Study of swelling and shrinkage characteristics of expansive soil using silica gel as an admixture

Uday A. Chaudhari[1] and Vanshika Mucchhara[2]

[1]M.Tech Geotechnical Engineering student, Department of Civil Engineering
Parul Institute of Technology, Waghodia, Vadodara

[2]Assistant Professor, Department of Civil Engineering
Parul Institute of Engineering and Technology, Waghodia, Vadodara

Abstract: Expansive soils are characterized as soil which undergo large volume changes on availability of moisture. The continuous cyclic wetting and drying process causes vertical and horizontal movement in expansive soil which leads to failure of engineering structure erected on such soils[1]. The expansive soil has very low bearing capacity, high plasticity, high compressibility, low permeability, high swelling and Shrinkage properties, due to presence of montmorillonite mineral. The expansive soil contains the clay particle of medium to high compressibility and cover nearly 20% of geographical area in India which is concern of study[2]. In this research, silica gel as admixture are used to aid the properties of parent material. This study aims to conduct soil stabilization of black cotton soil of North Gujarat region by using silica gel in different proportion. In this research paper, Silica gel is added 2%, 4%, 6%, 8% and 10% by weight to give comparison between the soil properties of untreated soil and treated soil. Due to addition of 10 % of silica gel by mass in virgin soil,l plastic limit increased by 16.72% and liquid limit decreased by 19.23% which ultimately decreases plasticity index by 57.5. Also it was found that MDD is decreased by 4.3 % , and free swell index decreased by 41.56 % on addition of 10% silica gel by mass.

Keywords: *Expansive soil, Silica gel, admixture, Stabilization.*

1.Introduction

Generally Civil Engineering structures are built on or underneath of the soil. The soil on which structures are to be built should be capable of withstanding load coming-out due structure for design useful period of time without any kind of failure. However, structure erected on black cotton or say expansive soil are subjected to cracking in major components of structure which lead to failure of structure. Expansive soils are the clay that have the characteristic property to swell and soften when there is availability of moisture, or shrink and dry-cracked when their moisture content is decreased. Soils containing the clay mineral montmorillonite generally exhibit these

properties. Besides this if soil contain clay belong to mica group, which includes illites and vermiculites then soil can be of expansive nature but does not cause significant problems[1]. Problems associated with expansive soils, which located in many regions of Gujarat particularly talking about Bharuch, Vadodara, and North Gujarat region. Besides this, Expansive soils are mostly found in the arid and semi-arid regions and it covers very large area of the world. It covers nearly 20% of the landmass in India and includes almost the entire Deccan plateau, Western Madhya Pradesh, parts of Gujarat, Andhra Pradesh, Uttar Pradesh, Karanataka, and Maharastra[3]. In this regions, damage due to swelling action has been observed clearly in the form of cracking and breakup of pavements; damage to building foundations, embankments and irrigation systems. Expansive soils can cause serious damage and distortion to structures, particularly for the light buildings and pavements built on them.

One of the most used method to control volume change is to stabilize expansive soils with help of admixtures that reduce volume change. The Engineering properties of expansive soil are depended on many factors which include properties of soil, environmental factors, stress condition, etc. which vary from place to place in particular region. Engineering properties of soil are determined by the Atterberg's limits, index properties, and other soil properties obtained by laboratory or field tests (Stated by Mitchell 1993)[4]. It is well known that the swell-shrinkage characteristics of expansive soils are closely related to soil plasticity index, free swell index, clay composition of soil.

This report presents lab tests to evaluate the effect of silica gel as admixture on expansive soil on Geo-technical behaviour of the expansive soil in terms of grain size distribution, Atterberg's limits, specific gravity, compaction characteristics, free swell, shrinkage percent, and unconfined compressive strength.

1.1 Objectives of the study

- To study the effect of silica gel on the properties of the expansive soil.
- To compare the changes in properties of untreated soil and soil with an admixture by conducting laboratory tests.
- To find out economic and optimum percentage of admixture to be added according weight of total soil mass.
- For the detail investigation of engineering properties of soil and to classify the type of soil.

2.Materials and Methods

2.1 Materials

Black Cotton Soil: Expansive soil sample used in this research work was collected from Limda Village, Vadodara city near Limda Lake from pit having depth about 1.5 m.

