Experimental Study on Strength Behaviour of Expansive Soil Treated with Phosphogypsum and Wood Ash

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Abstract: ***Developing countries like India focus their attention on the development of infrastructure like railways, roadways, airways and housing facilities. The stability of the structures to be built on the soil depends totally on the stability of the soil at which it rests. There are several soils that pose threat to the stability of the structures built on them. Expansive soil is one such problematic soil, widely spread across the world. Researchers have focused more on the use of potentially cost effective materials that are locally available from industrial and agricultural wastes to improve the properties of expansive soils. In this study the potential of two waste materials- wood ash (WA) and phosphogypsum (PG) to stabilize problematic clay soil samples were evaluated. Wood ash is the residue left after burning of woodand phosphogypsum is a waste by product obtained from the fertilizer industry. The effect of varying percentage of wood ash on the strength properties of two expansive soil samples stabilized with 4% phosphogypsum is presented. Strength characteristics of virgin soil samples as well as soil mixed with 4% phosphogypsum and 8%, 10%, 12% and 14% of wood ash respectively were found by UCC and CBR tests. The test results showed maximum strength of the soil samples when treated with 4% phosphogypsum and 12% wood ash. The use of two waste by-products, phosphogypsum and wood ash may serve as an effective and efficient way to stabilise the soil and minimise disposal problem caused by the waste materials.***

Keywords: UCC, CBR, Expansive soil, Phosphogypsum, Wood ash.

1. Introduction

Expansive soil is one of the tropical and major soil deposits in India, which is highly problematic in nature. When exposed to moisture regime, it shows either an enormous increase or decrease in volume, attributing to severe damages on structure built on such soils. Responsibility of Geotechnical engineers is to make alterations to such soils, thereby making it suitable for construction. Main focus should to be given to reduce the swelling and shrinkage and increase the bearing capacity of the soil. Constructing lightly loaded structures like foundations, retaining wall, pavement, canal linings etc., on such expansive soils, has been a challenge to the engineers, since their resistance to volume changes caused by the soil would be very less (Chen 1988). This paper describes the use of two wastes by products phosphogypsum and wood ash to stabilise the weak expansive soil samples collected.

2. Literature Review

For the past several years researchers have recognized the use of locally available materials which are cost effective and abundantly available as by products from industrial and agricultural activities to improve the properties of expansive soil with an aim to reduce stabilization costs, related to conventional stabilizing agents such as cement and lime.

Waste materials, such as fly ash, rice husk ash, sawdust ash, bagasse ash, and coconut shell ash etc., has been widely applied in practice in addition to cement and lime. [1-5]. Researches on the use of pozzolanic and calcium rich materials like wood ash in combination with materials like phosphogypsum are widely done which when successful, can replace cement stabilization resulting in a cost effective stabilization technique.

The use of PG results in reduction in cement content and suggested for an economic stabilisation technique and to use waste products effectively, cement can be replaced by Phosphogypsum [6]. PG and Flyash increases the volume stability of the expansive soil and maximum strength was obtained at 5% fly ash and 6% PG [7]. Treating expansive soil with gypsum and sand dunes shows that they effectively reduce the swelling of soil by balancing the electrical charge imbalance and reducing the diffused double layer [8]. The addition of 1% gypsum to the soil- lime and soil – fly ash mixtures accelerated the strength gain even at early period of curing [9]. The efficiency of Phosphogypsum as Hydraulic Binder in Calcium Sulpho Cement was studied and found that an insoluble material was formed when 70% PG was added to 30% CSA, thereby reducing the effect of contamination. Compressive Strength and Micro-Structural Analysis showcasing the formation of thin needle like ettringite, precipitating in the pores of the matrix valorizes Phosphogypsum as a Hydraulic Binder [10]. The effect of wood ashin stabilising expansive soil was studied and found a decrease in plasticity by 35%. There was considerable decrease and increase in MDD and OMC respectively. Strength increased by 49-67 % at 10 % WA. Though wood ash showed similar behaviour like lime, it cannot be substituted with lime since the strength gained is short lived [11].The effect of soft wood and hard wood ashes on soil stabilisation showed an increase in CBR upto 8% when mixed with 8% WA and confirmed that soft wood ashes yields better results than hard wood ash [12]. With a proper rate of application of WA, the soil stabilised with WA, reaches a bearing capacity similar to soil stabilised with burnt lime also results in reduction of CO_2 emission from calcination of $CaCO_3$. There can also be preservation of landfill capacities by recycling of wood ash. But the time taken for stabilisation with WA is quite high than that with burnt lime [13].

