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Assessment of the Geotechnical Properties of Lateritic Soil Stabilized with Glass Powder as Partial Replacement of Cement. A Case Study of Ado-Ikere Road, Southwestern Nigeria

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***Abstract* - The assessment of the properties of soil stabilized with glass powder as partial replacement of cement was investigated. Samples of lateritic soil were collected at varying depth from 0.5m into1.0m at a borrow pit along Ado Ikere road). The samples were air dried. Varying proportions of cement and glass power were used to prepare the mixture and these were expressed as percentage of the dry weight of soil sample. The results of these experiments showed that adding these additives resulted in a considerable reduction in the proportion of fine passing the various sieves in the grain size distribution study. These addictive substances were found in soil samples that were graded and classified properly. Furthermore, when these additives were used on soil samples, the results showed that the specific gravities were larger than in natural soil. The use of these chemicals resulted in lower C.B.R values in the samples than in the natural sample, according to the tests. Maximum dry density (MDD) decreased as the optimum moisture content was reduced, as evidenced by the compaction characteristic (OMC). The recommended value for cement soil stabilization with soil classification sand/gravel is B at 6%. Analysis of the additive showed Ca, Mg, Na and K. values which can be used as partial replacement materials in cement. The use of glass powder as a partial replacement for cement in soil stabilization was found to be ineffective in all geotechnical tests.**

Keywords: Additive Content, Glass Powder, Maximum Dry Density (MDD, Partial Replacement, Optimum Moisture Content (OMC).

I. INTRODUCTION

Soil stabilization is a technology that aims at improving soil strength and increasing resistance to softening by water through bonding the soil particles together, waterproofing the particles, or a combination of the two [2]; [5]; [7]. Soils in regions with soft clay subgrades and high water tables, such as Ado and Ikere in Ekiti state, have a tendency to shrink and swell, causing problems during and after the construction of pavement layers. The replacement of such soil with better quality borrow fill is not a good option for pavements due to the associated cost of excavation and hauling of the materials [3].

It is a usual practice to treat soils with some chemical stabilizers or calcium-rich stabilizers to enhance the soil strength for pavement [3]; [6].In this study, an effort will be made to assess the impact of glass powder on the geotechnical properties of lateritic soil for road construction. The quantum of waste generated from agriculture, industrial, commercial, as well as construction industries, has increased over the years as a result of the growth in the population, which places demands on goods and services [7]; [8]. The beauty of research in engineering practices is that it investigates the possibilities of converting wastes into useful materials for construction purposes.

1.1 Study Area

The research was carried out along Ado-Ikere Road in Ekiti State at 7.52o North latitude, 5.33o East Longitude, and industrial layout.It is located between latitudes 09035,22, N and 09030,36, N of the Equator and between longitudes 04048,11, E to 05030,13, E of the Greenwich Meridian.The study area has an undulating topography drained by the river Shagari, with an annual rainfall of about 1100 mm in the northern part and 1600 mm in the southern part. The rainy season spans between April and October and has an optimum temperature of 31 °C in the dry season and a minimum of 22 °C during the rainy season.

Figure 1: Map of Ekiti State Showing Ado – Ekiti(copied from Google)

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II. MATERIALS AND METHODS

2.1 Sample Collection and Analysis

Samples of lateritic soil were collected at varying depths from 0.5m to 1.0m at a borrow pit 1.4km away from Olujoda Hotel and the main road in Ado-Ikere road after the topsoil had been removed. The disturbed samples were bagged in sealed polythene bags to prevent moisture loss and labeled for onward transfer to the geotechnical laboratory at the Federal Polytechnic, Ado Ekiti. Organic debris material such as roots and leaves were removed. The samples were air-dried in an open space for 2 weeks.

Glass powder: The glass bottles used for this study were obtained from Coca-Cola's bottling depot, Ajilosun Ado Ekiti, Ekiti State. They were washed with distilled water, sun-dried, broken into smaller sizes with the use of a pestle, and passed through a certain sieve number. Variable proportions of cement and glass powder were used to prepare the mixture, and these were expressed as a percentage of the dry weight of un-soaked soil samples as shown in Table 1.0. The total additive content used was 2%, 4%, 6%, 8%, and 10% for each test carried out on the soil sample. The samples were subjected to some geotechnical parameters such as specific gravity, natural moisture content, grain size distribution, and atterberg limit, compaction, and California The bearing ratios and chemical compositions of the additives were determined.

III. RESULTS AND DISCUSSIONS

Summary of Material Proportions for Sample Preparation on the soil samples is shown in table 1.

