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Regression Analysis between Properties of Subgrade Lateritic Soil

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Abstract

The results of a study that considered the use of regression analysis that may have correlation between index properties and California Bearing Ratio (CBR) of some lateritic soil within Osogbo town of South Western Nigeria have been presented. For an appreciable conclusion to be established, lateritic soil samples were collected from eight (8) different borrow pits within the town and various laboratory tests including Atterberg Limits, Gradation analysis, California Bearing Ratio, Compaction and Specific Gravity were performed on the soil samples.Various linear relationships between index properties and CBR of the samples were investigated and predictive equations estimating CBR from the experimental index values were developed. The findings indicate that good correlation exists between the two groups (i.e Index properties and CBR values). However, the values of the CBR computed from the models are only to be used for preliminary in view of simplicity and economy and not acceptable alternatives to laboratory testing because of the anisotropic nature of lateritic soil and its heterogeneity.

Keywords

Borrow pits; Subgrade materials; Index properties; Carlifornia Bearing Ratio; Lateritic soil; Regression analysis.

Introduction

Index properties have wide applications in geotechnical engineering practice and a number of index properties which are easily recognized in soil mechanics have been outlined by many authors [1-4]. It is normal practice to try to predict the engineering behaviour of soils from their index properties. The properties form the basis for soil classification into groups where each group is said to have similar behaviour. Some authors [2,5] have given reasons for the use of index properties in predicting soil behaviour. Accordingly, many researches have made attempt at predicting some other engineering properties of soil such as compaction parameters [6,7] permeability [8,9] swelling pressure [10,11], consolidation parameters such as compression index [2,3], California Bearing Ratio [12-15] using index properties. However, soil composition affects index properties of soils. Most of these predictions often utilize atterberg limit values which are affected essentially by some soil compositional as well as environmental factors.

The strength of subgrade is the main factor in determining the thickness of the pavement. Subgrade strength is expressed in terms of its California Bearing Ratio (CBR) value. The CBR test is generally carried out in the Laboratory on remoulded samples of the subgrade, as described in [16-18]. The sample must be compacted at the equilibrium moisture content to the dry density likely to apply after the road has been constructed. It is to be noted that CBR test is widely accepted internationally as a reliable method of pavement design and is also used in soil classification of base and subbase (road base) materials for highway designs and construction. Thus it becomes necessary to add to the existing knowledge by using linear regression equations to predict the range of CBR values for use as a function of index properties where constraints as to the level of expertise and equipment arise in laboratory determination of CBR [19].

Laterites (or lateritic soils) as a soil group rather than well-designed materials are most commonly found in the leached soils of the humid tropics where they were first studied. According to [20] these soils are formed under weathering conditions productive of the process of laterization, the most important characteristic of which is the decomposition of ferro-alumino silicate minerals and the permanent deposition of sesquioxides (i.e. oxides of iron and aluminium – Fe_2O_3 and Al_2O_3) within the profile to form the horizon of material known as laterite. Term “laterization” was used by [21] to describe the processes that produce lateritic soils. Lateritic soils are being used in the construction of roads, highways, airfields, and earthdams and as the foundation of structures [14].

It should be noted that researchers have done a lot in using statistical parameters such as regression analysis in solving geotechnical problems. It was established by [12] that there existed a relationship between CBR and index properties and concluded that a strong correlation exist between the two tests and suggests that the method of a approach is sufficient to predict the range of CBR values expected through mathematical analysis without actually performing CBR laboratory tests on soil samples within the locality. Comparative study of CBR and Unconfined Compressive Strength (UCS) in the area of characterizing cohesive soils for pavement design and analysis in view of theoretical development and economy was carried out by [15, 22].

Recently, Osun State government has embarked upon mass construction of roads within the state capital, Osogbo and the surrounding towns to ease the means of transportation within the state. Most of these roads consisted mainly of transported materials. As a result of this, there is a need to replace them with good paving materials. Hence, eight borrow pits that have large quantities of good constructional materials for the pavement construction were identified after geotechnical investigation with respect to quality and quantity had been carried out. As a result of this, the study now considered the use of linear regression equations to correlate index properties and California Bearing Ratio values of lateritic soil within Osogbo, South Western Nigeria.

Materials and Method

The study commenced with deskwork and reconnaissance survey of the project area. Then, sampling was carried out through trial pitting which permitted a close examination of the sampling sites.

Preparation of specimens

Samples that have been collected via trial pitting were prepared in accordance with BS 1377, 1990 and Head, 1992. Prior to preparing the test specimens, the materials were air –

dried and broken into smaller fragments, care being taken not to reduce the sizes of the individual particles.

