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Study of Variation in Temperature in Concrete using Sensors

Shivam Adwani[1], Shubham Paunikar[2], Shubham Bhandare[3], Akshay Vitkar[4]

[1,2,3,4]UG Student, G.H. Raisoni College of Engineering and Management, Wagholi, Pune, India.

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Abstract - *The variation in temperature of concrete moulds is common but the effect on different grades of concrete is different and varies as per the type of cement for the same atmospheric temperature. To identify the trend of variation of temperature for the basic three grades i.e. M33 grade (Portland Slag Cement), M43 grade (Portland Pozzolana Cement), M53 grade (Ordinary Portland Cement), the thermo-coupled wired sensors is used to record the middle of the mould temperature and the top of the mould temperature.*

Key Words: (Portland Slag Cement, Portland Pozzolana cement , Ordinary Portland Cement, Thermo-coupled wired sensors)…

1. INTRODUCTION

Large amounts of concrete are used when building massive structures such as hydropower plants and dams. One primary issue is the heat generated in the concrete due to the cement hydration. As cement is a hydraulic binder, many chemical reactions occur during its hydration with water, resulting in temperature rise within the structure. When young concrete hardens, the temperature rises inside the structure contributing to temperature differences between the core and surface. This temperature rise in combination with limited movement of the structure due to adjacent parts will result in tensile stresses that may lead to cracks.

Temperature cracks can be located on the surface or they can go through the whole structure. Surface cracks usually appear when the temperature difference is high between the core and the surface in the expansion (warming) phase of the structure. However, they may also occur in the contraction (cooling) phase if the formwork is removed too early in cold weather. Through cracks mostly appear in the contraction phase and are usually correlated to the restraints against other structures or slabs. They may also occur in the expansion phase if the mean temperature within the casted part is large.

If the type of temperature variation in concrete structures is studied using sensors, then necessary steps and planning measures can be taken well in advance to avoid certain failure in upcoming decades. And even if the cracks appeared visible necessary measures can be taken to avoid the cracks such as by using certain admixtures to avoid the futher modifications in the structures.

1.1 Problem Statement

In order to ensure the quality and durability of larger projects, it is important to monitor and control concrete mix temperature, ambient temperature, and differential temperature in mass concrete elements. Temperature differences can cause stress that leads to thermal cracks, as well as loss of structural integrity, thus shortening the life and decreasing the strength of the mass concrete element. If the temperature goes below a certain number, the hydration of water can slow or stop meaning the concrete won't set properly and won't achieve optimal strength. When temperatures are properly monitored, it allows for appropriate adjustments to be made when needed.

Heat generation depends on many factors such as the compound composition, the initial temperature of the concrete, the ambient temperature, the shape of the mass concrete element, the volume to surface ratio, as well as other surrounding conditions. Generally, the higher the cement content, the more heat will be produced.

There are a number of ways in which you can regulate the temperature of mass concrete elements during a project starting with an initial cooling of the concrete mixture. This can be done with the use of chilled water, ice, or liquid nitrogen. Temperature regulation can also be done throughout the project by running cool water through cooling pipes which are installed before the concrete placement. In order to know when it is appropriate to undertake cooling processes, temperatures must be monitored in real-time.

Thermal cracking develops when the tensile stress of the concrete exceeds its tensile strength. This leads to various types of cracking, including random map cracks, series of vertical cracks in walls with the widest near the base of the wall, and uniformly spaced cracks in beams. In severe cases, these cracks can affect the integrity of the entire structure.

Generally, concrete temperature should be maintained above 10°C for adequate strength. Uniform temperatures need to be maintained a challenge with weather extremes.

High temperature issues with concrete include increased water demand and therefore cost, increased chance of shrinkage which leads to cracking, decreased concrete strength after 28 days, and increased potential for corrosion of reinforcements.

Low temperature issues with concrete includes water freezing in concrete capillaries at -2°C this can lead to cracks as the water expands when freezing. Up to a 50% strength reduction if concrete freezes before reaching 500 psi

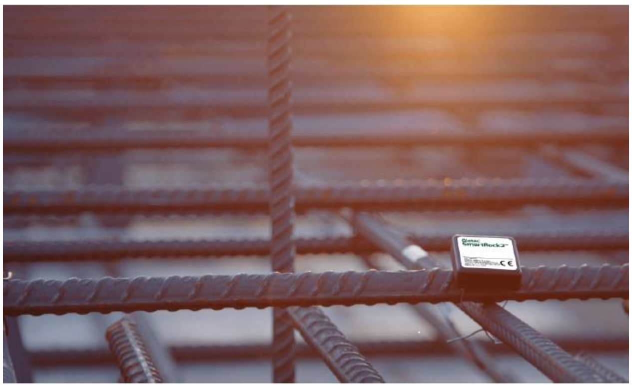

Fig -1: An Image showing wireless sensor embedded in concrete during curing process.

