EARLY PREDICTION OF LATERIZED CONCRETE STRENGTH BY ACCELERATED TESTING

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ABSTRACT

This paper presents the results of a laboratory investigation on the efficiency of the boiling water method of accelerated strength testing to predict the 28-day compressive strength of laterized concrete (concrete containing laterite as full or partial replacement of sand). The results of the work showed that the accelerated strength of the concrete was between 72 and 84% of its 28 days strength. A regression model relating the accelerated strength to the 28-day compressive strength based on the generated data is herein proposed as a power equation for use by engineers and other construction professionals for quality control and early strength assessment during construction of civil engineering infrastructure involving laterized concrete.

Keywords: *Accelerate strength, Laterized concrete, Regression model*

1. INTRODUCTION

The criterion for concrete strength requirement is always based on the characteristic compressive strength obtained after 28-day curing. This delay in testing of concrete seriously limits the control of the matrix during production and hampers quality assurance at early ages [1]. The use of a reliable accelerated strength testing method would add in no small measure to a better control over the properties of concrete in the field by enabling the concrete engineer to make necessary adjustment during proportioning of concrete early enough to avoid the production of sub-standard concrete [2]. The current speedy construction due to improved and innovative construction methods also calls for the potential strength of concrete to be determined at the earliest possible time after concrete has been placed [3]. Three standardized accelerated strength testing procedures given in ASTM C684-99 (2003) have been used both for a better control of concrete quality during production and also for the prediction of later-age strength. A description of these procedures, their advantages and limitations as summarized by Malhotra et al. [2] are presented in Table 1.

Table 1. ASTM Procedures for accelerated strength testing

Method	Procedure	Advantages	Limitations
Warm Water	Standard test cylinders in their molds are placed in water bath immediately after casting and maintained at 35°C (95°F) for a period of 24 h	1. Equipment is simple 2. Test results are available at 25 h	1. There is a need for overtime. 2. Strength gain, as compared with 24 h old normal moist-cured cylinders, is not high
Boiling water	Standard cylinders are moist-cured for 24 h and then cured in a water bath at 100°C (212°F) for 3.5 h and tested 1 h later, giving a total 28.5 h.	1. Equipment is simple and actual accelerated curing period is short. 2. Strength gain, as compared with 28.5 h old normal cured cylinders, is higher	1. There is need for overtime. 2. There is a possibility that products of hydration of cement may be slightly different from those obtained by normal moist-curing of cylinders.
Autogenous	Test cylinders immediately after casting are placed in insulated containers and are tested 48 to 49 h later.	1. There is no need for a site laboratory. 2. There is no need for external heat source	1. This is the least accurate of the three test methods. 2. The strength gain, as compared with normal 48 h moist-cured cylinders, is no high. 3. There is need for excessive overtime.

The results of a laboratory experimental program to investigate the efficiency of the Boiling water method of accelerated strength testing to predict the 28-day strength of laterized concrete is reported in this paper. Laterized concrete is a concrete containing laterite as a partial or full replacement for sand. This concrete holds quite a bright future wide-application in construction as indicated by several research findings [4-9].

2. JUSTIFICATION FOR THIS WORK

The need for early assessment of the strength of concrete to avoid the production of substandard structures with low structural integrity cannot be over-emphasized. The accelerated strength testing method has been very useful in this regard. This research work focuses on the use of the afore-mentioned method to develop a predictive model for the strength of laterized concrete. The novelty of this work stems from the fact that this is the first time an attempt has been made to develop such a model for the concrete.

3. MATERIALS

All the materials used for this work confirmed with the British Standards [10-14]. The cement used was ordinary Portland cement conforming to type 1 cement specified in BS 12:1978. The cement was purchased in bags of 50kg and transported to the Structures/Materials Laboratory of the Department of Civil Engineering, Cross River University of Technology (CRUTECH), Calabar, Nigeria. The fine aggregate was sharp river sand, while the coarse aggregate was crushed granite of maximum size 25 mm. Both aggregates complied with the requirements of BS 882. The laterite soils used was from a borrow pit located in the Calabar environ of Cross River State. The laterite was transported and stored in the laboratory before use. The grain size distributions of particles of the sand and of the laterite used are shown in Fig. 1.

