Roller Compacted Concrete Phase I

NCDOT Technical Assistance 2024-03
FHWA/NC/TA2024-03
September 2024

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RESEARCH & DEVELOPMENT

Technical Report Documentation Page

1. Report No. FHWA/NC/TA2024-03	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Roller Compacted Concrete Phase I		5. Report Date September 2024
		6. Performing Organization Code
7. Author(s) Amin Akhnoukh, PhD		8. Performing Organization Report No.
9. Performing Organization Name and Address Department of Construction Management East Carolina University Rawl Building 341-C Greenville, NC 27858		10. Work Unit No. (TRAIS)
		11. Contract or Grant No.
12. Sponsoring Agency Name and Address North Carolina Department of Transportation Research and Development Unit 1549 Mail Service Center Raleigh, North Carolina 276699-1549		13. Type of Report and Period Covered Final Report March 15, 2024 – June 15, 2024
		14. Sponsoring Agency Code FHWA/NC/TA2024-03
Supplementary Notes:		

16. Abstract

Since its first use in North America in the 1970s, RCC has been used on pavement projects in different climates under all types of vehicular loadings. Due to it's the RCC mix stiffness, RCC has provided superior performance under heavy wheel loads and difficult operating conditions. Typically, heavy-duty pavements have been constructed with RCC in log handling yards, intermodal terminals, freight depots, highway intersections, shoulders, parking lots, and other industrial applications. However, the past 10 years has brought an increase in the use of RCC to create cost-effective pavements for many conventional highway and street applications. In this research, different state DOTs were contacted to investigate and survey their current use of RCC mixes in rigid pavement projects, their advantages, limitations, and their feedback regarding existing and on-going RCC projects. South Carolina, Georgia, and Ohio DOTs provided extensive feedback that is presented in the following sections.

17. Key Words Materials, Concrete	18. Distribution Statement

19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 34	22. Price

Form DOT F 1700.7 (8-72) **Reproduction of completed page authorized**

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1.1 What is Roller Compacted Concrete?

Roller-compacted concrete (RCC), also known as rolled concrete (or roll-Crete) is a special type of concrete that has the same constituents as conventional concrete mixed with different proportions, and a higher percentage of supplementary cementitious materials (ex. Fly ash) in partial replacement of portland cement. RCC is produced using a mixture of dense-graded aggregates, portland cement, and water. Due to the low water-to-cement (powder) ratio of the RCC mix design and reduced voids, RCC is considered a "zero-slump" concrete (sometimes described as negative-slump concrete). Traditional RCC mix design constituents, compared to conventional concrete, is shown in **Figure 1.1.**

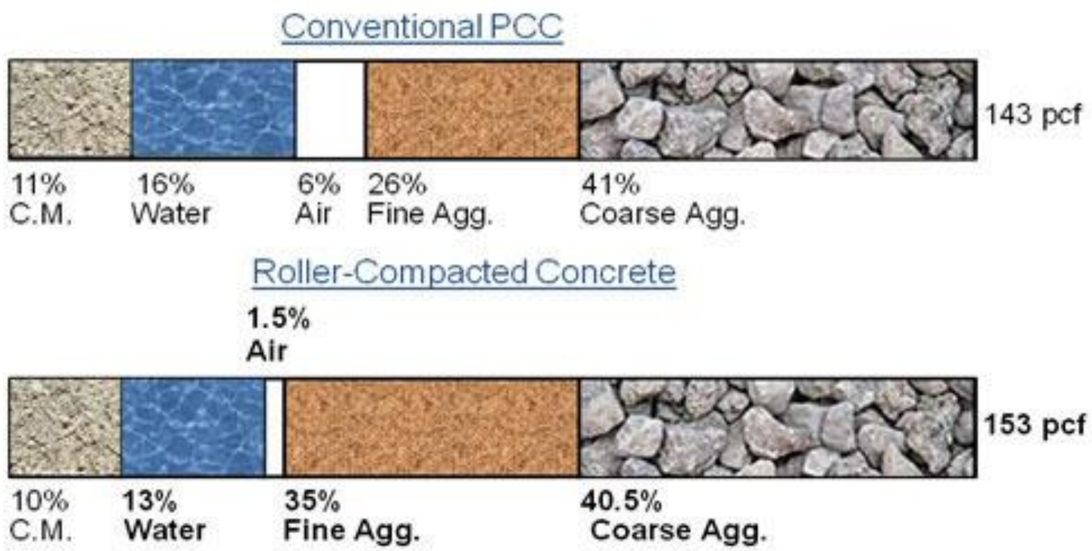

Figure 1.1. Roller-compacted concrete (RCC) mix design

Due to its texture, physical and mechanical characteristics, RCC is placed with a high-compaction asphalt type paver, as shown in **Figure 1.2**. and compacted to a high density using vibratory rollers. The placement and compaction techniques of RCC results in a high strength rigid pavement section with enhanced durability and enhanced long-term performance. The afore-mentioned characteristics provides RCC with material competitive advantages to be adopted in pavement projects.

Figure 1.2. Roller-compacted concrete (RCC) placement

RCC mixes are designed to attain compressive and flexural strengths required for different pavement projects. The smooth surface texture of RCC allows for its use in parking lots, roadways, intersections where high speed is not permitted. Alternatively, grooving and diamond grinding of RCC mixes are used by different state departments of transportation (DOTs) to achieve high speed skid resistance and surface regularity. In the United Kingdom, RCC pavement is covered by an asphalt surface course to meet high speed skid resistance and surface regularity requirements.

1.2 RCC History and Development

RCC was marginally applied in construction projects in the 1930s and the 1940s. RCC application was inconsistent and didn't conform to any known standards. RCC was further developed by the Canadian logging industry in the 1970s as the industry required an easy to construct material that provides a hard-wearing surface with high frost resistance (PCA, 2006). In the 1980s, the US Army Corps of Engineers (USACE) refined the RCC mix designs and utilized it in providing rigid pavement for military facilities in the United States. In addition, the USACE incorporated RCC in port construction and in providing durable rigid pavement to container handling facilities in the 1990s. The use of RCC in rigid pavement projects increased since 2000 in both public and private projects including low-volume road construction, parking lots, and military facilities. RCC road projects were built in Spain in the 1990s. It is recently reported that RCC roads are outperforming conventional rigid and flexible pavement projects in Spain (EUPAVE, 2019). The European Union (EU) launched a major EU research project termed Eco-lanes to investigate the possibility ofusing RCC in large scale projects. As an outcome, RCC roads have been constructed in many municipalities and rural roads in Turkey since 2009.

