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Roller Compacted Concrete: A Litrature Review

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ABSTRACT: *The development of the roller-compacted concrete (RCC) technology in the 1980s is considered by many as a significant breakthrough in the construction industry. RCC is now commonly used all around the world for the construction of dams and pavements, and for the rehabilitation of existing structures. This report is generated to collect state-of-the-art information on general definition, detailed history, development, various applications possible with RCC, Materials mixture proportioning, properties, design considerations, construction, and RCC related literature reviews are covered. Various literature and presentation referred to study more parameters which may impact feasibility, economy, impacts and quality parameters.*

In India, roller compacted concrete technology adopted by Irrigation Department, Government of Maharashtra, demonstration of RCC technology through construction of three dams. All three dams are working satisfactorily and encouraged by their performance and savings five more dam are being undertaken using this technology.

Keywords *– Applications, admixture, Fly ash, materials, mix design.*

I. INTRODUCTION

ACI 116 defines RCC as "concrete compacted by roller compaction; concrete that, in its unhardened state, will support a (vibratory) roller while being compacted. RCC is usually mixed using high-capacity continuous mixing or batching equipment, delivered with trucks or conveyors, and spread with one or more bulldozers in layers prior to compaction.RCC can use a broader range of materials than conventional concrete". *[1]*,RCC also Known as rollcrete *[2]*.

RCC Construction similar in principle to soil-cement and other earthwork construction. RCC technology developed considerably in the 1980s, after early research by Cannon (1972), Dunstan (1977), Hall and Houghton (1974), and the development of the roller-compacted dam (RCD) method in Japan in the 1970s. Also, in the 1980s, RCC was developed as a heavy-duty paving material for log sorting yards, tank hardstands, railroad sorting yards, and other industrial pavements. It also found application in roadways and parking areas. Roller-compacted concrete (RCC) has become an accepted material for constructing dams and pavements, rehabilitating and modifying existing concrete dams, and providing overflow protection of embankment dams and spillways. 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.

Conventional mass concrete versus RCC:

The principal difference in the two is the mixture consistency and the method of compaction. Internal compaction using immersion-type vibrators is used for conventional concrete, while external compaction with spreading equipment and vibratory rollers is used for RCC. The controls placed on mixture ingredient selection for conventional mass concrete will apply to RCC also. RCC mixture proportioning procedures are also similar to conventional concrete; however, RCC mixtures will normally contain less water and more fly ash / sand to limit segregation. Heat of hydration studies as required for conventional mass concrete work, are also required for RCC.(For more details please refer fig. No. 1)

RCC has been used as a construction material in the following applications

Concrete dams: RCC has been used to construct new gravity dams and arch dams worldwide and has been the most widely used application for this technology. RCC has also been used to raise concrete dams and to provide stability berms for static and seismic requirements.

II. Embankment overtopping protection and spillways: RCC has been used to armor embankment dams for overtopping flows. The armored embankment essentially functions as an auxiliary or emergency spillway. RCC has also been used to construct some service spillways that operate infrequently.

Pavements: RCC has been used in pavement construction. But, unlike soil-cement used in pavements, the RCC is exposed and typically not covered with another wearing surface. Typical thickness of the RCC pavement is 150–200 mm ~6–8 in.!, but thicker layers have been used. Where thickness greater than 300 mm ~12 in. is required to accommodate heavy loads, multiple layers of RCC are used.

IV. Slope protection: The use of RCC for slope protection is similar to that of soil-cement, except some of the material requirements may be different. Foundation stabilization: As with soil-cement, RCC can be used to provide stabilized foundations in the form of mass concrete. *[2]*

The main advantage of RCC pavement is 1. Fast construction with minimum labor, 2.High load carrying ability, 3.Early strength gain, 4.Durable, 5.Low maintenance, 6.Economical, 7. Special forms not required, 8.No reinforcing Steel. *[3]* RCC dams compared to embankment type dams, RCC usually gains an advantage when spillway and river diversion requirements are large, where suitable foundation rock is close to the surface, and when suitable aggregates are available near the site. Another advantage is reduced cofferdam requirements because, once started, an RCC dam can be overtopped with minimal impact and the height of the RCC dam can quickly exceed the height of the cofferdam. *[1]*

