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Freeze-thaw Resistance of an Alluvial Soil Stabilized with EcoSand and Asbestos-free Fiber Powder

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ABSTRACT

Stabilization of poor soils subjected to large daily temperature variations requires careful selection of suitable stabilizer for improvement of such soils. This study investigated the freeze-thaw resistance of an alluvial soil stabilized with EcoSand and asbestos-free fiber powder (AFP). Physical and mechanical properties of the soil were determined. The soil sample was stabilized with 5 variants of equal mixtures of the EcoSand and AFP in proportions of 2, 4, 6, 8 and 10%, with 1% sodium silicate and 1% fly ash, by weight of the soil. UCS tests were conducted before and after three freeze-thaw cycles, while keeping the sample at 0ºC for 8 hours and later at 30ºC for 8 hours for each cycle. It was found that the 8% EcoSand + AFP with 1% sodium silicate and 1% fly ash content provided an optimized increase of the freeze-thaw resistance of the soil. The use of a mixture of EcoSand and AFP as a soil stabilizer for regions of the world experiencing large temperature variation has the potential to improve the resistance of sand to freezing and thawing.

Keywords: Freeze-thaw test, soil stabilization, soil improvement, waste management.

1. Introduction

Soil stabilization has become one of the most investigated soil improvement techniques by researchers (Akinwumi, 2014; Gobinath et al., 2015; Ganapathy et al., 2017). The suitability of using various materials, such as marble dust (Akinwumi and Booth, 2015), precipitated silica (Gobinath et al., 2016), corncob ash (Akinwumi and Aidomojie, 2015) and reclaimed asphalt (Akinwumi, 2014), as soil stabilizers have been investigated. However, only a few studies have considered the effect of temperature variation on the stabilization of soils. The weather of a place influences the durability of any stabilized layer of soil in that place. When temperature variation becomes large such that a stabilized layer of soil experiences freezing and thawing daily, there is need to consider resistance to freezing and thawing, while selecting appropriate material to use as a stabilizer of the soil.

This research work aimed at investigating the effect of stabilizing an alluvial soil with EcoSand and asbestos-free fiber powder (AFP) on the freeze-thaw resistance of the soil. This is particularly important because freeze-thaw cycle in cold regions of the world influence the physical and mechanical properties of soils in agricultural or ecological environment. For instance, during seasonal cycles of freezing and thawing, water within the pore spaces of a soil expands and contracts. Soil stabilization can provide sufficient stability for earthwork structures to resist unfavorable weather conditions.

2. Materials and Methods

Asbestos is a material known for its resistance to heat, thermal insulation and tensile strength. Its high toxicity, being carcinogenic, made it banned in some countries of the world. Consequently, AFP, which is more environmentally- and public health- friendly, was mixed with EcoSand for stabilization of the alluvial soil. EcoSand is an organic amendment of natural zeolite used to add fertility to soils and it was reported that it does not decompose (Zeo, 2013). EcoSand, sodium silicate and fly ash were commercially procured for use for this research work. The alluvial soil was collected from Dharapuram, Tamilnadu, India near the Amaravathi river bank.

The specific gravity, Atterberg limits, compaction characteristics, unconfined compressive strength, consolidation, triaxial strength and permeability tests on the soil were determined following the procedures of the Bureau of Indian Standards (BIS) (1971, 1973, 1980, 1985, 1986).

EcoSand and AFP were mixed in equal proportions and added to the soil in varying percentages of 2, 4, 6, 8 and 10%, by weight of the soil. Also, a mixture of 1% sodium silicate and 1% fly ash, by weight of the soil was added to all the variant of the stabilized soil. To determine the freeze-thaw resistance of the soil and the stabilized soil, UCS were determined before and after subjecting each sample to three (3) freeze-thaw cycles. Each freeze-thaw cycle was obtained by keeping the sample at 0ºC for 8 hours and later at 30ºC for 8 hours.

3. Results and Discussion

The physical and mechanical properties of the alluvial soil are presented in Table 1. The soil has a specific gravity of 2.66. It is of low plasticity and strength. It has a high coefficient of permeability.
The grain size distribution of soil was determined by sieve analysis. The result of the analysis of particle sizes of the soil is presented in Figure 1.

