Accelerated Curing of Concrete Cubes Using Warm Water

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***Abstract*:-This research focuses on the use of accelerated curing of concrete by means of warm water at 35°C. The experiment was checked regularly to maintain same temperature all through thetime of heating.The workability and compressive strength properties of the concrete produced from mix ratio 1:2:4 have been ascertained. Compressive strength test on the hardened concrete at 7,14,21 and 28 days were as well obtained. From the results, the value obtained for the slump test corresponds to the design range of 25mm-100mm. The slump increased from 60mm in sample A to 65mm in samples B and C and then decreased to 50mm in samples D and E this can be associated with the variation in temperature as well as hydration. Furthermore, the hardened concrete was found to have lost some weight after curing, this is because weight loss is accompanied by strength gain. A relationship between the concrete cubes cured under 1-day in the accelerated condition and normal concrete at 28 days was established so that the 28-day strength can be predicted from the accelerated. The relationship has been found mathematically as: R28 = Ra [0.8026 ± 0.0001] -1. Where R28 = 28-day strength andRa = accelerated strength. Optimal temperatures used in this research work is 35 ± 2°C. The 35°C used is optimal and help the hydration products, calcium silicate hydrates to settle suitably. Problem of possible compressive strength losses due to induced thermal stresses were taken care of by allowing a delay period equivalently equal to the initial setting time to elapse, so that concrete gained some tensile strength before curing commenced.**

Key Words: **Concrete, Temperature, Accelerated, Curing, Compressive and Strength**

I. INTRODUCTION

1.1 Background of Study

The minimum acceptable strength of concrete in construction works is determined at its 28 day-compressive strength. To find this compressive strength, usually 28 days of moist curing is required. This 28 days waiting period is too lengthy for an ongoing project that requires a certain strength to wait before ascertaining the strength. Also at 28 days, concrete must have achieved the minimum required strength and will require a lot of energy and finance to remove in a case the required strength was not achieved. In a case were the concrete is of greater strength than the required, the uneconomical mix is just a waste of costly material. These necessitated the finding of the equivalent of 28days strength in 24 hours which is related to accelerate curing of concrete to which this study is devoted. Hence, for better quality control, an accelerated concrete curing procedure is needed tofacilitateand identifying the 28 day-strength in a day or so while the real concrete is still accessible and sufficiently soft to work on. Hence, accelerated curing techniques are becoming important Neelakantan *et al.,* (2014).

Accelerated curing is the process by which concrete is subjected to early hardening in other to achieve high early strength. These techniques are especially useful in the prefabrication industry, wherein high early age strength enables the removal of the formwork within 24 hours, thereby reducing the cycle time, resulting in cost-saving benefits (Erdem, 2003). The most commonly adopted curing techniques are steam curing at atmospheric pressure, warm water curing, boiling water curing and autoclaving, though, this work will adopt boiling water curing.

Concrete takes about 28 days to gain 90% of its strength. When the concrete has not attained sufficient strength, loss of water due to drying of concrete develops tensile strength in concrete which results in cracks. Hence, during this period, the concrete is kept in damp condition. The process of hydration is faster at higher temperatures and hence, gains strength quick (Hutchison *et al*., 1991). However, if the higher temperature leads to evaporation of water from the concrete mass which reduces the strength, an optimal temperature which is less than the evaporation temperature of water is preferred (Pheeraphan *et al*., 2002; Makul and Agrawal, 2012). Accelerated curing techniques use this concept and being utilized in the prefabrication industry enabling earlier removal of the reusable form work that makes business economical. In special situations such as repairing a busy road bridge, accelerated curing is very useful in reducing the detouring time.

According to Phalak et al., (2015), there is need for one to achieve the results of quality control samples while the main concrete is still accessible and sufficiently green to make its removal practicable, i.e. within 24hours after casting or thereabout. With the assistance of reliable test methods employing accelerated curing techniques, it is now possible to test the compressive strength of concrete within a short period and thereby to estimate whether it is likely to reach the specified strength at 28 days or not. The methods laid down in this standard may be used for quality-control purposes, or for the prediction of normal strength of concrete at later ages, by the use of an appropriate correlation-curve obtained by testing normally cured and accelerated cured concrete specimens of the same mix proportion.

II. THEORETICAL ANALYSIS

Traditionally, quality of concrete in construction works is calculated in terms of its 28 day-compressive strength. This procedure requires 28 days of moist curing before testing, which is too long a period to be of any value for either concrete construction control or applying timely corrective measures. If after 28 days, the quality of concrete is found to be dubious, it would have considerably hardened by that time and also might have been buried by subsequent construction. Thus replacement of the concrete mass of questionable attributes becomes very difficult and often impracticable. On the other hand, if the concrete is found to possess excessive strength than required, it would be too late to prevent wasteful use of cement on uneconomical mix proportioning. Hence, standard 28 days of cube testing of concrete is not feasible for quality control.