II. INDIAN EXPERIENCE IN RCC

In India, beginning of RCC technology was made through construction of two dams near Nashik under Ghathar Pumped Storage Scheme of Irrigation Department, Govt. of Maharashtra. These two projects worked as technology demonstration in India towards confidence building for its large-scale adaptation. On the basis of experience of construction of two dams (Saddle dam & Upper dam), Irrigation Department, Government of Maharashtra decided to construct the main dam (third dam) i.e. lower dam of Ghatghar Pumped Storage Scheme which is about 85 m high Ghatghar dam, (near Shahapur in Thane district of Maharashtra), country's first RCC (roller compacted concrete) dam. The upper dam is in Ahmednagar district. The Ghatghar project is the 10th fastest construction dam in the world. TCE, Mumbai, J. Power of Japan and Dr. M.R.H. Dunstan, UK, were the technical advisors. The RCC method involves placing the concrete on a continuous basis, in layers of 300 mm thickness. Then the vibratory roller does the compacting. The Ghatghar project uses fly ash produced at the coal-fired thermal power plants, in substantial proportion. Normally, 35 per cent fly ash is kept in fly ash + cement mixture. For the first time, the Ghatghar project used 60 per cent fly ash in the mixture. The results were better than expected. Then the fly ash proportion was increased to 70 per cent.

Materials Used in Roller compacted concrete

Design strength, durability requirements, and intended application all influence the selection of materials for use in RCC mix. The basic materials used to produce RCC include water, admixture, cementitious materials (cement and fly ash), and fine and coarse aggregates. *[3]*

A wide range of materials have been used in RCC and the guidance on materials provided in ACI 207.1R (Mass Concrete) may be applied to RCC. Application of materials is less demanding, more material options and subsequent performance characteristics are possible. The designer, as always, must evaluate the actual materials for the specific project and the proportions under consideration, design the structure accordingly, and provide appropriate construction specifications. *[1]*

Aggregates

The aggregates comprise approximately 75 to 85 percent of the volume of an RCC mixes and therefore significantly affect both the fresh and hardened concrete properties. Proper selection of suitable aggregates will result greater economy in construction and longer serviceability of RCC. Aggregates used in RCC mixtures contain both fine [finer than the 4.75 mm] and coarse fractions. RCC containing uncrushed gravel generally requires less water to attain a given consistency than that containing crushed gravel or stone. RCC containing crushed gravel or stone may require more effort to compact, and is less likely to segregate. It is also more stable during compaction and usually provides a higher flexural strength. RCC mixtures are typically not as cohesive as conventional concrete and therefore, aggregate segregation is an important concern. Greater economy may be realized by using the largest practical nominal maximum size aggregate (NMSA). Increasing the NMSA reduces the void content of the aggregate and thereby reduces the paste requirement of a mixture. Most RCC projects have used a NMSA 37.5 mm to 75 mm. There has typically not been enough material cost savings from using aggregate sizes larger than 75 mm to offset the added batching cost and cost of controlling the increased *[3]*

Water

Water quality for RCC is governed by the same requirements as for conventional concrete. *[3]*

Admixtures

Chemical admixtures have been effective in RCC mixtures that contain sufficient water to provide a more fluid paste. ASTM C 494, Types D (water-reducing and retarding) are the most commonly used chemical admixtures , however Admixtures should be evaluated with the actual RCC mixture before being used in the field. *[1]*. set Retarding admixtures may be beneficial in delaying the setting time of the RCC so that it may be adequately compacted or so that the bond between adjacent lanes or succeeding layers is improved. *[3]* Some cases durability point of view use of air entraining admixture is mandatory.

Cementitious materials

Cementitious materials used in RCC mixtures include Portland cement or blended hydraulic cement, and may include pozzolan (ref. fig. 2), or a ground granulated blast furnace slag. The selection of cement type should be based in part upon the design strength and the age at which this strength is required *[3]* Use of a pozzolan in RCC mixtures may serve one or more of the following purposes: 1) as a partial replacement for cement to reduce heat generation; 2) as a partial replacement for cement to reduce cost; and 3) as an additive to provide supplemental fines for mixture workability and paste volume. The rate of cement replacement may vary from none to 80 percent, by mass. RCC mixtures with a higher content of cementitious material often use larger amounts of pozzolan to replace Portland cement in order to reduce the internal temperature rise that would otherwise be generated and consequently reduce thermal stresses. *[1]* Roller-compacted concrete (RCC) dams, have developed extremely rapidly during 1980 to 1990 and are now an accepted form of dam construction. The majority of the recent RCC dams have contained a particular form of concrete in which high proportions of pozzolan are used in the cementitious content.Many forms of pozzolan have been used like Fly ash, GGBS etc., RCC dams are a potential significant user of pozzolan *[13]*.