Table 1: Physical and Geotechnical Properties of the Alluvial Soil

Properties	Result	Standard adopted
Specific gravity	2.66	BIS 2720 (iii):1980
Uniformity coefficient (C_u)	2.66	BIS 2720 (iv):1985
Coefficient of curvature (C_c)	0.806	BIS 2720 (iv):1985
Liquid limit	26.60%	BIS 2720 (v):1985
Plastic limit	23%	BIS 2720 (v):1985
Plasticity index	3.6%	BIS 2720 (v):1985
Maximum dry unit weight	21.43 kN/m^3	BIS 2720(vii):1980
OMC	13%	BIS 2720(vii):1980
Unconfined compressive strength (UCS)	46.85 kN/m^2	BIS 2720 (x):1973
Triaxial	31.40 kN/m^2	BIS 2720(xi):1971
Consolidation	0.001 cm^2/sec	BIS 2720 (xv):1986
Permeability test - Constant head	0.0091 cm/s	BIS 2720(xvii):1986
Degree of Saturation	47.35%	

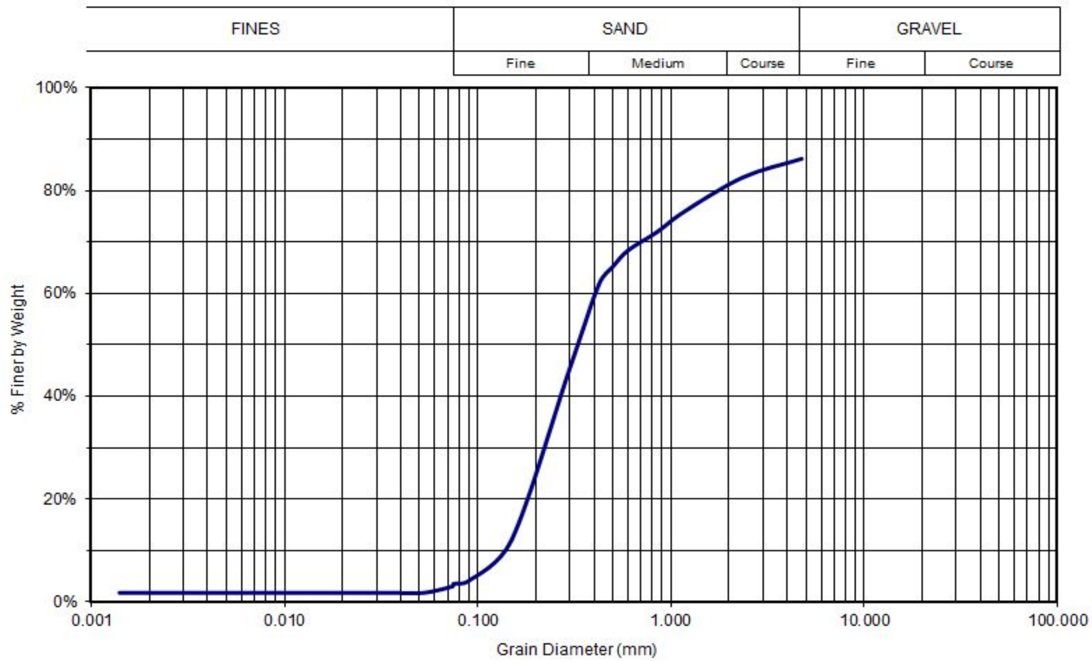

Figure 1: Grain size distribution curve of the alluvial soil

Figure 1 shows that the alluvial soil is predominantly sand. A large proportion of the sand is within the fine sand particle size range. The variation of the dry density of the unstabilized and stabilized soil samples with their water contents are presented in Figure 2.

