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EFFECT OF HIGH CURING TEMPERATURE ON MECHANICAL PROPERTIES OF CONCRETE

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ABSTRACT

It has been shown that Concrete increases in strength with age after setting. The strength at a particular age can be further increased by suitable curing of the concrete while it is maturing. Such curing comprises the application of heat and/or the preservation of moisture within the concrete. In this research work, an attempt has been made to study the influence of elevated curing temperature on mechanical properties of concrete. Mechanical properties such as comprehensive strength and pullout strength were investigated. Concrete Specimens were cured under three different temperatures and curing age 30^{0}C, 60^{0}C and 100^{0}C and 7, 14 and 28 days respectively. Compression test and pull out test were conducted on concrete cubes. The results showed strong positive relationship with correlation coefficient 0.779 between number of days and strength of concrete and the P–value 0.004 implies that the relationship is significant at 5% level while the coefficient of Determination (COD) indicates that number of days have 60.75% effect on strength of concrete. Correlation coefficient 0.932 with a P-value 0.013 and COD of 86.79% indicate that temperature has a very strong effect on strength of concrete. The regression analysis showed a unit increase in temperature will lead to 0.062 N/mm^2 increase in the strength of concrete. However the rate of concrete strength at the increase in temperature is lower than the increase in number of days, this implies a tendency for concrete to be weak in future with increase in temperature especially above boiling point.

Keywords: Concrete, curing, compressive strength, pullout strength, elevated temperature.

1. INTRODUCTION

Mixture of coarse aggregate, fine aggeregate, cemententious material and water in suitable proportions, placed and compacted wherever required, solidifies after a lapse of time into what is known as concrete. Concrete is one of the major materials often used for construction work. Concrete is expected to function for its expected life span without loading, fatigue, weathering, abrasion and chemical attack. Many researchers have proved that most of the qualities desired of concrete benefit by increased compressive crushing strength, such as strength in tension, shear, resistance to weathering, abrasion and wear and impermeability, these are classified as hardened properties of concrete. Exceptions to this rule are lightness and thermal insulation. The properties of fresh concrete though important but cannot be compared to the properties of hardened concrete which is retained throughout the entire life span of the concrete. These properties are however requiring of concrete structure for different purpose and occasions: Among the important strength test to be carried out in this study are the compressive strength test and the pull out test.

Compressive strength is the capacity of a material or structure to withstand loads tending to reduce size. In other words, compressive strength resists compression (being pushed together) by definition, the ultimate compressive strength of a material is that value of uniaxial compressive stress reached when the material fails completely. The compressive strength is usually obtained by means of a compressive test. Compressive strength is one of the most important engineering property of concrete which designers are concerned of. The test requisite differ country to country. The compressive strength of concrete are used to determine the concrete mixture and meet the strength requirement of a specific job. It is calculated from the failure load divided by the cross-sectioned area resisting the load.

$\sigma = F/A$ where F = Load applied (N), A = Area (m^2)

Generally speaking concrete used for residential purposes is around 17 MPa (MegaPascals), around 28 MPa for commercial uses, and as high as 70 MPa for other specified applications. The tests are required to determine the strength of concrete and therefore its suitability for the job. Pullout strength of hardened concrete is by measure the force required to pull an embedded metal insert and the attached concrete fragment from a concrete test specimen or structure (ASTM 900-01). The insert is either cast into the fresh concrete or installed in hardened concrete. Pullout tests are used to determine whether the in-place strength of concrete has reached a specified level. In addition, post- installed pullout tests may also be used to estimate the strength of concrete in existing constructions.

