INFLUENCE OF SPECIMEN GEOMETRY ON THE STRENGTHS OF LATERIZED CONCRETE

Felix F. Udoeyo[1], Robert Brooks[2], Philip Udo-Inyang[3] & Alonge M. Kehinde[4]

[1, 2, 3]Dept. of Civ. & Environ. Engineering, Temple University, 1947 N. 12th Street, Philadelphia, PA 19122, USA.
[4]Formerly, Student, Civ. Engrg. Dept., Univ. of Uyo, P. M. B. 1017, Uyo, Akwa Ibom State.

ABSTRACT

This paper presents the results of an experimental program that investigates the influence of specimen geometry on the compressive and split tensile strength of laterized concrete (LATCON). Four cylinder sizes were considered for the investigations: Ø150 mm × 300 mm, Ø150 mm × 250 mm, Ø100 mm × 200 mm and Ø100 mm × 100 mm. Analysis of variance tests showed that specimen geometry had significant impact on the strength of LATCON. The results further revealed that the average conversion factor (ratio of 28 days strength of non-standard cylinder to the strength Ø150 mm x 300 mm standard cylinder) was 0.90 to 1.18 for compressive strength and 0.46 to 0.91 for split tensile strength. A regression model using the data obtained in this study is also proposed to relate the 28-day strength of Ø100 mm x 100 mm nonstandard cylinder to that of Ø150 mm × 300 mm standard cylinders.

Keywords: *Influence of specimen geometry, Compressive strength, Split tensile strength Laterized concrete, Regression model*

1. INTRODUCTION

It is sometimes inevitable that non-standard specimens are used when evaluating concrete strength. One such instance is when assessing the strength of existing structures, when specimens of Ø100 mm × 100 mm are cored and tested for compressive strength. The most common test carried out on concrete is compressive strength. This test is easy and relatively inexpensive to carry out [1] Mindess. Many research findings relating the strength of non-standard plain concrete specimens to standard specimens have been published [2-5]. Conversion factors for relating the strength of non-standard plain concrete specimens to standard cylinders of size Ø150 mm × 300 mm based on some of these studies are provided in ASTM C 42 (1984) and BS 1881: Part 120 (BSI 1983). Little or no data exist in this regard with respect to laterized concrete (LATCON), a concrete containing laterite as a partial or full replacement for sand in the matrix. This experimental program was designed to study the effect of specimen geometry on the strengths of LATCON.

It is hoped that the results reported here together with the findings in other subsequent studies will assist in the development of guidelines for interpreting the strengths of non-standard LATCON specimens.

2. EXPERIMENTAL WORK

2.1 Materials

The "Eagle brand" of ordinary Portland cement was used for the production of concrete. This brand of cement has a medium hardening rate and is, according to the Nigerian Institute of Standards (NIS), suitable for most concrete work. The river sand used was obtained through a local supplier and had a specific gravity of 2.6. The Laterite used had a specific gravity of 2.53, and was obtained within the premises of the Federal University of Technology, Owerri (FUTO), conveyed in bags and stored in the Material/Structure laboratory of the university. The sieve analysis of the sand and laterite are presented in Table 1. The chemical composition of the Laterite which was analyzed by EMSL Analytical Inc in Westmont, New Jersey, U.S.A, is presented in Table 2. Granite with a specific gravity of 2.7 was used as coarse aggregate. The water used for the production of test specimens was a clean and colorless tap water.

2.2 Test Methods

A concrete mix proportion of 1: 1.8: 3.7: 0.50(cement: sand: coarse aggregate: water-cement ratio) was used for this investigation. The constituents were batched by weight and mixed manually. After the sand in each batch was replaced with 0, 10, 20, 30, 40 and 50% laterite, a pre-calculated amount of water was added and the whole lot mixed thoroughly until a homogeneous concrete was obtained. Prefabricated moulds of the required specimen sizes were oiled lightly. The prepared concrete was then poured into the moulds. The test cylinders were stripped from the moulds after 24 hours and then submerged in a tank with water maintained at 20 – 23°C. A total of 288 specimens were produced and tested according to BS 1881, 1970.

