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Cement Stabilized Crushed Iron stone in Pavement Construction

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Abstract
The strength of cement improved crushed ironstone for use as a base course in highway construction was investigated in this study. To determine the strength of the un-stabilized and stabilized samples, cement ratios of 5%, 10%, 15%, and 20% by weight of dry sample were used in conducting the tests. Sieve analysis, compaction, and CBR tests were done. The stone sample was classified as uniformly graded stones (Cu > 2) following AASTHO. A maximum dry density value of 23.45kN/m3, was observed at 5% optimum content. From the CBR experimental results, 7, 14, and 28days recorded 78.2%, 78.4%, and 78.42% respectively for the unstabilized sample. After stabilization, CBR values increased significantly with 182% at 7days, 216% at 14 days, and 250% at 28days. Regression and ANOVA studies were conducted on both control and stabilized crushed iron stones at different cement ratios and curing periods. Regression models considered CBR as a dependent variable and cement content as the independent variable. The R2 values from regression analysis were 0.9805 for 7 days, 0.982 for 14 days , and 0.992 for 28 days. The ANOVA results indicated that the effectiveness of cement for the stabilization of crushed iron stones is statistically significant.

Keywords: *Analysis of Variance, California Bearing Ratio, cement, compaction, crushed iron stones, regression analysis*

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I. Introduction

Aggregates form the major part of the pavement structures and are the prime materials used in pavement construction. Aggregates used in pavement construction have to primarily bear load stresses occurring on the roads and runways and have to resist wear due to abrasive action of traffic [4].ironstone is abundantly available in eastern Nigeria especially Anambra and Enugu states. Iron stone is a sedimentary rock, either deposited directly as aferruginous sediment or created by chemical replacement, that contain substantial proportion of the iron compound from which iron can be obtained commercially. It is crushed and used as aggregates for construction in the rural areas of south -eastern Nigeria[6,8].

Stabilization of aggregate is an effective method to improve aggregate properties and enhance the pavement performance. Cement stabilization has become a popular option to enhance pavement performance. Loads are distributed over a larger area, and stresses in the sub-grade are reduced [5]. Weak soils, weak stones, shale quarry dust, lateritic soils etc., that are poor and termed unsuitable for construction purposeshave more recently been subjected to improvement techniques such as stabilizationin other enhance engineering properties[11]. A cement bound crushed rocks has an advantage of durability and the ability to hold shape against traffic and adverse environmental conditions.

Cement can be used as an effective stabilizer for a wide range of materials.Cement stabilization involves the addition of small amount of cement to modify the soil or coarse aggregate properties[9]. Cement treated base gives additional strength and support without increasing the total thickness of the pavement layers. Based on project needs, cement stabilized base increases the construction speed, enhances the structural capacity, or in some cases reduce the overall time project. In addition, a stiffer base reduces deflections due to heavy traffic loads, thereby extending pavement life. Base thickness of cement stabilized crushed stone is reduced because of high bearing strength compared to un-stabilized base thickness [10].

[3] investigated the suitability of iron ore waste as partial replacement of coarse aggregates in concrete. The physio-chemical properties and aggregate tests such as crushing, abrasion, impact, shape test, the specific gravity and water absorption were evaluatedaccording to standards and the findings revealed to be within the limits indicating their applicability as a pavement material. Partial replacement by 20%, 40%, 60%, 80% and 100% with waste rock was tested for its mechanical properties and it was found that, 40% replacement of waste rock yielded highest compressive strength compared to the control mix.[6] conducted studies on the replacement of ironstone with crushed granite and river gravel up to 50%. Optimum results were obtained at 50% replacement ofironstone with crushed granite or river gravel resulting in compressive strength of 22 N/mm^2 anda flexural strength of 7.81N/mm^2 at 28days. Hence, recommended the use of ironstone in concrete production at 50% replacement of ironstone amist conventional aggregates.

This research is focused on investigating on the possibility of improving locally available weak stones with cement for their possible use as road base in place of granite for highway construction.Further, in this study, an increasing proportion of cement is added to the crushed iron stone and the effect of the stabilization on properties such as, optimum moisture content, maximum dry density, california bearing ratio and strength before and after exposure to water is observed.

II. Research Materials and Methodology

2.1 Materials and methods

In this investigation, the crushed iron stones used were obtained from Achi in Oji River, Enugu State. Portland cement available in Nigeria (the BUA cement, Brand name) in 50kg bag was used for the experiment. Clean portable water from IDC company limited laboratory was used in the preparation and soaking of the samples.

