

INVESTIGATION ON STRENGTH AND MINERALOGICAL CHARACTERISTICS OF PHOSPHOGYPSUM STABILIZED CLAY

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Abstract: The construction sites of desired qualities becoming increasingly difficult to find due to increase in urbanization. Among the various site conditions, the presence of expansive clays causes inadequate strength for the building and pavement construction. To improve the clayey soil by relatively simple technique such as chemical stabilization, and this study was carried out to investigate the possibilities of using an industrial waste, Phosphogypsum (PG) as a soil stabilizer having high potential as a pozzolanic material. The study investigates on microstructure and strength of clayey soils to examine the effects of stabilizer content and curing periods for a short term period. The strength characteristics were determined by the unconfined compression tests on treated samples at different curing periods of 3 days, 7 days and 14 days and further confirmed by microstructural consideration. The results indicated that the addition of Phosphogypsum resulted in an improvement of strength with increase in proportions of PG. Curing time of 14 days contributed to an increase in the Unconfined Compressive Strength, from 75 kPa to 119 kPa and 122 kPa to 257 kPa for both the clayey soils. SEM analysis showed the presence of the cementitious products in the treated clay resulted from PG-clay reaction, and strength attainment stages between the soil and PG with different percentages are assessed by X-Ray diffraction. From the experimental results it was observed a significant improvement in the stabilized soil properties within less period of curing. Thus the use of Phosphogypsum in clayey soil as a stabilizer proved an economical, successful additive to stabilize the subgrade soil.

Keywords: Phosphogypsum, Stabilizer, Unconfined compression test, SEM, curing period.

1. Introduction

The engineering structures which selected to construct on expansive clay soils can cause different issues related to soil properties. It may lead to prominent failures with adverse effect in the functioning of structures. The expansive soils are highly problematic since it shows high volume changing characteristics with the change in water content. There are many substantial studies has been carried out all to rectify the problems and the methods to solve the effects associated with the clayey soils^[1]. Among the primitive methods, the soil stabilization with the cement and lime and with combination treatments^[2,3,4] has proved as the rectifying method for reduces the swelling characteristics of expansive clays. Then many other methods are also conducted with the Bagasse ash^[5], RHA^[6,7], polymers^[8] etc are the stabilizing agents in clayey soils. Recently many waste products^[9,10] are also using in increasing amounts for soil stabilization providing a partial solution for its disposal problems.

In this point of view, a fertilizer industry by product, Phosphogypsum has used as a soil stabilizer in this study to find its effectiveness in pozzolonic effect with the expansive clay. Unconfined compressive strength tests were conducted on soil specimens to examine the development in strength characteristics of clay stabilized with Phosphogypsum. To investigate the chemical reactions and the reaction products formed during the stabilization process, are with analysed with the XRD analysis, and SEM observations.

2. Materials

2.1 Phosphogypsum

It is an industrial waste byproduct which having the cementing characteristics, having majorly consisting of CaO -32.27%, SiO₂ - 3.8% and SO₃- 44.56%. The

presence of lime in the form of CaO which imparts more strength for the stabilized soil. Substantially, the contents of SiO_2 and SO_3 chemical compositions results in hydration reactions which targets the strength attainment in stabilized form.

2.2 Soil

Two soil samples of expansive clay were collected from the limited depth for the stabilization process. The details of properties of soils are shown in Table 1 and as per the characteristics both the soil are classified as clay of high compressibility as per IS standards^[11].

Table 1. Properties of Soil Samples

Description		Sample 1	Sample 2
Free swell index(FSI),%		120	109
Particle size distribution	Clay (%)	70	66
	Silt (%)	28	32
	Sand (%)	2	2
Liquid limit W_L (%)		51	69
Plastic limit W_P (%)		20	22
Shrinkage limit (%)		7.7	9.9
Specific Gravity		2.23	2.4

2.3 Sample Preparation and Tests

Specimens were prepared by soil with stabilizer Phosphogypsum and the mix proportions were 2%, 4%, and 6% by dry weight of soil. The samples for UCC test are casted with the MDD and OMC obtained from compaction characteristics^[12] of untreated soils. Samples prepared have kept for curing by wrapping the specimens with plastic cover for periods of 3, 7 and 14 days. The specimens were tested for the strength after the specified curing periods by unconfined compression tests^[13]. After all tested samples had been oven dried, they were crushed and took for SEM and XRD analysis.

