EPiC Series in Built Environment
Volume 6, 2025, Pages 746–755
Proceedings of Associated Schools of Construction 61st Annual International Conference

Economic Benefits of Roller Compacted Concrete in Roadway Construction: A Comparative Analysis

Amin Akhnoukh[1], Mena Souliman [2], Mayzan Isied [2], and Sanjeev Adhikari [3]
[1] East Carolina University, [2] University of Texas Tyler,[3] Kennesaw State University

Roller compacted concrete (RCC), also known as roller 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 (SCMs). Due to texture, physical and mechanical characteristics, RCC is placed with a high-compaction asphalt type paver and compacted to a high density using vibratory rollers. The placement and compaction techniques of RCC results in a high strength rigid pavement with enhanced long-term performance. The aforementioned characteristics provide RCC with a material competitive advantage to be adopted in pavement projects. In this research, material cost of roadway segments designed and constructed using RCC is compared to different conventional pavement alternatives considering different project parameters including base and wearing surface material types, subgrade (soil) conditions, and highway level of traffic. The outcomes of this research showed that RCC pavement provides the departments of transportation with material cost savings regardless of the project parameters. Cost savings are maximized when RCC is used in highway construction with poor subgrade strength and under high traffic volumes. The incorporation of the research outcomes would provide DOT personnel with the required materials to improve roadway conditions within the United States.

Keywords: Roller compacted concrete (RCC), Supplementary cementitious materials (SCMs), Aggregates, Rigid pavement, Hot mix asphalt (HMA)

Introduction

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 (SCMs). SCMs like fly ash, micro-silica, and ground granulated blast furnace slag, are used in partial replacement of cement to enhance RCC mix mechanical properties, durability, and reduce the mix carbon footprint by minimizing cement utilization (Akhnoukh, 2021, 2020, and 2018, Akhnoukh and Ekhande, 2021, Akhnoukh and Soares, 2013). RCC is produced using a mixture of dense-graded aggregates, portland cement, and water. Due to the low water-to-cement (powder) ratio of 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.

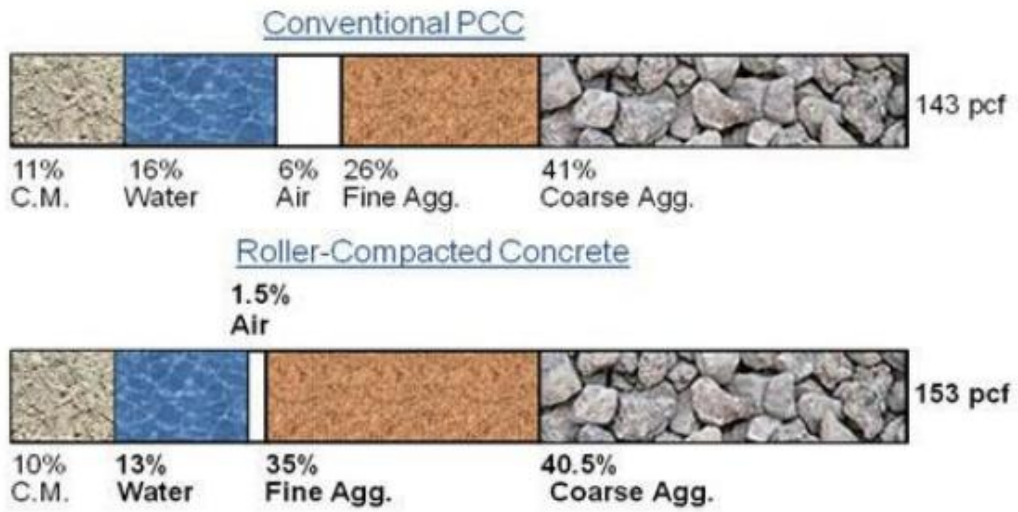

Figure 1. Roller-compacted concrete (RCC) mix designs

Due to RCC texture, physical and mechanical characteristics, RCC is placed with a high-compaction asphalt type paver (see Figure 2). RCC is compacted to a high density using vibratory rollers. The placement and compaction techniques of RCC results in a high 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. 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, and 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 skid resistance for high-speed routes. In the United Kingdom, RCC pavement is covered by an asphalt surface course to meet high speed resistance and surface regularity requirements.

