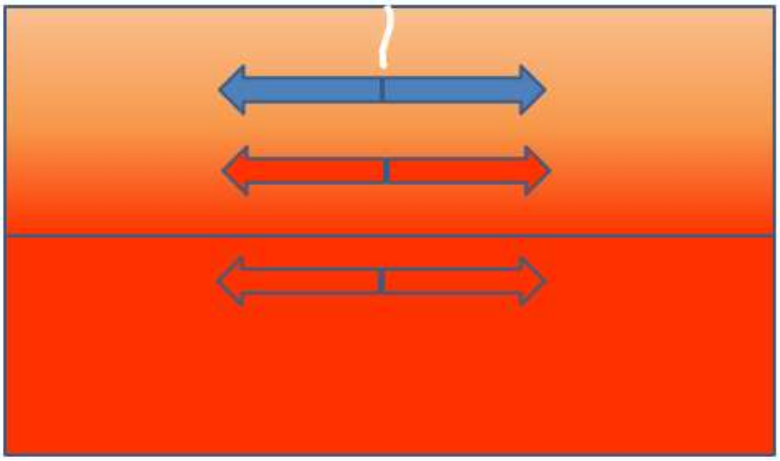
1. Phenomenon

Thick structures or the structures cast with mass concrete are susceptible to durability related issues due to the following phenomenon

- High Temperature differential that leads to Thermal cracking and
- High heat of hydration which leads to delayed ettringite effect

Hence, construction practice strongly advocates for "Temperature Control Methodology" in mass concreting as well as in other thick structures like columns cast with high grade.

2. Differential Temperature and its effect



- Heat generated from hydration would be enormously high in the core portion of concrete in thick structures due to exothermic property of concrete.
- Core portion of the section would expand due to heat
- Surface portion would not expand due to relatively lesser concrete temperature
- However, the expanding core portion would transfer the force of expansion to the top surface resulting in tensile stress on the top portion.
- Concrete would crack in weaker portion due its relatively low tensile strength

3. Delayed Ettringite Formation

When concrete temperature is high, conversion of sulphates into ettringite does not occur at the early stage of hydration. These sulphates are converted into Ettringite at later age with the presence of moisture. This phenomenon is called "Delayed Ettringite Formation". This could lead of concrete expanding with the potential to cracking.

4. Temperature Control Methodology

Controlling of placing temperature of concrete with the following combination

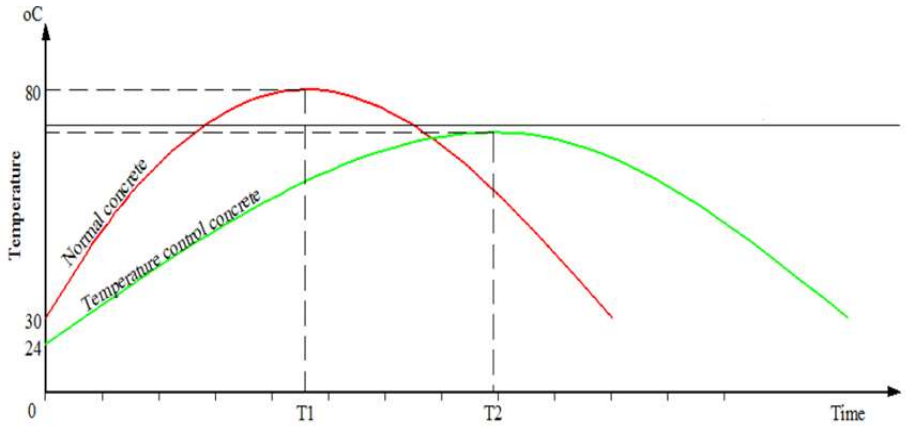
- Replacement of maximum possible OPC with Fly Ash or GGBS to reduce the heat of hydration. Fly Ash has better ability to reduce the heat of hydration than GGBS especially in places like Chennai
- Usage of low heat cement, if available
- Usage of Chilled water and or ICE
- Placing concrete with controlled temperature in the bottom 2/3rd portion and concrete with normal temperature in the top 1/3rd layer to minimize the temperature differentials across the thickness

Controlled Cooling Process of the structure after casting

- Insulating the sides of the structure (inside the formwork) to disallow the sudden cooling of the sides of the concrete during hydration/hardening
- Application of curing compound instead of water curing immediately after the concrete got hardened to avoid the sudden and excess cooling of the surface
- Insulating the surface of the structure by placing expanded Polystyrene sheets immediately after applying curing compound to avoid the sudden and excess cooling of the surface
- Keeping the side formwork intact for 7 days to avoid the sudden and excess cooling of the sides of the concrete structure
- Installing series of pipelines along the core portion of the structure, through which sending chilled water would reduce heat generated at early age.

