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Development of Analytical Relationships Among Engineering Properties of Lateritic Soil as Pavement Materials

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ABSTRACT

Laterite are soil types with the oxides of iron, aluminum, titanium, zircon, manganese, zinc and Quartz, they very significantly according to their location, climate and depth. Its use as pavement material depends on its index and engineering properties which are obtained experimentally in the laboratory or institution. Results on the strength and index properties of laterite as subgrade, sub base and base course material are collected from different geotechnical laboratories indicating the grain size distribution, Atterberg's limit, Compaction test and the CBR test for the lateritic soil. The obtained equations through the use of SPSS and Least Square regression analysis shows that there exist relations among the engineering properties of laterite with the former producing greater degree of accuracy, more flexibility and higher ease of computation. The application of these statistical tools in determining the engineering properties of lateritic soil will reduce the length of time spent obtaining these properties experimentally; reduction in construction cost and time spent and eliminate errors that are likely to occur during experiments.

Keywords: *Laterite, SPSS, Least-Square Regression.*

INTRODUCTION

Tropical weathering (Laterization) is a prolonged process of chemical weathering which produces a wide variety in the thickness, grade, chemistry and ore minerals [4]. Laterite can be used for variety of purpose ranging from block building, water supply, waste water treatment, road building etc.[1,6].

Index properties which include; the consistency limits test, water content test, maximum dry density etc. CBR is one of the internationally accepted alternative methods of pavement design; it is also employed in soils classification as base and sub-base course materials for their suitability for use in highway design [2].

The aim is to establish analytical relationships among Engineering Properties of Lateritic soil as pavement material which thereby provides a quicker and cheaper means of computing the index and strength values of lateritic materials through analytical relations without going through the rigor of the laboratory experiments. In achieving collection of data on soil samples at different borrow pit locations on which various strength and index tests have been carried out. Tests carried out enable their suitability and usability as pavement material and forms the basis of comparison among the through mathematical relations.

METHODOLOGY

- **Data collection :**Data was collected on the geotechnical properties of laterites from a quality-controlled laboratory where they were carried out in accordance [3].The tests are:
  - California Bearing Ratio (CBR)
  - Particle size analysis (F=% passing sieve 75 microns)
  - Atterberg's Limit
    - Liquid Limit (LL)
    - Plastic Limit (PL)
  - Compaction
    - Maximum Dry Density (MDD)
    - Optimum moisture Content (OMC)

Analysis of the data by:

Use of Least-Square Regression Equation in accordance to (5)

$$\sum X_1X_2=a\sum X_2^2+b\sum X_2X_3+c\sum X_2X_4+d\sum X_2X_5 \quad (1)$$

$$\sum X_1X_3=a\sum X_2X_3+b\sum X_3^2+c\sum X_3X_4+d\sum X_3X_5 \quad (2)$$

$$\sum X_1X_4=a\sum X_2X_4+b\sum X_3X_4+c\sum X_4^2+d\sum X_4X_5 \quad (3)$$

$$\sum X_1X_5=a\sum X_2X_5+b\sum X_3X_5+c\sum X_4X_5+d\sum X_5^2 \quad (4)$$

$$X_1=Z+aX_2+bX_3+cX_4+dX_5 \quad (5)$$

Where, $Z=X_1-aX_2-bX_3-cX_4-dX_5$

Note, X_1=CBR, X_2=Liquid limit, X_3=Plastic limit, X_4=Maximum Dry Density, X_5=Optimum moisture content

N.B The number of variables to be determined depends on the forms of equations to be used. For example, CBR against MDD and OMC has three variables so three equations was employed. The equation is

$$\sum X_1=aN+b\sum X_4+c\sum X_5 \quad (6)$$

$$\sum X_1X_4=a\sum X_4+b\sum X_4^2+c\sum X_4X_5 \quad (7)$$

$$\sum X_1X_5=a\sum X_5+b\sum X_4X_5+c\sum X_5^2 \quad (8)$$

For others, same protocol follows just by interchanging the variable used

Use of SPSS: The data are also imported into SPSS

I. RESULTS

For unsoaked CBR (Base course).

