Investigation on Engineering Properties of Soil-Mixtures Comprising of Expansive Soils and a Cohesive Non-Swelling Soil

Dr. Ch. Sudha Rani

Dept. of Civil Engineering, S.V.U.College of Engineering, Tirupati, Andhra Pradesh,, India

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 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. The present paper emphasized on investigation of soil mixtures comprising of three expansive soils mixed with a cohesive non-swelling soil pertaining to plasticity characteristics, compaction characteristics, Soil-mixtures are prepared with expansive soils adding different percentages of cohesive non-swelling soil varying from 15% to 35% by weight of expansive soil with 5% interval. The soil-mixtures. deals with the results pertaining to Engineering properties of soils i.e Strength Permeability, Swelling Pressure Values of soils-mixtures. Tests are conducted to find Strength, Permeability, Swelling Pressure, soil-mixtures. In general the soils with increase in Cohesive Non-Swelling(CNS) soil percentage.

Keywords – Expansive Soils , Plasticity Characteristics, Permeability, Soil Mixtures, Stabilization, Swelling Pressure

I. INTRODUCTION

Numerous methods exist for stabilization of soils . however, all methods fall into two broad categories. They are mechanical stabilization and chemical admixture stabilization. Some stabilization techniques use a combination of these two methods. Mechanical Soil Stabilization relies on physical processes to stabilize the soil, either altering the physical composition of the soil by mixing another soil and mixer (soil blending) . 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. Chemical stabilization relies on the use of an admixture to alter the chemical properties of the soil to achieve the desired effect (such as using lime to reduce a soil's plasticity).

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.

The present investigation involves with the 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 locally available cohesive non-swelling soil.

II. 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 very scanty concerning the strength and deformation characteristics of soil-mixtures comprising of expansive soils and cohesive non-swelling soils. Present investigation aims at studying the variation of engineering properties of expansive soils when mechanical stabilized by adding different proportions of cohesive non-swelling soil.

2.1 Soils Used

The soils are collected from different places of Andhra Pradesh, like Atmakur , near Kurnool, Gajulamandyam, near Tirupathi, Tiruchanoor near Tirupathi, Vedhapatasala in Tirupathi at different depths. The soils are designated for reference. The details of soil location and their designation are given in table 1.

Table 1 Details of soil used for testing

Soil Designation	Location
S1	Atmakur, near Kurnool
S2	Gajulamandyam, near Tirupathi
S3	Tiruchanoor near Tirupathi
S4	Vedhapatasala in Tirupathi
S5	Tiruchanoor near Tirupathi

S1, S2 and S3 soils are expansive soils selected for investigation. S4 and S5 soils are selected mixing with the above mentioned soils. Among these two soils, S4 is used for preparing soil mixtures as this soil in found to be Non-swelling and cohesive in nature.

2.2 Details of Tests Conducted

In order to meet the objectives of the present investigation tests are conducted as per the procedures stipulated in I.S. Code of Practice on five soils listed in the above table. The following tests are conducted

Grain Size Distribution, Liquid Limit, Plastic Limit, Light Compaction Test, Differential Free Swell Test, Triaxial Test, UnConfined Compression Test, Consolidation Test

Tests are aimed at studying the soil-mixtures. For this purpose Cohesive Non- Swelling Soil (S4) having Liquid Limit of 26% is mixed with three different expansive soils S1, S2 and S3 having Liquid Limits 57%, 144% and 61% respectively. The expansive soils are mixed with Cohesive Non Swelling soil which is coarser than 425µ as it will have influence on Liquid Limit of the soil. The soil mixtures are prepared by mixing S1, S2, and S3 soils with 0%, 15%, 20%, and 25%, 30%, 35% of S4 soil. Percentage of cohesive Non- Swelling soil was varying from 0% to 35%. The details of soil mixtures and the tests conducted on soil-mixtures are given in Table. 2.

III. RESULTS AND DISCUSSIONS

3.1 STRENGTH CHARACTERISTICS

3.1.1 Unconfined Compression Strength : The Unconfined Compression Strength of soil mixtures S2-S4 and S3-S4 are conducted in three series. The variation of Unconfined Compression Strength with percentage of CNS(S4) soil is shown in Fig.1. The increase in strength is attributed to increase in Maximum Dry Density of the soil mixtures.

