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Tensile strength of natural and lime stabilized clay soil in Rivers State using one indirect tensile testing technique (Splitting test)

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ABSTRACT

This paper investigates mainly the tensile strength and tensile properties of natural and lime stabilized clayed soil selected from Ikwerre Local Government Area in Rivers State using indirect tensile testing technique (splitting test).

The tensile strengths of compacted specimens of natural soil and lime stabilized soil were obtained using the split cylinder. The tensile stress and strain curves of the soils were evaluated. The compressive strength of the soils were also determined. The results reveal that both the tensile and compressive strengths increase with the addition of lime and with the increasing the curing time. Further more the results shows that the tensile strength is more sensitive to lime stabilization than the compressive strength. The stress-strain curves were regular at 2, 4, and 6% lime content and irregular at 0 and 8% this irregularity were due to the pattern of loading during the experiment.

Keywords: *Tensile strength, lime stabilization, split cylinder test, stress strain curves, Ikwerre clay.*

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I. INTRODUCTION

Tensile stresses can develop in highway pavement layers, at some distance from the wheel load, when the tensile stresses reaches or exceeds the tensile strength of the pavement layers cracking sets in which will result in excessive deflections and more stresses reaching the sub-grade layer. Therefore the higher the tensile strength of the pavement layers, the more sound roads. The natural soils have low tensile strength compared with the compressive strength, to improve the tensile strength properties, the soil needs to be stabilized.

Stabilization of a clayey soil improves its strength and other Engineering properties {1}{2}{3}. The tensile strength is one of the main properties which the pavement designer considers and always try to select a material with adequate tensile strength. The tensile characteristics can be measured by direct method, indirect method (Brazilian) and by bending method (Flexural).

In this paper the indirect tensile test will be used (splitting test).

{2} carried out flexural tension tests to investigate the tensile properties of compacted clays. They reported that the tensile strain decreased with the increase of compactive effort at comparable moisture contents. For a fixed compaction energy, the tensile strain increased with increasing moisture content up to the optimum.

{5} performed indirect tension test on a compacted well graded granular soil to study the effect of water content and compactive effort on the tensile strength. They concluded that the tensile strength decreased with an increase in water content, while the tensile strength increased with increasing the compactive effort for water content below the optimum and decreased slightly for water content below the optimum and decreased slightly for water content above the optimum.

{6} conducted a series of direct tension and unconfined compression tests on compacted loams and clay soils. They showed that the moisture content have a significant effort on the values of modulus of elasticity in tension and compression. {7} reported that the values of the initial tangent modulus from the flexural test of clay is greater in tension than in compression and their values are influenced by the moulding moisture content, thus the use of identical values for tension and compression in analysis of soil structure is not justified.

{16} studied the characteristics of cement stabilized lateritic soils using static load indirect tensile test and found out that increase in cement content and age of curing improves the basic properties of cement stabilized laterites. {8} measured the tensile strength of sub base material stabilized with cement, he found out that the tensile strength of stabilized material with 4% cement increased as the fine material increased up to 14% cement increased. For 8 and 12 percent of cement the maximum strength occurred at 6% of fine material then decreased. {15} investigated the tensile strength of Natural and lime stabilized mosul clays, he concluded that increasing the curing time of the clay improves the compressive strength more than the tensile strength and that the tensile stress-strain curves of stabilized specimens have irregular shape when the direct method of analysis is used and that the curves became more irregular when the percent of lime increased. In this study, the tensile strength characteristics of natural and lime stabilized clayey soil selected from Ikwerre Local Government Area of Rivers State were determined. The clay was stabilized with 0,2,4,6, and 8 percent of lime and cured for 7, 14, 21 days at laboratory temperature of about 28^0C. The tensile properties were obtained using the split cylinder (splitting test). The results of the test were analyzed using the indirect method of analysis.

II. MATERIALS AND METHOD

Soil:
The soil used in this study is clay obtained from Ikwerre Local Government Area of Rivers State. Table 1 shows some of the properties of the soil obtained using the relevant tests according to the ASTM standards{11}

Table (1) Index Properties of Soil

LIQUID LIMIT	45
PLASTIC LIMIT	25
PLASTICITY INDEX (PI)	20
GROUP INDEX (GI)	10
ASHTO CLASS	A-5
NATURAL MOISTURE CONTENT (5)	15
OPTIMUM MOISTURE CONTENT (%)	14
MAXIMUM DRY DENSITY (kg/m^3)	1835
% PASSING NO 200 (sieve size 75µm)	45
pH	8.3

Lime: The lime used in this study was hydrated lime and was procured in a 25kg bag from a reputable chemical store in Rivers State and was stored in a cool dry place away from weather effects. The chemical analysis of the lime used is shown in table 2.