Figure 2. Roller-compacted concrete (RCC) placement

Literature Review

RCC was marginally applied in construction projects in the 1930s and the 1940s.. RCC was inconsistent and didn't conform to any 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) modified 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 post 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 6 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 of using 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 (see Figure 3) as a pavement option in its Manual of Contract Documents for Highways (National Highways, 2020). Recently, North Carolina Department of Transportation (NCDOT) conducted a detailed research program to explore the advantages of RCC mixes in different highway applications As a result, NCDOT is currently depending on RCC mixes for shoulder pavement in different highways including the Interstate Roadways passing through the State of North Carolina (Akhnoukh, 2024).

Figure 3. RCC roadway construction in the UK using RCC

Based on differences in mix constituent design, the final mechanical properties of RCC mixes are evaluated using different set of standard tests which differs substantially from conventional rigid concrete pavement (see Table 1). 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).

Table 1. RCC properties testing versus conventional concrete (Hazaree, 2007)

	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

Research Objective and Methodologies

The main objective of this research is to evaluate the material cost of RCC compared to other rigid and flexible pavement alternatives under different project criteria/parameters. Considered project parameters include materials used for highway cross section construction, soil (subgrade) conditions, and the level of traffic (measured through the average daily traffic (ADT)). In order to achieve the research objective, highway segments are designed for different subgrade types and different traffic loading. Sections are designed using different materials including hot mix asphalt (HMA) placed on crushed stone base (CSB), hot mix asphalt placed on portland cement concrete (PCC) base, portland cement concrete pavement placed on crushed stone base, and HMA placed over RCC base. The cost of RCC alternative is considered the baseline for comparison. Alternative designs are compared to the RCC alternative to evaluate the RCC cost effectiveness.

Analytical Work

In this research study, the material cost of different pavement alternatives is considered under the following parameters:

a. Level of traffic including the following:
   1. Low traffic
   2. Moderate traffic
   3. High traffic
b. Soil conditions including the following:
   1. Weak (low) bearing capacity
   2. Average bearing capacity
   3. High bearing capacity
c. Materials used in the design and construction of roadway cross-section including the following:
   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

Six different combinations are developed considering the afore-mentioned parameters. The outcome of the material cost comparison is shown as follows:

Combination #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 a 2 in. HMA surface layer had average savings of 18%, 71%, and 34% compared to hot mix asphalt (HMA) over a cement-stabilized crushed stone base (CSB), hot mix asphalt (HMA) over a portland cement concrete (PCC) base, and portland cement concrete pavement (PCCP) on a crushed aggregate base, respectively. (see figure 4).

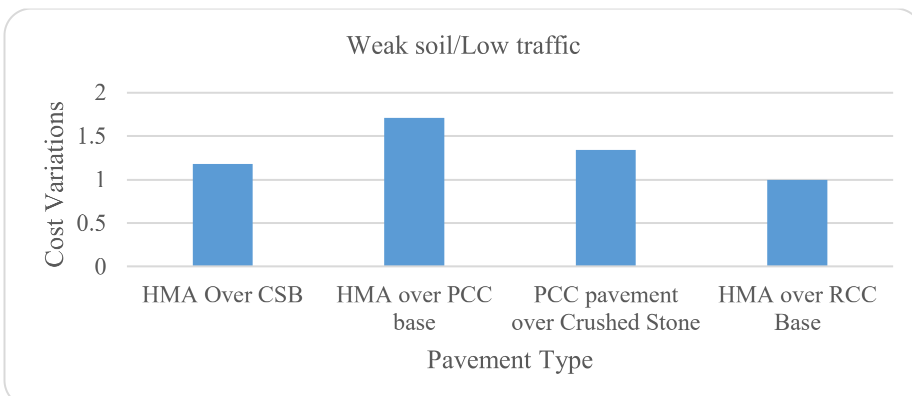

Figure 4. Cost comparison for different pavement types for weak soil and low traffic conditions

Combination #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 stone

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 (see figure 5).

