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Effect of different curing methods on the compressive strength of concrete

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ABSTRACT

Normal concrete was prepared with a water-cement ratio of 0.50. cube specimens were cast for testing the compressive strength at 7 and 28 days of curing respectively using three curing methods namely immersion, sprinkling and Plastic sheeting, curing to cure the cube specimens until the day of testing. Test results indicates that water curing (WAC) as well as sprinkling (spraying) curing provided much better results than membrane (Plastic Sheeting) method of curing. The rate of drying was significant when the specimens were subjected to membrane (Plastic sheeting) method of curing. This thus hampered the hydration process and thus affected the compressive strength property of the hardened concrete. 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 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).

Curing of concrete is a pre requisite for the hydration of the cement content. For a given concrete, the amount and rate of hydration and furthermore the physical make-up of the hydration products are dependent on the time-moisture-temperature history (Neil Jackson et al, 1996).

The necessity for curing arises from the fact that hydration of cement can take place only in water-filled capillaries. This is why loss water must be prevented. Furthermore, water lost internally by self-dedication has to be replaced by water from outside, i.e. ingress of water into the concrete must take place. (Neville, et al, 1987). Thus, for complete and proper strength developments, the loss of water in concrete from evaporation should be prevented, and the water consumed in hydration should be replenished. This the concrete continues gaining strength with time provided sufficient moisture is available for the hydration of cement which can be assured only by creation of favourable conditions of temperature and humidity. This process of creation of an environment during a relatively short period immediately after the placing and compaction of the concrete, favourable to the setting and the hardening of concrete is termed curing (Gambir, 1986).

A proper curing maintains a suitably warm and moist environment for the developments of hydration products, and thus reduces the porosity in the hydrated cements paste and increases the density of microstructure in concrete. The hydration products extend from the surfaces of cement grains, and the volume of pores decreases due to proper curing under appropriate temperature and moisture (Safiudeen et al, 2007). A proper curing greatly contributes to reduce the porosity and drying shrinkage of concrete, and thus to achieve higher strength and greater resistance to physical or chemical attacks in aggressive environments. Therefore, a suitable curing method such as water ponding (immersion), spraying or sprinkling of water, or covering with polythene sheet material is essential us order to produce strong and durable concrete.

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 normal concrete.

Materials and methods

Locally available crushed granite stones and fine aggregate (quartzite sand) were used as coarse and fine aggregate respectively. The fractions of different sizes of crushed granite stone and fine aggregates, as shown in Table 1 were in the ranges specified in Bs 812 (1960) methods for sampling and testing of aggregates. Ordinary Portland cement was used as the main binder. Portable water from borehole was used for preparing the concrete. It was also used for curing purposes. The major properties of the constituent materials are given in Table 2.

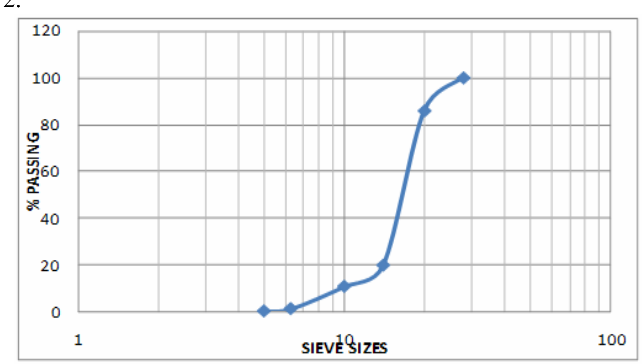

Fig 1: Particle size distribution curve for crushed granite stone

Mixture Proportions of Concrete

The normal concrete was prepared based on water cement ratio of 0.50 and a cement content of 340kg/m^3 to obtain a compressive strength greater than 20N/mm^2 at 28 days

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(Immersion method of curing). Quartzite sand was used with a quantity of 33.33% of total aggregates by weight. The concrete mixture was proportioned to have a minimum slump of 48mm and also a minimum compacting factor or 0.94. The concrete mixture was assumed to be fully compacted and the proportions of the materials were determined on the basis of absolute volume of the constituents. The details of mixture proportions are given is table 3 below.