3. RESULTS and ANALYSIS

A one-way analysis of variance (ANOVA) test was conducted to evaluate the influence of specimen geometry on the strengths of LATCON. The specimen geometry was considered the source of variation, the independent variable, while the compressive or split tensile strength was the dependent variable. The null hypothesis selected for the analysis was that the strengths of LATCON specimens do not depend on the specimen geometry. This hypothesis was rejected if the calculated variance ratio was greater than the tabulated value at p less than 0.05.
The results of the compressive and split tensile strengths of LATCON and plain concrete at the ages of 14 and 28 days for the specimen geometries are presented in Fig. 1, 2, 3 and 4. Each point of the plot is the average of the results of three identical test samples. For the non-standard cylinder the highest compressive strength was exhibited by Ø100 mm × 100 mm cylinders, with values ranging from 32.0 to 37.5 MPa for the 14 days strength and from 37.2 to 39.5 MPa for the 28 days strength. The lowest compressive strength was obtained for the Ø100 mm × 200 mm cylinders, with values ranging from 26.0 to 33.6 MPa for the 14 days strength and 29.0 to 34.0 MPa for the 28 days strength. The compressive strength of the standard cylinders ranged from 31.2 to 34.3 MPa for the 14 days strength and from 31.6 to 34.5 MPa for the 28 days strength. The trend observed for the split tensile strength was almost a reversal of that for the compressive strength with higher strength values determined for the longer specimens. The ANOVA tests presented in Tables 3, 4, 5 and 6 show that specimen geometry had a significant effect on the strengths of LATCON. The computed least significant differences (LSD) at p = 0.05 (see Table 7) show that both diameter and cylinder length had a significant impact on the strength of LATCON. The compressive strength of Ø100mm × 100 mm and Ø150 mm × 250 mm cylinders were higher than the strength of Ø150 mm × 300 mm standard cylinders in the range 15 to 18 % and 4 to 5 %, respectively, depending on the replacement level of sand by laterite. The compressive strength of the Ø100 mm x 200 mm cylinder was lower than that of the standard cylinder in the range 1 to 10 %. This finding on the strength of Ø100 mm× 200 mm cylinders as it relates to the standard cylinder contradicts the weakest link theory proposed by Weibull [6], which states that specimens with larger volumes are most likely to contain defects and therefore fail at lower stresses.

Presented in Fig. 5 and 6 are the 28 days strengths of non-standard LATCON specimens relative to those of standard Ø150 mm × 300 mm cylinders. Each point of the plot, the average of three test results, could be used as a conversion factor during the interpretation of the strength of non-standard specimens. Based on the data generated in this study the following regression model can be used to relate the strengths of nonstandard Ø100 mm × 100 mm LATCON specimens to those of Ø150 mm × 300 mm standard cylinders at 28 days. The model may also be useful when coring laterized concrete (also see Fig. 7 and 8 for the relationship).
For compression:

$$(f_c)_{100 \times 100} = 0.81(f_c)_{150 \times 300} + 11.64 \qquad (R^2 = 0.996) \text{ ------------------------------(1)}$$

For split tension:

$$(f_t)_{100 \times 100} = 1.11(f_t)_{150 \times 300} - 2.75 \qquad (R^2 = 0.949) \text{---------------------------- -(2)}$$

in which f_c and f_t are the cylinder compressive and split tensile strength in MPa, respectively; the subscript denote the size of the specimens in mm; and R is the correlation coefficient.
Specimen size effect on measured strength is an ongoing research topic with current interest and room for debate. The contribution of this paper comes from data presented regarding size effects that appear to differ from those exhibited by ordinary concretes specimens. Replacement of regular sand in concrete with laterite (LATCON) has received attention in research studies, particularly in regions where laterite is plentiful, such as India [7-10]. Conclusions of these papers are in agreement with those of this study, which state that compressive strength and split tensile strength of non-standard cylinders are comparable in magnitude to that of standard ones while the variation in split strength is significantly more than that of compressive strength.

3.1. Comparison of the Strength of LATCON and Plain Concrete

A comparison of the strength of LATCON and that of the plain concrete using the computed LSD (p = 0.05) in Table 7 will show that Ø100 × 200 cylinders had the highest significant differences between the 28 days strength of LATCON and plain concrete. As could be observed in Fig. 9 the compressive strength of LATCON specimen of the aforementioned geometry relative to those of plain concrete was between 0.853 and 0.988. The difference between the split tensile strength of LATCON and plain concrete was highest for Ø150 mm × 250 mm cylinders. From Fig.

10 it could be seen that the strength of LATCON of Ø150 mm × 250 mm cylinders relative to the strength of plain concrete specimen of the same geometry was from 0.630 to 0.969.

4. CONCLUSIONS

Based on the results of this experimental program and the ANOVA test conducted on the generated data it could be concluded that specimen geometry had a significant influence on the strengths of laterized concrete. The ratio of the 28 days compressive strength of non-standard cylinders compared to that of standard Ø150 mm × 300 mm cylinders varied from 0.90 to 1.18, while the split tensile strength varied from 0.46 to 0.91 for the investigated replacement levels of sand by laterite. A regression model relating the compressive strength of Ø100 mm × 100 mm to those of standard cylinder has also been proposed for use in the interpretation of cored LATCON.

