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Investigation on Soil-Mixtures Comprising of Expansive Soils Mixed With A Cohesive Non-Swelling Soil

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ABSTRACT:

Soil is naturally occurring material that is used for the construction of structures except the surface layers of pavements. This naturally occurring soil may not suit the design requirements of ongoing project. So, soil is to be prepared to meet the requirements called soil stabilization. Stabilization is the process of blending of different soils or mixing of additives (manufactured commercial products) to a soil to improve characteristics of the soil such as gradation, strength, durability, workability, plasticity etc. and thus making it more stable. It is required when the soil available for construction is not suitable for the intended purpose. In its broadest senses, stabilization includes compaction, preconsolidation, drainage and many other such processes. However, the term stabilization is generally restricted to the processes which alter the soil material itself for improvement of its properties. A cementing material or a chemical is added to a natural soil for the purpose of stabilization. Soil stabilization is used to reduce the Permeability and Compressibility of the soil mass in earth structures and to increase its Shear Strength. Soil stabilization is required to increase the bearing capacity of foundation soils.

Mechanical stabilization involves compaction by interlocking of soil-aggregate particles. The grading of the soil-aggregate mixture must be such that a dense mass is produced when it is compacted. Mechanical stabilization through soil blending is the most economical and expedient method of altering the existing material. Mechanical stabilization can be accomplished by uniformly mixing the material and then compacting the mixture. As an alternative, additional fines or aggregates may be blended before compaction to form a uniform, well- graded, dense soil-aggregate mixture after compaction. The choice of methods should be based on the gradation of the material. In some instances, geotextiles can be used to improve a soil's engineering characteristics. The three essentials for obtaining a properly stabilized soil mixture are

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i) proper gradation, ii) A satisfactory binder soil and iii) proper control of the mixture content. The stabilization method depends on the type of soil and its properties. The selection of type and determination of the percentage of additive to be used is dependent upon the soil classification and the degree of improvement in soil quality desired. Generally, smaller amounts of additives are required when it is simply desired to modify soil properties such as gradation, workability, and plasticity. When it is desired to improve the strength and durability significantly, larger quantities of additives are used

Keywords:

Expansive soils, Cohesive Non-swelling soils, PH values, Chlorides content and Sulphates Content.

1.Introduction:

Expansive soils, popularly known as black cotton soils in India, are one of the major regional deposits of India covering an area of about one fifth of the country's land area (about 3 lakhs sq. km). Soils containing the clay mineral Montimorillonite generally exhibit these properties. The mica-like group, which includes Illites and Vermiculate, can be expansive, but generally does not cause significant problems. Expansive soils swell and shrink in a marked way due to gain or loss in moisture content. Therefore, during summer when evaporation from the ground and transpiration due to vegetation exceeds the rainfall, the expansive soil dries up and moisture deficiency develops in the soil, giving rise to soil shrinkage. During the rains, the soil absorbs moisture and swells.

2. Literature Review:

Because of their susceptibility to high seasonal volumetric changes, extensive damages have been caused to residential buildings, highways, rail beds and other structures founded on them.



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Such soils are not peculiar to this country alone. Expansive soil deposits are found extensively in England (shrinkable clays), South Africa (pot clays), Australia (bay of bisca clays), United States of America (expansive clay soils), and Burma (desiccated alkaline soils) also, (Cokca 2001). During the last five decades, damage due to swelling action has been observed clearly in the form of cracking and breakup of pavements, building foundations, embankments and irrigation systems. In the United States alone, the expansive soils inflict about \$9 billion per year in damages to buildings, roads, airports, pipe lines and other structures which is more than twice the combined damage from earthquakes, floods, tornados and hurricanes (Jones and Holtz, 1973; Jones and Jones, 1987).

In general, expansive soils have high plasticity, and are relatively stiff. The expansive nature of soil is most obvious near the ground surface where the profile is subjected to seasonal and environmental changes. The pore water pressure is initially negative and the deposit is generally unsaturated. These soils often have some Montmorillonite clay mineral present. The higher the amount of monovalent cations adsorbed to the clay mineral (e.g. sodium), the more severe the expansive soil problem (Fredlund and Rahardjo, 1993).

