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Control of Shrinkage Characteristics of Expansive Soil by Using Low Compressible Soils

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Abstract. The Expansive soils constitute most of the soil types found in India. The use of expansive soils presents serious challenges to the geotechnical engineer as they can lead to excessive settlements and therefore be injurious to the health of major civil engineering structures such as embankments, nuclear power plants, etc. Therefore, understanding the composition of fine particles becomes very important in the geotechnical field, including mineralogy. An expansive soil sample was taken for the purpose of study of shrinkage factors including shrinkage limit, free swell index and the effect on the various soil parameters was observed. In this study an attempt has been made to reduce the excessive potential of the expansive soil by adding different proportions of low compressibility soils such as 10%, 15%, 20%, 25%, 30% and 35% by weight. The analysis of the test results presented in this paper shows that the shrinkage limit and free swelling index are satisfactory and indicate that adding low compressibility clays can reduce the expansive potential of soils thereby improving their compressibility characteristics. So that the properties of highly expansive soils can be altered with the help of low compressive soil mix in those areas. Such a quick process helps to find solutions to make complex soils suitable for the civil engineering structures.

Keywords: Shrinkage Limit, Shrinkage Index, Free Swell Index.

1 Introduction

The entire southern peninsula of India to the south of the Narmada River, which is spread over eight states of the country, is known as the Deccan Plateau. The pedogenesis of expansive soils is caused by minerals as well as high temperature and low rainfall, which is the main reason of the formation of an expansive type of soils. The Deccan Traps is the basalt lava plateau filled mainly with mica and iron ore minerals that are responsible for the formation of black cotton soil and other types of expansive soils. Expansive soils are widely distributed in most parts of India and about 20% of the land is covered by black cotton soils. Maharashtra, Tamil Nadu, Andhra Pradesh, Telangana, Kerala, Madhya Pradesh, Rajasthan and Gujarat are the most well-known regions of expensive soil deposits in India.

There are three basic particles available in soils as clay, silt and sand. Clay here is usually referred to as range in expansive soils if the clay is rich in hydrophilic minerals such as smectite group minerals, montmorillonite and kaolinite etc. It is also known as highly compressible soil. Due to its highly moisture-sensitive property, the change in soil volume increases significantly when exposed to water and contracts drastically when water is released. Due to the shrink and swell characteristics of expansive soils, these create the great problem for the stability of a structure. Therefore, any project in the field of civil engineering such as the construction of embankments, retaining walls, high-rise buildings, etc. should be seriously evaluated or analyzed for satisfactory performance. Many researchers have suggested a lot of solutions to encounter this problem, but most of them are difficult to execute in the field and economically expensive. Some researchers have suggested a mechanical technique like expulsion of air voids by compaction, stone or sand columns, cement or steel fiber grouting, soil stabilization by mixing suitable soil techniques and chemical treatment etc. Most of these techniques aim to change the physical and basic index properties of the expansive soil which controls the shrinkage and swelling behavior. To alter the behavior of expansive soil, soil mixing is one of the suitable methods to treat the expansive soil. By using the low compressibility soil, the liquid limit, Plasticity index, shrinkage limit, shrinkage index as well as free swelling index of the problematic soil can be improved. Seed et. (1962) [10] defined that a well-defined relationship can be established between the percentage of clay size and soil activity. Van Der Merwe (1964) [16], proposed a method based on prediction of heave from the plasticity index and percentage of clay fraction of soils to describe potential severity of volume change for clay soil. McCormack, D. E. and Wilding, L. P. (1975) [6] explained the phenomenon of swelling and found that expansive soils continue to swell at moisture contents above ⅓-bar tension, and continue to shrink at moisture contents below 15-bar tension and below the shrinkage limit. Thomas, P. J. (2000) [15] relate the soil shrink-swell with soil properties and to partition variability into map unit components. Taboada, A. M. (2003) [13] distinguished between soils with different magnitudes of swelling, as well as consequences on soil structural behaviour. Chertkov, V. Y. (2007) [2] presented that clay shrinkage curve, under the influence of a silt–sand admixture as well as inter/intra aggregate structure, is transformed to the soil shrinkage curve.

In the current study, an attempt has been made to control the shrink and swell behavior of the expansive soil by adding low compressibility soils in different proportions such as 10%, 15%, 20%, 25%, 30% and 35% by weight. The test results show that by adding low compressibility clay in the expansive soil, the shrinkage limit and FSI are can be controlled or improved up to the satisfactory level.