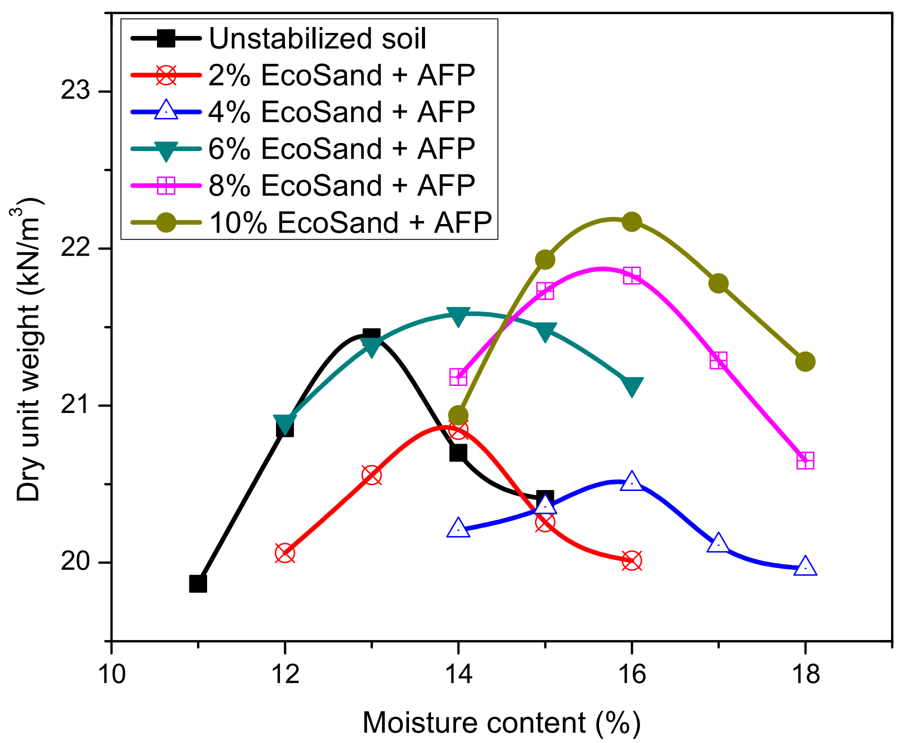

Figure 2: Optimum moisture content and Maximum Dry Density of the unstabilized and stabilized soil

Figure 2 shows that the stabilization of the soil with 4% EcoSand + AFP gave the least maximum dry unit weight (MDUW) of 20.5 kN/m^3 and the highest optimum moisture content, whereas the stabilization of the soil with 10% EcoSand + AFP gave the greatest MDUW of 22.2 kN/m^3.The unstabilized soil has an MDUW of 21.42 kN/m^3.

The stress-strain relationship of the unstabilized and stabilized soil samples are presented in Figure 3.

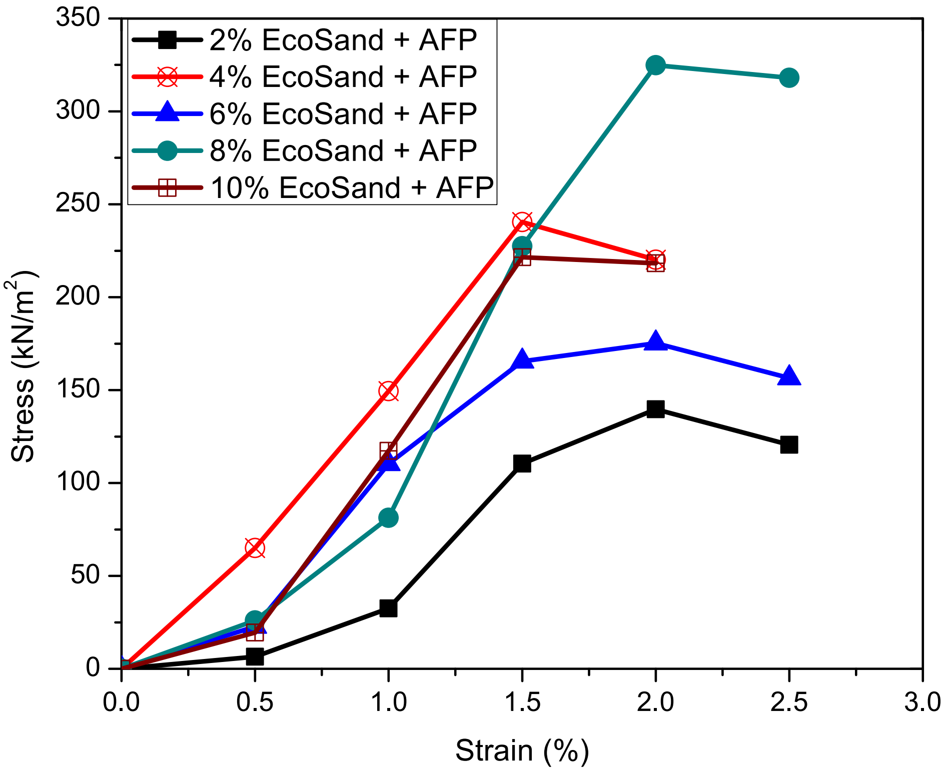

Figure 3: Stress-Strain relationship of the stabilized soil

It shows that the soil stabilized with 8% EcoSand + AFP, which gave the maximum strength of the stabilization variants, has a strength of 32.48 N/cm^2 and a strain of 2%. The 2% EcoSand + AFP has the minimum strength of 12.36 N/cm^2 and a strain of 2%.