3.1.2. Shear parameters

a) Cohesion : The strength characteristics of soil mixtures S1-S4, S2-S4 and S3-S4 are conducted in three series. The variation of cohesion with percentage of CNS (S4) soil is shown in Fig.2. The cohesion is found to decrease initially and then increase with increase in percentages of CNS soil (S4) for S1-S4 soil- mixtures.

b) **Angle of Internal Friction:**The variation of Angle of Internal Friction with percentage of CNS (S4) soil for S1-S4 soil-mixtures is shown in Fig.3.. The Angle of Internal Friction found to increase with increase in percentage of CNS soil (S4) for S1-S4 soil mixtures.

3.2 PERMEABILITY:

The variation of permeability of soil mixture S1-S4, S2-S4 and S3-S4 with increase in percentage of CNS soil(S4) is shown in Fig.4. From the graph it can be observed that the Coefficient of Permeability in increasing with percentage of CNS soil(S4) for all the three soil- mixtures. Permeability is increasing steeply for S3-S4 soil from 4.866692 x 103 percentage to 22.396015 x 103 percentage with increase in percentage of S4 soil and change is abrupt at 30 percent of S4 soil. At 30 percent of addition of S4 soil, the permeability of all three soil mixtures behave asymptotically. So 30 percent of CNS(S4) soil is optimum from permeability point of view.

3.3 SWELLING CHARACTERISTICS

3.3.1 Free Swelling Index: The Free Swelling Index of S1, S2 and S3 soil mixed with 0%, 15%, 20%, 25%, 30% and 35% of S4 soil is show in Fig.5. From graph, it can be observed that the Free Swelling Index is decreasing with percentage increase in S4 soil, for all three soil-mixtures due to increase in coarse fraction.

3.3.2 Swelling Pressure: The variation of Swelling Pressure of soil- mixtures S1 and S4, with percentage of S4 soil is shown in figure 6.6. A series of Consolidation tests are conducted using constant volume method for S1-S4 soil- mixtures. The variation of Swelling Pressure with percentage of CNS soil,S4 is shown in figure 6.6 for S1 and S4 soil mixtures. The Swelling Pressure is decreasing from 220kPa to130kPa. The basic mineral content of the mixed soil (S4) is helping in arresting the Swelling Pressure. The compressibility of soil mixtures is represented by compression index Cc under loading. The Cc values are found to increase with increase in percentages of CNS soil (S4) for S1-S4 soil mixtures.

Table 2 Properties of the Soils Used

S.N0.	TESTS	S1	S2	S3	S4	S5
1	Sieve Analysis					
	a) Gravel,(%)	1.00	1.70	1.00	3.68	15.00
	b) Sand, (%)	11.36	75.90	24.00	73.50	56.50
	c) Silt + Clay,(%)	87.84	22.40	75.00	23.83	28.50
2	Liquid Limit, (%)	57	144	61	26	69
3	Plastic Limit, (%)	31.18	63	18	16	20
4	Plasticity Index, (%)	25.82	81	43	10	49
5	IS Classification of Soil	MH	SC	CH	SC	SC
6	Free Swell Index (%)	50	270	100	10	180
7	Degree of expansion	LOW-MEDIUM	VERY HIGH	MEDIUM- HIGH	LOW	HIGH
8	Optimum Moisture Content (%)	13.5	10.5	14.5	14	12
9	Maximum Dry Density (kN/m3)	16.73	18.48	17.34	18.16	18.26
10	Undrained Strength Parameters					
	a) Cohesion (C, in (kPa))	192.68	84.61	77.60	75.65	80.75
	b) Angle of Internal friction (Φ, in degrees).	12.58	10.72	9.86	13.56	10.97
11	Consolidation					
	a) Compressive Index (Cc)	0.039	0.06	0.106	0.053	0.223
	b)Recompression Index,(Cr)	0.035	0.023	0.0315	0.014	0.265
	c)Swelling Pressure,(kN/m2)	85	112	195	0.00	195
12	Coefficient of Permeability, (k)cm/s	$8.532x10^{-6}$	$1.17x\ 10^{-7}$	$1.33x10^{-6}$	$1.01x10^{-6}$	$1.179x10^{-4}$

