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Study on Behaviour of Soil with Phosphogypsum as Stabiliser

K. Divya Krishnan[1], Mani Deepika[1], P. T. Ravichandran[1*], C. Sudha[1] and Ajesh K. Kottuppillil[2]

[1]Department of Civil Engineering, SRM University, Kattankulathur- 603203, Tamil Nadu, India; ptrsrm@gmail.com; er.divyakrishnan@gmail.com; manideepika.deepika@gmail.com; sudha.cvl@gmail.com
[2]Department of Civil Engineering, SAINTGITS College of Engineering, Kottayam - 686532, Kerala, India; ajesh202@gmail.com

Abstract

Background/Objective: Civil engineering structure resting on expansive soils needs more attention since it causes undesirable engineering behavior when the soil comes in contact with water. The areas consisting of expansive soil need a proper stabilization method to solve the site problems faced by the civil engineers. Pavements constructed on such soil shows signs of damage continuously during the service life of the pavement eventually increase the maintenance costs. Stabilization of these soils is a usual practice for improving the strength. **Methods:** In this work an attempt was made on the utilization of Phospho Gypsum (PG) with soil by adding various percentages of 2, 4, and 6% in soils and accessed their geotechnical behaviour for different curing periods. The effects of PG treatment on the microstructure and strength improvement of compacted expansive clays are studied based on Microstuctural analysis and Unconfined Compression tests for different curing periods of 0, 14 and 28 days. **Findings:** UCS performed on these mixes and identified that addition of phosphogypsum attained high strength with the increasing percent of phosphogypsum in soils. From the test results, it was observed that the UCS peak stresses were increases to 162kPa and 336kPa from 75 kPa and 122 kPa for soil samples S1 and S2 at 28days of curing. X-ray Diffraction and Scanning Electron Microscopy were carried out for microlevel analysis and the results confirmed the presence of minerals and cementation nature in the treated soil. **Improvement:** From the experimental study, it is observed that the treatment of the expansive soil with the addition of Industrial waste material Phosphogypsum is more efficient in subgrade modification and other geotechnical applications.

Keywords: Compaction, Phosphogypsum, Stabiliser, UCS

1. Introduction

Construction of structures over the problematic soil is a serious problem since its affect lifetime adversely. Such soils need the ground modification to improve the engineering characteristics to meet the design specifications. Among the ground modification methods, soil stabilization is widely used in connection with subgrade modification related to pavements and construction of other smaller structures. Regarding the effectiveness of soil stabilization technique, the selection of proper binder holds the primary role in the treatment process. Stabilization using waste products is one of the emerging options related to subgrade modification. The suitability of locally available waste materials in stabilization promotes a sustainable construction through reduction of its disposal problems. Stabilization of problematic soil has been done by addition of different types of industrial wastes[1-6]. To improve the engineering properties of the soil like strength, volume stability and durability, various admixtures used in the chemical treatment of soil[7-10]. By the researchers, an improvement in the shear strength behavior of expansive soil was also observed by stabilization using waste products[11-14]. This paper aims to investigate the strength and the microstructural development of phospogypsum treated clays using Unconfined Compressive Strength test, Scanning Electron Microscopy (SEM) and X-Ray Diffraction (XRD). For this purpose, samples with different percentages of stabilizer were prepared, which are compacted at Optimum Moisture Content (OMC) and tested at various curing periods to investigate the effectiveness of stabilizer.

* Author for correspondence

2. Materials

The soil samples were excavated from a depth of 0.6m from the ground level after removing the top soil. The collected soils were air dried, then pulverized and used for testing[15]. From Particle size analysis it was found out that 70% clay, 28% silt and 2% sand and 66% clay, 32 % silt and 2% sand for sample 1 and 2. Free swell[16] obtained are 63.6% and 80%. Similarly, the Atterberg limits[17] such as liquid limit, plastic limit and shrinkage limit are determined for sample S1 and S2 are 51.5%, 20%, 7.71% and 69%, 21.81%, 9.94% respectively. Based on free swell and Atterbergs limits, the soils are presenting them having high compressibility[18] with high swelling characteristics[19] in accordance with Indian Standard soil classification system. The compaction[20] and strength properties[21,22]for soil samples were also determined and were shown in Table 1. Phosphogypsum, the fertilizer industry waste was the stabilizer used to treat the soils, and its chemical compositions are presented in Table 2.