Mix proportioning methods

There is actually no commonly accepted procedure to proportion RCC mixtures. Over the years, several methods, using different approaches, have been successfully used throughout the world. Some were specifically developed to design RCC mixtures for dam construction while others are more general and can be used to proportion RCC mixtures for paving applications. Following are some of the typical method listed below

The ACI Mixture Proportioning Methods by ACI Committee 207
The US Army Corps of Engineers Proportioning Method
The Optimal Paste Volume Method
The Solid Suspension Model etc. *[15]*

III. LITERATURE REVIEW

Some of the prominent works attempted on RCC theme are explained in brief in this section.

M.N. Haque et al.[10] reported conceptive analysis of many inferior and marginal aggregates, waste products, and other deleterious materials which do not meet standards and specification to be use in the manufacturing of Roller compacted concrete ,pavement construction. RCC containing marginal aggregates becoming cost effective and competitive. Mechanically weak and poorly graded materials can be used to manufacture RCC of adequate strength for use in pavement structures. Marginal quality aggregate require higher amount of cement to produce similar strength. Silt content up to 10% in aggregate will improve workability and compatibility of RCC. Where Fly ash is locally available it can be use replace cement and fine aggregated in mix design and help gain in strength and durability to RCC pavements. All the construction sites it's difficult to arrange good quality of material hence adjust in the mix proportion is best approach to utilize the available resources to minimize the cost impact and saving in natural resources.

Schrader [8] presented t h e effect of compaction methods, water content, and other variables on density, pore pressure, practical construction problems in RCC construction. The mix has a no-slump consistency which precludes internal vibration. RCC is compacted by massive external forces rather than by being consolidated under its own weight with internal or external vibration. In fact, if it approaches a consistency that could be internally vibrated, damaging pore pressure may develop by roller compaction. Aggregate gradation is critical to compatibility and can differ from conventional concrete. Strength is dependent on the degree of compaction, but some latitude exists once the RCC mix nears its maximum density. Laboratory compaction methods are varied, and some are suited to only select mixes. The degree of field compaction achieved can be determined with the nuclear testing gauge

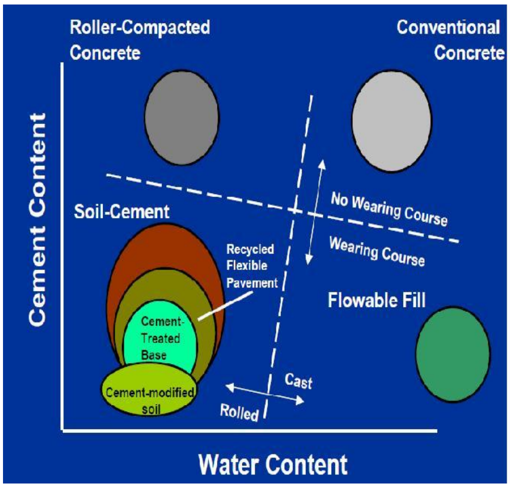
T. P. Dolen [12] reported interaction analysis of air content and the freeze-thaw (FT) durability of RCC and reported It is possible to entrain air in "more workable" RCC mixtures with Vebe consistency times ranging from approximately 5 to 35 seconds. Air entrainment improves the workability of RCC mixtures, resulting in lower Vebe consistency times and reduced segregation. FT durability of air entrained RCC increased from 66 to up to 409 percent above that of the non-air entrained mixtures.

Somjai Kajorncheapunngam and D. F. Stewart [14] reported Rise husk ash (RHA) regarded as Cementitious material in RCC due to high silica content. RHA is also used to partially replace cement to reduce heat of hydration as well a s to improve durability of RCC.Cost of RCC get reduces due to use of RHA ,from economical point of view this proposal shows great promises ,particularly in developing countries. Uses of RHA not only solve the cement shortage problem in developing countrie s but also help to conserve energy, resources, and the environment. Use of RHA will help to improve compressive strength of concrete50% cement replacement is possible with RHA in RCC.

