Bulletin No.4

RMCMA

Temperature Control of Concrete at Early Ages

In Quest of Quality Concrete

PRESIDENT'S MESSAGE

Ready Mixed Concrete Manufacturer's Association is pleased to publish its new bulletin on “Temperature Control of Concrete at early ages”. India is tropical country and ambient temperature in most parts of the country remains high during various times of the year. In addition, the constructions of massive concrete elements like Raft Foundations for High Rise Buildings, Pile Caps, Bridge Piers, Retaining Walls, etc., for infrastructure projects are increasing day by day. The temperature control of concrete under these conditions occupies important place for ensuring durability and sustainability of concrete structures.

The temperature control in early ages of concrete is required mainly due to two reasons. The first reason is the temperature gradient in concrete due to heat of hydration of cement which develops large variation in temperature within the body of the concrete. The second reason is when concreting is done at high ambient temperatures causing temperature differential due to high rate of evaporation of moisture from the concrete surfaces and drying of restrained surfaces resulting in development of shrinkage cracks adversely affecting performance of concrete.

Measures like use of chilled water, cement replacement/optimization, pre-cooling of aggregates, post cooling of concrete and operational management are some steps which can help in achieving the desired temperature control. In most of the recent and upcoming infra projects like Metros, Concrete Highways, Bridges, High rise buildings, etc. use of chilling plants / ice plants has become mandatory which shows the growing awareness and importance of temperature controlled concrete among government bodies and technocrats.

RMCMA is continuously endeavouring in educating the manufacturers and the consumers to use concrete with value additions for long term durability and sustainability. I am confident that the Bulletin will be found very useful in achieving this objective.

Er. Ramesh Joshi
(President, RMCMA)

INTRODUCTION:

"Thermal properties of concrete are related to the development of temperature gradients, thermal strains, warping and cracking in the very early age of concrete. The temperature gradient causes volume change and consequent cracking in restrained concrete, due to shrinkage or contractions and insufficient tensile strength or strain capacity of concrete at that time. Cracking is a weakening factor that may affect the ability of the concrete to withstand its design loads and may also result in poor durability and sustainability.

The temperature control in early ages of concrete is required mainly due to two reasons. The first reason is the temperature gradient in concrete (especially in thicker sections) due to heat of hydration of cement which develops large variation in temperature within the body of the concrete. The second reason is when concreting is done at high ambient temperatures causing temperature differential due to high rate of evaporation of moisture from the concrete surfaces and drying of restrained surfaces resulting in development of plastic shrinkage cracks. The plastic shrinkage cracks as well as micro-cracks within the concrete have harmful effects on durability and sustainability of concrete during its useful service life. In this bulletin the need of temperature control in early ages of concrete under both the cases is discussed in order to enhance performance of concrete."

2.0. Mass Concrete:

Concrete cast in massive sections requires special consideration in handling of heat of hydration and the temperature rise after casting. Uncontrolled temperature rise can result in unacceptable cracks or integral damage to the concrete. 'Mass Concrete' is defined in ACI 116R as "any volume of concrete with dimensions large enough to require that measures be taken to cope with generation of heat from hydration of the cement and attendant volume changes to minimize cracking". The cement-water reaction is exothermic by nature and if the heat generated is not quickly dissipated, the temperature rise can be quite high. It may cause significant rise in tensile stresses and strains from the volume change associated with the increase and decrease of temperature within the concrete mass. In concrete members of relatively large size, the rise in temperature can be of the order of 40 to 50°C above the placing temperature, unless the heat is quickly dissipated. The cracking due to thermal behavior may cause loss of structural integrity and monolithic action, or excessive seepage and shortening of the service life.

3.0. Thermal Behaviour of Mass Concrete:

The measures to control thermal cracking in mass concrete were initially developed in connection with construction of concrete dams. However, temperature induced cracking can be experienced in other concrete members like raft foundations, bridge piers and abutments, pile caps, thick walls, concrete lining in tunnels, and other structural elements. The principles of mass concrete practice can therefore be applied to general concrete works whereby certain technical, economic and other benefits can be realized. Thus 'Mass Concrete' includes not only low cement concrete used in dams and other massive structures but also moderate to high cement content concrete in structural members that require special considerations to handle heat of hydration and temperature rise. Thermal evolution over time is shown in Figure 1.