2 Material

The soil samples taken for improvement of highly expansive soil is comprised percentage of clay content of 72.7% and fine particles 96.8% by weight. According to the Unified Soil Classification System, the sample is classified as High Plasticity Clay (CH). The percentage of different particles (Clay, Silt and sand) as determined by the Mechanical analysis method as per IS:2720 (part-4) is presented in Table 1. The engineering and index properties of the soil like Atterberg limit, volume shrinkage,

shrinkage limit and free swell index is also presented in Table 1. The shrinkage limit and free swell index of the tested soil indicate that soil has high shrink and swell characteristics.

Table 1. Properties of fine-grained soil taken for improvement

0.002 mm & less	72.70
0.002 to 0.075 mm	26.10
0.075 to 0.425 mm	0.50
0.425 to 2.0 mm	0.60
2.0 to 4.75mm	0.10
4.75 mm & above	0.00
Liquid Limit	103.30
Plastic Limit	39.00
Plastic Index	64.00
Specific Gravity	2.37
Shrinkage Index	59.87
Shrinkage Limit (%)	4.43
Shrinkage Ratio	2.11
Volumetric Shrinkage (%)	1.49
Free Swelling Index (%)	203.0

3 Methodology

The following laboratory tests are carried out on the mixed soil samples taken for improvement as per the respective Bureau of Indian Standards:

- Specific Gravity IS: 2720 (Part-3)
- Mechanical Analysis IS: 2720 (Part-4)
- Atterberg's Limit: Liquid Limit and Plastic Limit IS: 2720 (Part-5)
- Shrinkage Factor IS: 2720 (Part-6)
- Free Swell Index (FSI) IS: 2720 (Part-40)

Classification of all the soil samples is as per IS: 1498.

3.1 Shrinkage Factor Tests

To understand the volume change potential of expansive soil, there are numerous direct and indirect methods available in the literatures. However, many methods for determining the shrinkage factors, namely shrinkage index (I_s), shrinkage ratio (R) and volumetric shrinkage (V_s) are found unsatisfactory. Expansive soils are highly retentive of moisture and undergoes to large volume change with the small change in water content. The value of shrinkage limit is very low in comparison of liquid limit and plastic limit. The liquid limit is the minimum percentage of water content at which the soil begins to flow, while the plastic limit is the minimum water content at which the soil behaves like plastic without elastic rebound, volume change and cracking.

In this present study, a method as described in the IS: 2720 (Part XX) has been chosen to determine the volume change behaviour of the expansive soil with the change in moisture content. The remolded soil has been used to determine the shrinkage limit. The low compressible soil is mixed with expansive soil in different proportions of 10%, 15%, 20%, 25%, 30% and 35% by weight and shrinkage characteristics is determined of each mix by the method as described in IS: 2720 (Part-5).

The shrink index (I_s) was calculated using the following equation as given in the IS: 2720 (Part-6).

$$\omega_s=\omega-((V-V_0)/\omega_0)\times 100 \quad (1)$$

where ω_s is the shrinkage limit in percent; ω is moisture content of wet soil pat, V volume of wet soil pat in ml, V_0 volume of dry soil pat in ml, and ω_0 weight of oven-dry soil pat in g.

3.2 Free Swell Index (FSI)

A geotechnical engineer always identified the damage possibilities to the structure due to swelling of expansive soil. For such identification, there are numerous methods to understand the swelling characteristics of expansive soil, free swell index is one of them. The swelling potential depends on several factors such as dry density, water content, structure load and chemical composition of soil etc. But the more critical condition that has been adopted by the many standards in laboratory investigation, is free swelling potential change i. e. swelling without any external interference. The following formula is used to calculate the free swelling index.

$$\textit{Free swell index, percent} = (V_d-V_k)/V_k \times 100 \quad (2)$$

Where V_d is the volume of the soil specimen read from the graduated cylinder containing distilled water, and V_k is the volume of the soil specimen read from the graduated cylinder containing kerosene.

In the present study, the free swelling index test is performed in accordance with the IS 2720 (Part 40) on the expansive soil as well as mixed soil samples.

4 Results

The test results of the shrinkage factor test of expansive soil and the mix. of expansive soil with low compressible soil in proportion of 10%, 15%, 20%, 25%, 30% and 35% by weight are presented in Table No. 2. The mechanical analysis test results show that clay particle size (less than 0.002 mm) is decreasing with the addition of low compressible soil and particle greater than clay sizes (0.002 mm) are increasing significantly.

