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The Effect of Curing Period and Curing Delay on Properties of Hardened Concrete- Review

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ABSTRACT

The curing of concrete is the process of keeping the moisture and temperature conditions of the concrete normal for the hydration reaction, allowing the concrete to develop hardening properties over time, and it is recognized worldwide that concrete must be fully cured to achieve optimal properties, and many studies clearly It is shown that delayed curing has a detrimental effect on concrete, and even delaying curing for one day has the greatest impact on strength. Although delayed curing increased the compressive strength of concrete, the strength reduction caused by delayed curing did not recover. This was demonstrated by wet jute curing processes using different curing protocols with initial water curing periods of 3, 7, 14, and 28 days in continuous air and continuous water, and delayed curing of 7 days, results including ordinary portland cement (OPC) requires at least 3 days to cure, while Pozzolanic Cement Concrete (PPC) requires longer. However, if PPCs have sufficient initial cure, they can reach the strength of OPCs in a reasonable amount of time. In practice, post-curing does not do much to increase the compressive strength of cast-in-place concrete after 3 days of initial curing.

Keywords—Curing, Hydration of Cement, Initial Curing, Compressive Strength

I. INTRODUCTION

Curing is the action taken to maintain the moisture and temperature conditions in the newly placed cement mix to allow the hydraulic cement to hydrate and when pozzolans are used, a pozzolanic reaction occurs which develops the latent properties of the mix and the goal of curing to prevent concrete moisture run off and maintain the proper concrete temperature for long enough. It is generally accepted that proper curing results in proper hydration of the cementitious material within the concrete. While all concrete hydrates to varying degrees of maturity over time, how quickly and to what extent this development occurs depends on the natural environment surrounding the concrete and the actions taken to alter that environment. Reduce the loss of water, heat, or both concrete; provide moisture and heat externally; or incorporate specialty materials into hybrid designs (ACI 308, American Concrete Institute).

II. CURING AND HYDRATION OF PORTLAND CEMENT

Hardening of concrete is important for its strength gain and durability (A.S. Al-Gahtani, 2010). Hydration is the chemical reaction that causes changes when Portland cement reacts with water. Whether at depth or near the surface, curing has a significant effect on the properties of hardened concrete such as strength, permeability, abrasion resistance, volume stability, early cracking tendency, and resistance to freeze-thaw and de-icing chemicals. During the hydration process, the chemical formation of the gel product requires water and fills the micropores formed between and within the gel product as the gel product is formed. The rate and extent of hydration depending on the availability of water (ACI

308, American Concrete Institute). The continuation of hydration reactions in Portland cement is essential to improve the potential strength and durability of concrete. This continuation depends on the type and fineness of cement, the type and the amount of supplementary material present, the water/cement ratio, and the curing conditions, especially at early ages (V. Bonavetti, et.al 2000). American Concrete Institute (ACI 308) mentioned that the objective of curing is to provide an appropriate environmental condition within a concrete structure (temperature and humidity) to ensure the progress of hydration reactions causing the filling and segmentation of capillary voids by hydrated compounds. many studies have shown that the Hydration of cement continues for years at a decreasing rate if the mixture contains water, and the temperature conditions are favorable. Once water is lost, hydration stops. To the best of the authors' knowledge, cement hydration can be completely stopped when the internal moisture content of the hardened cement paste is below 80%. Generally, with sufficient humidity and temperature, the increase in strength will last for more than 28 days. Curing is more important in high-performance concrete (HPC) than in normal concrete because most HPC has a water/binder (W/B) ratio well below 0.42 (A. Bentur and C. Jaegermann, 1991). In addition to the hydration process (Benjamin E. Byard, S.M.

ASCE, 2012) it was suggested that increasing the amount of internal curing water available in lightweight aggregates would increase the degree of hydration.

III. The Right Time for Curing Concrete

ACI 308 Recommended Practice recommends a 7-day moisture cure for most structural concrete. However, when the cement contains additional cementitious materials such as slag, natural pozzolan, and fly ash, the setting time should be extended to 14 days due to the slow hydration reaction between the additional cementitious material and calcium hydroxide. (Baris Ozer, M. Hulusi Ozkul, 2003) showed that pozzolanic cement concrete requires at least 7 days of initial water curing to show pozzolanic activity. Pozzolanic cement concrete that has been water cured for at least 14 days can reach the strength levels of OPC concrete that has been water cured for less than 2 months. However, the former concrete never achieves the strength of the latter concrete for continuous storage in water after an initial moisture cure of 3 days or less.