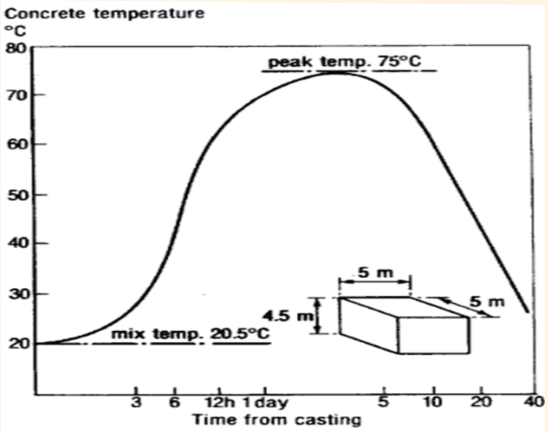

Fig 1 - Thermal Evolution overtime

It is the temperature differential or thermal gradient inside and across the concrete mass that causes cracking rather than the temperature rise alone. The temperature of inside concrete rises due to heat of hydration of cement as the hydration progresses. The rate of hydration of cement is increased at higher temperature and accelerates the heat generation and rapid development of thermal gradient. The concrete has low thermal conductivity and the heat generated within inside is dissipated rather slowly, while the outside surface cools down rapidly. If there is any restraint against free contraction during cooling, tensile strain and stresses develop along the peripheral surfaces of concrete. The tensile stresses developed during cooling stage are determined by five factors (1) thermal differential and rate of temperature change (2) coefficient of thermal expansion which tends to increase with increasing cement content and type of aggregates (3) modulus of elasticity (4) creep or relaxation, and (5) the degree of restraint. If the tensile stress developed exceeds the tensile strength of the concrete, cracking will occur (Houghton 1976).

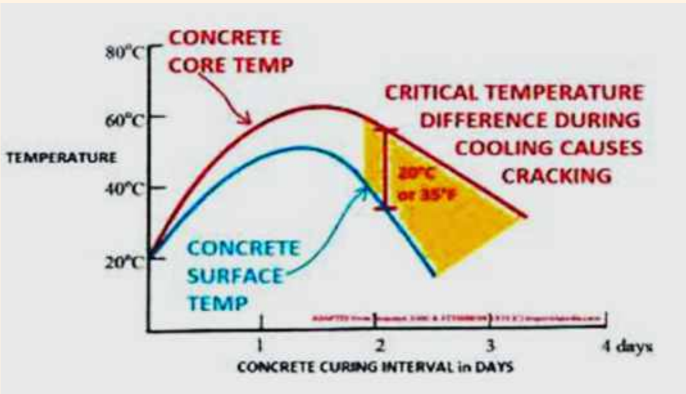

Fig 2 – Concrete Crack Formation vs Core Temperature

The inside temperature takes time to come to equilibrium with the ambient temperature. The temperature gradient developed between the hot internal concrete and cooler outer concrete surface is the major cause of cracking. The width and depth of cracks depend upon the magnitude of the temperature gradient and other factors as mentioned above. Heat escapes from a mass of concrete at a rate that is inversely proportional to the square of its least dimension. Therefore the size or dimension of the structural member becomes of prime importance. By way of example, a 150mm thick concrete wall can become thermally stable in about 1 to 2 hours, 1.5m thick wall may take about 7 to 10 days to reach a similar condition. The time taken in case of a 50m thick arch dam may be two years and upto 200 years in case of a 150m thick concrete gravity dam. ACI 211.1 states that "Many large structural elements may be massive enough that heat generation should be considered, particularly when the minimum cross sectional dimension of a solid concrete member approaches or exceeds 2 to 3 ft. (600 to 900mm) or when cement contents above 600lb per cubic yard (364 kg/m^3) are being considered".

If the rise of temperature and subsequent cooling were uniform throughout the mass of concrete, thermal stresses will not develop. Because of differential temperature, the expansion takes place inside the mass which is at higher temperature, will be restrained by the outside surface, which may have experienced some degree of cooling off. The tensile stresses are developed at the outside surface while stresses inside the mass are compressive in nature. If the tensile stresses exceed the tensile strength, cracks develop. As a general guidance, the temperature differential between the interior and the external surface of the order of 20°C to 30°C (depending upon type of aggregates) or more, causes cracking. Cracks also develop, when the thermal movements are restrained externally, e.g. concrete lining in tunnels in contact with rough rock surface, etc.

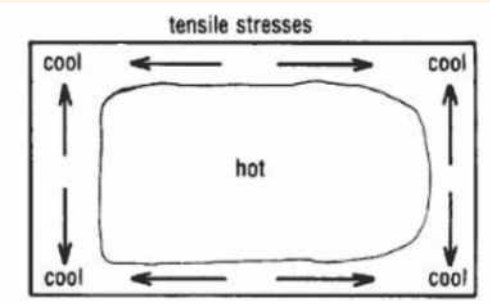

Figure 3a - Internal restraint

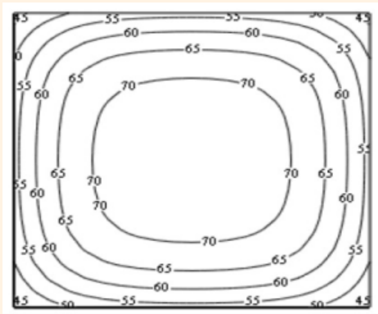
Figure 3b – Temperature differential

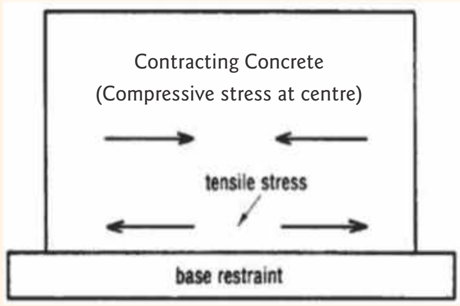

Figure 3c - External restraint

4.0 Effects of Hot Weather and Temperature Rise on Concrete:

In the absence of special precautions, the effects of hot weather on fresh concrete may be described as follows.

