Roller-compacted concrete (RCC) and its application in modern world of Technology

Shah Faisal Saleh, Faisal Farooq Rather, Malik Jasif Jabbar

Dept of Civil Engineering, Islamic University of Science and Technology, Awantipora, Jammu and Kashmir, India

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Abstract: *Concrete leads as the most frequently used construction material in the world because of its innumerable properties. Concrete is weak in tension almost one tenth of its compressive strength. Roller-compacted concrete (RCC) is a stiff mixture of aggregates, cementitious materials, and water with zero slump. RCC is consolidated or compacted in the fresh state by use of a roller with or without vibration. RCC typically is placed with asphalt paving equipment in thicknesses of 4 to 8 inches for pavement application. RCC has gained the attention of the paving industry in recent years and is becoming more popular day by day because of its low cost, rapid construction, and durable performance. The energy required to compact RCC mixtures to their maximum densities is much greater than for concrete of measurable slump. The largest difference between RCC mixtures and conventional concrete mixtures is that RCC has a higher percentage of fine aggregates, which allows for tight packing and consolidation .Fresh RCC is comparative stiff than typical zero-slump conventional concrete. Its consistency allows it to remain stable under vibratory rollers, yet wet enough to permit adequate mixing and distribution of paste without segregation. Some time admixtures or materials like fly ash are used to concrete to reduce the water content and produce more dry mix. The main advantage of roller compacted concrete is that it can be constructed without the use of dowel bars and we can also make a construction which does not require construction joints. RCC can be used in many areas of construction like in dams, pavement construction etc. This paper highlights the applications and materials required in roller compacted concrete.*

Key Words: **Innumerable, compressive, Aggregate, Consolidated, Compacted, Zero-Slump, Consistency, Segregation, Dowel bars.**

1. INTRODUCTION

Roller compacted concrete is a zero-slump concrete consisting of dense-graded aggregate and sand, cementations materials, and water. Because it contains a relatively small amount of water, it cannot be placed by the same methods used for conventional (slump) concrete. Roller compacted concrete has the same basic ingredient as conventional concrete: cement, water, and aggregates. The basic difference is that roller compacted concrete is a much drier mix with practically zero slumps. It is drier, and looks and feels like damp gravel. It does not require any forms, dowels, reinforcing steel & finishing. Its production provides a rapid method of concrete. The properties of RCC mainly depend on quality of raw materials used, the cementations material content, the degree of compaction and the quality control measures. For effective compaction, the mix should be sufficiently dry so that it can support the load of vibratory equipment and on the other side it should be sufficiently wet also to allow adequate distribution of paste binder throughout the mass. Also, the method of compaction is different than the conventional compacted concrete and it is compacted by vibratory or pneumatic-tired rollers. The objective of mix design is to produce a roller- compacted concrete mix that has sufficient paste volume to coat the aggregates in the mix and to fill in the voids between them. Any of the basic roller compacted concrete proportioning methods like those based on concrete consistency testing, and soil compaction testing may be used for mix design. RCC uses aggregate sizes often found in conventional concrete. However, the blending of aggregates will be different than that done in case of conventional concrete. Crushed aggregates are preferable in roller compacted concrete mixes due to the sharp interlocking edges of the particles, which help to reduce segregation, provide higher strengths, and better aggregate interlock at joints and cracks. From the 1980's onwards the use of RCC has increased for technical and economic reasons. In the USA, data shows that in 1998 about 2.5 million square meters of RCC was constructed and by 2008 this had increased to 8 million m2, i.e. more than tripled in ten years [1].Roller compacted concrete is one type of such concrete which has wide applications in the field of civil engineering construction in particular for mass concreting.

2. APPLICATION OF ROLLER-COMPACTED CONCRETE (RCC)

RCC is placed by asphalt pavers and compacted by vibratory rollers and hardened into concrete. RCC pavements can be used where there is a need for a strong, hard, wearing surface that will handle low-speed traffic.RCC for pavements is placed without forms, finishing, pointing, or surface texturing. Thus, RCC pavements can be constructed more rapidly and with less labor and expenses than traditional concrete. Because of the low water content used in the RCC mixture and resulting low water-cementitious materials ratio, RCC typically has strengths similar to, or greater than, conventional concrete.

