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Improving the Strength of Subgrade Soils using Locust Bean Waste Ash (LBWA)

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Abstract—*The result of a laboratory study on the improvement of the Strength of two Subgrade soils treatedwith Locust Bean Waste Ashis presented in this paper. Test results show that the unsoaked CBR values of subgrade soil classified as CI treated with 8 % LBWA content improved from 5.38 % for the untreated sample to 10.21 %, 11.94 % and 13.44% for the treated sample under 3, 7 and 21 days curing periods. Similarly, the unsoaked CBR values of the second subgrade soil classified as CH soil treated with 6 % LBWA content improved from 4.84 % for the untreated sample to 12.63 %, 12.96 % and 16.13 % for the treated sample under 3, 7 and 21 days curing periods. Soaked CBR values of CI treated with 8 % LBWA content improved from 2.04 % for the untreated sample to 9.14 %, 10.86 % and 12.10 % for the treated sample under 3, 7 and 21 days curing periods. Similarly, the soaked CBR values of the CH soil treated with 6 % LBWA content improved from 2.42 % for the untreated sample to 7.80 %, 10.21 % and 11.29 % for the treated sample during 3, 7 and 21 days curing periods.*

Keywords*: Ground improvement, Subgrade soils and CBR*

1. INTRODUCTION

The soils at construction sites are not always totally suitable for supporting physical infrastructure such as buildings, bridges, highways, tunnels and dams. Under these conditions, soil needs to be treated using ground improvement techniques. Similarly specific types of soil improvement techniques are required in the case of expansive soils and collapsible soil and in the case of earthquake prone areas [1].Objectives of ground improvement techniques include but not limited to increasing strength, reduce distortion under stress (increases stress-strain modulus), reduce compressibility (volume decreases due to a reduction in air voids or water content under loads). And this is being achieved by various means like use of additives, fibers, reinforcement among other means. This paper presented the result of a laboratory study on the improvement of the strength of two Subgrade soils treated with Locust Bean Waste Ash.

Improvement of the soils with ordinary Portlandcement hasbeen confirmed in its requirement for construction works [2 - 5] as revealed by [6] but the cost of improving soils with cement is very expensive. However, recent researchesby [6 - 12] and many more showedthat LocustBean Waste Ash (LBWA) being pozzolanic in nature is capable of reacting with free lime during hydration at ordinary temperatures to produce cementitious compounds (Calcium-Silicate-Hydrate “C-S-H” which provides the hydraulic binding property of the material). This study was aimed at ameliorating the social menace caused by the waste and to also improve the strength of subgrade soils for use as road construction.

2. MATERIALS

2.1 Soils

Two subgrade soilswere used in this study. The soil samples were air dried and then pulverized by mechanical means to obtainparticles passing sieve 4.75mm aperture as per [20]. The oxide compositions of the soilsbefore treatment were determinedusing the method of X – Ray Fluorescence spectroscopy and results are shown in Table 1.

2.2 Locust Bean Waste Ash

The LBWA used for this study was obtained locally from the burning of locust beanhusks. Thehusks were completely burnt under atmospheric condition, and then transported to thelaboratory. The oxide composition of the ashwas also determined by using the same X – Ray Fluorescence spectroscopyand results are shown in Table 1.

3. METHODOLOGY

Laboratory tests were conducted on the soil samples collected in accordance with the [13 - 19] for the characterization of the soils. The tests carried out for the characterization of the soils are free swell index (FSI) test, Atterberg limits tests, specific gravity test, grain size analysis, moisture density relationship, Unconfined Compressive Strength (UCS)tests and Un-soaked California Bearing Ratio (CBR) tests.

Table 1: Chemical composition of LBWA and Soil samples

Compounds	Concentric unit of the compounds (cps)		
	LBWA	CI Soil	CH Soil
Al – KA	109.364	337.27	341.907
Si – KA	741.711	3429.946	3228.253
Ca – KA	13620.50	3531.665	3957.285
Fe – KA	2610.11	22964.82	24652.85

Table 2: Properties of soil

Characteristics	Values	
	CI Soil	CH Soil
Specific gravity	2.69	2.68
Particle Size distribution a) Gravel (%) b) Sand (%) c) Silt + Clay (%)	 Nil 28 72	 0.18 31.04 68.64
Liquid limit (%) Plastic limit (%) Plasticity index (%)	43.6 19.6 24.3	53.2 18.13 35.07
Free Swell Index (%)	75	100
MDD (g/cm3) OMC (%)	1.74 17.5	1.67 18.0
UCS (kg/cm2)	1.5	2.1
Un-soaked CBR (%)	5.4	4.8

4. RESULTS AND DISCUSSIONS

The untreated soils were characterized based on the result of tests conducted in the laboratory. The results obtained are shown in Table 2. From these results, the two subgrade soils were classified as clay of intermediate compressibility and clay of high compressibility, as per [21] specification.

