International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Impact Factor (2012): 3.358

Model to Predict the Elastic Modulus of An A-5 Soil- Lime Mixture for Road Pavement Design in Rivers State Using one Indirect Tensile Testing Technique (Point Load)

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Abstract*: In Mechanistic design, the elastic property of the constituent material is very fundamental for a save and durable pavement, in this study one of the constituent materials of road pavement (laterite) used as a subbase material was modified using lime. 0%, 2%, 4%, 6% and 8% lime were mixed with the laterite and compacted at energy level of standard proctor of 100mm diameter by 80mm long split cylindrical mould, a total of 60 specimens were prepared in all and an average of 3 specimen was used for the test. The compacted specimens were moist cured and tested after 7, 14, 21, and 28 days. The CBR machine was used with an adaptation constructed by the researcher to load the specimen to failure through static load application, the point load indirect testing technique was used to obtain syresses and strains for the lime lateritic soil mixture, the spss programme was used to predict the Elastic Modulus from compressive Modulus, the result show that the predicted values were close to the measured values with an average R^2 value of 90% and that the Elastic and Compressive modulus increases with an increase in lime content up to 8% lime content*

Keywords*:* Prediction, Elastic Modulus, Compressive Modulus, Lateritic Soil, Mechanistic Design Point Load.

1. Introduction

Pavement materials include Portland Cement Concrete; Asphalt Concrete Cement bound materials, compacted soils, rocks and sub-grades. They are materials that terminate by fracture at or slightly beyond the yield stress generally referred to as brittle materials. They are isotropic (ie displays the same properties in all directions) and are assumed to be linearly elastic up to a certain stress level (referred to as the elastic limit). Therefore knowledge of the elastic properties of pavement is very essential in elastic theory for the mechanistic design of flexible and rigid pavements, including overlays, in this design method the pavement structure is regarded as linear elastic multilayered system in which the stress-strain solutions of the materials are characterized by the Young's Modulus of Elasticity (E) and poisons ratio (μ). The stress strain behaviour of a pavement material is normally expressed in terms of an elastic or resilient modulus. For cementitious stabilized materials, the selection of an appropriate modulus value to represent the material for design is complicated not only because of the difficulty in testing but also because different test methods give different values {1} and Pretorius {2}. The relationship above is generally nonlinear. Because of these difficulties {3} recommended using a relationship between flexural strength and the modulus of elasticity in lieu of testing. Numerous investigators have reported data relating strength and the modulus of elasticity of various cementitious stabilized materials. {4} examined the data published by {5}; {6} and others. From their examination they concluded that different relationships exist dependent upon the quality of the material been stabilized. They classified the material reported as lean concrete; cement bound granular material and fine grained soil cement. For a given strength level, they found the lean concrete to have the highest modulus and fine grain soil cement to have to have the lowest. {14} investigated the stress strain behavior of several soil cements, from their work an equation was developed that relates the resilient modulus in flexure to the compressive strength, cement content and a material constant which must be established for each material. The equation is as presented below;

$$E_r = K_f * 10^{\mu(CS)}$$

Testing of materials for highway pavement design and construction are now mostly based on the mechanistic design methods. These designs are based on structural approach in which properties of the pavement layers are tested and selected so that stresses and strains produced by loading of traffic do not exceed the capabilities of any of the materials in the pavement layers {10}. One of such methods is the indirect tensile test. The indirect tensile test has been successfully used for estimating the tensile and elastic properties of pavement materials in the laboratory. In the laboratory the elastic properties are generally evaluated by making either deformation measurements using linear variable differential transducers or strain measurements by attaching strain gauges to specimens. Also in the mechanistic approach the material properties which must be determined and known are the elastic modulus and poisons ratio of each layer. The elastic modulus can either be determined in the laboratory or correlated with conventional tests; in any case where there is need for laboratory testing the modulus should reproduce field conditions as accurately as possible {11}.

The strength of the stabilized material is a fundamental property required for design of pavements often specified and used for construction control .The type of test frequently used for control are the flexure beam test (FB), the Brazilian Split Cylinder test (BSC) Double Punch (DP), Point Load test (PL), Unconfined Compression test (UC) being perhaps the most common because of its relative simplicity. The tensile strength of the material is required for most design purposes; of the entire various test all except the unconfined compression test provides a measure of this property. However numerous investigators have found that the tensile strength obtained for a given material will vary depending upon which type of test is used. {13} found that flexural strength was generally about 1.5 times the split tensile strength, similarly data reported by {2} suggest that flexural strength is about twice the direct tensile strength. Relationships between unconfined compressive strength and the various measures of tensile strength have been reported by many investigators for soil cement mixtures, {5}found that flexural strength of soil cement was about 20% of the compressive strength. Other investigators have reported similar percentages 22.4% {1}; 13 to 25% by {12}, {13}. However, {14} recommended a more complex relationship; $F_s = 0.5 * C_s^{0.88}$

Where Fs = flexural strength
Cs = unconfined compressive strength.

