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Effect of Curing Period on the Properties of Concrete

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ABSTRACT
Concrete derives its strength by the hydration of cement particles and hydration requires sufficient moisture. The curing can be considered as keeping the concrete moist and warm enough so that the hydration of cement can continue. The principal aim of this study is to predict effect of curing period on the properties of concrete. The curing period was variable in this study. The properties of materials are determined according to ASTM specification and only one mix proportion is used.
In this study, a series of concrete cylinders were cast and cured for 0, 3, 7, 14, 21 and 28 days. Each specimen was tested at 28-days and basic properties such as compressive strength, tensile strength and modulus of elasticity were determined. Mix proportion 1:2:4 (by volume) was considered and water cement ratio was 0.5 (by weight). Specimens were immersed in water for curing.
The test result shows that compressive and tensile strength increases linearly and gradually with the increasing of curing periods respectively. Also increasing rate of tensile strength is slower for short period rather than long period.
Keywords: *Curing; Concrete strength; Hydration; Compressive and Tensile strength.*

I. INTRODUCTION

A concrete is a mixture of cement, water and aggregate which produces firm and hard mass. The quality and durability of concrete depend not only on the quality and properties of gradients but also on the method of preparation, placing, curing and environmental conditions to which it is exposed over its service life.

In the practical field a higher water-cement ratio is used, since the concrete is open to atmosphere, the water used in the concrete evaporates resulting drying surface and quick surface drying of concrete results movement of moisture from the interior to the surface and the water available in the concrete will not be sufficient for effective hydration which take place particularly in the top layer. If the hydration is to continue unabated, extra water must be added for a specified period to replenish the loss of water on account of absorption and evaporation (Shetty, 2005).

The development of the strength of concrete which starts immediately after settling is completed, continues for an indefinite period, though at a rate gradually diminishing with time. 80-85% of the eventual strength is attained in the first 28 days and hence this 28 days' strength is considered to be the criterion for the design. For laboratory test submerged method is the most effective method of curing.

Objectives

- ❖ Study the effect of curing period on the compressive strength of concrete.
- ❖ Find the effect of curing period on the modulus of elasticity of concrete.

II. MATERIALS AND METHODOLOGY

Properties of Concrete Ingredients

The strength of concrete is greatly influenced by the properties of ingredients. The following ingredients are generally used in concrete: Cement, Fine Aggregate, Coarse Aggregate and Water.

Cement

Holcim is one of the world's leading cement, for this study Holcim ordinary Portland cement was used. Its specific gravity ranges from 3.12 to 3.16 and weight 1208 kg/m3 (94lb/ft3).The specific gravity of cement use in this study was 3.15.

Fine Aggregate

It is the aggregate most of which passes through a 4.75 mm IS sieve and contain only that much coarser material as is permitted by the specifications. The fine aggregate that has been used in this study was mix of 50% Sylhet sand

and 50% local sand. The value of F.M of combined fine aggregate was 2.59 where the F.M of fine sand is 1.86 and coarse sand is 3.32

Coarse Aggregate

The aggregate most of which are retained on the 4.75mm IS sieve and contain only that much finer material as is permitted by specifications. Generally, brick chips are used as coarse aggregate. Brick chips are prepared by crushing first class bricks and 3/4" down grade chips are selected for this study.

Table 1: Properties of brick

Compressive strength	35.1 (MPa)
Absorption capacity	8.45% (by weight)

Properties of Coarse Aggregate

The test method for sieve analysis of coarse aggregate conforms to the ASTM standard requirements of specification C136. Maximum size of coarse aggregate was 3/4".

Table 2: Properties of coarse aggregate

Common properties	Brick aggregate
Dry unit weight	18.62
Absorption capacity (%)	12.47
Bulk specific gravity (S.S.D)	1.92
F.M	6.54

Water

Water is essential in the production of concrete in order to participate in chemical reaction with cement, to wet the aggregate, and to lubricate the mixture for easy workability. Since the quality of water effects the strength it is necessary to go in to the purely of water. Normally drinking water is used in mixing. Water having harmful ingredients, contamination, salt, oil, sugar or chemical is destructive to the setting properties of cement. It can disrupt the affinity between the aggregate and the cement paste and adversely affect the workability of mixture.

Preparation of Test Specimens

Production of quality of concrete requires meticulous care exercised at every stage of manufacture of concrete. The various stages of casting of test specimens are batching, mixing, placing and compacting and curing.

Batching

Weigh batching is the correct method of measuring the materials. For important concrete, invariably, weigh batching system is should be adopted. In this study weigh batching has been used for measuring water cement ratio and volume batching is used for measuring the materials.

Mixing

In this study concrete mixing had been done by the tilting type mixer machine. After loading the mixer machine, the mixing process should be continued till a thoroughly and properly mixed concrete is obtained. Speed of this mixer machine was about 15-20 rpm. Mixing time was 5-6 minutes.

Placing and Compacting

After mixing the concrete is placed in a cylindrical mold in three layers. Each layers compacted by a 25mm bar with rounded end. Compaction is accomplished by doing external work on the concrete. In this study compaction was done by manually. In the process of placing and mixing, air is likely to get entrapped in the concrete. If the air is not removed fully, the strength of concrete will decrease considerably.