There are factors which have the greatest effect upon this strength of concrete, among them are the cement to aggregate ratio, the compaction, the water to cement ratio of the mix and the method of curing. Curing according to Chithra and Dhinakaran (2014) is the process in which the concrete is protected from loss of moisture and kept within a reasonable temperature range. It can also be defined as providing adequate moisture, temperature, and time to allow the Concrete to achieve the desired properties for its intended use. Curing plays an important role on strength development and durability of Concrete, as it serves as key player in mitigating cracks which brutally influence durability. Curing conditions according to Chithra and Dhinakarah (2014), as strength gain is significant in the curing phase. Inappropriate curing may result into carbonation at early stage and reduces PH levels. In a bid to obtain good and high quality concrete certain measures have to be introduced to ensure good quality of curing process. The objectives of this research is to investigate the effect of high curing temperature on compressive and pull out strength of concrete cubes. The concrete behaviour at elevated curing temperature is of concern in predicting the safety of building and construction in response to current global warning conditions.

Many researchers in the field based on the field based on the available Literatures, focused on curing method, and performance of concrete after curing. However, few studies examine the effect of elevated curing temperature on strength properties of concrete. Mundle (2014) observed that the compressive strength increase after 72 hours of exposure to an elevated temperature up to 150^{o}c and after that the compressive strength of a concrete decreases with increasing temperature. Investigation by Eliverly and Evans (1964) confirmed that concrete specimens mixed in normal temperature and cured under high temperature (40^{0}c) have higher compressive strength than those mixed and cured under normal temperature. Cebeci (1987) states that concrete cured in water within (37^{0}c), is of higher strength up to 90 curing days and lower strength (360 days) compared with concrete cured within (17^{0}c). Konstantin et al. (2000) determined in their research that the compressive strength at 30^{0}c increases with time much faster compared to 20^{0} curing.

Cecconello and Iutikian (2012) investigate the effect of high curing temperature on concrete up to 14 days. The results reveal that concrete casted and cured at lower temperature develop strength slowly but later improves after 14 days: and the strength of concrete casted and cured at higher temperature readily gain strength but later reverse after 14 days. According to Selman (2001) compressive strength of concrete mixed and cast at temperature not exceeding (29^{0}c) and moist cured under hot weather for 7days, increases as the curing temperature is increased up to 90 days. The increase ranges between (4-22%) with respect to mixes cured at normal weather condition. Lo et al. (2009) Investigates effect of curing at higher temperature on compressive strength and carbonation depth of Pozzolaure structural lightweight concretes and pulverized Fuel Ash- and Silica Fumes incorporated lightweight. Concrete with PFA and SF as a cement substitute up to a percentage of 70 were compared. Results show PFA and SF incorporated concrete had greater strength under accelerated curing condition than under normal curing condition, but OPC mixes showed a different result that they gain higher strength under normal curing and lower strength under accelerated curing when compared with the former.

2. MATERIALS AND EXPERIMENTAL METHODS

2.1.Cement

Dangote ordinary Portland cement (OPC) was used throughout the experimental study. The cement complied with BS 12 and ASTM C150- standard specification for Portland cement.

2.2 .Aggregates

The importance of using the right type and quality aggregates cannot be overemphasized. The fine and coarse aggregates cannot be over emphasized. The fine and coarse aggregates generally occupy 60-75% of the concrete volume (70-85% by mass) and simply influence the concrete's freshly mixed and hardened properties, mixture proportion and economy. The coarse aggregate used was crushed granite chippings obtained from RatCon quarry site along Lagos/Ibadan expressway with size not greater than 20mm. The fine aggregate used was natural sand and not greater than 4.75mm.

2.3.Specimen's Preparation

The batching of the specimen was by weighing the constituent materials according to the adopted mix ration of 1:2:4. This ratio was adopted throughout with 0.55 water cement ratio. The mixing of the concrete specimen was done mechanically after which the slump and compacting sector test were carried out before casting into cube molds of 150mm x 150mm x 150mm in approximately 50mm layers with each layer given 35 strokes of the tamping rod. Specimen were held in the laboratory at an atmosphere of more than 95% relative humidity and ambient temperature, i.e. 25^{o}c before the cubes were demolded after 24 hours and the specimens oven cured at 30^{o}c, 60^{o}c and 100^{o}c for 7days, 14days and 28days.