Similar percentages have been reported for other cementitious stabilized materials; for example Thompson (1989) found that the flexural strength of lime soil mixture was about 25 percent of unconfined compressive strength. Bahrenberg (1990) reported flexural strength for lime ash aggregate mixture was 18-20 percent of the corresponding compressive strength. {15} reported the relationship;

$$ST = -11.38 + 0.1662\, C_s$$

Where ST = Split tensile strength
CS = Unconfined compressive strength psi

Swanson and Thompson (1967) carried out research on the fatigue characteristics of lime stabilized mixtures by performing flexural fatigue beam testing at various stress level. They established a relationship relating stress ratio to the number of load applications required to cause failure as;

$$S = 0.923 - 0.058 \log N$$

Where S = Stress Ratio
N = No. of Load application to failure

In this model Swanson did not consider elastic modulus which is an important input for the pavement layer design. {15} performed fatigue testing using the indirect tensile or diametral testing configuration, they found out that the effect of long term curing on stress ratio reduction improved fatigue properties as the lime-stabilized pavement layer ages. Little (1996) performed indirect testing on Colorado soils over a wide range moulding moisture contents and established a substantial improvement in tensile strength characteristics (compared to the untreated counterparts) over a wide range of moulding moisture contents. {16} found out that lime reduces PI and makes the soil more workable as the lime reacts with the clay surface .The reaction is mineralogy dependent ,but almost all plastic soils show a plasticity reduction and workability increases, some plastic soils(PI^S over 50) can be rendered non-plastic with lime. {17} carried out one dimensional swell test of the swell potential of lime-soil mixture and they pound out that the swell potential of a high PI clay with a swell pressure of 2,600kpa was reduced to 1,700kpa with 10% hydrated lime and was further reduced to 0kpa at 28days of cure at only 4% lime. {18} carried out a research on the evaluation of factors affecting the tensile properties of lime treated materials and found out that the indirect tensile strength is about 0.13 of the UC and that a reasonable approximation of the flexural tensile strength is about 0.25 of UC and concluded that lime can substantially improve tensile strengths. {9} carried out research on the Engineering properties of lime-soil mixtures and developed a generalized stress-strain plot for lime stabilized soils, he found out that lime stabilization stiffens the soil and that failure strain reduces from 2 or 3% to 1% or less, he also used UC and stress-strain data to approximate the elastic modulus from UC as;

$$E_M = 9.98 + 0.124\, UC \quad \text{in units of psi}$$

In most developing countries in Africa, laterite is widely used as a base material for construction of roads. However, due to lack of proper consideration of the qualities and properties of laterites for use as road base material, the roads fail soon after construction. It is therefore necessary to adequately characterize such materials and improve their quality. The major focus of the study is to develop a model using {8} to predict Elastic modulus of an A-5 soil stabilized with lime for use in road pavement design in Rivers State.

2. Materials and Methods

The laterite used were obtained from existing borrow pits in seven (7) local government area in Rivers State namely Emohua, Obio/Akpor, Ikwerre, Port Harcourt, Eleme, Etche, and Oyigbo. The properties of the laterites are indicated in Table 1.

Table 1: Properties of Lateritic soils from the seven Local Government Areas in Rivers State

Properties	**Values**						
	Emohua	Obio/ Akpor	Ikwerre	Port Harcourt	Eleme	Etche	Oyigbo
Liquid limit %	43	47	45	53	40	38	34
Plastic limit %	25	32	25	32	21	17	19
Plasticity Index (PI)	18	15	20	21	19	21	15
Group index (GI)	11	11	10	11	13	11	15
AASHTO Class	A-5	A-5	A-5	A-5	A-4	A-4	A-5
Natural moisture content (%)	16	18	15	21	17	17	18
Optimum moisture content %	14.25	13.50	14.00	15.50	14.20	15.60	14.50
Maximum Dry Density (kg/m^3)	1820	1780	1835	1958	1835	1790	1840

% passing No. 200 sieve size (75μn(	43	40	45	50	38	40	38

Table 2: Chemical Analysis of Lime

Composition	$Ca(OH)_2$	CaO	$CaCO_3$	l_2O_3	Fe_2O_3	S_1O_2	mgO	H_2O
Percent	71.3	6.0	6.3	0.18	0.04	11.0	4.19	0.09

Prior to the tensile and compressive strength tests, the dry density-moisture content relationships for the laterites were determined by compaction test, since all the laterites obtained from the various Local Government Areas fall in the same soil group using the AASHTO classification system. A-5 and A-4 soils which are all silt clay materials with more than 35% passing the 75μm sieve. The proctor method was adopted and the specimens were prepared and tested in accordance with BS 1377:1975. Before the preparation of the specimens, the laterites were all air dried and broken down to smaller form/units, with utmost care being taken as not to reduce the size of the individual particles. The samples were prepared by adding the required quantity of the stabilizer and water and then properly mixed by hand. Efforts were made to prepare the specimens to the maximum dry density and optimum moisture content of the respective mixtures. The required numbers of experimental units were prepared for each mix by the same personal so that strict control on quality could be maintained.

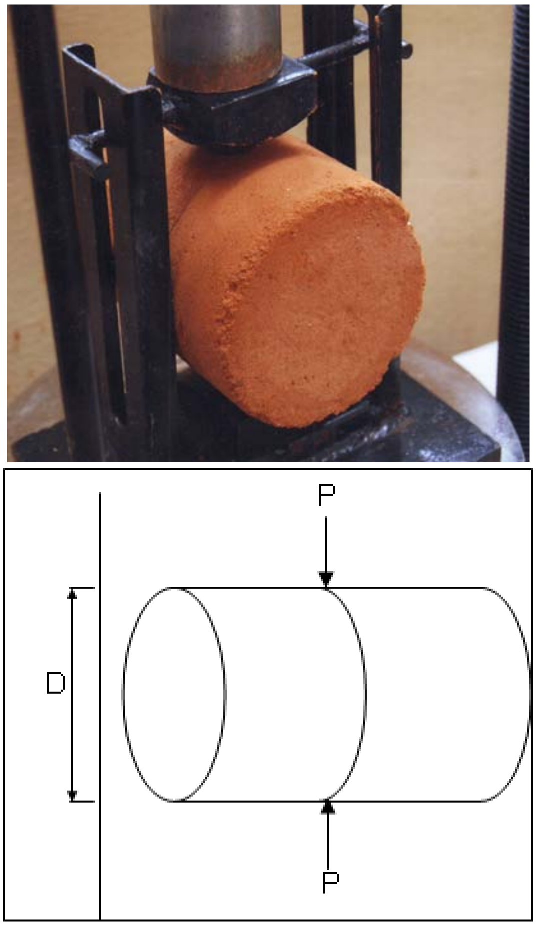
The test specimen had the dimensions of 100mm diameter by 80mm height and a total of 60 samples were prepared for the different levels of stabilization and a breakdown of the specimen into test units is shown in Table 3.