4.1 Grain Size Analysis

Grain size analysis was conducted to quantitatively find the distribution of the grain size of the soil sample. The soil samples obtained were prepared as specified in [20]. The test was conducted as per [15]. The test was conducted by taking about 300g of representative dry sample of then soaked in water for 24 hours. The soaked soil specimen was washed on the 75 µm sieve until the water passing the sieve was substantially clean. The fraction retained in the 75 µm sieve was oven dried and then put on the sieve set and agitated using mechanical shaker for 15 minutes. The amount retained in each sieve was weighed and recorded.

The grain size distribution of the fraction passing 75 µm Sieve was determined by performing hydrometer analysis on the portion of soil sample passing 75 µm sizes. The test was carried out as per [15] standard procedure. The hydrometer was calibrated and all corrections for meniscus error, dispersive agent error and temperature were applied as per [15]. The soil suspension was prepared using the dispersive agent and transferred to the 1000 ml measuring cylinder and shaken vigorously as per the standard procedure. The hydrometer was immersed to a depth slightly below its floating position and then allowed to float freely. Hydrometer readings were taken after periods of 0.5, 1, 2, and 4 minutes. The hydrometer was removed slowly, rinsed in distilled water and kept in a cylinder of distilled water at the same temperature as the soil suspension. The hydrometer was re-inserted in the suspension and readings taken after periods of 8, 15 and 30 minutes, 1, 2 and 4 hours after shaking. The hydrometer was removed, rinsed and placed in the distilled water after each reading. After 4 hours hydrometer readings was taken once or twice within 24 hours, the exact periods of sedimentation being noted. The diameter of the particle in suspension at any sampling time was calculated using equation (1), while the percentage finer than 'D' size particle with respect to hydrometer analysis and with respect total mass of soil sample taken for grain size analysis were calculated by using equation (2) and (3) respectively

$$D=\sqrt{\frac{30\mu}{980(G_S-G_W)}}\sqrt{\frac{H_R}{t}} \quad (1)$$

$$\%\text{ finer w.r.t. hydrometer} = R\times\frac{G_s}{(G_s-1)}\times 100 \quad (2)$$

$$\%\text{ finer w.r.t. total} = (\%\text{ finer w.r.t. hydrometer}) \times (\%\text{ finer than } 75\mu m) \quad (3)$$

Where,

D - Diameter of particle in suspension, in mm

µ - Coefficient of viscosity of water at the temperature of the suspension at the time of taking the hydrometer reading, in poises

G_S - Specific gravity of the soil fraction used in the sedimentation analysis

G_W - Specific gravity of water

H_R - Effective depth (corrected for meniscus error)

R - Effective depth corrected for meniscus, temperature and dispersive agent errors

T - Time elapsed between the beginning of sedimentation and taking of hydrometer reading in minutes.

The results obtained in both sieve analyses and hydrometer analyses are combined together and presented in table 3 below.

In the Table 3, the result of the sieve analyses is from the grain size between 4.75 mm to 0.075 mm, while that of hydrometer analyses covered from the 0.075 mm up to the end. The grain sizes distribution curves for the two soil sample are plotted and presented in figures 1 and 2 for the CI and CH soil samples.

From the grain size distribution curves of the two samples, it can be seen that both samples contained more than 50 % of fine grains sizes.

Table 3: Grain size analysis results for CI and CH soils

CI Soil sample		CH Soil sample	
Grain sizes, D (mm)	**Percentage finer (%)**	**Grain sizes, D (mm)**	**Percentage finer (%)**
4.7500	**100.0**	**4.7500**	**99.8**
2.3600	100.0	2.3600	98.8
1.1800	99.3	1.1800	95.9
0.6000	97.8	0.6000	93.5
0.3000	91.8	0.3000	85.9

0.1500	76.8	0.1500	74.0
0.0750	**65.0**	**0.0750**	**68.6**
0.0610	61.4	0.0603	60.6
0.0440	58.9	0.0431	59.4
0.0317	56.4	0.0308	58.2
0.0228	53.9	0.0222	55.8
0.0164	51.4	0.0158	54.6
0.0120	50.9	0.0118	52.2
0.0085	50.6	0.0085	49.0
0.0060	50.1	0.0061	47.3
0.0043	49.6	0.0044	42.4
0.0030	48.6	0.0031	41.2
0.0020	**47.31**	**0.0020**	**36.96**
0.0013	46.4	0.0013	34.0