3. Origin and Occurrence of Expansive Soils:

The key element which imparts swelling characteristics to any ordinary non-swelling soil is a clay mineral. There are several types of clay minerals of which Montmorillonite has the maximum swelling potential. The origin of such soil is sub aqueous decomposition of blast rocks, or weathering in situ formation of important clay mineral takes place under alkaline environments. Due to weathering conditions if there is adequate supply of magnesium or ferric or ferrous oxides and alkaline environments, along with sufficient silica and alluminium, it will favour the formation of Montmorillonite. The depth of expansive soil is shallow at the place of formation with the parent rock underneath. The alluvium deposits can be much deeper in low lying and flat areas, where these soils are transported and deposited.Expansive soils have been reported from many parts of the world, mainly in the arid or semi-arid regions of the tropical and temperate zones like Africa, Australia, India, South America, United States, and some regions in Canada. This never means that expansive soils do not exist elsewhere, because they can be found almost everywhere.

However, in the humid regions water tables are generally at shallow depth and moisture changes, which are responsible for volume changes in soils, are minimal excepting under extended drought conditions (Arnold, 1984; Shuai and Fredlund, 1998; Wayne et al. 1984).

4. Scope and Objectives of Present Study:

The present investigation involves with study of the feasibility of using expansive soil as a construction material in projects like irrigation and airfield, highway pavements, tank bunds, and earthen embankments, earth-retaining structures with and without addition of cohesive nonswelling soil. Wherever soil is used as a construction material; it is customary to stabilize the soils by mechanical means.

In nature, expansive soils may present with varying liquid limits and varying coarse fractions. Both liquid limit and coarse fraction can affect the properties of expansive soils. Hence the objectives of the present investigation are determination and study the effect on soil-mixtures without and with addition of different percentages cohesive non -swelling in expansive soil.

1.Plasticity Characteristics a)Liquid Limit b)Plastic Limit c)Plasticity Index 2.Swelling Characteristics a)Free Swelling Index b)Swelling Pressure **3.**Compaction Characteristics a)Maximum Dry Density (MDD) b)Optimum Water Content (OMC) **4.Strength Characteristics** a)Unconfined Compression Strength b)Shear Parameters (C, \emptyset) 5.Permeability 6.Chemical Analysis a) pH Value b) Chlorides Content and c) Sulphates Content

This project focuses on possibility of using locally available cohesive non-swelling soil so as to stabilize and improve the engineering behavior of expansive soil and determination of optimum percentage of Cohesive Non Swelling soil for better results.



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5. Visual Identification:

Potentially expansive soils are usually recognized in the field by their fissured or shattered condition (polygonal cracks during dry season) or by the typical structural damage caused by such soils to existing buildings.



Fig: 1 Polygonal Cracks



Fig: 2 Popcorn Structure



Fig: 3 Slicken Slides



Fig: 4 Gilgai Formation

6. Materials and Methods:

The usage of cohesive non-swelling soils is popular method of soil improvement owing to its availability, low cost and applicability to wide range of soils. However from literature review it is clear that only a few investigators considered the study of improvement of expansive soils using cohesive non-swelling soils accounting for Liquid Limit of the soils. Further, the literature is scanty concerning the strength and deformation characteristics of admixtures of expansive soils and cohesive non-swelling soils.Present investigation aims at studying the variation of physical and chemical properties of expansive soils for mechanical stabilization by adding different proportions of cohesive non-swelling soils. To achieve the said goals a series of tests are conducted in the laboratory. The details of the tests conducted, soils used, and the tests procedures are given in the following sections.