3. Results and Discussions

3.1 Strength characteristics

The development of soil strength, when stabilized with Phosphogypsum for two samples are shown in table 2. It was observed that the strength increases as the content of stabilizer increases and in both the soil samples there is remarkable increase in strength with 6% Phosphogypsum addition. The unconfined strength values of untreated soils were determined as 75kPa and 112kPa respectively. Figures 1 and 2 shows the stress strain relationships of untreated and treated soil with phosphogypsum with varying quantities.

Table 2. UCS values of treated soils at different curing periods

Description	Unconfined compressive strength value, kPa					
	Sample 1			Sample 2		
	3 days	7 days	14 days	3 days	7 days	14 days
Soil + 2% PG	77	84	100	115	134	221
Soil + 4% PG	81	88	112	121	176	224
Soil + 6% PG	83	95	119	130	208	257

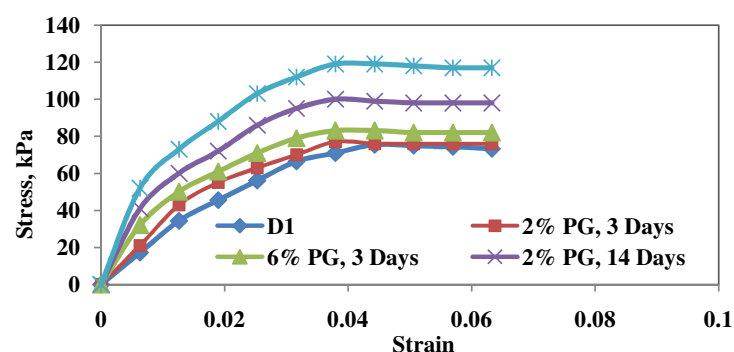


Figure 1. Variation in stress- strain relationship of untreated and treated sample 1 with PG

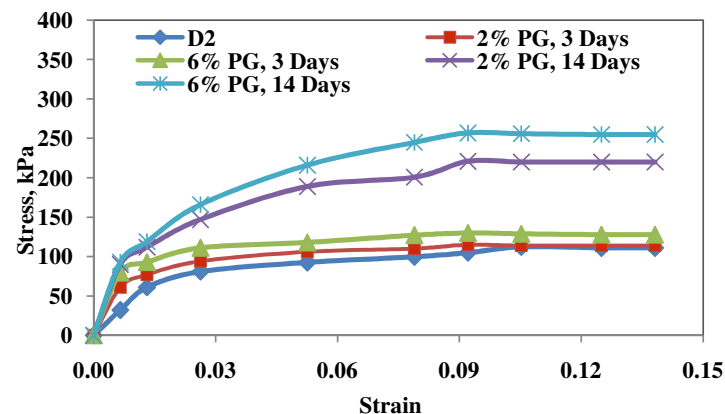


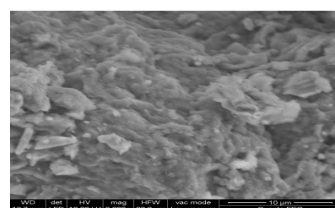
Figure 2. Variation in stress- strain relationship of untreated and treated s
ample 2 with PG

It can be clearly seen that the strength has gained in both the samples, when Phosphogypsum was in different increasing percentages of 2%, 4% and 6% compared with the untreated soil. It was observed that the 14 days strength of treated specimens was found approximately twice the strength of untreated soils. However the strength has attained in early stages of curing periods of treated soils, it has analysed in detail based on the microstructural studies

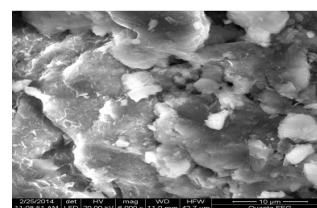
3.2. Microstructural Analysis by XRD and SEM

Based on the strength results obtained on stabilized soil, expansive soil with Phosphogypsum appeared suitable for soil stabilization. The results obtained from

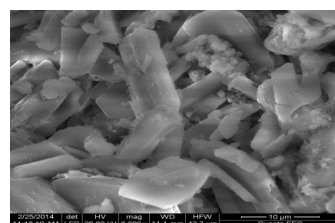
Unconfined Compressive Strength tests are compared with the results from XRD and SEM investigations. The results of Scanning Electron Microscopy obtained for untreated and selected treated samples are shown in Figure 3. The micrographs were taken from UCS test samples after 7 curing days. The soil samples in the untreated condition, forms individual clusters of various sizes are clearly obtained from SEM analysis. SEM results of 6% Phosphogypsum samples pozzolanic products and the reaction leads to the association of clusters into denser structure. The clear cemented structure in treated samples images, signifies the improvement in unconfined compressive strength of Phosphogypsum treated soil.



