Report on Roller-Compacted Concrete Pavements

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This report covers the present state of the art for roller-compacted concrete pavements. It contains information on applications, material properties, mix proportioning, design, construction, and quality control procedures. Roller-compacted concrete use for pavements is relatively recent and the technology is still evolving. The pavement consists of a relatively stiff mixture of aggregate, cementitious materials, and water, that is compacted by rollers and hardened into concrete.

Keywords: Aggregates; cements; compaction; concrete construction; concrete durability; concrete pavements; consolidation; curing; construction joints; density; mixing; placing; Portland cement; roller compacted concrete, strength.

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CHAPTER 1—INTRODUCTION

This state-of-the-art report contains information on applications, material properties, mix proportioning, design, construction, and quality control procedures for roller compacted concrete pavements (RCCP). Roller compacted concrete (RCC) use for pavements is relatively recent and the technology is still evolving. Over the last ten years several major pavement projects have been constructed in North America using RCC and the performance of these pavements has generally been favorable. Roller compacted concrete pavements are also gaining acceptance in several European countries and Australia.

The advantages of using RCC include cost savings as a result of the construction method and the increased placement speed of the pavement. RCC pavements do not use dowels, steel reinforcement, or forms. This also results in significant savings when compared to the cost of conventionally constructed concrete pavements.

Roller compacted concrete is used in two general areas of engineered construction: dams and pavements. In this document, RCC will be discussed only in the context of its use in pavements. RCC for mass concrete is discussed in ACI 207.5R.

Roller compacted concrete for pavements can be described as follows:

> A relatively stiff mixture of aggregate [maximum size usually not larger than $^3/_4$ in. (19 mm)], cementitious materials and water, that is compacted by vibratory rollers and hardened into concrete. When RCC is used as a surface course, a minimum compressive strength of 4000 psi (27.6 MPa) is generally specified.

The materials for RCC are blended in a mixing plant into a heterogeneous mass which has a consistency similar to damp gravel or zero slump concrete. It is placed in layers usually not greater than 10 in. (254 mm) compacted thickness, usually by an asphalt concrete paving machine. The layers are compacted with steel wheel vibratory rollers, with final compaction sometimes provided by rubber tire rollers. The pavement is cured with water or other means to provide a hard, durable surface. RCC pavements are usually designed to carry traffic directly on the finished surface. A wearing course is not normally used, although a hot mix asphalt overlay has been added, in some cases, for smoothness or rehabilitation. Transverse and longitudinal contraction joints for crack control are not usually constructed in RCC pavements.

RCCP has been used for a wide variety of applications. These include log sorting yards, lumber storage, forestry and mining haul roads, container intermodal yards, military vehicle roads and parking areas, bulk commodity (coal, wood chips) storage areas, truck and automobile parking, and to a lesser extent, municipal streets, secondary highways, and aircraft parking ramps.

CHAPTER 2—BACKGROUND

The first RCC pavement in North America was identified by the Seattle office of the U.S. Army Corps of Engineers. The project was a runway at Yakima, Washington, constructed around 1942. A form of roller compacted concrete paving was reported in Sweden as early as the 1930s.[1]

The first RCC pavement in Canada was built in 1976 at a log sorting yard at Caycuse on Vancouver Island, British Columbia. The decision to build RCC was the outgrowth of a pavement design which called for a 14 in. (356 mm) thick cement stabilized aggregate base and 2 in. (51 mm) asphalt concrete surface. As an alternative to the asphalt concrete surface, the owners decided to increase the cement content of the top 6 in. (152 mm) of cement stabilized material to 13 percent by weight to improve wear and freeze/thaw resistance. Cement content in the 8 in. (203 mm) base layer was set at 8 percent. The final result was a 4 acre (1.6 hectares) log sorting yard with an exposed, cement stabilized crushed gravel operating surface. No bonding grout was used between the two cement stabilized layers. Special effort was made by the contractor to complete both layers on the same day. Some minor delamination occurred after a few years of log stacker traffic. This observation lead to the requirement for a limitation on the maximum time between lifts. The

Caycuse Log Sorting yard has been in continuous use since 1976. The area of RCC pavement was doubled to 9 acres (3.6 hectares) in a 1978 expansion. A thin asphalt overlay was applied in 1987 as a minimum cost maintenance operation to improve pavement smoothness.

Following the success of the paving at Caycuse, three more RCC dry-land log sorting yards were built on Queen Charlotte Islands off the coast of British Columbia during 1976 to 1978. These pavements continue to perform well with little maintenance. By 1980 nearly 20 acres (8 hectares) of log sorting yards constructed with RCC were in operation in British Columbia. The next milestone in Canadian RCC pavement history came when a decision was made to build 12 miles (19.3 kilometers) of 7 in. (179 mm) thick RCC pavement for a coal mine haul road at Tumbler Ridge in British Columbia. A 4 acre (1.6 hectares) coal storage area was also built with a 9-in.-thick (229 mm) roller compacted concrete. The haul road was surfaced with bituminous concrete while the storage area remains as an exposed RCC pavement. This region of British Columbia undergoes severe winter conditions, with frost penetration to a depth of 8 ft (2.4 m). No distress from the severe winter climate is evident at the coal storage area, although some failures have occurred in the loaded wheel paths of the haul road.