5. REFERENCES

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Table 1. Grain Size Distribution of Sand and Laterite

Sieve Size (mm)	Percentage Passing	
	Sand	Laterite
2,36	95.2	93.7
1.18	51.4	82.4
600 micron	16.2	63.35
425 micron	7.6	51.4
300 micron	4.6	43.35
212 micron	3.0	37.25
150 micron	1.8	31.60
75 micron	-	24.85

Table 2. Physical and Chemical Properties of Laterite

Properties	Value
Moisture content (%)	0.22
Specific gravity	2.53
Loss on ignition	0.93
Chemical composition (%)	
SiO_2	77.80
Al_2O_3	18.40
Fe_2O_3	2.38
TiO_2	0.82
K_2O	0.13
MgO	0.13
P_2O_5	0.10
Cr_2O_3	0.09
SO_3	0.09
CaO	0.04
ZrO_2	0.03
MnO	0.01
ZnO	0.01

Table 3. ANOVA Results of 28 days Compressive Strength of LATCON and Plain Concrete

SV	DF	SS	MS	VR
Specimen geometry:				
0 % Replacement	3	55.28	18.43	705.17**
10 % Replacement	3	54.09	18.03	1326.00**
20 % Replacement	3	102.16	34.05	2115.20**
30 % Replacement	3	100.14	33.38	959.22**
40 % Replacement	3	116.79	38.93	1256.00**
50 % Replacement	3	104.82	34.82	2080.00**

SV = source of variation; DF = degree of freedom; SS = sum of square; MS = mean sum of square; VR = variance ratio; **$p \leq 0.001$

Table 4. ANOVA Results of 14 days Compressive Strength LATCON and Plain Concrete

SV	DF	SS	MS	VR
Specimen geometry:				
0 % Replacement	3	10.54	18.43	1.19 n.s
10 % Replacement	3	43.95	18.03	765.38**
20 % Replacement	3	137.25	45.75	3660.00**
30 % Replacement	3	104.77	34.92	6716.00**
40 % Replacement	3	88.81	29.60	1558.00**
50 % Replacement	3	192.80	64.27	5021.00**

SV = source of variation; DF = degree of freedom; SS = sum of square; MS = mean sum of square; VR = variance ratio; n.s = not significant; **$p \leq 0.001$

Table 5. ANOVA Results of 28 days Split Tensile Strength of LATCON and Plain Concrete

SV	DF	SS	MS	VR
Specimen geometry:				
0 % Replacement	3	8.71	2.90	4838.00**
10 % Replacement	3	8.17	2.72	4539.00**
20 % Replacement	3	8.56	2.85	3170.44**
30 % Replacement	3	8.82	2.94	9805.00**
40 % Replacement	3	8.31	2.77	1385.00**
50 % Replacement	3	8.06	2.69	2441.45**

SV = source of variation; DF = degree of freedom; SS = sum of square; MS = mean sum of square; VR = variance ratio; $^{**}p \leq 0.001$

Table 6. ANOVA Results of 14 days Split Tensile Strength of LATCON and Plain Concrete

SV	DF	SS	MS	VR
Specimen geometry:				
0 % Replacement	3	10.83	3.61	2579.00**
10 % Replacement	3	10.25	3.42	1178.00**
20 % Replacement	3	10.08	3.36	2239.00**
30 % Replacement	3	8.62	2.87	7179.00**
40 % Replacement	3	9.55	3.18	1061.00**
50 % Replacement	3	8.79	2.93	1222.00**

SV = source of variation; DF = degree of freedom; SS = sum of square; MS = mean sum of square; VR = variance ratio; $^{**}p \leq 0.001$

Table 7. Least Significant Differences (LSD) among Specimen Strengths

Strength (N/mm^2)	Laterite content (%)					
	0	10	20	30	40	50
28 days compression	0.69	0.50	0.54	0.80	0.75	0.56
14 days compression	7.39	0.59	0.48	0.31	0.59	0.49
28 days split tension	0.10	0.10	0.13	0.07	0.19	0.14
14 days split tension	0.16	0.23	0.16	0.09	0.24	0.21

