EFFECT ON CONCRETE BY DIFFERENT CURING METHOD AND EFFICIENCY OF CURING COMPOUNDS – 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project conventional curing methods have proven to be a costly affair as there are many practical issues and they have been replaced by Membrane curing compounds and Self-curing agents up to some extent as they can be used in inaccessible areas, Vertical structures, Water scarce areas etc.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.

KEY WORDS: Curing Compounds, Self-Curing agents, Wrapped Curing, Hardened Properties, Durability, Curing Efficiency.

1.0 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% [1]. 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 [2]. 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.

Curing temperature is one of the major factors that affect the strength development rate. At elevated temperature ordinary concrete losses its strength due to the formation of the cracks between two thermally incompatible ingredients, cement paste and aggregates. When concrete is cured at high temperature normally develops higher early strength than concrete produced and cured at lower temperature, but strength is generally lowered at 28 days and later stage [1]. A uniform temperature should be maintained through the concrete section to avoid thermal cracking. Laboratory tests show that concrete in dry environment can lose as much as 50 percent of its potential strength compared to similar concrete that is moist cured. Curing of the concrete is also governed by the moist-curing period, longer the moist-curing period higher the strength of the concrete assuming that the hydration of the cement particles will go on. American Concrete Institute (ACI) Committee 301 recommends a minimum curing period corresponding to concrete attaining 70% of the specified compressive strength [4].

Curing has a strong influence on the properties of hardened concrete; proper curing will increase the durability, strength, volume stability, abrasion resistance, impermeability and resistance to freezing and thawing [5].

A durable concrete is one that performs satisfactorily under the anticipated exposure condition during its designed service life. In addition to the normal concrete mix some additional compounds in proper dosage and materials such as fly ash are used to increase the durability and strength of the concrete mix.

“Curing techniques and curing duration significantly affects curing efficiency” Various degree of efficiency can be achieved by various in-situ curing methods. The effectiveness of the concrete curing method depends on the material used, method of construction and the intended use of the hardened concrete. Techniques used in concrete curing are mainly divided into two groups namely, Water adding techniques and Water-retraining techniques. Reliability and effectiveness of such curing methods are still under debate. This study presents the working comparison and the effectiveness of curing methods on several hardened properties of concrete such as compressive strength, flexural strength, initial surface absorption, ultrasonic pulse velocity and dynamic modulus of elasticity.

2.0 REVIEW OF LITERATURE:
2.1 Dry-Air Curing:
Dry curing is a curing method wherein the concrete cubes are left in open air to be cured at room temperature. Researchers have been working on the natural air drying of concrete since long. Md. Saifuddin et al [6] carried out experiments to study the effect of this type of curing on the properties of Microsilica Concrete (Microsilica was used as a 10% weight replacement of cement) with a water binder ratio of 0.35. Dry-air curing produced 15.2%, 6.59% and 3.36% reduction in compressive strength, dynamic modulus of elasticity and ultrasonic pulse velocity respectively, this was owing to the early
drying of concrete which virtually ceased hydration of the cement because the relative humidity within capillaries dropped below 80% (Neville [8]) and thus the formation of major reaction product Calcium silicate hydrate the major strength providing and porosity reducer stops before the pores are adequately blocked by it. Also, it caused 12.4% and 46.53% increase in initial surface absorption after 10 and 120 minutes respectively. This might be due to micro cracks or shrinkage cracks resulting from the early drying out of the concrete (Fauzi [3]). Experimental results indicate that Dry-curing is not an efficient method to achieve good hardened properties of concrete.

2.2 Water adding technique
Water adding techniques include Pounding or immersion, spraying or fogging and saturated wet covering.

2.2.1 Pounding or immersion is a curing method wherein the flat concrete surfaces such as slabs and pavements are cured by pounding of water around the perimeter of the surface with the help of sand dikes. It is an effective method as it maintains a uniform temperature in the concrete and also prevents the loss of the moisture from the concrete. This method is used in laboratory experiments wherein the specimens are dipped in water after 24 hours of casting. The specimens are than tested for the strength after 7 and 28 days. Since pounding require considerable supervision and labour, this method is generally used for small construction activity only.