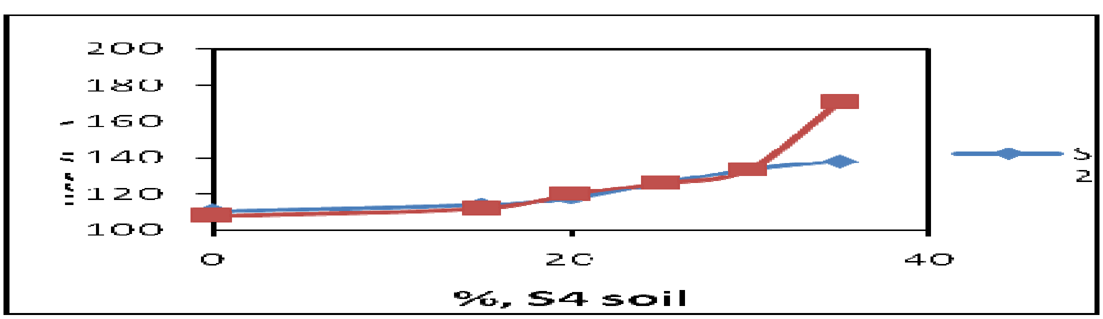

FIG 1 Variation of UCC for Soil-mixes S2-S4and S3-S4

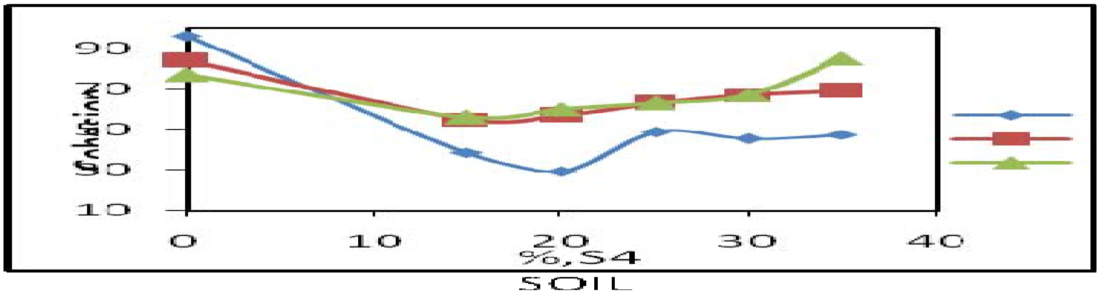

FIG.2 Variation of Cohesion for soil mixtures

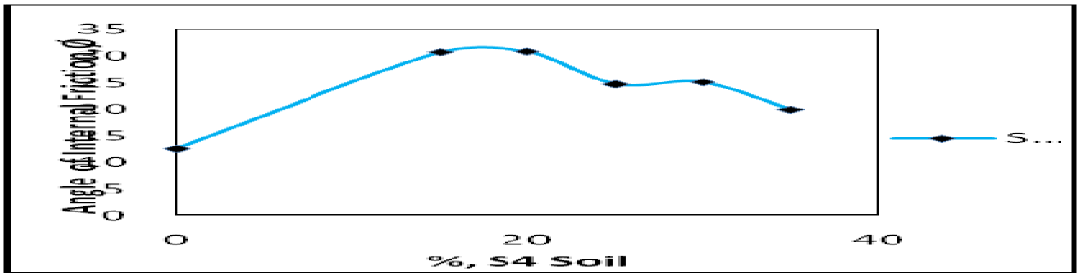

FIG.3 Variation of Angle of Internal Friction for soil mixtures(S1-S4)

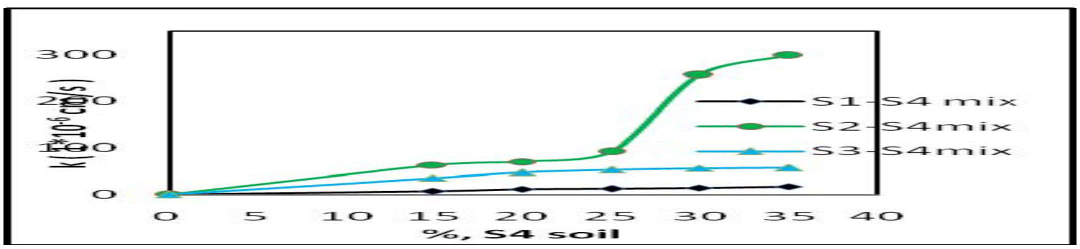

FIG.4 Variation of Coefficient of Permeability for soil mixtures(S1-S4,S2-S4 and S3-S4)