RCC was introduced to the UK in early 2000s. In 2002, a common application for RCC has been the construction of hard standings for the waste industry including composting facilities, In 2020, the British National Highways introduced high strength RCC (refer to **Figure 1.3**) as a pavement option in its Manual of Contract Documents for Highways (National Highways, 2020).

Figure 1.3. RCC roadway construction in the UK

1.3 Current RCC Applications in the United States

RCC is favored in construction applications in the United States market when high-strength and durability of pavement is required. In addition to the superior mechanical characteristics, RCC is characterized by speed of construction and its low-cost considering the overall project life cycle cost. The main applications of RCC include the following:

1. Parking lots, storage facilities, and distribution centers.
2. Turn lanes, bike paths, intersections, and general roadway pavement application.
3. Scrap yards, manufacturing facilities, and heavy haul roads.
4. Ports, harbors, and military facilities.

5. Industrial slab floors.
6. Airfield maintenance areas.

The main objective of this research report is to provide NCDOT personnel with technical information regarding the mix design, production, characteristics of RCC, and life cycle of RCC pavement projects compared to conventional flexible and rigid pavement projects. Specific objectives include the following tasks:

1. Investigate the characteristics of RCC mix individual ingredients, batching, mixing, placement, and finishing procedures.
2. Explore RCC projects conducted by other state DOTs, and investigate RCC project outcomes, advantages, and disadvantages.
3. Investigate the feasibility of using RCC pavement in roadway projects considering initial cost, and expenses required for maintenance and repair (project life cycle cost).
4. The research findings are compiled and presented to NCDOT personnel. Final research is formatted and divided as per the following section.

1.4 RCC Major Advantages

RCC provides construction personnel with several advantages that fit the needs required for pavement projects. Major RCC advantages include the following:

1. Expedited construction and the ability to open the roadways to traffic.
2. Cost-effective construction based on proved life cycle cost analysis.
3. Improved long term performance, high durability, and reduced need to preservation, maintenance, repair, and replacement.
4. No rutting or potholes are witnessed on RCC pavement projects.
5. RCC does not soften or lose its characteristics or mechanical advantages under high temperature.

1.5 Research Report

This report presents the research outcomes. The report includes the following chapters:

Chapter One – Introduction: to provide RCC definitions, brief history, and possible RCC applications.

Chapter Two – RCC Constituents and Mix Production: to list different RCC mix constituents, characteristics, and contribution to RCC physical and mechanical characteristics.

Chapter Three – RCC Applications in DOTs Projects: to list few case studies, advantages, disadvantages, Feasibility, and cost of RCC construction as compared to different pavement alternatives.

Chapter (2): RCC Constituents and Mix Production

RCC mix constituents are similar to conventional concrete mixes including a cement past (cement + water) and combined matrix of coarse and fine aggregates (sand and Limestone). Despite the similarity of RCC constituents, pavement thickness, and joints spacing to conventional rigid pavement, RCC is engineered and constructed differently. Major differences between RCC and conventional concrete pavement include:

1. RCC mixtures have “no” slump. Any slump is considered “too” much for RCC pavement projects. This strict slump requirement is compared to an average slump ranging from 1 in. to 4 in. for conventional rigid concrete pavement projects.
2. Due to the limited water content (low water-to-cement ratio), RCC mixes are produced most efficiently produced using horizontal, twin-shaft mixing chambers in a continuous or batch fashion.
3. RCC mixes are not susceptible to freeze-thaw cycles. Thus, air entrainment admixtures are not required for RCC mixes.
4. RCC does not need reinforcement steel bars. Load transfer is achieved at crack regions through aggregates interlock.
5. Construction equipment used in RCC pavement project differs from conventional concrete mixing, placement, and compaction.

2.1 Concrete Mixtures

The main objective of RCC mix design is to develop a mixture with maximized density at the lowest cement content. In order to attain the afore-mentioned objective, the following parameters are considered by the RCC mix designer:

1. The coarse aggregate nominal maximum size.
2. Water content and water-cement ratio.
3. Fine aggregate content.
4. Use of admixtures (if any).
5. Cementitious material content. This includes the content of portland cement and fly ash incorporated in the mix design.
6. Consistency of the concrete mix. This is a mandated requirement as the RCC mix needs to be stiff enough to sustain vibratory rolling, as shown in **Figure 2.1.**

Figure 2.1. Consistency (stiffness) of RCC mixture

2.2 Cementitious Materials

Different types of ordinary portland cement (OPC) are used in producing RCC mixes including Type I, Type II, and Type IP portland cements (ASTM C 150) or blended hydraulic cement (ASTM C595). Supplementary cementitious materials could be used in RCC mix development in partial replacement of OPC including Class F and Class C fly ash (ASTM C618), silica fume (ASTM C 1240), and ground granulated blast furnace slag (ASTM C989). The selection of cementitious content of RCC mix design is dependent on project conditions, required strength, and durability. Typically, a total cementitious content ranging from 240 to 360 kg. per cubic meter is used in RCC mixes.

2.3 Aggregate Content

RCC mixes are moisture sensitive. Thus, the percentage, size, gradation, and shape of aggregates used in mix development plays an important role in mix properties and long-term performance. Two main items are extremely important for aggregate selection and proportioning. This includes a) aggregate gradation, and b) aggregate mixture stability during pavement construction given moisture content fluctuations.

RCC experts advocates the use of the FHWA 0.45 power curve in proportioning aggregate sizes. The use of the 0.45 power curve provides the mix designer with a high packing order, minimized voids, and a higher mix stiffness/stability. The RCC aggregate gradation using the 0.45 power curve is shown in **Figure 2.2.** The improved packing order of the mix and reduced voids results in lower cement quantities requirement for mix production which results in improved mix sustainability, reduced carbon footprint, and a lower material cost for RCC mixes.

