# STUDY ON THE INFLUENCE OF ACCELERATED CURING METHODS ON THE PROPERTIES OF CONCRETE

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**Abstract -** Curing conditions play an important role in the hydration of the binder and in attaining the good properties expected from the hardened material. In the precast industry, curing is frequently equivalent with the use of temperature to abbreviate demoulding times and to increase productivity. There are several ways to cure concrete in the field. One form of curing that has become popular at precast prestressed concrete plants is accelerated curing. This sort of curing is favourable where early strength gain in concrete is significant or where extra heat is required to achieve hydration, as in cold weather. Accelerated curing diminishes expenses and curing time in the creation of precast individuals bringing about financial advantages. An essential worry with accelerated curing is the potential for increased moisture loss during the curing process. There are different types of accelerated curing methods, which includes electrical curing, steam curing, carbonation curing, microwave curing and chemical curing.

***Key Words***: Curing, Temperature, Hydration, Compressive strength, Durability.

## 1. INTRODUCTION

Curing is utilized for promoting the hydration of the cement, and comprises of a control of temperature and of moisture development from and into the concrete. Curing permits continuous hydration of cement and therefore ceaseless increase in the strength, when curing ceases strength gain of concrete also ceases. Moisture conditions are basic in light of the fact that the hydration of the cement for all intents and purposes stops when the relative humidity inside the vessels dips under 80% [1]. With lacking water, the hydration won't continue and the subsequent concrete may not have the desirable strength and impermeability. The continuous pore structure shaped on the close to surface may permit the entrance of deleterious agents and would cause different durability issues. Moreover due to early drying of the concrete micro-cracks or shrinkage cracks would create on surface of the concrete [2]. At the point when concrete is exposed to the environment evaporation of water happens and loss of moisture will reduce the initial water cement ratio which will bring about the inadequate hydration of the concrete and thus bringing down the quality of concrete. Different factors, for example, wind speed, relative humidity, atmospheric temperature, water cement ratio of the mix and type of cement utilized in the mix will influence the curing of concrete. Evaporation in the initial stage leads to plastic shrinkage cracking and at the phase of setting it leads to drying shrinkage cracking.

Curing temperature is one of the main considerations that influence the strength development rate. At raised temperature, due to the formation of the cracks between two thermally incompatible ingredients, cement paste and aggregates conventional concrete losses its strength. At the point when concrete is cured at high temperature regularly creates higher early strength than concrete delivered and cured at lower temperature, however strength is commonly brought down at 28 days and later stage [3]. A uniform temperature ought to be kept up through the concrete area to stay away from thermal cracking. Research facility tests show that concrete in dry condition can lose as much as 50 percent of its potential strength compared with 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 quality of the concrete expecting that the hydration of the cement particles will go on. American Concrete Institute (ACI) Committee 301 prescribes a minimum curing period corresponding to concrete accomplishing 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. "Curing techniques and curing duration significantly affects curing efficiency" Various degree of efficiency can be achieved by various 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 [5]. For accomplishing sufficient workability at low water-cement proportions, high-perfomance concrete incorporate the use of superplasticizers. Such admixtures can give such huge numbers of useful impacts in concrete. The effectiveness of such admixtures relies upon factors like nature and dosage of product, nature of cement and aggregate, water-cement ratio and ambient temperature. Elson John et.al. studied the effect of temperature on fluidity, water demand and setting time of cement paste with and without superplasticizer [6].

Sreekumar K et.al [7] conduct an investigation on the loss of workability, setting time, property relationship among's paste and concrete for different admixture and superplasticiser measurements. To find out the saturation superplasticizer dosage, flow analysis in paste can be utilized as a guideline. The investigation on setting time shows than results of paste and concrete are comparable. It is also found out that tests on the paste can be utilized as guide for optimising flow behaviours, setting time, compressive strength in concrete without doing tedious tests in concrete. Workability is one of the significant physical parameter of concrete which influences the durability, strength and the appearence of the finished concrete surface. The workability of concrete depends on the w/c ratio and the water absorption capacity of the aggregates. If the w/c proportion is more which results to bleeding or segregation[8].

Leny Thomas et.al [9] learned about the compatability of cement and water reducers with mineral admixtures. Incorporation of different chemical and mineral admixtures in portland cement and concrete modifies the hydration process and chemical interaction which leads to unexpected concrete behaviour. Premature loss of workability happens because of complex chemical reaction between various compositions in cement, chemical and mineral admixtures makes poor cement-admixture compatability. They discovered that silica fume gives more prominent compressive strength than other supplementary cementitious materials and increase in superplasticizer increases compressive strength but reduces workability.