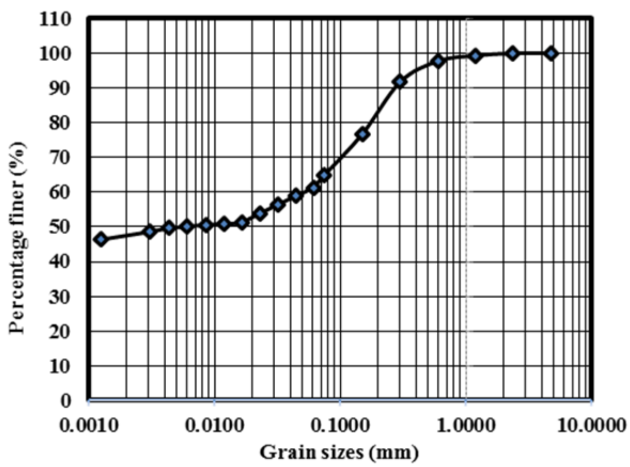

Fig. 1: Grain size distribution curve of CI soil

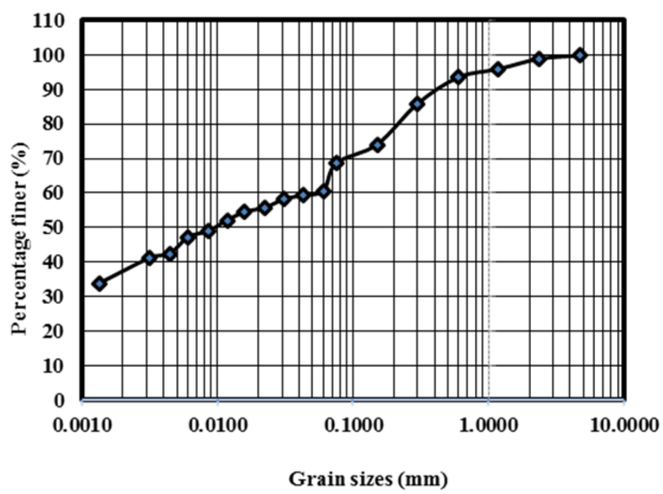

Fig. 2: Grain size distribution curve of CH soil

4.2 California Bearing Ratio (CBR) Tests

The California Bearing Ratio (CBR) tests of the two soils samples untreated and treated with optimum percentages of LBWA were performed in accordance with [18] standard procedure. The samples were prepared at optimum moisture content obtained from the standard proctor test, while the optimum content of LBWA was obtained from the UCS test [7]. The untreated and unsoaked soil samples were tested immediately after moulding whereas the treated and unsoaked soil samples were curing for 0, 3, 7 or 21 days (as the case may be) before testing. The untreated but soaked specimens were soaked for 96 hours after sample preparation before testing while the treated and soaked specimens were cured for 0, 3, 7 or 21 days (as the case may be) and then soaked for 96 hours and finally tested as per the standard procedure. After the required days of curing and / or soaking period, the samples were tested based on literature review. The result obtained for the CBR tests are shown in Table 4, Fig. 3.

Fig. 3 shows the graphs of CBR test result for CI soil sample at varying curing period, LBWA content and soaking conditions.

Table 4: Result of CBR test of soil sample 1 and 2

Soil	LBWA (%)	Curing period (days)			
		0	3	7	21
Unsoaked CISoil	0	5.38 %	N/A	N/A	N/A
	Optimum	8.60 %	10.21 %	11.94 %	13.44 %
Soaked CISoil	0	2.04 %	N/A	N/A	N/A
	Optimum	5.38 %	9.14 %	10.86 %	12.10 %
Unsoaked CHSoil	0	4.84 %	N/A	N/A	N/A
	Optimum	9.41 %	12.63 %	12.96 %	16.13 %
Unsoaked CHSoil	0	2.42 %	N/A	N/A	N/A
	Optimum	6.82%	7.80%	10.21%	11.29 %

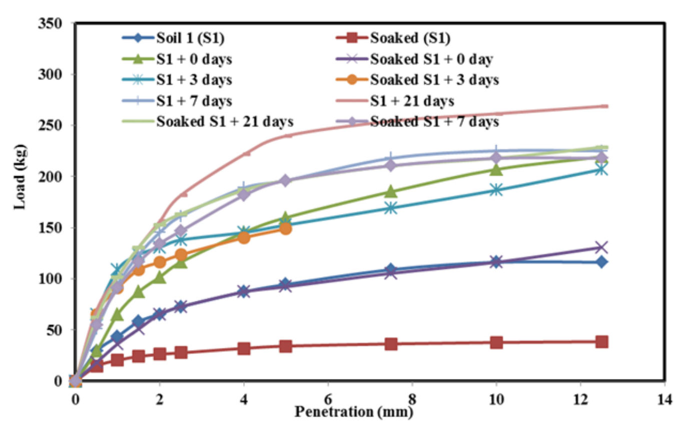

Fig. 3: Load penetration curves of CI soil

4.3 Effect of Soaking in the CBR Value of the Soils

The two untreated soils were tested under both unsoaked and soaked conditions. The results showed that both soils sample loses more than half of their strength due to soaking. Untreated CI soil CBR decreased from 5.38 % to 2.04 % while that of CH soil decreased from 4.84 % to 2.42 % due to soaking of the specimens.