4.1. Accelerated Setting:

The accelerated setting reduces the handling time of concrete and also lowers the strength of the hardened concrete. Quick stiffening may require undesirable re-tempering by addition of plasticizer or water. Another disadvantage from accelerated setting of concrete is formation of cold joints, which may increase the deterioration mechanism and adversely affect the performance and sustainability of concrete.

4.2. Increased Slump Loss:

Temperature rise increases slump loss in concrete. To compensate loss of workability either water content shall be increased, but to maintain same w/c for corresponding strength, cementitious content has to be increased, or the dose of admixture shall be increased. The first option is normally avoided due to increase in cost and second option is mostly adopted. The formulation of admixture shall be compatible to the climatic conditions, the content of retarder in admixture will vary depending upon the prevailing ambient temperature. Due care shall be given to choice of admixture to compensate the slump loss under different climatic conditions. The effect of temperature on slump loss is shown in Fig 4.

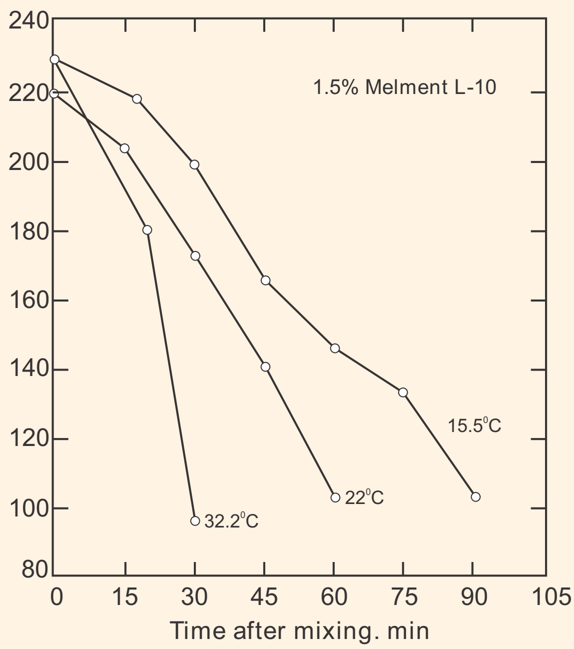

Figure 4 – Effect of Temperature on Slump Loss

4.3. Increased Water Demand:

At higher ambient temperature, the water demand in concrete increases. The relationship between ambient temperature and water demand is shown in Fig 5.

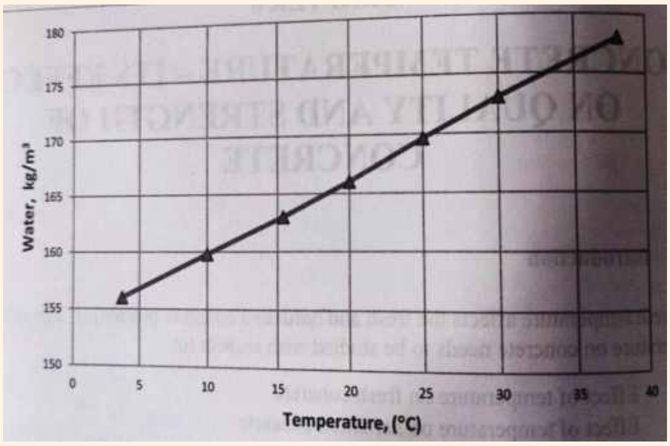

Figure 5 – Effect of Temperature on Water Demand

4.4 Increased Tendency to Crack:

Rapid-evaporation of moisture may cause plastic shrinkage and cracking. The most important factor influencing the plastic shrinkage cracking is the rate of evaporation of water from the surface of the concrete. This depends on the ambient temperature, the relative humidity, the wind speed and the concrete temperature. The intensity of cracking is found proportional to the maximum day temperature during construction.

4.5. Reduction in Strength:

Concrete mixed, placed and cured at elevated temperatures normally develops higher early strength but at 28 days or later day strength are generally lower. In addition larger the delay between casting and placing, greater is the strength reduction. It has been found that specimens moulded and cured at 38°C produced strength 73 percent of the specimen moulded and cured at 23°C [SP-23]. The relative humidity at the time of casting and curing has also significant influence on the initial and later date strength of concrete. The effect of temperature on compressive strength of concrete is showing in Fig 6.