2.1 RCC DAMS (RCCD)

The first application of RCC for dams' dates back to the 1960s, in which RCC was used for a new dam construction. The main economic advantages result from the following features of RCC dams:

(i) **Speed of construction:** Large volumes of (low or high paste) concrete can easily be placed with heavy equipment, thus shortening the construction period of these dams.

(ii) **Low unit costs of RCC:** The unit cost of low paste mass concrete is favorable; to reduce the heat of hydration a significant portion of cement is usually replaced by locally available pozzolanic materials or fly ash.

(iii) **Incorporation of spillway into dam body:** Due to the slope of the downstream face of 1:0.8 (gravity dams) to 1:0.4 (arch-gravity dams), the spillway can directly be incorporated into the dam body which helps to accommodate large floods and which are in need of large spillways.

(iv) **Use of shape of conventional dams:** Because the stresses in gravity type dams are low, the cross-sections of RCC dams are the same as those of conventional dams.

(v)**Heat generation:** RCC is more favorable while taking into consideration the heat dissipation which always remains a vital issue for mass concreting structures.

Because of the above advantages, RCC dams are interesting alternatives to conventional dams in most
parts of the world. An example of RCC dam is shown in the Figure-1 built along Santa Cruz River in Argentina popularly known as Puerto Santa Cruz Dam

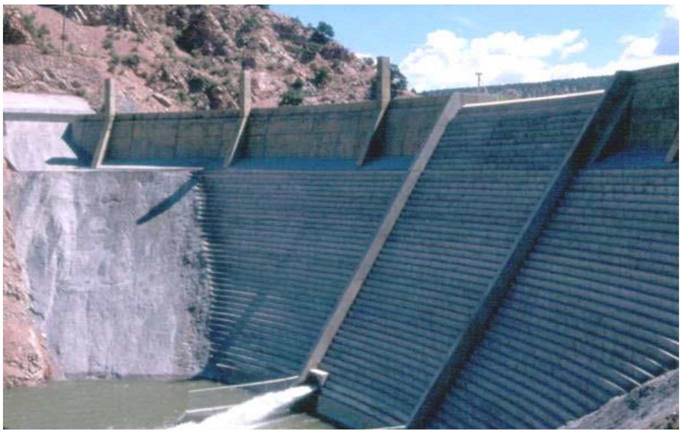

Figure. 1 RCC SANTA CRUZ DAM

2.2 RCC Pavements (RCCP)

RCC mixtures for pavements contain approximately three times as much cementitious material as RCC mixtures for dams. Usually, RCC mixtures for pavements contain less cementitious materials than conventional concrete mixtures. RCC pavement is much quicker to construct than conventional concrete pavement. RCC pavements do not require joints, dowels, reinforcing steel, or formwork. Relatively large quantities of RCC pavement can be placed rapidly with minimal labor and equipment, enabling speedy completion of tightly scheduled pavements. RCC pavement is much stronger and durable than asphalt pavement. RCC will not rut from high axle loads, or shove or tear from turning or braking of operating equipment. It will not soften from heat generated by hot summer sun or material stored on RCC floors (for example, compost). RCC resists degradation from materials such as diesel fuel. RCC pavement offers a substantial cost savings over conventional Portland cement concrete and asphaltic concrete pavements when used in heavy wheel load applications [2]. A first-cost savings of 15 to 25 percent can be expected, if RCC is specified as a pavement alternative for projects requiring wheel loadings of 23 to 55 tons (50,000 to 120,000 lb.).

Figure. 2 RCC Pavement

2.3 In repair and rehabilitation works:

Roller compacted concrete can be used for repair of already constructed surfaces and they increase the performance and durability properties by providing a strong coating like finish. RCC is often used to repair damaged overflow structures, to protect the embankments during overtopping and to build buttress so as to strengthen heavy dams [3].

3. Materials used in RCC

The basic materials used to produce RCC include coarse aggregates, fine aggregates, cementitious materials, water and chemical admixtures. The designer has to evaluate the actual material for the specific project and the proportion under consideration, design the structure accordingly, and provide appropriate construction specifications.