Test Procedures

The following tests: Atterberg limits, Particle grain analysis, California bearing ratio and Compaction test were carried out on each of the disturbed samples. Each test procedure is as follows:

- ***Grain size analysis:*** Representative sample of approximately 500kg was used for the test after washing and oven-dried. The sieving was done by mechanical method using an automatic shaker and a set of sieves.
- ***Liquid mimit determination:*** Soil sample passing through 425μm sieve, weighing 200g was mixed with water to form a thick homogeneous paste. The paste was collected inside the casangrade's apparatus cup with a grove created and the number of blows to achieve 12.5mm closure at varying moisture contents were recorded. Moisture content corresponding to 25 number of blows is taken as the Liquid Limit (LL).
- ***Plastic limit determination:*** Soil sample weighing 200g was taken from the material passing the 425μm test sieve and then mixed with water till it become homogenous and plastic to be shaped into a ball. The ball of soil was rolled on a glass plate to form threads which cracked at approximately 3mm diameter. The moisture content of the thread-like soil is taken as the Plastic Limit (PL).
- ***California Bearing Ratio (CBR):*** Fresh sets of 3kg air-dried soil were mixed with suitable amount of water of about 5% of its weight of water. The sample was completed following the standard procedure [16]. The sample was put in CBR mould in 3 layers with each layer compacted with 62 blows using 2.5kg hammer at a drop of 450mm (standard proctor test). The compacted soil and the mould were weighed and placed under CBR machine following the standard procedure. Load was recorded at penetration of 0.625, 1.9, 2.25, 6.25, 7.5, 10 and 12.5mm.
- ***Compaction test:*** Samples that were crushed to pass through 4.76mm (BS No.4) sieve aperture as outlined by [17] of about 3kg was used. The sample was mixed with suitable amount of water of 5% at the initial stage and later increased to 7%, 9%, 11% and 13% on subsequent tests. The soil was compacted using BS mould of 105mm diameter and 115.5mm height. The compaction was done in 5 layers. Each layer was compacted with

4.5kg rammer from a dropping height 300mm. This method is known as West Africa Standard (WAS). Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) were determined from the graph of dry density against moisture content [18].

Results and Discussion

Sieve Analysis

The percentage of the lateritic soil samples passing BS Sieves 2mm, 425µm and 75µm are shown in table 1.The percentage passing through No. 200 (75µm) BS sieve ranges between 10.5% and 24.7% showing that the soil samples are coarse materials according to Unified soil classification system (USCS). The soil samples can be basically suitable for subgrade construction as their percentage by weight finer than No. 200 BS sieve is less than 35%, according to [19] specification. The lateritic soil samples also belong to A-2-6 subgrade according to AASHTO method of classification as shown on Table 1.

Table 1. Summary of Grain size analysis, Atterberg Limit and Specific Gravity

Sample No	Grading % passing BS sieve			Atterberg Limits			Specific Gravity	AASHTO Classification
	2mm	425µm	75µm	LL(%)	PL(%)	PI(%)		
T1	68.9	51.7	21.5	33.0	18.8	14.2	2.68	A-2-6
T2	83.1	65.6	24.7	36.7	19.1	17.6	2.70	A-2-6
T3	88.2	50.0	18.6	38.0	20.6	17.4	2.66	A-2-6
T4	69.4	33.4	13.1	45.0	24.3	20.7	2.74	A-2-6
T5	54.8	32.2	10.5	28.6	17.4	11.2	2.77	A-2-6
T6	84.8	53.8	23.7	36.0	18.9	17.1	2.67	A-2-6
T7	77.6	42.4	20.3	36.0	18.0	16.0	2.66	A-2-6
T8	80.4	52.7	21.8	40.0	25.0	15.0	2.71	A-2-6

Atterberg Limits

The liquid limits of the soil samples range between 28.6% and 45% and plastic limits between 18.8% and 25% while plasticity index is between 14.2% and 20.7% as shown in table 1. Soils with liquid limit less than 30% are considered to be of low plasticity, those with liquid limit between 30% and 50% exhibit medium plasticity and those with liquid limit greater than 50% exhibit medium plasticity and those with liquid limit greater than 50% exhibit high plasticity. All samples exhibit medium plasticity except sample T5 which exhibit low plasticity. This type of liquid limit can be expected for silty soils which usually have typical values of 25% to 50% [13]. Also, a liquid limit of 50 (maximum) and a plasticity index of 15 (maximum) have been recommended, thus samples T2, T3 and T5 have fallen out of the recommendation.

Specific Gravity

The values of the specific gravity for the samples ranged between 2.66 and 2.77 as shown in table1. The specific gravity values are within the range recommended in [14]. Thus, lower specific gravity value indicates a coarse soil, while higher values indicate a fine grained soil.

Compaction

British standard light compactive effort was used. The maximum dry density (MDD) ranges between 1.98Mg/m^3 and 2.21Mg/m^3 while the optimum moisture content ranges between 10.81% and 12.52% as depicted in Table 2.