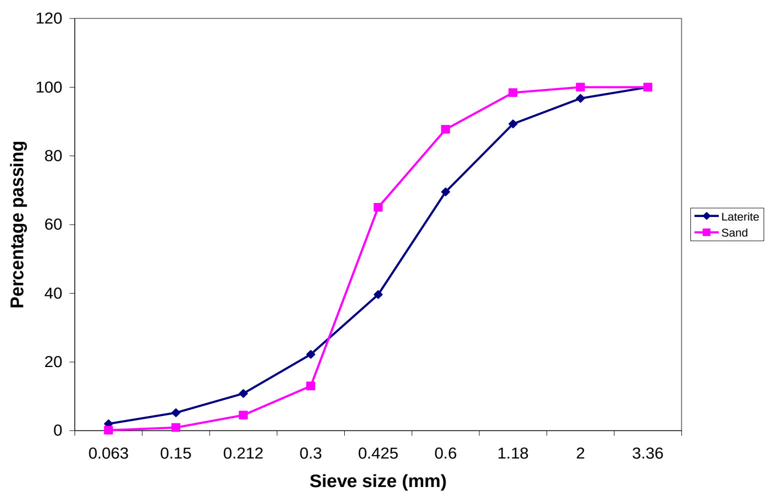

Fig.1. Grain-size distribution of laterite and sand

Tap water free from deleterious substances was used for concrete production. The physical properties of the materials used are presented in Table 2.

Table 2. Physical Properties of Materials used

Material	Property	Value
Sand	Specific gravity	2.60
Laterite	Specific gravity	2.50
Crushed granite	Specific gravity	2.66
	Crushing value	22 %
	Impact value	13 %
Cement	Specific gravity	3.15
	Initial setting time	50 minutes
	Final setting time	120 minutes
	Soundness	0.53mm

4. METHODS

A Concrete of mix proportion 1:2:4:0.55 (cement: sand: Coarse aggregate: water-cement ratio) designed for 28-day characteristic strength of 20 MPa was used throughout the laboratory experiment. Batches of concrete containing 0, 10, 20, 30, 40, and 50% of laterite by mass of sand were used as a replacement for the later. The concrete ingredients were mixed thoroughly manually with a pre-calculated amount of water. The fresh concrete was then placed in cubical molds of size 100 mm lightly oiled before casting of test specimens. A total of nine cubes were cast from each batch, and a set of three specimens for accelerated strength testing were moist-cured for 23 h, immersed in boiling water for 3.5 h, and then tested at 28.5 h for compression. The remaining two sets of three specimens each were cured in water for 28.5 hr and 28 days, respectively, at room temperature before testing for compression for comparison with the strength of the accelerated strength. The procedure for the compressive strength tests was according to BS 1881. For water absorption test specimens were weighed before and after immersion in water for 24 hr. Water absorption was then determined as the difference in the weight of specimen before and after immersion in water relative to the weight of specimen before immersion in water, expressed in percentage.

5. RESULTS AND DISCUSSION

The results of the accelerated compressive strength of laterized concrete as well as those of 28.5 hr- and 28-day strength are presented in Table 3.

Table 3. Properties of hardened laterized concrete

Laterite content (%)	Compressive strength (MPa)				Water absorption (%)
	f_{ac}	$f_{28.5h}$	f_{28d}	LSD (p = 0.05)	
Control	19.10 ± 0.10[a]	16.50 ± 0.50	26.70 ± 0.20	0.50	2.65
10	20.20 ± 0.15	18.40 ± 0.15	27.20 ± 0.32	0.08	1.95
20	21.80 ± 0.76	19.10 ± 0.40	27.50 ± 0.15	0.81	0.95
30	22.00 ± 0.67	19.80 ± 0.57	27.70 ± 0.21	0.35	0.79
40	23.70 ± 0.10	20.10 ± 0.32	28.20 ± 0.29	0.41	0.60
50	24.00 ± 0.30	21.70 ± 0.31	29.50 ± 0.50	0.61	0.34

a = standard deviation; f_{ac} = accelerated strength; $f_{28.5h}$ = 28.5 h strength; f_{28d} = 28-day strength;
LSD (p = 0.05) = least significant difference at 0.05 significance level.