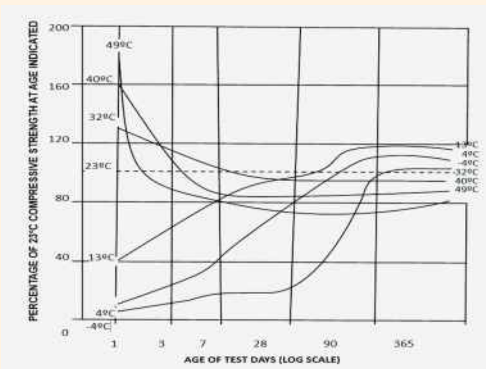

Figure 6 – Effect of Temperature on Compressive Strength of Concrete made with Ordinary Portland Cement (SP-23)

4.6 Delayed Ettringite Formation (DEF):

Ettringite $Al_2\ Ca_6\ H_{12}\ O_{24}\ S_3$ is the normal product at the early stages on hydration of cement under ambient temperature conditions. However, the ettringite formation is destroyed if the temperature of fresh concrete exceeds about 70°C (either as a result of applied heat or from heat evolved internally due to hydration of cementitious materials).

Ettringite will, however, slowly form after cooling of concrete and subsequent hydration of cement. The formation of ettringite at a later date leads to increase in the total solid volume of the cement paste and can be an expansive process. If there is insufficient space within the paste structure for ettringite to form then internal stresses causes, expansion and cracking may occur.

5.0. Assessment of Rise in Temperature in Concrete:

In massive structures of high volume to surface ratio, an initial estimate of the adiabatic temperature rise can be made from the formula (based on US Bureau of Reclamation);

$$T = \frac{CH}{S}$$

Where

T = temperature rise in degree centigrade of the concrete due to heat generation of cement

C = Proportion of cement in concrete by weight

H = Heat generation due to hydration of cement in cal/kg (at 28 day)

S = specific heat of concrete, cal/g/°C

Example:

Assuming a concrete weighing 2400kg/m^3 containing 300kg cement (53 grade OPC) and 100kg fly ash per cubic meter.

The heat of hydration of fly ash is assumed 50% of cement.

$$\frac{300 + (0.5 \times 100)}{2400} = 0.1458 \text{ kg of cement/per kg of concrete}$$

The heat of hydration of cement (28 days) is assumed 105 cal/g (refer Table-1). Specific heat of concrete normally varies between 0.35 to 0.45 cal/g/°C depending upon the nature of aggregates.

In this example, it is assumed 0.4 cal/g/°C

Therefore, $T = \frac{0.1458 \times 105}{0.4} = 38.2°C$

If the concrete is placed at 30°C, it can be expected to have a maximum temperature of 68.2°C at the interior of the member.

The types of cement, mineral admixtures and their quantity and type of aggregates have major effect on rise of temperature. If the mass concrete structures are not likely to be subjected to early age loading, then it may be prudent to design concrete mixes for later day strength, may be 90 days or even beyond. This would allow lowering of cementitious content and allow use of larger quantities of fly ash or ggbs for better economy and better control of temperature in mass concrete.

In large projects, generally a mock up is made at site to find the peak temperature and temperature differential at core and surface of the concrete. The temperature measurement is made by inserting thermocouples at the core and surface of concrete. The actual measurement of peak temperature in mock up coupled with theoretical, temperature assessment provides a fair estimate of peak temperature.

6.0. Temperature Measurement:

Before commencing concrete on a large project, it is advisable to cast a mock up at site and provide thermocouples to measure directly the in situ temperature (Figure 7). This is relatively cheap and simple, and gives a direct measurement of temperature differentials. The thermocouples should be located at the center and at the surface to measure the temperature extremes and hence the maximum differential. Monitoring can be either manual or automatic.

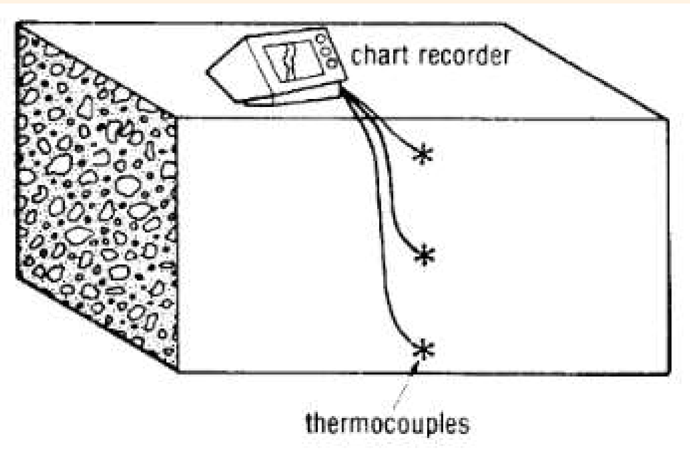

Figure 7: A typical arrangement of thermocouples in a mass pour to determine both the maximum temperature and temperature differentials

