Influence of Various Admixtures on The Swelling Characteristics of Clay

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Abstract. Expansive soils generally occur in arid and semi-arid regions of the world. It causes serious problems to the civil engineering structureslike, buildings and other structures, roads, pipelines, bridges, etc. Such soils swell, when given an access to water and shrink when they dry out. Several attempts were made by researchers to control the swell-shrink behaviour of these soils. The Swelling potential of the expansive soil mainly depends on the soil property, environmental factors and stress conditions. In this work, a detailed study on shrink - swell behaviour of expansive soil, and ways to control it by stabilizing with different proportions of the admixtures was made. In this paper, admixtures such as M-sand, fly-ash, river sand, beach sand and copper slag were used. They were used in different proportions of 2%, 5%, 10%, 12% and 15%. From the free swell index, it can be concluded that 10% copper slag effectively reduces swell compared to the other admixtures.

1. Introduction
Clay is a fine-grained soil material that combines one or more clay minerals with possible traces of quartz (SiO₂), metal oxides (Al₂O₃, MgO etc.) and organic matter[1]. Depending on the mineral, clay can appear in various colours from white to dull grey or brown to deep orange-red. Clay particles are smaller than 75µm[2]. The three main groups of clays are kaolinite, montmorillonite, andillite. Plasticity in clays are due to its mineralogy, particle size, geometry and water content. Clay becomes hard, brittle and non-plastic upon drying or firing[3].

Foundation is the lowest load-bearing part of any structure. Foundation on expansive soils is influenced by various engineering properties and characteristic nature of the soil[4]. Laying foundation on expansive soils, one has to clearly understand the engineering problems associated with that expansive soil and the type of foundation that could be adopted[5]. Testing methods and foundation reinforcement on expansive soils are vital in engineering. In general, expansive soils have less bearing capacity. To increase the bearing capacity of such soils, there are different techniques that are widely used[6]. One such method to reduce the swelling is cohesive non-swelling (CNS) technique. Generally, in this context, copper slag is used along with admixtures like flyash, beach sand, etc. to reduce the swelling. Thus, the main objectives of this study is to reduce the swelling behaviour of the clay by adding various additives[7].

2. Background Study
Several literatures were collected to study the swelling properties of expansive soils and measures to control it. The background study is briefly explained below. Alrubaye A.J.et. al (2015) worked on the...
properties of clayey soil, stabilized with lime. Experiments were conducted on physical and chemical traits of natural soil with different percentages of lime. Reduction in liquid limit and plastic limit was achieved in lesser quantities, but if it was added more than 9% then there was increase in liquid limit and shrinkage limit values [8]. Malekzadeh M. and Bilsel H. (2012) evaluated the effect of polypropylene fibre on swell and compressibility of expansive soil and studied the effect of polypropylene fibre on MDD & OMC. It was concluded that on addition of 0.5% to 0.75% fibre, swell decreases [9].

Dafalla Muawia (2017) investigated the compressibility and swelling properties of mixtures. It was found that the swelling and compressibility indices increase with increasing clay content. The inclusion of less expansive soil material as partial replacement of bentonite by one-third to two-thirds was found to reduce the compressibility by 60% to 70% for 10% and 15% clay content, respectively. The swelling pressure and swell percent were also found significantly reduced [10]. Muntohar A.S. (2003) has worked on the deformation characteristics of bentonite mixed with different amount and types of non-swelling soil. Clay mineralogy by X-ray diffraction test was performed on soil bentonite mixture and it was found that at low bentonite content, the rate of swelling was very slow with decrease in the particle size of the non-swelling fraction [11]. Rao M.R. and Rao A. (2010), studied the behaviour of expansive clays under lime or cement-stabilized fly ash cushion subjected to several wetting and drying cycles. It was found that the increase in the thickness of the cement- or lime-stabilized fly ash cushion, the band width of swelling and shrinkage over successive cycles decreases gradually and becomes almost negligible [12].

Widodo and Ibrahim (2012) have estimated the primary compression index ($C_c$) using physical properties of Pontianak soil. Empirical equations proposed by some researchers depending on the correlation between water content and liquid limit. The estimated compression index values were compared with the laboratory tests results [13]. Jain V.K. et.al (2015) studied the relationship between physical properties and the mechanical properties of the soil. Empirical model has been developed by Linear Regression method and is used for the investigation of relationships between dependent variable and independent variables [14].

3. Materials And Method

The additives that are chosen are, manufactured sand, river sand, copper slag, beach sand and fly ash. The physical properties of the clay is studied in detail and is shown in table 1. To understand the compatibility of the additives with the clay, its specific gravity is determined and is shown in table 2. Free swell or differential free swell, also termed as free swell index, and is the increase in volume of soil without any external constraint when subjected to submergence in water[15]. Differential free swell index was determined for different proportions of additives[16].
Figure 1. Free Swell Index Set up.

