Curing of Concrete: A Review

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Abstract— *The properties of hardened concrete, especially the durability, are greatly influenced by curing since it has a remarkable effect on the hydration of the cement. The advancements in the construction and chemical industry have paved way for the development of the new curing techniques and construction chemicals such as Membrane curing compounds, Self-curing agents, Wrapped curing, Accelerators, Water proofing compounds etc. With the growing scale of the project conventional curing methods have proven to be a costly affair as there are many practical issues and they have been replaced by Membrane curing compounds and Self-curing agents up to some extent as they can be used in inaccessible areas, Vertical structures, Water scarce areas etc .It is most practical and widely used curing method. In this review paper effort has been made to understand the working and efficiency of curing methods which are generally adopted in the construction industry and compared with the conventional water curing method.*

I. INTRODUCTION

Curing is the name given to the procedures used for promoting the hydration of the cement, and consists of a control of temperature and of moisture movement from and into the concrete. Curing allows continuous hydration of cement and consequently continuous gain in the strength, once curing stops strength gain of the concrete also stops. Proper moisture conditions are critical because the hydration of the cement virtually ceases when the relative humidity within the capillaries drops below 80%. With insufficient water, the hydration will not proceed and the resulting concrete may not possess the desirable strength and impermeability. The continuous pore structure formed on the near surface may allow the ingress of deleterious agents and would cause various durability problems. Moreover due to early drying of the concrete micro-cracks or shrinkage cracks would develop on surface of the concrete. When concrete is exposed to the environment evaporation of water takes place and loss of moisture will reduce the initial water cement ratio which will result in the incomplete hydration of the cement and hence lowering the quality of the concrete. Various factors such as wind velocity, relative humidity, atmospheric temperature, water cement ratio of the mix and type of the cement used in the mix. Evaporation in the initial stage leads to plastic shrinkage cracking and at the final stage of setting it leads to drying shrinkage cracking. [10]

Now a day construction is rapidly increasing and as concrete is inherent material for construction so its performance also very important for life of structure and it depends on the various parameters [1]. One of the most important parameters is Curing. Curing is the process of controlling the rate and extent of moisture loss from concrete during cement hydration. This can be achieved by various methods like; continuously wetting the exposed surface thereby preventing the loss of moisture from it, spraying the surface with water, leaving formwork in place, covering the concrete with an impermeable membrane after the formwork has been removed, by the application of a suitable chemical curing agent (wax etc.) and using chemicals as internal curing or by a combination of such methods. In order to obtain good quality concrete, an appropriate mix must be followed by proper curing in a suitable environment during the early stages of hardening [2]. Also for durability as well as performance of structure proper and homogeneous curing is necessary.

A. Methods Used For Curing Of Concrete

- Shading concrete work
- Covering concrete surfaces with hessian or gunny bags
- Sprinkling of water
- Ponding method
- Membrane curing
- Immersion curing
- Steam curing

II. STATE OF DEVELOPMENT

Curing plays an important role on strength development and durability of concrete. Curing takes place immediately after concrete placing and finishing, and involves maintenance of desired moisture and temperature conditions, both at depth and near the surface, for extended periods of time. Properly cured concrete has an adequate amount of moisture for continued hydration and development of strength, volume stability, resistance to freezing and thawing, and abrasion and scaling resistance.The length of adequate curing time is dependent on the following factors:

- Mixture proportions
- Specified strength
- Size and shape of concrete member
- Ambient weather conditions
- Future exposure conditions

