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Experimental Study of Engineering Properties in Synthetically Made Lime Treated Expansive Soils

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Abstract:
In India it is found in Rajasthan, Tamil-Nadu, Madhya Pradesh, Maharashtra, Gujarat and Orissa. Expansive soils undergo high swelling and shrinkage causes severe distress and damage to the structure overlaying. Hydrated Lime has been used as a soil stabilizer from Roman times.. Also, lime can stabilize soil through cementation which increases strength and stiffness remarkably. For this purpose, commercial high plastic clay (i.e.Bentonite) having liquid limit of 340% is mixed with different proportions to a residual soil having liquid limit 34% and four different soils were synthesized over a wide range of plasticity. The physical properties of raw soils were found out. The four soils were amended with different lime content and the index properties as well as engineering properties have been studied by conducting relevant experiments conforming to Indian standard code of practice. Special emphasis was made to understand the plasticity, swell and shrink characteristics, compaction characteristics and CBR of virgin soils and soils amended with different proportions of lime. Based on the experimental results it is observed that the liquid limit and plasticity reduces as lime content increases i,e. swell and shrink characteristics decreases with lime content. Also, lime has a significant effect on compaction and CBR characteristics of soil. The MDD of the soil decreases while OMC increases and the CBR value increases under both conditions of soaking.

Keywords: Expansive soil, lime stabilization, Plasticity, Compaction, California bearing value.

I. INTRODUCTION

Soil is one of the most commonly encountered materials in civil engineering. All the structures except few which are founded on solid rock, rest ultimately on soil. In India it is found in Rajasthan, Tamil-Nadu, Madhya Pradesh, Maharashtra, Gujarat and Orissa. Geotechnical engineers all over the world face huge issues, when structures founded on the soil which is expansive in nature. This expansiveness is imparted to such soils when they contain clay minerals like montmorillonite, illite, kaolinite etc. in considerable amount. Due to the clay minerals, the swelling soils expand on wetting and subjected to shrinkage on drying. These soils are commonly unsaturated.

The problem of instability of structures made on such soil is mainly due to lifting up of the structures on heaving of soil mass under the foundation on saturation during rainy season and settlement as a result of shrinkage during summer season.

Due to this cavity action, leading to loss of contact between the soil and structures at some points. This successively results in splitting of structure and failure due to loss of shear strength or unequal settlement, leading to progressive failure of structures. This paper presents the effect of lime (0%, 3%, 6%, 9%, 12% and 15%) on engineering properties of a synthetically prepared expansive soil.

The soil is prepared in four proportions i.e, 100% ES, 75%ES+25%RS, 50%ES+50%RS, 25%ES+75%RS Soil engineering tests like Atterberg limits, differential free swell test, Procter test for compaction characteristics, CBR test were conducted on virgin soil and soil-lime mixture.

II. MATERIAL USED AND LABORATORY TESTING PROGRAMME

Material

2.1 Soil:

The soil used in this investigation is prepared synthetically by mixing natural residual soil (RS) with commercial Bentonite (ES) by weight. Table 2.1 shows the physical properties of the soil used. All the tests mentioned in this research were conducted according to the procedure described by IS-2720 (Different parts).

2.2 Lime:

lime used in this investigation is a commercial lime available in the local market. Soil stabilization by lime involves the admixture of this material in the form of calcium oxide (quick lime) or calcium hydroxide (hydrated lime) to the soil. Calcium oxide may be more effective in some cases; however, the quick lime will corrosively attack equipment and may cause severe skin burns to personal. Quicklime will slake in the presence of moisture to produce hydrated lime as a finer powder. The lime used in this study was selected according to Standard IS specifications with regard to lime stabilization.This specification requires the use of high calcium hydrated lime $Ca(OH)_2$. The specific gravity of the lime used is found to be 2.4.

