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A Review on After-effect of Concrete by Different Curing Method and Efficacy of Curing Compounds

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Abstract—* Curing plays an important role if concrete has to perform the intended function over the design life of the structure or to be more precise it is the process of maintaining acceptable moisture content specifically within first 28 days to raise optimum cement hydration immediately after placement. The requirement for sufficient curing of concrete cannot be neglected as curing has a major influence on the properties of hardened concrete; proper curing will increase concrete properties like as strength, durability, volume stability, abrasion resistance, water tightness, resistance to freezing & thawing etc. Modern day's construction and chemical industry has paved way for the development of the new curing techniques and construction chemicals which includes membrane curing compounds, waterproofing compounds, wrapped curing, accelerators, self-curing agents, etc. With the growing of large scale of the project, conventional curing methods have proven not only to be a costly affair but at the same time cases for vertical structures, inaccessible areas such as high rise buildings, water scarce areas, etc. have many practical issues with conventional mode of curing thus have been replaced by membrane curing compounds and self-curing agents up to some extent. In this review paper effort has been made to understand the working efficiency and consequences of using different functional and commonly used curing methods which are adopted in the construction industry as equated with the conventional water curing method.

Keywords—* Curing Compounds, Self-Curing Agents, Internal Curing, Wrapped Curing, Hardened Properties, Durability, Curing Efficiency.

INTRODUCTION

Curing being most basic but yet of upmost important construction activity requires a lot of water. With growing technology and increasing construction activity the days are not so far that all the construction industry has to switch over to an alternative curing system, not only to save water for the sustainable development of the environment but at same time to promote indoor and outdoor construction activities even in remote areas where there is scarcity of water. Curing plays a key role in relieving cracks in concrete which severely affects the durability. Curing is the procedures used for stimulating the hydration of the cement and consisting of control of temperature and of moisture movement from and into concrete. Proper curing can prove aid to mitigate the appearance of unplanned cracking and increases durability, strength, volume stability, abrasion resistance, impermeability and resistance to freezing and thawing. Curing allows continuous hydration of cement and consequentially responsible for continuous gain in the strength, once curing stops strength gain of the concrete also stops. Proper moisture condition is an important and critical aspect as the hydration of the cement virtually ceases when the relative humidity within the capillaries drops below 80%. Without sufficient water, the hydration will not proceed and ultimately concrete might not possess the desirable strength and impermeability (1). 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 subjected 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 finally lowers down the quality of the concrete (2).

Various factors such as atmospheric temperature, wind velocity, relative humidity, water cement ratio of the mix and type of the cement used in the mix plays an impactful role on different properties of concrete. 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 also one of the important aspect that affect the strength development rate. At raised temperature ordinary concrete starts to lose its strength with due formation of the cracks between two thermally incompatible ingredients, cement paste and aggregates. Concrete cured at high temperature normally develops higher early strength than that produced and cured at lower temperature, but this strength lowers at 28 days and later stage (3). To all possible extent a steady temperature should be maintained through the concrete section so to evade thermal cracking. Laboratory tests show that concrete within dry environment can lose as much as 50% of its potential strength compared to similar concrete which has been moist cured. Curing of the concrete is also controlled 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 attaining70% of the specified compressive strength (4).Curing comes with a strong influence on the properties of hardened concrete as with proper curing will increase and improves the strength, durability, abrasion resistance, resistance to freezing and thawing, impermeability and volume stability (5). According to ACI-308 Code that states "internal curing refers to the process by which the hydration of cement occurs because of the availability of additional internal water which is not an integral part of the mixing water." Prevailing, curing of concrete means creating conditions such that water is not lost from the surface i.e. curing takes place 'from the outside to inside'. In case for 'internal curing' it is termed as curing of concrete 'from the inside to outside' through the internal reservoirs (in the form of saturated lightweight fine aggregates, superabsorbent polymers, or saturated wood fibers) created. 'Internal curing' is often also referred as 'Self curing' (6).