Table 3: Break down of specimen into test units silty clay materials (A-5) soil

AGE (DAYS)					
Test Method	Lime Content (%)	7	14	21	28
Point Load(PL)	0%	3	3	3	3
	2%	3	3	3	3
	4%	3	3	3	3
	6%	3	3	3	3
	8%	3	3	3	3

The specimens were moist cured for 7, 14, 21 and 28 days at constant moisture content and at laboratory temperature of about

2.1 Point Load (Non-Brazilian) Split Test



i)

Figure 1:

For the non-Brazilian test, applied compressive loads from opposite generators induces a horizontal tensile stress, and failure eventually occurred by splitting along a planes that run parallel to the direction of load application (figure 1). The maximum tensile stress occurring at the centre of the specimen is related to the applied load, P, the distance between the platens D, is given as an expression in equation 1

$$\sigma_t = \frac{KP}{D^2} \tag{1}$$

Where;
k = constant that assumes values from 0-5 to 1.0 with an average of 0.75
P = failure load in N
D = distance between the loading points diameter of the specimen in mm

The method used by Broch and Franklin 1972 was used. A simpler loading platens have been designed and constructed by the researcher in the absence of the original machine. The constructed type is adaptable to the concrete testing machine for loading and strain measurements see (fig2 and 3)

After obtaining the tensile strength of the material using the indirect tensile strength test methods. The strains (vertical and horizontal) were measured using strain gauges Demec No. 3463 strain gauge, to load the specimen the bearing strips were first positioned and aligned. The plunger of the CBR machine was then made to site on upper bearing strip before the load gauge was set on zero. The strain measuring tags were attached to each of the ends along the axes using super glue". Load was continuously applied (With few seconds shock to allow for strain gauging). The loading was done until failure load was obtained. Gage readings were taken at both ends so that the average of two vertical and two horizontal strain measurements were determined for each increment of load, the vertical and horizontal strains were recorded directly from Deme 3463 strain gage. Equations (1) was used to generate the tensile strength of the soil-lime mixture for the indirect tensile strength testing technique used.

2.2 Design and fabrication of Point Load Equipment

A steel material was used to produce a pointed cone of 60^o in angle. This angle was selected so that there could be an appreciable penetration of the platen into the moulded specimen. A metal plate was used at the side of the top and bottom of the cone plate to place them in position. The top of the cone is flat so that the crushing machine can rest on it. On the two side of the metal plate a space was created (i.e. a groove) whereby the top cone could move freely, while the bottom cone remains fixed on a flat plate surface. By the side of the top cone are two thin metals used handles to adjust the top cone i.e. to regulate the movement of the cone so that it will not slip off the made groove. Sliding down the upper cone into contact with the lower cone checked alignment of the cones. The loading frame was designed to accept specimens up to 10mm diameter, so that it could be used with most common sizes of moulded and cut specimens. The diagram of the designed and fabricated point loading device is shown in figure 2 while the photograph is shown in figure 3.

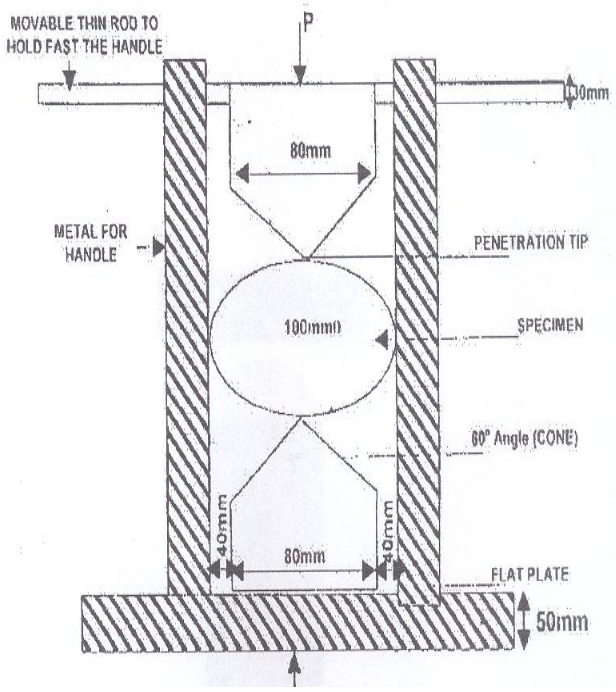


Figure 2: Diagram of fabricated point load equipment

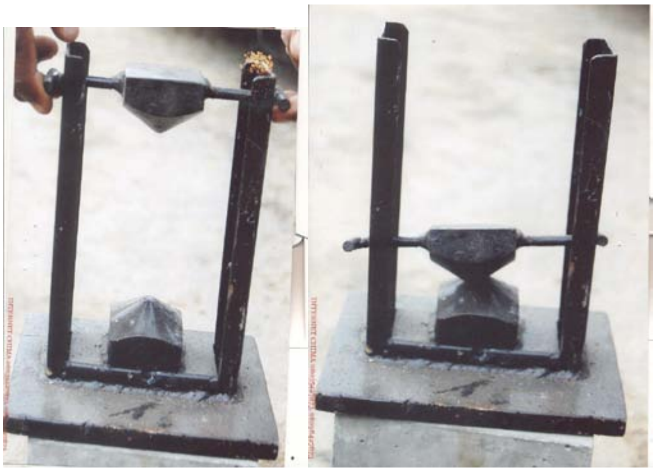


Figure 3: Photograph of point load equipment

2.3 Developed Models For Predicting Elastic Modulus Using SPSS

The following were the steps undertaken to develop the models that can be used to predict elastic modulus from compressive modulus of lateritic soils stabilized with lime content;

