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Improvement of Strength Characteristics of Expansive Soils Using Terrasil, Fly Ash and Cement by Forming Zyco Bond

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Abstract: Soil stabilization is a process which permanently changes the physical and chemical properties of soil. Soil stabilization is used to improve the bearing capacity of poor sub grade or sub-base soil to make it suitable to support structures like pavements, railways, foundations etc.Additionof nano particles to natural soil materials are often used to affect soilatomic structure thereby changing its permeability, strength and resistance properties. The addition of Cement (OPC) and terrasil is known to improve the strength of soils. This project primarily deals with the investigation of the strength characteristics of block cotton soil when mixed with a range of proportions of additives such as terrasil, fly ash and cement using CBR and UCC tests. The natural soil was tested according to Indian standards. The soil is classified as CH. Addition of cement and terrasil were based on the guidelines given by the ZYDEX Company. The test results show that the CBR and UCC values are similar for the proportions Cement (OPC) (3%) + terrasil (0.1%) and cement (OPC) (2%) + fly ash (5%) + terrasil (0.1%).

Keywords: *stabilization of soil, terrasil, cement, fly ash.*

1. Introduction

Soil is an important component in any type of civil engineering constructions. Developing countries like India needs good infrastructure like roadways, railways, buildings, power supplies etc, for their development. India has expansive soils in many parts of the country and it becomes challenging to construct stable structures in such conditions. Thus it becomes imperative to improve the soil properties to make it suitable for accepting structures. One of the ways to improve the soil strength and permeability related properties are to add different chemicals or nano material in different proportion to the soil. Depending upon the sogil type that need to be stabilized different types of additives are suggested. As the addition of additives to the soil increases the cost of the structures, efforts are constantly made to come up with additives or combination of additives which can improve the soil properties at a lesser cost. Many researchers have worked and continue to work in this field to develop different methods of stabilization techniques, which are economical and practical. By using 0.041% terrasil as stabilizer to CL soil, engineering properties of soil improved and 25% of pavement thickness reduced [1]. Adding 0.02% of zycobond to 0.04% terrasil, using these combinations of stabilizers to CL soil, the CBR value increased from 6.64% to 12.15% [2]. Addition of 1% PPC to above combination of stabilizers (0.04%

terrasil+0.02% zycobond) to CL soil, the CBR value increased from 6.64% to 21.81% [3]. Using 0.07% terrasil + 4% cement as stabilizers to the soil, CBR value increased 8 times, and UCC value improved 613% [4]. The percentage of addition of rough (coarse), fine fly ash improves soil properties and shows clear moisture density relationship. It was found that the peak strength reached by fine fly ash mixture was 25% more compared to rough fly ash [5]. Using Cement individually as a stabilizer to soil, improves soil properties. Adding 2% cement to soil, increases CBR value from 6.67 to 21.82% [6].Using cement and terrasil as stabilizer for sub grade soil stabilization, it affects the Granular sub-base (GSB),Dense Bituminous Macadam (DBM) layers of pavements, which shows that pavement thickness get reduced [12]. Terrasil was found to better at reducing permeability than geotextile with a 47.1% in cost reduction [13].

Experimental Programme

The main objective of this research was to study the improvement of engineering and index properties of soil when of stabilizers (cement, terrasil, fly ash) are added to black cotton soil. Different mix proportions of stabilizers are used. Standard laboratory experiments were conducted to evaluate different mix proportion, thereby helping in choosing the combination and proportion of additives which gives the same or better strength at a lesser cost.

2. Materials Used

Soil: Soil brought from mahabub nagar (district), Jamistapur village.

Cement: 43 grade Ordinary Portland Cement (OPC) with specific gravity of 3, complying with IS: 8112-1989.

Terrasil: It is Nanotechnology chemical, 100% organic silane. It forms Si-O-Si (glued or joinedTogether / formed a friendship) nano silicones surfaces in soil by converting water loving Silanol groups to water awful and disgusting Alkyl Siloxane groups. Terrasil is reported to increases frictional value of soil and decrease soil permeability. It was obtained from ZYDEX INDUSTRY.

Fly ash: It is a by product of thermal power plant, obtained from KBR Transport Company, KPHB, Hyderabad. Specific gravity of fly ash was 2.2.