Each value is the average of three test results. It may be noted from the results that generally there was a marginal increase in strength as the replacement level of sand increased. The mean compressive strength of cubes subjected to accelerated testing ranged from 19.1 ± 0.10 MPa to 24.0 ± 0.30 MPa. For the specimens cured for 28.5hr in water the mean strength values varied from 15.5 ± 0.5 MPa to 21.7 ± 0.31 MPa, while for the specimen cured in water for 28 days the strength ranged from 26.7 ± 0.20 MPa to 29.5 ± 0.5 MPa. To compare the accelerated strength and the strength of concrete after 28.5 hr and 28 days moist-curing, an analysis of variance (ANOVA) test was conducted (see Table 4).

Table 4. ANOVA results of compressive strength of plain and laterized concrete

Laterite (%)	SV	DF	SS	MS	$F_{calculated}$	$F_{tabulated}$
0	Curing	2	167.7	83.9	838.6	5.14
10	Curing	2	135.0	67.5	1350.0	5.14
20	Curing	2	109.0	54.5	209.7	5.14
30	Curing	2	108.6	54.3	201.0	5.14
40	Curing	2	101.6	50.8	758.2	5.14
50	Curing	2	98.7	49.4	335.9	5.14

A computed least significant difference (LSD) of between 0.08 and 0.81 presented in Table 3 at a significance level equal 0.05 obtained from the test indicates existence of statistical differences between the accelerated strength and 28.5 hr and 28-day strengths. The accelerated strength relative to 28.5-hour and 28-day compressive strength as shown in Fig. 2 and Fig. 3 was between 1.10 and 1.18, and 0.72 and 0.84, respectively. The relationship between accelerated strength and the strength upon standard moist curing in water for 28 days obtained by regression analysis is presented in Eq. (1):

