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SOIL STABLIZATION USING CEMENT

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ABSTRACT

The aim of the study was to improve the engineering properties Soil after stabilizing it with Cement. Soil stabilization by using cement is very easy technique for stabilization of soil. The chemical stabilizers for stabilization of soil are growing daily. In this study a laboratory experiment was conducted to evaluate the effects of water borne polymer on unconfined compression strength on sandy soil and CBR Test on clayey soil .The laboratory tests were performed including grain size of sandy soil, unit weight, and unconfined compressive strength test. The sand and various amounts of cement (20%, 30%, and 40%) were mixed with all of them into dough using hand mixing in laboratory conditions. The samples were subjected to unconfined compression tests to determine their strength after 7 days of curing. The results of the unconfined compressive tests show that the waterborne polymer increases the unconfined compression strength of soils which have susceptibility of liquefaction. Cement stabilization modified the engineering properties of soil through physical bonding. The amount of cement stabilization required to modify the engineering properties was directly related to specific surface of soil particle. Cement particles amended soils displayed a reduced performance compared to cement amended soils.

KEYWORDS: Stabilization, Soil, Cement, Road Construction

Soil stabilization is a regulated process to improve the soil by using additives in order to use it as base or sub base courses and carry the expected traffic and pavement loads. There are several methods by which soils can be stabilized. The most commonly used method is cement stabilization.

Cement Stabilization

Strength gain in soils using cement stabilization occurs through the pozzolanic. Cement contains the calcium required for the pozzolanic reactions to occur, however, the origin of the silica required for the pozzolanic reactions to occur differs. In lime stabilization, the silica particles are applied when the particles of clay is broken down. In cement stabilization, the cement already has the silica particles so there is no need to provide extra silica particles. Thus, in cement stabilization the stabilization is not dependent on the soil properties. There is in cement stabilization the only requirement that the soil have water for the complete hydration process to start.

Objectives of the Study

The effect of increase in moisture content on the soil behavior has been a major concern among the geotechnical as well as pavement engineers. Soil shows good performance at the optimum moisture content or below it; however the strength and stiffness of soils reduces rapidly as the moisture content increases from the optimum moisture content. Due to soft nature of soil in some regions and with the presence of high water table strength/stiffness of subgrade soil is too weak to support the pavement loads. In addition, some soils have great tendency to shrink/swell with moisture content and often creates serviceability problems during or after construction of the foundations or pavement layers.

The replacement of such soil with better quality of borrow soil fill is not always a good option. In order to solve with this problem, various techniques have been applied by engineers depending upon the types of the soil. For example, mechanical stabilization is preferred to coarse grained soils. But, in some regions, with soft clay subgrade and high water table, it is customary to treat the soils with some chemical stabilizers or calcium rich stabilizers. These stabilizers not only provide the working platform for construction through enhancing the strength of treated subgrade layer; but also can give the relatively stable sub-base for pavement.

Most of the soils have in situ moisture content higher than the optimum, and therefore the prediction of subgrade behavior based only on the property around the optimum or near the optimum on either side is not enough. The use of different stabilizers based on the properties of the raw to treated/stabilized subgrade soil has made it easier to construct pavement on high moisture contents and weak soil subgrade.

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LITERATURE REVIEW

Stabilization of residual soil with rice husk ash and cement (Basha *et al.*, 2004): - The effects on the consistency, density, and strength of residual soil are studied. It can be observed that cement reduce the plasticity of soils. In general, 6–8% of cement show the optimum amount to reduce the plasticity of soil. The effect of the addition cement on the unconfined compressive strength shows undoubtedly a very effective additive to enhance the strength of tested soils. The increase in CBR value corresponds to the increase in cement content.