3. Experimental Procedure

Specific gravity: soil specific gravity (G) was determined by using pycnometer as per guide lines of IS 2720-part 3.The average value of three samples has been taken as the specific gravity of soil.

Grain size analysis: Grain size distribution was done by using wet sieve analysis and hydrometer analysis as per guide lines of IS2720 part 4.

Atterberg limits: Liquid limit, plastic limit (Atterberg limits) were determined by using guide lines of IS2720 part5

Standard Proctor test: As per IS2720 part 7 compaction test (standard proctor test) was conducted to find out Maximum dry density and Optimum moisture content of soil.

CBR test: California bearing ratio (CBR) test were conducted to determine the mechanical strength of soil.CBR test were conducted as per guide lines of IS 2720 part 16. The tests were performed on soil with and without stabilizers.

UCC test: UCC (Unconfined Compressive) test was conducted to determine unconfined compressive strength of soil. UCC tests were conducted as per guide lines of IS2720 part 10. UCC tests were also performed on soil with and without stabilizers.

The following three sets of additives were used in the experiment.

Table 1 Additive Mix.

Additive mix	Cement (OPC) (%)	Terrasil (%)	Fly ash (%)
A	3	0.01	0
B	2	0.01	5
C	1	0.01	5

4. Experimental Results

- Soil Properties are improved after stabilization, possibly due to the addition stabilizers to natural soil.
- Soil Atterberg limits were improved, due to this change in Atterberg limits, the workability of soil increased.
- CBR values increased by addition of stabilizers. Mix A and Mix B got similar CBR values. All three mix proportions got higher CBR values compared to natural soil.
- If higher the CBR value, then the thickness of pavement is less. So here Mix A and Mix B are good for the design of pavement.
- UCS of Mix A and Mix B are higher compared to Mix C.

The experimental results were as given below in the tables.

Table 2 gives the properties of black cotton soil before stabilization.

Table 3 gives Atterberg limits of Block cotton soil before and after stabilization.

Table 4 gives Unsoaked CBR values at 2.5 mm penetration before and after stabilization.

Table 5gives Unsoaked CBR values at 5 mm penetration before and after stabilization.

Table 6 gives Final Unsoaked CBR values of before and after stabilization.

Table 7 gives Soaked CBR values at 2.5 mm penetration before and after stabilization.

Tables 8 gives Soaked CBR values at 5 mm penetration before and after stabilization.

Table 9 gives Final Soaked CBR values before and after stabilization.

Table 10 gives UCC strength values before and after stabilization.

Fig 1 shows Compaction curve of natural soil.

Fig 2 shows Unsoaked CBR values Comparison graph before and after stabilization.

Fig 3 shows Soaked CBR values Comparison graph before and after stabilization.

Table 2 Basic soil properties.

S.NO	PROPERTY	VALUE
1	Specific gravity	2.6
2	Consistency limits	
	Liquid limit (%)	73
	Plastic limit (%)	31
	Plasticity index (%)	42
3	IS soil classification	CH
4	Standard proctor compaction	

	OMC (%)	20.4
	MDD (g/cc)	1.58
	CBR Test value	
5	Unsoaked CBR (%)	26.9
	Soaked CBR (%)	2.4
6	UCS (Kg/cm^2)	1.5

Water content –Dry density relation using standard proctor test for untreated soil.

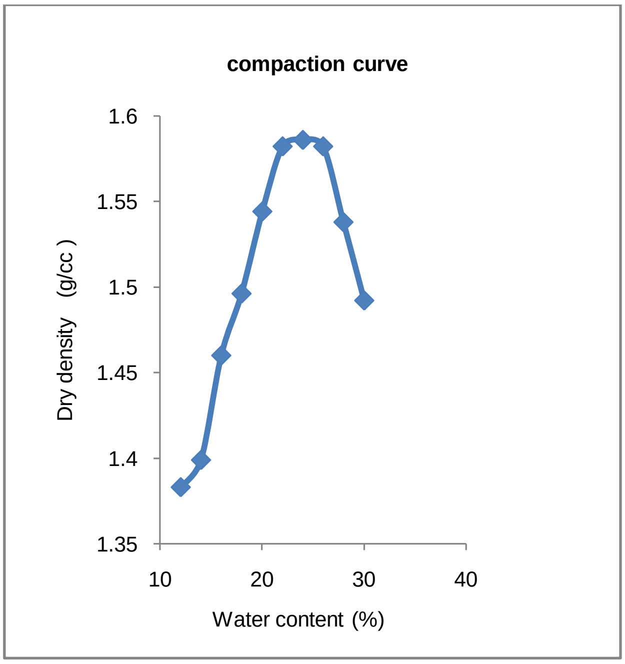

Fig 1: Water content v/s Dry density graph

From the graph OMC is 20.4% and MDD 1.58 g/cc.

