Study of Effect of Automated Curing on Mass Concreting

Raghvendra Raghuvanshi[1] Rajesh Joshi[2]
[1]M.Tech Scholar [2]Assistant Professor
[1,2]Rajiv Gandhi Proudyogiki Mahavidyalaya, Bhopal, India

Abstract— When fresh concrete is poured during the construction of large homogeneous structures, the heat generated due to hydration of cement present is considered. This heat generated is non-uniform in nature and highly depends on composition of cement. Volume change occur due to increasing temperature at early age of concrete. Thermal gradients are produced when the heat generated due to hydration reaction of cement is dissipated through the concrete to the surrounding environment, the lowest temperature occurs at the exposed surface and the highest temperature at the interior part of the concrete. Since the high temperature interior wants to expand it creates tensile stresses at the surface of the concrete. Since the tensile strength of concrete is not fully developed these tensile stresses may surpass the early age tensile strength of concrete and can produce cracks. New automated curing system for mass concrete has been developed to improve the quality of concrete structure and to save construction time and cost. The principle of this method is that the machine-controlled water circulation system of heated hardening water. Applied hardening water on the surface of mass concrete keeps the temperature distinction between centre and surface of the structure below the edge of specification. Mock-up test and field application have been conducted to investigate the performance of this system. In the results, new automated curing system reduced the chance of thermal crack occurrence and improved quality of the concrete structure as well. In this dissertation, 1m3 concrete cube of M40 grade is casted to check thermal stress and thermal cracks, along with 18, 150 mm * 150 mm * 150 mm concrete cube is also casted to check its compressive strength.

Key words: Automated Curing, Concrete, Thermal Cracks, Thermal Insulation Compressive Strength

I. Introduction

During the construction of large structures such as dams, piers of bridges, large foundation etc. The amount of heat is always considered that will be generated and the resulting volume change occurring due to change in temperature it. Volume changes occur due to varying temperature in the concrete structures which increase rapidly in the initial stages due to hydration of cement and decreases in the later stages as the reaction ceases. Per unit distance temperature variation between two points in a structure is called thermal gradient. These are produced when the heat being generated due to hydration reaction, and it gets dissipated to the surrounding environment. The temperature at the surface of the concrete is lower than the temperature at the core of the concrete. This lower temperature at the surface results in contraction of the exposed surface of the concrete. Since the interior concrete is more mature in comparison to the surface it restricts the contraction which creates tensile stress on the surface. The tensile strength of this early age concrete is not fully developed, if the tensile stresses developed due to temperature gradient are more than the undeveloped tensile strength of the concrete, cracking

An understanding of the mix proportion, environmental, and construction parameters that affect the development of mass concrete is crucial to provide a sustainable mass concrete structure. The concrete at an early age behaves according to the heat generated in the core of the concrete which in turn guides the distribution of temperature during hydration.

Specific heat capacity, thermal diffusivity and emissivity also effects the temperature profile of a concrete element. Also the rate of development of mechanical strength of concrete increase with temperature and therefore can be expressed as function of time and temperature.

Previous research in developing the numerical models for distribution of temperature in mass concrete has focused on using non-specific heat production function for temperature rise. Also the models made in the past have treated the heat generation due to hydration as uniform throughout the mix, which in fact is not practical. The heat generation is the function of time and temperature and is different at different location in the mass concrete.

The focus of this research is to correctly formulate the finite element (FE) model considering the non-homogeneous heat generation and distribution and to find out the resulting thermal gradients and the stresses at various points.

To analyse the effect of automated curing in mass concrete structures for the prevention of thermal cracks and comparing it with normal curing method. And also arrive at the mix proportions for M40 grade concrete using Pozzolana Portland Cement to reduce the heat of hydration and conduct experiments to determine the compressive strength of concrete cubes of M40 grade.