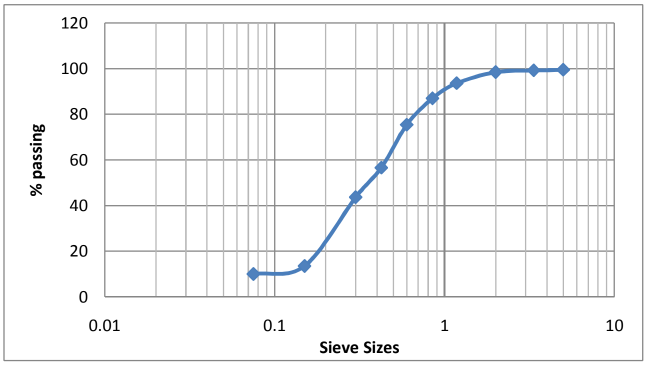

Fig 2: Particle Distribution Curve for Fine Aggregate

Testing of Fresh Concrete

The fresh concrete was produced using manual method of mixing in the civil engineering laboratory of F.U.T Minna. Immediately after mixing, the fresh concrete was tested for slump and compacting factor. The slump and compacting factor tests were determined according to Bs 812 (1960)

Preparation of Test Specimens

A total of 48 cubes having dimensions 150mm x 150mm x 150mm each were cast. The specimens were molded in oiled timbers moulds using three layers of filling and each layer tamped 25 times 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 removed from the wooden moulds at the age of 24± 2 hours.

Curing Methods

The test specimens were cured under three types of curing until the day of testing. These were water curing (WAC), sprinkling of water (SWC) and wrapping with plastic sheeting (PSC). In water curing, the specimens were weighed and immersed in water. Portable borehole water was used in water curing. In sprinkling method, the specimens were also weighed and kept moist by sprinkling water on the specimens 2 times daily (morning and evening) until the date of testing. In plastic sheeting, the specimens were weighed and wrapped in flexible plastic sheets until the testing date. At least 2 layers of wrapping were used to prevent moisture movement from concrete surface. The curing temperature was maintained at 27 $\pm$ 2^0c in all the curing methods.

Testing of the hardened concrete

The compressive strength of the test cubes were determined by crushing the cubes under the compression machine. A total of 48 cubes in all were crushed, 16 of these cubes were for immersion method, the next 16 cubes were for sprinkling method while the last 16 cubes were for membrane of these cubes were for sprinkling method while the last 16 cubes were for membrane method (Polythene Sheet). The length of curing dates considered was 7 and 28 days respectively.

Result And Discussions

Fresh Properties:

The slump and compacting factor of the concrete were 48mm and 0.94 respectively indicating that the concrete mix has adequate mobility and stability i.e the mix fall within the range of medium workability. The average result of 0.94 obtained as the compacting factor indicated that the concrete can be manually compacted. The concrete can also be used for heavily reinforced sections with vibrations (Neville et al, 1987).

Compressive strength

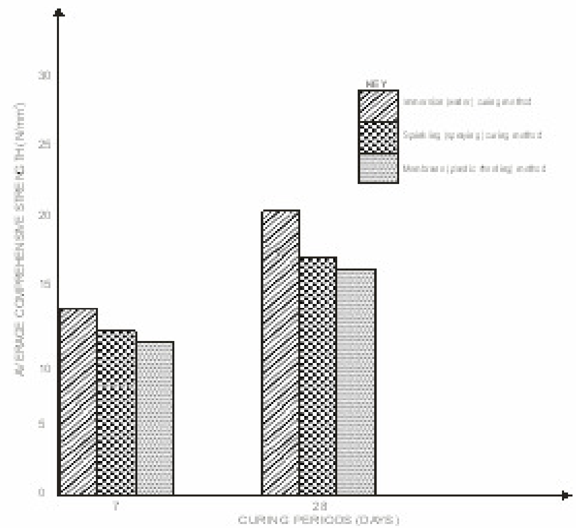

Fig 3: Graph of average compressive strength versus curing ages for Different methods of curing used in the experiment

The results of compressive strength have been presented in tables 4 - 9 and in the graphical representation of average compressive strength versus curing age for different methods of curing used in the experiment (see fig 3). In all curing methods, the compressive strength of the concrete increases with age. The highest compressive strength at all ages was produced by immersion (water) curing. The average compressive strength of water cured concrete was 13.56w/mm^2 and 20.34 N/mm^2 at 7 and 28 days respectively. Sprinkling method produced compressive strength close to immersion (Water) curing. Sprinkling method produced a compressive strength of 12.25w/mm^2 and 18.38N/mm^2 at 7 and 28 days respectively. The development of higher compressive strength in immersion (Water) curing and sprinkling method of curing is credited to sufficient moisture and suitable vapour pressure, which were maintained to continue the hydration of cement.