AIMS AND OBJECTIVES

A durable concrete is one that performs copacetic under the anticipated exposure condition during its designed service life span. Further, in addition to the normal concrete mixto increase the durability and strength of the concrete mix different additional compounds in proper dosage and materials such as fly ash is used. "curing techniques as well as its duration significantly affects curing efficiency" different degrees of efficiency can be achieved by different in situ-curing methods. The effectiveness of the concrete curing method majorly depends on the material used, method of construction and the intended use of the hardened concrete. Methodology used for concrete curing is mainly divided into two groups namely, Water adding techniques and Water-retraining techniques. Dependability and effectiveness of such curing methods are still under debate. To ensure that hydration continues, especially at the surface, the concrete must be cured. Curing means water at the surface of the concrete is retained to allow the concrete to hydrate to a point where it has a strong, durable structure. If curing is inadequate, the water evaporates and hydration stops, resulting in a low-strength concrete. Ultimately concrete won't develop maximum compressive strength, and cracking may occur. Durability of the concrete may also reduce due to inadequate hydration of the cementitious material.

Uninterrupted evaporation of moisture takes place from an exposed surface due to the difference in chemical potentials between the vapour and liquid phases. The polymers adjoin in the mix mainly form hydrogen bonds with water molecules and reduce the chemical potential of the molecules which furthermore reduces the vapour pressure, thus reducing the rate of evaporation from the surface. Moment the mineral admixtures react completely within a blended composite cement system, their demand for curing water (external or internal) increases and can be much greater than that required for a conventional ordinary Portland cement concrete. When this water is not easily available, significant autogenous deformation and (early-age) cracking may be observed. The chemical shrinkage that occurs during cement hydration mostly give rise to empty pores which are created within the cement paste, leading to a reduction in its internal relative humidity and shrinkage which may cause early age cracking.

Ambient atmospheric conditions can adversely influence the thermal and moisture structure of freshly poured concrete. If concrete becomes too warm or temperature gradients too large during the first several days after the concrete is poured or if there is insufficient water in the concrete, the concrete may crack or may not develop its maximum potential strength, reducing its long-term durability. Surface drying may even affect the underlying concrete, as water will be drawn from the lower levels into the dry surface concrete. Any significant internal drying also will slow or stop hydration and the structure may not gain adequate strength. Prevention of the loss of water from the concrete is of importance not only because the loss adversely affects the development of strength, but also because it leads to plastic shrinkage, increased permeability and reduced resistance to abrasion. For continuity of hydration, the relative humidity inside the concrete has to be maintained at a minimum of 80%. If the relative humidity of the surrounding air is that high, there will be a little movement of water between the concrete and the ambient air and no active curing is needed to ensure continuation of hydration. Internal curing is another method to provide the water to hydrate all the cement, accomplishing what the mixing water alone cannot do. In low w/c ratio mixes (under 0.43 and increasingly those below 0.40) absorptive light weight aggregate, replacing some of the sand, provides water that is desorbed into the mortar fraction to be used as additional curing water. The cement that is not hydrated by low amount of mixing water, will have more water available to it.

On the whole, the strength of concrete, its durability and other physical properties are affected by curing and application of the various types as it relates to the prevailing weather condition in a particular locality, as curing is only one of many requirements for concrete production, it is important to study the effect of different curing method which best adapts to each individual casting process. Advantages of proper curing includes: a less permeable, more water-tight concrete; reduced permeability means the concrete will be more resistant to freezing, salt scaling and attack by chemicals; prevents formation of plastic shrinkage cracks caused by rapid surface drying; increases abrasion resistance as the surface concrete will have a higher strength and significant reduction in scaling problems. Curing should begin immediately after the finishing operation. Minimal delay is especially important in hot and/or dry weather to avoid rapid evaporation from the concrete surface. The benefits of curing concrete are significant, as can be the problems if curing is not performed as detailed above. This study presents the comprehensive working comparison and the effectiveness of curing methods on several hardened properties of concrete such as compressive strength, initial surface absorption, flexural strength, dynamic modulus of elasticity and ultrasonic pulse velocity.

REVIEW OF LITERATURE

3.1. Dry-Air Curing:

In this curing method the concrete cubes are left in the open air to be cured at room temperature. Experimental results point out that Dry-curing is not an efficient method to achieve good hardened properties of concrete. Researchers have been working on the natural air drying of concrete from long back. Md. Safiuddin (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. The analysis showed up 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 cement as the relative humidity within capillaries dropped below 80% (Neville (1)) and thus the formation of major reaction product calcium silicate hydrate the major strength providing and porosity reducer stops before the pores are sufficiently blocked by it. At the same time it also, 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 (2)). Study by M. Naderi1, R. Sheibani, and M. A. Shayanfar (8) concludes comparing with wet curing systems, leaving the cubes in open air and dry laboratory conditions after 24 hours of casting, tends to produce lower compressive strength.