3. Materials and methods

3.1 Materials

Soil samples taken for the study are designated as sample A and sample B which was collected from Perungudi and Coimbatore respectively. Admixtures used were phosphogypsum and wood ash. Soil sample were collected from a depth of 0.6 m which was later dried and pulverized. Phosphogypsum is a by -product from the fertilizer industry and wood ash was taken from a paper industry at Jammu and Kashmir. The ash was obtained after incineration of wood at 800-1100 degrees. In this project, a combination of agricultural and industrial waste material has been used to stabilise the expansive soil.

3.2 Methods of Testing

Preliminary tests like Atterberg‟s limits, free swell index, specific gravity etc. were done on the soil samples. The free swell value of sample A ad sample B was found to be 101.8% and 108% respectively. % fines of sample A and B were 73.66% and 78% respectively. Thus according to IS 1498 the soil samples are classified as CH.

Proctor compaction was done on the soil samples. Strength determining tests like UCC and CBR were conducted on sample A and sample B at OMC and MDD. The values obtained at the end of the testing were very less and thus stabilisation needs to be done to improve the strength of the samples.

In this testing programme, the clay samples were mixed with four different percentages of WA (8,10, 12 and 14%) and with 4% PG by weight of dry soil and they were moulded at the optimum moisture content to achieve the targeted density. For all the soil-stabilizer combinations mentioned above, UCS and CBR tests were conducted to observe the changes in strength of clay samples.

Table 1: Index properties of soils

Soil Property	SAMPLE	
	A	B
Liquid limit (%)	68.78	66.64
Plasticity Index (%)	45.58	45.04
Free Swell (%)	101.8	108
Specific Gravity	2.625	2.65
MDD (g/cc)	1.489	1.44
OMC (%)	24	26

4. Test Results & Discussions

4.1 Unconfined compression test

UCC tests were conducted on virgin soil as well as treated soil samples and the results are discussed in table 2.

Table 2: UCC values of virgin soil and soil treated with 4% PG and varying percentages of WA.

WA %	UCC (kg/cm^2)					
	Sample A			Sample B		
	Curing period (days)			Curing period(days)		
	3	7	14	3	7	14
0%	0.91			0.98		
8%	4.8	5.9	5.9	5.4	7.4	9.6
10%	5.7	7.3	8.1	8.4	10.9	10.4
12%	5.5	7.8	8.6	9.9	13.7	16.2
14%	4.1	7.4	8.2	7.9	8.2	14.3

Variation of UCS with different admixture proportions for sample A and B is presented in Fig 1 and 2 respectively. From the results obtained it can be seen that, the unconfined compressive strength value of samples increased with increase in WA %.

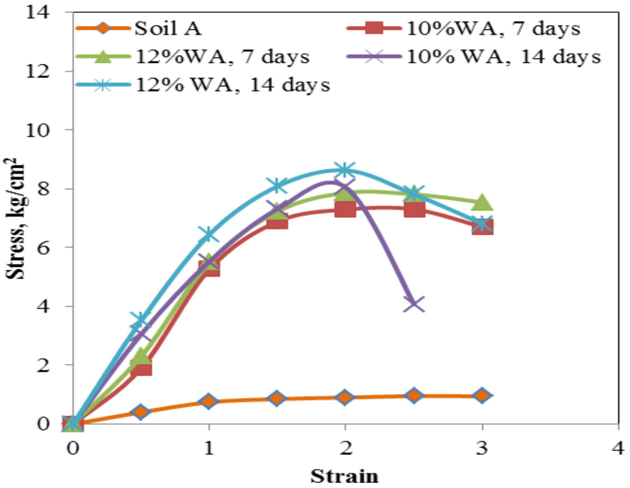

Figure 1: Stress – strain curve for sample A treated with different percentage of WA and 4% PG.

