Joints in Roller Compacted Concrete Pavements

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Abstract—Today, many roller compacted concrete pavements (RCCP) have been constructed in some parts of the world. RCC has recognized to be a reliable, economical and durable material for low speed and heavy-duty pavements. This innovative pavement has been used in urban street reconstruction, on residential subdivision roads, hard stands, commercial and industrial sites, automobile manufacturing facilities and interstate shoulders. Concrete is a material which is strong in compression, but relatively weak when placed in tension. Tensile stresses may build up in concrete pavements because of shrinkage during the hydration process, temperature and moisture changes, and/or traffic loadings. When the tensile Stresses are great enough, cracks occur. Joints are often used as a means of relieving stresses to control cracking. Joints can also serve to protect adjacent structures or to accommodate paving operations. With regarding to the importance of Joints, in this paper the joints, types of joints and its related matters are investigated.

Keywords—Concrete Pavement, Roller Compacted Concrete Pavement (RCCP), Joints.

I. INTRODUCTION

ROLLER Compacted Concrete (RCC) is a relatively new technology, although documents of its use in the reconstruction of estate roads in England go back to early 1940s. Over the past three decades RCC has been used in more than 100 projects. RCC is a durable, economical, and reliable technology in the construction of low speed heavy duty pavements, and has been employed successfully in many purposes, such as Storage areas, roads, Highway weigh stations, Airport aprons, container ports, Multimodal facilities, and Heavy industrial facilities such as logging and automobile manufacturing [1].

Roller-compacted concrete is one of JPCP- Jointed plain concrete pavement -pavements that is a zero-slump concrete consisting of dense-graded aggregate and sand, Portland cement, and water. Because it contains a relatively small amount of water, it cannot be placed by the same methods used for conventional Portland cement concrete (PCC). For pavement applications, RCC is usually placed with an asphalt paver, and density is achieved through compaction with a vibrating roller.

The principal advantages of RCC pavements are derived from the construction process used to create them. Construction costs are lower because there is less labor involved in placing the concrete (no formwork or finishing is required), and no reinforcing steel or dowels are used. With the low water-cement ratio there is less paste in the concrete matrix, so there is no bleed water and less shrinkage than in conventional PCC. The dominant role of aggregate in the concrete provides load transfer across control joints and cracks by using aggregate interlock, which eliminates the need for load transfer devices [2].

II. TYPES OF JOINTS IN RCC PAVEMENTS

A. Fresh vertical joints

A vertical joint shall be considered a fresh joint when an adjacent RCC lane is placed within 60 minutes of placing the previous lane, with the time adjusted depending on use of retarders or ambient conditions. Fresh joints do not require special treatment.

B. Cold vertical joints

Any planned or unplanned construction joints that do not qualify as fresh joints shall be considered cold joints and shall be treated as follows:

Longitudinal and Transverse Cold Joints are the Formed joints that do not meet the minimum density requirements and all unformed joints shall be cut vertically for the full depth. The vertical cut shall be at least 150 mm from the exposed edge. Cold joints cut within two hours of placement may be cut with an approved wheel cutter; motor grader or other approved method provided that no significant edge raveling occurs. Cold joints cut after two hours of placement shall be seeing cut 1/4 to 1/3 depth of the RCC pavement with the rest removed by hand or mechanical equipment. Any modification or substitution of the saw cutting procedure must be demonstrated to and accepted by the Engineer. All excess material from the joint cutting shall be removed [3].

Load transfer at longitudinal joints is achieved through aggregate interlock. Longitudinal joints should be tied with tie bars to prevent lane separation and/or faulting. The tie bars should be mechanically inserted and placed at mid-depth. When using Grade 40 steel, 5/8-inch by 30-inch or 1/2-inch by 24-inch tie bars should be used. When using Grade 60 steel, 5/8-inch by 40-inch or 1/2-inch by 32-inch tie bars should be used. These lengths are necessary to develop the allowable working strength of the tie bar. Tie bar spacing will vary with the thickness of the pavement and the distance from the joint to the nearest free edge [4].

