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Stabilization of Black Cotton Soil With Sand and Cement as a Subgrade for Pavement

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Abstract

Expansive soil (Black cotton soil) is very weak and does not have enough stability for any type of construction work. In pavement, subgrade layer is the bottommost layer underlying the base course or surface course. To make the subgrade soil stable, by improving its engineering properties is very essential. In the present work, stabilization of subgrade soil by using sand and cement (varying percentage of sand and constant percentage of cement by weight of soil) is used to enhance the strength of subgrade soil. The purpose of this study is to determine the optimum dose of the stabilizer, which improves the strength of soil (CBR less than or equal to 2% to more than 7%) which is suitable for pavement structure. To evaluate the strength of soil, various test have been performed such as sieve analysis, liquid limit, Plastic limit, Standard proctor test and CBR test in the laboratory. The result shows that the use of sand and cement in combination, increases the California Bearing Ratio values (CBR) i.e. the strength of soil to a great extent.

Keywords: Black cotton soil, stabilization, CBR, sand and cement, Pavement.

Introduction

Expansive soil is always problematic for the engineering structures due to its swelling and shrinkage behavior. It gets shrink when dried in summer and swells when wet in winter season. The structures on these soils experience large-scale damages. The property of expansive soil results cracks in the soil without any warning. These cracks are some time very large and suffer rigorous damage to the structure. Roads running through expansive soil regions are subjected to severe distress resulting in poor performance and increased maintenance cost. Again clayey soil having plasticity index more than 6 are required to be treated and stabilized before going to be used for construction as per the specification of Ministry of Road Transport & Highway, Government of India. To prevent the structure from such damages, stabilization of soil is required with the stabilizing materials like fly ash, lime, sand, bitumen, cement, rice husk ash etc. The engineering properties of Black cotton soil (B.C. soil) can significantly be improved with these stabilizing agents.

The technique of stabilizing the soil with sand and cement is being carried from long time. Mixing Portland cement, sand and pulverized black cotton soil with the optimum moisture content and compacting the mix to attain required density. The material obtained by mixing soil, cement and sand is known as cement sand soil. Cement in the range of 2 to 5 percent brings remarkable improvement in the engineering characteristics of B.C. soil. Similarly increasing proportion of sand as stabilizer also improves the properties of soil.

Soil–sand-cement is a well prepared mix of soil when water is added to the mix and compacted; the small proportion of cement is not able to bind all the particles to a coherent mass but it interacts with the silt and clay fractions and reduces their affinity to water and reduces the swelling behavior of mix modifies the properties of soil and increase the strength of soil.

Literature review

Cement contains calcium required for the pozzolanic reactions to occur. Further cement already contains silica thus stabilization with cement is fairly independent of soil properties. The only thing required is water for hydration process to begin and attributes to the improvement of strength and compressibility characteristics of soil. It has a long history of use as an engineering material and has been successfully employed in geotechnical applications.

Kowalski et al. [7], Portland cement is hydraulic cement made by heating limestone and clay mixture

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in a kiln and pulverizing the resulting material which can be used either to modify or to improve the quality of the soil or to transform the soil into a cemented mass with increased strength and durability. The amount of cement used will depend upon whether the soil is to be modified or stabilized.

Kent Newman and Jeb S.Tingle [5] in their study of previous research efforts. Portland cement was used as the stabilizer control for comparison of properties to the polymers and was used at concentration of 2.75%, 6% and 9%.

Previous research work have shown that the addition of inert material (sand) to swelling soil can be a method of stabilization of soil.

Bahai Louafi and Ramdane Bahar [1] in their experimental work have study the effect of performance of an addition of sand as stabilizer on swelling soil. Based on the study undertaken, they found that the addition of sand reduces consistency limits. They have also worked on introducing sand layer into two different configurations and found that these layers effectively reduce the swelling of soil.

Materials

The following materials are used in the study for stabilization of Black cotton soil.

1. Black Cotton Soil.

Black cotton soil sample were collected from Shankarpurheti, Tahasil Chamorshi District Gadchiroli in Maharashtra, India. The soil taken was air dried and pulverized to pass through IS 425 microns sieve and then oven dried at 110^0 C before testing.