Silica gel: Silica gel is an amorphous and porous form of silicon dioxide (silica), consisting of an irregular tridimensional framework of alternating silicon and oxygen atoms with nanometer-scale voids and pores. Silica gel's high specific surface area allows it to adsorb water easily, making it useful as a drying agent. Silica gel is often described as "absorbing" moisture material. Silica gel, may be freshly prepared from alkali silicate solutions, may vary in consistency from a soft transparent gel similar to gelatin or agar, or a hard solid.

Sample preparation: According to testing and treatment, the soil samples were prepared. Oven drying or air drying soil samples were required. With help of rubber covered mallet large lumps of expansive soil braked into fine soil. The virgin soil was taken out for testing purpose and remaining mass of soil mixed with silica gel manually to get uniform mix ratio for each varying silica gel proportions.

2.2 Methods

Initial water content: The test was conducted as per IS-2720 (1980) Part(II) [6].

Specific Gravity: Specific gravity which is the relative measure of the heaviness of the soil particles and here it is determined by density bottle. This test was conducted as per IS 2720 (1980) Part (III) [5].

Atterberg's Limits: The test includes determination of the liquid limits, plastic limits, plasticity index, shrinkage limits, etc. For the natural soil and soil with an admixture. The liquid limit, plastic limit and plasticity index tests were conducted as per IS-2720 (1985) Part(V) [10]. And Shrinkage limit a Shrinkage index were conducted as per IS-2720 (1972) Part (VI) [11].

Free Swell Index: The free swell index is also one of the most commonly used simple tests to estimate the swelling potential of the expansive soil. The test includes determination of the free swell index of the natural soil and the soil and admixture. The tests are conducted in accordance with IS: 2720 (1977) Part XL testing procedure[7].

Standard Proctor Compaction Test: The Standard Proctor test is carried out for determination of the maximum dry density (MDD) and optimum moisture content for the natural soil and soil with admixture. The tests are carried out as per IS 2720(1980) PART VII[9].