The main objective here is to assess and establish a relationshipbetween the accelerated concrete strength and the 28-day strength of the standard specimen so as to predict the 28-day strength from the accelerated concrete strength.The study will establish a correlation of the accelerated strength of a given mix determined by tests based on the accelerated curing methods, with the 28-day strength of the standard specimens. This relation between the two strengths is established prior to placing the concrete in the structure, so that the accelerated test can be used as a rapid quality control test for detecting variations in the mix proportions. Findings of this study could lead to a great economic benefits to the client and provide a new improved method of designing concrete mixes. It will therefore give construction engineers and researchers a better idea of the engineering properties of accelerated concrete cubes in relation to the 28-day strength of standard specimen.

III. MATERIALS AND METHODS

3.1 Materials used

The materials used for this research are; Coarse aggregate(granite of 22mm size), Fine aggregate(sharp sand), Cement(Dangote cement) and water(fit for drinking).

3.2 Methods applied

3.2.1 Normal Concrete Cube Test

Equipment

Compression testing machine, Auxiliary Platens and a balance with min of 10kg capacity

Procedure

1. Weigh each specimen, as-received or saturated.
2. Check the nominal dimensions and take measured dimensions of each specimen.
3. Determine the density of each specimen.
4. Immerse in water, for a minimum of 5 minutes, those cubes which have not been cured in water or where the surfaces have been allowed to dry. Remove the cubes from the curing or density water tank and test while they are still wet.
5. Carefully center the cube on the lower platen and ensure that the load will be applied to two opposite cast faces of the cube.
6. Without shock, apply and increase the load continuously at a nominal rate within the range 12MPa/min. to 24MPa/min. until no greater load can be sustained. Record the maximum load applied to the cube.

3.2.2 Accelerated Concrete Cube Test

Apparatus

Cover plate, curing tank and thermometer

Procedure

Thinly coat the cover plate with release agent to prevent adhesion of the concrete and place it in position to form a watertight seal: then immediately lower the specimens gently into the filled curing tank, ensuring that they are spaced accordingly. Totally immerse the specimens for a period of 24 h ± 15 min, continuously recording the water temperature which shall be maintained at 35 ± 2 ºC at all times except for a period not exceeding 15 min immediately after immersion of the specimens. Remove the specimens from the curing tank, demould the cubes and clearly mark each one with an identification number or code. Test the cubes (in accordance with BS 1881: Part 116) as soon as possible after removal from the curing tank.

IV. RESULTS AND DISCUSSIONS

4.1 Results

4.1.1 Results of Slump Test of Fresh Concrete Mix:

The following results were obtained from the slump cone, having height 300mm, the test was performed within 2minutes of batching and mixing.

Table 4.1: Slump of various fresh concrete samples 2mins after batching.

Sample	**Height of concrete(mm)**	**Slump of concrete(mm)**
A	235	60
B	235	65
C	235	65
D	250	50
E	250	50
F	250	50

4.1.2 Slump of the Fresh Concrete Mix

From Table 4.1, the value obtained from the slump test corresponds to the designed slump range of 25mm-100mm. The slump which increases progressively from sample A with value of 60mm to 65mm in samples B and C and then decreases regressively to 50mm for samples D and E. It can be deduced that the variation in slump across the samples is because of the time difference in taking the readings, this may be due to the hydration of cement. The difference is however insignificant since all the samples collected from the same concrete which are all representative of the entire mix fall within the design range of slump and as such are regarded as true slump. A true slump indicates that the concrete mix is efficiently workable.

4.2 Compressive Strength of Concrete

The various results obtained from the concrete from 24 hour of setting as tabulated are to be analyzed individually.

Table 4.2 Compressive Strength of Concrete (N/mm^2)

Date	Sample A	Sample B	Sample C
24 hours (accelerated curing)	8.84	9.33	7.56
7 days	6.89	7.16	7.33
14 days	7.37	7.60	8.22
21 days	9.11	9.51	9.84
28 days	10.34	10.75	11.00