Ananthi et.al.[1] This paper highlights the effect of curing agent polyethylene glycol (PEG-400) in the performance of concrete. From the results, it was seen that the optimum dosage of PEG 400 for maximum strength was found to be 2% for M40 grade. Muddassir Bora et.al.[2] The strength and durability of concrete depends on the curing of concrete. 'Internal curing' is often also referred as 'Self– curing.' Any negligence in in curing will interfere in the strength and durability of concrete. Ktftng Tan et.al.[3] The effect of curing conditions on strength and permeability of concrete was studied. The curing temperatures did not affect the water penetration of concrete, but affected the chloride penetration and compressive strength of concrete significantly. Nirav R Kholia et.al.[4] The properties of hardened concrete, especially the durability, are greatly influenced by curing since it has a remarkable effect on the hydration of the cement. This paper review about the materials used as self-curing agents, mechanism of self-curing and the properties of different type of concrete when subjected to self-curing method. Self-curing technology is the process which hydrates the cement internally in concrete, no external source needed for curing such as water curing [3]. Curing may be applied in a number of ways and the most appropriate means of curing may be dictated by the site or the construction method. The present paper is directed to evaluate effectiveness of different curing methods and study the influence of climate on the strength properties of concrete. Amal Viswam et.al.[7] Concrete is one of the most widely used construction material due to its good compressive strength and durability. K. Sumangala et.al.[8] Curing of concrete maintains satisfactory moisture content in concrete in its early stages so as to develop desired properties. Patel et.al.[9] In the 21st Century, expansion of cities as well as state construction process increase rapidly and concrete is the most frequently used construction material. In recent years various kinds of concrete were developed such as high performance concrete, fiber reinforced concrete, early strength concrete, recycled concrete, self-compacting concrete etc.

III. METHODOLOGY

There are various methods of curing. The adoption of a particular method will depend upon the nature of work and the climatic conditions. The following methods of curing of concrete are generally adopted. Curing of Concrete

- Shading concrete work
- Covering concrete surfaces with hessian or gunny bags
- Sprinkling of water
- Ponding method
- Membrane curing
- Steam curing

Silica fume, also known as micro silica is an amorphous polymorph of silicon dioxide, silica. It is an ultrafine powder collected as a by-product of the silicon and ferrosilicon alloy production and consists of spherical particles with an average particle diameter of 150 nm. The bulk density of silica fume depends on the degree of densification in the silo and varies from 130 (undensified) to 600 kg/m3. The specific gravity of silica fume is generally in the range of 2.2 to 2.3.

Table 1. Mix Proportion

Mix	Cement	Silica fume	Fine aggregate	Coarse aggregate	Water	Super plasticizer
M20	1	-	1.58	2.51	0.45	-
M40	1	0.1	1.9	3.16	0.36	0.02

A. Experimental Setup

- **Shading concrete work**; The object of shading concrete work is to prevent the evaporation of water from the surface even before setting. This is adopted mainly in case of large concrete surfaces such as road slabs.
- **Covering concrete surfaces with hessian or gunny bags** This is a widely used method of curing, particularly for structural concrete. Thus exposed surface of concrete is prevented from drying out by covering it with hessian, canvas or empty cement bags.
- **Sprinkling of water** -Sprinkling of water continuously on the concrete surface provides an efficient curing. It is mostly used for curing floor slabs. The concrete should be allowed to set sufficiently before sprinkling is started.
- **Ponding method** This is the best method of curing. It is suitable for curing horizontal surfaces such as floors, roof slabs, road and air field pavements. The horizontal top surfaces of beams can also be ponded. After placing the concrete, its exposed surface is first covered with moist hessian or canvas. After 24 hours, these covers are removed and small ponds of clay or sand are built across and along the pavements.

- **Membrane curing** The method of curing described above come under the category of moist curing. Another method of curing is to cover the wetted concrete surface by a layer of water proof material, which is kept in contact with the concrete surface of seven days. This method of curing is termed as membrane curing [4].
- **Steam curing** Steam curing and hot water curing is sometimes adopted. With these methods of curing, the strength development of concrete is very rapid. These methods can best be used in pre-cast concrete work. In steam curing the temperature of steam should be restricted to a maximum of 75°C as in the absence of proper humidity (about 90%) the concrete may dry too soon. In case of hot water curing, temperature may be raised to any limit, ay 100°C. After the specimens have been made, they shall be left to stand undisturbed in their moulds in a place free from vibration at a temperature of 27± 2oC for at least one hour, prior to immersion in the curing tank. The time between the addition of water to the ingredients and immersion of the test specimens in the curing tank shall be at least 1hour 30 minutes but shall not exceed 3hour and 30 minutes.