Koji Sakai [11] examined the importance of finding alternate material for fly ash, as availability of fly ash in some part of world is really an issue .It is very difficult to achieve high durable RCC and control of heat generation in dam construction without fly ash. One admixture that is replacing fly ash is granulated blast-furnace slag. Concrete with moderate low heat slag cement can provide the same or better performance as fly ash cement concrete by employing a rational combination of fineness and slag content. Also, the advantages of slag cement at longer ages were confirmed study clarified that concrete made with slag cement can be provided with the same or better performance when compared with a 30% fly ash cement concrete. Also, the advantages of slag cement at the longer ages were confirmed.

Nader Ghafoori and Yuzheng Cai [6] Conducted experiments on Laboratory –made roller compacted concrete with various combinations of cement (Type I and Type V for sulfate-resistant concrete), lignite dry bottom ash, and crushed limestone coarse to determine the suitability of use of bottom fly ash to manufacture long-term durability bottom ash roller compacted concretes. ***Richard Gagne et al. [17]*** Highlights the OPP fines (mining by-product referred to as OPP fines means *Ore Pretreatment Plant Fines*) is a very effective filler in RCC because its particle-size distribution is very similar to that of the cement. Therefore, a large proportion of the total fines content (cement or fly ash) can be replaced by OPP fines without significantly changing the workability of the RCC. A simple mathematical model, based on the results of the factorial analysis, is proposed to select the total fines content, the OPP fines replacement ratio, and the water/fines ratio of an RCC mixture as a function of the required Vebe time (5 sec. to 60sec.) and 91-d compressive strength (5 to 25 MPa). The OPP fines are a relatively inert material, and this had very little effect on heat generation during hydration.

IV. FIGURES



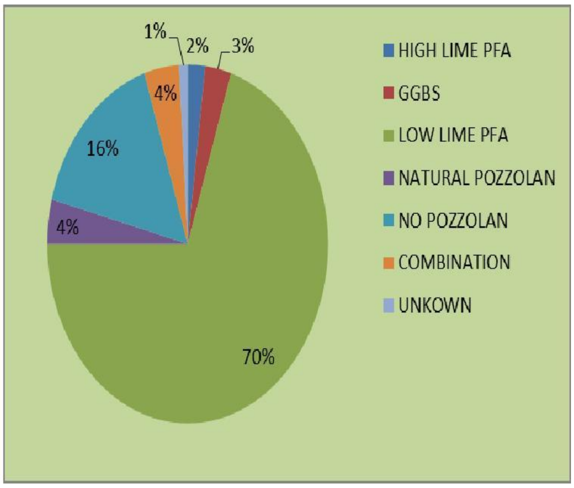


Fig.1.Cement-Based Concrete Materials [2] ***Fig.2.Use of pozzolona in RCC DAM Copleted up to 1992[13]***

V. SUMMARY AND CONCLUSION

A brief review of various methods of analysis of RCC concrete

I. Inferior and marginal aggregates, waste products, and other deleterious materials which do not meet standards and specification can be used in the manufacturing of Roller compacted concrete.

II. Fly ash can be use replace cement and fine aggregated in mix design and help gaining strength and durability to RCC pavements.

III. Durable concrete can be possible to produce with high-calcium dry bottom ash.

IV. RHA (Rice husk Ash) can also be used to partially replace cement to reduce heat of hydration as well as to improve durability of RCC.

V. *Ore Pretreatment Plant Fines* OPP is very effective filler in RCC because its particle-size distribution is very similar to that of the cement.

VI Adequate air- void system required to introduce in some cases to improve freezing and thawing resistance.

VII Air entrainment improves the workability of RCC mixtures, resulting in lower Vebe consistency

. times and reduced segregation.

VII I. RCC Strength is dependent on the degree of compaction, but some latitude exists once the RCC mix nears its maximum density.

IX. The development of new mixture proportioning methods, based on a better understanding of the physical properties of the material, will most certainly contribute to open new markets to RCC.

X. The use of these new mixture proportioning methods will also contribute to a more efficient use of mineral materials in RCC. Recent experience has clearly shown that both supplementary cementing materials and inert minerals can be used in RCC mixtures**.**

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