A. Factors Affecting Initial Curing

ACI 308, American Concrete Institute suggests that for a given condition, curing duration to achieve adequate hydration of Portland cement concrete depends mainly on the type (chemical and mineralogical composition) and the fineness of the cement. (A.S. Al-Gahtani, 2010) evaluated that Proper curing becomes very difficult under hot weather conditions as low humidity and high ambient temperature greatly assist in the evaporation of the mix-water. In general, curing ensures that the mixed water is available for cement hydration, According to Powers [6], a minimum of 80% humidity is required for hydration of cement. High wind and temperature increase the drying of concrete skin. Therefore, the recommendations of ACI Committee 305 regarding minimizing the rate of water evaporation, such as lowering the concreting temperature, increasing the humidity by water spraying, and erecting wind barriers, should be adopted.

B. Strength Vs Moisture Loss of Concrete

The water consumed in the formation of the gel products is known as the chemically bound water, or hydrate water. A mass fraction of between 0.21 to 0.28 of chemically bound water is required to completely hydrate a unit mass of cement depending on its phase composition. The more effective way to achieve a high degree of pore filling is to minimize initial paste porosity with a low w/cm and then to foster hydration by preventing loss of the internal mixing water, or externally applying curing water to promote the maximum possible degree of hydration. The maximum degree of hydration achievable is a function of both w/cm and the availability of water. the continued pore filling that accompanies sustained moist curing leads to a denser, stronger, less-permeable concrete (ACI 308, American Concrete Institute). (Baris Ozer, M. Hulusi Ozkul, 2003) indicated that the strength-gaining rates of the OPC concrete under varying initial water-curing periods are lower than those of the PPC concretes. The OPC concretes, except 14-day or continuously water-cured ones, show strength losses between 90 and 180 days. On the other hand, the pozzolanic cement concretes continue increasing strength beyond 90 days. (V. Bonavetti, et.al. 2000) proved that Curing cessation at 1-day results in a 14% to 22% of potential strength loss by these cements while this curing condition increases the loss of potential strength for plain concrete by about 32%. (A.S. Al-Gahtani, 2010) Results indicated that the strength development in the concrete specimens cured by covering with wet burlap was more than that in the specimens cured by applying water–based and acrylic-based curing compounds, also study indicated that curing compounds could be utilized in situations where curing with water is difficult. (Mateusz Radlinski, et.al. 2008) shown that Air drying lack of curing at an early age may result in reduced late exposure scaling resistance even if some remedial curing actions i.e., intermittent moisture supply are taken. (Benjamin E. Byard, S.M. ASCE,2012) suggested that the use of prewetted lightweight aggregates to provide internal curing in concrete can reduce or eliminate the stress development caused by autogenous shrinkage and also shown that Lower water-cement ratio concretes have increased autogenous shrinkage stress development due to the reduced capillary void size and increased capillary stress. According to (Javier Castro1; Robert Spragg,2012) Internal curing has emerged over the last decade as a method to improve the performance of low water-to-cement ratio (w/c) mixtures.

C. The Necessity and Sufficiency of Initial Curing for Concrete

(A.E. Abalaka, O. G. Okoli, 2013) results have shown that when concrete is subjected to limited early water curing, cement hydration would continue even when it is stopped. This would increase in compressive strength of the concrete and improved microstructure of the concrete compared to uncured concrete and has shown that the first six days of water curing were very significant in compressive strength development of concrete. (M. Maslehuddin, et.al. 2013) results indicated that the selected curing compounds were effective in decreasing the shrinkage strain and enhancing the corrosion resistance of both OPC and silica fume cement concretes. It was also noted that 3 days of wet burlap curing prior to the application of a curing compound was necessary for the OPC concrete while 7 days of wet burlap curing is required for the silica fume cement concrete.

D. Nature of Hardened Concrete Strength

The most important concrete property in structural design is compressive strength. If there is doubt as to whether the concrete in the existing structure has sufficient strength, the structural integrity and compressive strength of the concrete must be checked for quality (Ozyildirim & Carino, 2006). In practice, the compressive strength of concrete is first tested by casting cubes/cylinders from a batch of concrete used for the structure. These test samples were allowed to cure under

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favorable conditions until the test date. The results obtained from these tests can provide concrete-trained consultants with an indication of material properties, such as B. Estimation of porosity, density, compressive strength, etc., but general practitioners only have the latter. These standard tests are called control and compliance tests. If the strength of the standard tests fails, supplementary tests must be performed on the hardened concrete to confirm the in-situ concrete strength. The most common and reliable method to assess in-situ concrete is by testing concrete cores that are removed from the structure. The core testing of hardened concrete plays an important role in establishing the structural integrity and compressive strength of the concrete in existing structures. To ensure that concrete in an existing structure has sufficient strength for which it has been designed a great deal of time and effort should be put into the testing of concrete core specimens to establish whether the structural integrity is satisfactory (Bungey et al., 2006). The outcome of such tests is often used as the basis to decide on the quality of the concrete, as insufficient core strength may result in partial or full demolition of the structure or its members. Therefore, it is authoritative that the core specimen removal and testing for compressive strength follow set standards and rules so that the results are non-ambiguous and reliable.