The specimen in their moulds shall be gently lowered into the curing tank and shall remain totally immersed at 55± 2oC for a period of not less than 19 hours 50 minutes. The specimens shall be removed from the water, marked for identification, removed from the moulds and immersed in the cooling tank at 27± 2oC before the completion of 20 hours 10 minutes from the start of immersion in the curing tank. They shall remain in the cooling tank for a period of not less than 1 hour. After that the specimens shall be tested while still wet, not more than 2 hours from the time of immersion in the cooling tank.

IV. RESULT AND DISCUSSION

In this experimental work a total number of 42 cubes and 42 cylinders were cast and tested. Out of these, 36 cubes and 36 cylinders were tested for Immersion curing and wet gunny bags curing respectively. Out of which, 18 cubes and 18 cylinders were cast and tested for normal strength of concrete (M20) and medium strength of concrete (M40) through Immersion and wet gunny bags curing method. Remaining 6 cubes and 6 cylinders were tested for Accelerated warm water curing method.

Table 2: Test Result for Compressive Strength

Curing methods		Immersion curing(N/mm²)			Wet gunny bag curing (N/mm²)			Accelerated curing (N/mm²)
Curing(in days)		7	14	28	7	14	28	1
Grade of concrete	M20	13.88	18.67	24.6	12.5	17.7	23.2	22.43
	M40	26.83	33.83	43.6	25.56	32.2	41.3	40.7

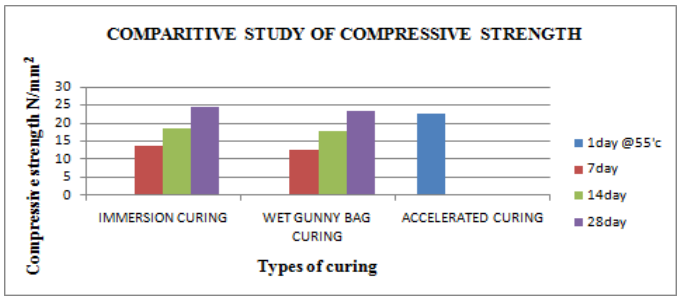

Fig 1: Effect of three types of curing on compressive strength of concrete for M20 grade of concrete

From Figure 1, it can be concluded that the compressive strength of concrete cubes by Immersion curing method was achieved that 56.42% and 74.8% of 28 days strength at 7 days and 14 days respectively for M20 grade of concrete. The compressive strength of concrete cubes by wet gunny bags curing method was achieved that 53.8% and 76.2% of 28 days strength at 7 days and 14 days respectively for M20 grade of concrete.

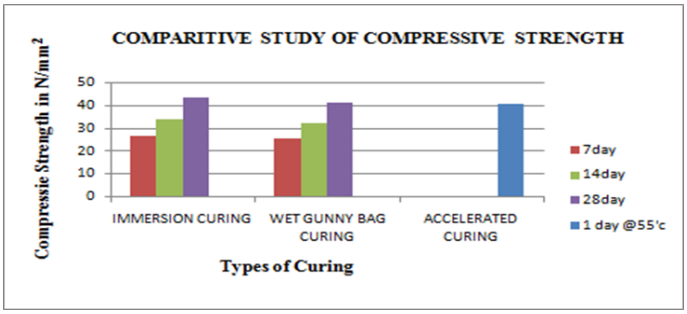

Fig 2: Effect of three types of curing on compressive strength of concrete for M40 grade of concrete

From Figure 2, it can be concluded that the compressive strength of concrete cubes by immersion curing method was achieved that 61.5% and 77.5% of 28 days strength at 7 days and 14 days respectively for M40 grade of concrete. The compressive strength of concrete cubes by Wet gunny bags curing method was achieved that 61.8% and 77.8% of 28 days strength at 7 days and 14 days respectively for M40 grade of concrete.