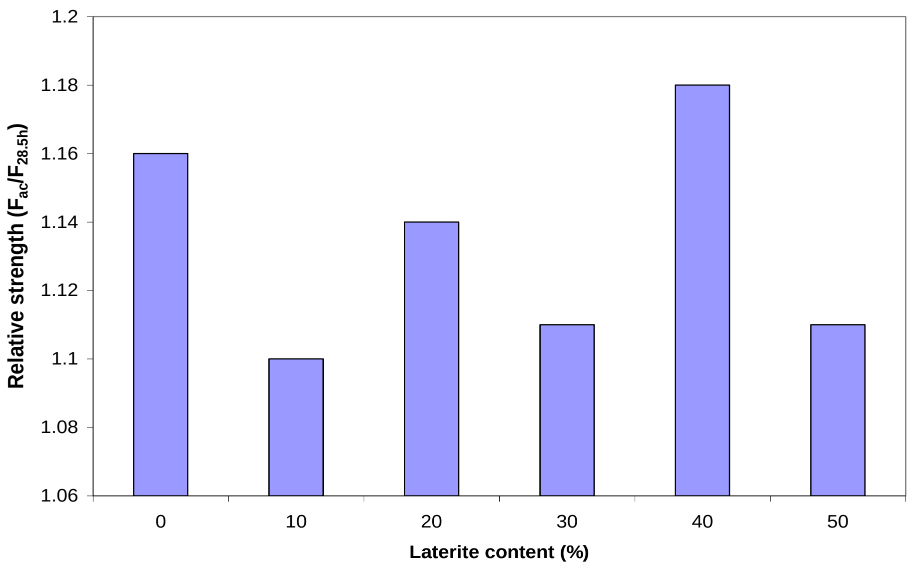

Fig. 2. Accelerated strength relative to 28.5 h strength of laterized concrete

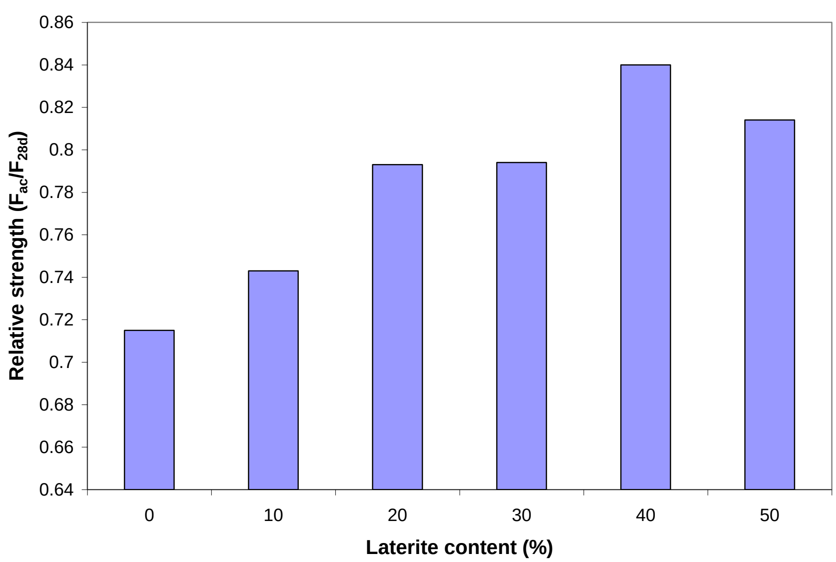

Fig. 3. Accelerated strength relative to 28-day strength of laterized concrete

$R_c = 0.99\ (R_a)^{0.38}$ (1)

Where R_c = ratio of compressive strength of laterized concrete to the 28-day compressive strength of the control concrete (concrete without laterite)
R_a = ratio of the accelerated strength laterized concrete to the 28-day compressive strength of the control concrete.

Fig. 4 shows the relationship between the accelerating strength and 28-day strength normalized by the strength of the control, while Fig. 5 shows the comparison of the experimental values of the 28-day compressive strength of laterized concrete compared with the calculated strength values using Eq. (1). As could be observed the equation slightly overestimates the strength of the concrete at 20 and 40 % replacement level of sand by laterite.
The results of the water absorption of laterized concrete with variation in laterite content are also presented in Table 3. As could be observed from the result, water absorption decreases with increase in laterite content. The explanation for the observed trend is that increasing laterite content enhances the water-repellent characteristic of the

matrix, and thus reduces the water absorption. The relationship between strength and water absorption as could be observed in same table shows that compressive strength of laterized concrete increases with decrease in water absorption. This trend seems reasonable since the strength of concrete decreases with increase in water content.