Gayathri Devi M et.al [10] conduct a study on effect of re-dosing superplasticizer to regain slump on concrete. This research is preliminary study about addition of second and third dose of superplasticizer to regain the slump, after it losses certain level of slump in concrete. To achieve this 53 grade ordinary portland cement and three distinct kinds of superplasticizers were utilized. They discovered that re-dosing of superplasticizer is conceivable to regain the slump in field and it was also discovered that there is not any adverse effect on compressive strength of concrete because of addition of second and third dose of superplasticizer in concrete. According to Merin K Abraham et.al[11] reducing the percentage of cement in concrete makes it more economical and environmental friendly. The cement replacement with various mineral admixtures improves the properties of concrete. The chemical admixtures are included in concrete to improve the properties in fresh and hardened state. In this study fly ash and GGBFS are used. They found out that the optimum percentage replacement of cement with mineral admixtures for better strength.

Curing conditions carry an important role in the hydration of the binder and in accomplishing the perfomance anticipated from the solidified material [12]. There are a few different ways to cure concrete in the field. One type of curing that has gotten well known at precast prestressed concrete plants is accelerated curing. An essential worry with accelerated curing is the potential for expanded moisture loss during the curing process[13]. There are various kinds of accelerated curing techniques, which includes electrical curing , steam curing, carbonation cuing, microwave curing, boiling water curing and chemical curing.

## 2. ACCELERATED CURING METHODS

Various methods of increasing the curing temperature of concrete have been employed in order to achieve high early strength. These strategies incorporate basic convection through the flow of boiling water or oil through formwork, or even through pipes inside the concrete individuals on account of hollow elements, electric resistance heating, and both low and high pressure steam curing and so forth. One of the downsides to an increased curing temperature is the increased rate of humidity loss to the surrounding condition, which can bring about serious shrinkage and cracking. Another issue is the quick difference in temperature inside concrete individuals, bringing about possibly enormous thermal stresses. In order to avoid these problems, any method of increasing the curing temperature must also involve the provision of adequate humidity in order to prevent excessive moisture loss, as well as careful cyclic implementation of temperature increase and decrease, in order to prevent the development of thermal stresses [14].

Steam Curing (SC) is the most widely recognized strategy utilized in precast plants to accomplish high temperature cycles while guaranteeing rich moisture supply. Although reliable and moderately simple to control, SC has poor energy efficiency and creates temperature gradients inside the components, along these lines initiating internal stresses. Otherwise, SC endures the impediments of being a surface-heating technique, accordingly it is truly constrained by thermal conductivity of the medium and greatest reasonable temperature. Also, it’s on location sending is unfeasible by and large because of the enormous equipments required (steam generators, conduits and transports, and so on). Steam curing may cause small micro cracks along the interface of aggregate and cement paste. It has been accounted for that the strength of concrete by steam curing could diminish in later stages, for example, 28 days or 90 days, when compared and concrete cured in air or in water. It may be possible to maintain a strategic distance from this strength loss by utilizing a plastic film to cover the top layer of the precast concrete. In this way, it is proposed that concrete by steam curing can have a lower water cement (binder) proportion or a more drawn out pre-setting time to prevent the smaller micro cracks in concrete and decrease of strength in later stage. Also, this type of concrete requires a generally long period for curing since heat must diffuse internal from the surface and the innately non-uniform temperature can produce thermal cracking[15].

Electric techniques are relatively unexplored other options, which produce heat by methods for the Joule effect [16,17]. Indirect or direct techniques can be recognized. For the indirect technique, surface or installed electric resistors (or the reinforcement bars) are deployed to supply heat. For the direct technique power is gone through the concrete, either by applying a voltage to the reinforcement bars (for example utilizing them as electrodes) or by methods for intentionally inserted electrodes [16]. W. Xuequan et.al. examined that EC is a volume-heating strategy, with for all intents and purposes no restriction to the power density that can be given, in this being like microwave heating [18]. Bredenkamp [19] examined the impact of EC on Portland cement based concrete in contrast with NC, estimating the compressive strength advancement from 4 h to 28 days, with the objective of optimising curing systems. Consistent intensities of electric field running from 300 to 500 V/m were analyzed. Strength of specimens exposed to EC was lower compared with that of specimens exposed to NC after 80 h.