Table 1. Compaction and strength characteristics of soil samples

Soil Sample	Compaction Characteristics		Strength Characteristics	
	MDD, g/cc	OMC, %	UCC (kPa)	CBR (%)
S1	1.5	25.73	75.41	1.45
S2	1.58	18.52	112	2.19

Table 2. Chemical composition of Phosphogypsum

IR	SO_3	SiO_2	LoI	CaO
4.92	44.56	3.8	16.5	32.27

3. Testing Procedure

3.1 Unconfined Compression Strength (UCS) Test

The UCS testing was performed according to IS: 2720 (Part 10) 1973. Soil samples treated with phosphogypsum in different percentages such as 2%, 4% and 6% were wrapped with thin plastic cover after the preparation until the curing periods of 14 and 28 days. The prepared samples were tested by applying axial compression load until failure keeping an axial strain rate of 1.25mm per minute after the sample reaches its curing period. For all the combination of soil and admixture mix and the curing period three specimens were made.

3.2 Microstructure Analysis

In this study, microstructure analyses of selected specimens were carried out using Scanning Electron Microscopy (SEM) and X- Ray Diffraction (XRD). After each UCS testing, the samples were dried in oven maintaining the temperature not more than 60o. From the dried samples, small specimens with fractured surfaces were used for scanning. The dried specimens are pulverized into fine particles having the size less than 75 microns are used for XRD for the identification of minerals.

4. Results and Discussion

4.1 Effect of Phosphogypsum on Unconfined Compressive Strength (UCS)

The UCC samples are prepared for both the untreated and treated samples, with the compaction characteristics of virgin soils. Figures 1 and 2 show the development of the unconfined compressive strength of stabilized soils with age for various percentages of phosphogypsum. The effect of mixing the phosphogypsum with varying percentages wit both the soil samples is shown in figure. Stabilizer combinations with higher dosages produce higher compressive strength. Table 3 shows the results UCS of treated and untreated samples at different percentages of phosphogypsum (PG) and curing periods. From the results it was observed that the UCS peak stresses are increased to 162 kPa and 336 kPa from 75 kPa and 122 kPa for soil samples S1 and S2 at 28 days of curing.

Table 3. UCS results of treated and untreated samples

Sample	UCS (kPa)						
	0 days	14 days			28 days		
	0%	2%	4%	6%	2%	4%	6%
S1	75	100	112	119	128	143	162
S2	122	221	224	257	276	292	336

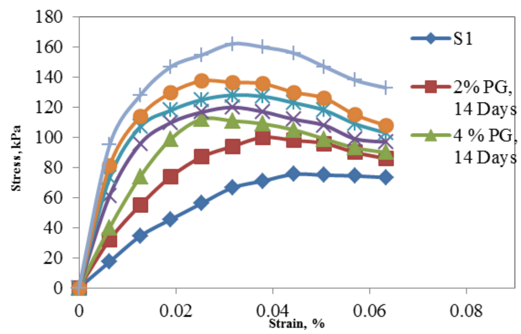


Figure 1. Stress-strain variation for soilS1 mixed with different percentagesof PG.