1.2 Objectives

1. To study the variation in temperature in concrete moulds of top, middle, atmosphere and water temperature for the requisite period of 28 days.
2. To calculate the mix design proportion for the mould of the M33 grade (portland slag cement), M43 grade (portland pozzolana cement) and M53 (ordinary Portland cement).
3. To fix the thermocouple wired sensor into the nine cubes of three each of M33 grades (portland slag cement), M43 grades (portland pozzolana cement), M53 grades (ordinary Portland cement) respectively.
4. To record the temperature variation from the nine cubes of three each of M33 grades, M43 grades and M53 grades respectively for the top of mould, middle of mould, water temperature and the atmospheric temperature using thermocoupled wired sensor.
5. To obtain the entire temperature data and arranging into the standard table for the requisite period of 28 days.
6. To evaluate the graphs from the obtained temperature data of requisite period of 28 days and deriving certain observations and conclusions from the entire graphs.

2. METHODOLOGY

When selecting temperature sensors, considering factors such as durability, accuracy, resolution, measurement range, memory, and battery life. For RMC sites, selecting sensors that are durable (able to withstand years of use in challenging conditions), have a minimum accuracy of ±0.5°C, able to capture the full range of expected temperatures, have a memory that is sufficient to record measurements atleast 30-minutes intervals during the deployment period, and have adequate battery life.

Three types of cement will be used for casting concrete i.e. Portland slag cement, Portland pozzolana cement and ordinary Portland cement of M33 grade, M43 grade, and M53 grades respectively.

Ten wired thermocouple sensors of term range 0^0-750^0 celsius and limits of error 2.2^ocelsius will be required for measuring internal and external measurement. Also specific limits of error greater than 1.1^0 celsius.

Thermocouple sensors to be casted at middle for internal measurement.

Following IS Code will be referred for materials:

IS 269:1989-Specification for OPC Cement 53 grade

IS 383:1970-Specification for coarse and fine aggregate from natural sources for concrete.

IS 456:2000-Code of practice for plain and reinforced concrete.

Types of materials will be cement, sand(less than 4.75mm) aggregates(more than 4.75mm)

The following basic components are needed to collect and access continuous temperature:

a) A temperature sensor
b) A Cube Mould of Size 150MM X 150MM X 150MM along with tamping rod of 1.6 metre long length to cast the concrete in it.

3. RESULTS AND OBSERVATIONS

3.1 Mix Design

Table -1: M33 grade mix design

For M33 grade (Portland slag cement)	
Cement	1.62kg
Fine Aggregates	1.96 kg
Coarse Aggregates	3.87 kg
Water cement ratio	0.4

Table -2: M43 grade mix design

For M43 grade (Portland pozzolana cement)	
Cement	1.62 kg
Fine Aggregates	2.03 kg
Coarse Aggregates	3.95 kg
Water cement ratio	0.4

Table -3: M53 grade mix design

For M53 grade (Ordinary Portland cement)	
Cement	1.62 kg
Fine Aggregates	2.13 kg
Coarse Aggregates	3.76 kg
Water cement ratio	0.4

3.2 Data collection

The data is collected with the use of thermocoupled wired sensors for the requisite period of 28 days. The cube was casted between 18 th January 2019 and 14 th febuary 2019 .The nine cubes were casted with thermo-coupled wired sensor in each cube from which the 3 cubes each of M33, M43 ,M53 grades respectively. For the first seven days the time interval for the recording of the temperature was kept 1 hours duration interval and 4 parameters readings were observed of the middle of the mould, top of the mould ,water temperature and atmospheric temperature from the respective nine cubes of 3 each of the respective grades (M33,M43,M53).

The data collection duration for the next 14 days was kept 3 hours intervals. That is from day 8 till day 21, and all the 4 parameters readings were collected from nine cubes of 3 each cubes of respective M33, M43, M53 grades respectively. Taking into account middle of mould, top of mould, water and atmospheric temperature.

For the remaining 7 days the duration was kept 4 hours intervals from day 22 till day 28 with the thermocoupled wired sensors and 4 readings from single mould from respective nine moulds.