In this project $1m^3$ cube is casted of M40 grade of concrete, Temperature sensor (T1) is casted inside the $1m^3$ cube and another sensor (T2) is placed on the surface of the cube, on microcontroller coding is done, i.e. if the temperature difference between two sensors (T1 – T2) is 20^o C or greater than 20^o C than pump which is fitted in tank (filled with warm water) starts to flow warm water on the surface of the cube, by the means of sprinkle shower, and it stops when the temperature difference between sensors goes down to 20^oC, after 28 days of curing thermal cracking is checked and also compressive strength is checked by the help of rebound hammer and also compare it with cube on which normal curing is done.

II. Methodology

a) Material Used: PPC cement conforming IS 1489: 1991 (Part-1), river sand and crushed stone confirming IS 383 is used as binding material and aggregate. Clean water used for production of concrete conforming IS 456.
b) Mix Design: M40 concrete is designed as IS 10262: 2009.

c) Casting: 1m^3 concrete cube of M40 grade is casted to check thermal stress and thermal cracks, along with 18, 150 mm * 150 mm * 150 mm concrete cube is also casted to check its compressive strength.

d) Curing: First of all, AC current is supplied to circuit, which is further changed to DC current, in circuit temperature sensors is fitted with microcontroller which takes temperature reading through ADC, This ADC converts analog value of temperature into digital value. This digital value is displayed by microcontroller into LCD. Whenever temperature difference between the internal and external faces of concrete is 20ºC or more than it, than the microcontroller switch on pump which is fitted in the water tank which lift the water to the sprinkler shower and flows water on the surface of the concrete, water filled in the tank is warm. Due to warm water flows over the surface of the concrete increases the temperature of the external face of the concrete, so that temperature internal and outer face of the concrete becomes same and heat liberated from the concrete slows down and prevent thermal cracking and increases compressive strength.

III. EXPERIMENT & RESULT

A. Temperature Variation

28 days curing system is setup and test is done after 7, 14 and 28 days of curing. Temperature is noted manually which is displayed on the LCD of the system, during the college timing (10:00AM to 5:30 PM) randomly 5 readings is taken which shows temperature difference 20ºC (T1-T2). Temperature variation reading is given in figure below.

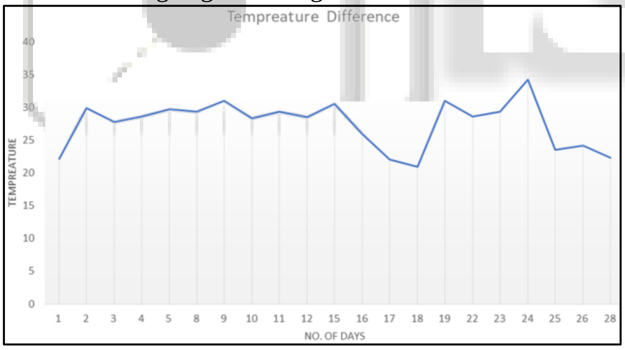

Fig. 1: Temperature Variation for Automated Curing System (Line Graph)

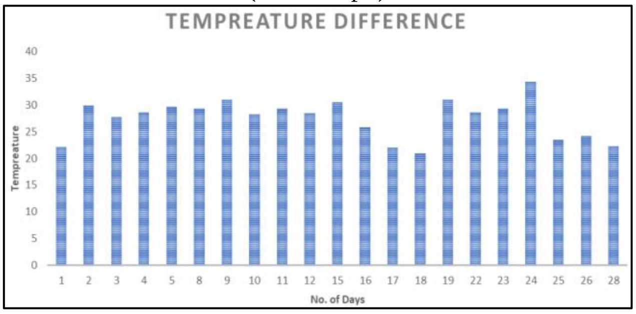

Fig. 2: Temperature Variation for Automated Curing System (Bar Graph)

B. Thermal Cracking

Temperature difference within a concrete structure may be caused by portions of the structure losing heat of hydration at different rates or by the weather conditions cooling or heating one portion of the structure to a different degree or at a different rate than another portion of the structure. These temperature differences result in differential volume change, leading to cracks. This is normally associated with mass concrete including large and thicker sections of column, piers, beams, footings and slabs. Temperature differential due to changes in the ambient temperature can affect any structure.