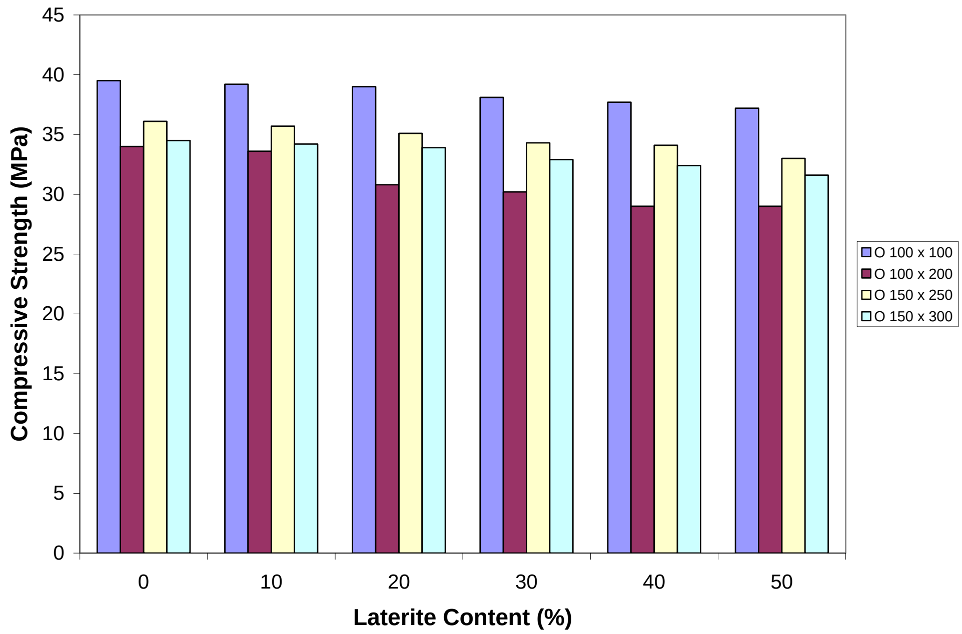

Fig. 1. Twenty eight days compressive strength of LATCON and plain concrete

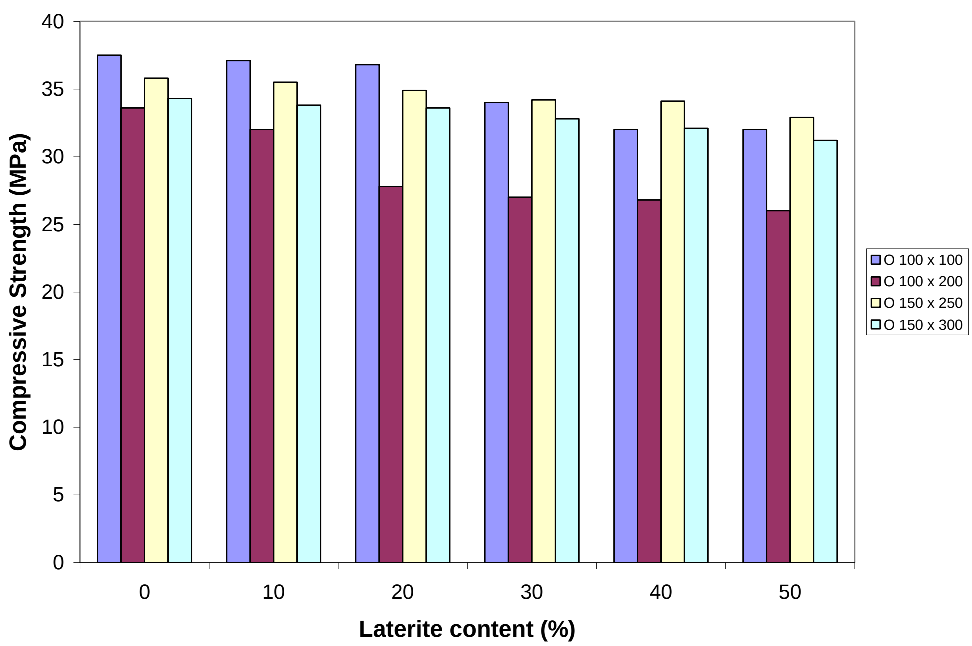

Fig. 2. Fourteen days compressive strength of LATCON and plain concrete of various geometry.