Table 4: Test Result for Split Tensile Strength

Curing methods		Immersion curing(N/mm²)			Wet gunny bag curing (N/mm²)			Accelerated curing (N/mm²)
Curing (in days)		7	14	8	7	14	28	1
Grade of concrete	M20	0.87	1.26	1.63	0.71	1.16	1.54	1.51
	M40	1.61	1.95	2.47	1.49	1.82	2.35	2.28

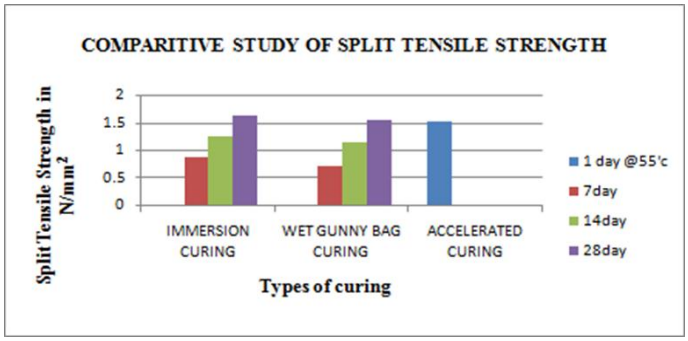

Fig 3: Effect of three types of curing on split tensile strength of concrete for M20 grade of concrete

From Figure 3, it can be concluded that the split tensile strength of concrete cylinders by Immersion curing method was achieved that 53% and 77.3% of 28 days strength at 7 days and 14 days respectively for M20 grade of concrete. The compressive strength of concrete cubes by wet gunny bags curing method was achieved that 46% and 75.3% of 28 days strength at 7 days and 14 days respectively After 28 days it was seen that the strength achieved by Immersion curing and Accelerated curing was 1.06% higher and 0.98% lesser than Wet gunny bag curing respectively for M20 grade of concrete.

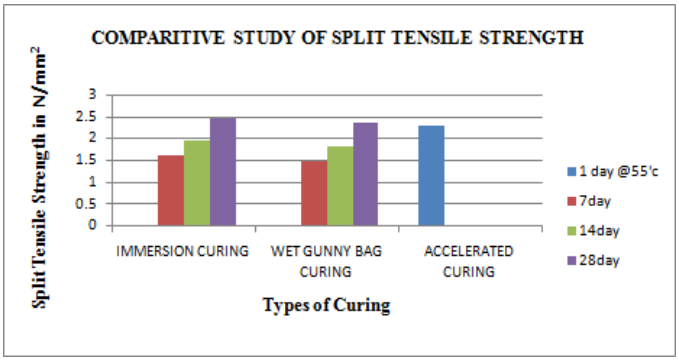

Fig 4: Effect of three types of curing on split tensile strength of concrete for M40 grade of concrete

From Figure 4, it can be concluded that the split tensile strength of concrete cylinders by Immersion curing method was achieved that 65.2% and 78.9% of 28 days strength at 7 days and 14 days respectively for M20 grade of concrete. The compressive strength of concrete cubes by wet gunny bags curing method was achieved that 63.4% and 77.4% of 28 days strength at 7 days and 14 days respectively .After 28 days it was seen that the strength achieved by Immersion curing and Accelerated curing was 1.05% higher and 0.97% lesser than Wet gunny bag curing respectively for M40 grade of concrete.

V. CONCLUSIONS

From the experimental test results the following conclusions were made,

II. The Immersion curing and Wet gunny bag curing attained an average compressive strength of 24.6 N/mm² and 23.2 N/mm² respectively for M20 grade of concrete at the age of 28 days. At same age, the Immersion curing and Wet gunny bag curing attained an average compressive strength of 43.6 N/mm² and 41.3 N/mm² respectively for M40 grade of concrete.

III. At the age of 28 days by Immersion curing and Wet gunny bag curing attained an average split tensile strength of 1.63 N/mm² and 1.54 N/mm² respectively for M20 grade of concrete. In case of M40 grade the average split tensile strength of 2.47N/mm² by Immersion curing and 2.35 N/mm² by Wet gunny bags curing respectively.

IV. The average compressive strength of concrete cubes with Accelerated warm water curing method equivalent to 28 days was found to be 22.43 N/mm² for M20 grade

V. The average compressive strength of concrete cubes with Accelerated warm water curing method was 40.7 N/mm² for M40 grade of concrete.

VI. The average split tensile strength of cylinder specimens by Accelerated warm water curing method which is equal to 28 days of curing was calculated as 1.51 N/mm² for M20 grade of concrete.

VII. The average split tensile strength of cylinder specimens by Accelerated warm water curing method was 2.28 N/mm² for M40 grade of concrete.

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