(Neville, 2001; Ozyildirim & Carino, 2006) noted that, in some cases, standard strength compressive strength results after 28 days indicated non-compliance. This raised doubts about the reliability and quality of the concrete used in the structure. In this case, an on-site inspection of the concrete structure is performed to determine whether the supplied concrete meets specifications and whether the structure has sufficient strength to support the loads for which it was designed (Bungey et al., 2006). One of the field tests that can be used to determine the compressive strength of an existing structure is the procedure of drilling a core sample and removing it from the cured concrete and sending it to a laboratory for compressive strength testing. The drilling, preparation, and testing of concrete cores taken from in-situ concrete should be done by experts in this field as the testing and interpretation of results may require a great deal of time and expense (Bungey et al., 2006). The outcome of such tests is often used as a basis to decide whether the existing concrete conforms to specifications, additionally can be used to identify which party is at fault. It can also determine whether the structural integrity of the concrete is sufficient, and if not, will determine whether the structure requires partial or full demolition based on the core. Therefore, the preparation and testing of concrete cores must follow established standards for the results to be unambiguous and reliable (Smith, 2014). Although these tests need to be performed and interpreted by experienced experts, many difficulties arise during both the planning and interpretation phases due to a lack of common sense (Bungey et al., 2006). Poorly skilled workers responsible for preparing and testing concrete cores may produce misleading results due to a lack of skills in preparing, testing, and interpreting core samples (Bungey et al., 2006).

IV. EFFECT OF DELAY CURING ON COMPRESSIVE STRENGTH

(Baris Ozer, and M. Hulusi Ozkul, 2003), the results show that curing conditions can affect the strength of OPC concrete and pozzolanic cement concrete. However, poor curing has a greater impact on the strength properties of pozzolan cement concrete than OPC. (V. Bonavetti, et.al. 2000) showed that the mechanical properties (compressive strength, tensile strength and elastic modulus) of concrete containing limestone cement are less sensitive to premature interruption of moisture curing. (K.N. Rahal, 2016) Experimental results show that the performance of outdoor poured and cured concrete generally deteriorates, especially for concrete that has not received adequate wet curing. The compressive strength of cores drilled from outdoor cast non-moisture-cured panels was 39% lower than that of lab-cured control panels. (Baris Ozer and M. Hulusi Ozkul, 2017) assessed that 7-day delayed water hardening had a greater effect on strength than adsorption compared to continuous hardening. Although the retarded samples exhibited strength in the samples that were initially water cured for 3 to 7 days, the adsorption capacities of the retarded samples were all equal to or slightly better or slightly lower than those of the continuously water cured concrete cement types tested. (Benjamin E. Byard, 2012) suggested that increasing the amount of internal curing water available in lightweight aggregates would increase the degree of hydration. After 7 and 28 days, the compressive and tensile splitting strengths of internally cured concrete were equal to or slightly greater than those of non-internally cured concrete. (Gaston Espinoza-Hijazin1, 2012) stated that the use of pre-wetted LWA as an IC agent does not reduce the strength of concrete nor increase its chloride ion permeability, and thus can be used to reduce autogenous shrinkage without negatively affecting other properties. The fact that internal curing favors autogenous shrinkage, but not compressive strength or chloride ion permeability, can be explained by ideal external curing conditions. It was also observed that autogenous shrinkage increased with increasing NP content. Since natural pozzolans undergo pozzolanic reactions at a later stage and require water to solidify, effective solidification strategies such as IC become critical. In addition, NP reduces the permeability of concrete, making external water supply (external curing) less efficient. (A. Bentur and C. Jaegermann, 1991) studies have demonstrated that in hot, dry environments, insufficient water hardening has only a slight adverse effect on skin strength, but a significant negative effect on skin performance, as demonstrated by the carbonation test. As estimated. Concrete with and without fly ash but with the same nominal strength showed similar strength changes when subjected to different water hardening treatments in mild and hot dry environments. Therefore, from a strength perspective, they can be considered comparable in terms of field performance.