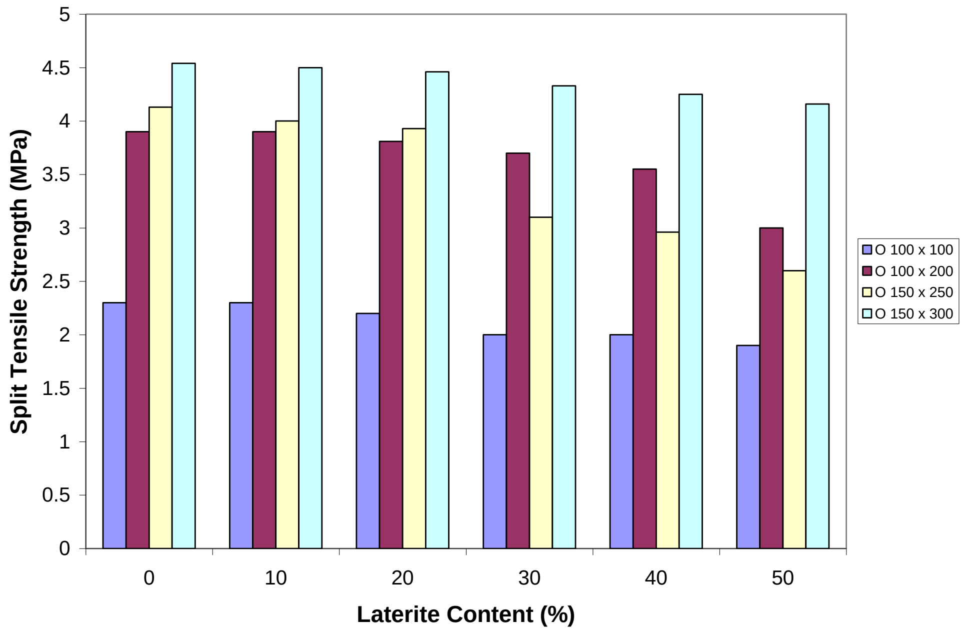

Fig. 3. Twenty eight days split tensile strength of LATCON and plain concrete

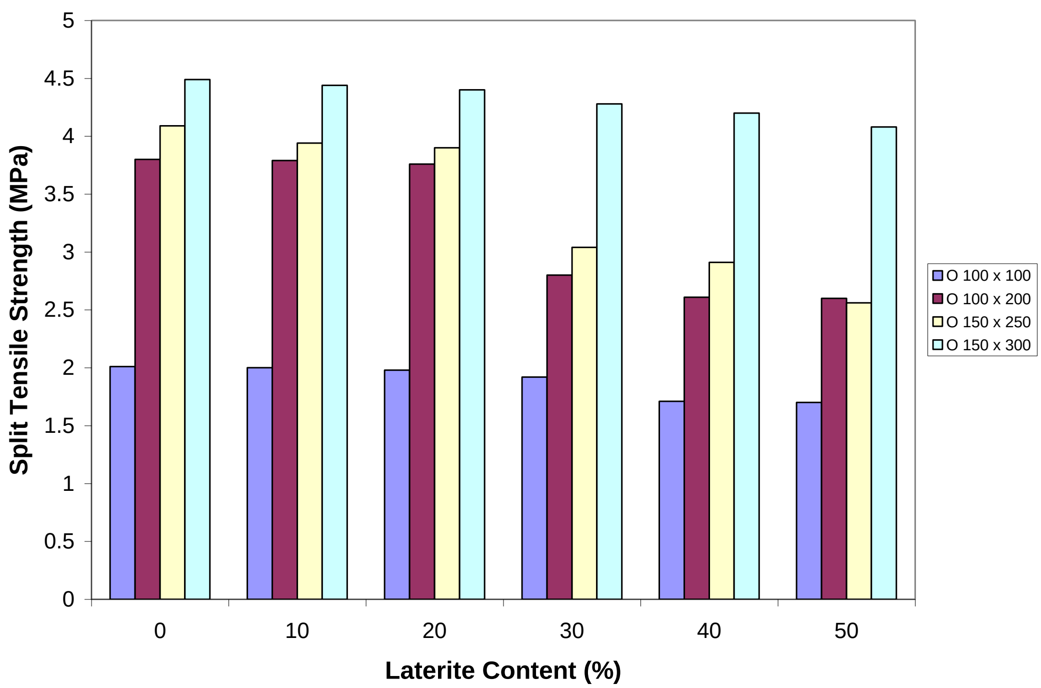

Fig. 4. Fourteen days split tensile strength of LATCON and plain concrete

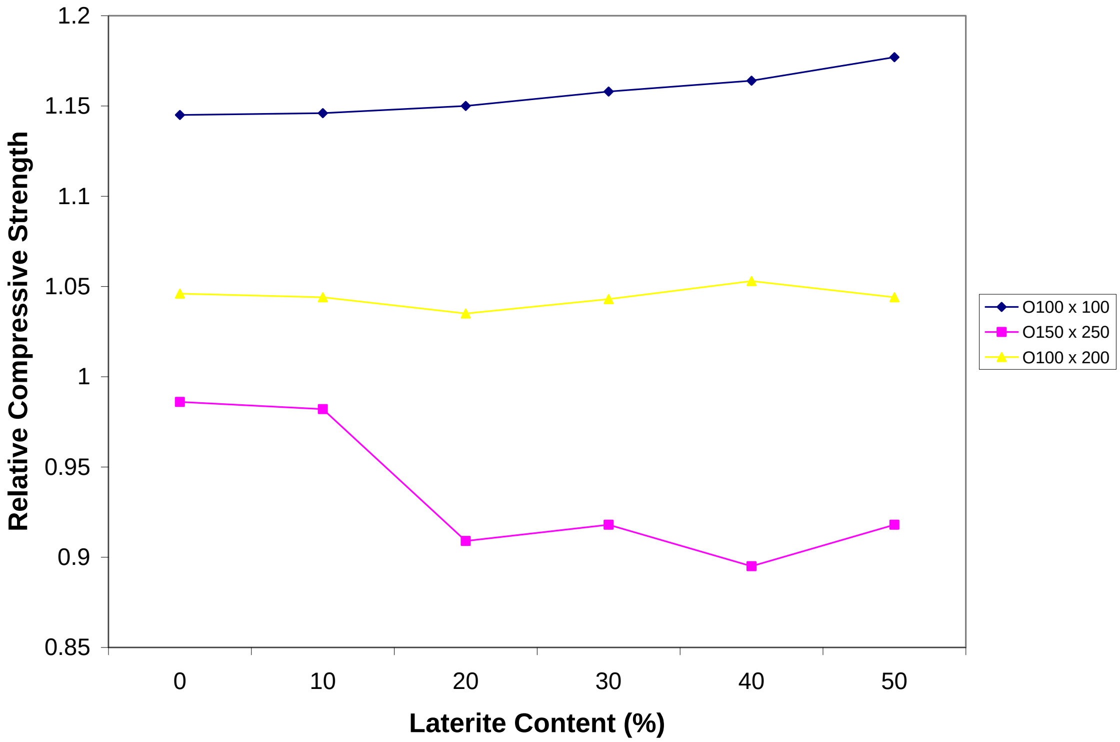

