IN-LB	Inch-Pound Units
SI	International System of Units

Compaction of Roller-Compacted Concrete—Report

Reported by ACI Committee 309

ACI PRC-309.5-22

American Concrete Institute
Always advancing

First Printing
July 2022
ISBN: 978-1-64195-182-1

Compaction of Roller-Compacted Concrete—Report

The technical committees responsible for ACI committee reports and standards strive to avoid ambiguities, omissions, and errors in these documents. In spite of these efforts, the users of ACI documents occasionally find information or requirements that may be subject to more than one interpretation or may be incomplete or incorrect. Users who have suggestions for the improvement of ACI documents are requested to contact ACI via the errata website at http://concrete.org/Publications/DocumentErrata.aspx. Proper use of this document includes periodically checking for errata for the most up-to-date revisions.

ACI committee documents are intended for the use of individuals who are competent to evaluate the significance and limitations of its content and recommendations and who will accept responsibility for the application of the material it contains. Individuals who use this publication in any way assume all risk and accept total responsibility for the application and use of this information.

All information in this publication is provided "as is" without warranty of any kind, either express or implied, including but not limited to, the implied warranties of merchantability, fitness for a particular purpose or non-infringement.

ACI and its members disclaim liability for damages of any kind, including any special, indirect, incidental, or consequential damages, including without limitation, lost revenues or lost profits, which may result from the use of this publication.

It is the responsibility of the user of this document to establish health and safety practices appropriate to the specific circumstances involved with its use. ACI does not make any representations with regard to health and safety issues and the use of this document. The user must determine the applicability of all regulatory limitations before applying the document and must comply with all applicable laws and regulations, including but not limited to, United States Occupational Safety and Health Administration (OSHA) health and safety standards.

Participation by governmental representatives in the work of the American Concrete Institute and in the development of Institute standards does not constitute governmental endorsement of ACI or the standards that it develops.

Order information: ACI documents are available in print, by download, through electronic subscription, or reprint and may be obtained by contacting ACI.

Most ACI standards and committee reports are gathered together in the annually revised the ACI Collection of Concrete Codes, Specifications, and Practices.

American Concrete Institute
38800 Country Club Drive
Farmington Hills, MI 48331
Phone: +1.248.848.3700
Fax: +1.248.848.3701

www.concrete.org

ACI PRC-309.5-22

Compaction of Roller-Compacted Concrete—Report

Reported by ACI Committee 309

Eamonn F. Connolly, Chair

Timothy P. Dolen
Christopher John Eagon
Chiara F. Ferraris
Dimitri Feys
John F. Gibbons
Vincent E. Hunt
Paul Jaworski
Hoa Lam
Patrick F. O'Brien Jr.
Larry D. Olson
H. Celik Ozyildirim
Steven A. Ragan
Luke A. Sevcik

Consulting Member

Jerome H. Ford

Roller-compacted concrete (RCC) is an accepted and economical method for the construction of dams and pavements. Achieving adequate compaction is essential to the development of the desired properties in the hardened material. The compaction depends on many variables, including the strength of the subbase, materials used in RCC, mixture design proportions, mixing and transporting methods, discharge and spreading practices, compaction equipment and procedures, and lift thickness. The best performance characteristics are obtained when the concrete is reasonably free of segregation; well-bonded at construction joints; and compacted at, or close to, maximum density.

This report summarizes experience in compaction of RCC in various applications and offers guidance in the selection of equipment and procedures for compaction, as well as for quality control of the work. Compaction equipment and procedures should be appropriate for the work. In dam or massive concrete applications, large, self-propelled, smooth, steel-drum vibratory rollers are most commonly used. The frequency and amplitude of the roller should be suited to the mixture and lift thickness required for the work. Other roller parameters, such as static mass, number of drums, diameter, ratio of frame and drum mass, speed, and drum drive influence the rate and effectiveness of the compaction equipment. Smaller equipment, and possibly thinner compacted lifts, are required for areas where access is limited.

Pavements are generally placed with paving machines that produce a smooth surface and some initial compacted density. Final density is obtained with vibratory rollers. Rubber-tired rollers can also be used where surface tearing and cracks would occur from steel-drum rolling. The rubber-tired rollers close fissures and tighten the surface.