Table .1. Engineering properties of soil showing IS classification

Engineering Properties	Values			
	100% ES	75%ES+25%RS	50%ES+50%RS	25%ES +75%RS
Liquid limit, WL (%)	364	208	136	48
Plastic limit, WP(%)	72	43	34	27
Plasticity index, IP (%)	292	165	102	21
IS classification	CH	CH	CH	CI
Free swell index, FSI (%)	680	522	450	96
Opt. moisture content (%)	27.75	25.8	21.4	16.8
Max. dry density,ϒd(g/cc)	1.36	1.48	1.55	1.62
UCS, σ (kPa)	305	322	345	402

Laboratory Testing Programme

2.3 Particle size distribution:

Particle size distributions of the studied soil conducted by Hydrometer analysis using a density hydrometer as following IS: 2720 (part 4)-1985 and are plotted in Fig.2.1 below and the corresponding physical properties in the Table 2.2. The gradation of soil revealed percentage passing No. 200 sieve (<0.075 mm) as 95%.

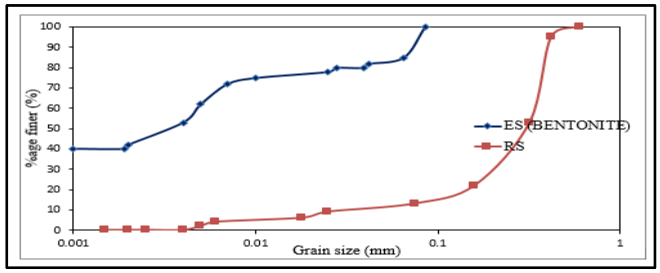

Figure.1. Grain size distribution curve for ES and RS

Table .2. Physical properties of soils

Physical Parameters	Value		Physical parameters	Value	
	ES	RS		ES	RS
Color	Grey	Brown	Shape	Platy	Sub-rounded
Silt and Clay (%)	100	86.94	Coefficient of uniformity, Cu	-	7.3
Fine Sand (%)	-	13.06	Coefficient of Curvature , Cc	-	2.2
Medium Sand (%)	-	-	Specific Gravity, G	2.79	2.6
Corse Sand (%)	-	-	Plasticity index, IP (%)	272	16

2.4 Atterberg limits tests: The PL, LL and PI were obtained following the method given in IS 2720(V), 1985. Variations in the PI of untreated and treated clayey soils were then studied. The PL tests were performed on material prepared for the LL test. Both PL and LL tests were con- ducted at room temperature. The values of plasticity properties of the untreated and lime treated samples of the expansive soil are shown in Table 2.3. To determine the free swell index of soil as per IS: 2720 (Part XL) – 1977 was used. Free swell or differential free swell, also termed as free swell index, is the increase in volume of soil without any external constraint when subjected to submergence in water.

Table.3. Liquid limit, Plastic limit, Plasticity index and FSI of soils for different lime content

Lime content (%)	LL, PL, IP, FSI (%)			
	100% ES	75%ES+25%RS	50%ES+50%RS	25%ES+75%RS
0	364,72,292,715	208,54,154,586	136,38,93,289	48,29,19,164
3	138,102,36,408	102,69,33,347	96,58,38,75	42,35,7,51
6	118,98,20,124	97,73,24,101	85,67,18,52	40,37,3,22
9	115,91,24,104	86,66,20,90	79,61,18,29	38,32,6,13
12	113,90,23,82	80,63,17,64	68,53,15,23	37,25,12,9
15	112,88,24,75	78,67,11,49	67,51,16,20	37,19,18,5

2.5 Compaction Characteristics: The compaction test is done in accordance with IS: 2720 (Part VII)-1980 and IS: 4332 (Part III)-1967.From the dry density and moisture content relationship, the optimum moisture content (OMC) and corresponding maximum dry density (MDD) were determined. Soils were then treated with varying percentage of lime. The lime contents were 0%, 3%, 6%, 9%, 12% and 15% of the dry weight of soil. This was done to study the effect of lime on compaction characteristic of soils. The values of the observations are shown in the table 2.4 below:

Table.4. Compaction characteristics of soils for different lime content

Lime Content (%)	100% ES		75%ES+25%RS		50%ES+50%RS		25%ES+100%RS	
	OMC (%)	MDD (g/cc)	OMC (%)	MDD (g/cc)	OMC (%)	MDD (g/cc)	OMC (%)	MDD (g/cc)
0	27.75	1.36	25.8	1.48	21.4	1.55	18.47	1.62
3	32.5	1.31	28.75	1.44	23.85	1.52	20.24	1.6
6	34.92	1.27	29.9	1.4	26.23	1.48	22.45	1.58
9	34	1.29	30.54	1.36	28.25	1.46	24.08	1.56
12	35.21	1.31	31.45	1.36	29.67	1.45	24.25	1.55
15	36.3	1.38	33.6	1.38	29.98	1.44	24.66	1.55

2.6 California bearing ratio test: The CBR test is done in accordance with IS-2720-PART-16-1979.The California Bearing Ratio Test (CBR Test) is a penetration test used for evaluating the bearing capacity of subgrade soil for design of pavements. It is carried out on natural or compacted soils under soaked or un-soaked conditions and the results obtained are shown in Table 2.5 below:

Table.5. Unsoaked and Soaked CBR values for varying Lime content

Lime Content (%)	100% ES		75%ES+25%RS		50%ES+50%RS		25%ES+75%RS	
	UCBR (%)	SCBR (%)	UCBR (%)	SCBR (%)	UCBR (%)	SCBR (%)	UCBR (%)	SCBR (%)
0	2.20	2.05	2.65	1.42	3.85	2.47	4.20	3.20
3	5.24	2.90	6.33	3.65	6.42	4.39	6.25	5.54
6	6.80	4.57	7.67	5.58	9.66	8.14	9.85	7.66
9	9.61	7.58	11.86	8.67	14.56	12.56	16.25	12.59
12	9.56	7.24	10.54	7.94	14.66	12.57	15.8	11.32
15	8.34	6.25	8.96	6.59	13.26	11.68	14.21	10.25

III. RESULTS AND DISCUSSION

3.1 Atterberg limits:

The reduction in liquid limit occurs as the lime is added to the soil, Ca+ ions are released into the pore fluid and results increase in electrolyte concentration which reduces the thickness of diffuse double layer held around soil particle leading to a lower liquid limit. He plastic limit is a measure of cohesion of soil particles against cracking and it is the water content of soil when it approaches a certain shear resistance. With the addition of lime, the thickness of diffuse double layer decreases which increase charge concentration and thereby viscosity of pore fluid, it results inter particle shear resistance, leading to an increased plastic limit.