The MDD and OMC values were used to calculate the optimum dosage of terrasil as per zydex protocol.

Table 3 Soil Atterberg limits with and without additives.

Using additives LL decreased and PL increased. Mix C Liquid limit value decreased more compared to Mix A and Mix C. Plastic limit increased more for Mix A compared to Mix B and Mix C. Similarly Plasticity Index value decreased more for Mix A compared to Mix B and Mix C.

Material	LL	PL	PI
Un treated CH soil	73%	31%	42%
Mix A	50.5 %	36.4 %	14.1 %
Mix B	54.5%	33.3 %	21.2 %
Mix C	56.5%	31.8 %	24.7 %

Table 4 UNSOAKED CBR Test result at 2.5mm penetration

The Unsoaked CBR value at 2.5mm penetration was similar for Mix A and Mix B. Unsoaked CBR value at 2.5mm penetration was similar for Mix C and untreated soil.

CBR Value at 2.5 mm standard penetration and standard load 1370 Kg				
SAMPLE	Untreated soil	Mix A	Mix B	Mix C
Load at 2.5 mm (In KN)	11.2	13.8	12.4	10.4
CBR value (%)	26.9	33.2	31.8	25.1

Table 5 UNSOAKED CBR Test result at 5mm penetration

The Unsoaked CBR value at 5mm penetration was same for Mix A and Mix B. Unsoaked CBR value at 5mm penetration of Mix C is less than untreated soil CBR value.

CBR Value at 5 mm standard penetration and standard load 2055 Kg				
SAMPLE	Untreated soil	Mix A	Mix B	Mix C
Load at 5 mm (In KN)	13	15.4	15.4	11.6
CBR value (%)	20.8	24.7	24.7	18.6

Table 6 UNSOAKED CBR Test result

The Unsoaked CBR value at 2.5 mm penetration is more than the 5mm penetration. So 2.5mm penetration values were taken as Unsoaked CBR values of respective tests.

CBR values				
SAMPLE	Untreated soil	Mix A	Mix B	Mix C
CBR value (%)	26.9	33.2	31.8	25.1

Unsoaked CBR Values Comparison Graph

Variation Unsoaked CBR values for different mix proportions (Mix A, Mix B, Mix C and Untreated soil) sown in below graph.

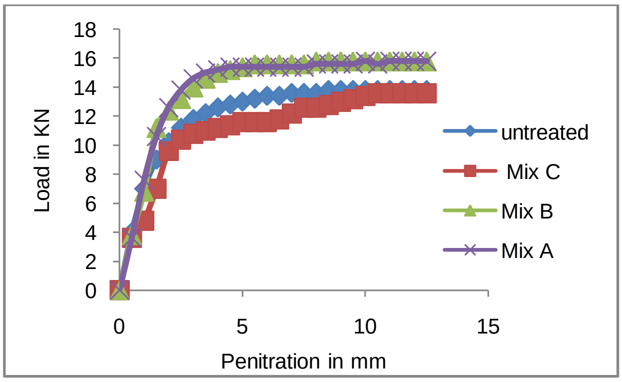

Fig 2: Load v/s Penetration graph

Table 7 SOAKED CBR Test result at 2.5mm penetration

The Soaked CBR value at 2.5mm penetration was similar for Mix A and Mix B. Soaked CBR value at 2.5mm penetration for Mix C was found less than Mix A and Mix B but greater than untreated soil.

CBR Value at 2.5 mm standard penetration and standard load 1370 Kg				
SAMPLE	Untreated soil	Mix A	Mix B	Mix C
Load at 2.5 mm (In KN)	1.2	13	12.8	9.4
CBR value (%)	2.4	31.3	30.8	22.6

Table 8 SOAKED CBR Test result at 5mm penetration

The Soaked CBR value at 5mm penetration was similar for Mix A and Mix B. Soaked CBR value at 2.5mm penetration for Mix C was found less than Mix A and Mix B but greater than untreated soil.