Inspection during placement and compaction is also essential to ensure the concrete is free of segregation before compaction and receives adequate coverage by the compaction equipment. Testing is then performed on the compacted concrete on a regular basis to confirm that satisfactory density is consistently achieved. Corrective action should be taken whenever unsatisfactory results are obtained. Roller-compacted concrete offers a rapid and economical method of construction where compaction practices and equipment are a major consideration in both design and construction.

Keywords: compaction; consolidation; dams; pavements; roller-compacted concrete.

CONTENTS

ACI PRC-309.5-22 supersedes ACI 309.5R-00(06) and was adopted and published July 2022.

CHAPTER 1—INTRODUCTION

1.1—Introduction

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. The production of RCC provides a rapid method of concrete construction similar in principle to soil-cement and other earthwork construction. Roller-compacted concrete technology developed considerably in the 1980s, after early research by Cannon (1972), Dunstan (1977), and Hall and Houghton (1974), and the development of the roller-compacted dam (RCD) method in Japan in the 1970s. Also in the 1980s, RCC found application in roadways and parking areas, and was developed as a heavy-duty paving material for log sorting yards, tank hardstands, railroad sorting yards, and other industrial pavements. Detailed information on the use of RCC in mass concrete and paving applications is contained in ACI 207.5R (Report on Roller-Compacted Mass Concrete) and ACI 327R (Guide to Roller-Compacted Concrete Pavements), respectively.

1.2—Scope

This report discusses the equipment and special construction procedures associated with the compaction of RCC, including characteristics of the mixture relevant to compaction and the effects of compaction on the desired properties of RCC. These properties include various strength parameters, watertightness, and durability. Differentiation is made between RCC used in massive concrete work and that used in pavements. The discussion also includes provisions for measurement of compaction. This report does not cover soil-cement or cement-treated base.

1.3—Description of RCC construction

Roller-compacted concrete gets its name from the heavy vibratory steel drum and rubber-tired rollers used to compact it into final form. Fresh RCC is stiffer than typical zero-slump conventional concrete, with a consistency that is stiff enough to remain stable under vibratory rollers, yet plastic enough to permit adequate mixing and distribution of paste and placement without segregation. RCC pavements are 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. For RCC dams, multiple lifts of concrete, generally 1 ft (300 mm) thick, are often continuously placed and compacted to construct a cross section that is a conventional concrete gravity dam. Variations in placing and compaction methodology have evolved in the past 20 years. For example, the sloping layer method (SLM) is to place five to 10 consecutive lifts on slopes ranging as steep as 20 horizontal to one vertical (H:V) to as flat as 50H:1V instead of horizontal lifts. Another RCC placing method, used primarily in Japan, is to spread three or more thin (approximately 9 in. [230 mm]) layers with a bulldozer before compacting them into one thick lift with a vibratory roller. One significant difference between an RCC dam and a conventional concrete dam is RCC dams are continuously placed from one abutment to the other, or within a series of larger (than typical dam) monoliths. A horizontal construction joint is produced between each lift in the RCC dam. In paving applications, individual lanes of concrete are placed adjacent to each other. The procedure is similar to asphalt-paving techniques. In some instances, two or more lifts of RCC are quickly placed and compacted to construct a thicker monolithic pavement section for heavy-duty use. Roller-compacted concrete is an economical, fast construction candidate for many pavement applications (Cannon 1972).

Several steps are required to achieve proper compaction of RCC construction:

1. A trial mixture should be developed to determine the water content necessary for optimal Vebe consistency

(ASTM C1170/C1170M) and density (ASTM C1170/C1170M) for each application.

2. A trial section should be constructed to validate the number of passes and establish the required moisture content and density.

3. The RCC should be placed on freshly compacted material, or if the surface is not freshly compacted, it can have several different lift surface treatments depending on the maturity of the previously placed lift. This can range from simple air-blowing, to vacuum cleaning, to full treatment as a cold joint.

4. For dams, roll from one abutment to the other continuously.

5. Consolidate the dam facing concrete, if used, and the interface between the dam facing and the freshly placed and compacted RCC. Refer to ACI 207.5R for various types of dam facing. For pavements, the top lift should be placed within 60 minutes of the lower lift (although this interval is dependent on the mixture and environmental conditions) to allow for adequate bonding between layers.