The UCS of the unstabilized and stabilized soil samples before and after being subjected to freeze-thaw cycles are presented in Figure 4.

Figure 4 shows that the stabilization of the soil with 8% EcoSand + AFP content presented the greatest resistance to weather as simulated by the freeze-thaw cycles. During the freeze-thaw cycles, water within the pore spaces of the soil expands and contracts repeatedly to induce stresses on the internal structure of the soil. The cementation of the soil particles, brought about by the application of increasing percentage of the mixture of EcoSand and AFP, helped to minimize the effect of the freezing and thawing until 8% EcoSand + AFP was applied.

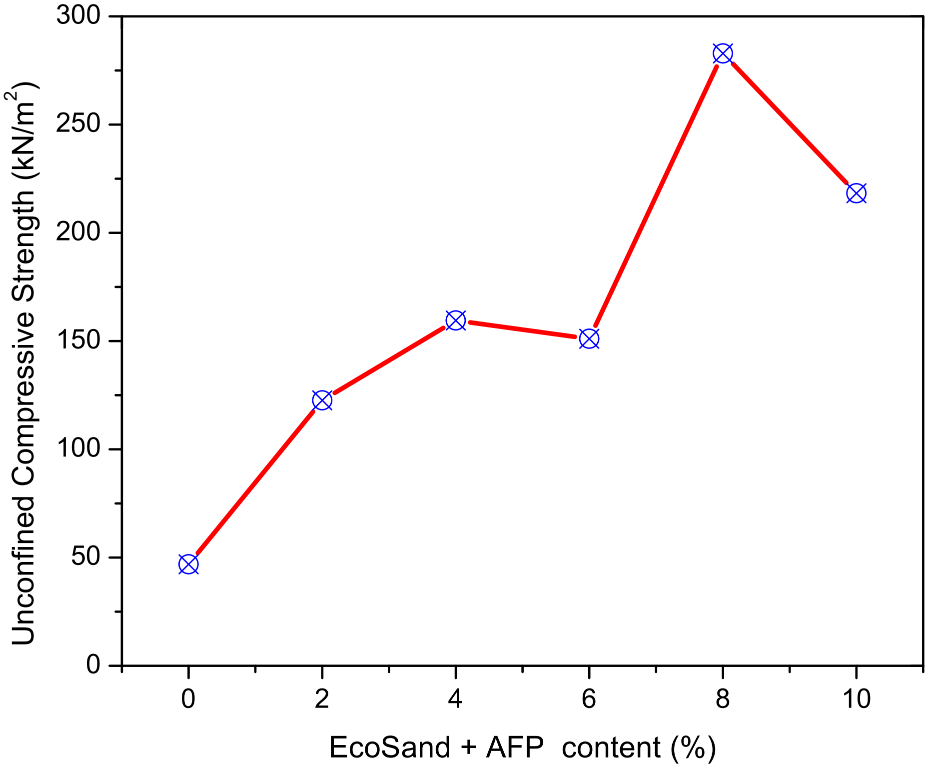

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Figure 4: UCS of the stabilized soil after being subjected to freeze-thaw cycles

4. Conclusion

This study was aimed at investigating the effect of stabilizing an alluvial soil with EcoSand and AFP on the freeze-thaw resistance of the soil. Sodium silicate (1%) and fly ash (1%) were added to the soil and stabilized soil in order to contribute to the cementation of the particles of the soil. The alluvial soil was classified as sand. Its fine-grained content is of low plasticity. The stress-strain relationship of the stabilized soil showed that the soil stabilized with 8% EcoSand + AFP with 1% sodium silicate and 1% fly ash produced the greatest strength of the stabilized soil.

The resistance of the stabilized soil to freeze-thaw generally increased as the percentage of % EcoSand + AFP increased. The optimum stabilizer mix content that produced the greatest freeze-thaw resistance is 8% EcoSand + AFP. This optimum stabilizer mix improved the freeze-thaw resistance of the soil by 503.8%. The use of a mixture of EcoSand and AFP as a soil stabilizer for regions of the world experiencing large temperature variation has the potential to improve the resistance of sand to freezing and thawing.

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