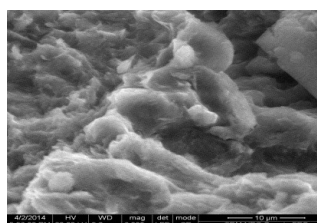
a. Untreated sample 1



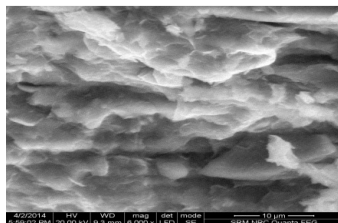
b. Untreated sample 2



c. Phosphogypsum



d. Sample 1 with 6% PG at 7
Days curing period

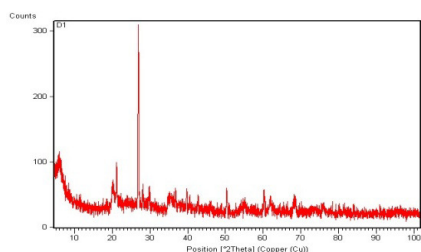


e. Sample 2 with 6% PG at 7 Days curing period

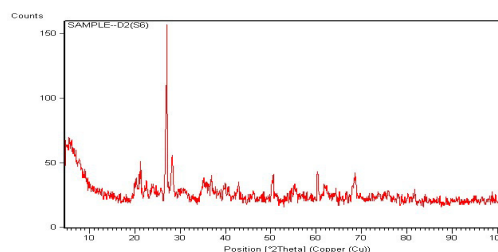
Figure 3. SEM Images of Phosphogypsum, Untreated and Treated Samples

With the addition of relatively smaller amounts of Phosphogypsum shows noticeable changes and it is based on the reactions that takeplace with the soil minerals. For this reason of development in strength, the cementitious

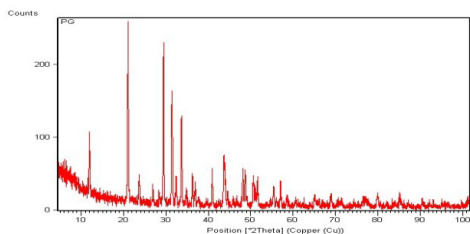
compounds with the exchange of minerals from admixture to soil are reflected on the XRD analysis. X-Ray diffraction patterns for untreated and treated samples are shown in Figure 4.



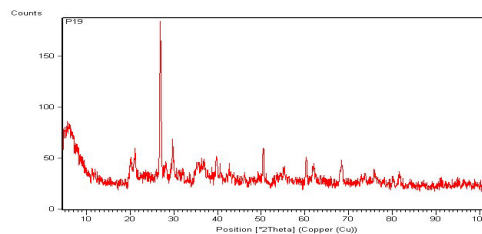
a. Untreated sample 1



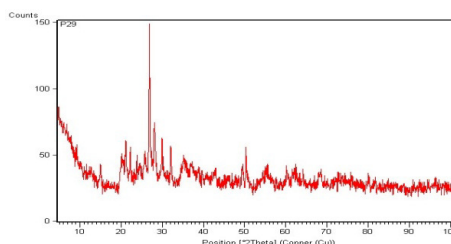
b. Untreated sample 2



c. Phosphogypsum



d. Sample 1 with 6% PG at 7 Days curing period



e. Sample 2 with 6% PG at 7 Days curing period

Figure 4. XRD results of Phosphogypsum, untreated and treated samples

Based on the evidence of SEM images of treated soil samples, the expansive clayey soil has improved by

Phosphogypsum as stabilizer with most suitable proportion of 6% which accelerated more the pozzolanic

reactions. While comparing the XRD results of untreated and treated samples, it was examined the peaks of intensities of minerals are more with the addition of higher percentage of Phosphogypsum and it is as because of progress in more pozzolanic reactions, which can contribute more strength in long term characteristics of expansive clay.

4. Conclusions

1. The development in soil strength was observed with increase in the content of stabilizer and at the curing time of 14 days contributed an increase in the Unconfined Compressive Strength, from 75 kPa to 119 kPa and 122 kPa to 257 kPa for both the clayey soils.
2. Microstructural studies reveals that Phosphogypsum as binder with expansive clay renders higher rate of pozzolanic reactions and leads to the bonding in the clay particles for denser morphology which has associated with increase in strength.
3. The use of Phosphogypsum in the expansive clays as stabilizer results in better improvement in strength characteristics and its use make a cost effective resource in soil stabilization.

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