1. Determine the elastic modulus of the soil mixture using the different indirect tensile testing techniques for the various lime contents
2. Determine the compressive modulus of the soil mixture using the different indirect tensile testing techniques for the various lime content
3. Obtain the logarithm of both elastic and compressive moduli for the different indirect tensile testing techniques for the various lime content
4. Write a non-linear regression equation that satisfies the condition of the proposed general form of the elastic - compressive model
5. Input stringed variables into the SPSS software for non linear analysis

Note: the proposed model is of the form;

$$E_M = a * C_M{}^{0.435\ln b} \qquad 2$$

Where;
E_M = elastic modulus
C_M = compressive modulus
a, b, c = experimentally determined co-efficient from non linear regression.
From equation 4.1, the logarithm form can be expressed as,

$$Log(E_M) = Log\left[a * C_M{}^{0.435\ln b}\right] \qquad 3$$

For convenience of use in the SPSS software the independent variable was expressed in the natural logarithm form. That is,

$$Log(E_M) = \frac{1}{2.3} Ln\left[a * C_M{}^{0.435\ln b}\right] \qquad 4$$

2.4 Developing Proposed Elastic - Compressive Moduli Models Using Non Linear Regression Approach in SPSS

A non linear model is one in which at least one of the parameters appear nonlinearly (Prajneshu, No Date). More formally, in a nonlinear model, at least one derivative with respect to a parameter should involve that parameter. To solve the non linear regression using SPSS the variables (dependent and independent) were first of all collated into different cells in the "**Data View**" dialogue box. Next these variables were stringed and coded into another dialogue box called the "**Variable View Cell**". Finally model syntax was developed that satisfies the condition of the general form of the non linear model (Draper and Smith, 1998).

- **Non Linear Model Syntax**

The non linear model syntax is of the form as shown below;

$$Y = 0.435 * Ln\left[a * (C_M **(0.435 * \ln b))\right] \qquad 5$$

Where,
Y = dependent variable = Log (E_M)
C_M = independent variable
a and b are co-efficients to be determined from the non linear regression equation. Equation 5 is the non linear syntax model that is synonymous with the general form of the proposed model used for analysis in the SPSS program.
Finally, in SPSS the command (**) means raising a variable to the power of the coefficient in the same bracket while the command (*) means multiplication.

3. Result and Discussion

3.1 Point Load Test

Table 4: Variations @ 7 Days Curing

Lime Content (%)	*Compressive Modulus, C_M (MPa)*	*Elastic Modulus, E (MPa)*
0	1333.333	611.6505
2	1536.364	732.8244
4	2557.522	1393.419
6	2761.905	1460.929
8	2814.081	1515.736

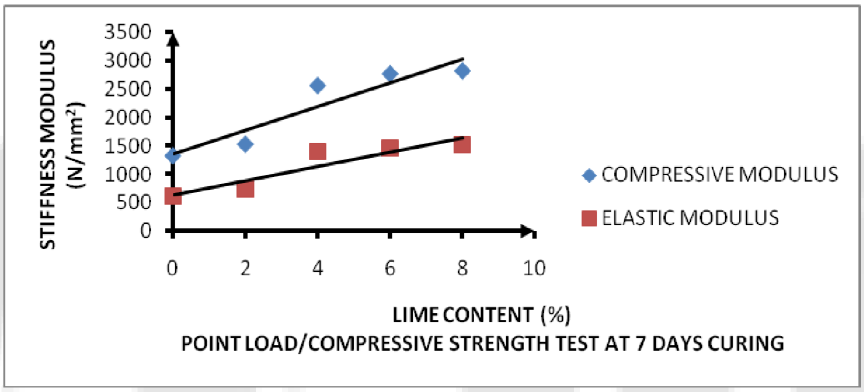


Figure 4: Point Load Stiffness Variation with Lime Content @ 7 Days Curing

Table 5: Variations @ 14 Days Curing

Lime Content (%)	Compressive Modulus, CM (MPa)	Elastic Modulus, E (MPa)
0	1364.706	568.8073
2	2096.33	655.4054
4	2533.793	1285.354
6	2818.408	1328.298
8	2900	1397.645