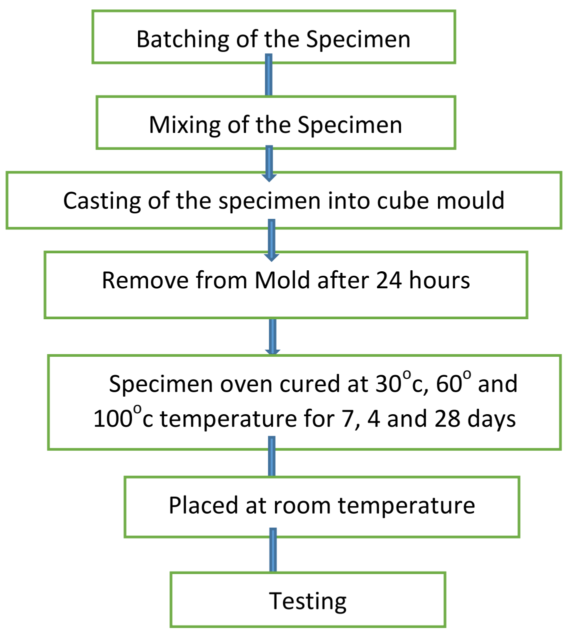
2.3.1.Test on the Concrete Samples

Tests on fresh concrete samples obtained as follows

Slump Test	75.0mm
Water cement ratio	0.55%
Mix proportion	M2O
Mode of mixing	Mechanical
Method of curing	Immersion in water

2.3.2.Flow Chart for Lab Work

Figure 1: Flow Chart for Lab Work



2.4.Testing Procedures

2.4.1.Compressive Strength Test

For the compressive strength test, a set of three standard cubes of 150mm x 150mm x 150mm size were texted using Electrically operated hydraulic compression machine with capacity of about 300KN. These were dance at different temperature 30^{o}c, 60^{o}c and 100^{o}c and at 7 days, 14days and 28days of curing. Compressive strength of any material is defined as the resistances to failure under the action of compressive force especially for concrete, compressive strength is an important parameter to determine the performance of the material during severe conditions. It is calculated by dividing the failure load with the area of application load.

$$\text{Compressive strength } (\mho) = \frac{\text{Failure load (KN)}}{\text{Area of application of load } (mm^2)}$$

2.4.2.Pullout Test

Pullout tests are used to determine whether the in-place strength of concrete has reached a specified level so that, other activities can proceed e.g. post-tensioning, termination of winter protection and curing. In addition, the strength of concrete is existing constructions may also be estimated using post-installed pullout tests.

The materials and tools used are:

(a) Pullout testing machine
(b) Concrete cone embedded with specially shaped steel rod.

The specimen is placed in the machine with the threaded shape from the embedded head attached to the machine. This is tie down by means of bearing plate& bearing ring after which the tension force is applied through the threaded shaft on the specimen. The reading on the calibration on the machine at the point threaded shaft detach itself from the specimen divided by the idealized area of frustum or area of specimen gives the pullout strength of that specimen.

3. RESULTS AND DISCUSSION

It is clear that the compressive strength pullout strength increases with curing days and at elevated curing temperature up to 100^{0}c. The result is better shown in figure 1. The line graph shows upward strength in different days at different temperature.

Table 1: Average compressive strength and pullout test result.