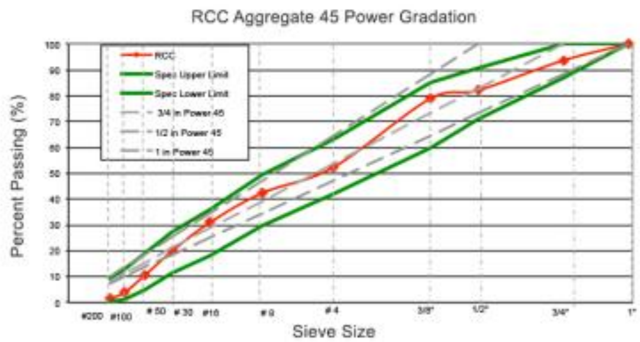

Figure 2.2. Example of RCC aggregate gradation using the FHWA 0.45 power curve

The mix stability and moisture sensitivity are important for RCC mix development. High stability is required to avoid causing problems during mix compaction. Mix sensitivity to moisture is evaluated using proctors test and establishing a correlation between dry density of the RCC mix (measured in pound per cubic feet) and the overall moisture content, as shown in **Figure 2.3** According to the figure, two density moisture curves are compared. The upper curve has a steeper slope and a narrower base which reflects a very high sensitivity to the moisture content, while the lower curve with a mild slope and wider base indicates that the moisture fluctuations have minimal effect on RCC mix stability. The later property is more desirable for RCC mix designs.

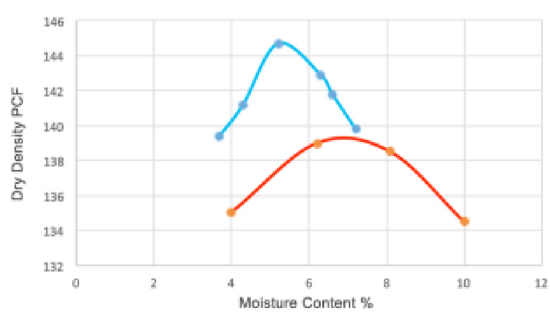

Figure 2.3. RCC sensitivity curve

2.4 Water

RCC mixes use the same water quality as conventional concrete mixes. Water-to-cementitious materials ratio in RCC ranges from 0.3 to 0.45. The aforementioned limitation is required to maintain the "negative" slump of RCC mixes.

2.5 Admixtures

Chemical admixtures are used in RCC mixes to attain specific requirements according to the project conditions. Admixtures used should comply with ASTM C494 and be approved by the project manager. RCC mixes use set-retarding admixtures when project location is far from RCC batch plant. Water reducers and high range water reducers (superplasticizers) are extensively used to reduce mixing time. Air entrainment admixtures are not used in RCC mixes due to the required dense packing order of the mix. Similarly, fibers are not used due to the inability of evenly distribute fibers within the mix.

2.6 Design Approach

RCC design process is included in different publications including the American Association of State Highway and Transportation Officials (AASHTO) Pavement ME design (AASHTOWare Catalog, 2015), American Concrete Institute 330 (ACI, 2008) and ACI 325 (ACI, 2002), RCC-Pave (PCA, 2002), American Concrete Pavement Association StreetPave (PCA, 1987), and the United States Army Corps of Engineers thickness design procedure (USACE, 2000) and the AASHTO Guide for Design of Pavement Structures (AASHTO, 1998).

RCC mix procedures included in the afore-mentioned specifications is focused on designing of mixes to combat fatigue cracks. Minimal attention is paid to jointing schemes, thickness of subbase and/or design variation of pavement layers given the traffic level and flow. Slab bending stresses in these procedures are typically greatest along the longitudinal pavement edge. For those procedures that delineate edge stress with respect to load transfer efficiency across the longitudinal joint, some design benefit can perhaps be gained by accounting for load position relative to that joint since its stiffness is rather low. One of the only options for reduced design stresses is by minimizing loading of the longitudinal joints, which can be facilitated by knowing the expected loading patterns. Additionally, strategic placement of flow patterns and break lines will facilitate reduced saturation and infiltration of joint interfaces and potential weakening of subgrade support. Another aspect of RCC pavement design pertains to the tightness or stiffness of the transverse cracks. Conventionally constructed RCC has not always included sawed joints, which has often resulted in some transverse cracks opening wider and moving more than others, manifesting poor load transfer characteristics that ultimately lead to localized joint failure. Saw cutting joints facilitates continuity between the design assumptions and the configuration of the constructed pavement section.

2.7 Construction of RCC Pavements

The major difference between RCC pavement and Jointed Concrete Pavement (JCP) in construction process is attributed to the following:

1. RCC is placed using a high-density asphalt paver.
2. RCC is compacted using a vibratory roller and accomplished through a combination of passes.
3. RCC is placed without forms. It does not require reinforcing steel or surface finishing.

Other differences between RCC and conventional concrete pavement is found in the texture of the final surface, as shown in **Figure 2.4.**

Figure 2.4. RCC surface texture as compared to conventional concrete pavement

Some have noted that an RCC surface can lose some fine aggregate in the initial years of service. This loss can be minimized if the surface is diamond ground after construction. Diamond grinding is often performed to facilitate roadway smoothness and provide for better surface texture with desirable characteristics.

2.8 Method of Batching and Mixing

Different types and sizes of aggregates are included in the mix development of RCC. The aggregate selection depends on the number of available aggregate bins at the mixing plant and the method of mixing. Mixers shown **Figure 2.5** are the standard recommendation for consistent production and mixing efficiency.

Figure 2.5. Twin shaft mixers used in RCC mix production

Based on contractors' survey, the following points should be considered when mixing RCC for pavement projects:

1. Mixing plants should have at least a two aggregate feed hopper to expedite and facilitate the mixing of different aggregate types. Otherwise, increased risk of segregation would exist if all-in aggregate mixing is conducted.
2. It is a good practice to limit the free fall height of mixed RCC into the truck mixer.
3. Twin shaft mixers are more efficient than pan or drum mixers. High energy provided by twin shaft is advantageous due to the stiff mix (with no slump)
4. Output of batch plants when RCC is produced could be one half its production rate when regular concrete mixes are produced. Thus, scheduling RCC pavement activities should consider lowered productivity rates when project activity duration is calculated.

5. Site based continuous mixers are typically used for larger RCC projects as they will feature. horizontal twin-shaft mixing chamber capable of high outputs of uniformly mixed material.
6. The critical factor governing output of RCC from continuous mixing plants is usually the rate of binder feeding, as the proportion of binder is significantly higher than in lower strength hydraulically bound mixtures (HBM).