2.2 Testing methods

Dry sieve analysis was done on the soil and crushed iron stone samples. Soil classification was done using the result obtained from electrical sieve analysis test. The knowledge of the grain size analysis is necessary for the determination of the relative proportion of the various grain sizes that makes up the crushed sample. Compaction test was done on the sample to determine the optimum moisture content and maximum dry density. Method employed is the Modified American Association of State Highway officials (Modified AASHO compactive effort). 6kg of a dry crushed stone passing through sieve size 37.5 (19mm) was weighed and used for this test. The sample was compacted in five (5) equal layers receiving fifty-five (55) blows at a fall height of 450mm for a rammer weighing 4.5kg.

California bearing ratio (CBR) test was done using an optimum moisture content of 5% obtained from compaction results. Four moulds of unstabilized samples were compacted. Three of which were used in establishing the average CBR value of the un-stabilized samples while the last mould was soaked and utilized in determining the variation in strength after 24 hours. The samples were stabilized at different cement percentages of 5%, 10%, 15% and 20%. Each cement ratio was mixed with water according to determined water-cement ratio of 6%, 8%, 10% and 12% respectively. The stabilized samples were compacted and three of them was utilized in evaluating the average CBR value of unsoaked sample after 7days, 14days and 28days. The last mould was then soaked and used to determine the variation in strength after 7 days.

III. Experimental Results

3.1 Particle size distribution

The sieve analysis for the samples were done and presented in Figure 1. The values, D_{60}, D_{30} and D_{10} were observed to be 10.1mm, 8.1mm and 6.4 respectively. Coefficient of curvature (C_u) and uniformity coefficient (C_c) were calculated as 1.02 and 1.58. Based on AASTHO, the sample was classified as uniformly graded stones ($C_u > 2$).

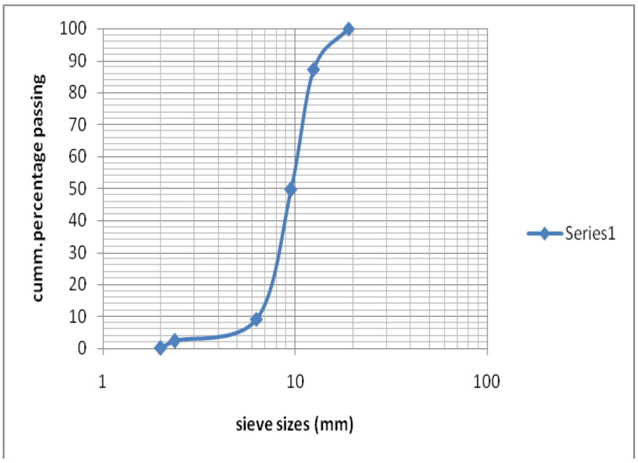

Figure 1: Sieve Analysis of Crushed Iron Stones

3.2 Compaction Properties

Graph of dry density against moisture content as seen in figure 2, was plotted to obtain the maximum dry density (MDD) and the optimum moisture content (OMC) of the crushed stone sample. The maximum dry density of the sample was observed at 23.45kN/m^3 which occurred at an optimum moisture content of 5%. After the point of maximum dry density at optimum moisture content, further increase in water content made it impossible to drive out air and resulted in more void spaces hence, reducing the dry density.

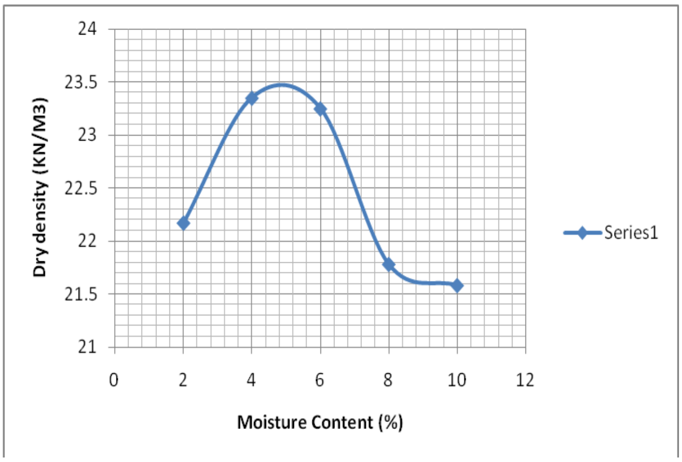

Figure 2: Compaction graph

3.3 California Bearing Test results

Table 1 shows that the CBR result for the unstabilized sample at 7, 14 and 28 days were 78.2%. 78.4% and 78. 42% respectively. The construction of highway pavement has a requirement which demands a minimum of California bearing ratio of 80%, 30% and 10% for stone base, sub-base and sub-grade materials respectively as confirmed also by[7].

