INFLUENCE OF CURING: A TECHNICAL STUDY TO INCREASE RATE OF CURING

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Abstract

Now a day's conventional concrete has been replaced by self-compacting concrete and Prestressed Concrete. Both of these types of concrete have less shrinkage, less creep and reduced deflection due to dead and live load. Material properties are improved in Pre-stressed concrete. Also total construction time is also less in case of pre-stressed concrete. One of the major properties of concrete that makes pre-casting economically feasible is its ability, under the proper conditions, to gain compressive strength extremely rapidly. In this study, we have discussed various methods of curing and different recent techniques to accelerate the curing rate. There are various methods to accelerate the rate of curing. Some are: 1) the use of physical processes, and 2) the use of admixtures to act as catalysts for the hydration process, resulting in the achievement of high compressive strengths in relatively short periods of time. Many physical processes used to increase the curing process are generally obtained by increases in curing temperature, introduction of moisture to curing environment.

Keywords: *Pre-stressed concrete, curing, admixtures, Self-compacting concrete, methods of curing*

1. Introduction

Curing is the maintenance of a satisfactory moisture content and temperature in concrete for a period of time immediately following placing and finishing so that the desired properties may develop. The need for adequate curing of concrete cannot be overemphasized. Curing has a strong influence on the properties of hardened concrete; proper curing will increase durability, strength, abrasion resistance, volume stability, and resistance to freezing [1] and thawing [2] and deicers. In modern construction practices main focus is set up on the faster and economical construction. This includes the use of waste materials and admixtures in concreting. As such, the construction industry is constantly searching for ways to improve their product. One means to this end is, rather than relying on improving construction implementation mechanisms such as scheduling, installation techniques, and quality control, is focusing on the industry's improved knowledge and development of materials and their behavior. One of such major method used for faster construction is Prestressed concrete. This type of concrete was developed in order to take advantage of the desirable properties of concrete and steel, chiefly compressive and tensile strength, respectively, in order to achieve structural solutions that were not previously possible. For many projects, the use of pre-stressed concrete is more desirable than reinforced concrete or steel for numerous reasons. Although a number of methods currently exist for the acceleration of the curing process, most precast manufacturers maintain relatively simple operations, and due to logistical and economic constraints, only employ one or two of the methods described herein. Despite recent advances in the use of admixtures, the primary method of accelerated curing in the precast industry today still seems to be the use of elevated curing temperatures, which are achieved through various means. The objective of this study is the description of the various methods employed in the precast industry for the purpose of accelerating the curing process of concrete, and their effects on the short and long term compressive strength of concrete. These various methods of accelerated curing can be divided into three main categories: physical processes, mineral admixtures, and chemical admixtures

2. Curing Process

Exposed slab surfaces are especially sensitive to curing as strength development and freeze-thaw resistance of the top surface of a slab can be reduced significantly when curing is defective. Curing is the process of watering concrete structure to understand the hydration process. When cement is added to water hydration reaction takes place. This hydration process is necessary for hardening of concrete. This curing process is done in three different steps. First curing stage is done immediately on addition of water to cement and aggregates to make a dry concrete mix. At first stage of curing the chemical reaction between water and cement occurs however the gain in hardness or compressive strength is minimum in first stage of curing. Second stage or process of curing begins on the initial setting of concrete mix. It starts with the rapid hydration process i.e. hardening of concrete starts with hydration. The specific rates of strength gain and overall duration of stage two depend on the particular mix design and curing conditions. Stage two of curing generally lasts six to seven hours, and the rate of compressive strength development is approximately 40%. The efficacy of elevated curing temperatures regarding their ability to increase the rate of strength gain is greatest during stage two. Third stage of curing begins when the proper reaction between cementious material and water occurs. During this phase less heat is generated by the hydration process, and a slower rate of strength development occurs. The application of elevated curing temperature has little effect on the rate of strength gain at this point.