7.0. Case Study of Evaluation of Temperature Rise:

In a mass concrete project in Mumbai, a mockup of 3m × 3m × 3m block of M-40 grade concrete was made to study the thermal behaviour of fresh concrete. Five thermocouples were installed at centre and at 4 faces, the following observations were made;

- Peak temperature 67.5°C at the centre.
- The peak temperature reached after 62 hours from batching of concrete.
- Maximum thermal gradient found 10.7°C between centre and bottom corner.

The temperature profile of the mockup is given in Figure 8.

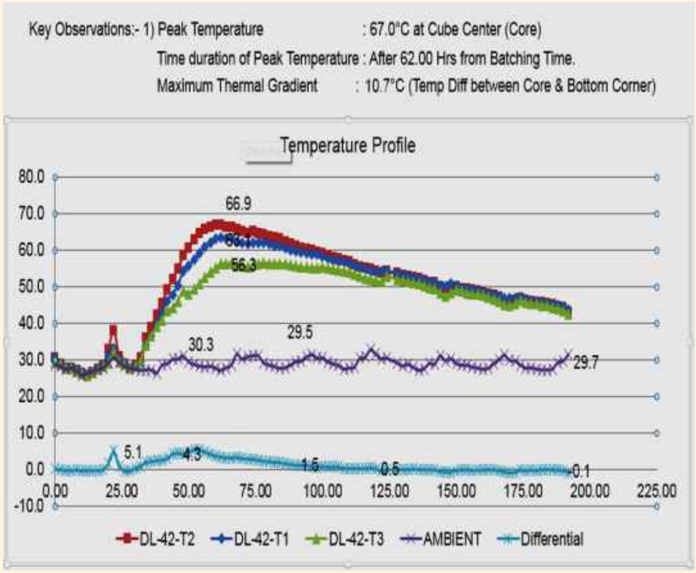

Figure 8: Temperature Profile of Mockup

8.0. Temperature Control Methods:

The five effective temperature control methods are (1) cementitious materials control, where the choice of type and amount of cementitious materials can lessen the heat-generating potential of concrete; (2) Effect of Aggregates Types (3) Precooling, where cooling of ingredients achieves a lower concrete temperature as placed in the structure; (4) Post cooling, where removing heat from the concrete with embedded cooling coils which limits the temperature rise in the structure, and (5) Construction management, where efforts are made to protect the structure from excessive temperature differentials by concrete handling, construction scheduling, construction procedures and curing methods. For general constructions, any concrete structure having lateral dimension of 0.75m or above may need appropriate mass concerting practices.

8.1. Cement and Cementitious Materials:

The cementitious content should not be greater than what is needed for design strength. As a thumb rule rise of 12°C. Per 100kg of cement use in concrete can be taken for guidance (IS: 457). However, it will also depend upon the thickness of the member.

The influence of thickness on temperature rise is clearly illustrated in Figure 9 and 10. As the minimum dimension increases, the rate of heat dissipation from the centre is reduced and the temperature rise is increased. In pours thicker than about 2.5m, the maximum temperature rise is largely unaffected by increasing pour size, but in the range 0.5 to 1.5m the change in maximum temperature rise is considerable.

The OPC cement shall be replaced by fly ash and ggbs upto 35% and 70% respectively as permitted by IS 1489 (Part-1) and IS 455, codes for PPC and PSC. As a rule of thumb that has worked fairly well has been to assume that pozzolana produces only about 50 percent as much heat as the cement it replaces (ACI 207.1R). Heat of hydration at different ages of commercially available cements in India is given in Table-1.

Table 1 – Heat of Hydration data of Indian Cements (Typical)

Types of cement	Heat of hydration			
	Period	cal/g	Joules /g	BTU/lb
43 grade OPC	3day	65	272.15	117
	7 day	80	334.96	144
	28 day	95	397.80	156
53 grade OPC	3day	75	293.09	126
	7 day	85	355.90	153
	28 day	105	439.63	189
Portland Pozzolan Cement (PPC)	7 day	64	268.00	115.20
	28 day	74	309.83	133.20
Portland Slag Cement (PSC)	7 day	60	251.22	108.00
	28 day	75	314.03	135.00

(1 calorie = 4.187 Joules = 0.00397 BTU)