Plastic sheeting (membrane) method of curing produced the lowest compressive strength at all ages. It caused a reduction in compressive strength of 1.89N/mm^2 and 2.92N/mm^2 at 7 and 28 days, respectively, as compared to water curing. The early drying of concrete stopped the cement hydration before the pores were blocked by adequate calcium silicate hydrate.

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. Sprinkling method of curing produces higher compressive strength than plastic sheeting.

Table 1: Gradation of crushed granite stone and quartzite sand

SIEVE SIZE	% FINER BY MASS	
	Crushed Granite Stone (Fineness Modulus: 4:81)	Sand (Fineness Modulus: 4.23)
28.00mm	100	-
20.00mm	85.91	-
14.00mm	19.86	-
10.00mm	10.82	-
6.30mm	1.28	-
5.00mm	0.29	99.48
3.35mm	-	99.21
2.00mm	-	98.47
1.18mm	-	93.60
850µm	-	86.97
600µm	-	75.40
425µm	-	56.62
300µm	-	43.66
150µm	-	13.53
75µm	-	10.03
Pan	-	0.

Table 2: Properties of the constituent materials of concrete

Materials	Properties
Crushed Granite Stone	Max. size: 20mm, unit weight: 1434.50kg/m^3 Specific gravity: 2.68, Absorption: 0.77%, Moisture content: or 14%, void ratio: 0.46, Porosity: 9.27%
Fine Aggregate	Max. size:5mm, unit weight: 1518.70kg/m^3 Specific gravity: 2.77, Absorption: 2.29%, Moisture content: 4.71%, void ratio: 0.45, Porosity: 0.07%
Ordinary Portland Cement	Specific Gravity: 3.15, unit weight: 1440kg/m^3
Borehole Water	Density: 1000kg/m^3, P^{H}= 6.9

Table 3: Mixture Proportions of Concrete

Constituents Material	Weight (Kg/m^3)
Crushed granite stone	1360
Fine aggregate	680
Ordinary Portland Cement	340
Portable Borehole Water	170

Table 4: Compressive strength of cubes cured for 7 days using immersion method of curing.

Identification Mark	Age of Curing (days)	Wt of Cube (KG)	Dimension of the Cube (mm x mm x mm	Density of Cube (Kg/m^3)	Area of Cube (mm^2)	Failure Load (KN)	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
F11	7	7.96	150 X 150 X 150	2358.52	22500	330.67	14.70	
F12	7	7.68	150 X 150 X 150	2275.56	22500	328.00	14.58	
F13	7	7.65	150 X 150 X 150	2266.67	22500	294.67	13.10	
F14	7	7.53	150 X 150 X 150	2231.11	22500	346.67	15.41	13.56
F15	7	7.90	150 X 150 X 150	2340.74	22500	310.67	13.81	
F16	7	7.84	150 X 150 X 150	2322.96	22500	273.33	12.15	
F17	7	8.04	150 X 150 X 150	2382.22	22500	280.00	12.44	
F18	7	7.79	150 X 150 X 150	2308.15	22500	276.67	12.30	

Table 5: Compressive strength of cubes cured for 28 days using immersion method of curing

Identification Mark	Age of Curing (days)	Wt of Cube (KG)	Dimension of the Cube (mm x mm x mm	Density of Cube (Kg/m^3)	Area of Cube (mm^2)	Failure Load (KN)	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
F21	28	7.52	150 X 150 X 150	2228.15	150 X 150	496	22.04	
F22	28	7.60	150 X 150 X 150	2251.85	150 X 150	492	21.87	
F23	28	7.92	150 X 150 X 150	2346.67	150 X 150	442	19.64	
F24	28	7.94	150 X 150 X 150	2352.59	150 X 150	520	23.11	20.34
F25	28	7.96	150 X 150 X 150	2358.52	150 X 150	466	20.71	
F26	28	7.83	150 X 150 X 150	2320.00	150 X 150	410	18.22	
F27	28	7.80	150 X 150 X 150	2311.11	150 X 150	420	18.67	
F28	28	8.19	150 X 150 X 150	2426.67	150 X 150	415	18.44	

Table 6:- Compressive strength of cubes cured for 7 days using sprinkling method of curing

Identification Mark	Age of Curing (days)	Wt of Cube (KG)	Dimension of the Cube (mm x mm x mm	Density of Cube (Kg/m^3)	Area of Cube (mm^2)	Failur e Load (KN)	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
S11	7	8.40	150 X 150 X 150	2488.89	150 X 150	323	14.37	
S12	7	8.50	150 X 150 X 150	2518.52	150 X 150	286	12.71	
S13	7	8.60	150 X 150 X 150	2548.51	150 X 150	274	12.18	
S14	7	8.76	150 X 150 X 150	2595.56	150 X 150	278	12.36	12.25
S15	7	8.48	150 X 150 X 150	2512.59	150 X 150	266	11.82	
S16	7	8.42	150 X 150 X 150	2494.81	150 X 150	266	11.82	
S17	7	7.90	150 X 150 X 150	2340.74	150 X 150	257	11.43	
S18	7	7.69	150 X 150 X 150	2278.52	150 X 150	254	11.29	

Table 7: Compressive strength of cubes cured for 28 days using sprinkling method of curing.