Table 2: CHEMICAL ANALYSIS OF LIME

Composition	**$Ca(OH)_2$**	**caO**	**$CaCO_3$**	**Al_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

Procedures of Testing

Specimens were prepared in accordance with BS1377:1975. 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 specimens were prepared by adding the required quantity of stabilizer 0,2,4,6, and 8% of lime 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 number of experimental units were prepared for each mix by the same personnel so that strict control on quality could be maintained. Test specimen had dimensions and number as shown in table 3.

Table 3: Details of Specimen size and number tested at various ages and their level of stabilization

Test type	**Specimen size**	**No. of specimens**	**Levels of stabilization**	**Remarks**
Split cylinder (SC)	100mm diameter by 80mm height	60	7,14,21 and 28 days	12.7mm loading strip

The breakdown of specimen into test units is as shown in table 4.

Table 4: Breakdown of Specimen into Test Units

Test method	Lime content %	Age (Days)			
		7	14	21	28
Split cylinder (SC)	0	3	3	3	3
	2	3	3	3	3
	3	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 28^0C. The specimens were stored in plastic containers with moist saw dust to prevent moisture loss during curing period and to preserve the moulding as much as possible.

III. SPLITTING TEST:

The CBR machine was used for the test with some adaptations constructed by the researcher. The CBR machine was used to apply load at rate of 1.25mm per minute as specified by ASTM{11} {12} and [13] Special Testing platens were fabricated to enable the sitting of the penetration piston on the test specimens. The platen or bearing strips are 12.7mm (0.5in) wide and 120mm (4.8in) long. This size was chosen because of the length of the specimen and to conform with the width reported in {17}. The bearing strip were inserted at the top and bottom of the specimen directly on the vertical axis that divide the specimen into two equal halves. To load the specimen, the bearing strips were first positioned and aligned. The plunger of the CBR machine was then made to sit on the upper bearing strip before the load gauge was set on zero. Before loading commenced the initial strain gauge readings were taken, load was continuously applied until failure occurred, the horizontal and vertical tensile strains were measured directly with Demec No 3463 strain gauge {14}, one division of the gauge represents 1.97 x 10^{-5}. This condition set up an almost uniform tensile stress over the vertical diamentrical plane, and fracture splitting of the specimen occurred along the loading plane as shown in fig. 1.

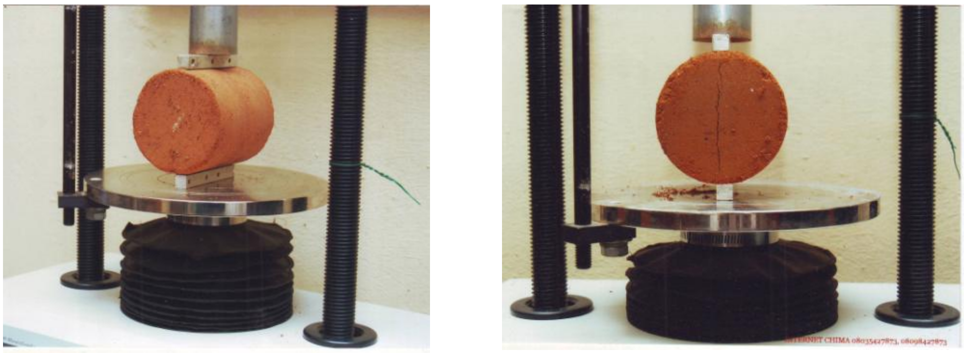


Fig. 1: Loading using the split cylinder indirect tensile testing technique.

The indirect tensile strength at failure is given in the equation

$$\delta t = \frac{2P}{\pi dt} \qquad \text{-- - - - -} \qquad 1$$

Where δt = tensile strength
P = load at failure (N)
D = Diameter (mm)
T = thickness of the specimen (mm)
The compressive strength is given in equation

$$\delta c = \frac{P}{A} \qquad \text{- - - - - -} \qquad 2$$

δc = compressive strength
P = load at failure (N)
A = cross sectional area of specimen (mm)

IV. RESULT AND DISCUSSION

The results for the failure loads with different percentages of lime using the split cylinder is shown in table 5 and the compressive strength in table 6