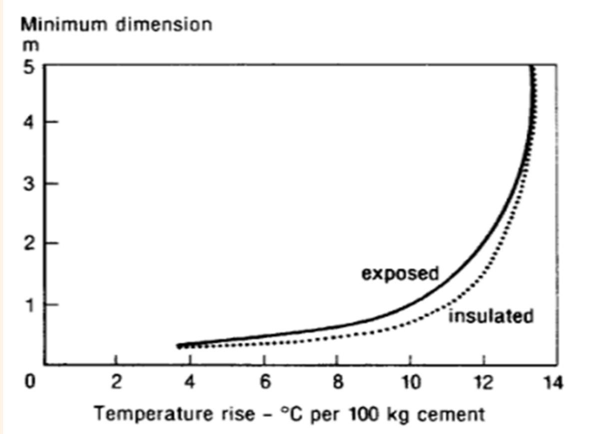

Figure 9 - Relationship between the temperature rise (°C per 100 kg of cement) and minimum dimensions of the member

8.1.1. Cement Replacements:

The use of either fly ash or blast furnace slag partially to replace OPC can result in considerable reductions in temperature rise. This is due largely to the reduced rate of hydration associated with these materials. The maximum level of replacement of fly ash does not normally exceed 30% - 35%. Blast furnace slag can be used to replace up to 70% of OPC, but in actual practice, it is limited to 45% to 55%. The effect of both materials on the specific temperature rise has been monitored in pours up to 4.5m deep (see Figure 10). It is not uncommon, with high levels of replacement using fly ash or blast furnace slag, to achieve a reduction in temperature rise of 50%. Triple blends can also be used if the environment and construction requirements so demand.

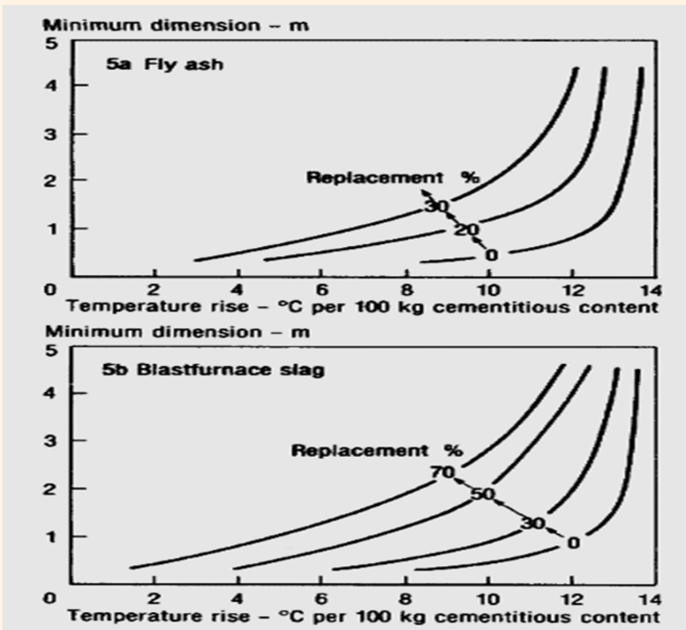

Figure 10 – The influence of partial OPC replacement on temperature

8.2. Effect of Aggregate Type:

Aggregates Shape, Size, coefficient of thermal expansion and thermal strain capacity have considerable effect on temperature rise in concrete. The coefficient of thermal expansion of aggregates derived from limestone, dolomite and sandstone rocks is lower compared to basalts and granites and their thermal strain capacity is also higher. The temperature differential between the core and skin of mass concrete pours, which may cause cracking is generally restricted to 20°C, but for aggregates derived from limestone or dolomite rocks, this limit can go up to 31°C (PCA-2013).

Aggregate size and shape also affects quantity of cementitious material for same strength of concrete. Use of 40 mm (MSA) can result in saving of cementitious material by about 10% over 20mm (MSA). Similarly a saving of up to 3% to 4% can be achieved by use of VSI crusher aggregates over jaw crusher aggregates.

8.3. Precooling of aggregates and water:

The effective and positive temperature control measure is precooling which reduces the placement temperature of concrete. Usually the fine and coarse aggregates and the water are separately cooled to the requisite temperatures. Mixing water may be cooled from 0°C to 4°C. Adding crushed ice or ice flakes to the mix is an effective method of cooling because it takes advantage of the latent heat of ice. However, addition of large quantity of ice to replace water may not be possible and for practical purpose, not more than 70% of water should be replaced by crushed ice. However, care must be taken to ensure that all the ice has melted before the concrete is placed.

The temperature of the aggregates has greatest influence on the temperature of the concrete, since aggregates comprise the greatest proportion of concrete mix. One of the methods of cooling is to chill the aggregates in large tanks of refrigerated water for a given period of time or by spraying cold water. Effective cooling of aggregates is also obtained by forcing refrigerated air through the aggregates while the aggregate is in stock pile or on conveyor belt. Sand may be cooled by passing it through vertical tubular heat exchangers. A chilled air blast directed on the sand as it is transported on conveyer belt may also be used. Sand may also be cooled by passing it through screw conveyers, the blades of which carry chilled water inside. Immersion of sand in cold water is not practical because of the difficulty in removing free water from the sand after cooling. This also leads to bulking of sand.