Table 2. volume change potentials of mixed soil

% of mixing clay		0	10	15	20	25	30	35
0.002 mm & less		72.70	67.90	63.40	59.60	58.90	54.75	52.31
0.002 to 0.075 mm		26.10	26.50	32.10	31.80	30.10	29.75	28.65
0.075 to 0.425 mm		0.50	2.20	2.20	4.30	5.23	7.50	8.49
0.425 to 2.0 mm		0.60	2.30	0.90	4.10	5.34	6.25	8.87
2.0 to 4.75 mm		0.10	1.10	1.40	0.20	0.43	1.75	1.68
4.75 mm & above		0	0	0	0	0	0	0
	LL	103.50	86.30	82.10	79.20	75.20	71.95	68.49
Atterberg Limits	PL	39.0	40.50	37.50	35.80	34.00	32.95	31.48
	PI	64.50	45.80	44.60	43.40	41.20	39.00	37.01
Specific Gravity		2.72	2.69	2.67	2.67	2.66	2.66	2.65
Shrinkage Index		60.07	38.37	34.30	31.86	27.21	23.44	20.26
Shrinkage Limit (%)		4.43	7.43	10.30	11.54	13.99	15.56	16.76
Free Swelling Index (%)		205.0	165.0	133.0	114.0	86.0	76.0	65.0
Degree of Expansion (%)		Very high	High	High	High	Medium	Medium	Medium

The graph presented in Fig. 1, Fig. 2 and Fig. 3 shows the relation of shrinkage limit vs. clay percentage, shrinkage index vs. clay percentage and free swelling index vs. clay percentage. It is evident from the Graph 1 that as the percentage of low compressible soil increases, the shrinkage limit increases (Shrinkage characteristics is decreasing). While the Graph 2 indicate that as the percentage of low compressible soil increases, shrinkage index decreases. Graph 3 indicate that with increase of low compressible soil, the free swelling index is decreasing.

It can be observed from the above graphs, that the effect of mixing the low compressible soil in expansive soil is appreciable up to 20 % quantity low compressible soil. Beyond that, the effect is not much prominent. So, it can be concluded that there is an optimum quantity of low compressible soil that can mixed with expansive soil to improve the shrink-swell characteristics of expansive soil. In the present study, the optimum quantity of low compressible soil is 20 %.

The study also shows that, shrinkage limit of the expansive soil is changes from 4.43 % to 16.76 % which indicate an increase of 278.33 % in shrinkage limit with addition of 35 % low compressible soil. The shrinkage index changes from 60.06 to 20.26 which indicate a 66.27 % reduction in shrinkage index. The free swell index changes from 205.0 % to 65.0 % which indicate a reduction of 68.29 % in free swelling characteristics of soil.

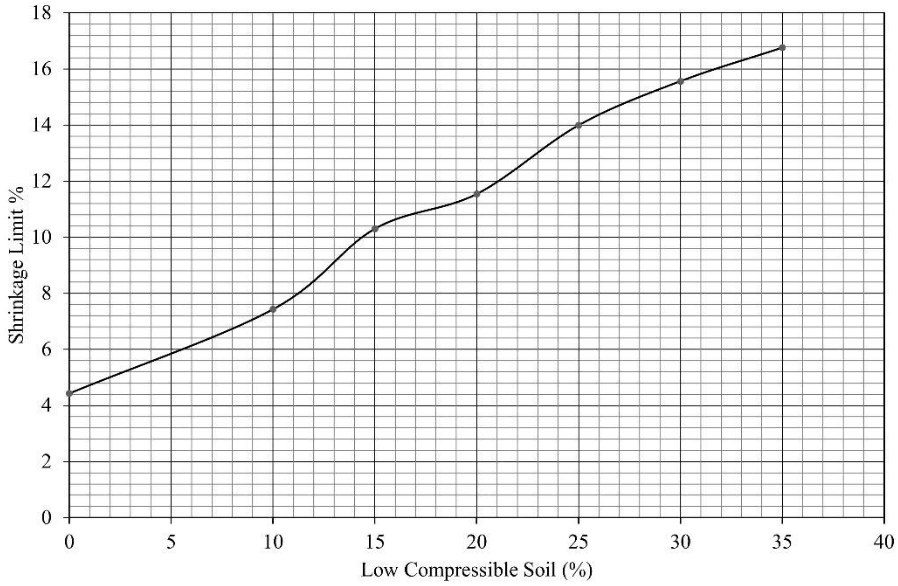

Fig. 1. Shrinkage Limit vs. Low Compressible Soil (%).

