Available online at www.elixirpublishers.com (Elixir International Journal)

Cement and Concrete Composites

Elixir Cement & Con. Com. 61 (2013) 16705-16708

ISSN: 2229-712X

Effect of various curing conditions on compressive strength of HPC

J. Karthikeyan and K.V.Pratap
Department of Civil Engineering, National Institute of Technology, Trichy, Tamilnadu, India.

ARTICLE INFO

Article history:
Received: 4 June 2013;
Received in revised form:
24 July 2013;
Accepted: 31 July 2013;

Keywords
Curing,
Methods of curing,
Burlap,
Wax coating,
Compressive strength.

ABSTRACT

High Performance Concrete (HPC) is that concrete which meets special performance and uniformity requirements that cannot always be achieved by conventional materials, normal mixing, placing and curing practices. The grade of concrete selected was control mix (CM) of M80. Investigation was carried out on mixes of partial replacement of cement with metakaolin (MK) 10% and silica fume (SF) 15%. Regression analysis equations were developed for each type of curing based on compressive strength and age of concrete (7, 14, 28 and 56 days). In this study the effect of various curing conditions on compressive strength of HPC were studied. The various curing conditions adopted were normal curing (NC), wet cover curing (WCC), membrane curing (MC) and accelerated curing (AC). Normal water curing includes immersion of concrete cubes in water. Wet cover curing includes covering concrete with burlap. Membrane curing includes application of wax coating on concrete cubes. Accelerated curing includes application of heat at ordinary pressure. The overall finding of this study suggests that concrete should be cured by water curing to achieve a better compressive strength.

Introduction

Concrete curing is one of the most important and final steps in concrete construction though it is also one of the most neglected and misunderstood procedures. It has long been recognized that adequate curing is essential to obtain the desired structural and durability properties of concrete. Proper curing of concrete is one of the most important requirements for optimum performance in any environment or application. It is the treatment of newly placed concrete during the period in which it is hardening so that it retain enough moisture to immunize shrinkage and resist cracking (Lambert Corporation, 1999).

With respect to high performance concrete, the amount of information available on the effects of various curing conditions on its properties is limited, and the current curing requirements for ordinary concrete may not be optimal for HPC. Since the strength development and durability characteristics of HPC may be different from ordinary concrete, it follows that new curing practices may be needed. Since high performance concrete is a relatively new class of concrete, additional research is needed to understand more fully the factors affecting the development of its physical and chemical characteristics. Good concrete can be ruined by the lack of proper curing practices like discontinuing curing operations prematurely, the use of lower water-cement ratios which tend to cause self-desiccation, use of several mineral admixtures in which curing takes longer periods of time for proper development of strength (Neville, 1996).

Proper curing of concrete is essential to obtain maximum durability, especially if the concrete is exposed to severe conditions where the surface will be subjected to excessive wear, aggressive solutions, or severe environmental conditions. Curing has major impact on the permeability of a given concrete. The surface will be seriously weakened by increased permeability due to curing. The importance of adequate curing is very evident in its effects on the permeability of the "skin" (surface) of the concrete. Survey conducted in the United States in 1979 estimated that 24% of concrete used in non-residential construction was not cured at all, and only 26% was cured in accordance with project specifications (Senbetta and Malchow, 1987).

It is important to understand the basic physical and chemical effects of curing on concrete mixtures. A fundamental understanding of these effects and how the curing process influences them will be the foundation upon which further advancements can be made in the curing requirements for HPC. Since the properties of concrete develop as result of hydration, much can be learned by studying the effects of different curing conditions on the characteristics of cement paste.

The curing of HPC has been identified as one of the critical areas in which more information and research are needed in order to realize the full potential of this class of concrete (Carino and Clifton, 1990).

The study present the effect of different curing methods on the compressive strength of concrete using Portland cement and finally identifies the most effective curing process for HPC.

Materials and methods

Locally available crushed granite stones and locally available river sand were used as coarse and fine aggregate respectively. Fine aggregate of zone II sand confining to IS (Indian Standard): 383-1970 and coarse aggregate of 12.5mm are used. Ordinary Portland Cement (OPC) confining to IS: 8112-1989 was used. Potable water from borehole was used for preparing the concrete. It was also used for curing purposes. Metakaolin and Silica fume mineral admixtures were used. Superplasticizer of GLENIUM B233 was used. AITCIN method was used for mix design of HPC. The major properties of the constituent materials were given in Table 1.