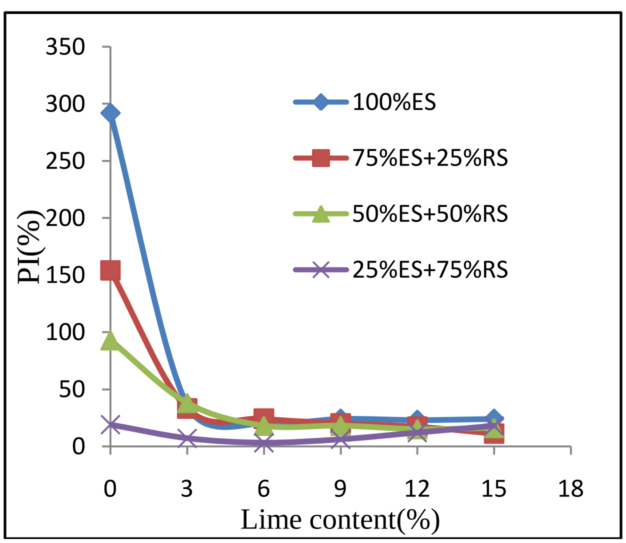

Figure. 3.1(a) Variation of Plasticity Index with lime content

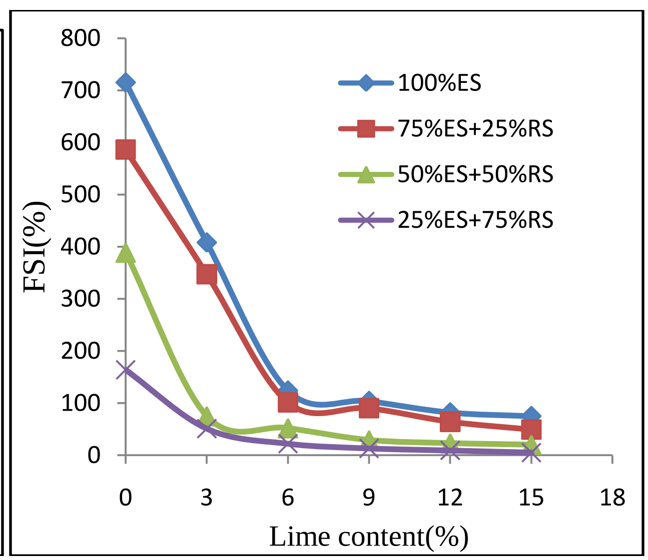

Figure.3.1 (d) Variation of FSI with lime content

A decrease in plasticity index has been observed as the lime content increases. The variations in plasticity index with lime content for soils are shown in Figure 3.1(a). The variation of free swell index with percentage of lime is illustrated in Figure 3.1(b).

3.2 Compaction characteristics

It is observed that the optimum moisture content is less and the maximum dry density is more for the soil 100%RS compared to other three soils. However, the expansive soil (i.e. 100%ES) has minimum dry density and maximum moisture content. Hence, the more the percentage of bentonite in the residual soil, more the moisture content and lesser the dry density. This is obvious as the affinity of expansive soil to water is much higher than the residual soil. The water molecules adsorbed to the surface of the clay minerals and higher amount of water is needed to lubricate the clay surface.