Fig. 5. Compressive strength of non-standard LATCON and plain concrete specimens relative to the strength of Ø150mm × 300mm standard cylinders

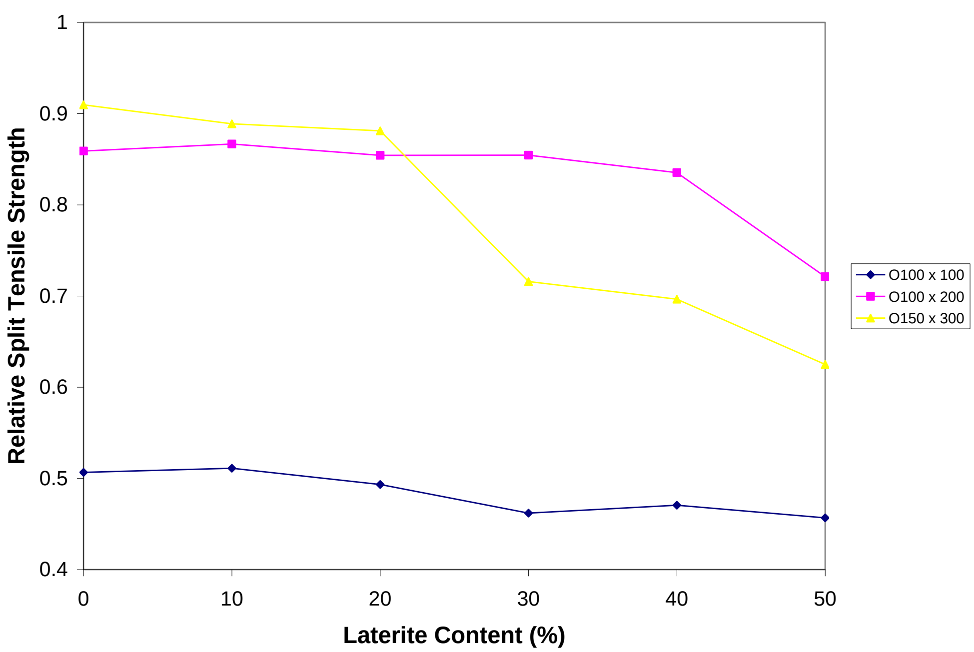

Fig. 6. Twenty eight days split tensile strength of non-standard LATCON and plain concrete specimen relative to the strength of Ø150 mm x 300 mm standard cylinder

