Mass Concrete with Reduced Heat of Hydration

Cement hydration is an exothermic reaction, which results in the release of substantial heat in mass concrete. ACI Committee 116 defines mass concrete as “Any volume of concrete with dimensions large enough to require that measures be taken to cope with the generation of heat from hydration of the cement and attendant volume change to minimize cracking.” Typical areas of application include, dams, tunnel linings and concrete piers as well as large size columns, beams, walls and foundations, where thermal action, durability and economics are of primary concern.

In large pours, differences between surface temperatures and inner concrete temperatures during the hydration process induce thermal stresses at the surface, which lead to thermal cracking. The ACI 207 manual of concrete practice provides useful guidance with regard temperature rises in traditionally placed and consolidated mass concrete. The type, content in the mix design and fineness of the cement as well as aggregate content and coefficient of thermal expansion, diffusivity and elasticity modulus, section surface area ratio, and placement ambient temperatures are all factors affecting temperature rise. Although temperature increases occur within 1 to 3 days after casting, it may take years for thick sections to cool down back to ambient temperatures, as the heat generated by the concrete inner body cannot easily dissipate.

ASTM C 186 – Standard Test Method for Heat of Hydration of Hydraulic Cement is used to ascertain whether the hydraulic cement under test meets the heat of hydration specification at any age. To reduce temperature rises, the hydration process should be slowed down by reducing cement content to the extent possible while selecting cements with low tricalcium silicate (C₃S) and tricalcium aluminate (C₃A) contents. The cement content and type used are essential elements contributing to limiting temperature rises.

Aggregates with low coefficients of thermal expansion can significantly enhance thermal resistance by reducing thermal stresses, in many instances by half. In the selection of aggregates for use in mass concrete, it is important to maximize large size coarse aggregates, with aggregate size restrictions arising from practical limitations due to the forms and reinforcing steels. Furthermore, it is important to combine aggregates of different sizes to produce a gradation approaching maximum density on compaction. The use of rounded-shape aggregates enhances concrete workability and thus allows for an optimization of the mix design. The coarse aggregates absorption rate (less than 3%), specific gravity (greater than 2.5) and percentages of deleterious materials are also important factors in designing mass concrete mixes.

The use of supplementary cementitious materials such as fly ash (with Class F preferred) and Ground Granulated Blast Furnace Slag (GGBFS) as replacements of cement, in ranges, which can be up to 60% to 75%, can significantly reduce the heat of hydration to the extent of 15 to 50%. Highly reactive materials such as silica fume and metakaolin are not recommended for used in mass concrete. In addition, it should be noted that most fly ashes when used as pozzolans improve the workability of concrete allowing 5 to 8 % water reduction.
To reduce the heat of hydration, water reducers and/or high range water reducers are used to minimize both cement and water contents. The consistency of mass concrete should be as stiff as possible albeit still workable enough for the mix to be adequately placed and compacted. As a matter of fact, such concrete can be designed to achieve 13 MPa to 25 MPa, which might be required for interior concrete of large gravity structures, using water cement ratios of 0.35 to 0.50 and slump values as low as 40 to 50 mm. Mass concrete may have air contents in the range of 3 to 5% or even increased to 8% as a means of increasing workability while keeping the water cement content low. In addition, in the field, it is preferable to ensure the stiff concrete can be handled even if such handling may require special equipment, rather than plan to add water to improve workability. It is best placed in successive layers of 10 to 15 cm thickness depending on the aggregates maximum size and the ability of the vibrator used to yield satisfactory results. In addition to water reducers and air entrainers, set-controlling admixtures are often required to ensure the inner concrete layers remain plastic so that successive layers can be placed and vibrated before the underlying layers set.

To reduce placement temperatures, flushing aggregates with cold water or alternatively pouring them in mixing water with flaked/crushed ice can cool the core of the concrete. The injection of liquid nitrogen in the mix water is an alternative pre-cooling method used to reduce the concrete temperature. In placement operations, the core of the concrete may be cooled, with cold water flowing in pipes embedded in the concrete, or the outer surface insulated to reduce temperature differentials between the center and surface. Expansion reinforcements are useful for minimizing cracks. It is important to note that when the pre-cooling method is used, lab concrete tests should be carried out at the lower temperature rather than ambient temperature due to the slower hydration of cement at lower temperatures.

Holderchem can assist contractors and engineers in the design of durable mass concrete incorporating, water reducers, air-entrainers, set controlling admixtures and supplementary cementitious materials. A selection of products available from within its range of products is listed herein below:

**Batimix WR 200**, a high performance liquid water-reducing admixture for concrete, based on selected high grade lignosulphonate materials.

**Batimix HWR 1400**, a liquid high-range water-reducing admixture for concrete, based on carefully selected chemical materials.

**Batimix AEA 110**, an aqueous solution of modified resins and surfactants used as an air-entraining admixture for all types of concrete.

**Batimix Retarder 210**, a synthetically produced set-retarding admixture for concrete based on selected gluconate modified organic polymers. It does not contain any corroding ingredient that could potentially attack steel, aluminium, or zinc embedments.

**Batimix Fly Ash DG3-P**, a Pozzolan for concrete meeting or exceeding the performance requirements of ASTM C 618 Class F. When added to the concrete mix in the correct proportions, it will significantly enhance concrete durability, strength and permeability. It allows easier placement, improving pumpability and finishability. It is also effective in
mitigating alkali-silica reactions in concrete. In mass concrete its use as a supplementary cementitious material is recommended as a means of controlling temperature rises.

**Batimix Slag DG3-P**, a Ground Granulated Blast Furnace Slag (GGBFS) used as part replacement of cement. It is primarily made of silica, alumina, calcium oxide and magnesia. It is classified in accordance with ASTM C989 in three different strength grades (80,100,120). Benefits include reduced heat of hydration, improved workability, better resistance to chlorides and sulphates and long term strength development. In mass concrete the use of GGBFS as a supplementary cementitious material is recommended as a means of controlling temperature rises.

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