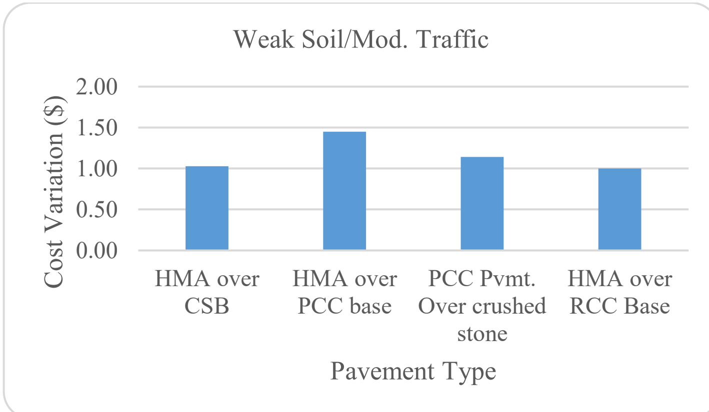

Figure 5. Cost comparison for different pavement types for weak soil and Moderate traffic conditions

Combination #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 stone

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 (see figure 6).

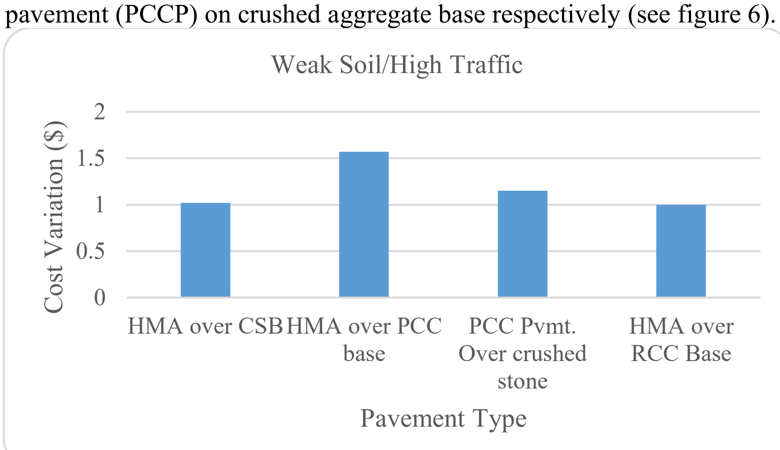

Figure 6. Cost comparison for different pavement types for weak soil and high traffic conditions

Combination #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 (see figure 7).

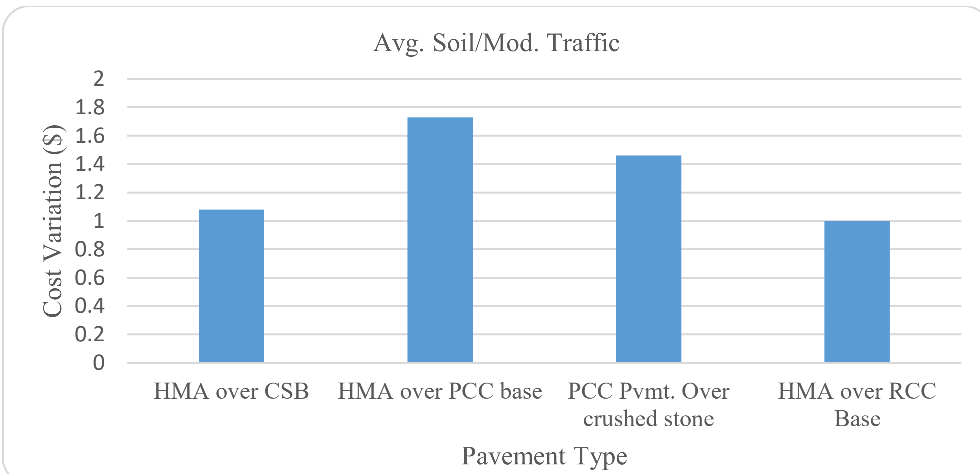

Figure 7. Cost comparison for different pavement types for average soil and moderate traffic conditions

Combination #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 (see figure 8).

