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Forecasting Geotechnical Characteristics of Diverse Soils through CIPW Norm Analysis

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Abstract

The fundamental physical attributes of a rock mass are dictated by the nature of the rock(s). Likewise, the foundational properties of a soil mass are intricately linked to the characteristics of its parent rock(s). Soil composition comprises minerals resulting from the weathering of rocks prevalent across the Earth's surface. To discern the impact of mineral composition on geotechnical properties, civil engineers can predict soil properties through normative mineral analysis, which delineates the mineral composition percentage. Normative mineral analysis involves a micro-level examination, using techniques like EDAX and SEM, to determine chemical composition, bond formation, surface texture, mineral structure, and element geometry. This research compared normative and engineering properties of four distinct soils, drawing conclusions by juxtaposing micro-level findings with experimentally derived index and engineering properties. The study revealed direct proportionality between Albite mineral percentage content and soil plasticity index, while hypersthene mineral content exhibited an inverse relationship. Additionally, the research affirmed that higher clay mineral percentages contribute to increased soil strength.

Keywords: Rock mass, Soil mass, Parent rock properties, EDAX, SEM

1 Introduction

2 Experimental investigation: Materials used

In this investigation, an attempt has been made to study the role of the mineralogical composition on the plasticity and the strength properties of the soil. The properties of the soil used and the macro and micro level tests conducted are presented in this work. The properties considered in this study are plasticity, pH, compaction, CBR, and Strength.

The soils used for this investigation are obtained from the different areas in and around Tirupati. In this study, four soil samples were collected from the near A. (SVEC, Geotech. lab), B&C (MRO Office, two samples), and D. (Gajulamandyam). The soils from the respective sites are taken, and the pebbles and vegetative matter present, if any, are removed by hand. It is further dried and pulverized and sieved through a sieve of 4.75 mm to eliminate gravel fraction if any. These dried and sieved soils are stored in air-tight containers ready for use. The soils are classified as CL, CH, CH, and CH, respectively, as per I.S. classification (I.S. 1498:1978). It indicates that one soil is of Low plasticity and the others are of High clay and plasticity content. The degrees of expansiveness is between 10% and 140%. The experimental program is broadly divided into pH, Swelling Characteristics, Compaction Characteristics, California Bearing ratio (CBR), Strength Characteristics, Normative Mineral Analysis Studies, Energy Dispersive Spectroscopy (EDS) studies for mineral analysis, and Scanning Electron Micrograph Studies. Present in the soil.

3 Results and Discussions

The results of liquid limits, plastic limits, and plasticity index conducted for different soil samples are tabulated in table1. From Table 1, it is observed that the liquid limit and plasticity index of the soil samples increases from the soil samples A to D values. The increase in the liquid limit and the plasticity index of the soil samples may be due to the increasing water holding capacity of the soil which is in turn depended on the clayey mineral.

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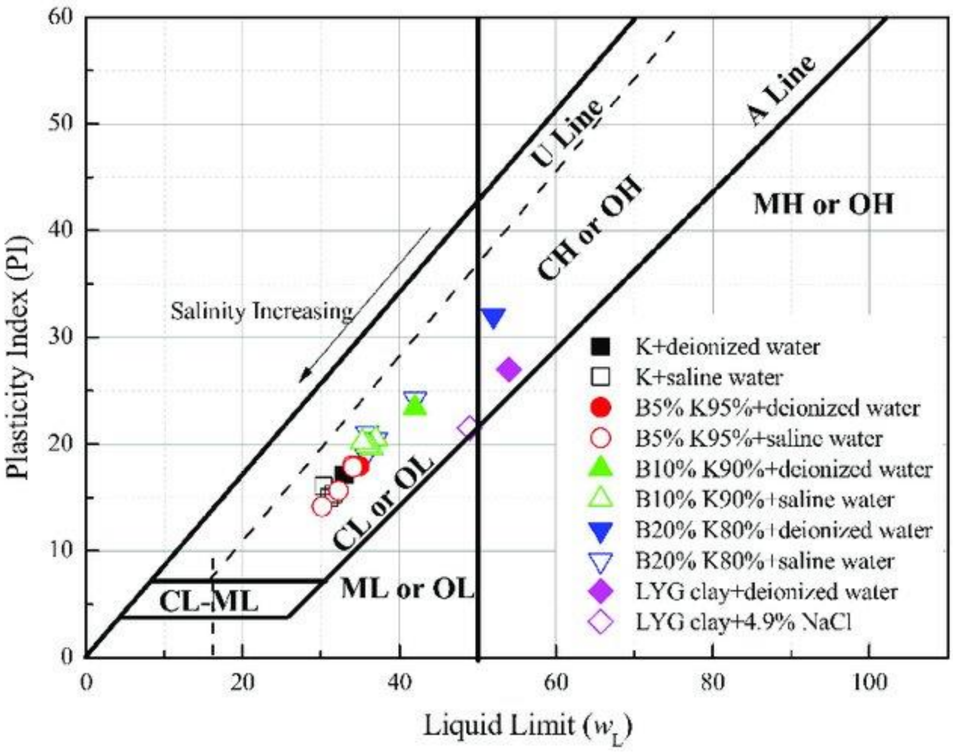