2.2.2 Fogging or Sprinkling is a curing method wherein a fine fog mist is frequently applied on the surface of the concrete through a system of sprayers or nozzles. It is an effective method of curing when the humidity is low or the ambient temperature is well above the freezing point. This method requires ample of water and a proper supervision.

2.2.3 Saturated wet covering is most often used curing method in the construction industry. In this method moisture retaining fabrics such as burlap cotton mats and rugs are used as wet covering to keep the concrete in a wet condition during the curing period, for if the drying is permitted, the cover will itself absorb the water from the concrete. Alternative cycles of wetting and drying during the early period of curing will cause cracking of the surface. The major disadvantage of this method is discolouring of concrete.

Researchers are working in order to identify the effectiveness of the water curing methods over other curing methods. M.V. Krishna et al [7]. Carried out an experimental study on the effect of elevated temperature on differently cured concrete of M40 grade and subjected to temperature of 150°C, 300°C and 450°C for 1 hour duration in muffle furnace. His study revealed that the 28-day compressive strength of the concrete specimen cured by water curing have been more than those cured by membrane curing in both heated and high temperature exposure condition. Weight loss in both conventional water cured concrete and membrane cured concrete are comparable.

Md. Safuddin et al [6] investigated the effect of different curing method on the properties of Microsilica concrete (Microsilica was used as a 10% weight replacement of cement) with a water binder ratio of 0.35. His study revealed that Water curing is the most effective method of curing as it produced highest level of compressive strength, dynamic modulus of elasticity and ultra sonic pulse velocity and lower level of surface absorption because of improved pore structure and lower porosity resulting from greater degree of hydration and pozzolanic reaction without any loss of moisture from the concrete specimen.

Water curing is the most efficient and preferred techniques in various construction projects, but they also encounter certain restriction in situ in construction of highways, canal lining, Shell structures, high-rise buildings and areas having deficiency of eater like Saursashtra region in Gujarat, Rajasthan.

2.3 Water retaining techniques:
Water retaining techniques include Membrane forming curing compound, plastic sheeting.

2.3.1 Curing Compound
Various types of curing compound are available in the market, mainly includes water-based, resin-solvent based, chlorinated rubber, wax based etc. Water based curing compound is most used curing compound world-wide [8]. These compounds are applied on the exposed surface of the concrete by the help of roller, brush or spray. Effectiveness of the curing compound is remarkable dependent on their application, time and generic type [9]. It is difficult to apply such compounds on the vertical surfaces. Curing efficiency (E) for a particular method of curing can be determined by the following equation (Cabrera et al [10]).

\[ E = \frac{k_1 - k_2}{k_1 - k_3} \times 100 \]

Where, \( k_1 \) = studied property of a non-cured specimen, \( k_2 \) = studied property of a specimen cured by the method being evaluated, and \( k_3 \) = studied property of water-cured specimen till age of testing. If the curing method is equally good as water-curing (\( k_2 = k_3 \)) then the value of \( E \) = 100%, while for poor curing method (\( k_2 > k_3 \)) the value of \( E \) tends to 0%.

This definition gives a convenient scale with which to assess the efficiency of chemical curing compounds or traditional methods (Cabrera et al [13]). Curing compounds namely, acrylic and water based are effective in decreasing plastic and drying shrinkage strain for both ordinary and blended cements and the curing efficiency of such compounds with respect to compressive strength are in the range of 84 to 96 percent [Al-Gahtani, 2010] [11].

G.E. Abdelaziz [12] investigated the effect of application time of water based curing compound on strength, hardness, sorptivity and porosity of blended concrete. His study revealed that application of WBCC in the early stage (within first 2 hours of casting) would yield best possible properties of concrete. The time of application of WBCC and pre-water curing had a greater effect on the durability properties of the concrete (sorptivity and porosity) than on mechanical properties (strength and hardness). He also suggested that compressive strength and Schmidt hammer tool are not suitable for assessing the efficiency of curing compound.