Stabilization of clayey soils with high calcium fly ash and cement (Kolias *et al.*, 2005):**-** This work shows that the potential benefit of stabilizing clayey soils with high calcium fly ash but this depends on the type of soil, the amount of stabilizing agent and the age. The study of the formation of the hydraulic products during the curing of clay containing as a stabilizing agent high calcium fly ash shows that a significant amount of to be rmorite is formed leading to a denser and more stable structure of the samples. A further addition of cement provides better setting and hardening and the combination of these two binders can increase the early as well the final strength of the stabilised material. The free CaO of fly ash reacts with the clay constituents (SiO_2 and the other aluminium silicates) leading to the formation of tobermorites and calcium aluminium silicate hydrates as well.

Santoni *et al.*, (2003) stabilized silty sand with several nontraditional stabilizers, including acids, enzymes, lignosulfonates, petroleum emulsions, polymers, and tree resins. UC tests were used as an index performance test for all samples. Samples were prepared in moist and dry test conditions. A total of six control samples, twelve nontraditional samples, and three traditional stabilizer samples were tested. The results indicated three polymers have the potential to increase the strength of silty sand in wet and dry conditions. For the traditional stabilizers, only cement provided significant strength improvement. Both the traditional and nontraditional stabilizers lost strength under wet conditions. The optimum additive dosage for the polymer emulsion ranged from 2.5% to 5% by weight of dry soil.

Tingle *et al.*, (2003) looked at the stabilization of clay soils using several nontraditional additives including several polymer emulsions. The purpose of this study was to develop a compare effectiveness of several different liquid stabilizers. Low- and high-plasticity clays were used in this study. Samples were subjected to wet and dry test conditions and were tested using unconfined compression. The nontraditional stabilizers were compared to more traditional ones, such as cement and lime. The unconfined compression results showed the polymer emulsions to have variable improvements in the dry condition with minimal loss of unconfined compressive strength in the wet conditions with both soil types. The optimum amount of fluid for polymer emulsions was in the range of 2-5% by dry soil weight. Overall, the products used in this study proved to be promising for use in low- volume roads.

Closing Remarks

All types of soil stabilization shows an improvement in the soil which can be seen with the improvement of UCS, Toughness, Tensile strength, CBR values.

Experimental Program

Testing was performed in accordance with all applicable Indian Standard Codes IS: 2720 (Part 16) 1979.The index properties tests are conducted first, then the soil optimum moisture content and dry density tests are conducted and at OMC, maximum dry density, the tests are performed. Soil index properties such as maximum dry unit weight, optimum moisture content, and specific gravity were used to classify soils. These tests were performed in accordance with their respective standards.

Materials Used

Clayey Soil: - Index properties

The result of index properties such as liquid limit, plastic limit, PI value is presented in Table below:

Table 1: Index Properties

Description of Index properties	Experimental Value
Liquid limit	30%
Plastic limit	18.50%
Plastic Index	11.50%
Shrinkage limit	14.65%

Particle size distribution - The grain size distribution of this soil sample has been shown in Table below:

Table 2: Grain size Distribution of Soil

IS sieve no	Wt. retained in gram	% wt. retained in gram	% wt. passing
4.75 mm	18.84	1.884	98.51
2.36 mm	17.2	1.72	95.25
1.18 mm	15.56	1.556	93.21
425 µm	12.51	1.251	92.13
300 µm	3.12	0.312	91.15
150 µm	22.3	2.23	89.91
75 µm	42.45	4.245	86.43

Based on the above properties the IS Soil Classification for the soil sample under test is 'CL'

Modified Proctor Compaction Test: - The result of modified proctor compaction test are represented in figure 1.

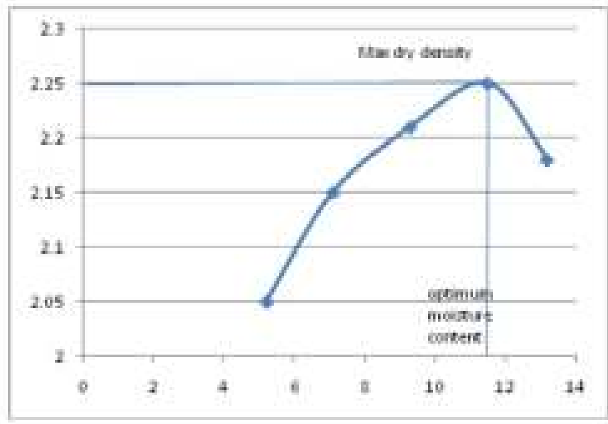

Figure 1: Result of modified proctor compaction test

From the figure 3.1 it is clear that, MDD = 2.25 g/cc, OMC = 11.5 %

Cement: - The cement used for the study is Portland cement 43 grade and the properties of which are given in Table 3.