2.9 Rolling Operations

Rolling of RCC mixes is crucial for successfully attaining the required pavement properties. Initially, RCC mixes are compacted using 10- to 12- ton vibratory rollers. The rolling pattern of RCC, shown in **Figure 2.6,** is adjusted during rolling as it is highly affected with site temperature and the moisture content within the RCC mix. Typically, rolling pattern is adjusted to attain a target density of 98 percent. Density is checked on-site using nuclear gage for the verification of roller efficiency.

Figure 2.6. RCC construction – Rolling pattern (FHWA, 2016)

Strength specimens are prepared using RCC mixes as per ASTM C 1435. Specimens are prepared using standard size cylinder of diameter 15 cm. or 10 cm. and heights 30 cm. or 20 cm respectively. Cylinders are prepared using a vibratory hammer for compressive strength testing, as shown in **Figure 2.7**. Finally, finish rolling is applied to the RCC pavement using a 3- to 6- ton roller to remove initial roller marks from the pavement surface.

Figure 2.7. Preparation of RCC compressive strength testing cylinders

2.10 RCC Properties Comparison with Conventional Concrete

Based on the afore-mentioned characteristics, batching, rolling, and jointing operations, the final mechanical properties of RCC mixes substantially differs from conventional rigid pavement mixes, as shown in **Table 2.1.**

Table 2.1. RCC properties comparison with conventional concrete (Hazaree, 2007)

Criteria	Conventional Concrete	Roller-Compacted Concrete
Consistency	Slump test, flow test	Ve-Be Method
Cement Content	Determined based on water demand and water-cement ratio	Generally, low cement content is included
Moisture Content	Determined by water cement ratio	Determined by optimum moisture content
Aggregate Gradation	Not very well graded	Well graded/high fine aggregate content
Fresh Concrete Properties	Slump	Ve-Be consistency, and optimum moisture content, maximum dry density methods
Spreading	Slipping from paving machines, and/or manually	Backhoe, loader, asphalt paving machine
Compaction	Internal or external vibrators	Rollers and/or compactors
Strength	Relatively low	Relatively high
Surface Roughness	Smooth	Rough and wavy due to roller compaction

Due to the absence of formwork and longitudinal reinforcement, RCC cost of construction is lower compared to conventional concrete pavement (Vahedifard et al., 2010). RCC constituents are similar to conventional concrete, however, the mix proportions would differ (Harrington et al, 2010 and Yildizel et al., 2018), as shown in **Figure 2.8.**

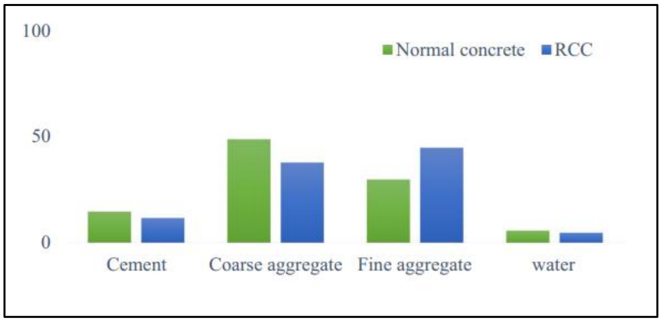

Figure 2.8. Comparison of RCC and conventional concrete constituents (Harrington et al., 2010)

RCC mixes, being a zero-slump concrete, relies heavily on quality of compaction. Thus, RCC mixes are substantially dry, but are wet enough to ensure cement hydration (Mehta and Monteiro, 2014). When well-compacted, RCC pavement is highly durable (Larrad et al., 2001). In addition, RCC mixes are resistant to different chemicals and lubricant materials due to their dense structure, and when SCMs are incorporated, RCC ability to resist alkali-silica reactivity is enhanced (Akhnoukh and Mallu, 2022 and Akhnoukh et al., 2016). Due to its durability, the market share of RCC in pavement application has exceeded 14.1 million square meters since in the period from 1975 till 2015 (Zollinger, 2015).

Chapter (3): RCC Projects & DOT Applications

3.1 RCC History

Since its first use in North America in the 1970s, RCC has been used on pavement projects in different climates under all types of vehicular loadings. Due to it's the RCC mix stiffness, RCC has provided superior performance under heavy wheel loads and difficult operating conditions. Typically, heavy-duty pavements have been constructed with RCC in log handling yards, intermodal terminals, freight depots, highway intersections, shoulders, parking lots, and other industrial applications. However, the past 10 years has brought an increase in the use of RCC to create cost-effective pavements for many conventional highway and street applications. In this research, different state DOTs were contacted to investigate and survey their current use of RCC mixes in rigid pavement projects, their advantages, limitations, and their feedback regarding existing and on-going RCC projects. South Carolina, Georgia, and Ohio DOTs provided extensive feedback that is presented in the following sections.

3.2 RCC Advantages

1. Fast pavement applications due to the absence of formwork, rebars, and dowels. In addition, the amount of finishing required for RCC pavement is minimal compared with conventional concrete (rigid pavement) and/or asphalt (flexible pavement).
2. Cost saving due to the absence of expensive reinforcement and due to the use of common conventional concrete mix constituents.
3. Labor saving due to the ability to concrete placement using asphalt pavers and compaction using vibratory rollers. Reduced labor need is also attributed to the minimal finishing required for RCC pavement.
4. RCC pavement are durable and require minimal maintenance as compared with other pavement types. This results in improved road conditions and reduced accidents and traffic impedance.
5. RCC mixes are environmentally friendly compared to conventional concrete. This is attributed to the reduced cement content required for RCC mix production. Reduced cement directly reduces the carbon footprint associated with RCC pavement projects.
6. The production and placement of RCC mixes in pavement projects does not require high temperature and does not result in producing vapors and fumes that could negatively impact the environment and the health of the construction workers.