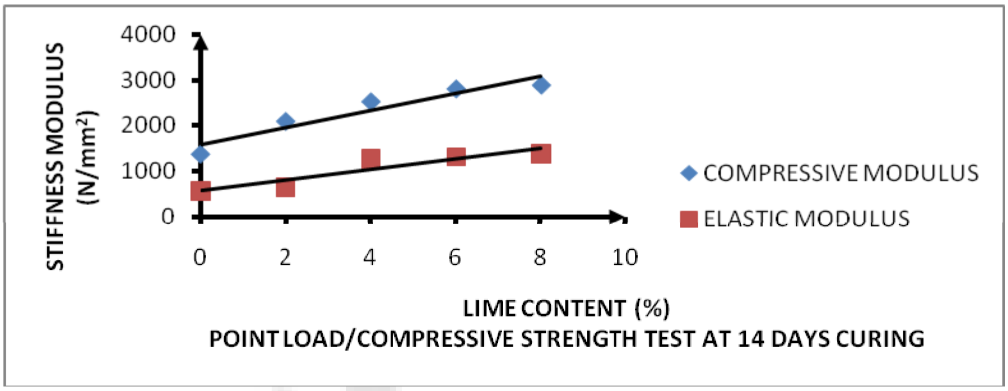


Figure 5: Point Load Stiffness Variation with Lime Content @ 14 Days Curing

Table 6: Variations @ 21 Days Curing

Lime Content (%)	*Compressive Modulus, CM (MPa)*	*Elastic Modulus, E (MPa)*
0	1273.585	565.2174
2	1692.41	633.1081
4	2013.17	1196.654
6	2125	1215.179
8	2279.767	1310.204

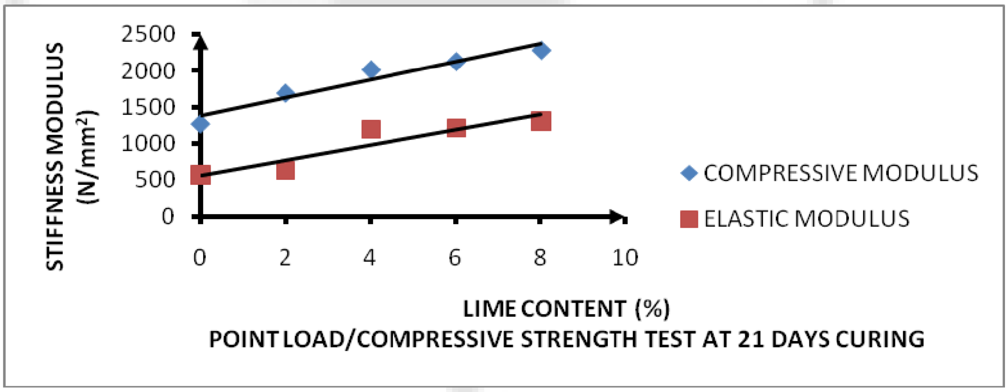


Figure 6: Point Load Stiffness Variation with Lime Content @ 21 Days Curing

Table 7: Variations @ 28 Days Curing

Lime Content (%)	Compressive Modulus, C_M (MPa)	Elastic Modulus, E (MPa)
0	1166.667	550.3876
2	1611.86	591.6084
4	1871.93	1002.222
6	1980.952	1175
8	2233.032	1274.169

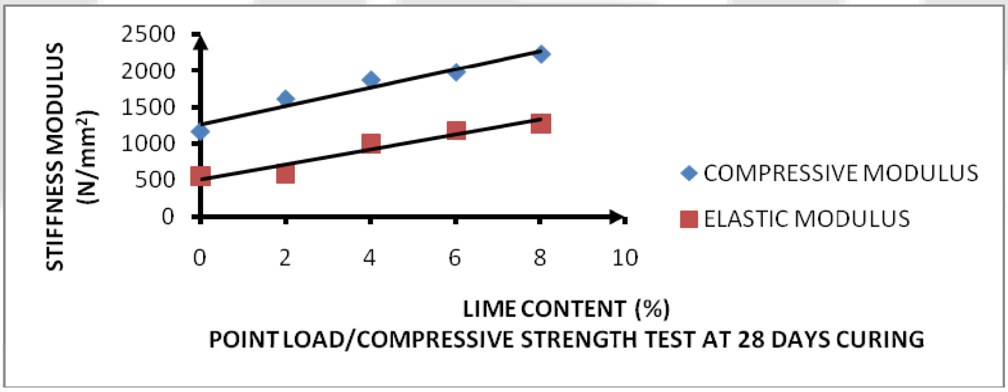


Figure 7: Point Load Stiffness Variation with Lime Content @ 28 Days Curing

3.2 Variation of Elastic Modulus (Em) and compressive modulus (Cm) of lateritic soil with lime content

For the various ages of curing the elastic modulus was increasing with increasing lime content, this goes to show that at 0% lime content the elastic modulus was low, but with the addition of lime it was increased see table(4-7) and fig(4-7) which means that lime increases the elastic modulus of lateritic soil. More so the tensile stress, compressive strain, and tensile strain were all increasing with increasing lime content as in (table 8-12), this finding is in line with Miller et al (2006), Thompson(1989). However the increase in elastic modulus was linear up to the highest lime content of 8% this could be as a result of the chemical reactions that took place during the process of stabilization, the addition of lime supplied an excess Ca^{+2} which goes to replace the weaker metallic cat-ions from the exchange complex of the soil. The exchange of this cat ions causes a reduction in the diffused water layer there by allowing clay particles to approach each other closely or flocculate, this finding is in line with Little et al(1995) the same trend was observed for all other ages of curing. Also the compressive modulus was increasing linearly with an increase in lime content, though the compressive modulus was higher than elastic modulus as shown in the table (4-7) and fig(4-7), This shows that compressive modulus is a very important parameter in the soil which is to be used as a pavement material, the compressive modulus needs to be higher since soils for highway pavement generally are good in compression this finding is in line with Larsen and Nussbaum (2005).