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Prior to placing fresh RCC mixture against a compacted cold vertical joint, the joint shall be thoroughly cleaned of any loose or foreign material. The vertical joint face shall be wetted and in a moist condition immediately prior to placement of the adjacent lane [3].

In Multi-lift Construction, the top layer shall be placed so that longitudinal joints in that layer will coincide with joints in the lower layers of the pavement. Transverse joints in the top layer shall coincide with transverse joints in the lower layers of the pavement [5].

C. Fresh horizontal joints.

For multi-layer construction a horizontal joint shall be considered a fresh joint when a subsequent RCC lift is placed within 60 minutes of placement of the previous lift. This time may be adjusted at the discretion of the Engineer depending on use of retarders or ambient weather conditions. Fresh joints do not require special treatment other than cleaning the surface of all loose material and moistening the surface prior to placement of the subsequent lift.

C.1. Horizontal Cold Lift Joints

For horizontal cold joints the surface of the lift shall be kept continuously moist and cleaned of all loose material prior to placement of the subsequent lift. The Engineer may require other action such as use of a cement slurry or mortar grout between lifts. If supplementary bonding materials are used, they shall be applied immediately prior to placement of the subsequent lift.

C.2. RCC Pavement Joints at Structures.

The joints between RCC pavement and concrete structures shall be treated as cold vertical joints.

D. Control joints (optional).

Control joints may be constructed in the RCC pavement to induce cracking at pre-selected locations. Joint locations shall be shown on the Plans or as directed by the Engineer. Early entry saws should be utilized as soon as possible behind the rolling operation and set to manufacturer’s recommendations. Conventionally cut control joints shall be saw cut to 1/4 depth of the compacted RCC pavement. Joints shall be seen cutting as soon as those operations will not result in significant raveling or other damage to the RCC pavement [3].

Cracks will develop in an RCC pavement slab as a natural result of the shrinkage process during curing. These cracks will normally occur on a random basis every 9-21 meters. Because there is no bleed water in RCC, there is less shrinkage cracking than that which occurs with conventional concrete.

The shrinkage cracks that occur in RCC pavements are usually small (less than 3 mm) and very good load transfer exists across the crack through aggregate interlock. This aggregate interlock is enhanced through the use of the dense-graded aggregates that are specified for RCC mixes. Long-term performance studies of RCC pavements have shown almost no evidence of crack faulting (the vertical displacement of the pavement slab at the crack), which provides further indication of the load transfer provided by aggregate interlock.

To improve the appearance of the final RCC product, control joints can be sawn every 8-12 meters to eliminate most of the random shrinkage cracking. Early-entry saw cutting can be performed on RCC usually within a few hours of compaction. Because of the load transfer provided by aggregate interlock, dowel bars are not used at control joints [6].

If the RCC is allowed to crack naturally, the first cracks will appear within 24 hours of placement and will typically be spaced from 9 to 21 m apart. To control this cracking and create a more aesthetically pleasing concrete surface, control joints should be constructed using early entry saws to a depth of 1/4 to 1/3 of the total layer thickness usually within two to three hours. PCA recommends that control joints be spaced no more than 6 m apart. Naturally occurring (uncontrolled) cracks are usually not sealed; sawed joints usually are sealed [7].

III. JOINT AND SEALANT PROPERTIES

A joint is a designed crack. Concrete pavements will crack due to shrinkage and temperature differences. The purpose of joint sawing and sealing is to ensure that cracks form at the proper locations and will be easy to maintain. Generally, transverse joints in JPCP or JRCP are initiated by sawing through the surface slab to create a plane of weakness. Joints are often sealed to reduce the amount of water flowing through the pavement and to prevent incompressible material, such as small stones, from becoming trapped in the pavement joint. Incompressible materials can lead to chips or spalls when joints close as temperatures increase [8].

