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Utilisation of Phosphogypusm and Flyash in Soil Stabilisation

K. Divya Krishnan*, P. T. Ravichandran, C. Sudha, V. Janani and Manisha Gunturi

Department of Civil Engineering, SRM University, Kattankulathur - 603203, Tamil Nadu, India; er.divyakrishnan@gmail.com, ptrsrm@gmail.com

Abstract

Background/Objectives: Buildable land with good natural bearing capacity is reducing and it leads to the construction of buildings on poor soils which are finally leads to structural foundation failures. This necessitated the use of available admixtures for the improvement of soil characteristics economically. Among the available resources, industrial by-products can be effectively used as admixtures since it can solve the hazardous problems due to its disposal. **Methods**: Grain size analysis and Atterberg's limits tests are conducted to classify the soils used in this study. To evaluate the effect of admixtures, strengths characteristics of soils were observed by Unconfined Compressive Strength and California Bearing Ratio tests. Weak soils having high expansive characteristics are used to study the activation of 5% fly ash blended with Phospho Gypsum (PG) at varying percentages of 2%, 4% and 6% with two weak soils at different curing conditions. **Findings:** Results shows higher strength development upto a percentage of 4% PG with 5% flyash with both the soils. Effect of curing periods on strength characteristics of treated soils at 7, 28 and 60 days were also considered in this study. Microstructural studies are also showing an improvement in microstructure which is examined in SEM micrographs and XRD results. The influence of flyash with different percentages of phosphogypsum on swelling characteristics shows a decrease in swell potential of treated soil with increase in curing periods. **Improvement:** This study gives an effective application of Phospho Gypsum and Fly Ash in geotechnical field by using it as a relevant soil stabilizer. Increase in CBR values were obtained with Fly Ash and Phospho Gypsum combinations with soils, which reduces the thickness of pavement and making more productive use of industrial wastes with considerable environmental benefits.

Keywords: Compressive Strength, Fly Ash, Phosphogypusm, Stabiisation

1. Introduction

Presently the need for soil modification was arising situation in construction industry, since the construction over good natural soil is found to be difficult due to increasing demands. It has been found that the structure resting on problematic soils causes immense damage to the foundation as well as superstructure. Among the numerous ground improvement techniques, soil stabilization proves an innovative treatment technique to exceed the difficulties of problematic soils. In some situations like pavement construction, the soil stabilization of the subgrade soil confirms to be a cost effective technique in construction by resulting reduction in the total depth of the layers of pavement. Considering the effectiveness of stabilization, the utilization of waste materials as additives suggests the soil strength improvement and solves the problem of disposal. Chemical methods with the use of fly ash, lime, cement etc has been increasingly utilized to improve the strength significantly[1–3]. Various researchers[4,5] have attempted to stabilize the black cotton soil. In soil stabilization the use of agricultural waste[6], is also becoming an effective admixture in increasing the bearing capacity of weak soils, because of the pozzolanic properties when it gets oxidized. With this view, an investigation was undertaken with industrial wastes to produce cementitious binders by blending the Fly Ash with Phosphogypsum for treating the expansive soils. The phosphogypsum with flyash combination increases the later strength development

**Author for correspondence*

by accelerated pozzolonic reactions has been studied for increasing proportions at different curing periods.

2. Test Materials and Properties

Two soils of different physical and geotechnical properties were selected from the sitesin Tamil Nadu is used in this study. One soil samples was collected from the site located in Tholudur-Vadagaram Pondi road and the other one was from the Perungudi. For the investigations, the selection of site was based on the observed structural damages caused on the many buildings and pavements in the areas. The two expansive soils used in the test programme were collected from a depth of 0.6 m below the ground level[7] and both the samples are varying in composition and its plasticity nature. The soils have a Free Swell Index (FSI)[8] of 120% and 109% respectively. Both the soils are classified as OH (organic clay with high plasticity)as per the Unified Soil Classification System and it was found that sample D1 contained 70% clay, 28% silt and 2% sand and 66% clay, 32% silt and 2% sand for sample D2 as per the grain size distribution. The geotechnical properties[9–12] of the soil are shown in Table 1. The UCC strength[13] values for virgin soil samples D1 and D2 were obtained as 75.41 kPa and 122 kPa obtained from samples prepared with maximum dry densities[14] of 15 kN/m^3 and 15.8 kN/m^3 and optimum moisture content vales of 25.73% and 18.52% respectively. The California Bearing Ratio (CBR) tests[15] were also conducted for the samples D1 and D2 and the values obtained as 1.45% and 2.19%.