Based on this, the CBR values thus obtained for the un-stabilized sample at the three different curing days did not meet the minimum requirement for base course material, Hence, the need for improvement by cement stabilization in order to increase the bearing capacity of the crushed stones and obtain a sample that is best suitable for base course in road pavement construction.

Table 1: CBR results for unstabilized and stabilized crushed stone samples

Cement added (%)	**CBR Values (%)**		
	7 days	**14 days**	**28 days**
0	78.2	78.4	78.42
5	110	122	142
10	142	162	186
15	165	195	220
20	182	216	250

At 5% cement replacement, results showed that stabilized crushed iron stone satisfied the Federal Ministry of Works [2]requirement for base-course materials. The strength increased proportionally with the cement mix ratios. The non-stabilized sample increased slightly by 0.2% with CBR value of 78.2% at 7days and 78.4% at 14 days. Furthermore, at 28 days a difference of 0.002% was observed between CBR at 14 days and 28 days. This can be due to the reduction in moisture content of the sample which conforms to the laboratory investigations by [1] that crushed rock loses its resilient modulus for about 20% to 25% for 1% rise in moisture content.

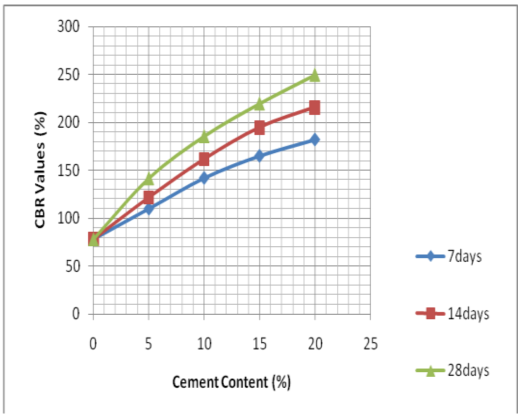

Figure 3: Graphical Plot of CBR values against Cement content

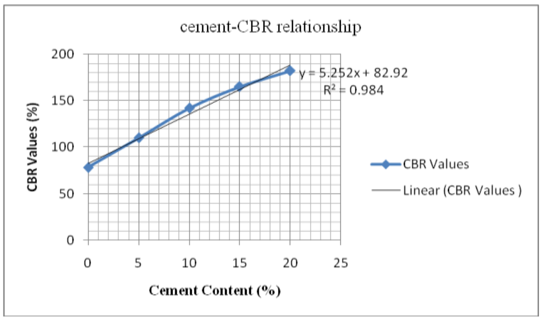

Figure 4a: Correlation between CBR values and cement ratios after 7 days

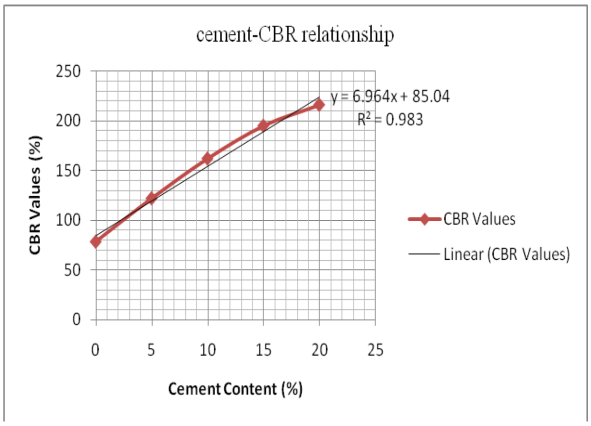

Figure 4b: Correlation between CBR values and cement ratios after 14 days

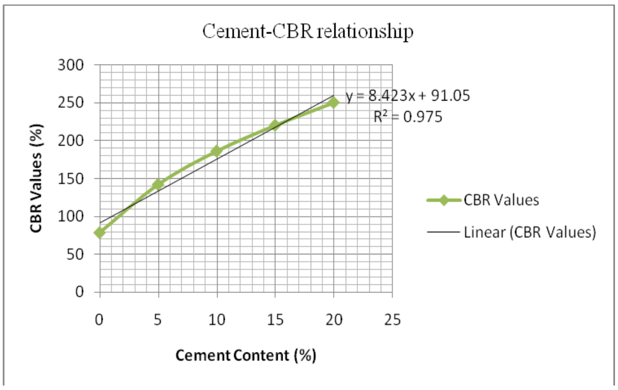

Figure 4c: Correlation between CBR values and cement ratios after 28 days

3.4 Statistical Analysis of the California bearing Ratio Measured Values obtained after Seven days

Results from the regression analysis on the CBR tests obtained using excel are presented in Table 2. For 7, 14 and 28 days, their R^2 values were 0.981, 0.982 and 0.992 respectively. Thus, the measured values are feasible.

