Guide to Roller-Compacted Concrete Pavements

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This guide provides owner-agencies, contractors, materials suppliers, and others with a thorough introduction to roller-compacted concrete (RCC) and its many paving applications. This guide describes RCC and how it works as a paving material, how it compares to concrete pavement, its common uses and benefits, and potential limitations compared to other paving materials. Troubleshooting guidelines are provided, as well as detailed overviews of RCC properties and materials, mixture proportioning, structural design issues, production and construction considerations, and quality control.

Keywords: industrial pavement; inspection and testing; joints; pavement; pavement design; roller-compacted concrete (RCC); RCC mixture proportioning; RCC pavement construction; RCC production.

CONTENTS

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CHAPTER 1—INTRODUCTION

Roller-compacted concrete (RCC) is an economical, fast construction candidate for many pavement applications. Because of its relatively coarse surface, RCC has traditionally been used for pavements carrying heavy loads in low-speed areas. In recent years, however, its use in commercial areas and for local streets and highways is increasing.

This guide is largely based on Harrington et al. (2010). The review panel for the Harrington report was made up largely of ACI Committee 327 members. With the cooperation of the Portland Cement Association, the report was used as the basis for this guide. Extensive changes were made during the committee review, including incorporating material from ACI 325.10R. Additional references and examples have been added.

CHAPTER 2—NOTATION AND DEFINITIONS

2.1—Notation

C = coefficient relating flexural and compressive strength with values ranging from 9 to 11
E = modulus of elasticity, psi (MPa)
f_r = flexural strength (third-point loading), psi (MPa)
f_c' = compressive strength, psi (MPa)
h = slab thickness, in. (mm)
k = modulus of subgrade reaction, psi/in. (MPa/mm)
σ = stress, psi (MPa)
ε = strain, in./in. (mm/mm)

2.2—Definitions

ACI provides a comprehensive list of definitions through an online resource, "ACI Concrete Terminology," http://www.concrete.org/Tools/ConcreteTerminology.aspx. Definitions provided herein complement that source.

curling—out-of-plane deformation of the corners, edges, and surface of a pavement from its original shape due to differential temperature within the pavement.

warping—out-of-plane deformation of the corners, edges, and surface of a pavement from its original shape due to differential moisture within the pavement.

CHAPTER 3—KEY ELEMENTS

3.1—Performance comparison of RCC to conventional concrete pavement

Roller-compacted concrete (RCC) gets its name from the heavy vibratory steel drum and rubber-tired rollers used to compact it into its final form. Roller-compacted concrete has similar strength properties and consists of the same basic ingredients as conventional concrete—well-graded aggregates, cementitious materials, and water—but has different mixture proportions. The biggest difference between RCC and conventional concrete mixtures is that RCC has a higher percentage of fine aggregates that allow for tight packing and compaction.

Fresh RCC is stiffer than typical zero-slump conventional concrete, with a consistency that is stiff enough to remain stable under vibratory rollers, yet wet enough to permit adequate mixing and distribution of paste without segregation.

RCC is typically placed with an asphalt-type paver equipped with a standard or high-density screed, followed by a combination of passes with rollers for compaction. Final compaction is usually achieved within 1 hour of mixing. Unlike conventional concrete pavements, RCC pavements are constructed without forms, dowels, or reinforcing steel. Joint sawing is not required, but when sawing is specified, transverse joints are spaced farther apart than with conventional concrete pavements.

RCC pavements are strong, dense, and durable. These characteristics, combined with construction speed and economy, make RCC pavements an excellent alternative for parking and storage areas including port, intermodal, and military facilities; highway shoulders; streets; and highways. RCC can also be used in composite systems as base material.

The use of RCC in public and private applications has been increasing steadily in recent years (Fig. 3.1), particu-

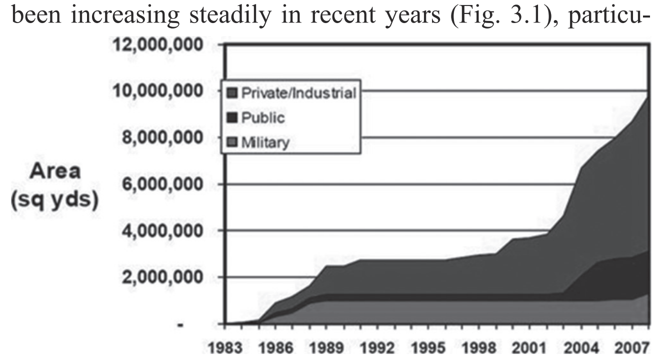

Fig. 3.1—Increasing use of RCC pavements (Pittman and Anderton 2009). (Note: 1 yd² = 0.8 m².)