3.2. Water adding technique:

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

3.2.1 Pounding or immersion –in this type of method wherein mostly the flat concrete surfaces like slabs and pavements are cured by pounding of water around the perimeter of the surface with the help of sand dikes. It is effectual method as it maintains a steady 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 being then 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. As per experimental analysis by Shabarish Patil, Rajat Vaidya, Vineethraj Math (9), effect of curing compounds on strength and durability of concrete mixes concludes, Irrespective of curing compounds employed and methodology of their application used, the water ponding method provides the higher strength and lower permeability than with curing compounds. i.e. efficiency of curing compounds as compared with wet curing is as less than 100% both for strength and for durability. The interpretations of both the curing compounds are almost same. However the curing compound CC-2 performed better than CC-1 under both the curing conditions. i.e. applying the curing compounds immediately after demoulding as well as after two days of water curing. This seems to be true for all the three normal concrete mixes i.e. M40, M30 and M20. Both the curing compounds proved less efficient for the Self Compacting Concrete mix, even lesser than for normal concrete mixes, no matter what the application method adopted was. This is found true from both strength and durability points of view. As the compressive strength of mix starts on increase the penetrability for chloride ions decreases. The Chloride ion penetrability is almost 50% less for SCC-M40 mix, compared to normal M40 mix, no matter what the curing conditions may be. As per study of T. James, A. Malachi, E.W. Gadzama, V. Anametemfiok (10), for effect of curing methods on the compressive strength of concrete. Ponding was the most effective method of curing. It comes out with the highest level in compressive strength and cube densities. This increase of both compressive strength as well as cube densities is a function of curing method. Totally uncured method or dry air curing produced the least compressive strength as well cube densities. Totally uncured concrete shrinks faster as compared to other curing methods.

3.2.2 Fogging or Sprinkling–the method constituting of 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 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. This method requires ample of water and a proper supervision.

3.2.3 Saturated wet covering - is most basic but yet very effective curing method in the construction industry. In this method moisture Alternative cycles of wetting and drying during the early period of curing will cause cracking of the surface. The major drawback 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 Rao (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 comes out with 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 (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 the highest level of compressive strength, ultra-sonic pulse velocity, dynamic modulus of elasticity, lower level of surface absorption due to improve 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 water like Saurashtra region in Gujarat, Rajasthan.

3.3. Water retaining techniques:

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

3.3.1 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 (19). 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 (20). It is difficult to apply such compounds on the vertical surfaces. For a particular method of curing, its efficency 'E' can be determined by the following equation.

$$E = [\ (K_1 - K_2)\ /(K_1 - K_3)\ ] \times 100$$

Where, k_1 = Calculated property of a non-cured specimen, k_2 = Calculated property of a specimen cured by the method being evaluated, and k_3 = Calculated property of water-cured specimen till age of testing. In case if curing method comes out to as equally good as water-curing ($k_2= k_3$) then the value of E tends to 100%, while for poor curing method ($k_2> k_3$) this value tends to 0%. The definition gives a convenient scale to assess the efficiency of chemical curing compounds or traditional methods. Curing compounds mostly, 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] (22) G.E. Abdelaziz (14) 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 the 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 Schmidth hammer tool is not suitable for assessing the efficiency of curing compound. Raghavendra and Aswath (23) from their 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 (25) 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. According to Ms. Akanksha A. Patil, Prof. M. R. Vyawahare (11), curing with curing compound Concure wb gives about 10% less compressive strength than Normal water curing. At same time curing with curing compound Materkure107i gives about 15% less compressive strength than Normal water curing. Areas with shortage of water, sustainability of water as well as compressive strength can also be achieved by using suitable chemical compounds for curing of concrete. As per experimental analysis from M.V. Krishna Rao, P. Rathish Kumar, Azhar M. Khan (12), the 28-day compressive strength of concretes with OPC, PPC & 10% OPC replaced by silica fume and cured by conventional wet curing have been more than the corresponding ones cured by compound curing. Curing compound produces somewhat same results as that of conventional wet curing for concrete with OPC while a marginal decrement is observed in concrete made of PPC and the other in which 10% of OPC is replaced by silica fume. From study of Nirav R Kholia, Prof. Binita A Vyas, Prof. T. G. Tank (13), the average efficiency of the curing compound increases with curing age initially by reduces at later age. Curing compound is significantly dependent on the time, i.e. time of application of the compound. Curing of concrete is majorly governed by two parameters Temperature and Period. As per study of G. E. Abdelaziz (14), tells about significant role for the application time of water-based curing compound (WBCC) on the various mechanical (strength and hardness) and durability related properties (sorptivity and porosity) of OPC, silica fume and fly ash concrete was noted. On increasing the time of application of WBCC from casting can lead to diminishing the possible positive effect of using such regime of curing. As a result, an early application of WBCC (within the first two hours from casting) is preferable, to achieve the best possible properties of concrete. Utilization of pre-water curing regime prior to the application of WBCC has remarkable optimistic effects on all considered properties of concrete. The sorptivity and porosity of OPC and OPC/blends are significantly reduced with increasing the period of pre-water curing; meanwhile, the hardness and compressive strength of these concretes can be improved with prolonging the period of pre-water curing. The efficiency of WBCC is significantly dependent on time of application, introducing pre-water curing regime prior to application of WBCC, inducing cement replacement materials into OPC mixes and considered tested property of concrete. As, per analysis from Princy K.P, Dr. Elson John (15), over study on the effectiveness of various curing methods on the properties of concrete Compare to normal water curing, concrete with water curing water proofing compound attained maximum compressive strength. Compared to normal water curing, concrete with waterproofing compound showed 12%, concrete with wax based curing compound showed 21%, and concrete with acrylic resin based curing compound showed 26 % decrease in flexural strength. Compared with normal water curing, concrete with waterproofing compound showed 7%, concrete with wax based curing compound showed 10%, and concrete with acrylic resin based curing compound showed 16% decrease in splitting tensile strength. The data developed from his study indicate that curing compounds could be utilized in situations where curing with water is difficult. From the two curing compounds investigated, wax based curing compound stands out to be performed better than acrylic resin based curing compound.