Also, the ANOVA results revealed p-value for 7, 14 and 28 days- 0.0052. 0.0075 and 0.0031were less than 0.05, thus, there is a very close relationship between the measured values and the predicted values for all three cases.

Table 2: Regression Output for 7days, 14days and 28 days

	7 days	14days	28 days
Multiple R	0.9902	0.9909	0.99606
R Square	0.9805	0.98189	0.9921
Adjusted R Square	0.9080	0.9728	0.9882
Standard Error	5.32447	6.76387	5.0398
Observations	4	4	4

Table 3: ANOVA Results

Duration	Stand. Error	Sig.	P- Value	95% Confidence Level	
				Lower Bound	**Upper Bound**
7 days	6.52112	0.00978	0.005209	61.941887	118.058112
14 days	8.28402	0.00909	0.007518	59.356735	130.643264
28 days	6.17252	0.00394	0.003134	83.441791	136.558209

The predicted linear equations for 7, 14 and 28 days are:

$$Y = 5.252X + 82.9 \quad (1)$$

$$Y = 6.954X + 85.04 \quad (2)$$

$$Y = 8.423X + 91.05 \quad (3)$$

Analysis observed from these predicted linear equations show that the measured and predicted values are very close.

3.5 Cost Analysis Results

Cost analysis was done in order to determine which among stabilized crushed iron stones and crushed granite would be cost effective in the execution of pavement construction works. The results are presented in Table 4 and 5 below.

Table 4: Cost Analysis

Material	Quantity	Cost Price (as at August, 2019)
BUA Cement	50kg	₦2500
Granite ($\frac{3}{4}$ inch)	1 ton	₦9000
Crushed Iron Stone	1 ton	₦2700

Table 5: Parameters Specifications

Parameters	Crushed Granite	Crushed Iron stones
Base Course Thickness	200mm	200mm
Pavement Width	3.5m	3.5m
Volume of Base Course required per meter	$0.7m^3$	0.7^3

section		
Density of material	2420kg/m^3	1694kg/m^3
Mass of Base course required	2380kg	1666kg

Calculations

1 ton (1020kg) is ₦ 9000 (crushed granite) and ₦7000 (crushed iron stones).The cost of 1694kg of base course using crushed granite is ₦14941.2 and ₦4408.27 for crushed iron stone (without cement). However, with cement the price is increased i.e.,5% of 1666kg (0.05 x 1666kg) is 83.3kg and thecost of 83.3kg of cement is ₦4165.0. Therefore, total cost of stabilized base course (crushed iron stone) is ₦8573.27.

From the results obtained above, it can be seen that the cost of stabilized crushed iron stone (₦8573.27) per meter length of a 3.5 lane of roadas base course material is cheaper than that of un-stabilized crushed granite base (₦14941.2).

IV. Conclusion and concluding remarks

4.1 Conclusion

The stabilization of locally available crushed iron stones for use base course in pavement construction using cement as the stabilizer was investigated in this study. From this investigation, the conclusions listed below were drawn:

1. The California bearing ratio value of the stone increased from 78.2% to 142% after complete strength development of cement at a minimum ration of 5% cement by weight of dry sample.
2. Based on the results, 5% cement by weight of the sample is the best suited to stabilized crushed iron stone for use as base course in highway pavements in order to satisfy the specifications of the Department of Highways provided the crushed iron stones obtainedfrom Enugu State are to be employed.
3. R^2 values obtained from regression analysis 0.981, 0.982 and 0.992 indicating the values are plausible.
4. ANOVA results showed p-value for 7, 14 and 28 days- 0.0052. 0.0075 and 0.0031 were less than 0.05 portraying a close relationship between measure and predicted values.
5. Also, the cost analysis evaluated using the stabilized crushed iron stone and granite as base course in highway construction revealed that the cost of using stabilized crushed iron stone was ₦8,573.27 per meter length of a 3.5 lane of road and ₦14,941.2 per meter length of a 3.5 lane of road for un-stabilized crushed granite base. Thus, stabilized crushed iron stones as base course material is cheaper.
6. Non-stabilized sample lost strength whereas stabilized sample gained little strength on exposure to water. This is due to absorption of moisture by the cement stabilized thoughafter complete strength development of the cement, exposure to water will not lead to further strength development.

4.2 Concluding remarks.

In Nigeria today, crushed granite has been the main base course material used in highway construction. However, from the results of this study cement stabilized crushed iron stone is recommended for used as road base coursein order to facilitate the fast completion of good roads and increased economic development and improved standard of living in the Nigeria.

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