Table 1: Properties of Black Cotton Soil

Grain Size Distribution	
Gravel (%)	0
Sand (%)	10.65
Silt (%)	89.35
AASHTO Classification	A-7-5
USCS	MH
IS Classification	MH
Specific Gravity	2.67

2. Sand:

Sand used for the work is clean and coarse sand passing through 4.75 mm sieve was oven dried for 24 hrs to eliminate sand's moisture before the conduction of tests.

Table 2: Properties of Sand

Grain Size Distribution	
Coarse sand (%)	48.6
Medium Sand (%)	32.4
Fine sand (%)	13
Specific Gravity	2.64

3. Cement:

The cement used is Portland pozzolanic cement (PPC) used for the study was purchased from the market with the specific gravity of 3.14 g/cc.

Methodology

Initially the properties of natural soil are determined. The soil is then stabilized with sand and cement. The amount of sand for stabilization is taken in the proportion of 10%, 20%, 30%, 40% by dry weight of soil and the amount of cement was taken as 2% by dry weight of soil. Using these proportions, mix samples were prepared as given below and a set of laboratory tests were performed to determine the index properties and CBR values of both natural soil and mixed proportion samples.

Mix Proportion Samples of soil, Sand and cement used for Stabilization.

1. Natural soil.
2. Soil +10% Sand +2% Cement.
3. Soil +20% Sand +2% Cement.
4. Soil +30% Sand +2% Cement.
5. Soil +40% Sand +2% Cement.

Experimentation

Soil classification is carried out from engineering point of view to find out the suitability of soil as a subgrade for construction of pavement.

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1. **Grain Size Analysis.**
Conducting sieve analysis test the soil is classified as: By AASHTO Classification Chart, it lies under the range of A-7 group, A-7-5 subgroup. And by Unified soil classification system (USCS) and IS Classification system the soil is classified as MH (Silt of High Compressibility).

2. **Atterberg Limit Test.**
The Atterberg limits are a basic measure of the nature of fine grained soil. Depending upon the water content of the soil, it may appear in four states namely Soild, Semi soild, Plastic, Liquid. In each state the consistency and behavior of the soil is different and thus so are its engineering properties. Thus, the boundary between each state can be defined based on a changes in the soil's behavior. These limits were created by Albert Atterberg and were later refined by Arther Casagrande. Liquid limit test, Plastic limit test and swelling index test are being carried out with the following results.

Table 3: Atterberg Limits of Soil -Sand –Cement Mixtures.

Soil Type	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Free Swell Index (%)
Natural Soil	70.2	37.51	32.69	200
Soil + 10% Sand + 2% Cement	61.6	31.81	29.79	170
Soil + 20% Sand + 2% Cement	56.8	30.29	26.51	140
Soil + 30% Sand + 2% Cement	50.2	29.08	21.12	90
Soil + 40% Sand + 2% Cement	50.0	29.21	20.79	40

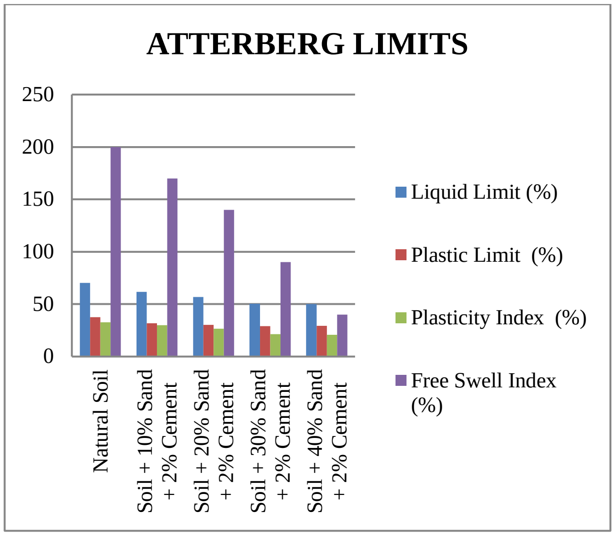

Figure 1: Comparison of Atterberg Limit of different proportion of soil Sample.

3. **Proctor compaction test.**
To assess the amount of compaction and the water content required in the field, compaction tests are done on the soil samples in the laboratory. The tests provide the following results, the optimum moisture content and maximum dry density of soil.