3.3 Arterial Streets Pavement Projects

Due to traffic constraints and the time required to place a multi-layer asphalt pavement, several state DOTs have chosen to use a single RCC lift for arterial roads pavement projects. RCC fast progress results in reduced agency and users cost. RCC pavement is used in arterial streets for different vehicular types including busses, trucks, and passenger cars. Due to the high-speed traffic in arterial roads, state DOTs prefer to conduct surface treatment such a diamond grinding or applying a think 2 in. to 3 in. asphalt surface course. The thickness of RCC is designed using the *ACI 325.12R Guide for Design or Jointed Concrete Pavement for Streets and Local Roads or the ACI 330R Guide for the Design and Construction of Parking Lots.*

3.3.1 Ohio DOT RCC Pavement Project for Arterial Streets

Ohio DOT utilized RCC in the reconstructed Lane Avenue pavement in Columbus, Ohio. The RCC pavement had a total thickness of 8 in. (20.3 cm.). The RCC layer was surfaced by a 3 in. (7.5 cm.) layer to provide smooth surface for high-speed traffic. The RCC pavement layer was constructed under traffic for this four-lane arterial street, as shown in **Figure 3.1**

Figure 3.1. RCC pavement constructed in arterial street in Columbus, Ohio

3.3.2 South Carolina DOT RCC Pavement Project for Arterial Streets

South Carolina DOT reconstructed US 78 in Aiken, South Carolina using RCC pavement. This RCC project was completed in 2009. One RCC layer with 10 in. (25.5 cm.) was used to replace an existing full depth of asphalt layer, as shown in **Figure 3.2**. The RCC layer pavement was diamond ground for this four-lane highway section to provide sufficient texture for anti-skidding purposes.

The RCC pavement option was selected by SCDOT as the asphalt deterioration reached to a point where preservation or resurface treatment grew a non-viable option.

Figure 3.2. RCC pavement of US-78 in Aiken, SC

The RCC mix design for the US-78 in Aiken, SC contained Type I/II portland cement, a water-cement ratio of 0.41 (based on saturated surface dry of aggregates), and aggregate content as shown in **Table 3.1**. The RCC mix had a 3-day compressive strength of 4,240 psi and a final 28-day compressive strength of 5,250 psi.

Table 3.1. Grain size distribution for blended aggregate for SCDOT RCC US-78 Project, Aiken, SC

Sieve Size	Percent Finer	
	Sample	SCDOT Specification
1 in.	100	100
¾ in.	97.5	90-100
½ in.	89.4	70-100
3/8 in.	80.3	65-85
#4	59.1	40-60
#16	33.9	20-40
#100	9.4	6-18
#200	5.3	2-8

The RCC surface had an initial IRI measurement ranging from 100-120 in. per mile (upon placement). Seven days later, a milling machine was used to remove higher surface spots of RCC. This was followed by diamond grinding to an IRI measurement ranging from 50-60 in. per mile. The surface texture of the RCC pavement is shown in **Figure 3.3.**

Figure 3.3. US-78 RCC pavement roughness in Aiken, SC

3.3.3 RCC in U.S. Interstate System – Georgia Department of Transportation

In 2004, RCC was introduced to the U.S. interstate system by Georgia Department of Transportation. RCC was used for the 17.3-mile shoulder construction project on I-285 in Atlanta, GA. Shoulder thickness up to 8 in. (20 cm.) was poured without major disruption to traffic. The RCC mix used 0.5-in. maximum size aggregate and had a 4,000-psi final compressive strength. A 98% of the lab maximum density was required for the RCC pavement. Georgia DOT RCC mix design is shown in **Table 3.2.** RCC mix design for Georgia DOT I-285 project, Atlanta, GA

Table 3.2. RCC mix design for Georgia DOT I-285 project, Atlanta, GA

Constituent	Quantity (lbs.)	Weight Ratio (%)
Cement	500	12.3
Aggregate	3300	81.2
Water	266	6.5
Total	4066	100

3.4 Material Cost of RCC versus Conventional Pavement

The life cycle cost analysis of different pavement alternatives considers initial cost incurred by the DOT and road users. Initial cost during the life span of a pavement project are as follows:

3.4.1 Initial Cost

Initial cost includes the design costs, expenses incurred during the bidding process, cost of materials included in a roadway segment, construction costs (equipment, labor, overheads). Material costs are substantially affected by soil conditions and the highway anticipated level of traffic. In this study, the material cost of construction is considered for the following criteria:

a. Material

1. Hot mix asphalt (HMA) over cement stabilized crushed stone base (CSB)
2. Hot mix asphalt (HMA) over portland cement concrete (PCC) base
3. Portland cement concrete pavement (PCCP) on crushed aggregate base
4. Hot mix asphalt (HMA) over RCC pavement

b. Soil Conditions

1. Weak soil
2. Average soil
3. Good soil

c. Level of Traffic

1. Low traffic
2. Moderate traffic
3. High traffic

The combination of the afore-mentioned conditions resulted in the following material cost relations:

- **Case #1**

Condition	**HMA over CSB**	**HMA over PCC base**	**PCC Pvmt. Over crushed stone**	**HMA over RCC Base**
Weak Soil/Low Traffic	2.5 in. Surf 10 in. CSB	2.5 in. surf. 6 in. PCC Base	7 in. PCC pave. 4 in. crushed stone	2 in. Surf. 6 in. RCC base

The cost comparison for RCC pavement compared to different types is conducted by considering comparing the cost of all alternatives to the RCC pavement cost. For pavement projects conducted in weak soil with low traffic, the use of RCC with HMA 2 in. surface layer had average savings of 18%, 71%, and 34% as compared to hot mix asphalt (HMA) over cement stabilized crushed stone base (CSB), hot mix asphalt (HMA) over portland cement concrete (PCC) base, and portland cement concrete pavement (PCCP) on crushed aggregate base respectively, as shown in **Figure 3.4**.