3.1 Coarse Aggregate:

To produce high quality RCC, both the coarse and fine aggregate fractions should be composed of hard, durable particles and the quality of each should be evaluated by standard physical property tests. Compared to RCC containing naturally rounded gravel, RCC containing crushed stone generally requires more water to attain a given consistency and more effort to compact. However, it is more stable during compaction and usually provides a higher flexural strength. Owing to the low water content, the danger of segregation of RCC is high. In order to minimize segregation during handling and placing of RCC and to provide a closed and relatively smooth surface texture, the maximum aggregate size is often limited to approximately 20 mm (¾ in.) [4].

3.2 Fine aggregate:

RCC mixtures are less susceptible to segregation during handling and placing when the fine-aggregate content is increased over that recommended for conventional concrete mixtures. In order to improve the smoothness of the top surface of RCCP and to obtain a closed surface, it is recommended that non-plastic fines passing a 75-µm (No. 200) sieve be in the 5 to 10% range ACI Committee 325 recommends fines content of 2 to 8% [5].An increase in the quantity of the fine fraction leads to addition of more water to keep the concrete consistency within a workable range. It has been reported that the Increase in water content did not significantly affect compressive strength at constant cementitious materials content. It appears that, regardless of the cementitious materials content, the mechanical strength of RCC increases with the amount of fines in the mixtures because of the very low water to cementitious materials ratio used and high compaction achieved. Test results indicate that marginal aggregates (such as shale, greywacke, dune sand, silt, and clay), when compared with standard quality aggregates, require higher cementitious materials contents to achieve similar strengths.

3.3 Cementitious materials: Commonly used binding materials are as following:-

3.3.1 Fly ash:

Cementitious materials content of a typical RCC mixture for pavement is about 11 percent of concrete by mass. The amount of fly ash is usually about 20-30 % by mass of the total binder content for typical highway pavement. Fly ash in RCC partially replaces Portland cement and optimizes the amount of fine material in the mixture. It also improves placement characteristics. In addition, fly ash contributes to strength development due to its pozzolanic properties. When used to replace a portion of cement, fly ash generally decreases the water requirement of concrete mixtures having a measurable consistency.. In order to increase the amount of fine particles, fly ash can also be used as a partial replacement of sand. Fly ash can be added when available aggregates do not contain enough fines [6].

3.3.2 Blast furnace slag and phospo-gypsum:

Blast furnace slag and phospho-gypsum (a by-product of phosphoric acid production) were found to increase the setting time of RCC, thus allowing an increased time for construction.

3.3.3 Silica fume:

Silica fume and superplasticizer can be used to improve strength and frost resistance of roller-compacted concrete. The quality of RCC is directly related to the degree of compaction obtained, and the dry density can be taken as a measure of compaction. It was found that the use of super plasticizer led to an increased dry density of RCC. The effect was even more pronounced when both superplasticizer and silica fume were added to an RCC mixture. When used alone, silica fume did not increase the dry density of RCC. The amount of silica fume is usually limited to maximum 10% by mass of the total binder content

3.4 Water and chemical admixtures:

Water quality for RCC is governed by the same requirements as for conventional concrete. [7] Entraining a consistent amount of air in RCC is quite difficult, particularly with mixtures having no measurable slump. The formation of air bubbles is only possible if a sufficient amount of water is available. For an air-entraining agent to be efficient there must be enough water to form a film around each bubble. When the quantity of water added to the RCC mixture is significantly decreased, water tends, first of all, to cover solid surfaces. There is thus a competition for water between the bubbles and the solid particles. Below certain water content, the efficiency of the air-entraining agent is thus minimized, even at fairly large dosages. The water content of most RCC mixtures is usually of the order of the minimum quantity required to entrain air [8] .It was found that attempts to entrain air in RCC mixtures can be successful if the air-entraining agent is premixed with the cementitious paste (a mixture of cementitious materials and water), a small portion of the coarse aggregate, and a super-plasticizer before adding the sand.. The addition of a set-retarding admixture can also be effective to allow a delay of the rolling process without the formation of cold joints. However from durability point of view use of air entraining admixture is mandatory.

4. CONCLUSIONS

RCC has got a lot of benefits including excellent durability, even under freeze-thaw conditions; eliminates seepage through pavement. It enhances construction, reduces cost and minimizes labor. It resists abrasion, eliminates need for surface course and reduces cost. RCC does not have the same appearance as other types of concrete but is not as pretty and smooth as regular concrete. The mix design and construction methods that make roller-compacted concrete so fast, easy, cheap, and durable also create a surface texture that gives it a characteristic coarse finish.

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