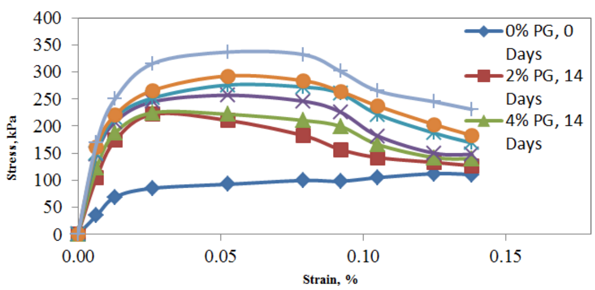
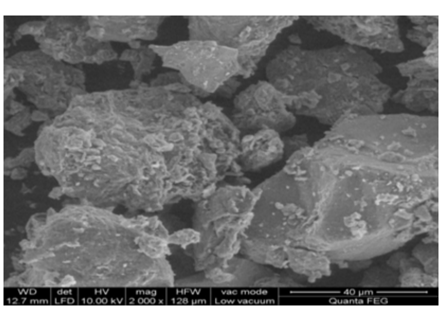


Figure 2. Stress-strain variation for soilS2 mixed with different percentages of PG.

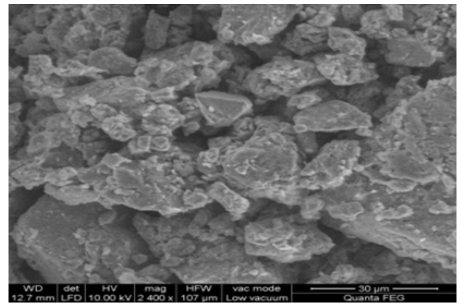
4.2 Effect of Phosphogypsum on Microstructure

4.2.1 Scanning Electron Microscopy (SEM)

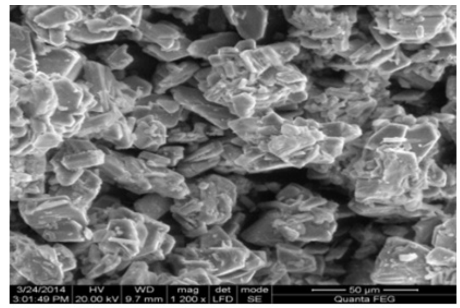
Figure 3 shows the SEM-micrograph of untreated and treated clay samples of selected samples. Many pore spaces in the structure of untreated soil between the clusters show no cementing products. Figures 3 (a) and (b) shows the micrographs of stabilized samples S1 and S2 after 14 curing days with 2% and 4% PG. SEM micrographs show the clear evidence of structure changes of soil for untreated and treated samples with phosphogypsum. The micrographs of treated soil samples show the formation of cementing products, which were clearly visible, that induces the decrease in pore spaces in soil fabric.



