STUDY ON THE INFLUENCE OF THE METHODS OF CURING ON THE STRENGTH PROPERTIES OF CONCRETE

By

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ABSTRACT

Curing is the process of maintaining hardened concrete under moist condition. Curing must be undertaken for reasonable period of time, to ensure that the concrete achieves its potential strength and durability. Efficient and uninterrupted curing contributes to the superior quality of concrete. This paper aims to compare the strength parameters of M40 and M25 grade concrete under various methods of curing. For this study, we adopted curing by Immersion and Surface Curing methods. We also adopted Membrane Curing, in which the curing would be done by the application of pigmented emulsions of linseed oil on the concrete surface. Finally, after the concrete specimens have undergone curing for a certain period of time, they are tested for strength parameters such as Compressive Strength and Flexural Strength and the conclusions are drawn from it.

Keywords: Curing Methods, Immersion Curing, Membrane Curing, Pigmented Emulsions of Linseed Oil, Strength Parameters, Surface Curing.

INTRODUCTION

Concrete is considered to be one of the most versatile, legendary and strongest building materials. It is known for its simplicity in manufacturing and can be casted to fit any structural shape. It is readily available in urban areas, at an affordable cost (Bureau of Indian Standards [BIS], 2016).

Practice of concrete provides the following advantages: High durability, good fire resistance, negligible maintenance and importantly greater compressive strength. Concrete also offers some limitations such as, poor tensile strength (which could be improved by providing Reinforcement) and formwork requirement (unignorable).

Another limitation that comes into picture is that, concrete, could not attain higher strengths immediately after hardening. For this, the concrete need to be cured for a certain period of time. Curing, is a process of reducing the extent of moisture loss from concrete by providing moist conditions for the surface of concrete during cement hydration. Since the hydration of cement does take time for days and weeks together, curing must be undertaken for reasonable period of time if concrete is to achieve its potential strength and durability.

Curing is done to attain good quality concrete, with greater strength parameters. Curing is essential if the concrete is to perform its intended function during the design life of the structure, whereas excessive curing time may lead to rapid increase in the construction cost of the project and unnecessary delays (BIS, 2000).

If within the curing period, natural temperatures of concrete are in the acceptable range of values, then moisture content need not be controlled. If the natural temperature is outside the acceptable range of values, moisture content needs to be regulated for controlling the temperature of concrete, as it influences concrete's strength.

There are various methods of curing, including the following:

- Electrical Curing (Tighare & Singh, 2017).
- Membrane Curing by Curing Compound (Gawatre et al., 2017).

- Curing using Calcium Chloride ($CaCl_2$) (Gowsika et al., 2020).
- Using Wax based Curing Compound (Patil et al., 2016).
- Using High Pressure Steam Curing (Shaikh et al., 2017).
- Using Spray and Fogg Curing (Kalbande et al., 2017).
- Curing by Immersion (Kholia et al., 2013).

Many other methods are used.

1. Objectives

- To study and analyze the influence of curing on the strength of concrete.
- To analyze the influence of the method of curing on the strength parameters of concrete.
- To find the suitable optimistic and feasible method of curing to attain higher level of strength with ease of application.

2. Materials Used

2.1 Cement

Cement is one of the basic construction material that will be generally in powdered form and hardens upon the addition of water to it. It can serve as a binding material to aggregates for obtaining strength. It possesses cohesive and adhesive properties. The cement used for this study is Portland Pozzolana Cement of 53 Grade (BIS, 2013).

The properties of the cement used is presented in Table 1.

2.2 Fine Aggregate

The Aggregate passing through 4.75 mm sieve could be called as Fine Aggregate (BIS, 2016). Generally, Fine Aggregate is a filling material for the Concrete. The Fine Aggregate used for this study is River Sand collected from Local RMC Plant. The Specific Gravity of the Fine Aggregate used is 2.65.

2.3 Coarse Aggregate

The Aggregates passing through 20 mm IS sieve and retained on 4.75mm IS sieve could be called as Coarse Aggregate (BIS, 2016). Generally, Coarse Aggregate is a material that enhances the strength and stability for the Concrete. The Coarse Aggregate used for this study is collected from Miyapur Quarry. The Specific Gravity of Coarse Aggregate used is 2.83.