Identification Mark	Age of Curing (days)	Wt of Cube (KG)	Dimension of the Cube (mm x mm x mm	Density of Cube (Kg/m^3)	Area of Cube (mm^2)	Failure Load (KN)	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
S21	28	8.76	150 X 150 X 150	2595.56	150 X 150	485	21.56	
S22	28	8.58	150 X 150 X 150	2542.22	150 X 150	429	19.07	
S23	28	8.42	150 X 150 X 150	2494.81	150 X 150	411	18.27	
S24	28	8.31	150 X 150 X 150	2462.22	150 X 150	417	18.53	18.38
S25	28	8.19	150 X 150 X 150	2426.67	150 X 150	399	17.73	
S26	28	8.08	150 X 150 X 150	2394.07	150 X 150	400	17.78	
S27	28	8.25	150 X 150 X 150	2444.40	150 X 150	386	17.16	
S28	28	7.86	150 X 150 X 150	2328.89	150 X 150	381	16.93	

Table 8: Compressive strength of cubes cured for 7 days using the Membrane Method (Plastic Sheeting).

Identification Mark	Age of Curing (days)	Wt of Cube (KG)	Dimension of the Cube (mm x mm x mm	Density of Cube (Kg/m^3)	Area of Cube (mm^2)	Failure Load (KN)	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
P11	7	8.44	150 X 150 X 150	2500.74	150 X 150	264	11.76	
P12	7	8.24	150 X 150 X 150	2441.48	150 X 150	272	12.12	
P13	7	8.18	150 X 150 X 150	2423.70	150 X 150	266	11.85	
P14	7	7.94	150 X 150 X 150	2532.59	150 X 150	257	11.44	11.67
P15	7	7.90	150 X 150 X 150	2340.74	150 X 150	273	12.15	
P16	7	7.83	150 X 150 X 150	2320.00	150 X 150	252	11.20	
P17	7	7.68	150 X 150 X 150	2269.63	150 X 150	254	11.29	
P18	7	7.60	150 X 150 X 150	2278.52	150 X 150	260	11.56	

Table 9: Compressive strength of cubes cured for 28 days using the Membrane Method (Plastic Sheeting).

Identification Mark	Age of Curing (days)	Wt of Cube (KG)	Dimension of the Cube (mm x mm x mm	Density of Cube (Kg/m^3)	Area of Cube (mm^2)	Failure Load (KN)	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
P21	28	8.80	150 X 150 X 150	2607.41	150 X 150	397	17.64	
P22	28	8.51	150 X 150 X 150	2521.48	150 X 150	409	17.64	
P23	28	8.31	150 X 150 X 150	2462.22	150 X 150	400	17.78	
P24	28	8.20	150 X 150 X 150	2429.62	150 X 150	386	17.16	17.42
P25	28	7.93	150 X 150 X 150	2349.63	150 X 150	410	18.22	
P26	28	7.72	150 X 150 X 150	2287.41	150 X 150	378	16.80	
P27	28	7.69	150 X 150 X 150	2278.52	150 X 150	381	16.93	
P28	28	7.67	150 X 150 X 150	2272.59	150 X 150	375	16.67	

This is attributed reduced the moisture movement from concrete specimens leading to enhanced degree of cement hydration.

3. Plastic sheeting method of curing produces lowest level of compressive strength. This is because the moisture movement from the concrete specimen is higher in plastic sheeting method, which did not provide and any protection against early drying out of concrete. Hence hydration of cement reaction was abated.
4. The extent of moisture movement was greatly dependent of the method of curing. Greater moisture movement occurs under plastic sheeting (membrane) method, and it significantly affected the strength property of the concrete.
5. Normal concrete should be cured by water curing (immersion) method in order to achieve good hardened properties. Water curing produces no loss of moisture, and therefore enhances cement hydration reaction. In case of water shortage, sprinkling curing can be adopted instead of wrapped (plastic sheeting) curing.

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