3. Observations

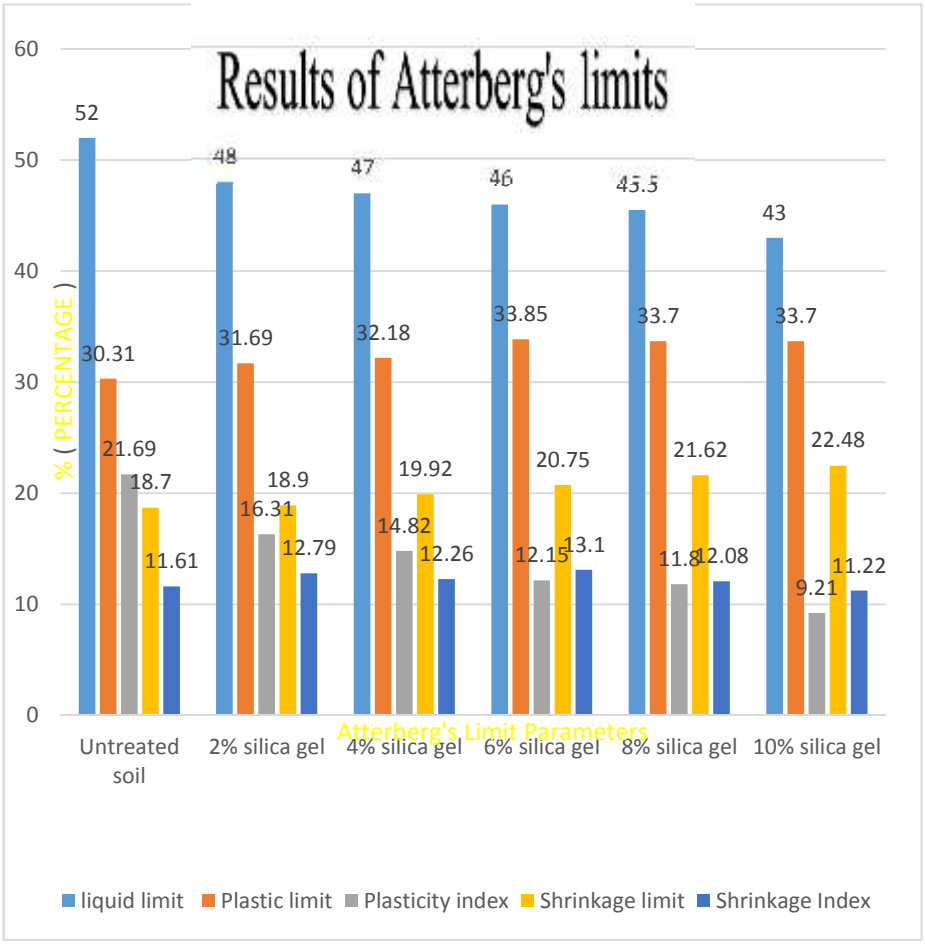

Figure 3.1 Observation of Atterberg's limit Test

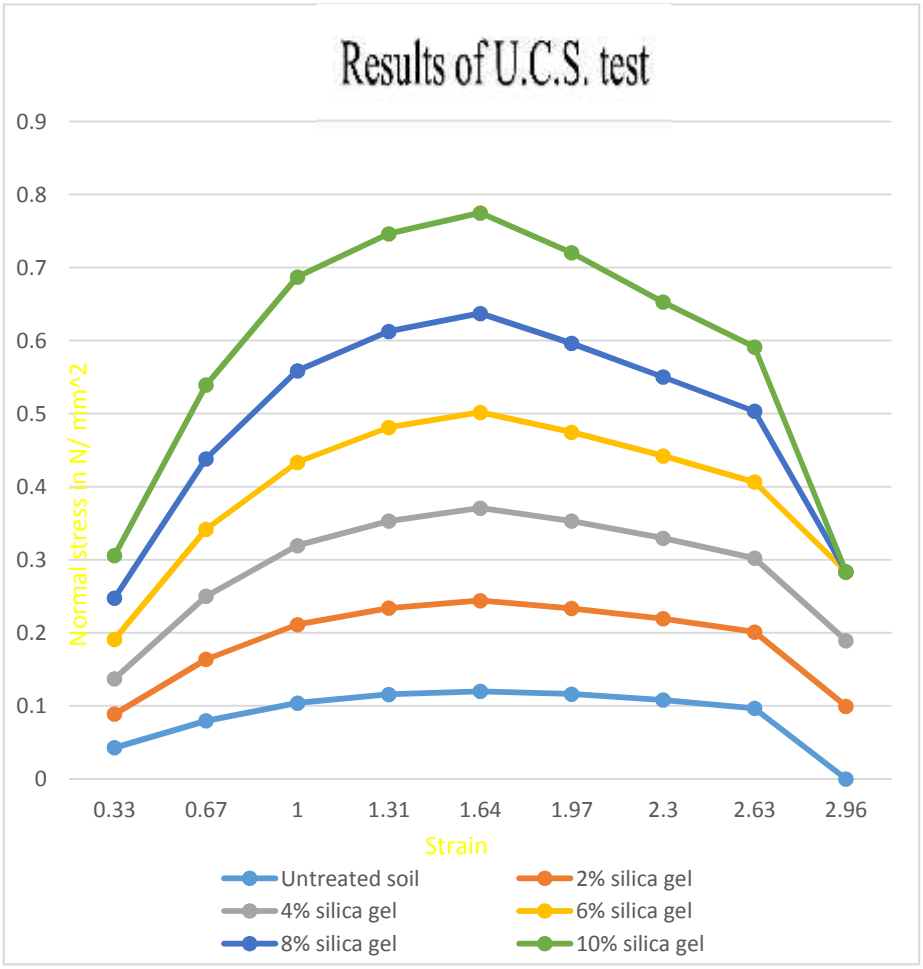

Figure 3.2 : Observation of Unconfined Compressive Strength Test Results

4. Results

Table 4.1 Test results on virgin soil and Treated soil

Test Conducted	Properties	Virgin soil	2 % silica gel	4 % silica gel	6 % silica gel	8% silica gel	10 % silica gel
1.Determination of moisture content	Moisture content	7.6 %	-	-	-	-	-
2.Determination of specific gravity	Specific gravity	2.51	2.49	2.26	2.22	2.0	1.98
3.Free Swell Index	Swell Index	41.6	32.41	28.41	25.71	24.63	24.34
4.Atterberg's limit	Soil classification	MH	MI	MI	MI	MI	MI
5.Standard proctor test	OMC in % MDD in g/cc	15.7 1.59	14.9 1.585	14.7 1.575	14.3 1.57	14.2 1.565	14 1.53
6.UCS test	UCS strength in N/mm^2	0.12	0.124	0.126	0.130	0.135	0.138
	Cohesive strength in N/mm^2	0.06	0.062	0.063	0.065	0.067	0.069