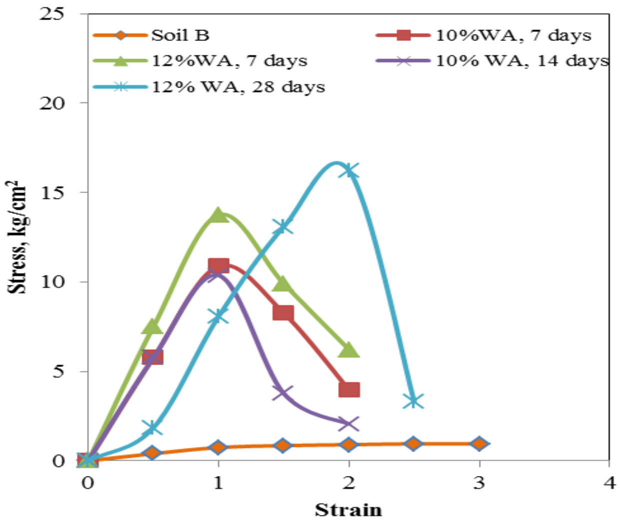

Figure 2: Stress – strain curve for sample B treated with different percentage of WA and 4% PG

The UCS value of virgin soil A and B was 0.91 kg/cm^2 and 0.98 kg/cm^{2}respectively. After 14 days of curing, at 12% WA and 4% PG, the strength increased to 8.6 kg/cm^2 and 16.2 kg/cm^2. The impact of curing period on the strength gain of the soil sample was also studied and is shown in fig 3. From the figure it can be seen that, for every increase in the curing period, the strength gained by the soil kept increasing. The rate of strength gain was high from 3 days to 14 days than from 7 days to 14 days. This is due to the availability of more time for reaction to take place.

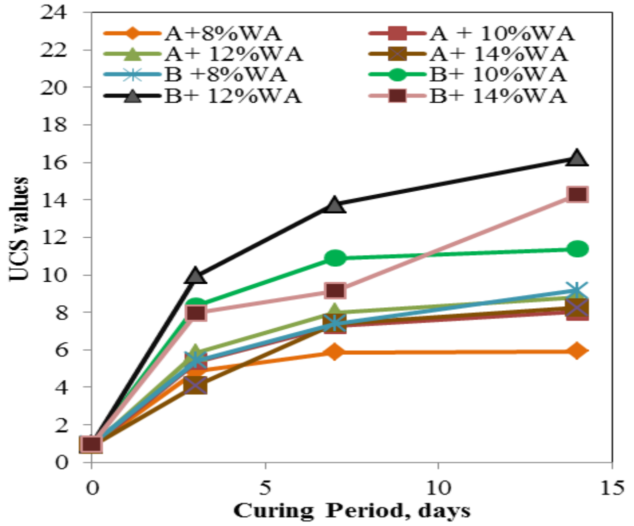

Figure 3: Effect of curing periods on the strength development of treated soil samples

4.2 California Bearing Ratio

Strength developed by the soil samples on addition of admixtures is also tested by conducting CBR test and the results are discussed below. The CBR of virgin soil A and B was 3.14 % and 2.11 % respectively. These values are very less and thus the soil needs to be stabilised to increase its strength. 4% PG along with varying percentage of WA is added to the soil and the results are shown in the table.

Table 3: CBR values of virgin soil and soil treated with 4% PG and varying percentages of WA.