Fig -2: An Image showing Casted cubes including sensors

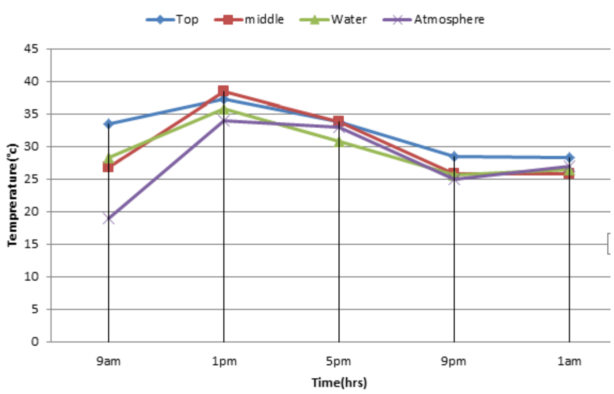

Chart -1: Sample chart showing variation in temperature with respect to particular hours of 4 hrs duration time interval

4. CASE STUDY

The trend of variation while observing the M33 grade PSC (Portland slag cement) graphs all together for the period of 28 days derives the peak duration of variation and the increasing of the temperature in the afternoon slot as the maximum till 3 pm and gets decreased thereafter till the minimum by the increasing night as the effect of the atmospheric temperature as the readings were taken during the winter season of january and february month in which the temperature is minimum at night and that's what the readings and the graphs shows us. The variation was observed maximum during the first seven days and later the trend remained slightly linear in terms of variation till day 21 and for the remaining seven days the trend of variation almost declined as the graphs and readings were linear and common for the M33 grade PSC.

The Observation of the all M43 grade PPC (portland pozzolana cement) for the requisite of 28 days shows us the repetitive trend for the PPC the duration of increasing is same during the afternoon slot and decreasing afterwards till the night. The difference observed is the increasing in temperature is earlier in the afternoon as compared to PSC. The temperature increases earlier and also decreases earlier in the PPC as it is fly ash based and differ in the chemical composition for the same atmospheric conditions.

The study of the temperature variation from all the M53grade OPC (ordinary Portland cement) derives the certain observations regarding the temperature variation. The variation of temperature was observed maximum in OPC as compared to PSC and PPC for the requisite period of 28 days. As the OPC is rich in alkalies and chemical compositions of particles the effect of variation is observed maximum in it. For the first seven days the variation is observed even maximum similar to PSC and PPC, but after that the variation remained slightly constant as the days were increasing. The maximum temperature of OPC was observed in the morning slot and afternoon slot for the initial days, and even in some cases the evening slot also debuted to maintain it's firmity and mark to increase the temperature. The overall atmosphere effect was observed at the middle of mould and in some readings the water and atmosphere were similar in trends in the graphs.

5. CONCLUSIONS

- The chemical composition of OPC includes maximum amount of alkalis and due to it's chemical composition the variation of increasing temperature was not only observed in morning and afternoon slot, but in cases evening slot also marked the debutant of increasing temperature.
- As the reduction of heat of hydration effect on temperature is observed minimum in portland slag cement of M33 grade and the portland pozzolana

cement, the concrete of both PSC and PPC can be effectively suggested for the use in green house building making where the effect of atmospheric temperature will be observed minimum on the buildings.

- As the portland pozzolana cement varies it's increasing temperature only in the morning and the afternoon slot as compared to ordinary portland cement, which has addition in the evening slot also, the effect of temperature increasing is minimized in PPC and as both PPC and OPC have similar chemical composition, only differs in the grinding process of the final stage, so why not to use PPC in the construction of green house buildings as compared to OPC. And even PPC is available in the M53 grade which will reduce the increasing temperature of evening slot and will only limit it to morning and the afternoon slot.
- As per the grade of concrete the strength of the OPC (M53) is maximum as compared to our respective PSC (M33) and PPC (M43), the OPC can be used in high rise and multi-storied buildings whereas for the small storied buildings the PSC and PPC can be utilized and even the manufacturing cost of PSC and PPC will be less as compared to OPC.
- From all the observations and analysis of the temperature variation and the parameter the PSC and PPC, it is clear that the PSC and PPC are the environment friendly cement and if possible these two cements should be largely used and suggested in the future construction practices and projects of the construction industries

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BIOGRAPHIES

Mr. Shivam Adwani
(UG Student of G.H. Raisoni College of Engineering and management, wagholi, Pune)

Mr. Shubham Paunikar
(UG Student of G.H. Raisoni College of Engineering and management, wagholi, Pune)

Mr. Shubham Bhandare
(UG Student of G.H. Raisoni College of Engineering and management, wagholi, Pune)

Mr. Akshay Vitkar
(UG Student of G.H. Raisoni College of Engineering and management, wagholi, Pune)