Development of Compressive Strength for Concrete with Different Curing Durations

A. Latif [1], M. U. Rashid[2], K. Kheder[3], T. Sultan[4], F. Mehvish[5]

[1,4,5]Department of Civil Engineering, University College of Engg. & Tech. BZU. Multan, Pakistan
[2]Senior Engineer, WR Division, NESPAK, Lahore, Pakistan
[3]Department of Civil Engineering, College of Engineering, Salman bin Abdul Aziz University, P. O. Box 655, AlKharj 11942 Saudi Arabia
[1]engrabid1997@gmail.com

Abstract-Durability and properties of concrete are deliberately affected by curing process which also influences the hydration process of cement. The whole effort is being carried out to study the "Effect of curing duration on compressive strength of concrete" by using British and American standard specimens. By proper curing concrete perform well for all the design life of the structure. In our study, all other parameters (W/C ratio, Temperature, Material, curing method) that can affect the strength of concrete kept constant except curing durations. The Variable parameter of the study includes the curing durations (7, 14, 21, 28, 60 and 90 days). To achieve the aim of this study total 72 cubes and cylinders specimens were cast with OPC (Ordinary Portland cement). Half of Specimens (Cubes and Cylinders) are placed in a water tank and remaining half are placed in air before testing (compression strength test). The results of tests indicate a decrease in compressive strength for all duration of uncured cubes and cylinders as compared to cured cubes and cylinders that indicate good results. The majority of the cubes and cylinders tested, showed a significant improvement in compressive strength by increasing the duration of curing.

Keywords-Compressive strength, duration, curing, hydration process, OPC (Ordinary Portland cement)

I. Introduction

This paper addresses the impact of improper curing in reducing the properties and compressive strength of concrete. In Pakistan and developing countries, proper curing of concrete is usually neglected at construction sites and very few organizations get the advantages of proper curing of concrete. Construction is very important in any community of the world and concrete is a material through which desire shape of structures are acquired. The hydration process of cement stops when relative humidity decreases below 80% but due to an efficient curing such as water curing the decrease of relative humidity can be controlled [1-2]. Proper curing is essential primarily to keep the concrete moist during the strength gaining process [3]. Proper Curing is act as a tool to control the rate of evaporation during hydration process from concrete [4-6].

In arid to semi-arid countries evaporation occurs at higher rates due to high temperature/wind, which decreases the amount of available moisture by reducing the relative humidity and retarding the process of hydration for cement. In severe circumstances, hydration process of cement is eventually stopped. When the hydration is stopped, sufficient calcium silicate hydrate (CSH) cannot develop from the reaction of cement compounds and water which is the major product of cement hydration providing strength and proper curing is only the technique to develop the adequate amount of CSH [7-8].

This study presents the effect of curing on hardened properties such as compressive strength. The cured and uncured samples have been compared to investigate its effect at different ages i.e. 7, 14, 21, 28, 60 and 90 days.

II. Methodology

Several methods of curing are as follows:

Water curing.

Wrapped curing.

Dry-air curing.

The most convenient option is water curing and considered for the study. The conventional curing involves dipping the specimens in water at 25 C^0 at the end of 24 hours of casting after allowing for air drying. Two types of specimens i.e. cubes and cylinders according to British and American standards were used for curing and comparing results respectively. According to standards material statement was prepared and accordingly the cement, fine and course aggregates were used for casting of the cylinders and cubes. While selecting materials, the following general precautions considered.

Newly stocked cement

Well graded fine and coarse aggregates

The required tests were performed to check the suitability and characteristics of concrete ingredients. The material fulfilled the criterion were finally selected for preparing concrete and casting cubes and cylinders. Compaction was done by using vibrating table and other criterion to avoid segregation and bleeding etc. were also taken under consideration. Specimens were cured in water pond as shown in Fig. 1 and finally tested to drive the required effects and results of compressive strength of different duration. Cubes and cylinders according to British and American standards respectively, were casted to check the compressive strength of the concrete. Necessary precautions were observed at all the stages of the study.

Fig. 1. Curing pond for specimens

Compression strength was determined by using compression testing machine, presented in Fig. 2, for each cured and uncured cube and cylinder specimen. Load applied is noted directly from the computer screen of the compression testing machine and compressive strength is calculated by using the following relation:

$$\text{Compressive strength} = \frac{\text{Load Applied by machine}}{\text{Area of Cube/Cylinder}}$$

The concrete mix materials used in the study are shown in Table I.