Table 1: Material Proportions for Sample Preparation

Experimental No(label)	Soil sample	Cement (%)	Glass powder(%)
A	98.0 96.0 94.0 92.0 90.0	2.0 4.0 6.0 8.0 10.0	_ _ _ _ _
B	98.0 96.0 94.0 92.0 90.0	1.5 3.0 4.5 6.0 7.5	0.5 1.0 1.5 2.0 2.5
C	98.0 96.0 94.0 92.0 90.0	_ _ _ _ _	2.0 4.0 6.0 8.0 10.0
D	100	_	_

=Soil sample+ cement; B=Soil sample+ cement+ glass powder; C=Soil sample + glass, D=Soil only

3.1 Natural Moisture Content

Table 2 shows the natural moisture content conducted on three samples to determine the amount of moisture content present in the soil as a percentage of its dry mass. The moisture content was calculated as a percentage of the dry soil mass by using equation;

$$M_C = \frac{M_{2-M_3}}{M_{3-M_1}} \times 100$$

Table 2: Natural Moisture Content for the Three Samples

	SAMPLE A		SAMPLE B		SAMPLE C	
	A	B	A	B	A	B
A	23.0	19.5	19.2	9.2	11.1	10.2
B	72.7	67.0	66.8	37.3	64.6	45.1
C	68.5	63.2	62.6	34.0	61.6	42.0
M/C	9.2	8.7	14.6	13.3	5.9	9.7
A M/C	8.95		14.6		7.8	

M/C = moisture content, AM/C = Average moisture content

From the table 2, values of the material moisture contents of the soil samples varied from 7.8% - 14.6%. Which are, however, within the recommended value of 5% - 15% [1]:[4]This is an indication that the soil samples have average water absorption capability.

3.2 Specific Gravity

The specific gravity of samples A, B, and C is shown in Table 3 and can be defined as the weight in air of a given volume of a soil particle to the weight in air of an equal volume of distilled water.

Table 3: Summary of the Specific Gravities of Sample A, B, and C

		SAMPLE A		SAMPLE B		SAMPLE	
		A	B	A	B	A	
A.	Wt of density bottle	17.0	16.3	17.9	18.3	17.5	
B.	Wt of bottle + soil	29.2	27.8	28.4	31.0	31.1	
C.	Wt of bottle + soil + water	49.4	47.9	50.8	48.7	50.9	
D.	Wt of bottle + water	42.0	40.9	42.3	43.1	42.0	
M/C	Gs = w2–w1 / (w4-w1) – (w3 – w2)	5.10		7.06		5.94	
A M/C	Average Value	2.55		3.53		2.97	

Values of specific gravity varied between 2.55 and 2.97. It shows that these soils contain a large number of clay materials having fallen between 1.6 and 2.9. Lateritic soils of this nature may have reduced strength and stability under wheel load[1]:[4].

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Table 4: Summary of Atterberg Limit Result

SAMPLE	GLASS POWDER			
	RATIO	LL	PL	PI
A	0%	13	0	13
	2%	14.8	0	14.8
	4%	17.4	0	17.4
	6%	14.4	0	14.4
	8%	15.9	0	15.9
	10%	14.8	0	14.8
B	0%	27.9	12.7	15.2
	2%	25.2	15.4	9.8
	4%	17.9	13.6	4.3
	6%	17.2	14.8	2.4
	8%	34	18	16
	10%	34.85	11	23.9
C	0%	22.9	11.8	11.1
	2%	23.4	12.8	10.6
	4%	22	13.6	8.4
	6%	20.4	17.3	3.1
	8%	22.4	12.9	9.5
	10%	20.8	9.5	11.3

The moisture content value obtained under the atterberg limit test (comprising of the liquid limit, plastic limit, plasticity index) is as shown in Table 4. In sample A there is an increase in liquid limit at 2%, 4% 8% and decreases at 6% and 10% this shows that the additive affects the atterberg limit result.

Table 5: Summary of Compaction

SAMPLE	GLASS POWDER		
	RATIO	MDD	OMC (%)
A	0%	2,294	16.9
	2%	2,124	8.3
	4%	2,144	7.4
	6%	2,110	7.0
	8%	2,155	6.8
	10%	2,018	9.1
B	0%	2,062	9.1
	2%	1,271	8.3
	4%	1,266	8.8
	6%	1,209	9.5
	8%	1,228	12.1
	10%	1,200	10.4
C	0%	2,244	13.8
	2%	2,039	12
	4%	2,149	15.6
	6%	2,018	15.8
	8%	2,028	13.2
	10%	2,018	15.8

Table 5 shows the corresponding value of MDD and OMC of the samples in ratio 0%, 2%, 4%, 6%, 8%, 10%. The result of the MDD, shows that there is no improvement in MDD. This shows that glass powder as an additive affected the dry density of the soil negatively such that, there is the maximum dry density at 0%.