Mixture Proportions of Concrete

The HPC was prepared based on water cement ratio of 0.3 and a cement content of 500kg/m^3 to obtain a compressive strength greater than 80N/mm^2 at 28 days (by NC). The details

Tele:
E-mail addresses: jk@nitt.edu

of mixture proportions for CM of M80 are given is table 2. Mix design details after the replacement of cement are given in table 3.

Table 1: Properties of the constituent materials of concrete

Materials	Properties
Crushed granite stone	Maximum size : 12.5mm, Specific gravity : 2.72
Fine aggregate	Maximum size : 4.74mm, Specific gravity : 2.65, Fineness modulus : 2.45
Ordinary Portland Cement	Specific gravity : 3.01
Borehole water	P^H=7, Density=1000kg/m^3
Mineral admixtures	specific gravity: Metakaolin=2.5 Silicafume=2.2
Superplasticizer	Type: GLENIUM B233 specific gravity : 1.09

Table 2: Mixture Proportions of Concrete

Finalised Mix	Cement (Kg/m^3)	Fine Aggregate (Kg/m^3)	Coarse Aggregate (kg/m^3)	Superplasticizer (l/m^3)	Water (l/m^3)
CM (M80) (AITCIN METHOD)	500	727.64	1075	5.503	138.72

Table 3: Finalised mix proportions for MK and SF

Components	Replacement levels	
	MK-10%	SF-15%
Water(lit)	150.36	155.36
Cement(kg)	449.88	439.05
Mineral admixture(kg)	49.99	77.48
Coarse Aggregate(kg)	1074.32	1074.32
Fine Aggregate(kg)	718.91	684.94
Superplasticizer(lit)	5.503	6.34

Testing of Fresh Concrete

The fresh concrete was produced by using concrete mixer in the civil engineering laboratory of NIT Trichy. Immediately after mixing, the fresh concrete was tested for slump.

Preparation of Test Specimens

A total of 192 cubes having dimensions 100mm x 100mm x100mm each were casted. The specimens were moulded in oiled cast iron moulds (confining to IS: 10086-1882) using three layers of filling and vibration is done by using the vibrator to expel the entrapped air. The tops of the cubes were marked after a while for identification purpose. Immediately after this, the specimens were kept in a cool place in the laboratory. The specimens were demoulded from the cast iron moulds at the age of 24 ± 2 hours. The work plan for the casting of cubes in the project was shown in table 4.

Curing Methods

The test specimens were cured under four types of curing until the day of testing. These were Normal Water Curing, Wet Cover Curing, Membrane Curing and Accelerated Curing. In NC test specimens were immersed in water for the desired period (7, 14, 28 and 56 days). In WCC a thick burlap was covered on the cubes and wetted daily for 2 times (morning and evening). In MC test specimens were coated with bee wax with a minimum thickness of 2mm, so that no evaporation and escape of water would occur. In accelerated curing the test specimens were cured by boiling water at 100˚C ± 2˚C in accelerated curing tank for 3.5 hours for obtaining 28 days strength (confining to IS:9013-1978).

Testing of the hardened concrete

The compressive strength of the test cubes were determined by crushing the cubes under the compression machine (confining to IS: 516 – 1959). A total of 192 cubes in all were crushed, 48 of these cubes were for NWC method, the next 48 cubes were for WCC method, next 48 cubes were for MC method, while the last 48 cubes were for AC method. The length of curing dates considered was 7, 14, 28 and 56 days for each type of curing.