The fluid stage (for example the pore solution at later stages) is the current-conductive segment of portland cement based concrete [20, 21]. The amount and synthesis of the fluid stage change significantly from solid blending to setting and hardening. The most extreme estimation of conductivity is watched 2–4 h subsequent to blending. At that point, a quick diminishing of conductivity happens as water is limited by hydrating cement particles, along these lines lessening the measure of free fluid stage [22, 23]. As per Krylov [20], transitional resistance shows up at the electrode interface because of a twofold electric layer framed by electrons in the metal and particles in the fluid stage. This makes a snag to the entry of electric flow from the metal to concrete and may cause electrochemical phenomena, for example, expansion of air bubbles and drying brought about by movement and dissipation of moisture close to the terminals. This viewpoint is exceptionally pertinent while applying EC to SFRC as each metal fiber implanted in the concrete matrix viably goes about as an electrode, spanning across two regions at various electric potential.

A.Susanto et.al [24] researched that DC flow instigated "curing" and maturing phenomena in cement based materials. Mortar cubes were exposed to DC current flow stream of 1 A/$m^2$ and 100 mA/$m^2$ ; faucet water and calcium hydroxide were outer environment. curing was performed for 112 days, during which period, compressive strength, porosity and electrical resistivity of the mortar cubes were checked. The outcomes show that DC "curing" in the tap water will leads to quicken degradation process in the mortar cubes for example brings about increased ageing. Meanwhile DC "curing" in calcium hydroxide arrangement can possibly quicken "cuing" without negative symptoms. Bredenkamp [19] expressed that DC curing is one of the most vitality productive strategies for accelerated curing of concrete and after the underlying capital expense for equipment, the running expenses of direct electric curing are generously lower than that of remotely applied heat curing (steam, autoclave, and so on).

Maxim Kovtun et.al [25] learned about the direct electric curing of alkali actuated fly ash concretes: an apparatus for more extensive use of fly ashes. In this examination, low calcium fly ash, sodium hydroxide, and sodium silicate were utilized to create soluble base actuated fly ash concretes exposed to direct electric curing at 60°C. The resistivity of alkali actuated fly ash cement paste firmly relies upon the sort of activator utilized. Sodium hydroxide gives essentially lower resistivity than sodium silicates. The resistivity of portland cement paste is extensively higher which demonstrating that less vitality is required for direct electric curing of alkali activated fly ash concretes. Compressive strength acquired as 33.8 MPa and 48.5 MPa at 2 and 28 days for soluble base actuated fly ash concrete and fly ash concrete enacted with sodium hydroxide individually can be accomplished after moderately short direct electric curing (2 h of warming and 3 h of isothermal relieving, which can be actualized during off-top hours). Soluble base actuated fly ash concretes of comparative composition cured at ambient temperature accomplish compressive strength of 10.9 MPa at 28 days.

Baoju Liu et.al [26] learned about the impact of curing conditions on the permeability of concrete with high volume mineral admixtures. The impact of mineral admixtures and curing conditions on the porousness of concrete with high volume mineral admixtures is examined. Fly ash and ground granulated blast furnace slag (GGBFS) are utilized to replace 50% cement, the water retention, capillary water absorption, sorptivity coefficient, electric transition and carbonation depth of concrete with mineral admixtures are tried under various curing conditions, for example, the curing time, relieving humidity and relieving temperature. From this investigation it is acquired that water retention, capillary water absorption, sorptivity coefficient, electric transition and carbonation depth of concrete reduce with the more extended standard curing time, higher curing moistness and suitable relieving temperature, and diminishing with the increasing of GGBFS content.

A.S. Al-Gahtani [27] explored the impact of curing techniques on the properties of plain and blended cement concretes. The concrete specimen were set up with Type I, silica fume, and flyash cement concretes. They were cured either by covering with wet burlap or by applying two sorts of curing compounds, to be specific water-based and acrylic-based. The impact of relieving techniques on the properties of plain and blended cement concretes was evaluated by estimating plastic and drying shrinkage, compressive strength, and pulse speed. Results show that the quality improvement in the concrete specimens cured by covering with wet burlap was more than that in the specimen relieved by applying water and acrylic-based curing compound.

Pradip Nath[28] directed a study on the impact of GGBFS on setting, workability and early strength properties of fly ash geopolymer concrete restored in encompassing condition. The point of this examination is to accomplish fly debris based geopolymers reasonable for curing without raised temperature. By utilizing ground granulated blast furnace slag (GGBFS) as a little piece of the fastener fly ash based geopolymer concrete for curing in encompassing condition can be proportioned for desirable workability, setting time, and compressive strength. Increment of GGBFS in the fly debris based geopolymer blend lessens the workability and setting time. Slump of concrete and flow of mortar diminished with the increment of slag.