Flyash and phosphogypsum were used as the additives. Fly ash which was generated in the combustion of sub bituminous coals exhibiting bonding characteristics is collected from Neyveli in Tamil Nadu is used in this study. Phosphogypsum is another admixture used, which is the by - product obtained during the production of ammonium phosphate fertilizer.

2.1 Preparation of Specimens

Specimens are prepared by blending the fly ash with phosphogypsum in different proportions were kept for different curing periods of 7, 28 and 60 days. The range of addition of phosphogypsum was 2, 4 and 6% with fixed 5% of flyash. The tests were performed on compacted soil specimens with the admixtures added in different percentages for determining the strength characteristics and followed by the free swell tests, in order to evaluate the changes swelling potential of the soils. The test involves compacting the natural soils and stabilized soil in the UCC and CBR mould with its optimum moisture content and maximum dry densities. Mineral identification and microstructural changes in untreated and treated soils are also studied with X-ray diffraction technique and Scanning Electron Microscopy.

Table 1. Geotechnical properties of soils

Sample designation	Specific gravity	Liquid Limit (%)	Plastic Limit (%)	Shrinkage Limit (%)
D1	2.23	51.5	20	7.71
D2	2.37	69	21.81	9.94

3. Strength Tests

3.1 Unconfined Compressive Strength (UCS) test

The results of the compressive strengths values obtained foruntreatedsoil and soil samples stabilized with the addition of phosphogypsum and flyash, cured at room temperature for increasing curing periods of 7, 28 and 60 days are listed in Table 2.

It was seen that the compressive strengths test conducted on treated soils are greatly developed compared with the strength of untreated soil samples. Figures 1 and 2 shows the changes in the modification of the unconfined compressive strength with respect to curing time for soil samples D1 and D2. The influences of stabilizers on the strength gain of the treated soils are shown in Figure 3. It is noticed that the effect of fly ash and PG on strength is due to its pozzolanic reactions with the soil samples. Increase in strength achievement is more in soil samples with the admixture content and increase in curing periods. While compared with the virgin soil results, the UCS values obtained for treated soil samples D1 and D2 with

Table 2. UCC values of treated soil samples

Soil	% PG	UCS value, kPa		
		7 days	28 days	60 days
D1	2	224.86	286.219	375.41
	4	238.99	303.69	401.00
	6	266.45	355.76	452.19
D2	2	268.11	380.35	665.78
	4	285.41	406.39	709.02
	6	292.13	423.68	743.60

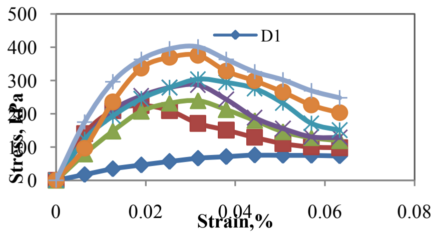

Figure 1. Stress-strain curves for untreated and treated D1 soil sample.

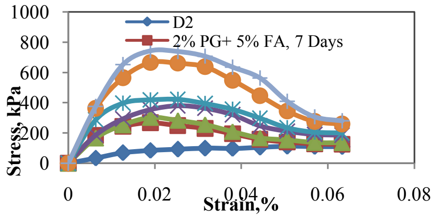

Figure 2. Stress-strain curves for untreated and treated D2 soil sample.

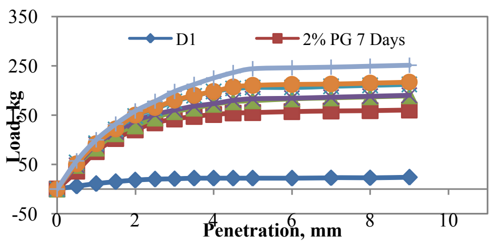

Figure 3. Load – penetration curves for untreated and treated D1 soil sample.

6% PG with 5% flyash at 60 days curing period shows an increase of 5.99 and 6.33 times respectively.

3.2 California Bearing Ratio (CBR) Test

The CBR results of the natural clay soil samples D1 and D2 are found to be 1.45% and 2.19% respectively. Since these values are below the standard specified values required for sub-grade material demands the treatment. The soil samples used for the determination of CBR values are prepared with the optimum moisture content and maximum density which are obtained from compaction characteristics, tested as per IS: 2720 (Part 16). Table 3 shows the variation in CBR values withuntreated soil samples with treated for different curing periods. Figure 3 and 4 shows that the load penetration graphs of the stabilized soil samples atspecified curing periods. It was observed that an increase in CBR values for the treated soils D1 and D2 by 13.5% and 14.6% with the effect of admixture percentage of 6% PG with 5% FA at a curing period of 60 days.