Fig. 1: Plasticity Index Chart

3.1 Unconfined Compressive Strength test values

The strength values that are obtained are tabulated in Table 4, from the table explains that the strength has increased from sample A to D, i.e., 27.97kN/m^2, 53.44kN/m^2, 102.53kN/m^2, and 158.13kN/m^2 respectively. It is observed that the quartz has no direct influence on the soil strength, but the increase in strength may be attributed to the increase in the ratio of the clay minerals to the non-clay mineral (here in this study, Illite and orthoclase are considered as clay minerals and quartz is considered as non-clay mineral). Figure 3, the load vs. axial strain plot, depicts that soil sample B has more ductile failure corresponding to the other samples.

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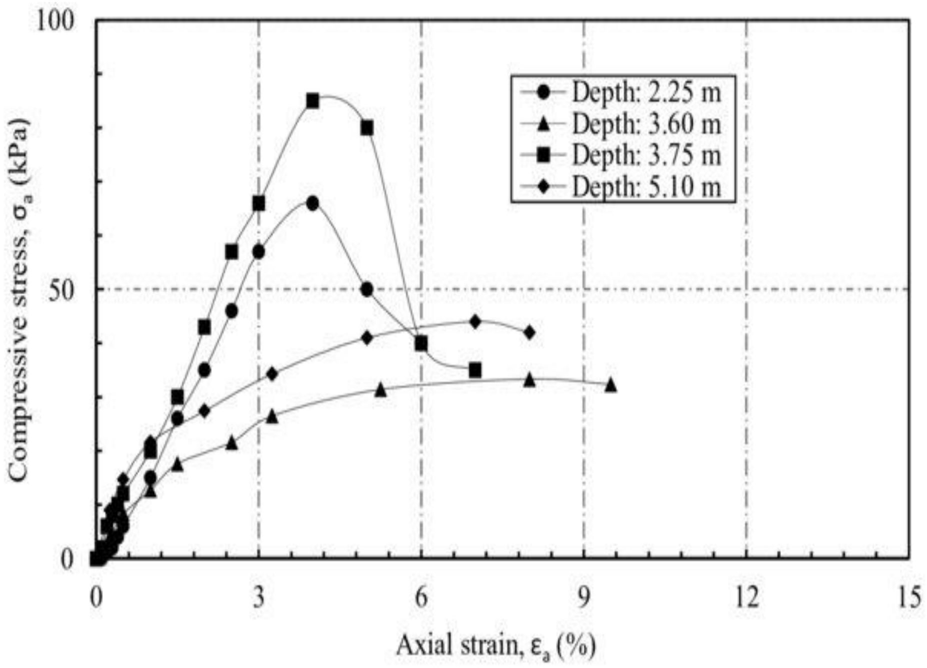

Fig. 2: Plot of UCC Strength against axial strain for samples A through D

3.2 California Bearing Ratio values (CBR)

The values obtained from California Bearing Ratio (CBR) test were tabulated in table 5. The table shows that the penetration values at 2.5mm penetration are greater than the 5mm penetration, and the CBR values are gradually increasing from sample A to D.

3.1 Tri-Axial test

The cohesion values of the soil samples A, B, C, and D are 0.21 kg/cm^2, 0.71 kg/cm^2, 0.75 kg/cm^2, and 0.31 kg/cm^2, respectively. The values of Φ for soil samples A, B, C, and D are 24˚, 30°, 27° and 35° respectively are tabulated in Table 6.