Thermal cracks caused by excessive temperature differentials in mass concrete appear as random pattern cracking on the surface of the member. Checkerboard or patchwork cracking due to thermal effects will usually appear within a few days after stripping the framework. Temperature related cracks in pavement and slab look very similar to drying shrinkage cracks. They usually occur perpendicular to the longest axis of the concrete. They may become apparent any time after the concrete is placed, but usually occur within the first year or summer – winter cycle. Table shows thermal cracking observation of mass concreting.

Curing Days	Observation	
	Normal Curing	Automated Curing System
7 Days	One Minor Crack Observed	No Cracks Observed
14 Days	Two Crack Observed (One Broad and One Minor)	No Cracks Observed
28 Days	Five Cracks (Three Broad and Two Minor)	No Cracks Observed

Table 1: Observation of Thermal Cracking

C. Compressive Strength

Result shows that automated curing gives better result for compressive strength when it is compared to normal curing. Table 7 and figure 6-7 shows result compressive strength test performed on mass concrete. Figure shows increase in compressive strength of concrete after automated curing.

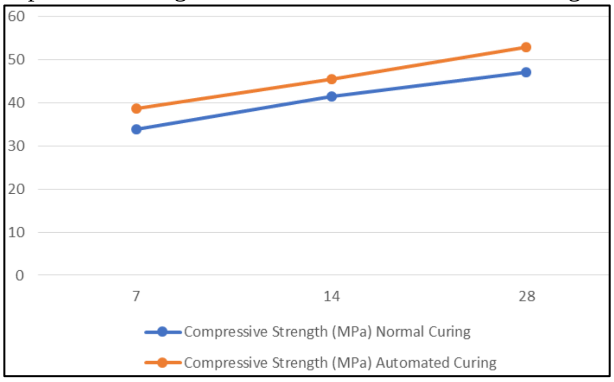

Fig. 3: Result of Compressive Strength Test (Line Graph)

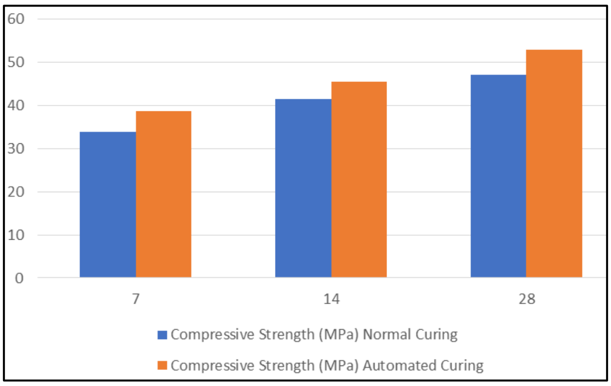

Fig. 4: Result of Compressive Strength Test (Bar Chart)

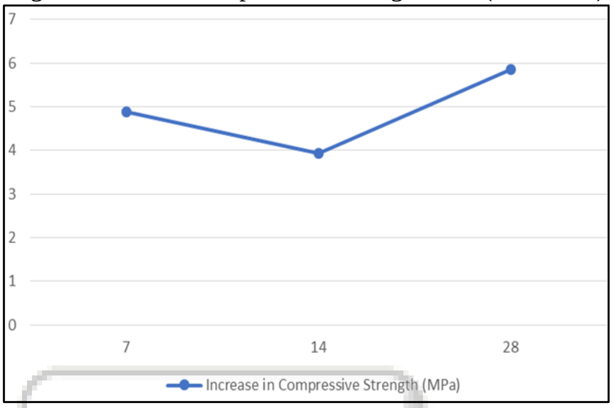

Fig. 1: Increase in Compressive Strength after Automated Curing

IV. Conclusion

Result obtained from current study are as follows:

1) When Temperature difference between the inner and outer surface of concrete reached to 20°c, automated curing started and its shows much better performance on mass concreting over thermal cracking. Minor cracks which observed on the surface of concrete can be eliminated by automated curing system.
2) Compressive Strength of mass concrete is increased after introduction of automated curing in mass concreting, after 28 days of automated curing result shows increment of 5.86 Mpa.