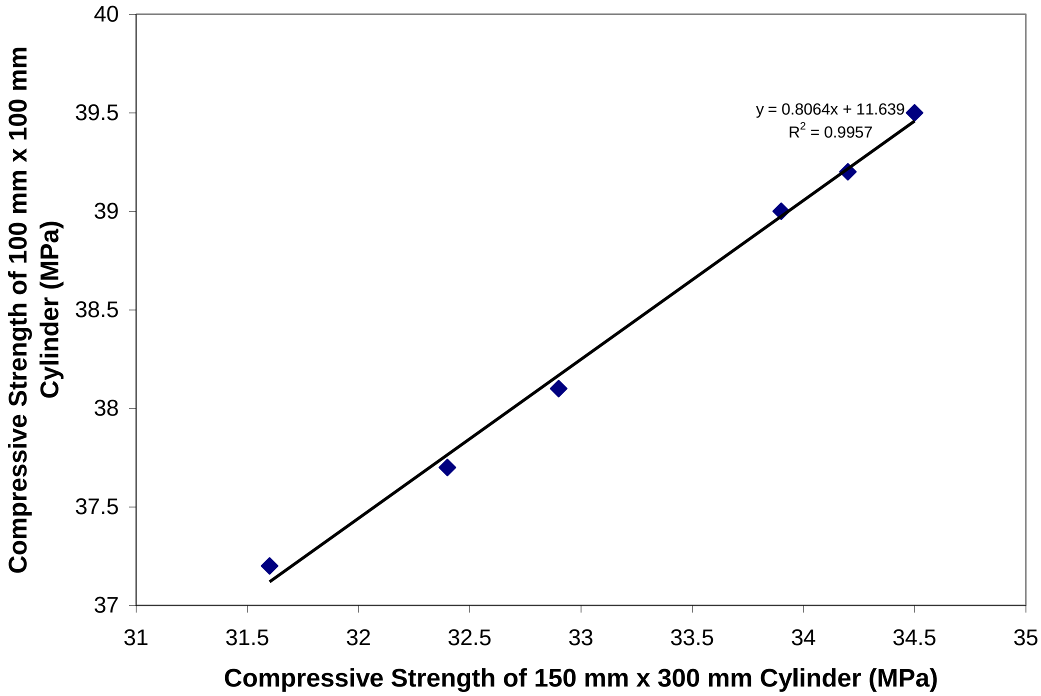

Fig. 7. Relationship between mean 28 days compressive strengths of Ø100 mm ×100 mm cylinders and Ø150 mm × 300mm standard cylinders

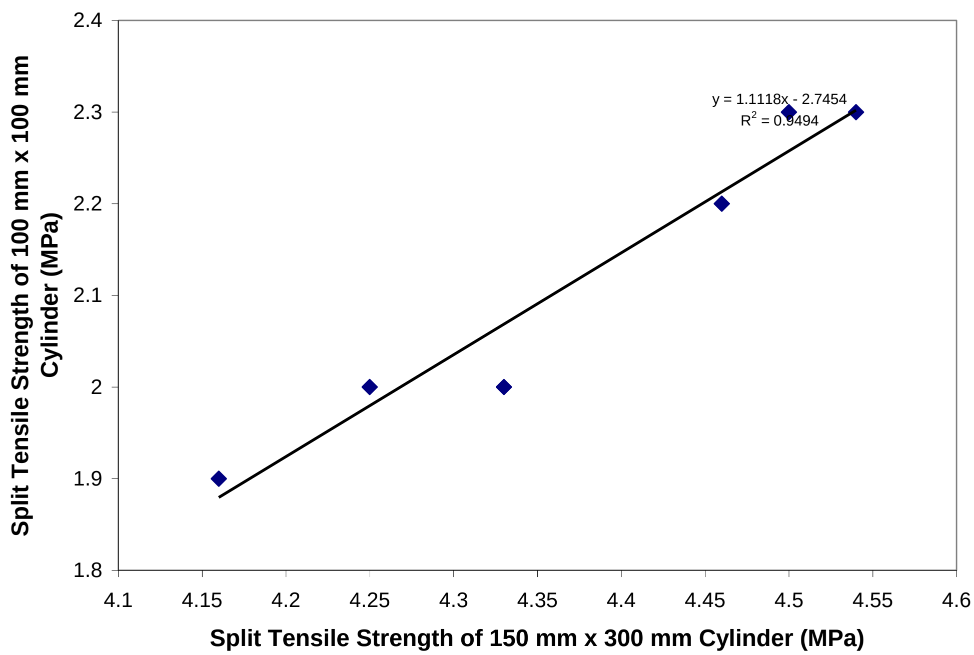

Fig. 8. Relationship between mean 28 days split tensile strengths of Ø100 mm ×100 mm cylinders and Ø150 mm × 300mm standard cylinders