S.No	Property of Cement	Result
1	Grade of Cement	53
2	Fineness (m^2/kg)	390
3	Standard Consistency (%)	33.5
4	Setting Time (minutes)	
	a) Initial	30
	b) Final	550
5	Soundness in Le-Chat Expansion (mm)	0.5
6	Compressive Strength (MPa)	
	a) 72 +/- 1hr.(3 days)	28.6
	b) 168 +/- 2 hr.(7 days)	38.6
	c) 672 +/- 4 hr.(28 days)	58.0

Table 1. Properties of Cement Used

2.4 Water

Water is the main ingredient used to mix all the contents. The usage of any other water may contain salts, it will cause decrease in strength of concrete. Therefore, potable water is used.

2.5 Curing Compound

In this study, for the purpose of Membrane Curing, we have adopted the chemical which is a pigmented emulsion of linseed oil. After its application and drying, it attains a bonded white colored appearance. It is not affected by natural weathering. The visual appearance of this chemical is presented in Figure 1.

2.6 Gunny Bags

Gunny Bags are used for surface curing. These bags are generally made of Jute material and are wrapped around the concrete specimen. These bags are damped with water from time to time as a medium of curing. The Gunny Bag used for the study is presented in Figure 2.

3. Methodology

For this study, we have adopted 2 concrete mixes (Reddy, 2013).

They are M40 Concrete (Design Mix) which is made with respect to BIS (2009) and M25 Concrete (Conventional Mix). The proportions for these mixes are M40 grade (1:1.67:2.92) and M25 grade (1:1:2) and the water cement ratio is taken as 0:5 for both the mixes.

The concrete is mixed with the above specified materials on both the mixes and is casted in Cubes and

Figure 1. Chemical used for Membrane Curing

Figure 2. Gunny Bag

Prisms for Formwork and is allowed to harden for 24 hours. Then 9 cubes and 9 prisms are cured by Immersion Curing for each grade. Similarly, another 9 cubes and 9 prisms are cured by Surface Curing and Membrane Curing. Finally, we have subjected these cubes to Compression and Flexure Tests and have drawn the results (Reddy, 2013).

4. Process of Curing

4.1 Immersion Curing

This curing is done by immersing the hardened concrete specimen in water for a certain period of time. This curing could give results confining only to laboratory. Practically, on site, we cannot ever adopt this Immersion Curing. The Immersion Curing is represented in Figure 3.

4.2 Surface Curing

This curing had been done by wrapping the concrete surface with a water retaining medium (Kumar & Maruthachalam, 2013). For this study, we have adopted Gunny bags and wrapped them against the concrete specimen and damped these bags from time to time. This type of curing could be adopted on site, and usually uses low amount of water. The process of Surface Curing is presented in Figure 4.

4.3 Membrane Curing

As mentioned in this method, we have adopted pigmented emulsions of linseed oil, as a curing agent. This material would be in liquid form and should be applied in 3 layers for the surface of concrete and must be allowed to dry. Then the concrete is left in open atmosphere for a certain period of time and later proceeded for testing. The application of curing compound is shown in Figure 5.

5. Results and Discussions

After the specimens are cured, they are subjected to Compressive strength and Flexural strength tests. Each test result is tabulated and analyzed.

5.1 Compression Test Results

Compression Test is done by subjecting compression load on the concrete cube surface in Digital Compression Testing Machine.

The results for this test are presented in Table 2 and Figures 6, 7 respectively.

Figure 3. Immersion Curing

Figure 4. Sprinkling of Water on Prism Covered with Gunny Bag

Figure 5. Application of Curing Compound

Size of cube for compression testing = 150*150*150mm

Compressive strength of concrete = Compressive Load/ (Surface area of cube)

5.2 Flexure Test Results

Flexure Test is done on concrete prism, by subjecting the Flexural Load in Flexure Testing Machine. According to IS 456:2000, the Flexural Strength of Concrete at 28 days age would be 0.7* (fck) 0.5 MPa (BIS, 2000). (where, fck is the grade of concrete).