CBR Value at 5 mm standard penetration and standard load 2055 Kg				
SAMPLE	Untreated soil	Mix A	Mix B	Mix C
Load at 5 mm (In KN)	1.4	14.8	15.8	11.6
CBR value (%)	2.2	23.7	25.3	18.6

Table 9 SOAKED CBR Test result

The soaked CBR value at 2.5 mm penetration is more than the 5mm penetration. So 2.5mm penetration values were taken as soaked CBR values of respective tests.

CBR values				
SAMPLE	Untreated soil	Mix A	Mix B	Mix C
CBR value (%)	2.4	31.3	30.8	22.6

Soaked CBR Values Comparison Graph

Variation Soaked CBR values for different mix proportions (Mix A, Mix B, Mix C and Untreated soil) sown in below graph.

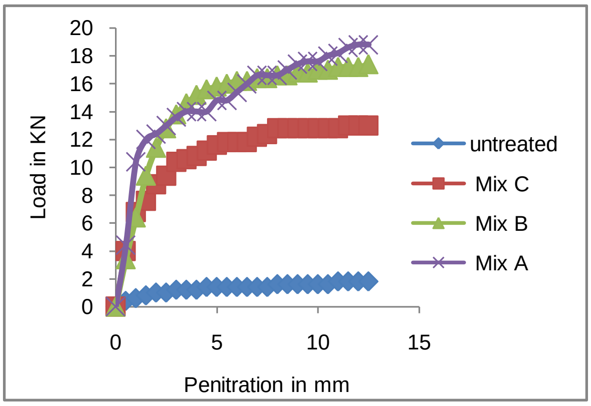

Fig 3: Load v/s Penetration graph

Table 10 UCS vales of soil with and without stabilizers

UCS values were Greater and similar for Mix A and Mix B .Mix C UCS value was slightly greater than untreated soil.

UCS values				
SAMPLE	Untreated soil	Mix A	Mix B	Mix C
UCS (Kg/cm^2)	1.5	7.7	6.8	1.9

5. Discussion

When significant reactions take place, the soil stabilization occurs. Those reactions are hydration, carbonation, ion exchange, pozzolona action etc. These reactions occurs when cement, fly ash, lime mixed with soil in the presence of water.

Due to hydration process free lime occurs, ion exchange predeceases positively charged calcium ions on surface of clay particles, this action decreases the plasticity of soil either by decreasing LL and increasing PL or decreasing PL and increasing LL, depending upon additive.

After these reactions pozzolona action take place. In this process alumina and silica present in clayey soil react with free lime in the presence of water, it forms cementitious gel. This cementitious action gives strength to soil.

Here we added fly ash (class F), cement (OPC) and terrasil to soil. Cement, Fly ash formed cementitious properties and Terrasil formed Si-O-Si (Siloxane bond), water proofing surface. Due to this action strength increased, and soil particles bonded closely by filling pore spaces.

Due to all the above reactions and their results, the plasticity index of soil decreased by decreasing LL and increasing PL. CBR and UCC strength values increased.

6. Conclusion

Based on experimental results and discussions it can be concluded that:

➢ The liquid limit of CH soil decreases and Plastic limit of CH soil increases with addition of stabilizers to the soil. Due to change in PL and LL, plasticity value decreased. Decrement of PI value will increase the workability of soil.

➢ CBR Values were increased by the addition of stabilizers to soil. CBR values of additive Mix A and additive Mix B were similar, where as for additive mix C decreased.

➢ UCC strength of soil increased with the addition of stabilizers to soil.UCC strength values of additive Mix A and additive Mix B were good in strength compared to additive Mix C.

In conclusion Additive Mix A and additive Mix B were good in strength and similar, but economic point of additive Mix B is best, because in additive Mix B we are decreasing 1% cement compared to additive Mix B and using 5% fly ash. Fly ash is a by product cheaper than cement. The stabilization of soil soil-cement-fly ash-terrasil is very useful as sub grade or sub base material due to increased CBR value decreases the thickness pavement.

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