8: Point Load Test Results @ Failure Loads

Table 4.9: Point Load Test @ 7 Days Curing

Lime Content (%)	Elastic Modulus, E (MPa)	Tensile Stress (MPa)	Compressive Strain (10^{-4})	Tensile Strain (10^{-4})
0	611.6505	0.0063	0.15	1.03
2	732.8244	0.0096	0.29	1.31
4	1393.419	0.0974	1.49	6.99
6	1460.929	0.129	1.74	8.83
8	1515.736	0.1493	2.39	9.85

Table 9: Point Load Test @ 14 Days Curing

Lime Content (%)	Elastic Modulus, E (MPa)	Tensile Stress (MPa)	Compressive Strain (10^{-4})	Tensile Strain (10^{-4})
0	568.8073	0.0062	0.17	1.09
2	655.4054	0.0194	0.45	2.96
4	1285.354	0.1018	1.54	7.92
6	1328.298	0.1319	1.74	9.93
8	1397.645	0.1543	2.65	11.04

Table 10: Point Load Test @ 21 Days Curing

Lime Content (%)	Elastic Modulus, E (MPa)	Tensile Stress (MPa)	Compressive Strain (10^{-4})	Tensile Strain (10^{-4})
0	565.2174	0.0078	0.22	1.38
2	633.1081	0.00937	0.77	1.48
4	1196.654	0.03219	1.63	2.69
6	1215.179	0.1361	1.8	11.2
8	1310.204	0.1605	3.36	12.25

Table 11: Point Load Test @ 28 Days Curing

Lime Content (%)	Elastic Modulus, E (MPa)	Tensile Stress (MPa)	Compressive Strain (10^{-4})	Tensile Strain (10^{-4})
0	550.3876	0.0071	0.23	1.29
2	591.6084	0.00846	1.38	1.43
4	1002.222	0.02255	1.6	2.25
6	1175	0.03948	2.19	3.36
8	1274.169	0.1687	4.45	13.24

3.3 Point Load Test Calibration for Lime – Lateritic Soil Mixture

Table 12: 7 Days Curing

Lime Content (%)	Compressive Modulus, C_M (MPa)	Log C_M (MPa)	Elastic Modulus, E (MPa)	Log E (MPa)
0	1333.333	3.124939	611.6505	2.786503
2	1536.364	3.186494	732.8244	2.865
4	2557.522	3.407819	1393.419	3.144082
6	2761.905	3.441209	1460.929	3.164629
8	2814.081	3.449337	1515.736	3.180624

By applying equation 5 in the SPSS program, the experimental coefficients were determined from table 1a(ii) is as follows;

a = 0.108; b = 15.873; see [Table 1c (i)]

The resulting prediction model equation in syntax form becomes;

$$Y = 0.435 * Ln[0.108 * (C_M ** (0.435 * \ln 15.873))] \quad 6$$

Since Y = Log (E_M), the actual prediction model equation can be written as;

$$LogE_M = Log\left[0.108(C_M)^{0.435\ln 15.873}\right] \quad 7$$

$$E_M = 10^{0.435Ln\left[0.108(C_M)^{0.435\ln 15.873}\right]} \quad 8$$

Equation 8 can be used to predict elastic modulus of lime – lateritic soil mixtures cured at 7 days for point load given compressive modulus with a correlation value of $R^2 = 0.997$.

Table 13: 14 Days Curing

Lime Content (%)	Compressive Modulus, C_M (MPa)	Log C_M (MPa)	Elastic Modulus, E (MPa)	Log E (MPa)
0	1364.706	3.135039	568.8073	2.754965
2	2096.33	3.32146	655.4054	2.81651
4	2533.793	3.403771	1285.354	3.109023
6	2818.408	3.450004	1328.298	3.123296
8	2900	3.462398	1397.645	3.145397

By applying equation 5 in the SPSS program, the experimental co-efficients were determined from table (2ci) is as follows;

a = 0.010; b = 30.398; [See: Table 2c (i)]

The resulting prediction model equation in syntax form becomes;

$$Y = 0.435 * Ln[0.01 * (C_M ** (0.435 * \ln 30.398))] \quad 9$$

Since Y = Log (E_M), the actual prediction model equation can be written as;

$$LogE_M = Log\left[0.01(C_M)^{0.435\ln 30.398}\right] \quad 10$$

$$E_M = 10^{0.435Ln\left[0.01(C_M)^{0.435\ln 30.398}\right]} \quad 11$$

Equation 11 can be used to predict elastic modulus of lime – lateritic soil mixtures cured at 14 days for point load given compressive modulus with a correlation value of $R^2 = 0.882$

Table 14: 21 Days Curing

Lime Content (%)	Compressive Modulus, C_M (MPa)	Log C_M (MPa)	Elastic Modulus, E (MPa)	Log E (MPa)
0	1273.585	3.105028	565.2174	2.752216
2	1692.41	3.228506	633.1081	2.801478
4	2013.17	3.30388	1196.654	3.077969
6	2125	3.327359	1215.179	3.08464
8	2279.767	3.35789	1310.204	3.117339

By applying equation 5 in the SPSS program, the experimental coefficients were determined from table (3ci) is as follows;

a = 0.004; b = 44.517; [See Table 3c (i)]

The resulting prediction model equation in syntax form becomes;

$$Y = 0.435*Ln[0.04*(C_M**(0.435*\ln 44.517))] \quad 12$$

Since Y = Log (E_M), the actual prediction model equation can be written as;

$$LogE_M = Log\left[0.04(C_M)^{0.435\ln 44.517}\right] \quad 13$$

$$E_M = 10^{0.435Ln\left[0.04(C_M)^{0.435\ln 44.517}\right]} \quad 14$$

Equation 14 can be used to predict elastic modulus of lime - lateritic soil mixtures cured at 21 days for point load given compressive modulus with a correlation value of $R^2 = 0.901$