Similarly, the treated soils samples experienced some decrease in their CBR values due to the effect of soaking. At 3 days curing periods, the CBR of treated CI and CH soil samples reduced from 10.21 % to 9.14 % and 12.63 % to 7.8 % respectively. Similar decrease in the CBR happen in other days of curing as it is shown with the aid of using bar charts in figure4for the CH soil (S2).

From the figure4 it can be seen that at every curing time, the CBR value of the treated soil sample under soaked and unsoaked conditions decreases.

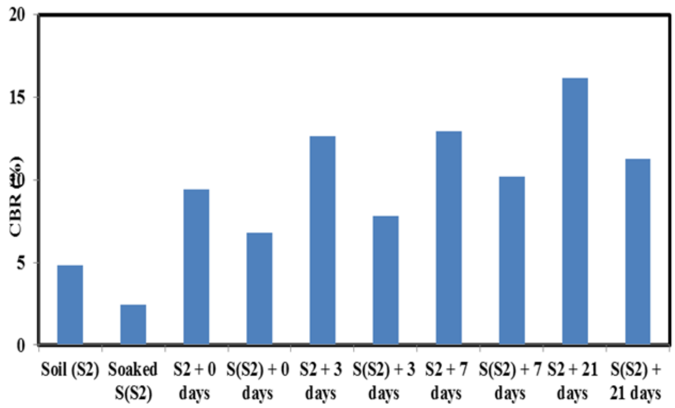

Fig. 4: Distribution of CBR results of CH soil, S2

4.4 Effect of Curing Time on the CBR of Treated Soil Samples

The effect of curing time on the two soil samples treated with the optimum content of LBWA was studied at 0, 3, 7 and 21 days. The result obtained showed that the CBR value increase with an increase in curing time. The percentage increase in CBR value was calculated for each curing period due to the treatment with LBWA by comparing the unsoaked CBR value of the untreated soil with the CBR value of the treated soil at a given curing period. The calculated percentage increase in CBR is presented in table 5. From these results, it can be seen that a maximum increase in unsoaked CBR of 150 % and 233 % were attained by the CI and CH soilssamples at 21 days curing periods and at 8 % and 6 % LBWA content respectively.

The maximum increase of soaked CBR of 125 % and 133 % were attained by the CI and CH soils samples at 21 days curing periods and at 8 % and 6 % LBWA content respectively. The minimum increase in unsoaked CBR of 60 % and 90 % were attained by the CI and CH soils samples at 0 day curing periods and at 8 % and 6 % LBWA content respectively. Similarly, the minimum increase in soaked CBR of 0 % and 40 % were attained by the CI and CH soils samples at 0 day curing periods and at 8 % and 6 % LBWA content respectively

Table 5: Percentage increase in CBR values of soils sample 1 and 2 treated with optimumcontent of LBWA at varying curing period

Soil type	Curing period (days)			
	0	3	7	21
Unsoaked CI soil	60 %	90 %	122 %	150 %
Soaked CI soil	0 %	70 %	102 %	125 %
Unsoaked CH soil	95 %	161 %	168 %	233 %
Soaked CH soil	41 %	61 %	111 %	133 %

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6. CONCLUSIONS

The unsoaked CBR values of CI soil treated with 8 % LBWA content improved from 5.38 % for the untreated sample to 10.21 %, 11.94 % and 13.44% for the treated sample under 3, 7 and 21 days of curing period. Similarly, the unsoaked CBR values of the CH soil treated with 6 % LBWA content improved from 4.84 % for the untreated sample to 12.63 %, 12.96 % and 16.13 % for the treated sample under 3, 7 and 21 days of curing period.

The Soaked CBR values of CI treated with 8 % LBWA content improved from 2.04 % for the untreated sample to 9.14 %, 10.86 % and 12.10 % for the treated sample under 3, 7 and 21 days of curing period. Similarly, the soaked CBR values of the CH soil treated with 6 % LBWA content improved from 2.42 % for the untreated sample to 7.80 %, 10.21 % and 11.29 % for the treated sample during 3, 7 and 21 days of curing period.

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