While these developments were going on in Canada, there was growing interest in RCC by various organizations in the United States where RCC for dams was being evaluated in several test projects. During the early 1980s, engineers at the United States Army Corps of Engineers started studying the use of RCC for pavement construction at military facilities. A small test road for tracked vehicles, 9 in. to 13 in. (229 mm to 330 mm) thick, 470 yd^2 (392 m^2) was built at Ft. Stewart, Georgia, in 1983, and a tank test road 10 in. to 13 in. (254 mm to 330 mm), 590 yd^2 (493 m^2), was constructed at Ft. Gordon, Georgia, in the same year. RCC test road construction by the Corps of Engineers continued in 1984 when 1870 yd^2 (1564 m^2) of 8.5 in. (216 mm) thick pavement was built for a tank trail at Ft. Lewis, Washington.

In 1984, the question of freeze/thaw durability of RCC remained to be addressed. The Corps of Engineers constructed a full scale test pavement at the Cold Regions Research Engineering Laboratory in Hanover, New Hampshire, where a complete range of climatic conditions could be simulated. The test program was successful, and in a memorandum to all field offices, dated Jan. 25, 1985, the use of RCC paving for "horizontal construction" was encouraged, where appropriate, for all facilities administered by the Corps of Engineers.[2]

The first full scale RCC pavement designed and built by the Corps of Engineers was a tactical equipment hardstand at Ft. Hood, Texas, in 1984.[3] The area of the project was 18,150 yd^2 (15,175 m^2). A 10 in. (254 mm) thick slab was specified and a flexural strength of 800 psi (5.5 MPa) was achieved. This project provided the Corps of Engineers with valuable information about maximum aggregate size, single versus multiple lift construction methods, compaction procedures, curing and sampling of RCC material. During 1986, the Corps of Engineers built a tracked vehicle hardstand at Ft. Lewis, Washington. The area of the pavement was 26,000 yd^2 (21,753 m^2) with a thickness of 8.5 in. (216 mm).

The interest in RCC heavy duty pavement began to expand beyond the logging and mining industries by the mid-1980s. The Burlington Northern Railroad selected RCC for 53,000 yd^2 (44,313 m^2) of paving at a new intermodal facility at Houston, Texas in 1985,[4] and 128,000 yd^2 (107,021 m^2) of intermodal yard paving at Denver, Colorado, in 1986. In 1985 the Port of Tacoma, Washington, constructed two areas of RCC pavement totalling 17 acres (6.9 hectares).[5,6] Also, large areas of RCC pavement were constructed at the Conley and Moran Marine Terminals in Boston between 1986 and 1988.

The largest RCC pavement projects undertaken to date include the more than 650,000 yd^2 (543,464 m^2) of 8 and 10 in. -(203 and 254 mm) thick RCC pavement placed at the General Motors Saturn automobile plant near Spring Hill, Tennessee, and 89 acres (36 hectares) of 10 in.- (254 mm) thick RCC pavement placed at Ft. Drum, NY. Both were constructed in 1988-89 and were used as parking areas and roads.

Apart from the reported use of RCC at Yakima, Washington, in 1942, the only example of an airport installation is at the Portland International Airport in 1985.[7,8] The 14-in. (356 mm) RCC pavement with an area of 9 acres (3.6 hectares) is used for overflow short term aircraft storage.

There has been a growing interest in the use of RCC paving for low to moderate traffic streets, and secondary highways. Municipal street pavements have been built in Portland, Oregon; Regina, Saskatchewan; and Mackenzie, British Columbia.

Fig. 2.1 to 2.4 illustrate typical RCC pavement practices. Fig. 2.5 illustrates typical RCC pavement surface at Ft. Drum, New York, and Fig. 2.6 shows a close-up of the pavement surface adjacent to a sawed longitudinal construction joint. Fig. 2.7 shows a close-up of an acceptable RCC pavement surface at Ft. Bliss, Texas, and Fig. 2.8 shows a close-up of an excellent RCC pavement surface.

CHAPTER 3—MATERIALS

3.1—General

Pavement design strength, durability requirements, and intended application all influence the selection of materials for use in RCC pavement mixtures. The basic materials used to produce RCC include water, cementitious materials (cement and fly ash), and fine and coarse aggregates. Generally, the cost of materials selected for use in RCC pavements is almost the same as the cost of materials used in conventional portland cement concrete. However, some material savings may be possible due to the lower cement contents normally needed in RCC pavement mixtures to achieve strengths equivalent to those of conventional concrete.

3.2—Aggregates

The aggregates comprise approximately 75 to 85 percent of the volume of an RCC pavement mixture and therefore significantly affect both the fresh and hardened concrete

Fig. 2.1—RCC placement using modified asphalt pavers

Fig. 2.2—Vibratory roller compaction

properties. Proper selection of suitable aggregates will result in greater economy in construction and longer serviceability of RCC pavements. In freshly mixed RCC, aggregate properties affect the workability of a mixture and its potential to segregate and the ease with which it will properly consolidate under a vibratory roller. The strength, modulus of elasticity, thermal properties, and durability of the hardened concrete are also affected by the aggregate properties.

Aggregates used in RCC pavement mixtures contain both fine [finer than the 4.75 mm (No.4) sieve] and coarse fractions, although the fractions may be preblended and stockpiled as a single aggregate on large projects. The coarse aggregate usually consists of crushed or uncrushed gravel, crushed stone, or a combination thereof. The fine aggregate may consist of natural sand, manufactured sand, or a combination of the two.

For high quality RCC, both the coarse and fine aggregate fractions should be composed of hard, durable particles and the quality of each should be evaluated by standard physical property tests such as those listed in ASTM C 33. If lower