Result and Discussions

The results of compressive strength have been presented in table 5. The graphical representation of results was shown in figure 1-7 based on average compressive strength vs. age of concrete for different methods of curing used in the project. Regression equations and regression coefficients were shown in table 6. In all curing methods, the compressive strength of the concrete increases with age. The highest compressive strength at all ages was produced by NC. In the case of MK-10%, for NC maximum compressive strength (103N/mm^2) has been attained and similarly for WCC maximum compressive strength (101.3N/mm^2) and MC (87.6N/mm^2) has been attained for 56 days. This is because in the case of metakaolin the formation of hydration products were more and reliable irrespective of the method of curing. In the case of SF-15%, for AC maximum compressive strength (84.6N/mm^2) has been attained for 56 days. This is because at ambient temperatures, SF has developing enough binding properties with cement for the formation of sufficient hydration products. The regression equations developed were useful for the prediction of future compressive strength values for different methods of curing discussed in the project work.

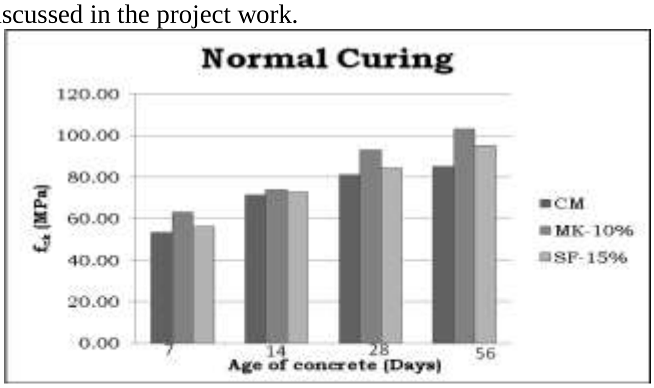

Fig 1 Compressive strength vs. age of concrete for NWC

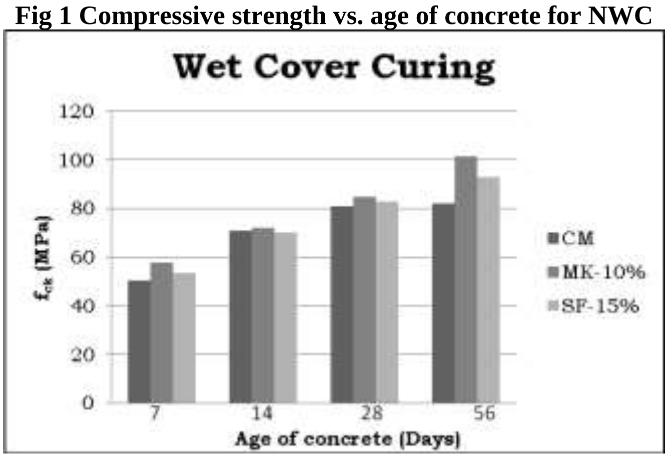

Fig 2 Compressive strength vs. age of concrete for WCC

Table 4 Work plan of the project

Mix	Normal Water Curing				Wet Cover Curing				Membrane Curing				Accelerated Curing			
	Number of days for curing															
	7	14	28	56	7	14	28	56	7	14	28	56	7	14	28	56
Control Mix (M80)	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
MK-10%	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
SF-15%	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4

Table 5 Compressive Strength of HPC

No. of days	Compressive strength of specimen (N/mm^2)											
	Control Mix				MK-10%				SF-15%			
	NWC	WCC	AC	MC	NWC	WCC	AC	MC	NWC	WCC	AC	MC
7	53.23	50.35	41.9	45.75	62.98	57.85	45.22	48.15	56.33	53.38	48.70	45.45
14	71.3	70.88	50.30	59.93	74	71.88	54.1	62.28	72.93	70.2	64.8	61.58
28	81.3	80.8	62.8	67.05	92.88	84.88	67.83	73.58	84.4	82.85	73.1	70.85
56	85	82.1	73.4	79.5	103	101.3	78.1	87.6	95.1	93	84.6	81.8

Table 6 Regression equation and Regression coefficient (R^2)

Mix	Normal Curing		Wet Cover Curing		Membrane Curing		Accelerated Curing	
	Regression equation	R^2	Regression equation	R^2	Regression equation	R^2	Regression equation	R^2
Control Mix M80	y = 15.195ln(x) + 27.314	0.916	y = 15.174ln(x) + 25.729	0.857	y = 15.635ln(x) + 16.375	0.986	y = 15.437ln(x) + 11.011	0.995
MK-10%	y = 20.046ln(x) + 23.362	0.986	y = 20.681ln(x) + 17.229	0.998	y = 18.705ln(x) + 12.055	0.998	y = 16.212ln(x) + 12.911	0.994
SF-15%	y = 18.438ln(x) + 22.14	0.988	y = 18.975ln(x) + 18.204	0.987	y = 17.071ln(x) + 13.952	0.986	y = 16.735ln(x) + 17.835	0.983

