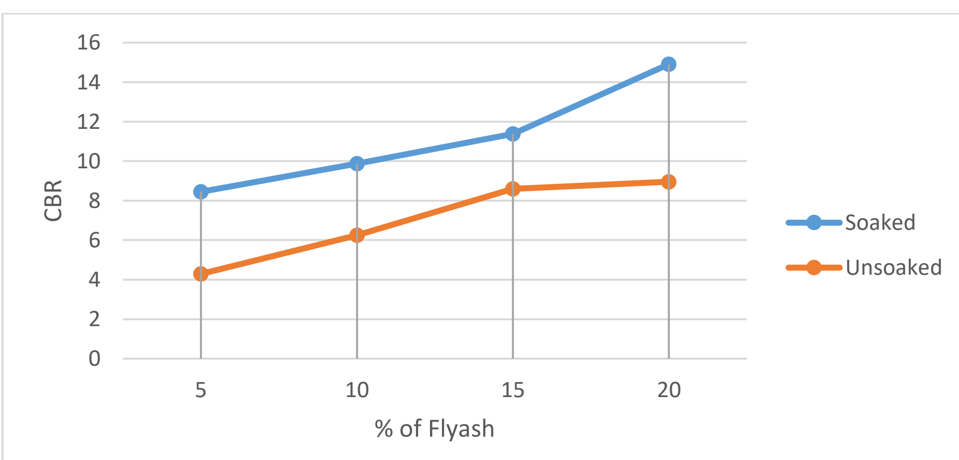

Figure No. 4 Soaked and unsoaked CBR Test

From figure no. 4 the graph shows the soaked and unsoaked CBR test with 2.5mm and 5 mm penetration for various proportions of waste material and flyash. It indicate that the CBR value get enhances, specifically for waste material containing 7% of admixture with 20% flyash which is 8.61 and 14.91 respectively, which is greater than the value for a 5 mm penetration. So that it can be concluded that as we will increase the percentage of waste material. The percentage of increase in CBR value as compared to 0% of waste material is 42.60% for unsoaked CBR test and 51.45% for soaked CBR test.

COST ANALYSIS

Assume Traffic Density for Highway or Expressway = 50 msa

According to IRC 37-2018 the CBR value is use for designing the thickness of pavement. The figure of Catalogue for Pavement with Bituminous Surface Course wth Granular Base and Sub Base of thickness of pavement vs design traffic in MSA (Million Standard Axle) depend upon the value of CBR % determine from the test according to IS 2720 part 16.

i) The CBR value of soil sample is 8.5 %.

For 8% CBR the thickness of Pavement is 605 mm.

∴ Thickness of Pavement for 8.5 % CBR is 642.8 mm by Interpolation.

ii) The CBR value of soil + waste material is 14.81%

∴ Thickness of Pavement is 575 mm for 15% CBR.

∴ Thickness of Pavement for 14.81 % CBR is 567.7 mm by Interpolation.

The thickness of pavement decrease almost by 75 mm i.e. 11.68%. So it can concluded that cost of Highway construction decreases.

CONCLUSION

The stabilization of road embankment totally depends on soil strength, and this can achieved by adding an admixture to the soil. After addition of waste material from 0% to 9% and fly ash from 0% to 20% by dry weight of soil, the following conclusion have been evaluated.

- The Optimum moisture content decreased for the modified proctor test and the maximum dry density increased with 7% of admixture and 15% of fly ash.
- The maximum CBR value was achieved at 20% fly ash and 7% admixture for both soaked and unsoaked tests.
- In the direct shear test, the strength parameter was maximum at 15% flyash and 7% admixture under a normal stress of 15 $kg/cm^{2.}$
- From this research it can be concluded that admixture of Waste Glass, Plastic waste, Rice Husk, Baggase Husk Ash and fly ash have the potential to alter the laterite soil properties making it suitable for various civil engineering applications.
- As the thickness of pavement decrease by 75 mm, so the cost of road embankment also decreases.

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Author contributions

Mr. Toshnil Boraste wrote the main manuscript, prepared figures and tables and Dr. Amit Sharma reviewed the manuscript.

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