2.1 Methods of Curing

Concrete can be kept moist (and in some cases at a favorable temperature) by three curing methods:

- Methods that maintain the presence of mixing water in the concrete during the early hardening period. These include ponding or immersion, spraying or fogging, and saturated wet coverings. These methods afford some cooling through evaporation, which is beneficial in hot weather.
- Methods that reduce the loss of mixing water from the surface of the concrete. This can be done by covering the concrete with impervious paper or plastic sheets, or by applying membrane-forming curing compounds.
- Methods that accelerate strength gain by supplying heat and additional moisture to the concrete. This is usually accomplished with live steam, heating coils, or electrically heated forms or pads.

The method or combination of methods chosen depends on factors such as availability of curing materials, size, shape, and age of concrete, production facilities (in place or in a plant), esthetic appearance, and economics. As a result, curing often involves a series of procedures used at a particular time as the concrete ages [3].

2.1.1 Ponding and Immersion

On flat surfaces, such as pavements and floors, concrete can be cured by ponding. Earth or sand dikes round the perimeter of the concrete surface can retain a pond of water. Ponding is an ideal method for preventing loss of moisture from the concrete; it is also effective for maintaining a uniform temperature in the concrete. The curing water should not be more than about 11°C (20°F) cooler than the concrete to prevent thermal stresses that could result in cracking. Since ponding requires considerable labor and supervision, the method is generally used only for small jobs [4].

2.1.2 Fogging and Sprinkling

Fogging and sprinkling with water are excellent methods of curing when the ambient temperature is well above freezing and the humidity is low. A fine fog mist is frequently applied through a system of nozzles or sprayers to raise the relative humidity of the air over flatwork, thus slowing evaporation from the surface. Fogging is applied to minimize plastic shrinkage cracking until finishing operations are complete. Once the concrete has set sufficiently to prevent water erosion, ordinary lawn sprinklers are effective if good coverage is provided and water runoff is of no concern. Soaker hoses are useful on surfaces that are vertical or nearly so.

2.1.3 Wet Coverings

Fabric coverings saturated with water, such as burlap, cotton mats, rugs, or other moisture-retaining fabrics, are commonly used for curing .Treated burlaps that reflect light and are resistant to rot and fire are available. Burlap must be free of any substance that is harmful to concrete or causes discoloration. New burlap should be thoroughly rinsed in water to remove soluble substances and to make the burlap more absorbent. Wet, moisture retaining fabric coverings should be placed as soon as the concrete has hardened sufficiently to event surface damage.

3. Chemical Admixtures for Accelerating Curing

Calcium: Historically, the use of calcium, particularly in the form of calcium chloride, was thought to be an effective acceleration technique in concrete. However, numerous problems resulting from the inclusion of calcium-chloride in concrete mixes has resulted in its ban from use in concrete in several countries around the globe. The inclusion of calcium chloride in reinforced and pre-stressed concrete can be extremely detrimental, as the chloride can contribute greatly to corrosion of the reinforcing steel. Nonetheless, studies have shown that calcium chloride has a significant impact on early strength gain of concrete. The use of 1% of calcium chloride relative to the weight of cement in a mix has resulted in an increase of strength after 24 hours of 300%. On the other hand, very small concentrations of calcium chloride, on the order of 0.0005-0.05% by weight of cement, can have a severe retarding effect on the hydration process. In applications in which metal is not embedded in concrete, the use of calcium chloride as an accelerator is still permitted. Additional suggestions regarding the use of calcium chloride as an accelerator include never using concentrations greater than 2% by cement weight, and being cautious when using it in concrete subjected to steam curing, if used in concrete containing dissimilar metals, in concrete slabs supported on permanent galvanized steel forms, and in colored concrete. Calcium chloride should not be used in pre-stressed concrete due to possible corrosion hazards, in concrete containing embedded aluminum, in concrete subjected to alkali-aggregate reaction or exposed to sulfates, in floor slabs intended to receive dry-shake metallic finishes, in hot weather, and in mass concrete.