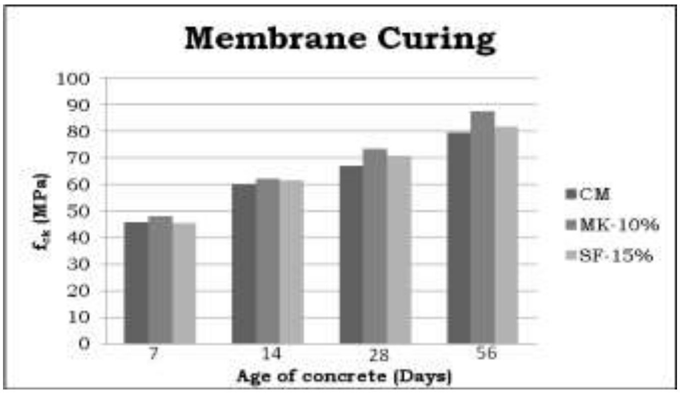

Fig 3 Compressive strength vs. age of concrete for MC

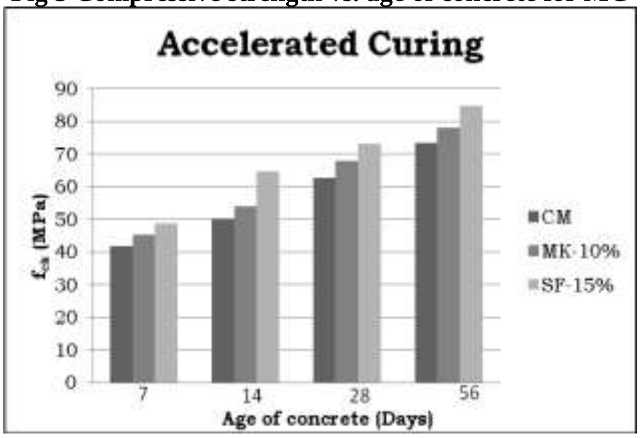

Fig 4 Compressive strength vs. age of concrete for AC

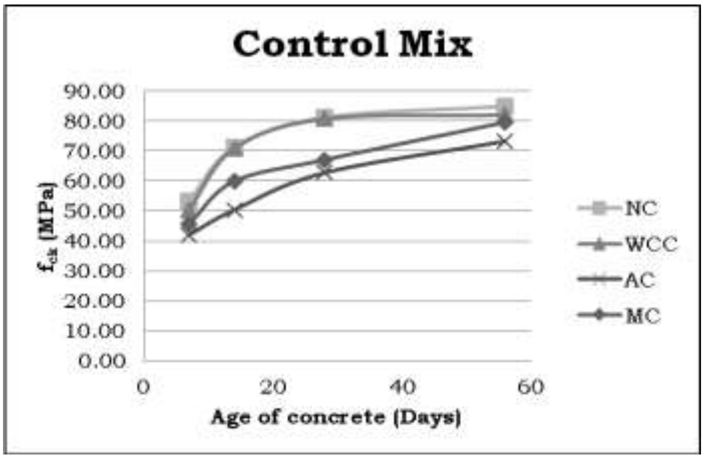

Fig 5 Compressive strength vs. age of concrete for CM

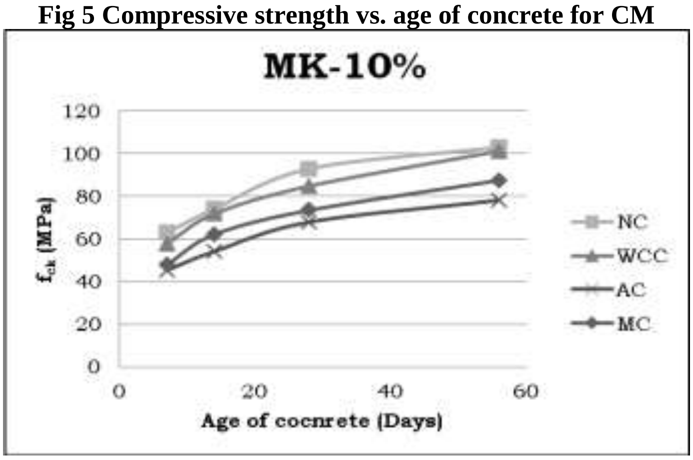

Fig 6 Compressive strength vs. age of concrete for MK-10%

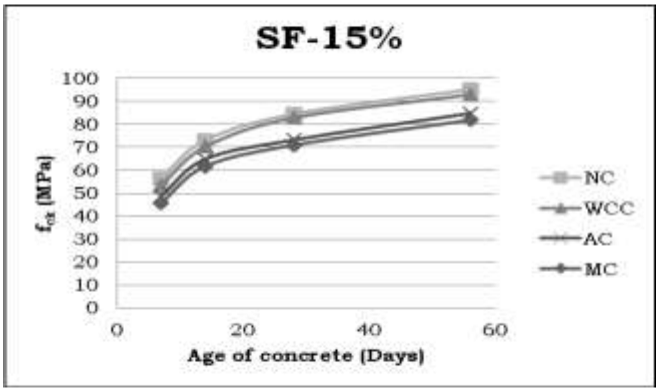

Fig 7 Compressive strength vs. age of concrete for SF-15%

Conclusions

1. Water curing was the most effective method of curing. It produced the highest level of compressive strength. This is due to improve pore structure and lower porosity resulting from greater degree of cement hydration reaction without any loss of moisture from the concrete specimens.
2. In Normal Water Curing condition for 28 days, MK-10% is giving 14.24% and 10.05% more compressive strength than compared to CM M80 and SF-15% respectively.
3. In Wet Cover Curing condition for 28 days, MK-10% is giving 4.5% and 2.45% more compressive strength than compared to CM M80 and SF-15% respectively.
4. In Membrane Curing condition for 28 days, MK-10% is giving 9.74% and 3.85% more compressive strength than compared to CM M80 and SF-15% respectively.
5. In Accelerated Curing condition for 28 days, SF-15% is giving 16.4% and 7.77% more compressive strength than compared to CM M80 and MK-10% respectively.

References

1. Krishna Rao MV, Rathish Kumar P and Azhar M. Khan. A Study on the influence of curing on the strength of a standard grade concrete mix. 2010; Architecture and Civil Engineering Vol. 8; No 1; pp. 23 – 34.