Table 5: RESULT OF FAILURE LOAD USING THE SPLIT CYLINDER TEST IN (N)

Lime Content %	AGE IN DAYS			
	7	14	21	28
0	350	420	450	320
2	500	560	591	720
4	591	598	620	810
6	527	1210	1638	2132
8	1285	1840	2240	2845

Table 6: RESULT OF COMPRESSIVE STRENGTH

Lime Content %	AGE IN DAYS			
	7	14	21	28
0	450	620	750	950
2	950	1100	1250	1280
4	1289	1295	2010	2103
6	2112	2140	2148	2450
8	2453	2457	2465	2520

Table 7: RESULT OF TENSILE STRENGTH (N/mm^2)

Lime Content %	AGE IN DAYS			
	7	14	21	28
0	0.028	0.033	0.036	0.038
2	0.039	0.044	0.047	0.057
4	0.047	0.048	0.049	0.064
6	0.042	0.096	0.130	0.169
8	0.102	0.146	0.178	0.226

Table 8: RESULT OF COMPRESSIVE STRENGTH (N/mm^2)

Lime Content %	AGE IN DAYS			
	7	14	21	28
0	0.057	0.079	0.095	0.121
2	0.121	0.140	0.156	0.163
4	0.164	0.165	0.256	0.268
6	0.142	0.272	0.272	0.319
8	0.312	0.313	0.314	0.321

The results are the average of at least three tests

Table 9: Ratio of Tensile to compressive strength $\delta t / \delta c$ (%)

Lime Content %	AGE IN DAYS			
	7	14	21	28
0	49.1	41.8	31.9	28
2	32.2	31.4	30.1	35.0
4	28.7	29.1	19.1	24.0
6	26.8	35.3	47.8	53.0
8	32.7	46.6	56.7	70.4

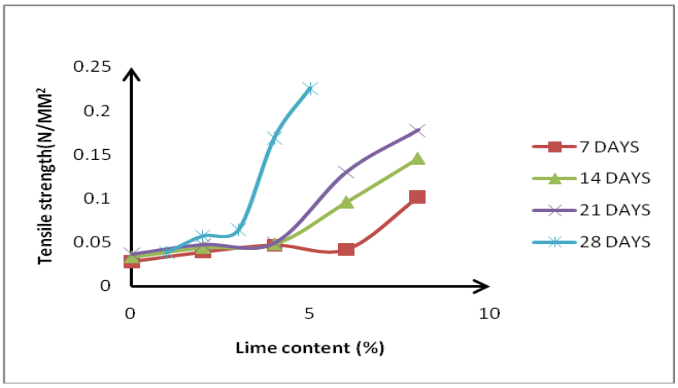


Fig1: Effect of lime on tensile strength

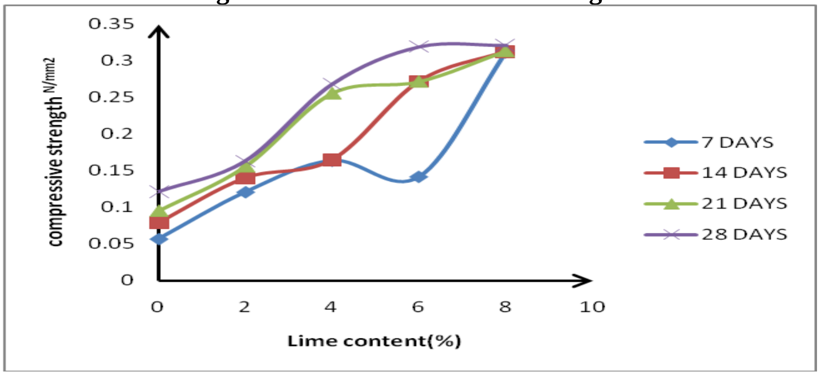


Fig2: Effect of lime on Compressive strength

The tensile strength of the untreated soil is 0.038N/mm^2 in 28days, when 2%, 4%, 6% and 8% of lime was added and specimens cured for 28days, the tensile strength increased to 0.054, 0.064, 0.169 and 0.226N/mm^2, which means that as lime was added with the curing day increased, the tensile strength increased. The increase in the tensile strength with the increase of the percentage of lime is a function of the amount of lime, type of the clay minerals and curing conditions. Similar behaviour was found in compressive strength with the same percentages of lime. The sharp reduction in tensile strength when the soil is treated with 6% lime and cured for 7 days is simply because of the extra lime that is acting as a filter material with the short curing period. This extra lime is the result of the uncompleted reaction in 7days between lime and clay minerals as observed by {8}and{15}. Similar behaviour was observed in compressive strength with the same percentage of lime, also the values started converging at 8% irrespective of the number of days of curing and for the compressive strength there is an indication of convergence to a peak value as lime content increases from 6% to 8%, this means that although an increase in lime content increases the compressive strength irrespective of the number days curing except for the drop noticed in the 7days curing strength . There is an indication that beyond the lime content of 8% the compressive strength is independent table(7)fig1 and table(8)fig2 .