CONCLUSIONS AND RECOMMENDATIONS

From the results of this study, the following conclusions can be summarized.

i. Initial curing is more effective for concrete with higher cement content; a minimum curing time of 3 days is sufficient for concentrated mixes in hot weather, and a minimum curing time of 7 days for thinner mixes (lower cement content) Will suffice.
ii. After the curing is stopped, a large amount of water evaporates in the concrete in a short time, so it is necessary to protect the concrete from rapid water loss and temperature changes with burlap or other effective curing methods.
iii. Due to a large amount of water loss in a short period of time after stopping hardening, rapid shrinkage occurs, but the degree of shrinkage in the later stage is not greatly affected by hardening.
iv. Delaying concrete hardening in hot weather adversely affects the compressive strength of all mixes, with the greatest impact on the first day of delay.
v. Increasing the curing time after delayed curing from 3 to 7 days increased the compressive strength of the concrete, but did not compensate for the decrease in strength caused by the delayed curing.
vi. Delaying, curing, and stopping curing results in significant changes in concrete length (shrinkage, expansion, then shrinkage); this behavior is undesirable because it increases the tendency to crack, especially at early age.

REFERENCES

1. ACI 308, American Concrete Institute – Guide to Curing Concrete.
2. V. Bonavetti, H. Danza, V. Rahhal, E. Irassar, “Influence of initial curing on the properties of concrete containing limestone blended cement” Cement and Concrete Research 30 (2000)703 ± 708.
3. Baris Ozer, M. Hulusi Ozkul, “The influence of initial water curing on the strength development of ordinary Portland and pozzolanic cement concretes” CEMCON-02406 (2003).
4. A.E. Abalaka, O. G. Okoli, “Influence of curing regime on strength development of grade C60 concrete” International Journal of Modern Engineering Research (IJMER) Vol.3, Issue.2, March-April. 2013 pp-709-714.
5. A.S. Al-Gahtani, “Effect of curing methods on the properties of plain and blended cement concretes” Construction and Building Materials 24 (2010) 308–314.
6. K.N. Rahal, “Effects of improper moist curing on flexural strength of slabs cast under hot weather conditions” Construction and Building Materials 110 (2016) 337–345.
7. M. Maslehuddin, M. Ibrahim. Shameem, M.R. Ali, M.H. Al-Mehthel, “Effect of curing methods on shrinkage and corrosion resistance of concrete” Construction and Building Materials 41 (2013) 634–641.
8. Baris Ozer, and M. Hulusi Ozkul, “Effect of Initial Water Curing on Sorptivity Properties of Ordinary Portland and Pozzolanic Cement Concretes” ASCE J. Mater. Civ. Eng.,29(8): 04017073 (2017).
9. Mateusz Radlinski; Jan Olek; and Tommy Nantong, “Effect of Mixture Composition and Initial Curing Conditions on Scaling Resistance of Ternary Concrete” ASCE, J. Mater. Civ. Eng., (2008) 20 (10): 668-677.
10. Benjamin E. Byard, S.M. ASCE; Anton K. Schindler, M. ASCE; and Robert W. Barnes, M. ASCE, “Early-Age Cracking Tendency and Ultimate Degree of Hydration of Internally Cured Concrete” J. Mater. Civ. Eng., 2012, 24(8): 1025-1033 /(ASCE)MT.1943-5533.0000469.
11. Gaston Espinoza-Hijazin; Álvaro Paul; and Mauricio Lopez, Ph. D, “Concrete Containing Natural Pozzolans: New Challenges for Internal Curing” J. Mater. Civ. Eng., 2012, 24(8): 981-988.
12. A. Bentur and C. Jaegermann, “Effect of Curing and Composition on The Properties of The Outer Skin of Concrete” J. Mater. Civ. Eng., 1991, 3(4): 252-262.
13. Javier Castro; Robert Spragg; and Jason Weiss, M. ASCE, “Water Absorption and Electrical Conductivity for Internally Cured Mortars with a W/C between 0.30 and 0.45” J. Mater. Civ. Eng., 2012, 24(2): 223-231.
14. M. Neville. (2011). Properties of Concrete (5th Edition.). Pearson Education Limited. Essex. ISBN: 0-582-40626-9.
15. Bungey, J. H., Millard, S. G., & Granthan, M. G. (2006). Testing of Concrete in Structures (4th Edition.). Taylor & Francic. London and New York. ISBN: 0849314852.
16. Ozyildirim, C., & Carino, N. J. (2006). Chapter 13: Concrete Strength Testing. In J. f. L. J. H. Pielert (Ed.), \Significance of test and Properties of concrete and Concrete-Making Materials (pp. 125–140). ASTM International. West Conshohocken.