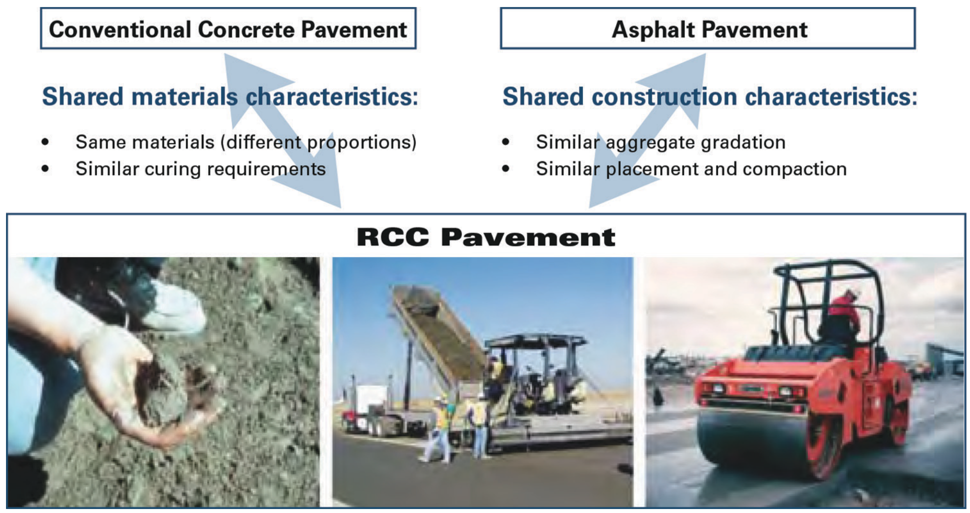

Fig. 3.2a—RCC combines aspects of conventional concrete and hot-mix asphalt paving materials and construction practices (Harrington et al. 2010).

larly in the construction of low-volume roads and parking lots (Pittman and Anderton 2009).

3.2—Materials and structural performance properties

RCC pavements combine various aspects of conventional concrete pavement material practices with construction practices typical of asphalt pavements (Fig. 3.2a). However, while RCC pavements are compacted in the same manner and have similar aggregate gradation (Chapters 5 and 6) as asphalt pavements (Fig. 3.2b), the materials and structural performance properties of RCC are similar to those of conventional concrete pavement.

With well-graded aggregates, proper cement and water content, and dense compaction, RCC pavements can achieve strength properties equal to those of conventional concrete, with low permeability.

RCC mixtures should be dry enough to support the weight of a vibratory roller after placement, yet wet enough to ensure an even distribution of paste. Proper proportioning is essential for ensuring that the mixture has sufficient paste to coat the aggregate particles and fill the voids of the compacted mixture. Coating the aggregate particles is essential to obtain a strong and durable pavement and ensure load transfer through aggregate interlock.

Compaction is the process by which the aggregate particles in the RCC mixture are forced closer together, reducing the amount of air voids in the mixture and increasing the density of the pavement structure. Increased density makes the pavement suitable for load-bearing applications. Rolling should occur before cement hydration begins to harden the paste between the aggregate particles.

Achieving proper density during the rolling process helps prevent non-uniform compaction and isolated weak areas. Depending on the specific mixture and laydown equipment used, external mechanical compaction by rollers could result in a 5 to 20 percent reduction in volume and pavement thickness.

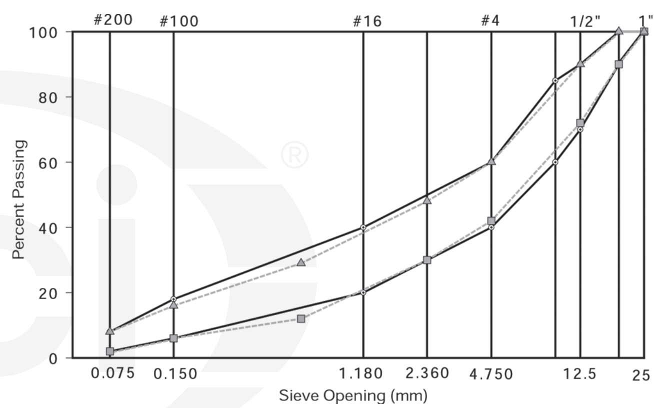

Fig. 3.2b—Aggregate gradation of RCC (without symbols) is similar to aggregate gradation of intermediate HMA layer (with symbols) (Harrington et al. 2010).

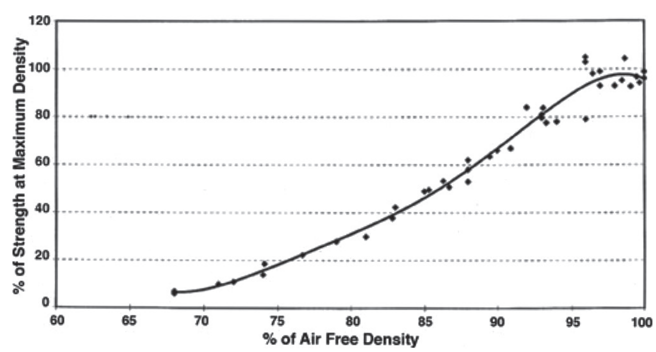

Fig. 3.2c—Strength versus density for various RCC mixtures (Schrader 1992).