Analysis using SPSS as the analyzer gives the followings;

$$CBR=92.134-0.738LL+0.842PL-0.985MDD+0.027OMC \quad (1)$$

$$CBR=87.579-0.653LL+0.805PL+0.787MDD+0OMC-0.055F \quad (2)$$

$$CBR=87.876-0.736LL+0.838PL \quad (3)$$

$$CBR=89.309-0.665LL+0.812PL-0.052F \quad (4)$$

$$CBR=61.441-0.220SS+13.305MDD-0.074OMC \quad (5)$$

CBR=68.164+9.752MDD-0.545OMC (6)

F=-30.505+16.122MDD+2.136OMC (7)

MDD=2.210-0.01LL+0.007PL (8)

CBR=88.317-0.251F (9)

LL=34.323-7.405MDD+1.300OMC (10)

PL=1.628+6.262MDD+0.525OMC (11)

OMC=3.305+0.2805LL-0.114PL (12)

Using the regression formulae;

CBR=0.684-0.29LL+1.20PL+27.80MDD+1.30OMC (13)

CBR=91.2-0.80LL+0.873PL (14)

CBR=71.22+8.43MDD-0.584OMC (15)

MDD=2.23-0.0114LL+0.00083PL (16)

LL=43.21-11.20MDD+1.18OMC (17)

PL=-1.68+7.70MDD+0.565OMC (18)

OMC=2.929+0.281LL-0.11PL (19)

CBR=-4.971+3.805F (20)

F=-31.547+16.568MDD+2.150OMC (21)

F=-11.545+1.372LL-0.487PL (22)

For Subgrade

Using SPSS for the analysis

CBR=66.295-0.0311LL+0.044PL-23.570MDD-0.982OMC (23)

CBR=65.737-0.029L+0.04PL-23.462MDD-0.980OMC+0.011F (24)

CBR=7.529-0.026LL-0.012PL+0.024F (25)

CBR=8.187-0.030LL-0.010PL (26)

CBR=15.744+0.019F-4.735MDD (27)

CBR=65.319-23.626MDD-0.979OMC (28)

CBR=6.683+0.021F (29)

LL=2.207+1.347PL (30)

LL=-36.816+20.393MDD+1.771OMC (31)

F=27.453-0.164LL+0.301PL (32)

PL=-25.767+1.335OMC+13.302MDD (33)

MDD=1.913+0.000LL+0.00006PL (34)

Using the regression formulae

CBR=8.256-0.0145LL-0.026PL (35)

CBR=75.76-28.13MDD-1.022OMC (36)

MDD=1.901+0.00114LL-0.001PL (37)

LL=-119.9+61.01MDD+2.148OMC (38)

PL=-77.32+38.480MDD+1.564OMC (39)

OMC=13.329-0.009LL+0.065PL (40)

CBR=6.668+0.0244F (41)

F=26.543-0.3222LL+0.667PL (42)

For Sub base

Using SPSS for the analysis

CBR=295.348-0.332LL-0.169PL-2.426OMC-106.952MDD (43)

CBR=5.181+0.329LL+1.022PL (44)

CBR=305.825-0.443LL-0.203PL-2.439OMC-110.455MDD+0.041F (45)

CBR=4.804+0.388LL+0.989PL-0.031F (46)

CBR=5.181+0.329LL+1.022PL (47)

CBR=107.216+0.030SS-34.755MDD (48)

CBR=214.474-77.528LL-1.826OMC (49)

F=-12.040+1.894LL-1.047PL (50)

LL=-3.895+1.818PL (51)

PL=78.475-0.426OMC+26.410MDD (52)

CBR=33.551+0.139F (53)

OMC=7.168+0.165LL+0.59PL (54)

Using the regression formulae

CBR=0.07+0.281LL+0.099PL+0.32OMC+1.97MDD (55)

CBR=359.75-4.18OMC-136.74MDD (56)