3.3 Free Swell Index

The bonding between particles with the presence cementitious elements limits the volume increase in clays soil. This cementation process occurred as a result of pozzalonic reactions takes place with the FA and PG treated soils and which reduces the swell potential. A subsequent reduction in the Free Swell Index values is observed in both soils with the increase in admixture content. Table 4 presented the free swell index of treated soils samples D1 and D2. Increase in curing time also influencing in the reduction of swell value of this treated soil samples.

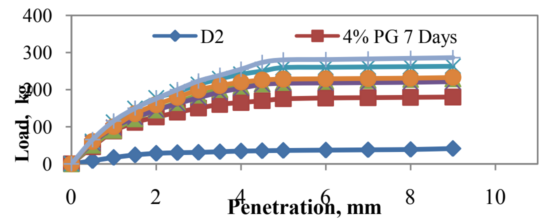

Figure 4. Load – penetration curves for untreated and treated D2 soil sample.

Table 3. CBR values of treated soil samples

Soil	% PG	CBR, %		
		7 days	28 days	60 days
D1	2	9.78	11.02	12.04
	4	10.51	11.9	13
	6	11.1	12.6	13.5
D2	2	8.90	11.24	12.55
	4	10.14	11.82	13.06
	6	12.04	14.16	14.6

Table 4. FSI values of treated soil samples

Soil	% PG	FSI, %		
		7 days	28 days	60 days
D1	2	90	70	60
	4	80	60	55
	6	60	55	50
D2	2	85	65	60
	4	70	60	50
	6	60	55	45

4. Microstructural Analysis

4.1 Scanning Electron Microscopy (SEM)

The SEM results shown in Figure 5 indicates the microstructure of typical samples used in this study. Phosphogypsum, flyash and untreated soil sample micrographs shows a pore structure which having more reactive surface results in pozzalonic reactions and resulting in cementatious products by stabilization. Figure 5 (d) indicates that large quantities of hydrated products are propagated with the aging of soil samples by fly ash–phospogypsum binder, and it indicates the strength development in treated soil. The cemetatious products which are formed by the soils stabilized with Phosphogypsum and Flyash, makes the particles integrate with each other and results in better performances compared to unstabilized soil.

4.2 X-Ray Diffraction (XRD)

X-ray images of additives and representative untreated and treated samples for 28 day specimens stabilised with 6% PG along with 5% FA are shown in Figure 6. The various hydraulic compounds that are appeared in hydration process of soil with admixture combination shows the higher peak in XRD images. The effect of the addition of PG along with flyash has enhanced the formation of hydraulic compounds in faster rate. XRD patterns of soil sample shows that there is a remarkable difference in the hydration products in specimens in untreated and treated conditions.

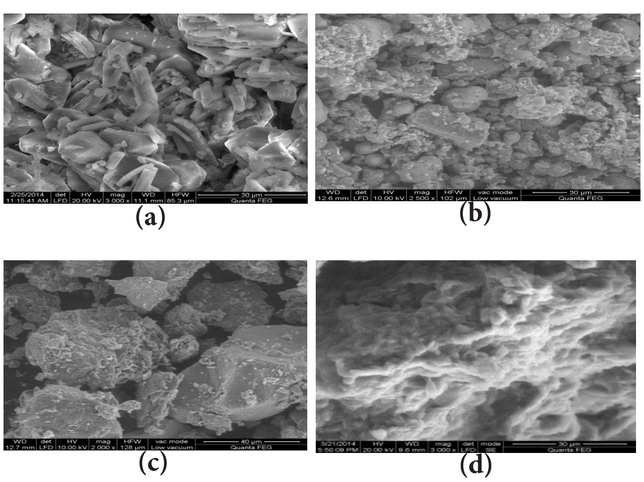

Figure 5. SEM micrographs of additives, untreated and treated soil sample. **(a)** Phosphogypsum. **(b)** Flyash. **(c)** Soil D1. **(d)** Soil sample D1+ 5% flyash +6% phosphogypsum at 28 days of curing.