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Table: 1 Details of soil used for testing:

Soil	
Designation	Locations
S1	Pembarthi, Warangal, (at 2.9 m depth)
S2	Keshavapur, Warangal (at 3 m depth)
S3	Ambala ,Warangal (at 2.9 m depth)
S ₄	Kamalapur, Hanmakonda (at 2.5 m depth)
S ₅	Chintagattu, Hanmakonda (at 4 m depth)

6.1 Details of tests conducted on soil mixtures

		Soil Mixtures	Tests conducted			
S.No	Mixtures using S ₁	Mixtures using S ₂	Mixtures using S ₃	Liquid Limit, Plastic Limi Free Swell Index, Odomet Test (Consolidation Test),		
1	$S_1 + 0 \% S_4$	$S_2 + 0 \% S_4$	S ₃ +0 % S ₄	Light Compaction Test, Tri-		
2	S ₁ +15% S ₄	S ₂ + 15% S ₄	S ₃ + 15% S ₄	axial Test, Unconfined		
3	S ₁ +20% S ₄	S ₂ +20% S ₄	S ₃ +20% S ₄	Compression Test, , Swelling Pressure		
4	S ₁ + 25% S ₄	S ₂ + 25% S ₄	S ₃ + 25% S ₄	Permeability Test, pH		
5	S ₁ + 30% S ₄	$S_2 + 30\% S_4$	$S_3 + 30\% S_4$	values, Chlorides and		
6	S ₁ +35% S ₄	S ₂ + 35% S ₄	S ₃ + 35% S ₄	sulphates Contents.		

6.2 Properties of the Soils used for investigation

S.NO.	TESTS	S1	S2	S 3	S4	S 5
	Sieve Analysis					
1	a) Gravel,(%)	2.6	2.9	1.8	4.5	5
I	b) Sand, (%)	21	29	18	37	40
	c) Silt + Clay,(%)	76	68	80	58	55
2	Liquid Limit, (%)	62	72	61	35	31
3	Plastic Limit, (%)	31	36	28	30	25
4	Plasticity Index, (%)	31	36	33	5	6
5	IS Classification of Soil	СН	CH	CH	CL	CL
6	Free Swell Index (%)	125	210	135	55	48

7	Degree of expansion	CRITICAL	SEVERE	MARGINAL	NON CRITICALLL	NON CRITICAAL
8	Optimum Moisture Content	24.8	26.2	25.4	17.1	17.7
9	Maximum Dry Density	1.51	1.54	1.5	1.71	1.73
10	Undrained Strength					
	a) Cohesion (C, in	10	7	12	1.8	2.3
	Coefficient of Permeability,	0.522.10-6	1 17 10-7	1 22 10-6	1 01 10-6	1 170 10-4
11	(k)	8.332X10	1.1/X 10	1.33X10	1.01X10	1.1/9X10
12	P ^H values	8	9.9	9.26	9.01	6.71
13	Chlorides (% by mass)	0.24	0.47	0.71	0.69	0.2
14	Sulphates(% by mass)	0.21	0.49	0.25	0.22	0.36

7. Results and Discussions:

Expansive soils in nature may contain coarse fraction in varying proportions. Fraction coarser than 425μ has no effect on plasticity characteristics but has on mechanical properties. I.S Light Compaction test, Triaxial Shear Test, Unconfined Compression Test were conducted on three expansive soils namely S1, S2 and S3 with and without adding S4 soil. The proportions of the S4 soil added are kept equal to 15%, 20%,25%,30% and 35% by weight of expansive soil. The index properties of the soils used are already presented in chapter 3, Table 3.4. All three soils are classified as CL and CH as per I.S Classification method with Liquid Limits of 62%, 72% and 61% respectively. The results pertaining to Compaction Characteristics, Strength Characteristics are presented in subsequent sub sections respectively.

7.1 Liquid Limit:

Table 7.1 Variation of Liquid Limit for soilmixes

	S1 & S4		S ₂ & S ₄		S3 & S4	
(%)	LL	% Decreas e	LL	% Decreas e	LL	% Decrease
0	62	-	72	-	61	-
15	51	17.74	59	18	52	14.75
20	46	25.80	56	22.22	48	21.31
25	43	30.64	54	25	46	24.59
30	41	33.87	52	27.8	44	27.86
35	38	38.70	51	29.16	41	32.78

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Graph:7.1 Variation of Liquid Limit for Soilmixes (S1-S4, S2-S4, and S3-S4)