Injection of liquid nitrogen into mix water has also been effectively used to lower concrete temperature. In most cases, the placing temperature of concrete less than 18°C can be achieved with injection of liquid nitrogen.

Figure 11 - Injection of liquid nitrogen to cool concrete

8.4. Post cooling of concrete:

Post cooling is a means of crack control mainly used in dam construction. Concrete temperature can be effectively controlled by circulating cold water through thin walled pipes embedded in concrete. This will reduce the temperature of freshly laid concrete by several degrees. Post cooling will create a flatter temperature gradient between the warm concrete and the cooler exterior atmosphere, which in turn helps in avoiding temperature cracks.

If the formwork has to be removed, it is best to loosen the shutters initially, but keep them in place for a period of, say, 24 hours. This allows the surface to cool slowly, resulting in less severe thermal gradients. When the shutters are removed altogether, they must be replaced by insulating drapes to maintain the temperature differentials within the acceptable limits.

8.5. Construction Management:

The climate factors affecting concrete in hot weather are high ambient temperature and reduced relative humidity, such climatic conditions are common in many parts of India. A higher temperature of the fresh concrete results in a more rapid hydration and leads to accelerated setting. High temperature results in greater evaporation loss and increase of mixing water. With the increase in concrete temperature, the slump (workability) decreases, it was reported that approximately 25mm decrease in slump resulted for each 11°C increase in the concrete temperature (SP-23). Rapid evaporation may cause plastic shrinkage and cracking and subsequent cooling of concrete would induce tensile stresses. The plastic shrinkage is likely to occur when the rate of evaporation exceeds the rate at which water rises to the surface, but it has been recently found that cracks also form under a layer of water and become apparent on drying. The cracks formed at initial age of concrete adversely affect the durability and sustainability of concrete during its service life. Any operation of concreting done at atmospheric temperature above 40°C or any operation of concreting where the temperature of concrete at the time of its placement is expected to be beyond 40°C is not recommended without proper precautions (IS 7861-Part I). The ideal temperature of fresh concrete for placing is between 15°C to 25°C. It otherwise needs heating or cooling as shown in Fig 13.

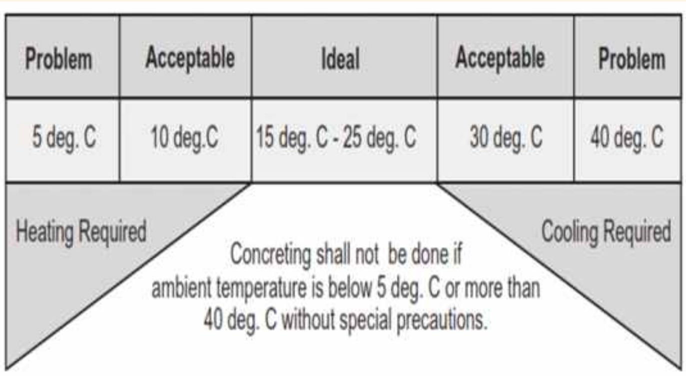

Figure 13

9.0 Curing:

In order to obtain good quality concrete, the placing of an appropriate mix must be followed by curing in a suitable environment during the early stages of hardening. The necessity of curing arises from the fact that hydration of cement can take place only in water filled capillaries. For this reason, a loss of water by evaporation from the capillaries must be prevented. The rapid initial hydration forms products of poor physical structure, probably more porous. This leads to lower strength and higher permeability in the hardened concrete.

Once the concrete has attained some degree of hardening sufficient to withstand surface damage (approximately 12 hours after placing), moist curing shall commence. The actual duration of curing shall depend upon the mix proportions, size of the member as well as the environmental conditions. However, it shall be not less than 7 days if Portland Cement is used and 10 days if pozzolana or slag cement is used. Continuous curing is important, because the volume changes due to alternate wetting and drying promote the development of surface cracking. If the wind velocity is more than 15km/hour, then wind breakers shall be provided especially in case of pavements. The curing water shall not be much cooler than the concrete because of the possibilities of thermal stresses and resulting cracking.

10.0. Role of Admixtures:

The dose of admixture shall be adjusted during the placing operation under varying ambient temperature to maintain same workability. If the seasonal changes are modest like in coastal areas, the same admixture with different doses may meet the requirement of varying ambient temperatures. However, if seasonal changes are severe like in North India, where summer temperature may go up to or beyond 45°C and winter temperature may go down to 5°C, the same admixture will not be effective during summer and winter. The change in formulation of the admixture and content of retarder will need adjustment to meet the requirements of summer and winter seasons. It is observed that SNF based admixtures are not so effective in extreme weather conditions as PCE based admixtures. The formulation of PCE based admixtures is more robust to address the issues of workability retention and shall be preferred in mass concreting and hot weather concreting operations over SNF based admixtures.