Table 3: Properties of cement

Fineness (Sq.m/kg) Min.	Soundness By	Setting Time		Compressive Strength(MPa)			
	Le- Chatlier Apparatus	Initial Minutes	Final Minutes	1 day	3 day	7 day	28 day
225	10	30	600	NS	23	33	43

TESTS FOR INVESTIGATION

California Bearing Ratio Testing

The CBR is the only test which can figure out the strength of a subgrade. By performing this test we can check the strength of different kind of subgrade materials .The California bearing ratio test is done by which one can find out or design the strength or thickness of subgrade layer. The CBR value is inversely proportional to the thickness of the pavement layer. If subgrade layer is stronger, than there is higher CBR value, so less thickness is required and vice-versa, The CBR test determines the thickness of various elements constituting the pavement. The CBR test is defined as the ratio of force per unit area required to penetrate soil mass by a circular plunger of 50mm at the rate of 1.25mm/min. Observations obtained between the load resistances versus plunger penetration. The California bearing ratio, is expressed as the ratio of the load resistance of a given soil sample to the standard load at 2.5mm or 5mm penetration, expressed in percentage.

CBR = (Test load/Standard load) × 100

The standard load for 2.5mm and 5mm penetrations are 1370 kg and 2055 kg respectively. The CBR test is obtained on a small scale penetration of dial gauge reading with probing ring divisions. Initially the experiments were conducted to find out various properties of soil such as the index properties and the grain size distribution etc. After this heavy compaction tests were conducted to find out the optimum moisture content & corresponding maximum dry density.

Sample Preparation

All CBR samples are prepared by first measuring the necessary amount of soil to fill a standard CBR mold into a 4 kg plastic bag. The amount of water required to bring the soil to optimum moisture content is added and blended until homogenously distributed. Chemical additives are used they are added at the desired content to the moist soil mixture. The chemical added is then blended with the soil-water mixture.

Unconfined Compression Testing

The Unconfined Compression (UC) testing was done for fine-grained material treated with polymer emulsion. The Soil test loading frame used in CBR testing was modified by exchanging the penetration piston with a 4 inch plate.

The samples are compacted in a 4 inch × 8 inch mold using modified proctor compaction. After compaction samples were extruded from the mold and wrapped in rubber membrane to prevent excess air from curing the samples. A strain rate of 0.6 inches per minute was used with the measurements taken after every 0.01 inches to a strain of 15% (up to 1.23 inches). Sandy soils with a different rate of cement mixing were used and various percentages of waterborne polymers were added to soils to investigate the compressive strength of stabilized samples. The soils were dried before using in the mixtures. Firstly, the required amounts of polymer as a percent of dry weight of the sample and cement were mixed and then added to dry soils. The amount of aqueous polymer was chosen as 2, 3, and 4% by total weight of dry sample and the amount of cement was chosen as 20, 30, and 40% by weight of dry sample, respectively and the mixed sample was placed into the mould. After 24 hours later, the specimens were taken out of the moulds and specimens were stored in the curing room at the temperature ranging from 21 to 25 centigrade and then tested at 7 days.

The polymer mixture was developed in to dough using proper Kneading by hand. The uniformly mixed dough was subsequently placed into a steel mold measuring 150 mm in height and 300 mm in diameter. Unconfined compressive strength testing was performed on all extracted specimens with a constant stress rate by manually controlled test machine. The data acquisition system was used to note the applied load. Each of specimen was loaded until the peak load was obtained.

Following Table 4 presents the consistency classification for fine-grained soils (Terzaghi et al.,1996).