Table 4 : Proctor Compaction Test of Soil -Sand –Cement Mixtures.

Soil Type	Optimum Moisture Content (%)	Maximum Dry Density(KN/m3)
Natural Soil	28.00	1.29
Soil + 10% Sand + 2% Cement	24.10	1.53
Soil + 20% Sand + 2% Cement	19.20	1.56
Soil + 30% Sand + 2% Cement	15.00	1.71
Soil + 40% Sand + 2% Cement	14.00	1.77

4. **California Bearing Ratio (CBR) test.**
The California bearing ratio (CBR) test was developed by the California Division of highway as a method of evaluating soil-subgrade and base course materials for flexible pavement. The CBR is a

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measure of resistance of a material to penetration of standard plunger under maximum density and optimum moisture conditions. The test consists of causing a cylindrical plunger of 50 mm diameter to penetrate a pavement component material at 1.25 mm/minute. The load, for 2.5 mm and 5 mm are recorded. The load is expressed as a percentage of standard load value at a respective deformation level to obtain CBR value. The soil samples for CBR test were prepared as per standard procedure. The CBR value is determined corresponding to both 2.5 mm and 5 mm penetration, and greater value is to be used for the design.

CBR = (Test load /Standard load) x 100

Table 5: Standard Load for CBR Test.

Sr. No.	Penetration (mm)	Standard load (Kg)
1	2.5	1370
2	5.0	2055
3	7.5	2630
4	10.0	3180
5	12.5	3600

Graph is been plotted between the penetration and penetration load and the value of CBR is found out. By evaluating the soaked CBR value of the subgrade soil the thickness of the flexible pavement can be determined through design chart recommended by Indian Road Congress (IRC-37-2012).

Results

Table 6: California Bearing Ratio (CBR) test of Soil -Sand –Cement Mixtures.

Sr. No.	Soil Type	Soaked CBR (%)
1	Natural Soil	1.93
2	Soil + 10% Sand + 2% Cement	3.05
3	Soil + 20% Sand + 2% + Cement	3.53
4	Soil + 30% Sand + 2% Cement	5.14
5	Soil + 40% Sand + 2% Cement	7.39

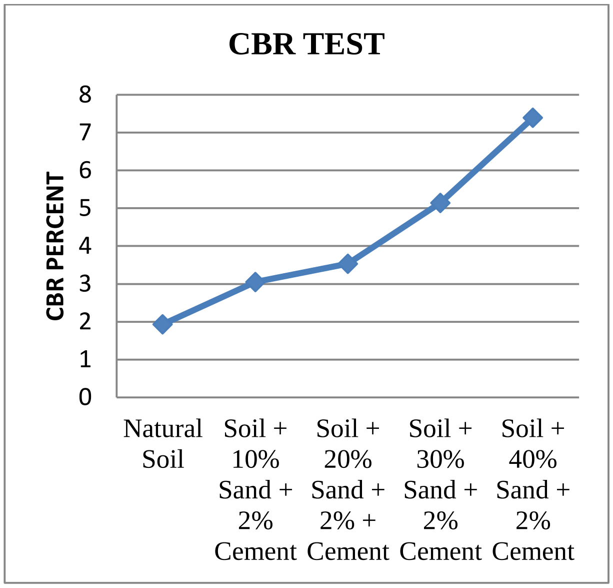

Figure 2: Comparison of CBR of different proportion of soil Samples

Conclusion

The study reveals that the CBR value increases with the increase in sand content and reaches to a desirable CBR value for subgrade of pavement. Normally soaked CBR value is considered for pavement design. Experimentally it is found that the addition of sand content in the soil results in the improvement of soaked CBR value from 1.93% to 7.39%. The maximum CBR is obtained while using 40% sand and 2% cement with the natural soil. Atterberg limits i.e. Liquid limit, plastic limit, plasticity index and free swelling index goes on decreasing with the increase in sand content. Whereas moisture content goes on decreasing and maximum dry density increases with increasing sand content.The black cotton soil after stabilizing with sand and cement for higher MDD & CBR shall be taken for further improvement in CBR value using Geo-textile reinforcement.

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