Table 10: Increasing percentage of tensile strength and compressive strength of stabilized soil under different curing conditions and lime contents.

Lime content (%)	Tensile strength N/mm^2				Increasing tensile strength	Compressive strength N/mm^2				Increasing tensile strength
	Age Days					Age Days				
	7	14	21	28		7	14	21	28	
0	0.028	0.033	0.036	0.038	25.7	0.057	0.079	0.095	0.121	12.3
2	0.039	0.044	0.047	0.057	46.2	0.121	0.140	0.156	0.163	34.7
4	0.047	0.048	0.049	0.064	36.2	0.164	0.165	0.256	0.268	63.4
6	0.042	0.096	0.130	0.169	134.7	0.142	0.272	0.272	0.319	18.6
8	0.102	0.146	0.178	0.226	121.6	0.312	0.313	0.314	0.321	12.0

The effect of lime on the tensile strength (δt) and compressive strength (δc) can be visualized by considering the ratio ($\delta t / \delta c$) as shown in table (9). For 0% the ratio is 31.4% at 28 days. When lime is added and the specimen cured for 28 days the ratio become 35.0, 24.0, 53.0 and 70.4% for 2,4,6 and 8% of lime respectively, this means that the relative increment of increase in tensile strength is more than that in compressive strength for 2%, 6% and 8% while for 4% lime the relative increment in compressive strength is more than that in tensile strength.

The percentage of increase in tensile strength and compressive with respect to untreated soil are shown in table 10. This table shows that the tensile strength is generally more sensitive to the lime than the compressive strength

Table 11: Load, stress and strain Deformation result for 0% lime content cured for:

7DAYS			14DAYS			21DAYS			28DAYS		
Load (N)	**Stress N/mm^2**	**Strain x 10^{-5}**	**Load (N)**	**Stress N/mm^2**	**Strain x 10^{-5}**	**Load (N)**	**Stress N/mm^2**	**Strain x 10^{-5}**	**Load (N)**	**Stress N/mm^2**	**Strain x 10^{-5}**
25	0.0019	0.16	65	0.0034	0.47	72	0.0057	0.66	65	0.0052	0.47
29	0.0023	0.19	68	0.0044	0.49	75	0.0059	0.71	68	0.0054	0.49
32	0.0033	0.20	72	0.0044	0.51	76	0.006	0.73	72	0.0057	0.56
41	0.0033	0.23	77	0.0052	0.55	82	0.0065	0.79	77	0.0061	0.61
43	0.0034	0.28	79	0.0056	0.67	85	0.0068	0.85	79	0.0063	0.73
47	0.0037	0.29	81	0.0058	0.69	90	0.00716	0.9	81	0.0064	0.88

Table 12: Load, stress and strain Deformation result for 2% lime content cured for:

7DAYS			14DAYS			21DAYS			28DAYS		
Load (N)	**Stress N/mm^2**	**Strain x 10^{-5}**	**Load (N)**	**Stress N/mm^2**	**Strain x 10^{-5}**	**Load (N)**	**Stress N/mm^2**	**Strain x 10^{-5}**	**Load (N)**	**Stress N/mm^2**	**Strain x 10^{-5}**
78	0.0062	0.76	96	0.0076	0.99	380	0.0302	1.41	920	0.0732	3.1
82	0.0065	0.79	110	0.0088	1.12	430	0.0342	1.91	931	0.0741	3.21
95	0.0076	0.85	118	0.0094	1.21	470	0.0374	2.20	941	0.0749	3.33
97	0.0077	0.88	124	0.0099	1.29	491	0.0391	2.25	961	0.0764	3.43
99	0.0079	0.95	127	0.0101	1.31	525	0.0418	2.51	971	0.0773	4.21
104	0.0083	0.96	133	0.0106	1.33	550	0.0438	2.60	979	0.0778	4.35

Table 13: Load, stress and strain Deformation result for 4% lime content cured for:

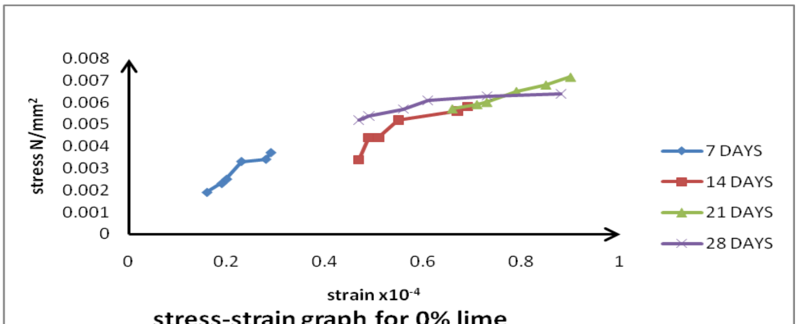
7DAYS			14DAYS			21DAYS			28DAYS		
Load (N)	**Stress N/mm^2**	**Strain x 10^{-5}**	**Load (N)**	**Stress N/mm^2**	**Strain x 10^{-5}**	**Load (N)**	**Stress N/mm^2**	**Strain x 10^{-5}**	**Load (N)**	**Stress N/mm^2**	**Strain x 10^{-5}**
1151	0.0916	5.01	1236	0.0983	5.02	1403	0.1116	4.62	1592	0.1267	4.91
1163	0.0925	5.21	1248	0.0993	5.30	1421	0.1131	4.85	1598	0.1271	5.26
1171	0.0932	5.63	1296	0.1031	5.41	1433	0.1140	5.33	1618	0.1287	5.85
1181	0.0939	6.03	1312	0.1043	5.62	1441	0.1147	5.74	1622	0.1291	6.42
1191	0.0947	6.21	1325	0.1054	6.66	1472	0.1171	6.34	1635	0.1301	6.56
1197	0.0952	6.36	1342	0.1068	6.71	1531	0.1218	6.81	1643	0.1307	7.47

Table 14: Load, stress and strain Deformation result for 6% lime content cured for:

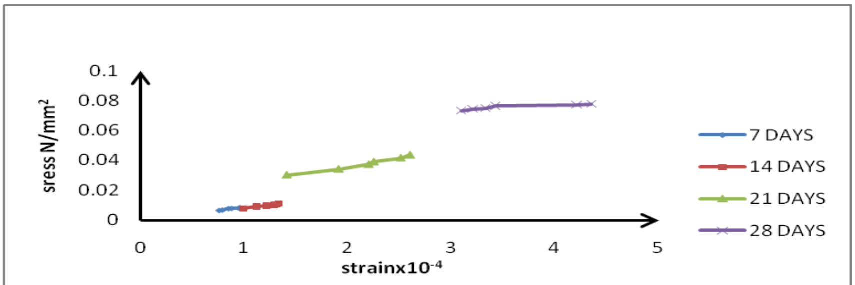
7DAYS			14DAYS			21DAYS			28DAYS		
Load (N)	**Stress N/mm^2**	**Strain x 10^{-5}**	**Load (N)**	**Stress N/mm^2**	**Strain x 10^{-5}**	**Load (N)**	**Stress N/mm^2**	**Strain x 10^{-5}**	**Load (N)**	**Stress N/mm^2**	**Strain x 10^{-5}**
1651	0.1314	4.61	1720	0.1369	3.84	1741	0.1385	3.97	1900	0.1432	4.04
1658	0.1319	4.96	1723	0.1371	4.44	1756	0.1397	4.49	1821	0.1449	5.30
1664	0.1324	5.41	1725	0.1373	4.82	1759	0.1399	5.73	1826	0.1453	6.73
1668	0.1327	6.53	1728	0.1375	5.72	1766	0.1405	5.86	1830	0.1456	7.91
1673	0.1330	7.31	1731	0.1379	5.91	1775	0.1412	6.56	1841	0.1465	8.60
1683	0.1339	7.65	1734	0.1379	6.42	1783	0.1418	7.35	1850	0.1473	8.95

Table 15: Load, stress and strain Deformation result for 8% lime content cured for:

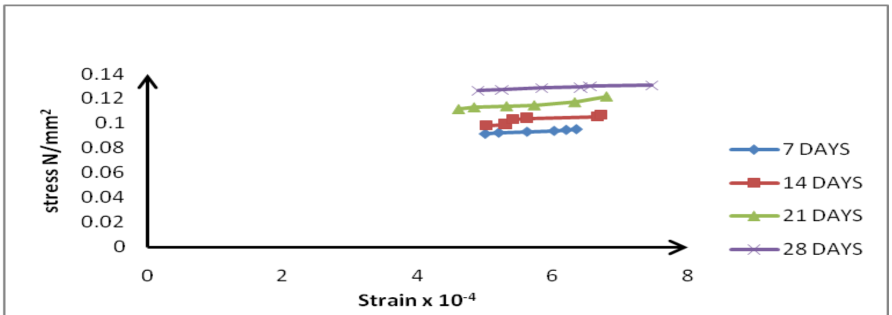
7DAYS			14DAYS			21DAYS			28DAYS		
Load (N)	**Stress N/mm^2**	**Strain x 10^{-5}**	**Load (N)**	**Stress N/mm^2**	**Strain x 10^{-5}**	**Load (N)**	**Stress N/mm^2**	**Strain x 10^{-5}**	**Load (N)**	**Stress N/mm^2**	**Strain x 10^{-5}**
1915	0.1542	4..98	1995	0.1587	5.25	2090	0.1662	5.20	2141	0.1704	5.42
1918	0.1526	5.68	1998	0.1589	6.80	2096	0.1667	6.75	2148	0.1709	7.43
1923	0.1530	6.15	2013	0.1602	7.91	2110	0.1678	9.40	2156	0.1705	8.60
1927	0.1533	7.90	2018	0.1606	8.93	2114	0.1682	12.02	2160	0.2749	10.21
1933	0.1538	8,20	2026	0.1612	9.64	2119	0.1686	12.90	2166	0.2757	11.65
1938	0.1542	8.95	2031	0.1616	10.21	2112	0.1688	13.20	2174	0.5535	14.01



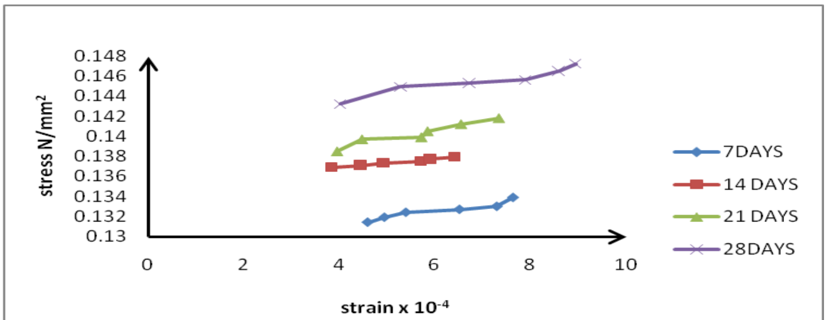
stress-strain graph for 0% lime



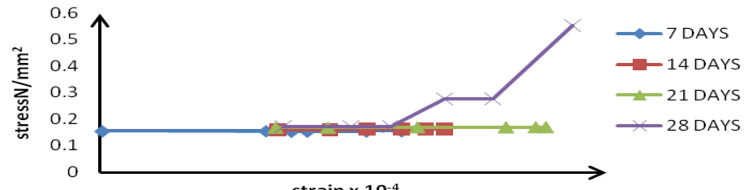
stress-strain graph for 2% lime



stress-strain graph for 4% lime



stress-strain graph for 6% lime



stress-strain graph for 8% lime

The value of tensile stresses and strains that occurred when the split cylinder was loaded were used to draw the stress-strain curve for both the untreated and lime stabilized specimens as shown in table 11-15 and (fig 3-fig 7). In general the curves of the stress strain for 0% and 8% are irregular for their various days and some regularity was observed for 2, 4, 6%. The reason for the irregularity could be attributed to the loading pattern and the amount of load that occurred on the specimen, also the loads were increasing as the stresses and strains were also increasing for all the lime contents.

V. CONCLUSIONS

The following conclusions can be drawn from this study:

1. The tensile strength of the stabilized materials increases with the addition of lime. The increments of increasing ranged from 25.2 to 121.6 percents, while the increments in the compressive strength range from 12.3 to 120.1 percent using the splitting test.
2. Increasing the curing time of lime improves the compressive strength more than the tensile strength.
3. The tensile stress-strain curves was regular at 2, 4, and 6% but became irregular at 0 and 8% lime content.
4. The $\frac{\delta t}{\delta c}$ ratio also increases as the age of curing increases.
5. Increasing loads caused increased in both tensile stress and tensile strain of both the natural and stabilized specimens.

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