7.2 Plastic Limit

Table: 7.2 Variation of Plastic Limit for soilmixes

S4-	:	S1 & S4		S ₂ & S ₄		S ₃ & S ₄		
soil (%)	PL	% Decrease	PL	% Decrease	PL	% Decrease		
0	31	-	36	-	28	-		
15	28	8.33	33	8.33	26	7.14		
20	26	16.12	28	22.22	25	10.71		
25	24	22.58	26	27.78	22	21.4		
30	23	25.80	25	30.55	21	25.6		
35	22	29.03	24	33.33	20	28.57		



Graph:7.2 Variation of Plastic Limit for Soilmixes (S1-S4, S2-S4, and S3-S4)

7.3 Plasticity Index Table: 7.3 Variation of Plasticity Index for soil mixes.

S4-	S4- S		:	S ₂ & S ₄	S ₃ & S ₄	
soil (%)	PI	% Decrease	PI	% Decrease	PI	% Decrease
0	31		36		33	
15	23	25.8	26	27.28	26	21.2
20	20	35.48	28	22.22	23	30.3
25	19	38.71	28	22.22	24	27.27
30	18	41.93	27	25	23	30.3
35	16	48.38	27	25	21	36.36



CONCLUSIONS :

The present work emphasized on investigation of soil mixtures comprising of three expansive soils (S1,S2,S3) mixed with a Cohesive Non-Swelling(S4) soil pertaining to Plasticity Characteristics, Compaction Characteristics, Strength Characteristics, Swelling Characteristics, Permeability, pH values, Chlorides Content and amount of Sulphates. Soil-mixtures are prepared with expansive soils adding different percentages of cohesive non-swelling (S4) soil varying from 15% to 35% by weight of expansive soil with 5% interval. The soil-mixtures are designated as S1-S4, S2-S4 and S3-S4 throughout the work for reference Tests are conducted on the prepared soil-mixtures as per procedures laid down in IS Codes.



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Both the Liquid limit and Plastic limit values all the soil mixtures (S1-S4, S2-S4 and S3-S4) decreased with the increase in percentage of Cohesive Non-Swelling soil(S4).

1)The Plasticity Index values of the soil mixtures also decreased with increase in percentage of Cohesive Non Swelling soil(S4)

2)There is a decrease in Optimum Water Content with increase in Cohesive Non Swelling soil (S4) for S1-S4 and S3-S4 mixes whereas Optimum Water Content increased for S2-S4 soils combinations.

3)The maximum Dry Unit Weight of the soil mixtures increase slightly with increase in percentage of Cohesive Non Swelling soil (S4)) for S1-S4 and S3-S4 mixes and decreased for S2-S4 mixes.

4)Strength parameters are reported for S1-S4 soil mixtures .The angle of internal friction of the S1-S4 increased for 15% and 20% of S4 soil. The values decreased gradually forS1-S4 mixes with 25%, 30% and 35% of S4 soil. Cohesion values of these mixes decreased for 15% and 20% of S4 soil and then increased up to 35%. The cohesion values for all soil- mixes (S1-S4,S2-S4 and S3-S4) less than the original soil (0% S4 soil) respectively at all percentages of S4 soil.

5)The Unconfined Compressive Strength of the soil mixtures improved with the increase in Cohesive Non Swelling soil (S4) percentage.

6)The Coefficient of Permeability (k) values of the soil mixtures increased with addition of S4 soil from 15% to 35% percentage.

7)The Swelling Index and Swelling Pressure decreased with increase in percentage of cohesive Non Swelling soil (S4) for all soil-mixes.

8)The PH values of the soil mixtures lowered with increment in percentage of Cohesive Non Swelling soil (S4).

9)The Chlorides content reduced for all the soil mixtures with percentage increment of Cohesive Non Swelling soil (S4).

10)The Sulphates Content of the soil mixtures decreased with increase in percentage of Cohesive Non Swelling soil(S4).

11)It is a cost effective technique for improvisation of the swelling soils.

12)Improvisation mechanisam is very easier and less time taken.

Future scope of work:

The present investigation can be extended for developing design guide lines for judging the suitability of the soil-mixtures as a cohesive non-swelling soil layers for various applications in the construction industry. Further the work can incorporate the chemical analysis for finding Carbonates content and microscopic analysis to understand the complete behavior of these expansive soils and the soil-mixes prepared.

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