3.1 Super Plasticizers(High-Range Water Reducers)

Although not technically characterized as accelerators, high-range water reducing (HRWR) admixtures contribute to, "large increases in early concrete strengths under both normal and accelerated curing conditions,".The use of these admixtures results in either increased concrete workability while maintaining a target strength level, or increased strength while maintaining a desired workability. In general, a water reducing admixture results in reduced water demands for a given mix. Traditional water reducing admixtures consisted of lignosulfonic acids, hydroxylated carboxylic acids, or processed carbohydrates; these have been shown to provide up to approximately a 10% reduction in mix water requirements while maintaining the same workability [5]. More recently, HRWR admixtures have been employed that are composed of, "organic polymers, either sulphonated melamine or sulphonated naphthalene formaldehyde condensates, and may readily reduce the mix water content of up to 20-25% while maintaining the desired slump," In addition, corrosion concerns are not associated with the use of HRWR admixtures, as they do not contain added chlorides. The chemical composition of cement also can affect the efficacy of HRWR admixtures [8].

4. Mechanical Methods for Accelerated Curing

An increased curing temperature will result in an increased rate of strength gain. But this increase in temperature up to certain limits. After this limit this increase in temperature does not affect the compressive strength but can dismantle the structural properties of concrete. Typical curing mean temperature is 700^{o} C. Major drawback of increasing this temperature is increased rate of humidity loss to the surrounding environment, which can result in severe shrinkage and cracking.

Another problem is the rapid change of temperature within concrete members, resulting in potentially large thermal stresses. When using elevated temperatures in order to increase the curing rate of concrete, three main factors should be considered: rate of temperature rise, maximum curing temperature, and heating time. Traditionally, it has been thought that early strength gains are offset by lower 28-day strength. As such, specifications often restrict maximum curing temperatures to between 650 and 700C. An increased curing temperature also results in an increased rate of humidity loss to the environment.

4.1 Conduction/Convection Used for Accelerated Curing

One of the most fundamental methods for rapidly increasing the curing temperature of concrete is through the employment of simple conduction/convection techniques. The temperature of the forms may be increased either electrically or by pumping hot oil or hot water through them. The direct contact between the concrete and the forms with an elevated temperature results in conductive heat transfer. By utilizing convection as well, in the form of flowing hot oil or water, the rate of thermal energy transfer is increased, thereby increasing the rate of curing temperature increase. As with all accelerated curing methods involving elevated temperatures, precautions should be taken to provide sufficient humidity to prevent drying of the concrete, and proper insulation of the formwork will result in a more energy efficient increase in curing temperature.

4.2 Electrical Resistance Curing

Electrical resistant curing includes the use of special coils of wire i.e. the generation of heat through electrical resistance. By imposing an electrical current through reinforcing steel, or through additional wires, heat is generated inside the concrete as a result of the provided electrical resistance, resulting in an increased curing temperature. When steel forms are used, this method may also be used by applying electrical currents directly to the formwork, or by attaching electrical resistance elements to the forms. It has been shown that the effects of increased water cement ratio on compressive strength are less for concrete that has been electrically cured when compared to concrete that has been cured under standard conditions.

4.3 Low-Pressure Steam Curing

Steam curing is a process in which elevated curing temperatures and the addition of moisture during the curing process are both used in order to accelerate the rate of strength gain. These methods can be applied simultaneously, with an increase in temperature as a direct result of steam injection, or individually, in which case an initial temperature elevation is achieved through some alternate means and is followed by an increase in humidity through steam injection. Low-pressure steam curing is frequently used in very dry climates and in applications when the controlling the loss of moisture is imperative. The basic method of steam curing at atmospheric pressure, for the most part, follows the same stages present in any accelerated curing process involving elevated curing temperatures.

4.4 High-Pressure Steam Curing (Autoclaving)

Although generally reserved for the production of concrete masonry units in the United States, high pressure steam curing, also known as autoclaving, has been successfully employed in the production of prestressed precast concrete elements in Japan and Germany. During this process, the increase of curing temperature and humidity are combined with an increase in pressure; as such, elements in this manner must be cured in some type of enclosed vessel. This restriction limits the use of the technique to relatively small elements for typical applications. One of the benefits of this technique is that extremely low water cement ratios can be utilized in the initial mix design. In the case of concrete blocks, the elements are produced through extrusion machines, without the use of formwork, using no-slump concrete [7].