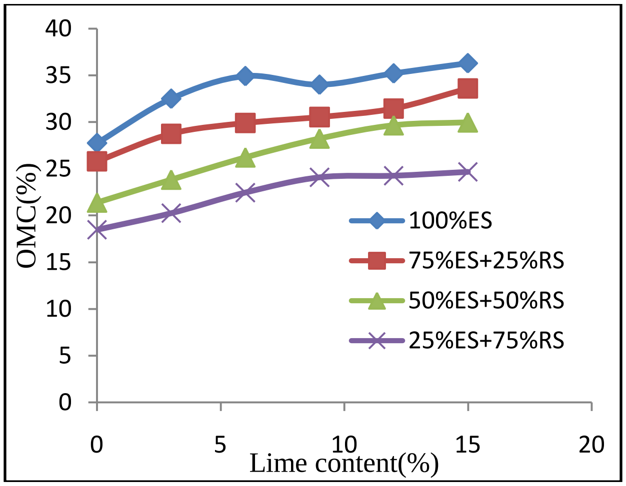

Figure.3.2(a) Variation of MDD with lime content

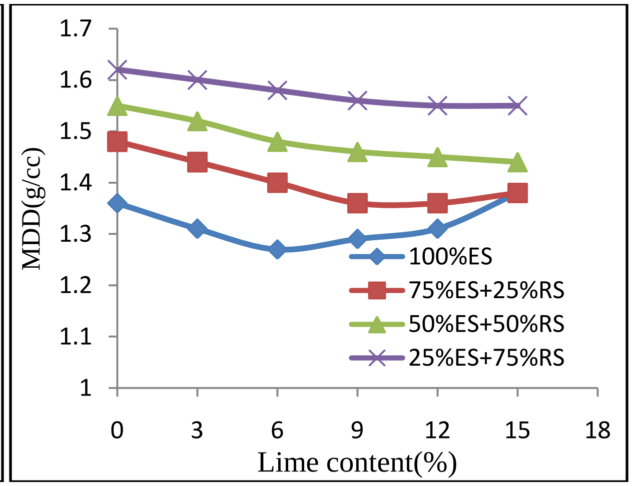

Figure.3.2(b) Variation of OMC with lime content

At lower percentage of lime reacts very quickly with soil, Base Exchange, aggregation and flocculation occurs resulting increased void ratio leading to a decrease in the density of the mix. Beyond this lime content, addition of lime is utilized for pozzolanic reactions causes an increase in optimum moisture content and, more water is retained in the void space between the particles which water content may increase.

3.3 California bearing ratio test

California bearing ratio tests were conducted on all the soil mixtures. The CBR tests were initially conducted on untreated expansive soil sample and CBR value in terms of percentage is determined for untreated soil sample.

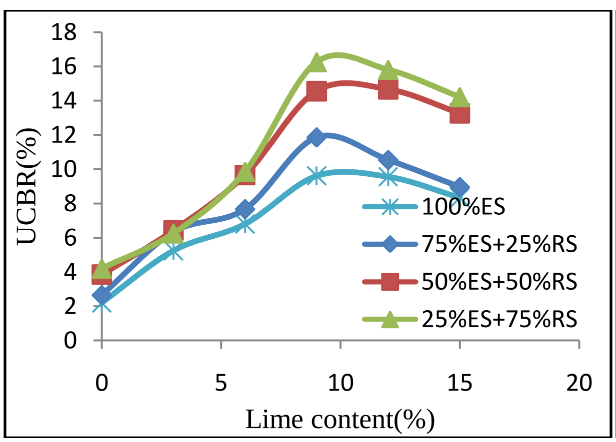

Figure. 3.3(a) Variation of UCBR with different lime contents

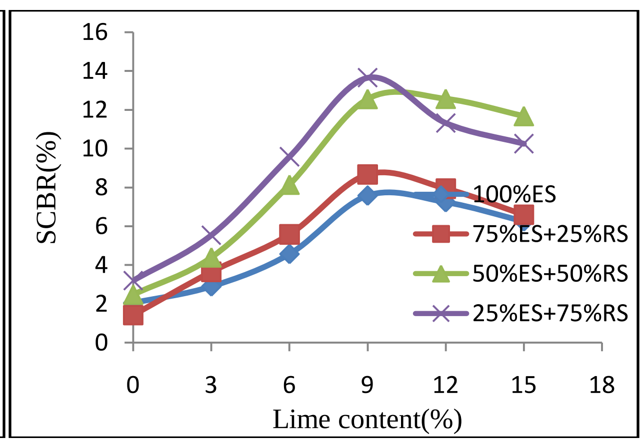

Figure.3.3(b) Variation of SCBR with different lime contents

The CBR value under unsoaked conditions is large as compared to the CBR value under soaked conditions. Due to the improvement in gradation of the soil due to the addition of lime to expansive soil.

IV. CONCLUSIONS

Many of the important engineering properties of soils can be enhanced by the addition of lime. The properties of such soil-lime mixtures vary and depend upon the type of soil. To develop and understanding of the possible mechanisms involved, a series of experiments through variation of parameters were carried out, based on which the following conclusions are drawn:

1. The liquid limit of soil decreases with an increase in lime content. This result is obtained due to reduction in thickness of double layer as the electrolyte concentration increases in the pore fluid. The plastic limit of soil increases with lime contents as the charge concentration of pore water increases, the viscosity increases and offers high resistance against interparticle movement. The plasticity of soil reduces with increased lime

content. There is a significant reduction in free swell index of high plastic clay at low lime content in comparison to other low and medium plastic clays.

2. The compaction characteristics of soils vary significantly at low lime content. The optimum moisture content increases and maximum dry density decreases with increased lime content.

3. The load penetration resistance of all the types of soils is increased remarkably as shown by CBR test under both conditions of soaking.

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