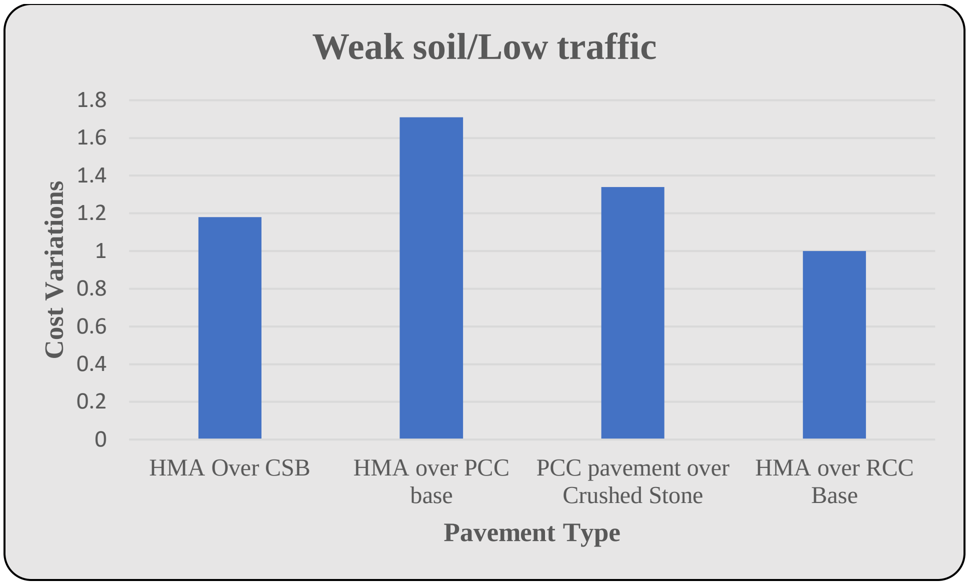

Figure 3.4. Cost comparison for different pavement types for weak soil and low traffic conditions

- **Case #2**

Condition	HMA over CSB	HMA over PCC base	PCC Pvmt. Over crushed stone	HMA over RCC Base
Weak Soil/Mod. Traffic	2.5 in. Surf 4.5 in. Binder 14 in. CSB	2 in. surf. 4 in. binder 10 in. PCC Base	13 in. PCC pave. 6 in. crushed stone	2.5 in. Surf. 14 in. RCC base 4 in. crushed st.

The cost comparison for RCC pavement compared to different types is conducted by considering comparing the cost of all alternatives to the RCC pavement cost. For pavement projects conducted in weak soil with low traffic, the use of RCC with HMA 2 in. surface layer had average savings of 3%, 45%, and 14% as compared to hot mix asphalt (HMA) over cement stabilized crushed stone base (CSB), hot mix asphalt (HMA) over portland cement concrete (PCC) base, and portland cement concrete pavement (PCCP) on crushed aggregate base respectively, as shown in **Figure 3.5**.

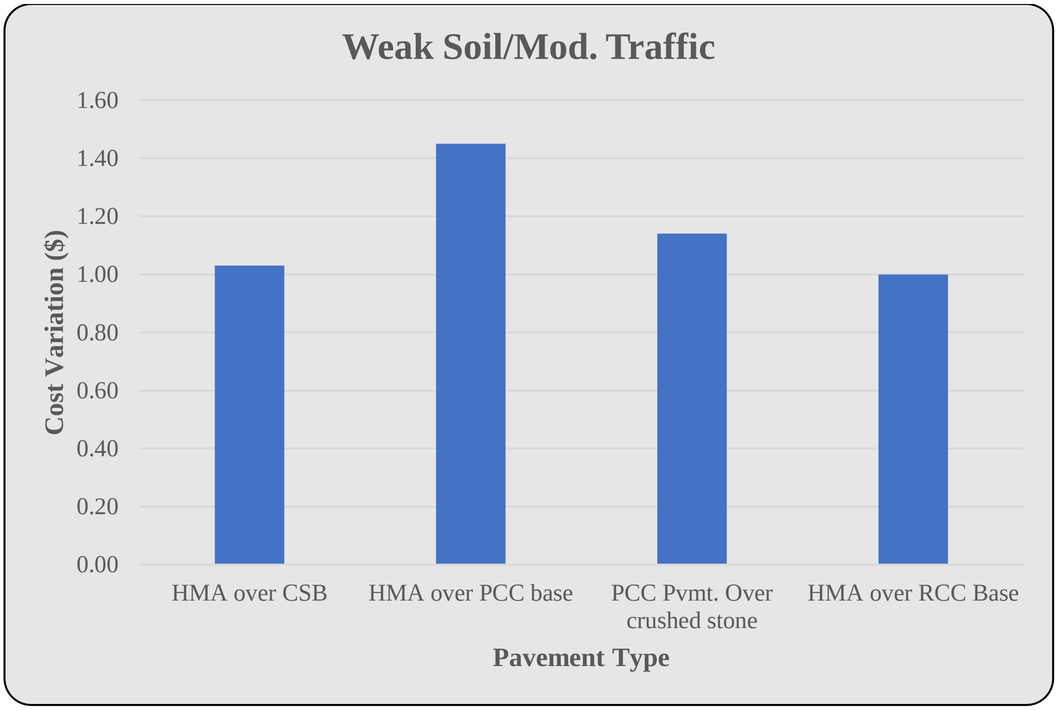

Figure 3.5. Cost comparison for different pavement types for weak soil and Moderate traffic conditions

➢ **Case #3**

Condition	**HMA over CSB**	**HMA over PCC base**	**PCC Pvmt. Over crushed stone**	**HMA over RCC Base**
Weak Soil/High Traffic	4 in. Surf 5 in. Binder 13 in. CSB	2 in surf 4 in. binder 13 in. PCC Base	13.5 in. PCC pave. 12 in. crushed stone	3 in. Surf. 15.5 in. RCC base 4 in. crushed st.

The cost comparison for RCC pavement compared to different types is conducted by considering comparing the cost of all alternatives to the RCC pavement cost. For pavement projects conducted in weak soil with low traffic, the use of RCC with HMA 2 in. surface layer had average savings of 2%, 57%, and 14% as compared to hot mix asphalt (HMA) over cement stabilized crushed stone base (CSB), hot mix asphalt (HMA) over portland cement concrete (PCC) base, and portland

cement concrete pavement (PCCP) on crushed aggregate base respectively, as shown in **Figure 3.6**.