He Zhimina et.al(29) cnducted an investigation on the properties of steam cured concrete by including mineral admixtures. In this examination compressive strength, dry shrinkage, against chloride porousness and pore structure tests are directed. From the test outcomes it is seen that mineral admixtures improved the perfomance of concretes. By utilizing fly ash and GGBFS high demoulding strength and later strength picking up rate for steam cured concrete is acquired. Steam restored concrete with mineral admixtures demonstrate a generally excellent protection from the infiltration of chloride particles and less dry shrinkage compared with clear concrete.

NattMakul et.al [30] led an investigation about applications of microwave energy in concrete and cement. Regular curing techniques have numerous impediments. At the point when water curing is utilized, long periods are expected to arrive at the necessary quality. Steam curing results non-homogeneous curing due to non-uniform temperature disseminations. At the point when admixtures are utilized, durability issues may happen. Warm curing techniques are particularly powerless to negative impacts on sturdiness in both the early and long term stages. For instance, high-temperature curing at at atmospheric pressure was appeared to bring about diminished long term strength and durability issues [31, 32, 33]. Movement of warmth source from the outside surface of a warmed cementitious material to the inside structure(e.g. through the communication between the microwave field and the warmed material) can bring about a rough cement water interaction and volumetric warmth generation. This idea serves a reason for microwave relieving. Utilization of microwave energy accelerated strength development in portland cement mortar without decreasing the drawn out quality of the concrete. The strength of the concrete specimens started to diminish when the last w/c proportion was less than0.40 [34].

In another study, microwave curing during the first 24h reduced the induction period of hydration [35,36]. Key parameters for microwave curing include the microwave power, application time, duration of microwave heating [37], thermal runaway, and over heating within the sample [38]. When optimal microwave power was applied in a discretized fashion through feedback temperature control, very good results were obtained for concrete [39]. From the work of Sohn and Johnson, it is obtained that the optimal microwave-curing of type 1 Portland cement mortars at 40 and 60 ˚C, whereas other temperatures were incompatible with curing.

Microwave energy can be utilized in relationship with a vacuum framework, for dry out the concrete. At a most extreme temperature of 60˚C, with a last w/c proportion 0.38, the ideal microwave restoring time is procured as 45min. In this procedure, microwave relieving expanding the rate of hydration of cement while reduces the measure of free water, demonstrated that a compacted/less permeable cement [40]. At the point when microwave energy was applied with a ceaseless belt drier comprising of 14 packed air-cooled magnetrons of 800 W each (maximumof11.2kW),the microwave energy quickened the early-age compressive strength of the cement paste, however didn't influence the later-age strength. Microwave curing decreased the energy utilization and curing time. For all intents and purposes, microwave-helped relieving has been end up being a valuable procedure for construction applications and for fixing harmed concrete asphalts. Leung and Pheeraphan [41] examined the early-age and long haul compressive strength of concrete specimen from microwave curing sort 3 portland cement and financially accessible fast solidifying concrete containing quickening admixtures. The compressive strength of microwave cured concrete (w/c proportion of 0.55) that was restored for 45 min expanded to 19.2MPa at4.5h. Researches dependent on the Common wealth Scientific and Industrial Research Organization(CSIRO)of Australia found that the utilization of microwave restoring patterns of under 6 h allowed sufficient quality for formwork evacuation and wire-strand prestressing, without disabling the concrete quality.

Microwave warming offers good creation and high product performance for precast concrete. Warmth restoring impacts the perfomance(i.e., thermal reaction, early-age strength, and durability) of a choose range ofconcrete materials for bridge development. Microwave warming produces extensively lower temperature inclinations contrasted with steam warming. For instance, when quick microwave relieving patterns of under 6 h were utilized, compressive strengthss of up to 25MPa were accomplished in top quality precast concrete. Repeating the mass heating rate with microwave heating didn't cause any decay in the close surface quality, dissimilar to in conventional steam heating.

Despite the fact that the underlying expense of the microwave equipment may be costly, microwave restoring can decrease the measure of cement utilized in concrete and can quicken early-age concrete curing in different applications. In any case, this restoring technique could impactsly affect the performance(i.e., warm reaction, early-age quality, and durability)of some concrete blends. Along these lines, a reasonable microwave framework and proper curing methodology should be resolved.