3.3.2 Plastic Sheet – Covering of plastic sheets such as polyethylene film are generally 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. Safuddin (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 as the wrapped curing moisture movement from the concrete surface was hindered due to the impervious layer of a film and as a result good amount of moisture was available to complete the hydration process. According to M. Naderi1, R. Sheibani, and M. A. Shayanfar (8) Among the curing systems employed in this research, covering with wet hessian and polythene sheet produced the highest concrete compressive strength and In comparison to covering with wet hessian and polythene sheet, the immersion curing system, produced lower compressive strength. According to study of Md. Safuddin (6) Wrapped curing produced higher compressive strength, ultrasonic pulse velocity and dynamic modulus of elasticity but lower initial surface absorption than dry-air curing. This is characteristic to reduce moisture movement from concrete specimens, leading to enhance degree of cement hydration and pozzolanic reaction.

3.3.3 Self Curing Concrete – Nowadays, first priority of any construction site is high early strength in concrete. Early age concrete strength without costly heat treatment is of greater significance in the construction industry (Cangiano, (24)). According to Gowripalan (26), 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 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 vapor pressure. Physical moisture retention also occurs. Which, ultimately 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 (25)). Nagesh (27) carried out an experimental study to investigate the use of water soluble polyvinyl alcohol as a self-cutting agent. He concludes that concrete mixes integrating 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 quantity 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 (23))Vilas and Bhavikatti (25) 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 dose of accelerator and for a given age of concrete all the water cured specimens acquired the stipulated design strength whereas at the same time none of the specimens cured by curing compound comes out to attain the same. On an average efficiency of the curing compound was found to increase in the early stage of curing but reduced at the later stage. As per experimental analysis by A Sreenivasa kumar, Dr. T Suresh Babu (16), to find effect of self-curing compound on strength and durability of M25 mix concrete he concludes that optimum strength values for both the self-curing agents were found and among both the agents PEG-200 is a best and good self-curing agent because in terms of durability and normal compressive strength aspects it was giving good results as compared with both conventional concrete and Poly Ethylene Alcohol (PAE). At the place of Water scarcity areas these types of agents will give a better result. Young's Modulus of concrete was also found asin a rage of safe. Crepe formation also seems to get reduce due to addition of these agents. According to experimental study by J R Ramesh and B. Balakrishna Bharath (17), Strength of self-curing concrete is relatively high when compared with conventional concrete. It is the viable answer to many problems faced due to lack of proper curing. It is an alternative to conventional concrete in desert regions where scarcity of water is a major problem.