11.0. Recommendation:

Mass concrete requires special knowhow in mix-design, batching, transportation, placing and curing of concrete. Prior evaluation of thermal behaviour of concrete through mockup is helpful in achieving desired results. Similarly the hot weather concreting also needs, suitable precautions to avoid subsequent problems of cracking and durability.

The Member companies of RMCMA possess requisite expertise in mass concreting as well as hot weather concreting operation. The Member companies possess large number of data and past experience on the subject which helps them to ensure durability and sustainability of concrete under these special circumstances.

It is suggested that the help of Member companies of RMCMA shall be taken by the concerned Project Authorities for achieving best results while undertaking works of Mass concrete and concreting in hot weather.

12.0. Conclusions:

1. The most direct approach to keep concrete temperature down is by controlling the temperature of its ingredients. Aggregates and mixing water exert most pronounced effect by virtue of their quantity and specific heat respectively.

    * Keep aggregates under shade
    * Cool aggregates by sprinkling water
    * Use cooled water or crushed ice in the mix.

2. Mix should be designed to have minimum cementitious content consistent with other functional requirements such as durability. The use of SCMs like fly ash and ggbs shall be maximized in the mix.

3. Use of PCE based admixtures and retarders is beneficial during hot weather to reduce water demand and to retain workability.

4. Ambient temperature shall be below 40°C at the time of placement. Concreting may be planned during morning and evening hours or during night when ambient temperatures are low.

5. The period between mixing and delivery shall be kept to an absolutely minimum.

6. Formwork, reinforcement and subgrade shall be sprinkled with cool water just prior to placement of concrete.

7. The speed of placement and finishing should be maximized. Sufficient men and machinery shall be employed to handle and place the concrete immediately on delivery. Standby source of concrete shall be available in case of any breakdown at batching plant to avoid cold joints.

8. Immediately after compaction and surface finish, concrete shall be protected from evaporation of moisture (1 to 2 hrs. after placing). It shall be covered with wet (not dripping) gunny bags, hessian, cloth etc.

9. Once concrete has attained some degree of hardening sufficient to withstand surface damage (approx. 12hrs. after placing), moist curing shall commence. The moist curing during hot weather shall not be less than 14 days.

10. Carry curing continuously, because the volume changes due to wetting and drying promote development of surface cracking.

13.0. References:

I. SP 23, Handbook on Concrete Mixes, Bureau of Indian Standards, New Delhi pp 123-130.

ii. IS 7861(Part 1) (year) Code of Practice for extreme weather concreting, Part – 1 Recommended practice for hot weather concreting.

iii. ACI 211.1 Standard Practice for selecting proportions for Normal, Heavyweight, and Mass Concrete.

iv. ACI 116R-90 Cement and Concrete Terminology, SP-19(90) Parts I and II

v. ACI 207.4R-98 Cooling and Insulating Systems for Mass Concrete.

vi. ACI 207.IR

vii. 'Concrete Sustainability' by Dr. N. V. Nayak and A. K. Jain pp 123-133

viii. Hand book on 'Quality and Productivity Improvement of Concrete by Dr. N. V. Nayak and Manish Mokal pp - 8.1 to 8.15

ix. Concrete Society Digest No. 2 published by Concrete Society, UK.

x. Portland cement Association, USA publication - 2013

ABOUT RMCMA

"The Ready Mixed Concrete Manufacturer's Association (RMCMA), India is a non-profit industry organisation of leading ready mixed concrete producers from India established in March 2002. The vision of RMCMA is to make Ready-Mixed concrete the preferred building material of choice as the best environment-friendly material of construction. The RMCMA is committed to provide leadership to the Ready Mixed Concrete industry in India. It promotes the interests of the entire Ready Mixed Concrete industry in India, without sacrificing the interest of end users, designers, specifiers, owners and other stake holders.

RMCMA strongly supports the Quality Scheme for RMC Plants as spearheaded by Quality Council of India (QCI) and BIS. RMCMA through its efforts have already brought about 350 RMC plants throughout the country under certification scheme. RMCMA is endeavouring that all RMC plants in India shall be brought under the umbrella of 3rd party certification. RMCMA is focused on following activities

1) Organising Training Program for "Concrete Technologist of India" at different cities.
2) Creating Awareness about advantage of quality concrete in construction.
3) Certification of RMC Plants through QCI and BIS
4) Participation at National and International level to promote RMC
5) Formulation and revision of Codes pertaining to concrete and RMC
6) Safety, Health and Environment requirements at RMC Plants.
7) Dissemination of Knowledge amongst Civil Engineers and QC professionals.
8) Participation in Seminars/ Conferences and Exhibitions for promotion of RMC."

RMCMA Members

- UltraTech Cement Ltd.
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