Table 4: Consistency classification for fine-grained soil

Classification	Description	Un-confined compressive strength qu (lb/in2)
Very Soft	Thumb penetrates easily,	<3.5
Soft	Thumb will penetrate about 1 inch	3.7-6.9
Medium	Thumb will penetrate about 0.25 inch	6.9-13.9
Stiff	Thumb will penetrate about 0.5 inch	13.9-27.8
Hard	Thumb will not indent soil	27.8-55.5
Very Hard	Thumb will not indent soil	>55.5

RESULT AND DISCUSSION

The results of 7 days curing on unconfined compression strength results were shown in table 5 and Fig. 2.

Table 5

	Variation in Cement content		
Unconfined Compression Strength(Mpa)	20%	30%	40%
	5.1	8.2	9.7
	8.5	8.8	10.4

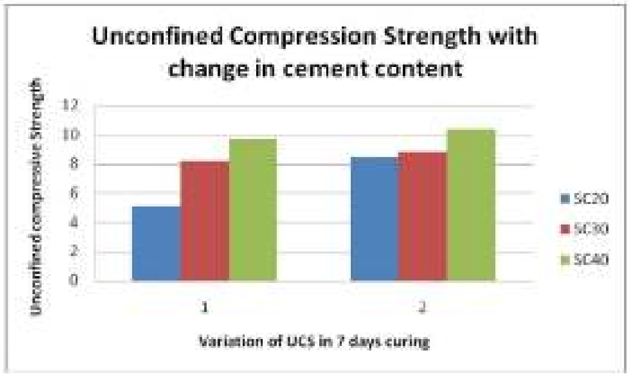

Figure 2

Mix ID's: - SC20=Soil+20%, cement SC30=Soil+30%, cement SC40=Soil+ 40% cement.

CBR Test Results

The result of CBR test of soil sample taken at 20% cement content and 2% polymer content under different times of soaking are presented in Table 6 and fig. 3.

Table 6: Increase in CBR Values

Days of Soaking	0	1	2	3	4
S	44.85	13.25	10.45	5.5	5.32
SC20	59.56	16.6	18.85	7.64	6.42

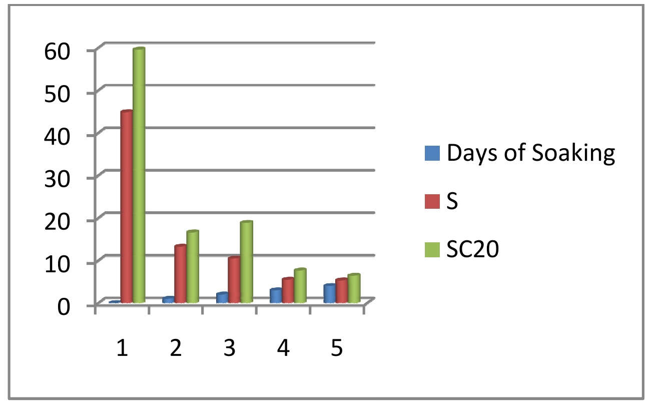

Figure 3: Variation in CBR Values with days of Soaking

Mix Id's:- S=Soil without Stabilization, SC20=Soil with cement 20%

Design of Flexible Pavement (IRC: 37-2012)

Assume Traffic Volume=100 msa i.e,N=100 msa

From IRC: 37-2012, At CBR=5.35, Thickness of pavement=714 mm

At CBR=6.42, Thickness of pavement=675 mm Decrease in Pavement thickness is as:

With cement 20%=39mm.