III. Test Results and Discussions

The current study on different curing durations verifies that proper curing of concrete can achieve higher compressive strength due to the less extent of moisture loss and greater degree of hydration process.

TABLE I
Concrete Mix Materials

No.	Description of materials	Source of materials
1	Fine aggregate	Chenab sand
2	Coarse aggregate	Sakhi-Sarwar crush
3	Cement	D.G Cement
4	Water	Tab water (drinkable)

Fig. 2. Testing of specimen in compression testing machine

The test results of all the concrete cubes and cylinders are summarized in Table II and Table III, whereas their graphical representation is shown in Fig. 3 and Fig. 4 respectively. The results and discussions regarding to compressive strength of cubes and cylinders with and without curing have been elaborated as follows:

The compressive strength of concrete cubes and cylinders having proper curing was higher than the uncured concrete cubes at 7, 14, 21, 28, 60 and 90 days curing ages as shown in Fig. 3 and Fig. 4.

The increase of avg. compressive strength for cubes from 7 days to 14 days, 14 days to 21 days, 21 days to 28 days, 28 days to 2 months and 2 months to 3 months is 168 psi, 341 psi and 221 psi, 165.7 psi and 65.5 psi respectively.

TABLE II
SUMMARIZED RESULTS OF COMPRESSION TEST FOR CURED AND UNCURED CUBES SAMPLES

Curing Duration	Sample No.	Cured Cubes Samples		Sample No.	Uncured Cubes Samples		Rate of Increment in Strength	
		Compressive Strength	Average Compressive Strength		Compressive Strength	Average Compressive Strength	Increment	%Age
Days		psi	psi		psi	psi	psi	%
7	1	3004.54	2982.79	4	2897.75	2617.72	365.08	12
	2	2994.98		5	2526.01			
	3	2948.86		6	2429.39			
14	7	3094.15	3003.14	10	2907.68	2804.95	198.19	7
	8	2954.45		11	2844.16			
	9	2960.82		12	2663.00			
21	13	3508.42	3487.65	16	3402.34	3272.40	215.25	6
	14	3483.14		17	3246.48			
	15	3471.40		18	3168.39			
28	19	3618.47	3468.08	22	3367.11	3170.42	297.65	9
	20	3496.90		23	3130.74			
	21	3288.86		24	3013.42			
60	25	3779.56	3504.37	28	3482.63	3280.52	223.86	6
	26	3527.63		29	3354.11			
	27	3205.93		30	3004.80			
90	31	3870.78	3671.59	34	3482.63	3280.51	391.08	11
	32	3527.60		35	3354.11			
	33	3616.39		36	3004.80			