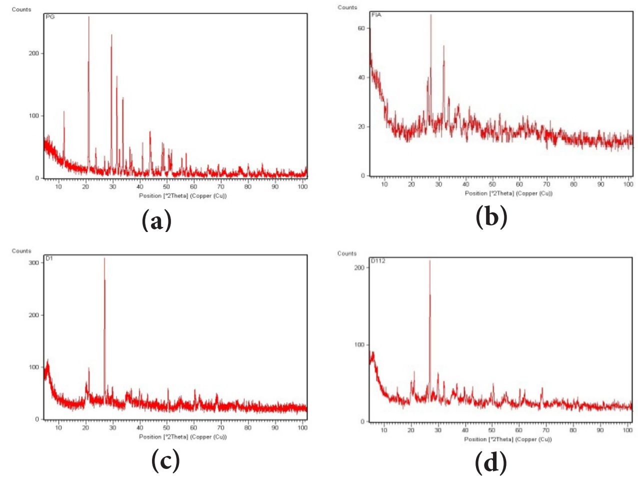

Figure 6. XRD results of additives, untreated and treated soil sample. **(a)** Phosphogypsum. **(b)** Flyash. **(c)** Soil D1. **(d)** Soil Sample D1+ 5% flyash +6% phosphogypsum at 28 days of curing.

5. Conclusion

An increase in strength was observed for treated soil samples and the UCS values obtained for treated soil samples D1 and D2 with 6% PG with 5% flyash at 60 days curing period shows an increase of 5.99 and 6.33 times respectively. Similarly the CBR values for the treated soils D1 and D2 are increased by 13.5% and 14.6% with the effect of admixture percentage of 6% PG with 5% FA at a curing period of 60 days.

A reduction in FSI from 120% and 109% of untreated soils to 50% and 45% for treated soil sample when the Phosphogypsum content was increased from 0% to 6% with 5% flyash at curing period of 60 days.

SEM and XRD images justifies that the soil treated with the fly ash and Phosphogypsum changes the mineralogy in the treated soils by the production of hydraulic compounds.

The fly ash with phosphogypsum treatment is effective in developing the strength characteristics of problematic soils and making more productive use of industrial wastes with considerable environmental benefits.

6. References

1. Kolias S, Rigopoulou VK, Karahalios A. Stabilisation of clayey soils with high calcium fly ash and cement. Cement and Concrete Composites. 2005;27(2):301–13.

2. Ogundipe, Moses O. An investigation into the use of lime-stabilized clay as subgrade material. International Journal of Scientific and Technology Research. 2013; 2(10):82–6.
3. Nalbantoglu Z. Effectiveness of class C fly ash as an expansive soil stabilizer. Construction and Building Materials. 2004; 18(6):377–81.
4. Moses G, Osinubi KJ. Influence of compactive efforts on cement- bagasse ash treatment of expansive black cotton soil. World Academy of Science, Engineering and Technology. 2013; 1541–8.
5. Al-Zoubi MS. Undrained shear strength and swelling characteristics of cement treated soil. Jordan Journal of Civil Engineering. 2008; 2(1):53–62.
6. Fattah MY, Rahil FH, Al-Soudany KYH. Improvement of clayey soil characteristics using rice husk ash. Journal of Civil Engineering and Urbanism. 2013; 3(1):12–8.
7. IS: 2720 (Part 1), Methods of test for soil: Preparation of dry soil sample for various tests. New Delhi: Bureau of Indian Standards; 1983.
8. IS: 2720 (Part 40), Methods of tests for soil: Determination of free swell index of soil. New Delhi: Bureau of Indian Standards; 2002.
9. IS: 1498, Classification and identification of soils for general engineering purposes. New Delhi: Bureau of Indian Standards; 1970. p. 1–28.
10. IS: 2720 (Part 3), Methods of tests for soil, Determination of specific gravity. New Delhi: Bureau of Indian Standards; 1987.
11. IS: 2720 (Part 5), Methods of tests for soil: Determination of liquid limit and plastic limit. New Delhi: Bureau of Indian Standards; 1985.
12. IS: 2720 (Part 6), Methods of tests for soil: Determination of shrinkage factors. New Delhi: Bureau of Indian Standards; 1972.
13. IS: 2720 (Part 10), Methods of tests for soil: Determination of unconfined compressive strength. New Delhi: Bureau of Indian Standards; 1973.
14. .IS: 2720 (Part 7), Methods of tests for soil: Determination of water content-dry density relation using light compaction. New Delhi: Bureau of Indian Standards; 1987.
15. IS: 2720 (Part 16), Methods of tests for soil: Laboratory determination of CBR. New Delhi: Bureau of Indian Standards; 1987.