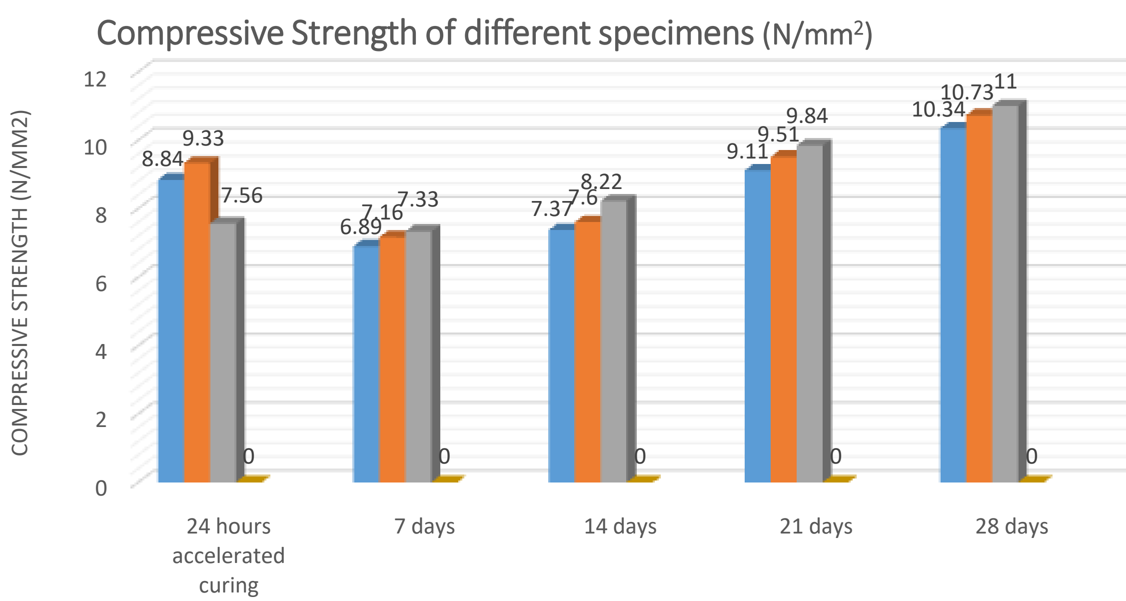

Figure 4.1 Compressive Strength of Concrete at 24 hours accelerated curing and 7, 14, 21 and 28 days normal curing (N/mm^2)

From Table 4.2 and figure 4.1 the various compressive strength have a constant and progressive strength growth from 7 days to 28days. The 24 hours accelerated concrete strength was found to differ from the 28-day normal curing by some reasonable margin. Therefore, there is the need to develop a correlation by which the 24-hour strength can be related to the 28 days strength so that by subjecting a concrete to heating in a water bath for 24 hours, the 28-day strength can be inferred.

The average compressive strength for:

28 days, Fcu =10.34 + 10.75 + 11.00 = 10.697N/mm^2 (1)

24-hour accelerated curing, Fcu =8.84 + 9.33 + 7.56 = 8.577N/mm^2 (2)

Where: R28 = 28-day compressive strength of concrete cured under normal conditions

Ra = 24-hour compressive strength of concrete cured using warm water.

It is evident from figure 4.1 that the concrete has achieved a greater proportion of its 28-day strength, the percentage difference between the average strength of the samples cured under accelerated conditions and that of those cured under normal conditions are related by the equation:

$R_{28} = Ra\ [0.8018 \pm 0.0001]^{-1}$……………………..…………………. equ (3)

V. CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This research has proved that:

i. For concrete withmix ratio 1:2:4, cured under accelerated conditions (using warm water at 35°C). It's one day strength is related to the 28-day strength by equation (3).
ii. Concrete requires at least 28-days after casting to achieve the minimum strength that can be used to measure the suitability at a particular job. That is, 1-7 day strength of a given concrete mix cured under normal conditions is not suitable to predict the 28-day strength.
iii. Compressive strength losses are possible due to thermal stresses that are induced by high temperatures which make water in the pores to exact pressure.
iv. The increase in strength of concrete is directly proportional to hydration, since a greater proportion of the 28-day strength was achieved at an elevated temperature in the accelerated curing, it follows also that hydration is more rapid at elevated temperature.

5.2 Recommendations

Following the conclusion drawn from this research, I would recommend that:

i. The experiments must be done with small error, variation in the test results should not exceed 0.05 from the standard, care must be taken when undertaken the experiments and apparatus must be confirmed to be in good condition.
ii. Test methods related to accelerated curing should be employed for in situ rapid control measures as it is capable of informing on the characteristics of a concrete mix, thereby helping to improve the quality of a mix should it be found dubious.
iii. In order to minimize the effect of compressive strength losses due to high temperatures and pore pressures it is necessary to allow a delay period to elapse before commencing the curing process to allow the concrete to gain a certain minimum tensile strength. The delay period should be taken to be equivalently equal to the initial setting time, since it has been found to give satisfactory results.
iv. Although there are several tests methods in this aspect, those involving optimal temperatures between 35°C and 82°C have been more reliable, because beyond this temperature, losses in the later age strength of concrete has been found to be considerably higher.
v. Due to the need for a sustained specific temperature of 35°C required over a 24-hour period, I highly recommend that results from accelerated curing be used to determine 28-day compressive strength only where a reasonable precision could be guaranteed over the course of the experiment.