The fig. 1 represents two graduated cylinders. One containing distilled water and other containing kerosene. The kerosene is a non-polar liquid, so it does not react with any material. The Free swell index of the mixtures are determined as shown in Eq. 1.

Free swell index,
\[ FSI = \frac{V_d - V_k}{V_k} \times 100\% \]  
where,
- \( V_d \) = volume of soil specimen read from the graduated cylinder containing distilled water.
- \( V_k \) = volume of soil specimen read from the graduated cylinder containing kerosene.

4. Results And Discussion

The results obtained from the various tests are elaborated in detail. Free Swell test is the most simple and quick test that is widely adopted to determine the swelling characteristics of the clay.

5. Properties Of Clay

Oven dried samples were used for the entire analysis. The specific gravity of the clay was determined to be 2.72. The sample that was used for the analysis had 35% of fine sand and about 58% of clay content as shown in figure 2. The sample was washed with 75 micron sieve and the sample lesser than 75 micron were oven dried and used for free swell tests\[17,18\]. From the Atterberg limits it is determined that the sample is low plastic clay (CL). The sample contained an organic content of about 2.5%. Standard Proctor test was conducted and the sample was found to have maximum dry density at 1.86g/cc and optimum moisture content at 14.6% as shown in figure 3.

| Table 1. Properties Of The Clay Sample |
|-----------------|-----------------|
| **PROPERTIES**  | **VALUE**       |
| INITIAL MOISTURE CONTENT (%) | < 0             |
| SPECIFIC GRAVITY          | 2.72            |
| PARTICLE SIZE DISTRIBUTION |                |
| a) COARSE SAND (%)      | 0.02            |
| b) MEDIUM SAND (%)      | 6.00            |
| c) FINE SAND (%)        | 35.19           |
| d) SILT (%)             | 0.72            |
| e) CLAY (%)             | 58.2            |
| ATTERBERG LIMITS         |                |
| a) LIQUID LIMIT (%)     | 29.25           |
| b) PLASTIC LIMIT (%)    | 14.19           |
| c) SHRINKAGE LIMIT (%)  | 6.20            |
| SOIL TYPE               | CL              |
| FREE SWELL INDEX(%)     | 70              |
| ORGANIC CONTENT (%)     | 2.49            |
| OPTIMUM MOISTURE CONTENT (%) | 14.6        |
| MAXIMUM DRY DENSITY (g/cc ) | 1.86     |
6. Properties Of Admixtures

The various admixtures that were chosen for the study are M-sand, River sand, Beach sand, Copper slag and Fly ash[19,20]. The admixtures chosen for this study did not show any swelling behaviour, as determined from the free swell test. The specific gravity values of the various admixtures are listed in table 2. The values were from 2.00 to 3.6. The wide range in the specific gravity did not have any influence in the test results.

| Table 2. Specific Gravity Of Admixtures |
|-----------------------------------------|
| M-Sand | River Sand | Beach Sand | Copper Slag | Fly-Ash |
| Specific Gravity | 2.09 | 2.64 | 2.49 | 3.62 | 2.00 |
7. Influence Of Admixtures On The Swell Behaviour Of Clay
The admixtures were added to the original clay sample in different proportions, namely 2%, 5%, 10%, 12% and 15%. The test samples were prepared by volume batching method. The results obtained from the tests are consolidated and presented in figure 4. From the figure it could be concluded that there is no change in free swell index by the replacement of clay with M-sand [21,22]. The swell index has been reduced at 12% replacement of clay with river sand and fly ash. The DFI has been reduced at 10% replacement of clay with copper slag.

![Differential free swell test result](image)

**Figure 4.** Differential Free Swell Test Results

8. Conclusion
The soil was chosen for this study is of CL type, according to IS classification. The index and physical properties of the soil was determined. The soil has specific gravity of 2.72, differential free swell index is 70% and coefficient of consolidation is 0.449 mm²/sec. In this soil 2%, 5%, 10%, 12%, 15% of various additives like m-sand, fly-ash, river sand, copper slag and beach sand were added and its swelling properties were determined.

The differential free swell index was determined for all the samples and it is found that the swell index has been reduced at 12% replacement of clay with beach sand and significantly increases with increase of proportions. By comparing the results, it is found that, replacement of clay with 10% copper slag gives optimum free swell index, hence this can be suggested as the suitable admixture to control swelling behaviour of the soil, used in this study.

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