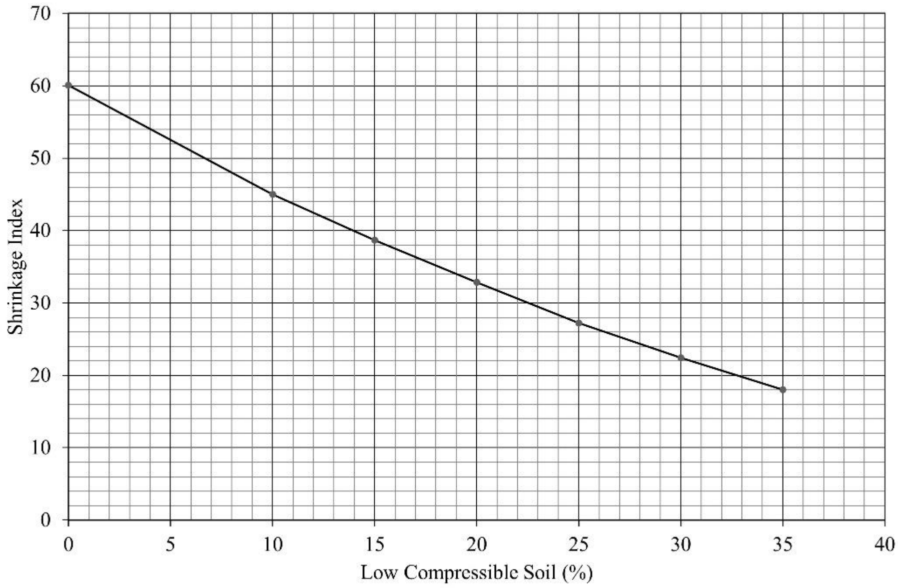

Fig. 2. Shrinkage Index vs. Low Compressible Soil (%).

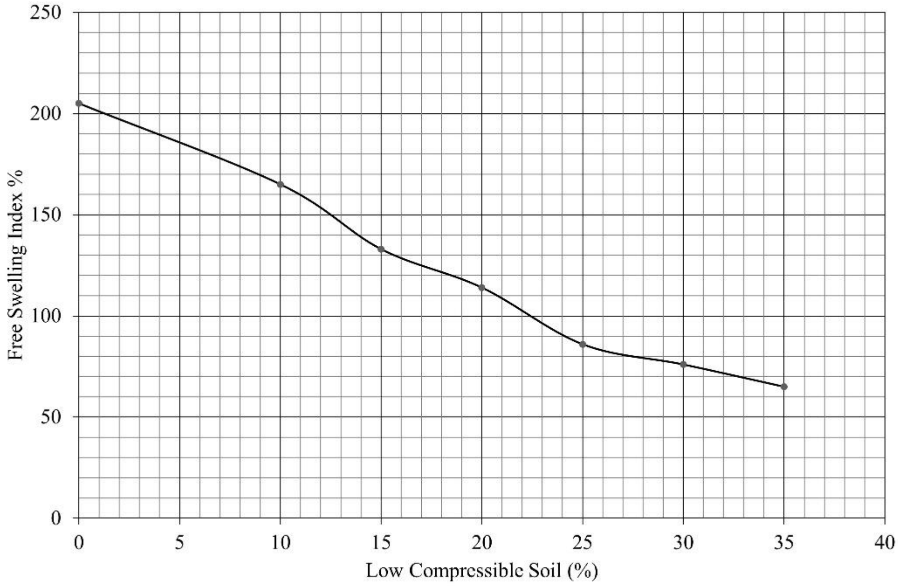

Fig. 3. Free Swelling Index vs Low Compressible Soil (%).

5 Conclusion

In conclusion, this study has shown that shrink-swell characteristics of the expansive soil can be controlled by mixing the low compressible soil and the optimum quantity of low compressible soil is 20 %. Strong correlations were found between the shrinkage limit, the shrinkage index and the free swell index with the percentage of low compressible soil. As the percentage of low compressibility soil increases in expansive soil, the shrinkage limits curve exponentially increases whereas the shrinkage index and the free swelling index decrease exponentially.

It is also concluded that the shrinkage limit and the free swelling index are on the satisfactory level and indicate that adding low compressible soil can decrease the expansive potential of soils thereby improving their compressibility characteristics. Therefore, the properties of highly expansive soil can be altered with the help of low compressive soil mix.

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