Curing of Concrete

Fresh concrete gains strength the most rapidly during the first few days and weeks. Structural design is generally based on the 28-days strength, about 70 percent of which is reached at the end of first week after placing. The final concrete strength depends greatly on the conditions of moisture and temperature during this initial period.

In this study water curing method was used for curing of concrete. Test specimens were immersed in curing tank for 3-days, 7-days, 14-days, 21-days, 28-days. Some specimens were immersed for 25-days which were not immersed in water first 3-days after casting. Some specimens were immersed for 21-days which were not immersed in water first 7-days after casting. Some specimens were allowed for no curing totally.

Testing of Concrete Specimens

Testing of harden concrete plays an important role in controlling and confirming the quality of cement concrete work. Following tests have been commonly used to determine the properties of hardened concrete.

Test for Compressive Strength

Compression test is the most common test conducted on hardened concrete. In this study cylindrical specimens were used. The size of the cylinder specimens was 6in. dia. and 12 in. height. Universal testing machine was used to loading **Fig 1**. Capacity of the testing machine 1000 KN and rate of loading was 250 KN/minute. The test method conforms to the ASTM standard requirements specification C39 for cylinder. The compressive strength of test specimens of concrete was determined at 28-days but curing period was different for different specimen.

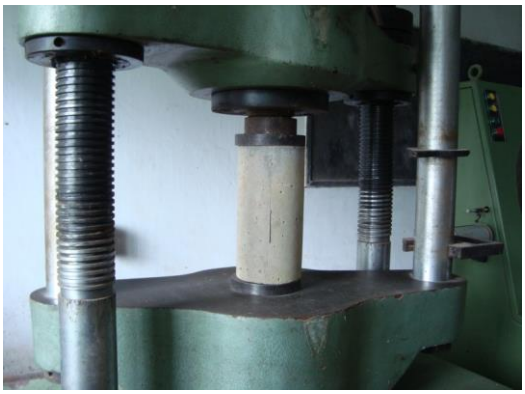

Fig 1: Photo view of set up of compressive strength

Test for Modulus of Elasticity

The modulus of elasticity is determined by subjecting a cylinder specimen to uniaxial compressing and measuring the deformation by means of dial gauges fixed between certain gauge lengths **Fig 2**. Dial gauge reading divided by gauge length will give the strain and loads are divided by area of cross section will give the stress. A series of reading is taken and stress-strain relationship is established. Thus the modulus of elasticity Ec (N/mm2), that is, the slope of the initial straight portion of the stress-strain curve, is seen to increase as the strength of concrete increases. The modulus of elasticity values obtained will usually be less than modulli derived under rapid load application (dynamic or seismic rate, for example) under slow load application (extended load duration) provided other test condition being same.

Fig 2: Photo view of set up for modulus of elasticity test

III. RESULTS AND DISCUSSIONS

Compressive Strength of Concrete

The compressive strength of concrete varies with the curing period. In this study it has been obtained that the variation is linear (**Fig 3**). The result of compressive strength of concrete are summarized in **Table** *3*.

Table 3: Test result of compressive strength

Curing Period (day)	Compressive Strength (MPa)
No curing at all	15.67
3	17.68
7	17.25
14	20.08
21	22.46
28	24.31

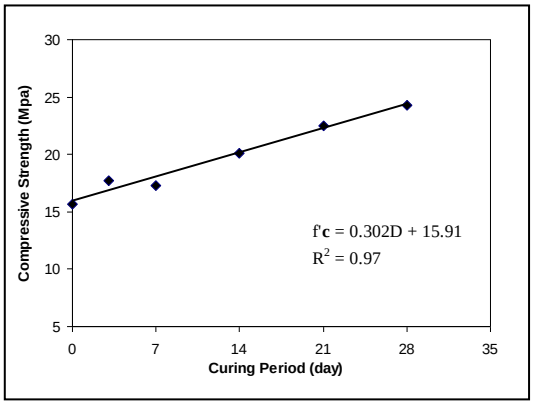

Fig 3: Relation between the compressive strength and curing period.

The following equation is suggested to express the relationship

$$f'_c = 0.302D + 15.91 \quad \text{..... (1)}$$

Where, f'_c= Compressive strength of concrete in Mpa, D= Curing period in day

From the test results we obtain that the specimen which were cured for 0, 3, 7, 14, 21 days attained 65%, 69%, 74%, 82%, 91% strength as compared to the strength of 28 days cured specimen. The strength of concrete increases almost linearly with the curing period, so from the experimental data it can be say that proper curing up to a specified period is must be required for attaining the desired strength of concrete.

Modulus of Elasticity of Concrete

The modulus of elasticity is determined by the formula,

$f'_c = \frac{2P}{\pi LD}$ (Hossain. N, Concrete structure)

The modulus of elasticity is affected by curing period but no relationship can be defined with such limited number of experimental data. The variation of modulus of elasticity is shown in

. The result of modulus of elasticity is summarized in **Table** *4*.