Table 15: 28 Days Curing

Lime Content (%)	Compressive Modulus, C_M (MPa)	Log C_M (MPa)	Elastic Modulus, E (MPa)	Log E (MPa)
0	1166.667	3.066947	550.3876	2.740669
2	1611.86	3.207327	591.6084	2.772034
4	1871.93	3.27229	1002.222	3.000964
6	1980.952	3.296874	1175	3.070038
8	2233.032	3.348895	1274.169	3.105227

By applying equation 5 in the SPSS program, the experimental coefficients were determined from table (4ci) is as follows;

a = 0.005; b = 40.320; [See Table 4ac (i)]

The resulting prediction model equation in syntax form becomes;

$$Y = 0.435*Ln[0.05*(C_M**(0.435*\ln 40.82))] \quad 15$$

Since Y = Log (E_M), the actual prediction model equation is can be written as;

$$LogE_M = Log\left[0.05(C_M)^{0.435\ln 40.82}\right] \quad 16$$

$$E_M = 10^{0.435Ln\left[0.05(C_M)^{0.435\ln 40.82}\right]} \quad 17$$

Equation 17 can be used to predict elastic modulus of lime – lateritic soil mixtures cured at 28 days for point load given compressive modulus with a correlation value of $R^2 = 0.882$

3.4 Verification of derived model for point load test for lime lateritic soil mixture

Table 16: 7 Days Curing

Lime Content(%)	*C_M*	*E_M (Measured)*	*E_M (Predicted)*
0	1333.333	611.6505	609.399
2	1536.364	732.8244	723.8187
4	2557.522	1393.419	1343.751
6	2761.905	1460.929	1475.209
8	2814.081	1515.736	1509.11

The predicted E_M values was obtained by applying equation 8 while the measured was obtained from the laboratory

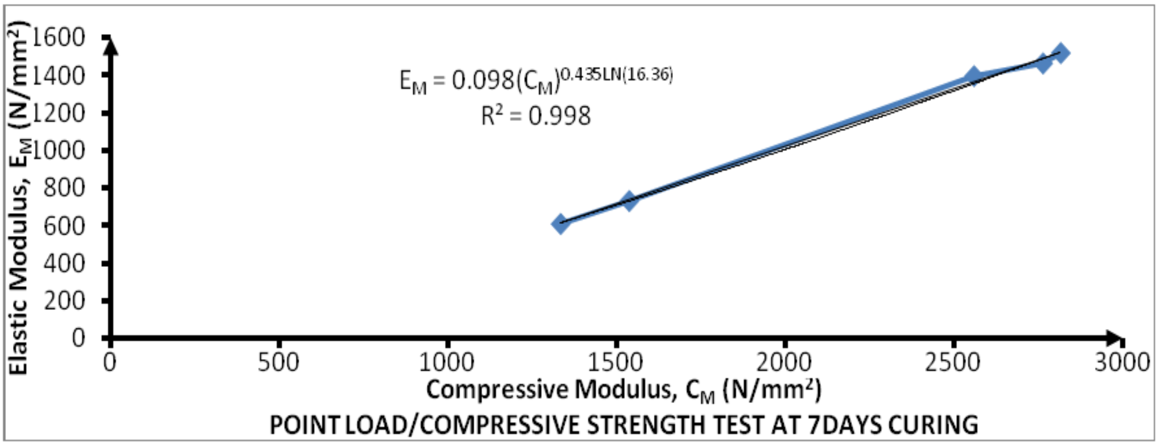


Figure 8: Prediction of Elastic Modulus from compressive strength using PL @ 7days

Verification of derived model for point load test for lime lateritic soil mixture

Table 17: 14 Days Curing

Lime Content (%)	C_M	E_M (Measured)	E_M (Predicted)
0	1364.706	568.8073	511.3108
2	2096.33	655.4054	885.354
4	2533.793	1285.354	1128.219
6	2818.408	1328.298	1292.781
8	2900	1397.645	1340.84

The predicted E_M values were obtained by applying equation 11 while the measured was obtained from the laboratory.

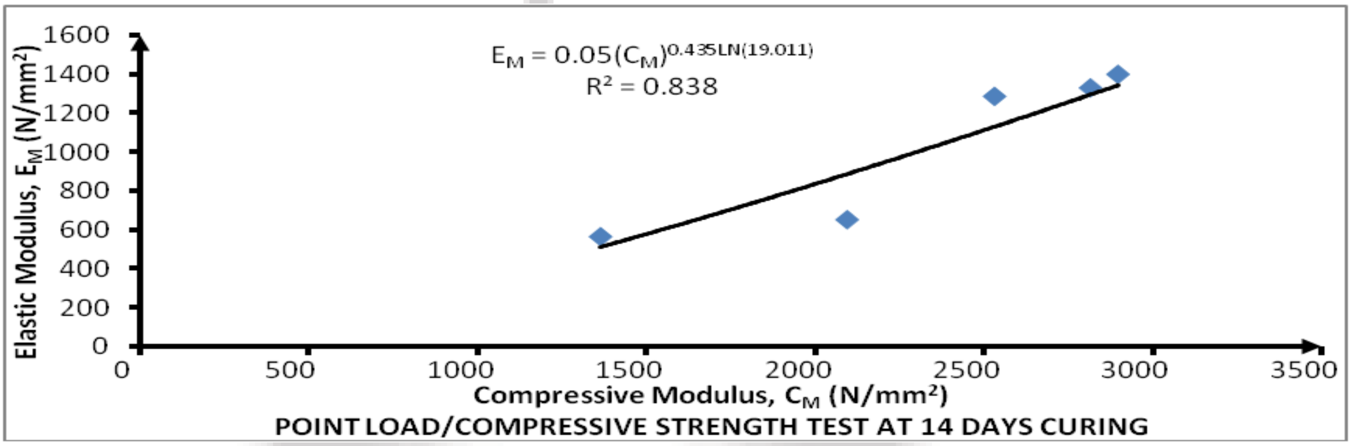


Figure 9: Prediction of Elastic Modulus from compressive strength using PL @ 14days