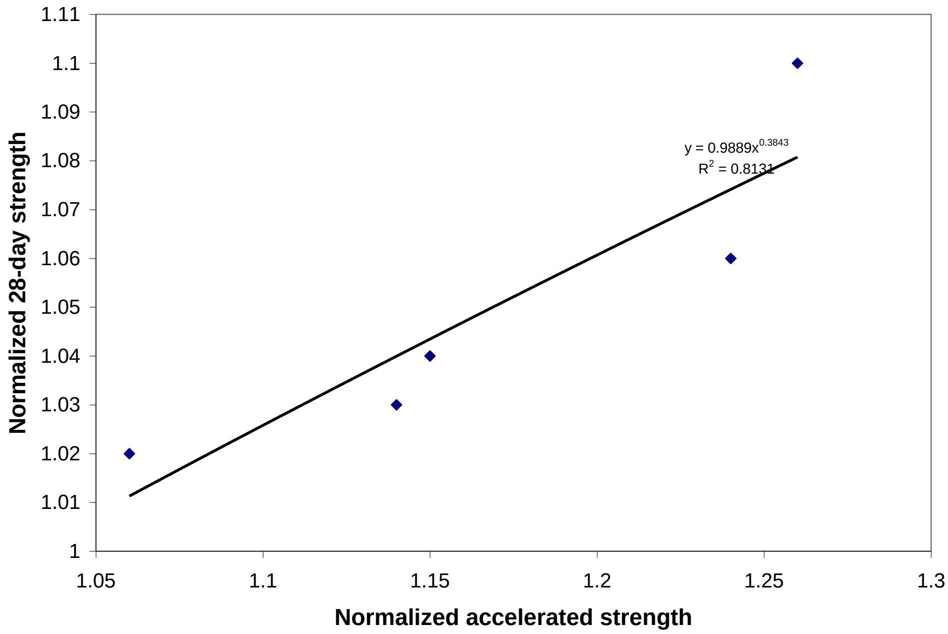

Fig. 4. Normalized accelerated strength versus normalized 28-day strength of laterized concrete

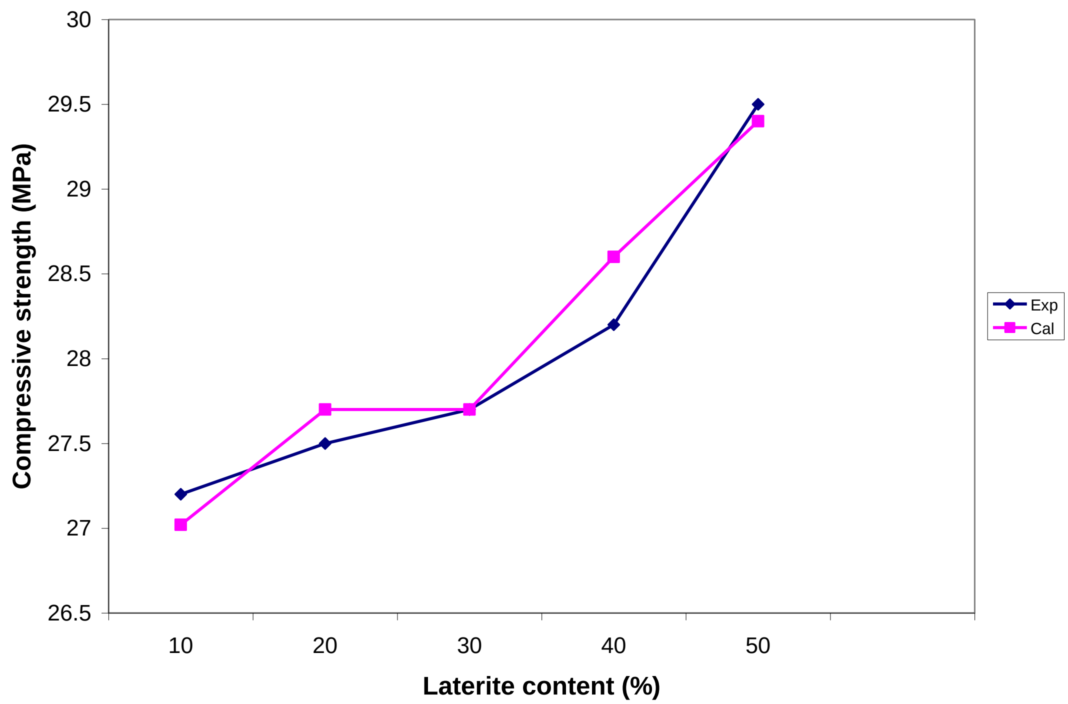

Fig.5 Comparison of experimental and calculated 28-day compressive strength of laterized concrete

6. CONCLUSIONS

The values of accelerated strength of laterized concrete obtained in this work were greater than the strength of standard moist-cured concrete of corresponding age, implying the enhancement of hydration process and consequently the strength development through the boiling water method of accelerated strength testing. This is indicative of the applicability of this method for early strength assessment of laterized concrete.

A power equation has been proposed for early prediction of the 28-day strength of laterized concrete once the 28-day strength of control concrete and the accelerated strength of laterized concrete are known. It is hoped that this model will prove useful to concrete professionals when ensuring quality at early stages of construction with laterized concrete.

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