Size of prism for flexure testing = 500*100*100mm

Flexure strength of concrete = (Maximum flexure load* length of prism/ width*depth^2)

The results for this test are presented in Table 3 and Figures 8, 9 respectively.

Grade of Concrete	Type of Curing	Average Compressive Strength (MPa) 7 Days	14 Days	28 Days
M40	Immersion	25.43	35.95	58.00
	Surface	20.26	32.65	39.94
	Membrane	21.35	33.68	43.14
M25	Immersion	19.01	21.57	33.64
	Surface	17.87	19.33	28.40
	Membrane	18.43	20.05	29.68

Table 2. Compression Test Results for Various Curings and Concrete Grades

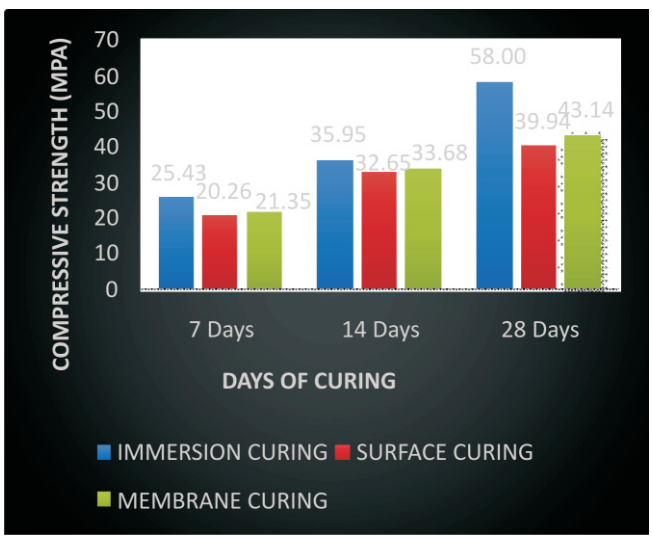

Figure 6. Variation of Compressive Strength in M40 Concrete for Various Curings

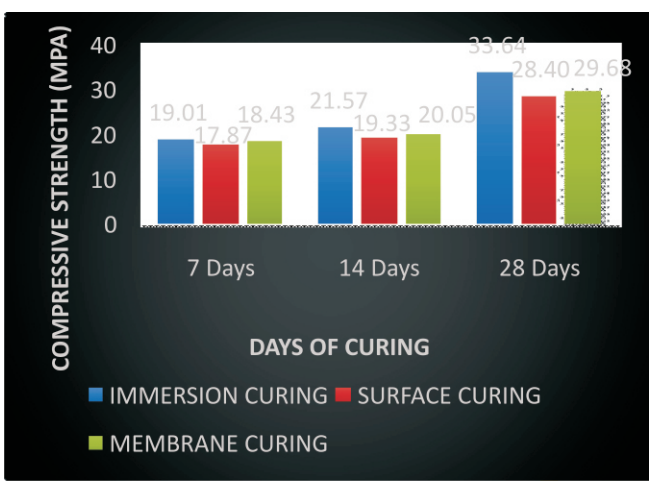

Figure 7. Variation of Compressive Strength in M25 Concrete for Various Curings

Grade of Concrete	Type of Curing	Average Compressive Strength (MPa) 7 Days	14 Days	28 Days
M40	Immersion	2.58	3.20	4.97
	Surface	1.91	2.92	3.80
	Membrane	2.12	3.98	4.35
M25	Immersion	2.98	3.46	3.70
	Surface	1.95	2.20	2.58
	Membrane	2.50	3.26	3.50