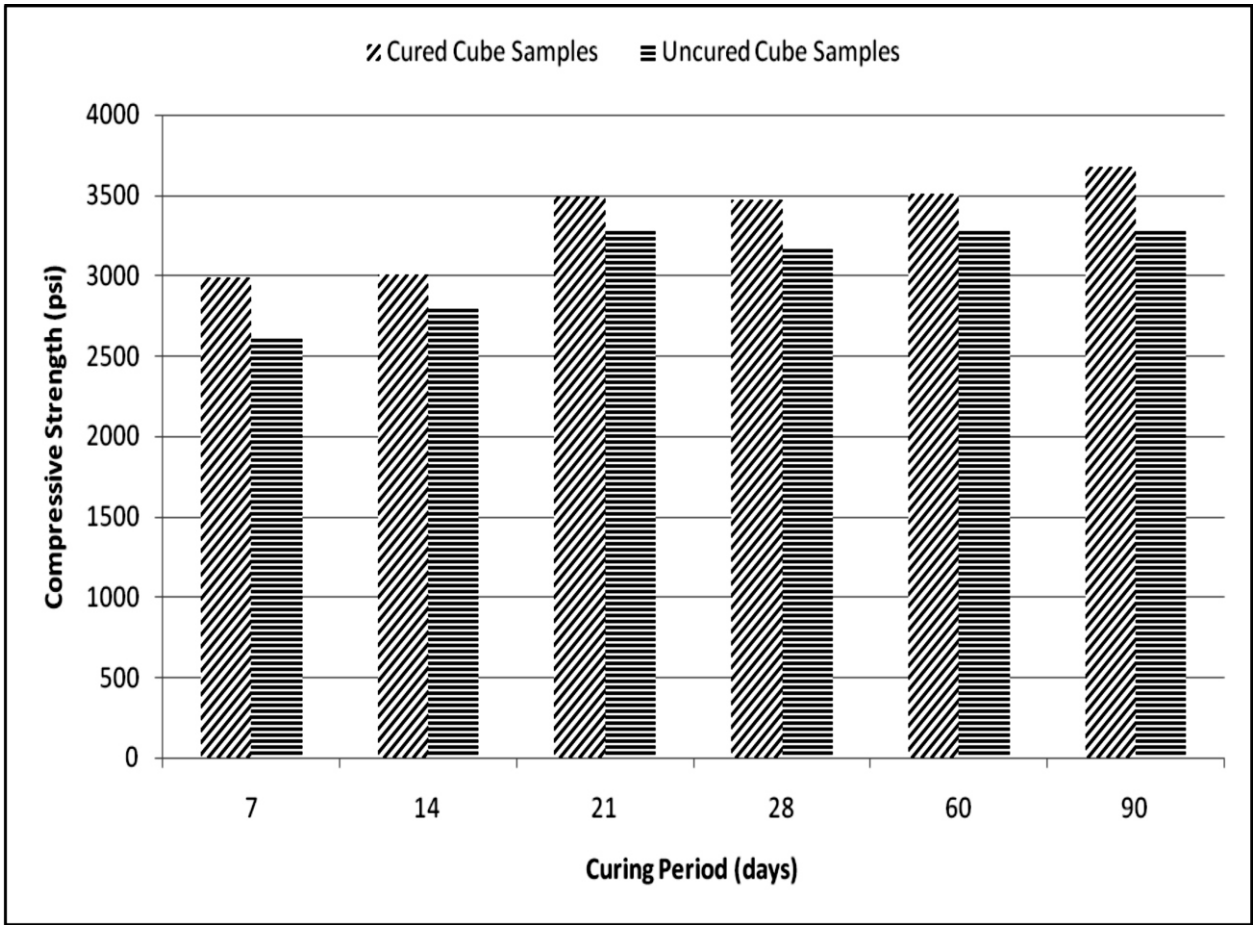

Fig. 3. Graphical representation of comparison of cured and uncured cubes

TABLE III
RESULTS OF COMPRESSION TEST FOR CURED AND UNCURED CYLINDER SAMPLES

Curing Duration	Sample No.	Cured Cylinder Samples		Sample No.	Uncured Cylinder Samples		Rate of Increment in Strength	
		Compressive Strength	Average Compressive Strength		Compressive Strength	Average Compressive Strength	Increment	%Age
Days		psi	psi		psi	psi	psi	%
7	1	2090.58	1887.39	4	1611.85	1492.94	394.46	21
	2	1805.62		5	1497.35			
	3	1765.98		6	1369.63			
14	7	2041.23	2100.58	10	1953.15	1841.59	258.99	12
	8	2098.15		11	1995.00			
	9	2162.38		12	1576.63			
21	13	2492.65	2315.02	16	2091.87	1959.03	355.99	15
	14	2397.95		17	1935.54			
	15	2054.46		18	1849.68			
28	19	2762.27	2661.71	22	2316.94	2022.27	639.44	24
	20	2729.89		23	2153.94			
	21	2492.97		24	1595.93			
60	25	3083.56	2805.66	28	2411.50	2172.26	633.40	23
	26	2764.62		29	2154.83			
	27	2568.80		30	1950.46			
90	31	3156.88	2905.25	34	2572.30	2300.08	605.18	21
	32	2916.61		35	2252.61			
	33	2642.27		36	2075.33			