CBR=9.01+0.346LL+0.813PL (57)

OMC=-7.137+0.162LL+0.592PL (58)

MDD=2.874-0.00982LL-0.0246PL (59)

LL=197.55-1.495OMC-72.8MDD (60)

PL=76.624-0.397OMC-25.383MDD (61)

CBR=33.808+0.132F (62)

F=348.58-4.139OMC-135.04MDD (63)

F=-11.656+1.9123LL-1.094PL (64)

II. DISCUSSIONS FROM THE EQUATIONS

For Base course (From equation 1-22)

- CBR is inversely proportional to liquid limit, inversely

proportional to OMC, directly to MDD and directly proportional to plastic limit.

- Liquid limit is directly proportional to plasticity index. i.e. inversely to Plastic limit and it also varies inversely to MDD and directly to OMC
- Percent passing sieve 75microns is inversely proportional to CBR
- Percent passing sieve 75microns is directly proportional to LL and inversely to PL; so it is directly proportional to plasticity index.
- MDD is directly proportional to PL and inversely to SS and OMC varies inversely to PL.
- OMC varies directly to LL and inverse to PL
- PL varies directly to both MDD and OMC.

Subgrade (From equation 23-42)

- CBR varies directly to PL, inversely to LL, MDD and OMC and directly to percent passing sieve 75 microns.
- Percent passing sieve 75 microns varies directly to PL and inverse to LL.
- PL varies directly to OMC and MDD
- LL varies directly to PL
- MDD varies directly to LL and inversely to PL
- OMC varies inversely to LL and directly to PL

Sub base (From equation 43-64)

- CBR varies inversely to LL, OMC, MDD and directly to percent passing 75 microns sieve and PL
- Percent passing 75 microns sieve varies directly to LL and inversely to PL , OMC and MDD
- LL varies directly to PL, inversely to OMC and MDD.
- PL varies inversely to OMC and directly MDD
- OMC varies directly to both PL and LL
- MDD varies inversely to both LL and PL

Table 1.0: Operational differences between SPSS analysis and Least-square regression analysis

Parameters	**SPSS**	**Least-Square regression**
Ease of computation	Relatively high	Smaller
Time employed in analysis	Smaller	Takes longer
Technicality	Relatively high	Lesser
Projected degree of accuracy	About 90%	About 82%
Computation mode	Digital	Analogue
Constraints	Needs electronic appliances for the computation	Requires vast knowledge of arithmetic
	It is a software which in rural areas might not be available	Involves a lot of paper works
Probability of error	About 0.1	About 0.2
Number of variables	Large	Lesser
Flexibility	High	Low
Operation cost	High	Lesser
Projected Numerical differences(Range) for the courses between practical and analytical method	CBR=±2	CBR=±5
	MDD=±0.2	MDD=±0.3
	LL=±2	LL=±2
	PL=±2	PL=±3
	F=±2.5	F=±5.5
	OMC=±1.0	OMC=±1.0
Electricity requirement	Yes	No

III. CONCLUSION

Statistical analysis carried out on the various soil samples shows that there exist correlations among the Engineering Index Properties of the samples.

Engineering Index Properties of soil samples can be used as a good determinant for the strength characteristics of laterite without going through the rigor of Laboratory experiments.

SPSS analysis and least square regression method are effective tools for correlation determinant with both giving relatively accurate results with SPSS analysis gives more accurate result compared to least square regression analysis, has more flexibility and higher ease of computations but for smaller construction works it is unadvisable because of the relatively high operational cost and technicality.

IV. RECOMMENDATION

The least square Regression formulae and SPSS analysis can be approximately used to determine the Strength Property (CBR) of a lateritic soil in relation to its Index Properties.

In order to reduce the probability of error and for further research works, wider range of consultations and number of samples should be used in the analysis, quality controlled laboratory should be consulted for proper efficacy and authenticity of the results to be used and results to be used should not necessarily conform to federal Ministry of Works specifications for roadwork because of its practicability.

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