Roller Compacted Concrete

The development and use of Roller Compacted Concrete (RCC) in the early 70’s caused a major shift in the construction practice of mass concrete dams and locks. This type of concrete has been widely used for backfill, sub-base, and concrete pavement construction. It has also been used to build concrete gravity dams because of the low cement content and incorporation of fly ash that reduces heat of hydration, as compared to conventional mass concrete placements. RCC found high acceptance in the building of commercial parking areas, industrial storage facilities, parking pavements, waste transfer areas, container port and dock storage areas, truck and freight terminals, military applications where speed of construction is essential, and low volume, urban / rural roads, and hard shoulders.

RCC offers numerous advantages over traditional concreting methods. For instance, cement consumption is lower, formworks are not required because of the “layer placement” method, and pipe cooling is unnecessary because of the low temperature rise. RCC allows for concrete to be hauled by end dump trucks, spread by small bulldozers, or specially modified asphalt pavers and compacted by vibratory rollers. Hence, the cost of transporting, placement, and compaction of concrete can be significantly reduced. Experience has shown that with RCC dams can be finished 1 to 2 years earlier.

ACI 207.5R-89 defines RCC as concrete consolidated by roller compaction methods. It primarily differs from conventional concrete in its consistency requirements, as it must support a roller while being compacted. RCC is a zero slump concrete whose properties are strongly dependent on the mixture proportions, quality of compaction, and thickness layer applied. If the lift is too thin, the placement rates will be small, thereby reducing the advantages of using RCC while if too thick, the compaction may not prove adequate, creating horizontal layers of higher porosity, thus compromising strength and durability. Thicknesses within 15 to 90 cm are generally used. Compaction should be done within 15 minutes but no later than 45 minutes after mixing. Good curing, with surface kept well moistened until placing the next layer, is essential. Bonding between the various layers can be improved by reducing the time of casting and/or increasing the paste content of mixtures. When used in paving and backfilling applications, RCC often incorporates recycled concrete aggregates derived from the pavements being replaced.

RCC is generally proportioned, optimizing the water content so that it yields the highest dry density. It does not rely on the traditional approach of minimizing the water-to-cement ratio to maximize concrete strength. Instead, the quantity of water that is most suitable for the operation of vibrating roller on the wet mix is deemed optimal. As for all mass concrete works, the use of low heat generating cements and mineral admixtures such as Fly ash (Class C or Class F), limestone, slag, and natural pozzolan are recommended. The size of coarse aggregates has a significant influence on the degree of compaction in small layers. It is less marked in relatively thicker layers, particularly when large vibratory rollers are employed. Hence, aggregates greater than 76 mm in diameter are seldom used in RCC to avoid problems in layer spreading and compacting.

There is no unanimously accepted lab methodology to simulate field conditions in preparing laboratory samples. ASTM C 1176 is used for making cylindrical test specimens from concrete when the standard procedures of rolling and internal vibration, as described in ASTM practice C 31, are not practicable. It is used for stiff to extremely dry concrete mixtures commonly used in roller-compacted concrete construction. This practice is used instead of rodding or internal vibration, which cannot properly consolidate concrete of this consistency. The main yardsticks of RCC performances can be outlined as follows:

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Concrete strength: When the volume of paste exceeds the volume of voids between aggregates, the compressive strength that ensues is dependent on the water-to-cement ratio, as predicted by Abram’s rule. When the cement paste may not fill the voids between aggregates, Abram’s rule does not apply and strength becomes often a function of moisture content.

Elastic modulus and Poisson’s distribution: The elastic modulus of concrete is a very important mechanical parameter reflecting the RCC ability to deform elastically. It is defined as the slope of the stress-strain curve within the proportional limit of a material. As with traditional concrete, the elastic modulus of RCC is a function of the volume and type of aggregates, degree of hydration, and water-to-cement ratio. The thermal stresses generated by the heat of hydration are proportional to the concrete elastic modulus. Therefore, concrete mix designs with low elastic modulus are most attractive.