Raghavendra and Aswath [13] from there comparative study on different curing methods reported that the efficiency of the membrane curing compound is 90% as compared to conventional standard water curing...
method. Nada [15] also got the same results. The compressive strength ratio of field curing using curing compound to standard curing reveals that, there is no ratio fall under 85% and this results also complies with the ACI 318 requirements, the results indicates 92.11% as minimum field-standard ratio.

2.3.2 Plastic Sheet:
Plastic sheets such as polyethylene film are used to cure concrete. Polyethylene films are lightweight, impervious hence prevent the moisture movement from the concrete and can be applied to simple as well as on complex shapes. Major disadvantage of this type of curing is that it causes patchy discoloration especially if the concrete contains calcium chloride. Discoloration is more pronounced when the film develops wrinkles and it is difficult and time consuming on a large project to place the sheets without wrinkles. Polyethylene film should confirm to ASTM C171.

Md. Saifuddin et al [6] Wrapping curing is more efficient than dry-air curing as it results in greater compressive strength, ultrasonic pulse velocity and dynamic modulus of elasticity and lower surface absorption. This is because wrapped curing moisture movement from the concrete surface was hindered due to the impervious layer f the film and as a result good amount of moisture was available to be used throughout the hydration process.

2.3.3 Self curing concrete:
Primary requirement of fast-track construction is high early strength in concrete. Early age concrete strength without costly heat treatment is of greater significance in the construction industry (Cangiano, [14]). According to Gowripalan [16], the mechanism of self curing can be explained as follows: “Continuous evaporation of moisture takes place from an exposed surface due to the difference in chemical potentials (free energy) between the vapour and liquid phases. The polymer added in the mix mainly form hydrogen bonds with water molecules and reduce the chemical potential of the molecules which in turn reduces the vapour pressure. Physical moisture retention also occurs. This reduces the rate of evaporation from the surface” Self-Curing concrete is the newly emerging trend in the construction industry. Water soluble alcohols are general used as self-curing agents. With conventional ingredients it is possible to design reasonably good fast track concrete mixture using admixture (Vilas et al [15]).

Nagesh [13] carried out an experimental study to investigate the use of water soluble polyvinyl alcohol as a self cutting agent. He concluded that Concrete mixes incorporating self-curing agent has higher water retention and better hydration with time as compared to conventional concrete. Use of 0.48% of polyvinyl alcohol by the weight of cement as a self curing agent provides higher compressive, flexural as well as tensile strength than the strength of conventional mix. With increase in the percentage of polyvinyl alcohol there is a reduction the weight loss of concrete. Efficiency of the self- cured concrete is 92.5% as compared to the conventional standard water curing method (Raghavendra and Aswath [13])

Vilas and Bhavikatti [13] investigated the effect of non-chloride hardening accelerator and the type of curing on the compressive strength of the pavement concrete, produced with Portland Slag Cement (PSC). His study revealed that for a given dosage of accelerator and for a given age of concrete all the water cured specimens acquired the stipulated design strength where as none of the specimens cured by curing compound could attain the same. The average efficiency of the curing compound was found to increase in the early stage of curing but reduced at the later stage.

3.0 CONCLUSIONS

- Conventional water curing is the most efficient method of curing as compared to Membrane curing, Self-curing, Wrapped curing and Dry-air curing methods.
- Using Membrane curing and Self-Curing methods one can achieve 90% of efficiency as compared to Conventional Curing method. Self Curing method is most suitable for high-rise buildings especially in columns and inaccessible areas. Membrane curing compounds are most practical and widely used method it is most suitable in water scarce area.
- Wrapped curing is less efficient than Membrane curing and Self-Curing it can be applied to simple as well as complex shapes.
- Dry-Air curing should be avoided at the construction sites because designed design strength is not achieved by this method.
- The average efficiency of the curing compound increases with curing age initially by reduces at later age.
- Application of the curing compound is significantly dependent on the time of application of the compound.
- Curing of concrete is mostly governed by two parameters Temperature and Period

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