Analysis for cost of Pavement per km road length

Sr. No.	Particulars	Amount in Lacks
1	Compacting original ground supporting As clause 303.5.2 1000x0.286x3.60 = 1029.6cum , Total = 1029.6 cum @ 29	**0.29**
2	Construction of Granular Sub Base As Clause 401 1000x3.60x0.286 = 1029.6cum, Add for passing zones = 3 x 22.5x 2.40 x 0.286 = 46.33cum, Total :- 1075.93 Cum @ 709/cum	**0.69**
3	WBM Grade III As per clause 405, By mechanical means, 1000x3.30x0.25 = 825. Cum, Add for passing zones = 3 x 2.40 x 0.25 x 22.50 = 40.5 cum, Total :- 865.5Cum @ 1198/cum	**10.36**
4	Providing and laying bituminous macadam As per clause 405, By mechanical means, 1000 X 3 X 0.128 = 384Cum, Add for passing zone = 3 x 2.70x 22.50 x 0.128 = 23.32cum, Total:- 407.32 @ 6932/Cum	**28.23**
5	Providing and applying primer coat as per clause 502, By mechanical means, 1000x 3 = 3000 Sqm, Add for passing zone = 3 x 22.50 x 2.70 = 182.25 sqm, Total = 3182.25 @ 43/sqm	**1.36**
6	Providing and applying tack coat, as per technical specification clause 503, Quantity as per item No. 5 =3182.25 sqm @ 16/sqm	**0.51**

7	20mm thick open graded premix carpet using bituminous, as per Technical Specification Clause 508, Quantity as per item No. 5 = 3182.25 sqm @141/sqm	**4.49**
8	Providing and laying seal coat for sealing the voids as per technical specification clause 510, Quantity as per item No. 5= 3182.25 sqm @ 54/ sqm	**1.72**
9	Berm Filling with approved material as per technical specification, 301.5 2x 1000 x 0.90+1.20 x 0.286 = 1800 Cum @ 258/Cum	**4.64**

Total cost per Km =59.23 lac

Cost Assessment of cement (20%) Stabilized Soil

Sr. No.	Particulars	Amount in Lacks
1	Compacting original ground supporting As clause 303.5.2 1000x0.252x3.60 = 907.2cum , Total = 907.2 cum @ 29	**0.26**
2	Construction of Granular Sub Base As Clause 401 1000x3.60x0.252 = 907.2cum, Add for passing zones = 3 x 22.5x 2.40 x 0.252 = 40.82cum, Total :- 948.02 Cum @ 709/cum	**0.67**
3	WBM Grade III As per clause 405, By mechanical means, 1000x3.30x0.25 = 825. Cum, Add for passing zones = 3 x 2.40 x 0.25 x 22.50 = 40.5 cum, Total :- 865.5Cum @ 1198/cum	**10.36**
4	Providing and laying bituminous macadam As per clause 405, By mechanical means, 1000 X 3 X 0.123 = 369 Cum, Add for passing zone = 3 x 2.70x 22.50 x 0.123 = 22.41cum, Total:- 391.41 @ 6932/Cum	**27.13**
5	Providing and applying primer coat as per clause 502, By mechanical means, 1000x 3 = 3000 Sqm, Add for passing zone = 3 x 22.50 x 2.70 = 182.25 sqm, Total = 3182.25 @ 43/sqm	**1.36**
6	Providing and applying tack coat, as per technical specification clause 503, Quantity as per item No. 5 =3182.25 sqm @ 16/sqm	**0.51**
7	20mm thick open graded premix carpet using bituminous, as per Technical Specification Clause 508, Quantity as per item No. 5 = 3182.25 sqm @141/sqm	**4.49**
8	Providing and laying seal coat for sealing the voids as per technical specification clause 510, Quantity as per item No. 5= 3182.25 sqm @ 54/ sqm	**1.72**
9	Berm Filling with approved material as per technical specification, 301.5 2x 1000 x 0.90+1.20 x 0.286 = 1800 Cum @ 258/Cum	**4.64**

Total cost per Km =51.14 lac

CONCLUSION

The strength of sandy soil mixtures has increased with increment of cement contents up to about 30% and from above 30% cement content; the strength of the soil almost becomes constant.

The increase in Un-confined compressive strength is more at start of 20% cement addition in the sand, and then its increase is not much when cement content is increased.

Cement addition into the clayey soil reduces the pavement thickness and hence the cost of pavement to a good extent.

It has been observed that the CBR values increases with increase in cement content.

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