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# An Introduction to Rolling Compacted Concrete (RCC) in Construction of Roads

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**Abstract**

Rolling compacted concrete is a no-slump concrete which is compacted with rollers and spread in base materials. This kind of concrete could be used with a wide range of aggregation. Regarding that road construction is growing up in Iran and maintenance costs of asphaltic concrete pavements are too high, these materials can be a good substitute. In this paper physical and mechanical characteristics and mixing design of RCC is investigated.

**Keywords**: RCC, Physical and Mechanical properties, Mixing design, Administrative points.

## 1. Introduction

By definition, concrete is made up of three portions, including cement paste portion (cement and water), aggregate portion (gravel and sand) and transition portion (interfacial transition zone), that help mold concrete. Special concretes are those that have particular characteristics or are mixed in uncommon ways. RCC is categorized as a special type of concrete with a specific mixing method.

The first reports about RCC are from 1876 in Scotland while vibration concrete is only about 50 years later. So before and after World War I in many countries concrete was compacted by rollers. In 1930s, vibration of concrete had spread in engineering construction and building materials. Due to the fact that in 1970s bitumen was growing in cost which itself leads to increased asphalt concrete costs, usage of this material became more attractive. Canadian engineers were the pioneers of using RCC in 1970.

In RCCs base materials mixing design has a large range of aggregates and cement factors. The next step of using this material was spreading of them without asphaltic pavements in

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Vancouver in 1976. This kind of cover proved to be a good experience, and its durability on the soft clays showed a good behavior.

## 2. Using of RCC

This material has several uses such as waterproofing elements, slope of embankment dams, and stabilization of foundations. The important usage of this material is for road construction industry. The thickness of road materials depends on strength of sub base, period of road management, traffic loads and surcharge condition. This kind of concrete is exposed as opposed to soil cement and typically its thickness is between 15 to 20 centimeters, which increases up to 30 cm for heavy traffic loads.

## 3. Components of mixing design

***Cements:*** type and content of Portland cement or Pozzolanic cements depends on condition and serviceability of the road structure. Usually factor of cement varies about 60-300 kg/m$^3$ but in many projects is about 100-180 kg/m$^3$ for a curing time of 90 days to reach target compressive strength. It is advised that using Portland cements of type 1 and type 2 with a moderate hydration power is more desirable.

Suitable selected Pozzolans should satisfy standards like ASTM C 618. Pozzolans of class F, C and N are better for a moderate hydration power and resistance to sulfate attack. The amount of Pozzolans could decrease the cost of construction.

***Water:*** the only constraint for water is it should be without acidic and alkali materials which can make delays in curing time. Most of the mixing designs with 50 mm aggregate need a water factor of about 90 to 120 kg/m$^3$.

***Aggregates:*** there is not a significant difference between NMSA, sand and fine aggregates for RCC and concrete but the aggregates in RCC should obey the rules of standard ASTM C 33 and some limitations have to be satisfied in sites according to performance of RCC and site condition. Aggregates with acicular or tabular aggregate are not suitable for concretes but they can be used in RCC because the higher forces are used for compaction of RCC. Results show that 40% acicular aggregates in RCC would not make any serious problem in the mixture.

The base layer thickness is not affected by the NMSA when its diameter is 3 times bigger and it is a recommended to use large vibrator rollers for construction. For RCC, the Portland cement association prefers NMSA to be restricted to 1.5 inches and 35% to 60% of the soil to pass from sieve 4 and 5% to 10% to pass from sieve 200. Also the plastic limits should be restricted to 5%.

## 4. Method of mixing design

There are 2 methods for mixing design of RCC with different approaches. One of them is concerned with soil and another deals with concrete.

***Concrete approach:*** according to this method RCC is defined as concrete and the controller parameter is its consistency. In this method, the concrete should satisfy water to cement ratio, aggregate to fine ratio and cement to Pozzolans ratio. The goal of this method is optimization of aggregates in order to decrease the cement factor. Therefore some mechanical factors such as compression strength, tensile strength and durability should be satisfied.

***Soil approach:*** in this method RCC is defined as embankment and the controller parameter is the maximum dry density which is calculated with standard proctor test. For this reason the cement content and moisture of the mixture should be evaluated versus one another.

## 5. Physical and mechanical properties

***Density:*** the density of RCC is a function of several factors such as: grading of soils, energy of compaction, fine materials, and porosity of RCC. A good mixing design has the same amount of gravel, sand and silt materials, because they can be compacted better with each other to make a dense matrix. Gap graded aggregate is not suitable for this method. The density range of RCC is about 2300 to 2450 kg/m$^3$.