Table 3. Flexure Test Results for Various Curings and Concrete Grades

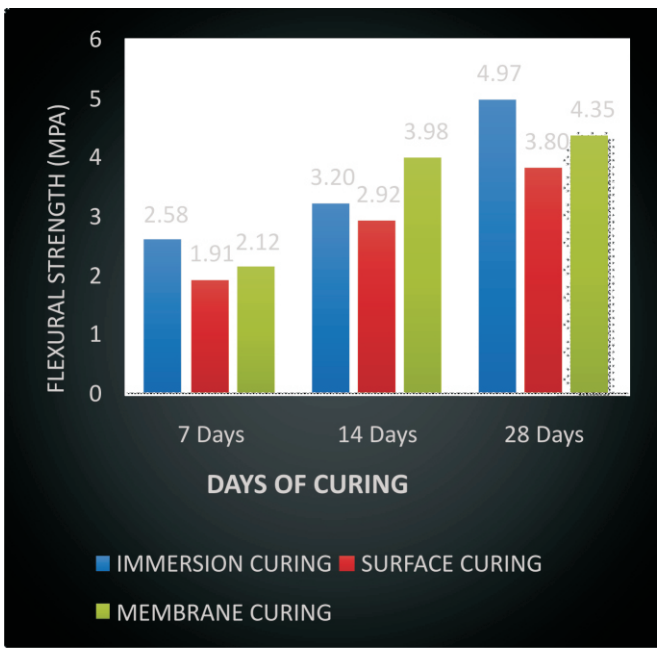

Figure 8. Variation of Flexural Strength in M40 Concrete for Various Curings

Conclusions

- After all the testing processes are done, we can initially state that, there is obvious increase in strength of concrete with increase in the time of curing.
- There are variations in the amount of increment in the strength of concrete depending on the method of curing.
- The pattern of increase of strength is observed to be almost same in all the 3 methods of curing.
- The results for Immersion Curing are extremely high in both M40 and M25 concretes. The compression test results ended at 0.40 times more than the average

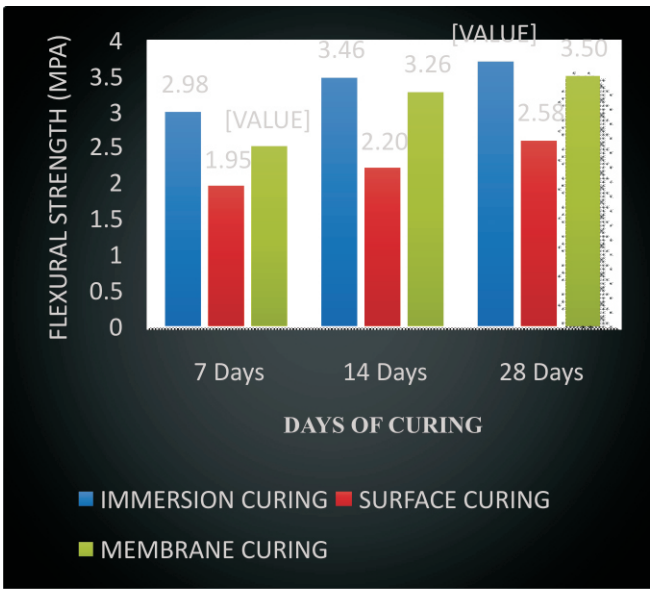

Figure 9. Variation of Flexural Strength in M25 Concrete for Various Curings

requirement of both the concrete grades. Also, the Flexural strength test results are also really satisfactory by the time 28 days of curing period is done.

- Coming to Surface Curing, its results are also agreeable. We have achieved up to 99% of compressive strength, and 97% of flexural strength by the end of 28 days.
- When looking into Membrane Curing, we have achieved about 0.13 times more compressive strength than required and 99% of flexural strength by the end of 28days.
- Coming to the feasibility and application of the methods of curing, Immersion Curing could only be done in the laboratory and it is almost practically impossible to apply it on site.
- Whereas, Surface Curing could be done on site, by simply applying Gunny Bags or Jute bags to the concrete surface, but we have to surely sprinkle the surface of the bags from time to time. Today its application can be seen during the construction of columns and rigid pavements. It demands resources like water, labor, machinery for this purpose.
- Finally, Membrane Curing is found to be extremely cost efficient, less water consuming and efficient

method for curing. This method has given us very satisfactory results. It does not demand any source of maintenance until the completion of the curing process.

- Therefore, Membrane Curing done using pigmented emulsions of linseed oil would be the best method for curing on-site. It does not involve any scale of resources including water, man-power, electricity etc., throughout the process of curing. It also enables simplicity in usage.
- This Membrane Curing could be successfully used in the places where there is scarcity for water and direct water curing is a challenge.

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