3.4. Internal Curing techniques:

Internal curing provides water to keep the relative humidity (RH) high, keeping self-desiccation from occurring. Internal curing eliminates largely autogenous shrinkage. Internal curing maintains the strengths of mortar/concrete at the early age (12 to 72 hrs.) above the level where internally & externally induced strains can cause cracking. Internal curing comes with an aid to make up for some deficiencies of external curing, both human related (critical period when curing is required is the first 12 to 72 hours) and hydration related (as the hydration products clog the passageways needed for the fluid curing water to travel to the cement particles thirsting for water).

Potential Materials for Internal Curing includes:

a. Lightweight Aggregate (natural and synthetic, expanded shale)
b. Super-absorbent Polymers (SAP) (60-300 nm size)

c. SRA (Shrinkage Reducing Admixture) (propylene glycol type i.e. polyethylene-glycol)

Following factors establish the dynamics of water movement towards the unhydrated cement particles:
i. Thirst for water by the hydrating cement particles seems to be very intense,
ii. Capillary action of the pores in the concrete comes out be very strong, and
iii. Water in the properly distributed throughout the particles of LWA (fine) is very fluid.

3.5 Steam Curing:

It is the process of gaining high early strength under high atmospheric pressure and temperature (40^0C and 215^0C). It is mostly used for Pre-caste concrete members. Houssam A., Toutanji, Ziad Bayasi (18), conducted study to assess the effects of three curing conditions on hardened silica fume concrete. The measured properties were compressive strength, flexural strength, and rapid chloride permeability. Curing methods applied were steam, moist and air curing. These specific conclusions were specimens under steam curing experienced the highest compressive strength as compared to both moist and air curing for all mixtures. Under steam and moist curing, the compressive strength of concrete was practically unaffected by increasing the silica fume content beyond 10%, with the exception of the specimens with 30% silica fume exposed to moist curing. With the addition of silica fume beyond 15%, the flexural strength was significantly decreased, regardless of the curing conditions. It was difficult to interpret which of the two curing, steam or moist curing, had a more pronounced effect on the flexural strength of silica fume concrete. Results show that the effect of curing on flexural strength is not the same as that on compressive strength in silica fume concrete. Compared to moist, steam curing decreased the permeability of silica fume concrete whereas air curing it increased permeability. The change of permeability caused by curing is strongly dependent on the silica fume content of the mix. However, concrete with about 30% silica fume content exposed to air curing seems to experience a significant increase in permeability. This is attributed to the extensive shrinkage cracking, which develops due to air curing.

CONCLUSIONS

- The cap of moisture movement was greatly dependent of the method of curing. Moisture movement occurred abundantly under dry-air curing and therefore it significantly affected the properties of concrete. Continuously water cured concrete specimens provided a better rate of strength development compared to other curing conditions.

- Water curing is the most effective method of curing compared to Membrane curing, Self-curing, Wrapped curing and Dry air curing methods. It produces the maximum highest level of compressive strength, dynamic modulus of elasticity and ultrasonic pulse velocity, and the lowest level of initial surface absorption. The reason is dueto improved pore structure as well as lower porosity resulting from pozzolanic reaction without any loss of moisture from the concrete specimens and higher degree of cement hydration.

- Using Membrane curing and Self-Curing methods one can achieve maximum of 90% efficiency as compared to Conventional Curing method. Self-Curing method seems to be the most suitable for high-rise buildings especially in columns and inaccessible areas. Membrane curing compounds are most practical and widely use method it is most suitable in water scarce area.

- In terms of efficiency the outcomes shows with wrapped curing being less efficient than Membrane curing and Self-Curing it can be applied to simple as well as complex shapes.

- All the methods of curing considered, except air curing produced concrete specimens that met the minimum compressive strength specified by the available code. Dry-Air curing should be avoided at the construction sites because design strength of structure is not achieved by this method.

- The concrete element exposed to a higher medium temperature should be well-cured to ensure high performance of concrete. The evaporation of water from concrete at an early age must be prevented to avoid the decrease in strength, modulus of elasticity, and other hardened properties of concrete. The suitable medium temperature environment associated with an adequate period of water curing plays an important role in the hydration process to produce the concrete with desired hardened properties.

- In areas with acute-shortage of water, supportable of water can be achieved by using the suitable chemical compounds for curing of concrete. The average efficiency of the curing compound increases with curing age initially but reduces at later age.

- Significant role for the application time and temperature of curing compound on the various mechanical (strength and hardness) and durability related properties (sorptivity and porosity). An early application of water based curing compound (within the first two hours from casting) is preferable, to achieve the best possible properties of concrete.

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