Role of Retarder in mitigating the temperature effect further

Addition of retarding admixture shall be made essential in Mass concrete, especially when PCE based admixture is used. While PCE based admixture has the tendency to show “sudden withdrawal effect” leading to faster reaction of cement particles, Retarders tends to work to control the faster reaction. Hence, usage of Retarder in concrete add to the dual benefit of reducing the peak temperature of concrete and delaying the onset of peak temperature.



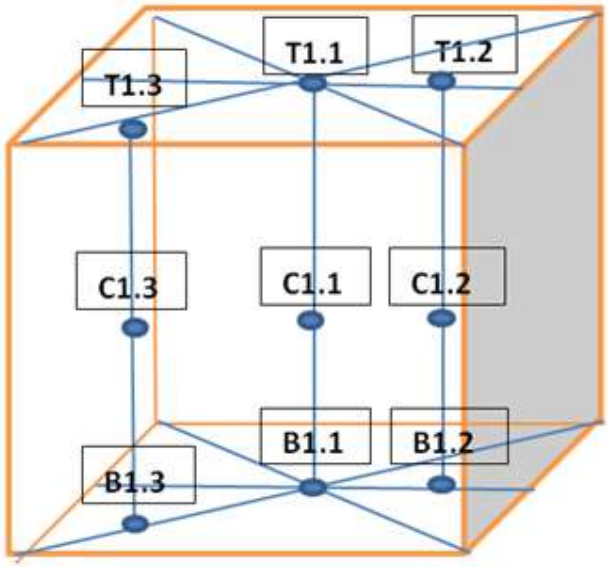
As shown in the above picture, reduction of peak temperature from 80^0 to 70^0 and shifting of peak temperature from time 1 (T1) to time 2 (T2) were possible with the addition of Retarder in a mass concrete. 35% Fly Ash too was used in this concrete mix.

5. Temperature measurement

Thermocouples are installed in the critical locations to be measured, before placing of concrete. After placing of concrete temperature readings are taken with the help of Digital meter at regular intervals.

Location of Thermocouples

1. At Core portion – To measure the peak Temperature
2. Near Surface @ 300mm to 500mm below – To measure temperature difference
3. Near Corner @ 300mm to 500mm away – To measure temperature difference
4. At Bottom @ 300mm to 500mm above – To measure temperature difference



Measurement

- Ambient temperature and fresh concrete temperature readings are measured and recorded just before placing the concrete.
- Ambient temperature and concrete temperature post casting are measured at the pre-installed points of thermocouples and recorded, from finishing of casting time for the next 96 hours, at a regular interval.
- Temperature measurement is continued at 6 hours interval for the next 48 hours.
- Peak temperature is expected to reduce at around or just before 72 hours and the insulation placed at top surface of the raft could be removed once the differential temperature between the core and the surface is measured to be less than 10^0C.

- Similarly, when the difference between the ambient temperature and concrete temperature near surface and corner is measured to be less than 5^0C, formwork along with insulation can be removed.

Strength Development

- Due to the addition of Fly Ash as a partial replacement to OPC, strength development would be gradual and slow in comparison with the mix with pure OPC. The major advantage with addition of fly ash is that the reaction goes beyond 28 days age, and strength gain could be noticed till 90 days age. Hence strength of concrete at 28 days, 56 days and 90 days shall be measured and 90 days strength shall be considered as design strength of concrete. It is a well-known factor the structures like Raft or Pile will be subjected to their design loads only after the completion of the entire structure, which requires at least few months duration. Hence it Is advisable to have a gradual strength gain pattern in structures like Raft or Pile that could help in mitigating the effects caused by high heat of hydration in the structures.

For SC Square

Sd/-
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