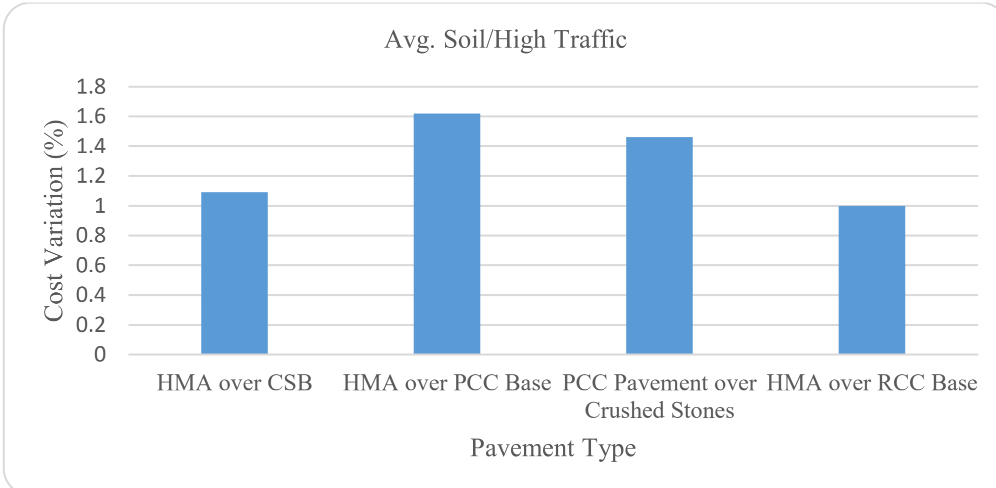

Figure 8. Cost comparison for different pavement types for average soil and high traffic conditions

Combination #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 stone

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 (see figure 9).

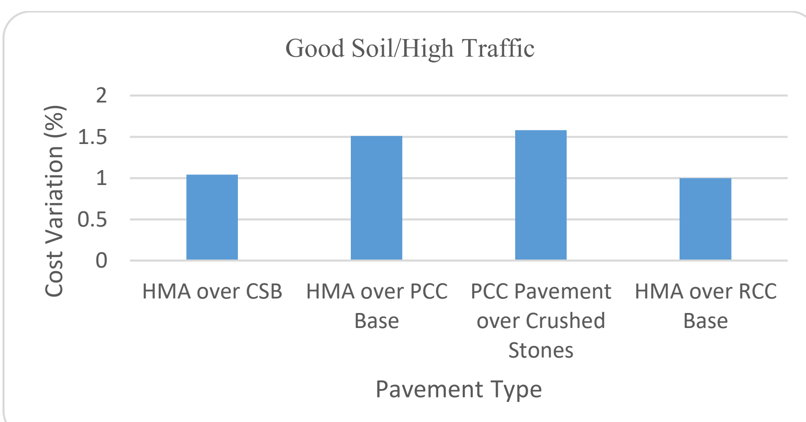

Figure 9. Cost comparison for different pavement types for average soil and high traffic conditions

Conclusions

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. Overall, RCC presents a robust and economical solution for enhancing the performance and longevity of roadways, particularly in challenging conditions.

References & Appendices

Akhnoukh, A.K. (2021). Application of supplementary cementitious materials in precast concrete industry. Sustainability of Concrete with Synthetic and Recycled Aggregates, Book Chapter DOI: 10.5772/intechopen.100249

Akhnoukh, A.K. (2024). Roller compacted concrete phase I. Research Report, FHWA/NC/TA2024-03

Akhnoukh, A.K., and Ekhande, T. (2021). Supplementary cementitious materials in concrete industry – a new horizon. Proceedings of the International Road Federation World Meeting and Exhibition, pp. 450-457

Akhnoukh, A.K. (2020). The use of micro- and nano-sized particles in increasing concrete durability. Particulate Science and Technology, Vol. 38, No. 5, pp. 529-534 https://doi.org/10.1080/02726351.2018.1467988

Akhnoukh, A.K., and Soares, R. (2018). Reactive powder concrete application in the construction industry in the United States. Proceedings of the 10th International Conference of Construction in the 21st Century, Sri Lanka

Akhnoukh, A.K. (2018). Implementation of nanotechnology in improving the environmental compliance of construction projects in the United States. Particulate Science and Technology, Vol. 36, No. 3, pp. 357-361. https://doi.org/10.1080/02726351.2016.1256359

EUPAVE. (2019). Roller compacted concrete pavements available to the whole pavement building industry. European concrete pavement association

Harrington, D., Abdo, F., Adaska, W., and Hazaree, C. (2010). Guide for roller-compacted concrete pavements. Trans Project Reports Institute for Transportation, 2010

Hazaree, C. (2007). Transport properties and freeze-thaw resistance of roller compacted concrete (RCC) for pavement applications. Thesis, Iowa State University, 2007

National Highways. (2020). CD226 design for new pavement construction. Design Manual

PCA. (2006). Production of roller-compacted concrete. Portland Cement Association

Yildizel, S.A., Timur, O., and Ozturk, A.U. (2018). Abrasion resistance and mechanical properties of waste glass fiber reinforced roller-compacted concrete. Mechanics of Composite Materials, Vol. 54, 2018