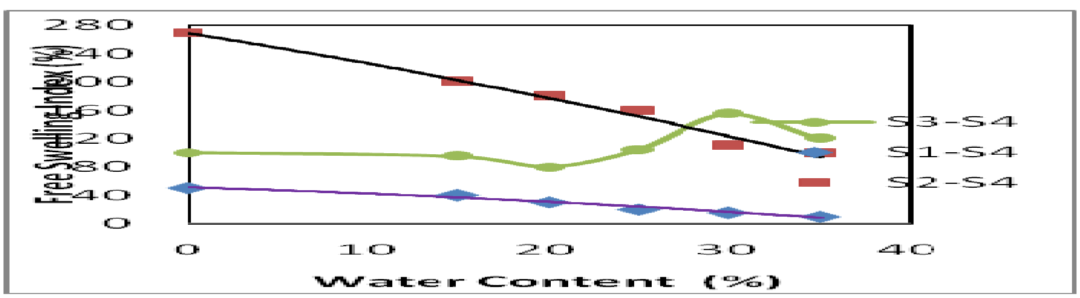

FIG5 Variation of Free Swelling Index for soil-mixtures (S1-S4, S2-S4, and S3-S4)

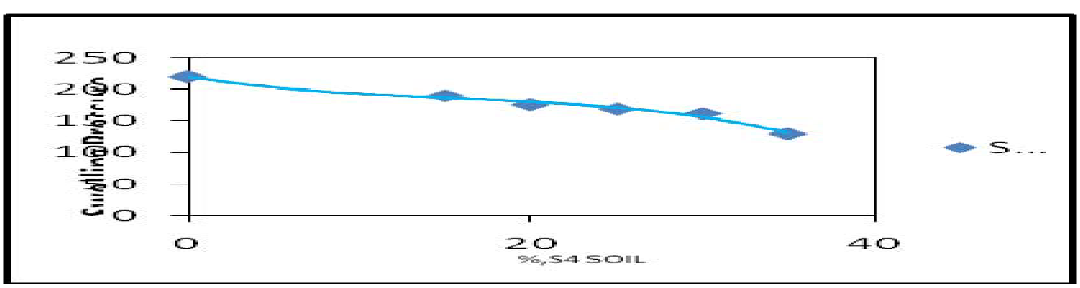

FIG 6 Variation of Swelling Pressure for S1-S4 soil mixtures

Table 3 Properties of S1-S4 Soil- mixtures

S.No.	Description	S1	S1+15%S4	S1+20% S4	S1+ 25% S4	S1+ 30% S4	S1+ 35% S4
1	Strength Parameters Angle of Internal Friction, Φ, in degrees Cohesion, C in kPa	12.58 96.62	30.72 38.62	30.83 29.25	20.12 48.8	25.09 45.33	19.91 44.41
2	Unconfined Compressive Strength, (kPa)	193.24	77.24	58.5	97.6	90.66	88.82
3	Compression Index, Cc	0.039	0.042	0.049	0.051	0.062	0.14
4	Coefficient of Permeability, (k) cm/s	$1.26x10^{-7}$	$8.02x10^{-6}$	$1.19x10^{-5}$	$1.28x10^{-5}$	$1.47x10^{-5}$	$1.72x10^{-5}$

Table 4 Properties of S2-S4 Soil- mixtures

S.No.	Description	S2	S2+15%S4	S2+20% S4	S2+ 25% S4	S2+ 30% S4	S2+ 35% S4
1	Shear Strength Parameters Cohesion, C in kPa	50.25	55.5	59	60	63	64.25
2	Unconfined Compressive Strength, (kPa)	100.5	111	118	120	126	128.5
3	Coefficient of Permeability, (k) cm/s	$1.17x10^{-7}$	$3.56x10^{-5}$	$4.76x10^{-5}$	$5.35x10^{-5}$	$5.66x10^{-5}$	$5.76x10^{-5}$

Table. 5 Properties of S2-S4 Soil- mixtures

S.No.	Description	S3	S3+15%S4	S3+20% S4	S3+ 25% S4	S3+ 30% S4	S3+ 35% S4
1	Shear Strength Parameters Cohesion, C in kPa	54	56	60	63.25	66.75	85
2	Unconfined compressive strength, (kPa)	108	112	120	126.5	133.5	170
3	Coefficient of Permeability,(k) cm/s	$1.33 x10^{-7}$	6.34x10-5	7.10x10-5	9.22x10-5	2.56x10-4	2.98x10-4