According to Natt Makul et.al [42] MW curing is a new superior curing technique for concrete at a beginning time. Under the idea of an admissible most extreme temperature of not more than 80 ˚C, the suitable defer time was 30 min, and applying MW energy for 45 min could improve the greatest 8h early-age compressive strength of the MW-cured concrete. In MW relieving with a 45 min application time, a definitive drying shrinkage and decrease strain were higher than those of the autoclave restoring technique.

According to Devender Sharma,et.al [43] Accelerated Carbonation curing (ACC) is an inventive restoring method for precast concrete units, which brings about sequestration of the carbon dioxide gas and its transformation into stable items. Carbonation restoring was done for 12 hours, trailed by either fixed packcuring or water splash curing for 3 days. As far as compressive quality, porosity and pH of the blend, alongside SEM the impact of carbonation curing was examined. From the microstructure examination presence of C-S-H gel and CaCO3 for the carbonated mortars, adding to the extra strength and decreased porosity.

Jinbang Wang et.al (44) examined quickened carbonation of solidified cement paste and impact of porosity. The dissemination and movement mechanism of carbon dioxide in permeable cementitious materials was the key point that limits the improvement of materials carbonation rate. This paper likewise learned about the impacts of paste porosity constrained by water to cement ratio (w/c) on carbonation and the paste micro structures development. After accelerated carbonation for 4 h the compressive strength of concrete individuals incredibly improved, which is because of the decrease of porosity of hardened paste. $C_2S$, $C_3S$ and some hydration results of $Ca(OH)_2$ after 1 d hydration are the significant reactants in accelerated carbonation process.

The durability of cement based materials, for example, mortar and concrete normally experiences water and synthetic ingression, which erodes the loadbearing steel reinforcement. Both physical and chemical decay concrete structures with reinforcement is regularly firmly identified with the entrance of water. Chemical substances, for example, chloride and sulphate particles go into concrete with water, causing corrosion of strengthening steel bars and sulphate disintegration, respectively [45].

Sallehan Ismail et.al [46] conducted a study on mechanical and durability properties of concrete joined with with treated recycled concrete aggregate (RCA) under various curing conditions. Three distinctive curing conditions were applied, to be specific persistent typical water curing (NW), starting water restoring for 28 days before exposure to an outdoors domain, open air environment (OA), and beginning water curing for 28 days before exposure to seawater (SW). They found that ocean water impressively deteriorates the compressive strength of RAC. Penetrability and porosity of specimens are influenced by restoring systems. Utilization of untreated RCA for the most part lessens the mechanical quality and strength of the concrete paying little mind to the restoring conditions. Joining the recycled RCA helps limit the decrease in the mechanical strength and durability of the concrete especially under a drawn out restoring period.

Mahdi Koushkbaghi et.al [47] led an investigation on acid resistance and durability properties of steel fiber-reinforced concrete incorporating rice husk ash and recycled aggregate. Recycled concrete aggregate (RCA) delivered from concrete waste has as of late been a decent option in contrast to natural aggregate on account of the expanded spotlight on economical turn of events and ecological advantages. When compared with normal aggregate concrete fusing RCA shows inferior properties. The second rate properties of RCA concrete can be improved by including supplementary cementitious materials (SCMs). Generally utilized SCMs in the concrete business are fly ash and silica fume, which improve the mechanical and strength properties of concrete. It is discovered that as the percent of RCA expanded, the compressive strength, splitting tensile strength decreased and properties of concrete identified with water transport of water retention, chloride dispersion and corrosive assault diminished.

## 3. SUMMARY

This paper summarizes different types of accelerated curing methods, which includes steam curing, electrical curing, microwave curing, hot water curing and carbonation curing. By using accelerated curing methods early strength gain in concrete is possible. Like most chemical reactions, the rate at which hydration happens is entirely powerless to temperature changes; with expanded temperatures, the rate essentially increments. The execution of raised curing temperatures is a generally straight forward procedure, and it tends to be accomplished without a serious deal of innovative work. Subsequently, this is the essential technique presently utilized by business precast producers. Concrete when exposed to MW-warming instruments the time- dependent dielectric properties and thermal properties require investigation. DC current prompted curing in calcium hydroxide solution can possibly quicken relieving and would bring about a good quality concrete. To determine the threshold of positive and/or negative influence of DC current on the properties of concrete based materials, further study is required.

By using recent advances in material technology, various admixtures (mineral and chemical) can be utilized, both directly and indirectly, as accelerating agents. In any case, contrasted and expanded restoring temperatures, the utilization of admixtures as quickening agents can present various expected issues and troubles. . For make use of admixtures as accelerating agents should have a thorough understanding about the behaviour of admixtures and their effects on the properties of concrete.

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