5. Discussion

By adding increasing percentage of silica gel in natural soil decrease in liquid limit, plasticity index, MDD, specific gravity is observed; while there is increase in plastic limit, shrinkage limit, shrinkage index and cohesive strength of soil.This is mainly due to presence of silica gel; silica gel is mainly composed of silicon dioxide or silica (SiO2). On addition of silica gel as a admixture in soil this silicon dioxide react with calcium and other minerals present in soil and form dicalcium silicates, tricalcium silicates, etc silicates. Trisilicates compound hydrates and hardens rapidly and responsible for initial set and strength gain while other silicates hydrates slowly and increase strength gradually.

From the observations it clear that mixing of silica gel in expansive soil reduce the swelling properties effectively, it is clearly visible by adding 10 % silica gel admixture in soil by mass, it brings down the value of free swell index from 41.66% to 24.34%.

Besides this liquid limit and plasticity index is lower down by about 10%. But there is concern of worry due to decrease in specific gravity of soil on increasing percentage of silica gel admixture. Therefor combination of silica gel with another admixture which increase the specific gravity of soil is preferred.

6. Conclusions

Based on the experimental studies the following conclusions were drawn.

1. Soil used in this project was classified as MH, silt having liquid limit grater then 50. Hence proper treatment of compaction or use of suitable admixture is required to stabilise the soil.
2. Silica gel admixture reduces the free swell index and swelling properties but reduction in specific gravity is concern of worry. Thus another suitable admixture to increase specific gravity, along with silica is used for the purpose of soil stabilization.
3. The decrease of the maximum dry unit weight with the increase of the percentage of silica gel is mainly due to the lower specific gravity of the silica gel compared with expansive soil and immediate hydration process which reduces the density of soil. The decrease in dry density with increase in silica gel is also not desirable result.
4. The unconfined compressive strength of the natural soil was 0.12 N/ mm^2 and on adding 10 % silica gel admixture it slightly increased to 0.138 $N/mm^{2.}$

6. References

PAPERS:

1. Masoumeh M. and Masoud D. “Swell-Shrink Behavior of Expansive Soils, Damage and Control” Electronic Journal of Geotechnical Engineering.2012, vol. 17,2673-2682.
2. Zhang J. and Cao X. “Stabilization of expansive soil by lime and fly ash” Journal of Wuhan University of Technology. December 2002, vol. 17, issue 4, pp 73-77
3. Prajapat S.: “Review On Stabilization Of Black Cotton Soil By Using Stabilizing Materials.” International Journal Of Scientific Research And Review7 (1), (2019).
4. P.V.Subba Reddy and K.M.Rao. “ Identification of Expansive Soils and Assessment of Expansion Potential by Fuzzy Approach” Electronic Journal of Geotechnical Engineering, 2009. volume 14, pp 2-8.

14.

IS CODES:

5. IS:2720 (1980) Part III (Second Revision), Indian Standard methods of test for soils: Determination of specific gravity of fine grained soils. BIS, New Delhi.
6. IS:2720 (1973) Part II (Second Revision), Indian Standard methods of test for soils: Determination of water content. BIS, New Delhi.
7. IS: 2720 (1977) Part XL (Second Revision), Indian standard methods of test for soils: Determination of free swell index of soils. BIS, New Delhi.
8. IS: 1498 (1970) (Reaffirmed 1987), Indian standard classification and identification of soils for general engineering purposes. BIS, New Delhi.
9. IS 2720 (1980) Part VIII (Second Revision), Indian standard methods of test for soils: Determination of water content-dry density relation using light compaction. BIS, New Delhi.
10. IS:2720 (1985) Part V (Second Revision), Indian Standard method of test for soils: Determination of liquid limit and plastic limit. BIS, New Delhi.
11. IS: 2720 (1972) Part VI (Second Revision), Indian Standard method of test for soils: Determination of Shrinkage factors. BIS, New Delhi.
12. IS:2720 (1991) Part XI (Second Revision), Indian Standard method of test for soils: Determination of unconfined compressive strength. BIS, New Delhi.

BOOKS:

13. Dr. B. C. Punmia, Er. Ashok. K. Jain, and Dr. Arun K. Jain. Soil Mechanics and Foundations; 17th Edn; Laxmi Publications Private Limited, New Delhi, 1994, page 111- 131.