From this table, it is noticed the cohesion values are increases from samples A to C, and the cohesion of sample D decreases compared with the soil samples B and C. And also, the angle of internal friction is gradually increasing from sample A to D.

3.2 Comparative study

In this study, the mineral compositions are compared with the plasticity and strength characteristics of the soil samples. Out of the eleven mineral compositions, the major minerals Albite, Anorthite, Quartz, Hypersthene, and Orthoclase are considered for comparison.

3.3 Plasticity characteristics

1) The Albite percentage in soil sample A is 4.91, which is the least among all the samples, and the Plasticity index (Ip) of sample A is 8 percent which is also the least among all other soil samples, so it can be said that the increase in Albite causes an increase in Plasticity index (Ip).
2) The percentage of Albite in sample B is higher than in sample A. Hence sample B has more plasticity compare to sample A.
3) The percentage of Albite in soil sample C is higher than in soil sample A, and soil sample C is more Plasticity Index than soil sample A.
4) The Albite percentage in sample D is higher than in samples A, B, and C. Hence sample D has more Plasticity Index than samples A, B, and C.
5) By observing the above results, it is depicted that Albite percentage is directly influenced by the plasticity index of the soil and also the percentage of Hypersthene inversely proportional to the plasticity index of the soil sample.

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3.4 Strength characteristics

1) The strength of sample A has shown the least strength, i.e.., Unconfined Compressive Strength (UCC), California Bearing Ratio (CBR) & Tri-axial test. The ratio of the clay minerals (il+or) to the non-clay minerals (Q) is (i.e., 1:2) lesser in samples B, C, and D. So, soil sample A has less binding capacity than other samples, and also the quartz percentage soil A is less than the other soil samples.
2) The strength of sample B (UCC, CBR & Tri-axial tests) is more than sample A, and the ratio of the clay minerals increased from 1:2 to 1:3, so we may deduce that the increase in the ratio of the clay minerals caused an increase in strength of the soil. This may be due to the increased binding capacity between the minerals.
3) The strength of sample C (Unconfined Compressive Strength (UCC), California Bearing Ratio (CBR)& Tri-axial tests) is more than soil samples A and B, also, the ratio of the clay minerals increased from 1:3 to 1:4, so we may deduce that the increase in the ratio of soil minerals causes an increase in strength of the soil. This may be due to the increase in the binding capacity between the various minerals.
4) The strength of soil sample D ((Unconfined Compressive Strength (UCC), California Bearing Ratio (CBR) & Tri-axial tests) is more than soil samples A, B, and C also, the ratio of the clay minerals increased from 1:4 to 1:5, so we may deduce that the increase in the ratio of clay minerals cause an increase in the strength of the soil. This may be due to the increase in the binding capacity between the various minerals.

4. Soil fabric studies

Fabric studies of any soil sample include the study of the arrangement of the soil particles at the micro and sometimes at the Nano levels of the soil. This gives qualitative information about the soil. It has been established that fabric influences the engineering behavior of soil (Keller, 1985). Fabric analyses are useful in research to reveal how mechanical properties relate to particle associations and arrangements. Fabric information can be used to deduce details of the depositional and post-depositional history of a deposit. The effects of different sampling methods can be assessed through the study of fabric changes. Insights into the mechanics of strength mobilization, the nature of peak and residual strengths, and the stress-strain behavior of soils can be obtained through fabric analyses. Also, qualitative visualization of the reaction products formed in different carbonated-treated systems can be studied using scanning electronic micrographs. It is seen that the fabric of the soil, which is a dispersed structure in a natural state, assumes a flocculated structure on treatment with any carbonate. The extent of variation varies from the type of carbonate. No attempt has been made to quantify the change in the microstructure. The following images show the fabric arrangements in the soil samples. For each sample, photographs were taken at 10µ and 2µ ranges.

CONCLUSIONS

- Plasticity characteristics rise sequentially from Soil A to D, attributed to increasing clay mineral percentages (Albite) in the respective samples.
- The percentage of Hypersthene mineral exhibits an inverse relationship with the plasticity index across Soil A to D.
- Unconfined compressive strength (UCC) and shear strength parameters, both cohesion (c) and angle of internal friction (Φ), ascend with higher ratios of clay minerals to non-clay minerals.
- California Bearing Ratio (CBR) values experience an increase from Soil A to D, corresponding to the elevated ratio of clay minerals to non-clay minerals.

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