3.3 Califonia Bearing Ratio (CBR) Result

Table 6, 7, and 8 show the corresponding value for the control and treated samples at 2.5mm and 5.0mm penetration. The table shows an improvement in CBR value at 4% in sample A, 6% in sample B, and 10% in sample C this is an indication that the additive affected the soil samples differently.

$$\text{CBR at 2.5} = \frac{\text{force}}{\text{Standard value (13.24)}} \times 100$$

$$\text{CBR at 5.0} = \frac{\text{force}}{\text{Standard value (19.96)}} \times 100$$

Table 6: Summary of CBR (Sample A)

PENETRATION	0%	2%	4%	6%	8%	10%
0.5	**0.20**	**0.40**	**1.15**	**1.08**	**0.21**	1.00
1.0	**0.33**	**0.80**	**1.80**	**1.55**	**0.64**	1.20
1.5	**0.48**	**1.15**	**2.35**	**2.00**	**0.90**	1.44
2.0	**0.60**	**1.50**	**2.75**	**2.43**	**1.08**	1.87
2.5	**0.73**	**1.88**	**3.15**	**2.93**	**1.41**	2.13
3.0	**0.85**	**2.23**	**3.50**	**3.13**	**1.79**	2.64
3.5	**0.98**	**2.63**	**3.88**	**3.58**	**2.14**	3.01
4.0	**1.10**	**3.05**	**4.18**	**3.90**	**2.64**	3.48
4.5	**1.20**	**3.05**	**4.48**	**4.98**	**2.87**	3.96
5.0	**1.33**	**3.93**	**4.75**	**4.63**	**3.11**	4.12
5.5	**1.45**	**4.33**	**5.05**	**4.95**	**3.61**	4.62
6.0	**1.50**	**4.75**	**5.33**	**5.28**	**3.92**	4.91
6.5	**1.68**	**5.13**	**5.60**	**5.60**	**4.13**	5.25
7.0	**1.55**	**5.58**	**5.80**	**5.86**	**4.34**	5.54
7.5	**1.90**	**6.00**	**6.05**	**6.15**	**4.78**	5.73
CBR Value @ 2.5	**5.51**	**14.2**	**23.79**	**22.13**	**10.65**	16.1
CBR Value @ 5.0	6.6	19.69	23.79	23.19	15.58	20.64

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Table 7: Summary of CBR (SAMPLE B)

PENETRATION	0%	2%	4%	6%	8%	10%
0.5	0.08	0.04	0.35	0.50	0.20	0.48
1.0	0.19	0.09	0.68	0.77	0.25	0.85
1.5	0.35	0.42	1.15	1.25	0.38	1.18
2.0	0.55	0.76	1.60	1.89	0.46	1.53
2.5	0.84	0.96	2.0	2.11	0.60	1.85
3.0	0.12	1.12	2.4	2.53	0.73	2.23
3.5	1.24	1.38	2.75	2.94	0.83	2.55
4.0	1.58	1.54	3.13	3.41	0.95	2.88
4.5	1.92	1.84	3.40	3.72	1.08	3.23
5.0	2.09	2.02	3.73	4.01	1.18	3.60
5.5	2.20	2.23	3.98	4.35	1.26	3.90
6.0	2.45	2.51	4.25	4.47	1.40	4.25
6.5	2.64	2.72	4.48	4.52	1.50	4.55
7.0	2.96	2.84	4.68	4.58	1.63	4.85
7.5	3.01	2.93	4.73	4.88	1.75	5.15
CBR Value @ 2.5 (%)	6.34	7.25	15.11	15.94	4.53	13.97
CBR Value @ 5.0 (%)	10.47	10.12	15.69	20.09	5.92	18.04

Table 8: Summary of CBR (SAMPLE C)

PENETRATION	0%	2%	4%	6%	8%	10%
0.5	0.02	0.65	0.04	0.01	0.65	1.33
1.0	0.09	0.18	0.22	0.28	0.97	2.13
1.5	0.13	0.23	0.54	0.43	1.21	2.93
2.0	0.32	0.60	0.72	0.58	1.46	3.70
2.5	0.67	1.05	0.92	0.75	1.72	4.40
3.0	0.99	1.45	1.06	0.93	1.98	4.55
3.5	1.10	2.00	1.13	1.08	2.09	4.65
4.0	1.38	2.50	1.22	1.25	2.33	4.75
4.5	1.67	3.05	1.31	1.45	2.43	4.93
5.0	1.91	3.58	1.47	1.58	2.59	5.05
5.5	2.04	4.13	1.81	1.78	2.88	5.10
6.0	2.11	4.63	1.84	1.95	3.01	5.13
6.5	2.33	5.13	1.97	2.15	3.08	5.13
7.0	2.47	5.60	2.12	2.33	3.23	5.16
7.5	2.61	5.90	2.22	2.53	3.32	5.23
CBR Value @ 2.5	5.06	7.93	6.95	5.66	12.99	33.23
CBR Value @ 5.0	9.57	17.94	7.36	7.92	12.98	25.30

IV. CONCLUSION

This study has shown that there is no improvement in the properties of the soil. The higher the percentage quantity of glass powders the higher the reduction of the soil strength. Furthermore, it can be concluded based on the result obtained from the sieve analysis that the soil is sand/ granular, which may be the reason for the ineffectiveness of the glass powder.

Recommendation

It is recommended that further research should be carried out to determine the optimum amount of this additive for effective clay soil stabilization, which seems to have a value between 4% and 8% of powdered glass content. The effect of the powdered glass on other kinds of soils such as laterite should also be investigated to determine whether similar results will be obtained which will help to establish it as an all-round or general soil stabilizer.

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