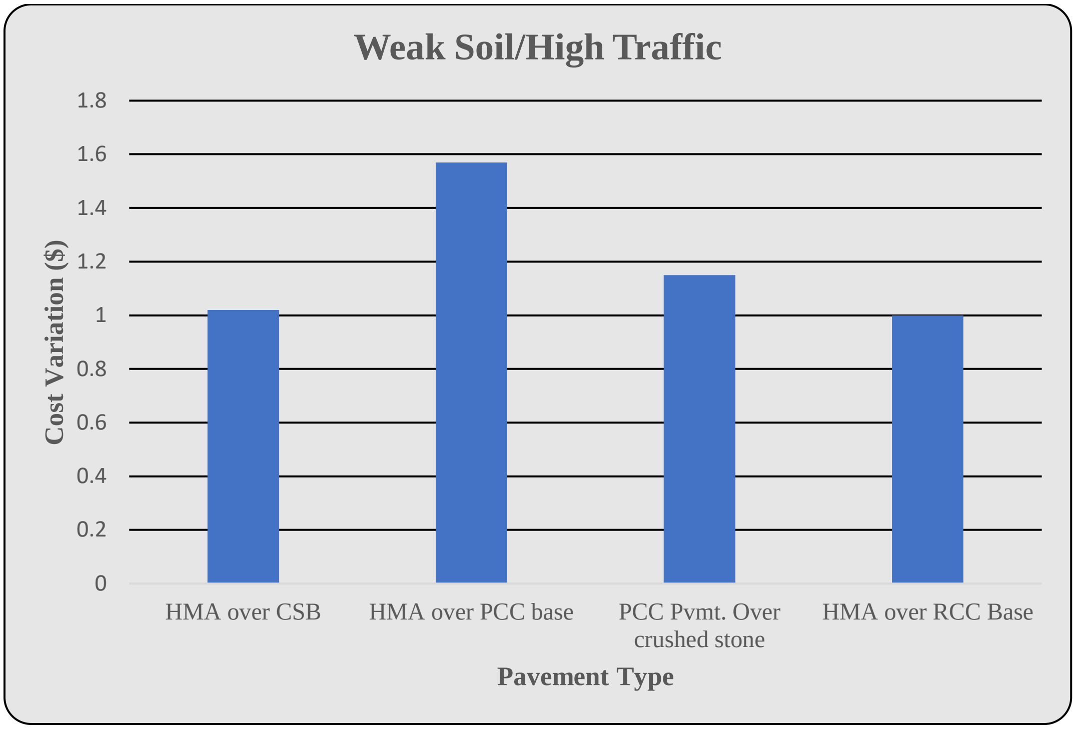

Figure 3.6. Cost comparison for different pavement types for weak soil and high traffic conditions

- **Case #4**

Condition	HMA over CSB	HMA over PCC base	PCC Pvmt. Over crushed stone	HMA over RCC Base
Avg. Soil/Mod. Traffic	2 in. Surf 4 in. Binder 7 in. CSB	4 in. binder 8 in. PCC Base	10.5 in. PCC pave. 6 in. crushed stone	2 in. Surf. 8 in. RCC base 4 in. crushed st.

The cost comparison for RCC pavement compared to different types is conducted by considering comparing the cost of all alternatives to the RCC pavement cost. For pavement projects conducted in weak soil with low traffic, the use of RCC with HMA 2 in. surface layer had average savings of 8%, 73%, and 46% as compared to hot mix asphalt (HMA) over cement stabilized crushed stone base (CSB), hot mix asphalt (HMA) over portland cement concrete (PCC) base, and portland

cement concrete pavement (PCCP) on crushed aggregate base respectively, as shown in **Figure 3.7**.

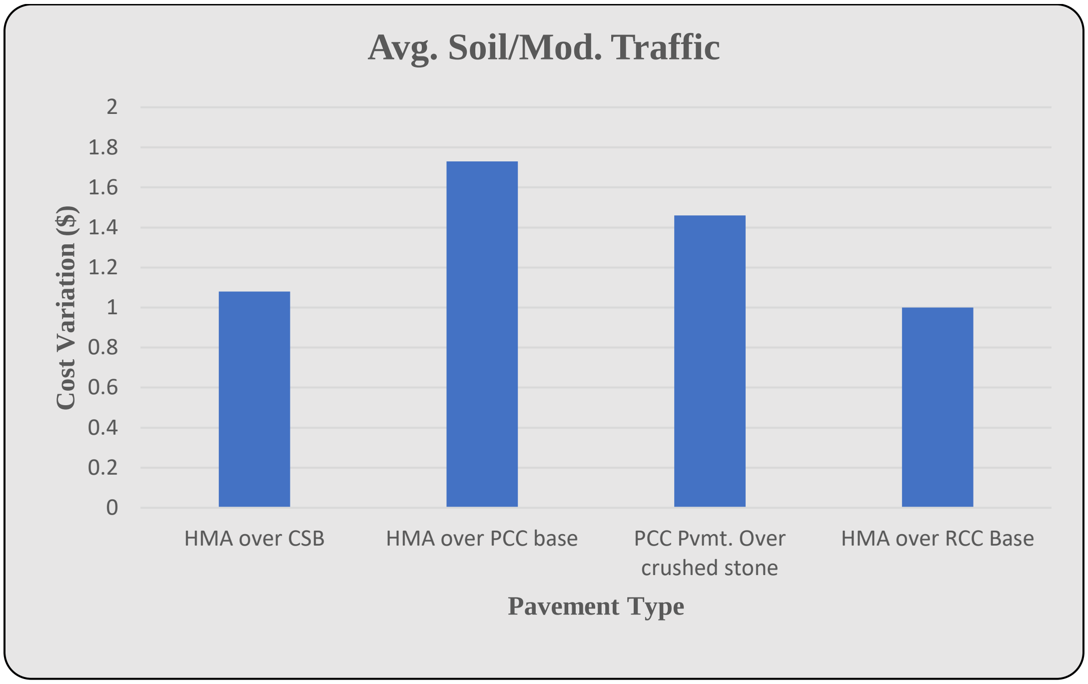

Figure 3.7. Cost comparison for different pavement types for average soil and moderate traffic conditions

➢ **Case #5**

Condition	**HMA over CSB**	**HMA over PCC base**	**PCC Pvmt. Over crushed stone**	**HMA over RCC Base**
Avg. Soil/High Traffic	2 in. Surf 4 in. Binder 9 in. CSB	2.5 surf. 9.5 in. PCC Base	11 in. PCC pave. 9 in. crushed stone	2.5 in. Surf. 8.5 in. RCC base 4 in. crushed st.