Days	Temperature			Pullout
	30^{o}c	60^{o}c	100^{o}c	
7 days	12.99	11.87	15.15	31.7
14 days	13.22	15.3	18.66	41.82
28 days	16.64	20.09	24	41.97

Figure 1: Line Graph Of Relationship Between Strength Of Concrete And Number Of Days At Different Temperatur

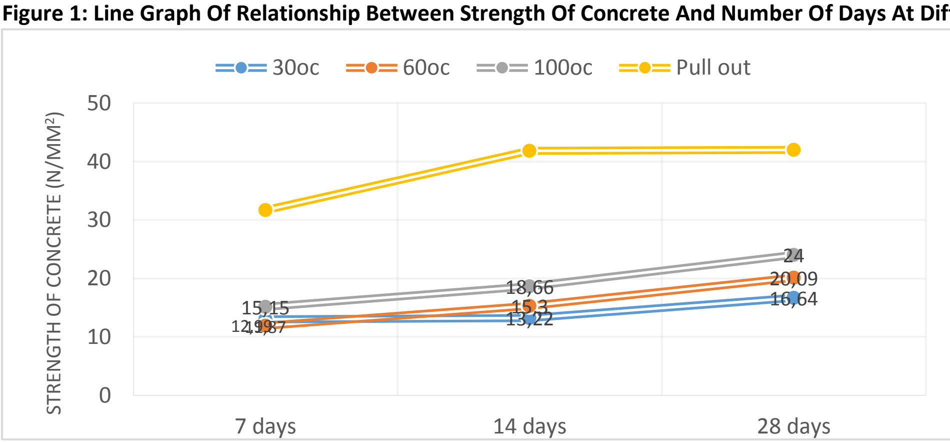


Table 2: Two-Way Analysis of Variance (ANOVA)

Source of Variation	SS	df	MS	F	P-value	F crit
Temperature	30.34	2	15.17	6.30	0.058	6.944
Days	71.45	2	35.72	14.83	0.014	6.944
Error	9.63	4	2.41			
Total	111.42	8				

Table 2 shows that Temperature F- value is 6.30 with the degree of freedom 2 and 4, and the p-value 0.058 which is higher than 0.05 (level of significant); hence, strength of concrete across different temperature are not significantly different. For Number of days, the F- value is 14.83 with the degree of freedom 2 and 4, and the p-value 0.014 which is less than 0.05 (level of significant); hence, strength of concrete across different Number of days are significantly different.

Table 3: Correlation Table between Number of Days and Strength of Concrete (Pull out)

Variable	Mean	Std Dev	Nr	COD	(%)	P-value
Days	16.33	9.56	6	**0.779**	**60.75**	**0.004**
Strength (N/mm^2)	1.647	0.256				

The correlation coefficient 0.779 shows that there is a fairly strong positive relationship between Number of Days and Strength of Concrete and the p- value 0.004 implies that the relationship is significant at 5% level while the coefficient of Determination (COD) indicated that Number of Days has 60.75% effect on strength of concrete.

Table 4: Regression Analysis of the Relationship between Strength of Concrete and Temperature

Coefficients	Standard Error	T Stat	P- value
Intercept	13.10	0.313	0.015
Temp	0.06	0.005	0.048

Table 4 above shows the regression analysis result which depicts that the **Strength of Concrete = 13.10 + 0.062 Temperature.** The regression equation shows that the strength of concrete will be **13.10 N/mm^2 at 0^{o}C** and a unit increase in temperature will lead to **0.062 N/mm^2** increase (impact) in the strength of concrete.

4. CONCLUSIONS

Based on the results and discussion presented above the following conclusions can be drawn

- At 7 days, 14 days and 28 days the strength of concretes cured at 100^{o}c are more greater than cured at 30^{o}c and 60^{o}c. Also the concrete cured at 60^{o}c is greater in strength than concrete at 30^{o}c.
- The increased average strength of concrete with increase in temperature is lower than the increase average strength of concrete with increased in number of days (see Table 1). Therefore, it shows tendency that there will be weak concrete in future with increased temperature.
- From Table 2, the p- value show the strength of concrete across different temperatures are not significant to that of strength of concrete across different number of days
- The regression analysis slowed a unit increases in temperature will lead to 0.062 N/mm^2 increases in the strength of concrete.

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