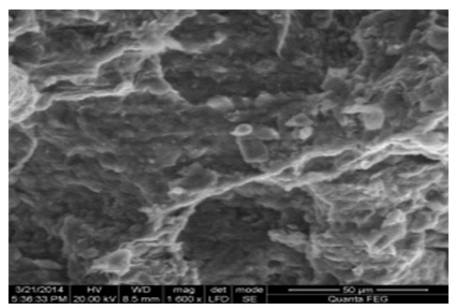
a. Soil sample S1



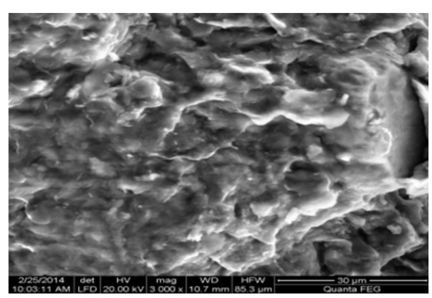
b. Soil sample S2



c. Phosphogypsum



d. Soil sample S1+2% PG

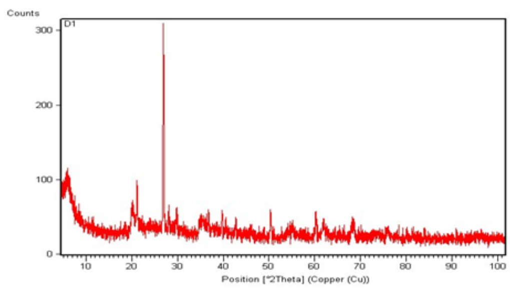


e. Soil sample S2+4% PG

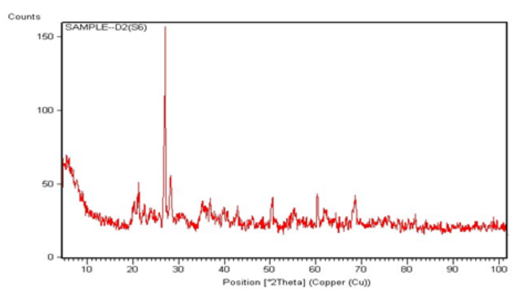
Figure 3. SEM micrographs of admixture, untreated and treated soils for 14 days of curing.

4.2.2 X- Ray Diffraction (XRD)

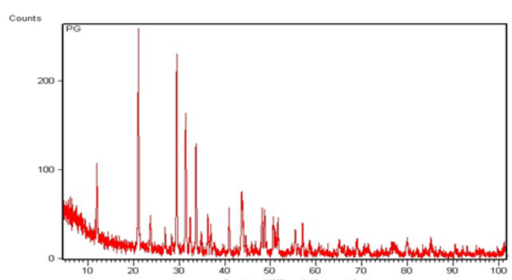
Energy dispersive spectroscopy shows an X-ray mapping of each element which is present in the samples. The XRD tests were performed on virgin soils, stabilizer and treated specimens are shown in Figure 4. The comparison between XRD diagrams of treated samples cured for 14 days for both the soil samples with untreated soils shows that there is a remarkable increase of the minerals indicated by each peak which contributes the formation of pozzolonic compounds. Thus, the effect of the addition of phosphogypsum is attributed, which has enhanced the effect of offering easy production of hydraulic compounds at the early ages of curing time.



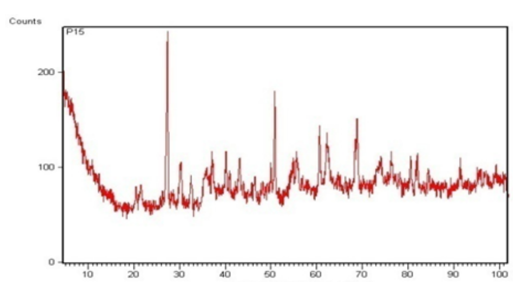
a. Soil sample S1



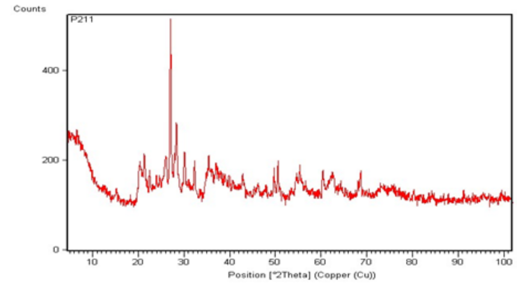
b. Soil sample S2



c. Phosphogypsum



d. Soil sample S1+ 4% PG (14 days)



e. Soil sample S2+4% PG (14 days)

Figure 4. XRD results of admixture, untreated and treated soils.

5. Conclusion

The study confirms the viability of producing stabilized soils of good strength with PG. The soil modification promoted an increase in strength of 162kPa and 336kPa from 75 kPa and 122kPa for soil samples S1 and S2 at 28days of curing.

The increase in unconfined compressive strength of both the soil treated with 6% phosphogypsum from 14 to 28days is in the order of 30 to 35%.

Microstructures of treated soils are totally changed after stabilization and it was showing a clearevidence of cemented structure by the formation of pozzolanic compounds with the addition of PG.

The use of phosphogypsum as a stabilizer in the soil helps in converting this industrial waste into detoxified material and can use as a useful material in the field of construction industry.

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