IV. CONCLUSIONS

The present paper emphasized on investigation of soil mixtures comprising of three expansive soils (S1,S2,S3) mixed with a Cohesive Non-Swelling(S4) soil pertaining to Strength, Swelling and Permeability Characteristics, Soil-mixtures are prepared with expansive soils adding different percentages of Cohesive Non-Swelling(CNS) soil (S4) 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. The following conclusions are drawn based on the test results

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.

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

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

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

REFERENCES

[1] Chen, F. H. (1988). "Foundations on expansive soils", 2nd Ed., Elsevier Science, New York.
[2] Cokca, E. (2001). "Use of Class C fly ashes for the stabilization of an expansive soil." Journal of Geotechnical and Geoenvironmental Engineering, 127(7), 568-573.
[3] Hausmann, M. R. (1990)."Engineering Principles of Ground Modifications". New York: McGraw Hill.
[4] Katti,R.K.(1969),"Shear strength and swell pressure characteristics of expansive soils,"Proceedings of the 2nd International Res. And Engg. Conf. on expansive clay soils, Texas,A and M University press,pp.334-347.
[5] Katti,R.K.(1978),"Search for solutions to problems on Black Cotton soils,,1st L.G.S Annual lecture, Indian Geotechnical society, New Delhi, India.
[6] Khanna and Justo(1987), "Highway Engineering", Nemchand and Brother, Roorke(U.P).
[7] Nalbantoglu, Z., and Tuncer, E., (2001), "Compressibility and Hydraulic Conductivity of a Chemically Treated Expansive Clay," Canadian Geotechnical Journal, Vol. 38, pp. 154-160.
[8] Phani kumar,B.R., Rekha, V.A. (1995), "Swelling behaviour of a remoulded expansive clay," Journal of Institution of Engineers (India).Civil Engineering division, vol.76,pp.1-5.
[9] Seed,H.B., WoodWord R.J., and Londegren, R.(1962)." Prediction of swelling potential for compacted clays ",procendings ASCE SM & FE , devision 88 no.SM3,pp.53-67.
[10] Sudharani, Ch., etal (2004) "Identification and assessment of Engineering properties of soil using a Knowledge Based System", International e-Conference, Indian Institute of Technology, Chennai.
[11] Sudha Rani Ch. and V. Phani Kumar (2011) " Prediction of Compression Index of Soils Using Artificial Neural Networks (Anns)", International Journal of Engineering Research and Applications(IJERA), Vol 1, Issue 4, Pg.no. 1554-1558.
[12] Sudha Rani Ch and K Mallikarjuna Rao (2012), "Compositional And Environmental Factors Role On Compression Index ",International Journal Of Civil Engineering And Technology (IJCIET), Volume 3, Issue 2, July- December (2012), pp. 392-403.
[13] Sudha Rani Ch (2013), " Prediction of Swelling Pressure Of Expansive Soils Using Compositional and Environmental Factors", International Journal Of Civil Engineering And Technology (IJCIET) Volume 4, Issue 3, May - June (2013), pp. 134-142.
[14] Sudha Rani Ch and K Mallikarjuna Rao(2013),"Statistical Evaluation of Compression Index Equations", International Journal Of Civil Engineering And Technology (IJCIET), Volume 4, Issue 2, March - April (2013), pp. 104-117.
[15] Sudharani, Ch., etal (2009),"Identification of Expansive Soils and Assessment of Expansion Potential by Fuzzy Approach", Electronic Journal of Geotechnical Engineering(EJGE),Vol. 14 [2009], Bund. L.
[16] Sudharani Ch etal (2010), " SIVACS: Knowledge Based System Developed for Soil Identification and Assessment of Volume Change Characteristics", Electronic Journal of Geotechnical Engineering(EJGE), Vol. 15 [2010], Bund. J.
[17] Sudharani etal (2013), " Artificial Neural Networks (ANNS) For Prediction of Engineering Properties of Soils", International Journal of Innovative Technology and Exploring Engineering (IJITEE), Volume-3, Issue-1, June 2013, .pp 123-130.