Table 4: Test result of modulus of elasticity

Curing Period (day)	Modulus of elasticity (Mpa)
No curing at all	45,880
3	42,700
7	44,350
14	42,610
21	45,630
28	44,400

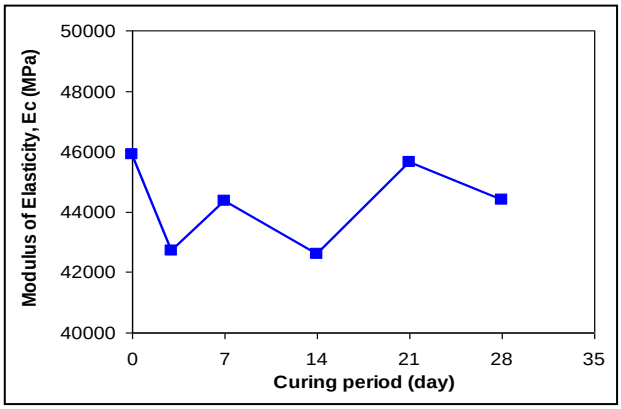

Fig 4: Variation of modulus of elasticity with curing period.

Relation between Compressive Strength and Tensile Strength

Depending on the curing variation the relation between compressive strength and the tensile strength is established. The relation is shown **Fig 4**.

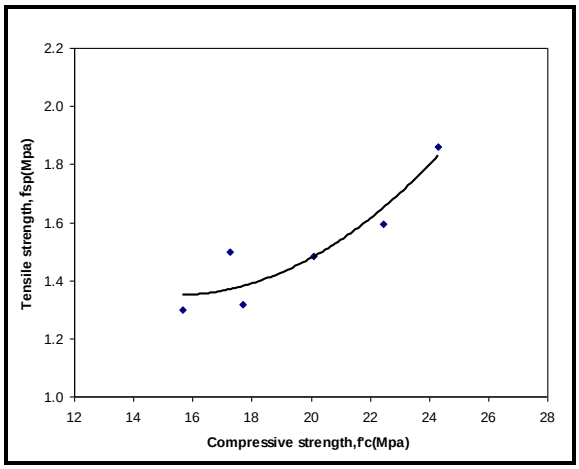

Fig 4: Relation between Compressive strength and Tensile strength in different curing period

Result show that the tensile strength is increasing with the increasing of compressive strength. This rate of increasing is lower than the increasing rate of compressive strength. The curve shows that the rate of increasing of tensile strength is lower in less compressive strength and higher in larger compressive strength.

$$f_{sp} = 0.0061 f_c'^2 - 0.188 f_c' + 2.8 \quad \text{..... (2)}$$

Where,

f_{sp}= Tensile strength of concrete (MPa)

f_c'= Compressive strength (MPa)

Table 5: Table of the test results

Curing period (day)	Compressive Strength, f_c' (MPa)	Tensile strength, f_{sp} (MPa)	Modulus of elasticity, E_c (MPa)	Unit Weight Kn/m^3	Water absorption (By weight)	Ratio $f_{sp}/\sqrt{f_c'}$	Ratio $E_c/\sqrt{f_c'}$
No curing at all	15.67	1.30	45880	19.80	12.56%	0.083	11590
3	17.68	1.32	42700	20.20	13.78%	0.074	10155
7	17.25	1.50	44350	20.21	13.85%	0.087	10680
14	20.09	1.48	42613	21.42	12.75%	0.074	9508
21	22.46	1.60	45633	20.30	13.15%	0.071	9628
28	24.31	1.86	44400	20.73	13.13%	0.076	9005
Curing period: 4th to 28th days	20.77	1.42	49120	21.10	13.78%	0.068	10778
Curing period: 8th to 28th days	21.72	1.40	45237	20.95	12.89%	0.064	9707

IV. CONCLUSIONS

Concrete is the most widely used construction materials. When other factors remain same the quality control is the main factor to get good concrete. Curing of concrete is essential in attaining the desired strength of concrete. Concrete hardens and gain strength as it hydrates. The hydration process continues over a long period of time. It happens rapidly at first and slows down as time goes by. However, hydration occurs only if water is available and if the concrete temperature stays within a suitable range. During the curing period initially concrete surface needs to be kept moist to permit the hydration process. So it is clear that for attaining desired strength, the concrete must be cured sufficiently up to a specified period.

The main objective of this project work is establishing a relationship among curing period and different properties of concrete. Analyzing the result, it has been figured out that

(i) Compressive strength increases linearly up to 28 days with the increasing in curing periods and compressive strength can be determined by using the equation

$$f_c' = 0.302D + 15.91$$

(ii) Tensile strength increases gradually with the increasing in curing periods, the increasing rate is lower in short curing period becomes higher in longer period and the tensile strength can be determined by using a two-degree equation

$$f_{sp} = 0.0061 f_c'^2 - 0.188 f_c' + 2.8$$

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Write acknowledgements in a separate section at the end of the article before the references, if any. List here those individuals who provided help during the research.

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