The cost comparison for RCC pavement compared to different types is conducted by considering comparing the cost of all alternatives to the RCC pavement cost. For pavement projects conducted in weak soil with low traffic, the use of RCC with HMA 2 in. surface layer had average savings of 9%, 62%, and 46% as compared to hot mix asphalt (HMA) over cement stabilized crushed stone base (CSB), hot mix asphalt (HMA) over portland cement concrete (PCC) base, and portland

cement concrete pavement (PCCP) on crushed aggregate base respectively, as shown in **Figure 3.8.**

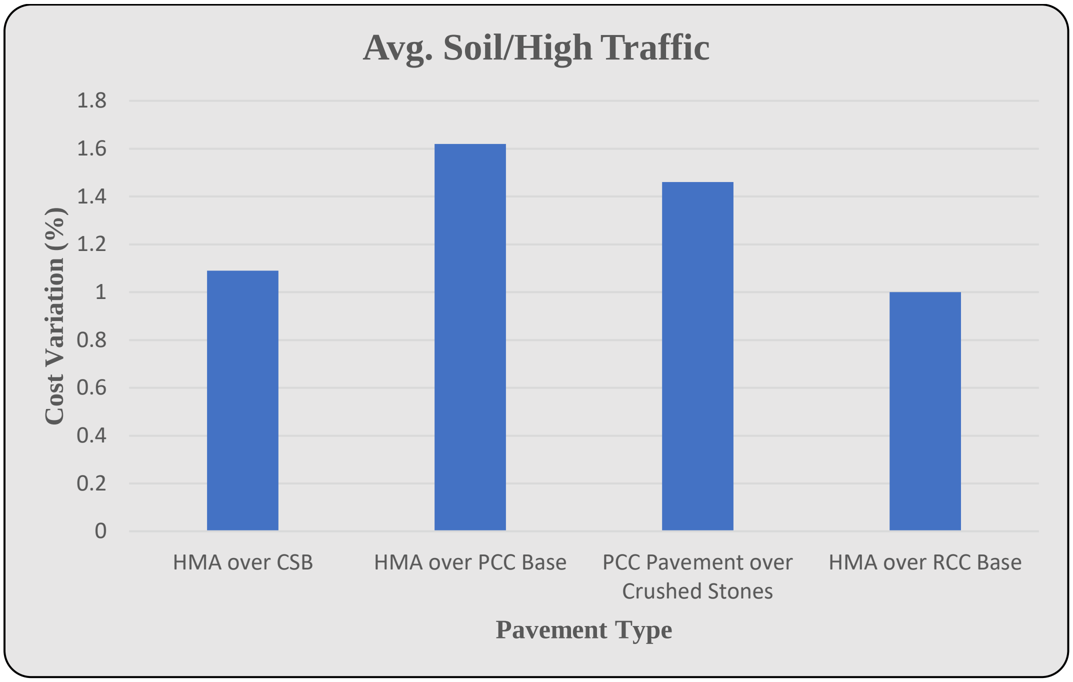

Figure 3.8. Cost comparison for different pavement types for average soil and high traffic conditions

- **Case #6**

Condition	HMA over CSB	HMA over PCC base	PCC Pvmt. Over crushed stone	HMA over RCC Base
Good Soil/High Traffic	1.5 in. Surf 4 in. Binder 7 in. CSB	2.5 in. surf. 7.5 in. PCC Base	10.5 in. PCC pave. 9 in. crushed stone	2.5 in. Surf. 7 in. RCC base 4 in. crushed st.

The cost comparison for RCC pavement compared to different types is conducted by considering comparing the cost of all alternatives to the RCC pavement cost. For pavement projects conducted in weak soil with low traffic, the use of RCC with HMA 2 in. surface layer had average savings of 4%, 51%, and 58% as compared to hot mix asphalt (HMA) over cement stabilized crushed stone base (CSB), hot mix asphalt (HMA) over portland cement concrete (PCC) base, and portland

cement concrete pavement (PCCP) on crushed aggregate base respectively, as shown in **Figure 3.9.**

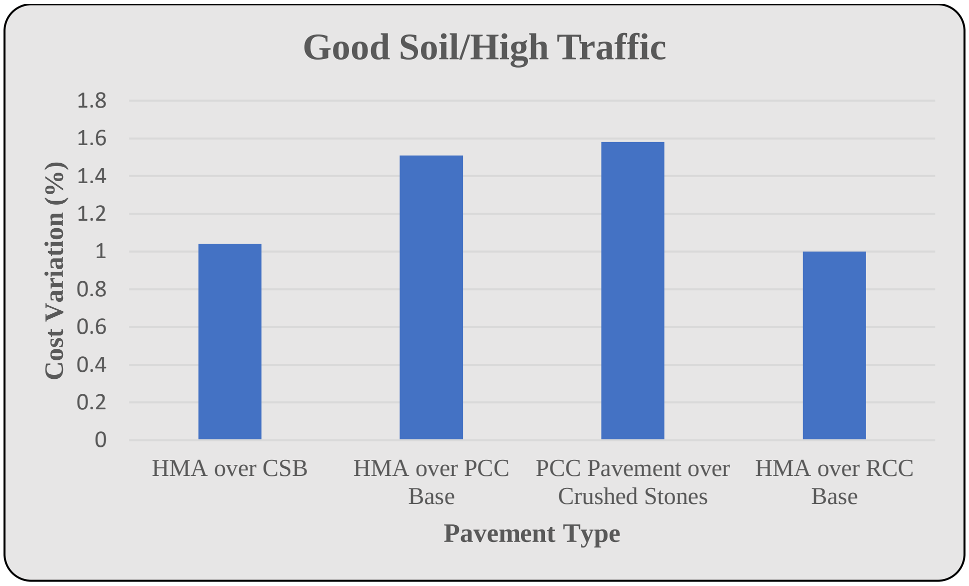

Figure 3.9. Cost comparison for different pavement types for average soil and high traffic conditions

3.4.2 Cost Comparison of Pavement Options

Based on the afore-mentioned cases, RCC pavement option provides DOT personnel with an economic option regardless to the site condition (soil capacity) or ADT for the constructed highway. The savings incurred when RCC pavement is selected varies from a 2% savings when compared with hot mix asphalt (HMA) over cement stabilized crushed stone base (CSB) in case of weak soil and high traffic and 73% savings when compared with hot mix asphalt (HMA) over portland cement concrete (PCC) base. RCC advantages are maximized when used in highways with relatively high traffic.

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