CBR%						
WA %	Sample A			Sample B		
	Curing period(days)			Curing period(days)		
	3	7	14	3	7	14
SOIL	3.14			2.11		
8%	11.26	21.19	23.31	28.6	42.11	53.16
10%	12.71	24.69	26.48	31.78	45.56	55.09
12%	15.89	25.23	34.31	33.38	47.88	56.82
14%	10.59	22.58	33.18	27.78	37.61	51.12

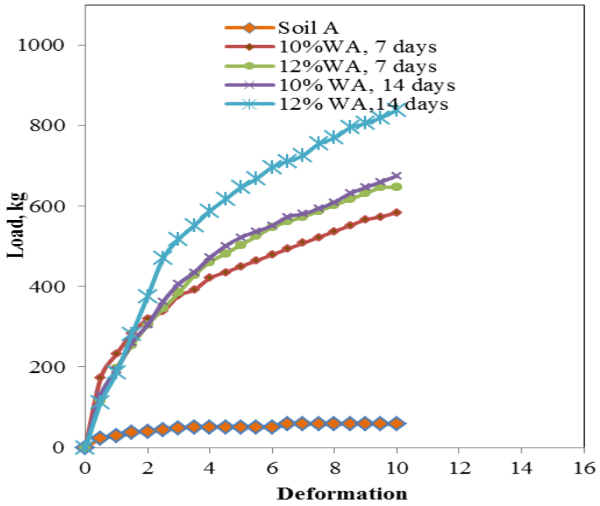

Figure 4: Load deformation curve for sample A treated with different percentage of WA and 4% PG.

CBR value of sample A and B increased from 3.14% and 2.11% to 34.31% and 56.12% respectively after 14 days of curing. Curing increased the CBR value considerably.

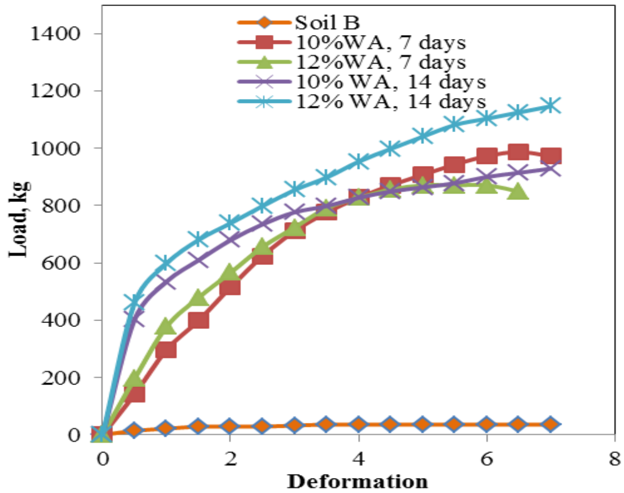

Figure 5: Load deformation curve for sample B treated with different percentage of WA and 4% PG.

5. Conclusions

The conclusion of this project work is as follows.

1) PG and WA, two waste materials are effective in increasing the strength of the weak expansive soil samples collected. The UCS value of sample A increased from 0.91 kg/cm^2 to 8.6 kg/cm^2 and for sample B, from 0.98 kg/cm^2 to 16.2 kg/cm^2 after 14 days of curing. The CBR value increased from 3.14% and 2.11% to 34.31% and 56.82% respectively for sample A and sample B.
2) The strength gained by the soil samples depends upon the percentage proportion of the admixtures added as well as time allowed for curing. 4% PG and 12% WA was found to be the maximum percentage proportion of admixtures which yielded maximum strength in the soil sample.
3) As the time allowed for curing increased the rate of strength gained also increased.
4) The strength development is due to the reaction between PG, WA and soil minerals, resulting in the formation of cementitious compounds.

5) Waste materials, which are posing disposal problems and threat to environment, were efficiently used as stabilizer to improve the properties of problematic expansive soil samples collected.

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