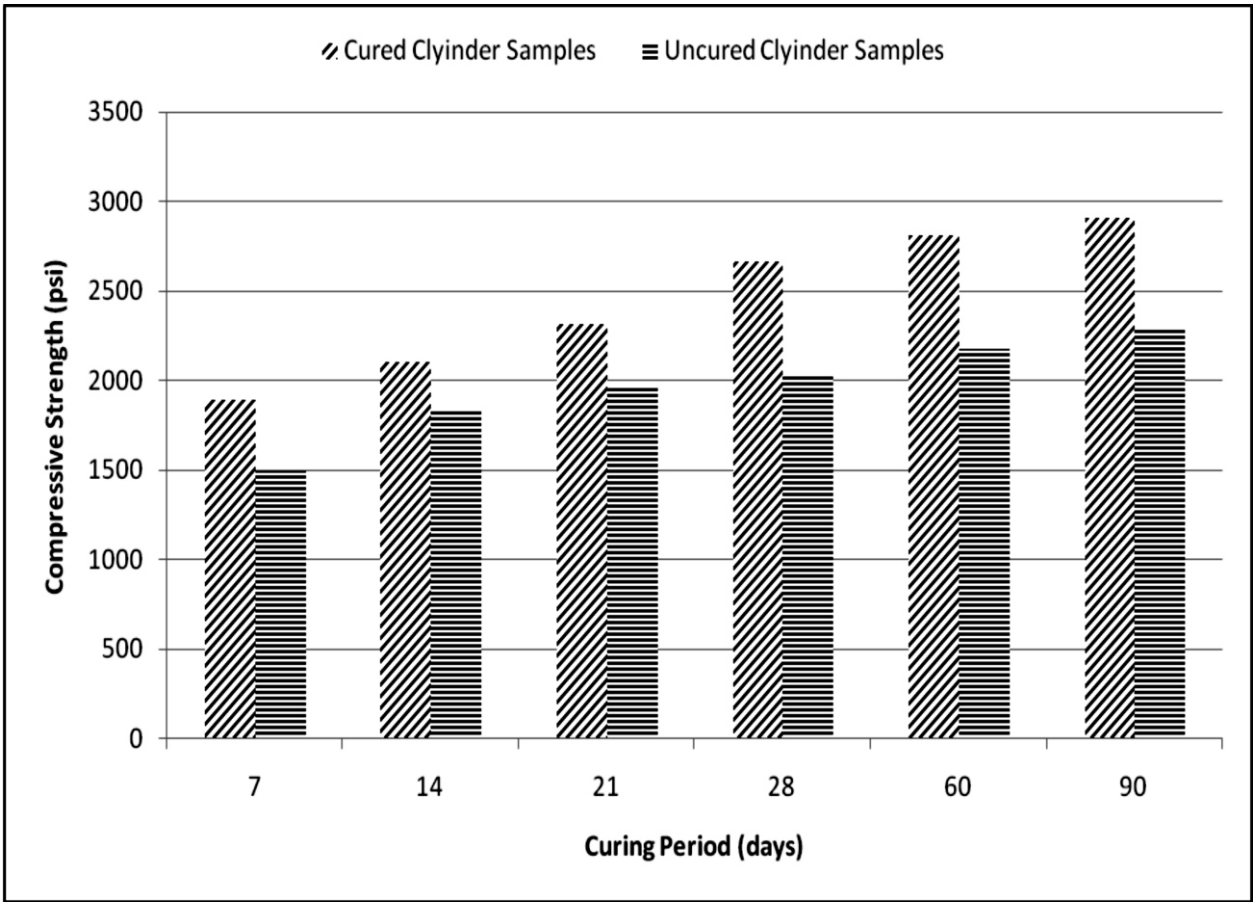

Fig. 4. Graphical representation of comparison of cured and uncured cylinders

The increase of average compressive strength for cylinders from 7 days to 14 days, 14 days to 21 days, 21 days to 28 days, 28 days to 2 months and 2 months to 3 months is 367 psi, 314.5 psi, 237 psi, 253 psi, and 203 psi respectively.

It can be seen that there is increase in strength with the increase in curing duration. This increase in strength due to proper curing shows the availability of moisture for hydration process. For all durations, the maximum average compressive strength of cured concrete samples is 12% higher than uncured samples.

The rate of increase of average compressive strength for cubes due to curing from 7 days to 14 days, 14 days to 21 days, 21 days to 28 days, 28 days to 2 months and 2 months to 3 months is in ranges of 7%, 18%, 31%, 46%, 62% and 62% respectively.

The rate of increase of average compressive strength for cylinders due to curing from 7 days to 14 days, 14 days to 21 days, 21 days to 28 days, 28 days to 2 months and 2 months to 3 months is 9%, 13%, 15%, 21% , 23% and 24% respectively.

IV. Conclusions

It is important to know that all the theoretical and practical values of compressive strength are calculated at the point of complete failure. The conclusions of the study are as follows:

Compressive strength of cured samples is much higher than uncured samples.

The compressive strength of concrete can be increased by enhancing the curing duration up to a certain limit.

The age of concrete plays an important role for compressive strength. As the age increases, the compressive strength of concrete also increases for both the cured and uncured samples**.**

In uncured samples, the moisture escapes from the specimens that increase porosity and reduces compressive strength of concrete.

Curing needs care in hot weather condition. Minimum 28 days curing for plain cement concrete is recommended and at least 14 days curing should be done at all construction projects.

V. Recommendations

In this study, curing is done by conventional method, further, it is recommended that the study can be carried out by changing the curing method (wrapped curing/dry-air curing) and checked its effects on compressive strength of concrete.

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