Minimizing air void content in the RCC mixture is crucial to its durability. Excess air voids allow penetration of air and water. Non-entrained air weakens the mixture, while excessive water can weaken the mixture and also cause materials-related distresses in the aggregates and damage from freezing and thawing (F-T).

Table 3.3—Comparison of conventional concrete and RCC materials and construction practices

	Pavement type	
General materials and practices	**Conventional concrete pavements**	**RCC pavements**
Mixture materials proportions	Well-graded coarse and fine aggregates typically account for 60 to 75 percent of the mixture by volume. A typical *w/cm* is 0.40 to 0.45, which makes a cement paste wet enough to thoroughly coat the aggregate particles and fill spaces between them.	Dense- and well-graded coarse and fine aggregates typically comprise 75 to 85 percent of RCC mixtures by volume. RCC mixtures are drier than conventional concrete due to their higher fines content and lower cement and water contents.
Workability	The mixture is plastic and workable so that it can be manipulated by the paving machine and relatively stiff (slump is generally approximately 2 in. [50 mm]) to hold shape after extrusion from the paving machine.	The mixture has the consistency of damp, dense-graded aggregates. RCC's relatively dry and stiff (less than zero slump) mixture is not fluid enough to be manipulated by traditional concrete paving machines.
Paving	The mixture is placed ahead of a slipform paving machine, which then spreads, levels, consolidates through vibration, and extrudes the concrete. Typical thicknesses are 8 to 12 in. (200 to 300 mm) but can be greater.	Typically, the RCC mixture is placed with a heavy duty, self-propelled asphalt paving machine, using a high-density single- or double-tamper bar screed to initially consolidate the mixture to a slab of uniform thickness. These types of pavers are essential to high-quality placement, especially in thick pavement applications. Forms are not required. RCC is usually placed in lifts of 6 to 8 in. (150 to 200 mm) with a 4 in. (100 mm) minimum and 10 in. (250 mm) maximum.
Compaction (primarily the removal of non-entrained air)	Compaction occurs internally. Initially, internal vibrators and surface vibrators on the paving machine vibrate the plastic concrete, releasing air. After the concrete is extruded from the machine and before initial set occurs, additional compaction occurs through the settlement of solids (cements and aggregates) and the upward movement of water to the surface (bleeding).	Compaction is accomplished externally by compacting the concrete with rollers, typically within the first 60 minutes after mixing and before the paste begins to harden.
Finishing	Finishing is conducted before initial set occurs. Conventional concrete is usually mechanically textured to improve friction.	Although the surface of RCC pavement typically has an open texture similar to asphalt, use of smaller aggregates, additional cement, or both, can create a denser surface that is closer to that of conventional concrete. RCC can be textured through diamond grinding.
Hydration	Proper hydration of the concrete mixture is critical to the long-term durability of the concrete pavement. To assist in hydration, it is essential to cure the concrete.	Proper hydration of the RCC mixture is critical to its long-term durability. To assist in hydration, it is essential the concrete be cured.
Curing	Thorough curing is required as soon as possible after finishing. This is critical for controlling water evaporation from the concrete surface so that it is available for cement-water hydration, which results in a strong, hardened paste that fills voids and binds aggregate particles.	Thorough curing is required as soon as possible after roller compacting. This controls water evaporation from the concrete surface so that it is available for cement-water hydration, which results in a strong, hardened paste that binds the aggregate particles.
Cracking, load transfer, and reinforcement	In conventional jointed pavements, the crack location is controlled by cutting joints, across which transverse dowel bars are used for load transfer for pavements 8 in. (200 mm) or thicker, and longitudinal tie bars are used to help ensure aggregate interlock. In continuously reinforced pavements, tight cracks are allowed to occur in a naturally closely spaced pattern and the steel reinforcement, together with aggregate interlock, assists in load transfer.	Joints are not usually sawed in RCC industrial applications. When sawing is not specified, random cracks 15 to 30 ft (4.6 to 9.1 m) apart are tight to enable load transfer through aggregate interlock. When sawing is specified to control random cracks, it is typically in applications with car and truck traffic. Fewer joints are sawed in RCC than in conventional concrete pavements, and they are spaced farther apart (15 to 30 ft [4.6 to 9.1 m] transversely). Because of the way RCC is consolidated, it is not possible to place dowels or tie bars in RCC pavements.

The best performance characteristics are obtained when RCC is reasonably free of segregation and is consistently compacted throughout the entire lift at, or close to, maximum density. The strength of RCC drops appreciably as its density drops (Fig. 3.2c) (Schrader 1992; Delatte and Storey 2005).

3.3—Performance differences between RCC and conventional concrete pavement

Table 3.3 shows a comparison of conventional concrete and RCC materials and construction practices. RCC mixtures typically have a lower volume of cementitious materials, coarse aggregates, and water than conventional concrete mixtures, and a higher volume of fine aggregates, which fill the air voids in the pavement system (Fig. 3.3a). Fine aggre-