2. El-Dieb AS. Self-curing concrete: Water retention, hydration and moisture transport, Construction and Building Materials. 2007; 21; 1282-1287.
3. Adam Neville and Pierre-Claude Aitcin. High performance concrete- An overview. 1998; Materials and Structures; Vol.31; pp.111-117.
4. Senbetta E, Malchow G. Studies on Control of Durability of Concrete Through Proper Curing, Concrete Durability, Katharine and Bryant Mather International Conference, SP-100, J.M. Scanlon Ed., American Concrete Institute, Farmington Hills. 1987; MI; pp. 73-87.
5. IS 456-2000. Plain and reinforced concrete – code of practice. Bureau of Indian Standards.
6. IS 516-1959. Methods of tests for strength of concrete. Bureau of Indian Standards.
7. IS 9013-1978. Method of making, curing and determining compressive strength of accelerated-cured concrete test specimens. Bureau of Indian Standards.
8. IS 10086-1982. Specification for moulds for use in tests of cement and concrete. Bureau of Indian Standards.
9. IS 15388-2003. Silica fume – specification. Bureau of Indian Standards.
10. IS 8112-1989. 43 grade Ordinary Portland Cement – specification. Bureau of Indian Standards.
11. Shetty MS. Concrete technology. S.Chand publications. (2005).
12. Shaheer Ali K. Strength, durability and microstructural studies in HPC. M.Tech thesis, National Institute of Technology, Tiruchirappalli, India. (2010).
13. Ramdeep Gowtham A. Strength and durability studies on self curing concrete. M.Tech thesis, National Institute of Technology, Tiruchirappalli, India. (2011).