3.5 Verification of derived model for point load test for lime lateritic soil mixture

Table 18: 21 Days Curing

Lime Content (%)	C_M	E_M (Measured)	E_M (Predicted)
0	1273.585	565.2174	506.145
2	1692.41	633.1081	800.4258
4	2013.17	1196.654	1058.828
6	2125	1215.179	1155.241
8	2279.767	1310.204	1293.866

The predicted E_M values was obtained by applying equation 14 while the measured was obtained from the laboratory

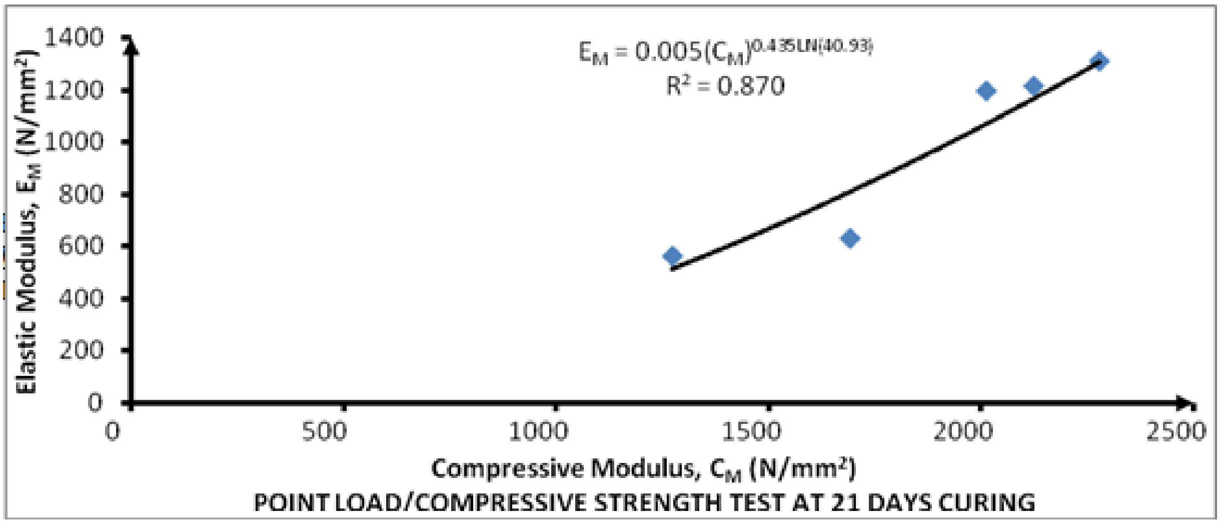


Figure 10: Prediction of Elastic Modulus from compressive strength using PL @ 21days

3.6 Verification of derived model for point load test for lime lateritic soil mixture

Table 19: 28 Days Curing

Lime Content (%)	C_M	E_M (Measured)	E_M (Predicted)
0	1166.667	550.3876	444.0763
2	1611.86	591.6084	748.1008
4	1871.93	1002.222	952.3051
6	1980.952	1175	1043.381
8	2233.032	1274.169	1265.838

The predicted E_M values were obtained by applying equation 17 while the measured was obtained from the laboratory.

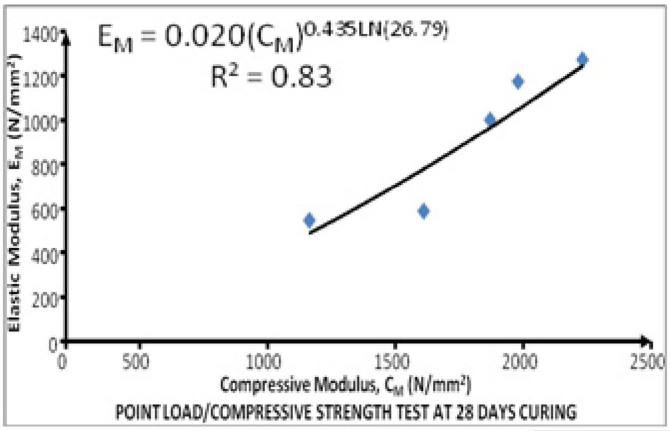


Figure 11: Prediction of Elastic Modulus from compressive strength using PL @ 28days

3.6 Verification of derived Predictive Models

Part of the work was devoted to the verification of the derived models developed by comparison with measured values. The method of verification was done through the use of multiple correlations by determining R^2 values as shown in the graphical plots, fig (8-11) the determination of R^2 was found to be very good with an average of over 90% recalling that the model prediction for the elastic modulus is ok, since in highway engineering Elastic modulus is very essential mainly in the sub-base layer of the pavement.

4. Conclusions

The following conclusions can be drawn from this study

1. The Elastic and Compressive modulus increases with an increase in lime content up to 8% lime content.
2. The predicted values were close to the measured values with an average R^2 value of over 90%
3. The models developed from this work can be used to predict Elastic modulus from compressive modulus using the point load test at different days of curing using lime.
4. The predicted Elastic Modulus can be used for the Mechanistic design of pavement.
5. Futher improvement can be done in this work using other stabilizers apart from lime and other techniques to verify the outcome of this research.

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