Creep: Concrete creep is defined as the deformation of a structure under sustained load. Basically, long term pressure or stress on concrete can make it change shape. This deformation usually occurs in the direction of the force being applied. RCC with high creep is normally associated to concrete with lower compressive strength, and lower elastic modulus. The long-term deformation of RCC depends on the amount and type of aggregates, water cement ratio, age of loading and duration of loading. Lean concrete with large amounts of fines also shows high creep.

Thermal properties: As for conventional mass concrete, the rise in adiabatic temperature, i.e. without gain or loss of heat, is a factor of the quantity and type of cementitious material used in RCC. The specific heat, conductivity, and coefficient of thermal expansion depend on the type of aggregates incorporated in the mixture.

Durability: The coefficient of RCC permeability is a critical parameter for long-term performance of dams, particularly where no impermeable membrane is used at the upstream dam’s face. The moisture content of concrete should not exceed the critical saturation point in non-air entrained RCC to resist weathering action as otherwise resistance to freeze-thaw cycles would be poor.

Although chemical admixtures may exhibit limited effectiveness in RCC mixtures of dry consistency, it is customary to use water reducing and air entraining admixtures for better workability. In addition, the incorporation of set-retarding admixtures could be of particular interest to extend the elapsed time prior to concrete hardening and reduce the risk of cold joints with subsequent placings.

The Batimix range of chemical and mineral admixtures recommended for RCC systems includes:

**Batimix HWR 1400**, a naphthalene-based admixture designed to provide adequate dispersion of the cement particles to achieve better hydration and workability with reduced moisture content. While normally used in traditional concrete mix designs for its water reducing properties, it is used in RCC to enhance the cement mix hydration and workability. This admixture can be offered blended with set-retarders or set-accelerators to meet specific project requirements.

**Batimix HWR 1500**, a polycarboxylate-based admixture, highly efficient in dispersing cement grains and improving concrete durability. While normally used in traditional concrete mix designs for its water reducing properties, it is used in RCC to enhance the cement mix hydration and workability. This admixture can be offered blended with set-retarders or set-accelerators to meet specific project requirements.
Batimix Retarder 210, a hydration-controlled admixture used as a stabilizer to slow down the hydration process and reduce the risks of cold joints formation between various RCC layers.

Batimix AEA-120, a concentrated aqueous solution of modified resins and surfactants used as air-entraining admixture for RCC placed in cold weather climates. This admixture increases durability and resistance to damage from frost and de-icing salts.

Batimix Fly Ash DG3-P, a supplementary cementitious pozzolanic material used to reduce cement hydration rates in RCC systems. When added to the concrete mix, the ultra-fine fly ash particles significantly improve the particle packing by physically filling the voids in the cement paste.

Batimix Silica Fume 710, a powder silica fume mineral additive used to produce high performance concrete. When added to the concrete mix, the ultra-fine silica fume particles significantly improve the particle packing by physically filling the voids in the cement paste. This leads to a denser concrete skeleton with reduced level of bleeding. On the other hand, this product reacts chemically with the calcium hydroxide present in the cement paste, yielding a calcium silicate hydrate gel that significantly enhances strength, water/chloride impermeability, and durability.

Batimix Slag DG3-P, a Ground glass blast furnace slag (GGBFS) used in RCC. Concrete with moderate low-heat slag cement can significantly enhance the performance of RCC by employing a rational combination of fineness and slag content and provide significant advantages at longer ages.

References:
ACI 207.1-R05, “Guide to Mass Concrete”, American Concrete Institute, 2005.
ASTM C 1176 / C1176 M - 08, “Standard Practice for Making Roller Compacted Concrete in Cylinder Molds Using a Vibrating Table.
ASTM C31 / C31M – 12, “Standard Practice for Making and Curing Concrete Test Specimens in the Field”

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