***Compressive strength:*** curing time of RCC is 28 days and the UCS of RCC depends on quality of gradation, gravel content, cement factor, W/C, and condition of curing. According the researches, the UCS of RCC is about 2750 to 7000 kPa.

***Tensile strength:*** this quantity is very important because the base materials are under wheel loads. Hensen and Reinhards estimated that 7% to 13% of UCS is ITS. Also the PCA has proposed the following equation:

$$R = 0.61 f_c^{\ 0.73} \qquad (1)$$

where R and $f_c$ are tensile strength and compressive strength respectively.

***Shear strength:*** shearing strength parameters which are used in design of structures are internal friction angle and cohesion, regarding the interlocking joint of base and sub base layers. Table 1 shows shearing parameters of RCC materials in road construction:

**Table 1**: Shearing Strength Parameters of RCC

| Type | C (kPa) | (deg)φ |
|---|---|---|
| Massive RCC | 800-4100 | 35-70 |
| RCC with grout in joints | 500-4100 | 35-70 |
| RCC without grout in joints | 0-4100 | 35-70 |

***Durability:*** strength of materials in resisting erosion and volume changes is called durability which is evaluated by loss of weight. Some of these are introduced here.

***Resistance against thawing and freezing cycles:*** resistance against volume changes caused by freezing, thawing, wetting and drying cycles. Experience shows that freezing and thawing effects are more critical than wetting and drying effects. RCC is made of gravel which means its resistance is very high. According to PCA reports RCC with UCS more than 14000 kPa has a good resistance against freezing and thawing. In concrete, production of air bubbles can increase durability but in RCC this phenomenon does not occur. Due to the fact that durability tests are expensive, it is good to have in mind that whenever RCC's strength is more than 15 MPa, durability requirements are automatically satisfied.

***Erosion resistance:*** this strength is a function of UCS, quality of aggregate and gravel size. RCC with UCS of 9500 kPa could provide the required erosion strength.

***Permeability:*** this quantity is a function of isotropic properties of materials. In RCC use of mastics in joints could improve the permeability. The permeability of RCC is close to that of concrete.

## 6. Design and execution of road layers

There are a lot of method for designing a road construction which AASHTO has more famous and favorite of designers. In this method layer factors (a) have in reverse relationship with number of layers. This factors show the relation between layer numbers (SN) and thikness (D) of layers. The following equation shows this relationship:

$$SN = a_1 D_1 + a_2 D_2 + a_3 D_3 \qquad (2)$$

where $a_i$ is layer factor of pavement, base and sub base and $D_i$ is the thickness of the corresponding layer.

Material handling and spreading: The process of mixing, handling, spreading and compacting must be done in minimum time. As a rule, for matrices of RCC with or without Pozzolans this operation should be carried out in 45 minutes at 21 °C. For higher and lower magnitudes of temperature this time increases and decreases respectively.

Handling of RCC could be done with scrapers, dump truck or conveyor belts for road construction. Using these machines can increase the speed of operation about 750 $m^3$/hr. Spreading and flatting of RCC could be done with scraper, dump truck or bulldozer. In the following figure this procedure is shown:

**Fig. 1:** Handling and spreading of RCC

***Compacting:*** One of the most important difference between concrete and RCC is the method of compacting. Concrete compaction is done by the weight of paste and aggregates while the compaction of RCC is done by an external force. Compacting should be done in less than 10 minutes and after 30 minutes spreading should be done. The roller passes is usually between 4 to 6 times for every 15 to 30 cm.

***Curing:*** After the process of handling, curing should be done and keeping the surface moisturized is important. The operation has to be stopped in rainy days. Experiments show that if the surface is clean, mastic can improve the curing condition.

***Quality control:*** This step has a vital role for final production. ASTM C 1040 should be carried out 4 times per day by supervisors.

## 7. Conclusion

-History and usage of RCC makes it a good option to substitute asphalt concrete.

-Soil-cement is used in place of Roller-Compacted Concrete (RCC) in projects. Both the soil-cement and RCC are compacted mixtures of cement, water and aggregates; however, the main difference is in the type and size of the aggregate particles. The soil used for soil-cement is generally natural fines, while the aggregates used in RCC contain particles larger than 19mm.

-The difference in application is that, the soil-cement is commonly used for protection of earth dam slopes, whereas the RCC is usually used in massive sections such as gravity dams.

-All types of soils, except, the organic soils, plastic clays and reactive sands can be used in RCC. The most economical soils for this application are those containing 5% to 35% of fines passing sieve No. 200. The soils containing more than 2% of organic materials are strictly prohibited to be used in RCC.

-The strength and durability of RCC is less than concrete. But use of RCC is restricted in few special structures such as roads and dams.

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