6. Roll the proper number of passes before placing the next lift.

7. Use a tamper or small compactor along edges where a roller cannot operate.

8. Record test results and maintain a site quality-control program.

1.4—Importance of compaction

The effect of compaction on the quality of RCC is significant. Higher density relates directly to higher strength, lower permeability, and other important properties. RCC mixtures are generally proportioned near the minimum paste content to fill voids in the aggregate, or at a water content that produces the maximum density when a compactive effort equivalent to the modified Proctor procedure (ASTM D1557) is applied. The use of RCC in either massive structures or pavement construction needs to address the compaction of each lift because of its influence on performance. Failure to compact the concrete properly can lead to greater risk of seepage paths and reduce the stability in RCC dams or reduce the service life of RCC pavements. Using the "maximum density" theory for soils compaction, RCC for dams would have a moisture content that is 1 to 2% "wet of optimal," whereas RCC pavements are proportioned closer to "optimal" for density. This difference is due to the thicker lifts and larger aggregate common in dams compared to pavements, where segregation of the coarse aggregate and difficulty in compacting thicker lifts is a concern.

In the 1980s, core sampling from RCC dams revealed instances of voids and low density in the lower one-third of lifts of RCC that had been placed and compacted in 1 ft (300 mm) lifts (Drahushak-Crow and Dolen 1988). Although lower density at the bottom of lifts can be attributed to lack of compactive effort, it is more commonly due to insufficient workability for full-depth compaction and segregation of the mixture during the construction process. This causes excessive voids in the RCC placed just above the previously compacted lift. Segregation is a major concern in dams because it can lead to greater risk of seepage and the potential for a continuous lift of poorly bonded RCC from one abutment to the other, which could affect the sliding stability. Roller-compacted concrete dams constructed in earthquake zones can also require tensile strength across the horizontal joints to resist seismic loading. At Willow Creek Dam, seepage through a non-watertight upstream face and segregation at lift lines required remedial grouting (USACE 1984). This RCC dam was considered safe from a sliding stability standpoint due to its conservative downstream slope of 0.8 horizontal to 1.0 vertical. The construction of RCC arch-gravity dams with very steep downstream slopes necessitates bonding across lift joints and is critical to the stability of these structures. It is now common in RCC dams to have a Vebe consistency ranging from 10 to 20 seconds in accordance with ASTM C1170/C1170M using a 27.5 lb (12.5 kg) surcharge. Some mass mixtures are being placed at higher Vebe consistency and others are being placed with Vebe times less than 10 seconds and may even use internal vibration adjacent to formwork (Dolen et al. 2019).

In pavements, flexural strength is dependent on thorough compaction at the bottom of the pavement section, while durability is dependent on the same degree of compaction at the exposed surface (Amer et al. 2004; Delatte and Storey 2005). Furthermore, construction joints between paving lanes are locations of weakness and are particularly susceptible to deterioration caused by freezing and thawing, unless good compaction is achieved.

CHAPTER 2—DEFINITIONS

2.1—Definitions

Please refer to the latest version of ACI Concrete Terminology for a comprehensive list of definitions.

The terms "compaction" and "consolidation" have both been used to describe the densification process of freshly mixed concrete or mortar. In ACI 309R, "consolidation" is the preferred term used for conventional concrete work. For the purposes of this document on RCC, however, the term "compaction" will be used for all types of RCC mixtures because it more appropriately describes the method of densification.

CHAPTER 3—MIXTURE PROPORTIONS

3.1—General

Roller-compacted concrete (RCC) mixtures should be proportioned to produce concrete that will readily and uniformly compact into a dense material with the intended properties when placed at the design lift thickness. Procedures for proportioning RCC mixtures are provided in ACI 211.3R, ACI 207.5R for mass concrete, and ACI 327R. Also, the mixture design process should consider the desired engineering properties, construction requirements, and economics. This can be completed using several mixture proportioning methods that have been used successfully for roller-compacted concrete pavement (RCCP) structures. However, the most common mixture proportioning methods