5. Mineral Admixtures for Accelerating Curing Cement

Whenever rapid strength gain is of concern, such as in precast applications, type III Portland cement should be used in order to maximize early strength achievement. Type III Portland cement is both chemically and physically similar to type I Portland Cement; the primary difference is that type III Portland cement particles have been ground finer. The use of type III cement, when combined with any of the numerous additional curing techniques described below, can result in the achievement of very high strengths in very short periods of time.

5.1 Silica Fumes

Micro-silica, or silica fume, is an extremely reactive, pozzolanic material. In one study it was used as a cement replacement for the primary purpose of increasing overall concrete compressive strength. Not only did the results show an increase in long term strength, but they indicated an increase in concrete strength at all ages.

5.2 Fly Ash

Like silica fumes, fly ash can be used as a cement replacement material. Fly ash is one of the byproducts formed by modern power plants; it is a coal combustion byproduct, and is collected by electrostatic precipitators used to filter combustion gases. Unlike silica fumes, however, fly ash does not result in improved early strength of concrete. In fact, the results of the same study mentioned previously in which silica fumes was shown to increase concrete strength show that the replacement of cement by fly ash resulted in decreased early strengths.

6. Conclusions

By concluding this study many number of admixtures are used in increasing rate of curing. With recent advances in material technology, a number of admixtures (mineral and chemical) can be used, both directly and indirectly, as accelerating agents. However, compared with increased curing temperatures, the use of admixtures as accelerators can introduce numerous potential problems and difficulties. The major methods that exist for the purpose of accelerating the curing process of concrete is of two types: physical processes and admixtures. Like most chemical reactions, the rate at which hydration occurs is very susceptible to temperature changes; with increased temperatures, the rate significantly increases. The implementation of elevated curing temperatures is a relatively straight forward process, and can be achieved without the need for a great deal of research and development. As a result, this is the primary method currently employed by commercial precast manufacturers. Until the behavior of admixtures and their effects on other properties of concrete are readily understood, their use as primary accelerating agents in the commercial precast industry will likely remain relatively sparse. Until some significant incentive or motivation is provided, such as significant increases in energy costs and decreases in admixture costs, currently employed curing methods involving elevated curing temperatures will likely continue to prevail.

References

[1] ACI Committee 305, “Hot-Weather Concreting, (1999) ” ACI 305R-99, American Concrete Institute, Farmington Hills, Michigan, 17 pages.

[2] ACI Committee 306, (1997) “Cold-Weather Concreting, ACI 306R-88, Reapproved 1997”, American Concrete Institute, Farmington Hills, Michigan, 23 pages.

[3] Burg, Ronald G., (1996) “The Influence of Casting and Curing Temperature on the Properties of Fresh and Hardened Concrete”, Research and Development Bulletin RD113, Portland Cement Association, 20 pages.

[4] “German Committee for Reinforced Concrete,” (1989) Recommendation on the Heat Treatment of Concrete Deutscher Ausschuss fuer Stahlbeton, Deutsches Institut fuer Normung (DIN), Berlin, 13 pages.

[5] Verbeck, George J., and Helmuth, R. A., (1968) “Structures and Physical Properties of Cement Pastes,” proceedings, Fifth International Symposium on the Chemistry of Cement, vol. III, The Cement Association of Japan, Tokyo, page 9.

[6] French, Catherine, Alireza Mokhtarzadeh, Tess Ahlborn, Roberto Leon, (1998) “HighStrength Concrete Applications to Prestressed Bridge Girders,” Construction and Building Materials, Vol. 12, Elsevier Science ltd., Great Britain, pp. 105-113.

[7] Gerwick, Ben C. Jr., (1993)” Construction of Prestressed Concrete Structures, Second Edition”, John Wiley & Sons, Inc., New York, NY, pp. 19-23, 91-94.

[8] Heritage, Ian, Fouad M. Khalaf, and John G. Wilson, (2000) “Thermal Acceleration of Portland Cement Concretes Using Direct Electronic Curing,” ACI Materials Journal, pp. 37-40.

[9] Lanier, Michael, PCI SCC FAST Team, (2003) “Interim Guidelines for the Use of SelfConsolidating Concrete in PCIU Member Plants,” PCI Journal, pp. 14-18.