References

[1] Neerej K.P et. al.; Automatic Curing System for Concrete Structures; National Conference on Science, Engineering and Technology (NCSET – 2016); Volume: 4 Issue: 6 136 – 139; ISSN: 2321-8169.

[2] Matthias Bock et. al.; Development and construction of an automated curing system for CFRP-Slittapes; Advanced Intelligent Mechatronics, Kaohsiung - Taiwan, 2012.

[3] Ju-hyung Ha et. al.; DEVELOPMENT OF AUTOMATED CURING SYSTEM FOR MASS CONCRETE, Hyundai Engineering & Construction, Research & Development Division 102-4 Mabuk-dong, Giheung-gu, Yongin-si Gyeonggi-do, 446-716, Korea.

[4] Ju-hyung Ha et. a.l; A Study on the Thermal Crack Control of Large Turbine Foundation using Automated Curing System; The 31st International Symposium on Automation and Robotics in Construction and Mining (ISARC 2014).

[5] Ung-Kyun Lee et. al.; Mass Concrete Curing Management Based on Ubiquitous Computing; Computer-Aided Civil and Infrastructure Engineering 21 (2006) 148–155.

[6] Sanket Jiwane et. al. ;Automated painting and UV curing system based on Arduino; International Journal of Current Engineering and Technology; MITCOE, &DIAT, Pune,AMET-2017, IJCET INPRESSOSpecial Issue-7, March 2017; pp. 132-135; E-ISSN 2277 – 4106, P-ISSN 2347 – 5161.

[7] Ministry of Knowledge Economy, The sixth basic plan for electricity supply and demand, MKE Announcement 2013-63, Ministry of Knowledge Economy, Korea, 2013.

[8] Korea Concrete Institute, Concrete standard specifications, Korea Concrete Institute, 2009.

[9] ACI Committee 207, Report on Thermal and Volume Change Effects on Cracking of Mass Concrete, 207.2R-07, American Concrete Institute, 2007.

[10] ACI Committee 209, Prediction of Creep, Shrinkage, and Temperature Effects in Concrete Structures, 209R-92, American Concrete Institute, 2008.

[11] Ha, J.H., Jung, Y.S. and Cho, Y.G., Development of Automated Curing System for Mass Concrete. The International Symposium on Automation and Robotics in Construction and Mining 2013, Montreal, Canada, 2013.

[12] Ha, J.H., Cho, Y.G., Hyun, T.Y., Lim, C.K. and Seo, T.S., Control of Thermal Crack in Mass Concrete using Automated Curing System. Journal of the Korea Concrete Institute, Vol. 25, No. 2, pp. 195-200, 2013.

[13] Ha, J. H., Cho, Y. G., Hyun, T. Y., Lim, C. K. Seo, T. S. and Lee, K. C., Field application of concrete automated curing system (I).Proceedings of the Korea Concrete Institute, Vol. 24, No. 2, pp. 725- 726, 2013.

[14] Ha, J. H., Cho, Y. G., Hyun, T. Y., Lim, C. K. Seo, T. S. and Lee, K. C., Field application of concrete automated curing system (II). Proceedings of the Korea Concrete Institute, Vol. 25, No. 1, pp. 635-636. 2013.

[15] Ha, J. H., Cho, Y. G., Lee, K. C., Lim, C. K. And Seo, T. S., Field application of concrete automated curing system (III).Proceedings of the Korea Concrete Institute, Vol. 25, No. 2, pp. 43-44, 2013.

[16] Committee B/525/2, Structural use of concrete -Part 1: Code of practice for design and construction, BS 8110-1:1997, British Standards Institution, 1997.

[17] Han, C. G., Oh, S. G., Shin, D. A., Jeon, C. K. And Kim, J., The insulating curing method of cold weather concreting using double bubble sheets, Journal of the Korea Concrete Institute, Vol. 18, No. 6, pp. 51-59,2006.