Table 2. Summary of California Bearing Ratio values and Compaction parameters

Sample No	**CBR**		**MDD (Mg/m^3)**	**OMC (%)**
	Unsoaked %	**Soaked %**		
T1	66.7	29	2.13	11.58
T2	79.3	33	2.09	11.98
T3	78	30	2.18	11.15
T4	85	32	2.20	10.90
T5	64	26	1.98	12.52
T6	73	31	2.16	11.23
T7	77	34	2.04	12.34
T8	84	33	2.21	10.81

California Bearing Ratio

The construction of highway pavement requires to meet regulatory minimum California Bearing Ratio which should not be less than 80% (unsoaked), 30% (soaked) and 10% (soaked) for base, subbase and subgrade materials respectively. Thus, requiring careful selection of materials. The study herein, presented an empirical approach for calculating or predicting California Bearing Ratio (CBR) which serves as the most important factor during road pavement construction.

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The values of California bearing ratio have been shown in table 3. It has unsoaked CBR ranges between 64 and 85% which that of its corresponding soaked samples range between 26 and 33%. The percentage decreases from unsoaked CBR to soaked CBR. This implies that as water is absorbed into the compacted specimen, the resistance to penetration becomes drastically reduced.

It has been recommended by Federal Ministry of Works and Housing [18] that the values of CBR for road base, subbase and subgrade should not be less than 80%, 30% and 10% respectively under soaked condition. It can be seen that samples T1 and T5 do not satisfy the condition for both road base and subbase. The materials can only qualify as subgrade material. In the other way, when looking at angle of the calculated value there is slight contradiction because the values satisfy the conditions for the base and subbase materials. Also, for the soaked California bearing ratio, samples T1 and T5 have values that are less than 30% from the experimental point of view but greater than 30% from the calculated value.

Computational Analysis of Regression Analysis

Table 3 presents the summary of the computation of linear regression equations for different categories of test results while Table 4 presents the summary of the experimental and calculated values of the California Bearing Ratio, compaction parameters as a function of other index values.

Table 3. Linear regression equation for different categories of tests

Description	Linear regression
CBR (unsoaked) vs. Liquid limit	CBR = 0.031 LL + 83.19
CBR (unsoaked) vs. Plastic limit	CBR = 0.8 P.L + 65.31
CBR (unsoaked) vs. Specific gravity	CBR = 10.43 S.G + 56.19
CBR (unsoaked) vs. MDD	CBR = 8.66 MDD + 65.88
CBR (soaked) vs. Liquid limit	CBR = 0.22 L.L + 28.87
CBR (soaked) vs. Plastic limit	CBR = 1.04 P.L + 13.56
CBR (soaked) vs. Specific gravity	CBR = 9.42 S.G + 10.91
CBR (soaked) vs. MDD	CBR = 50.28 MDD – 70.22

Attempts were made to establish correlations between California bearing ratio values and index properties of the soil samples using linear regression analysis [23].

The results of the experimental analysis show that California Bearing Ratio values for the unsoaked samples ranges between 66.7% and 85% while that of the calculated value ranges between 79.2% and 85.3%. In the same vein, the experimental results for the soaked

CBR values shows that the values range between 26% and 34% while that of the calculated values range between 29.3% and 40.9%.

Table 4. Summary table for experimental and calculated values

Sample No.	T1	T2	T3	T4	T5	T6	T7	T8
Experimental value of unsoaked CBR	**66.7**	**79.3**	**78**	**85**	**64**	**73**	**77**	**84**
Calculated value of CBR (LL)	84.2	84.3	84.4	84.6	84.1	84.3	84.3	84.4
Calculated value of CBR (PL)	80.4	80.6	81.8	84.8	79.2	80.4	79.7	85.3
Calculated value of CBR (SG)	84.1	84.4	83.3	84.8	85.1	84.0	83.9	84.5
Calculated value of CBR (MDD)	84.3	83.9	84.8	84.9	83.0	84.6	83.6	85.0
Experimental value of soaked CBR	**29**	**33**	**30**	**32**	**26**	**31**	**34**	**33**
Calculated value of CBR (LL)	36.1	36.9	37.2	38.8	35.2	36.8	36.8	37.7
Calculated value of CBR (PL)	33.1	33.4	34.9	38.8	31.7	33.2	32.3	39.6
Calculated value of CBR (SG)	36.2	36.3	36	36.7	37.0	36.1	36.0	36.4
Calculated value of CBR (MDD)	36.9	33.8	39.4	40.4	29.3	38.4	32.4	40.9

Conclusion

The results of the analysis indicate that there is a close relationship between CBR values, Compaction and index properties. The results of the experimental values show that sample T1 and T5 do not satisfy the requirement for both road base and subbase.

It can thus be safely concluded that regression analysis provides a sound background for predicting California bearing ratio of samples for preliminary assessment and not an acceptable alternative to laboratory testing.

It is recommended for future research that regression based models such as two ways ANOVA and computer based reliability analysis be carried out on a wider variety of soil samples so as to specify the range of applicability of the derived model viz-a-viz the input variables.

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