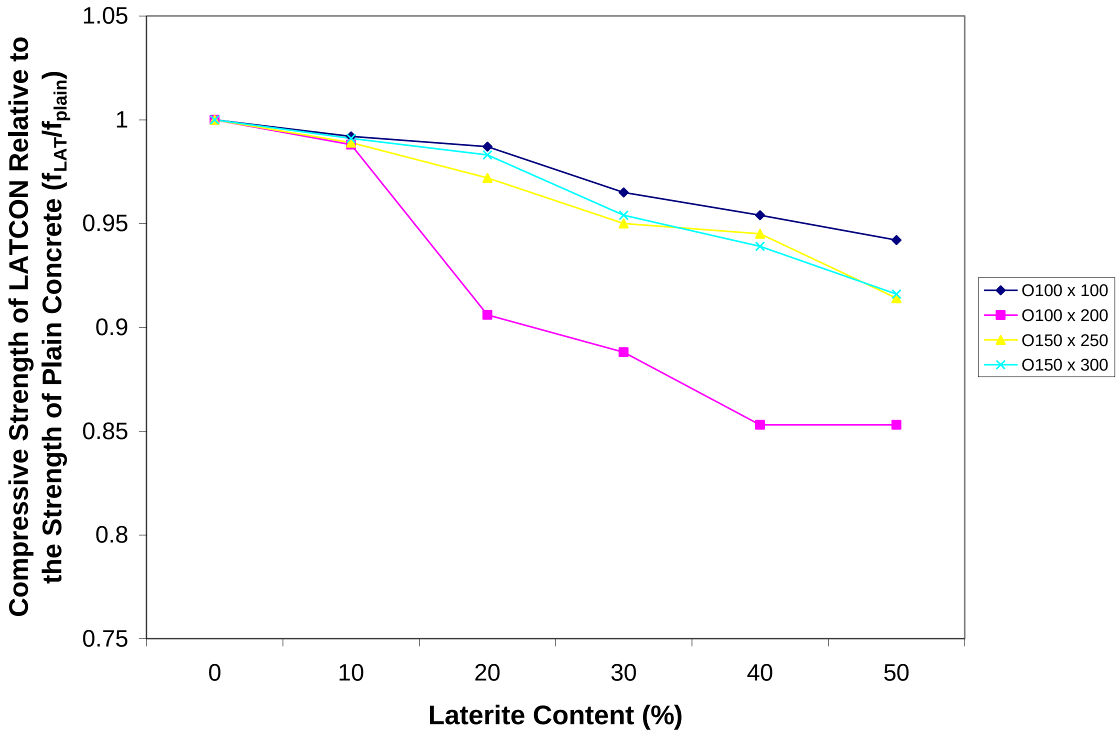

Fig. 9. Twenty eight day compressive strength of LATCON relative to the strength of plain concrete.

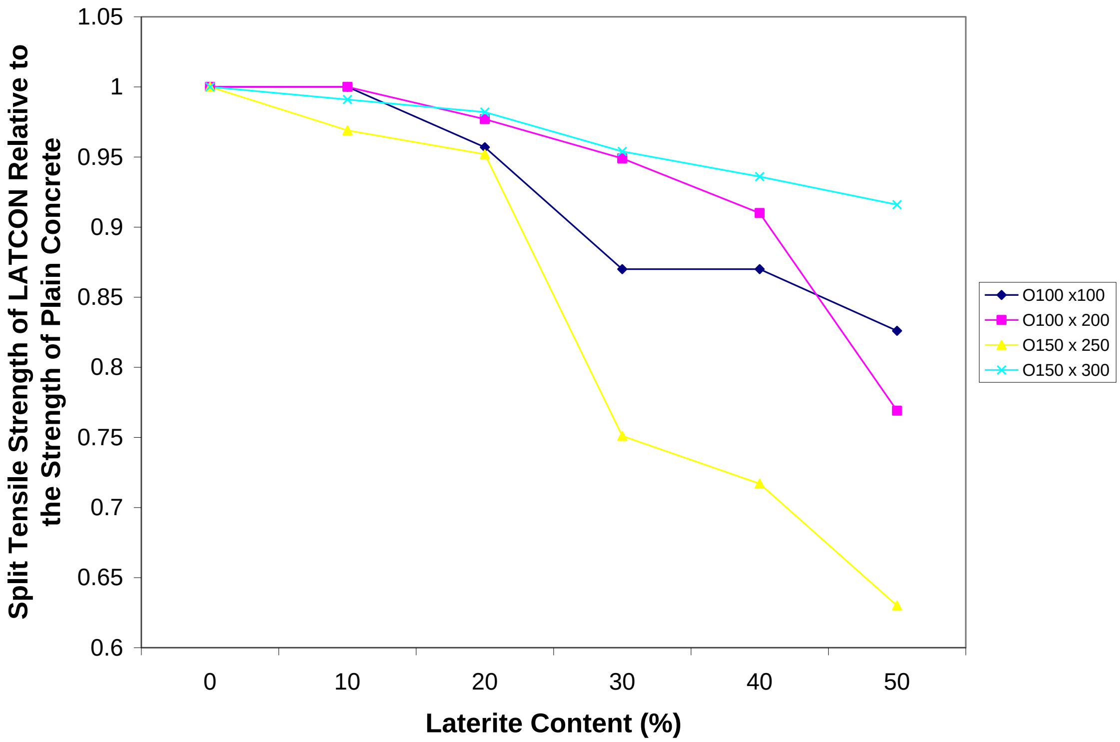

Fig. 10. Twenty eight day split tensile strength of LATCON relative to the strength of plain concrete