The purpose of a joint sealant is to deter the entry of water and incompressible material into the joint and the pavement structure. It is recognized that it is not possible to construct and maintain a watertight joint. However, the sealant should be capable of minimizing the amount of water that enters the pavement structure, thus reducing moisture-related distresses such as pumping and faulting. Incompressible should be kept out of the joint. These incompressible prevent the joint from closing normally during slab expansion and lead to spilling and blowups.

Sealant behavior has a significant influence on joint performance. High-type sealant materials, such as silicone and preformed compression seals, are recommended for sealing all contraction, longitudinal, and construction joints. While these materials are more expensive, they provide a better seal and a longer service life. Careful attention should be given to the manufacturer's recommended installation procedures. Joint preparation and sealant installation are very important to the successful performance of the joint. It is therefore strongly recommended that particular attention be given to both the construction of the joint and installation of the sealant material.

When using silicone sealants, a minimum shape factor (ratio of sealant depth to width) of 1:2 is recommended. The maximum shape factor should not exceed 1:1. For best results, the minimum width of the sealant should be 3/8 inch.
The surface of the sealant should be recessed 1/4 to 3/8 inch below the pavement surface to prevent abrasion caused by traffic. The use of a backer rod is necessary to provide the proper shape factor and to prevent the sealant from bonding to the bottom of the joint reservoir. This backer rod should be a closed-cell polyurethane foam rod having a diameter approximately 25 percent greater than the width of the joint to ensure a tight fit.

When using preformed compression seals, the joint should be designed so that the seal will be in 20 to 50 percent compression at all times. The surface of the seal should be recessed 1/8 to 3/8 inch to protect it from traffic [4].

IV. JOINT PLACEMENT

The placement of pavement joints can greatly affect the overall performance of a concrete pavement. This is especially true for jointed concrete pavements. If the joint layout is not properly designed, uncontrolled cracking can occur. IDOT has developed standard joint layouts, but special conditions may exist that require a site specific joint layout design.

When adjacent lanes are to be constructed in stages it is important to plan the layout of the joints before any pavement is placed. Sometimes new pavement is constructed adjacent to existing pavement. When this occurs the designer must make provisions in the plans to match the existing joints. A detailed joint survey prior to plan preparation can help to avoid problems [9].

V. THE PROPER JOINT SPACING FOR RCC PAVEMENTS

There have been many RCC pavement projects that have been built without contraction joints and have performed satisfactorily. In particular, industrial pavements where appearance is not a major concern and the design incorporates the random cracking, contraction joints have been eliminated for economic reasons. Random cracks will typically form from about 30 ft (9 m) to more than 60 ft (18 m) apart. Since it is impractical to install dowel bars in RCC, the load transfer is provided through aggregate interlock. Crack openings that form randomly at long spacing tends to be wide and consequently will provide less aggregate interlock than closely spaced cracks.

For projects where crack control is important, contraction joints are used to control the location of cracking in the concrete. Joint spacing should follow similar concepts as used for conventional concrete pavement. Because RCC has less shrinkage than conventional concrete, the control joints can be spaced further apart. Proper joint spacing depends on pavement thickness, concrete and sub base properties, aggregate type and climatic conditions.

Current practice for RCC pavements is to space control joints from 20 ft (6m) to 30 ft (9m). As a rule of thumb, transverse joint spacing should be about 40 times the pavement thickness with a maximum spacing of 30 ft (9 m). The reason for the 30 ft (9m) maximum spacing is to ensure that the shrinkage cracks are narrow enough to provide adequate load transfer.

It is also important to keep the slabs as square as possible. Transverse joint spacing should not exceed 125% to 150% of the longitudinal joint spacing. Joints should be sawn as soon as the concrete has obtained adequate strength to resist raveling of the joint edges. Early entry saws work best for this type of work, and can often be used within 2-3 hours after compaction. The depth of the saw cut should be at least one-fourth the thickness of the slab (D/4) and have a minimum width of 1/8 in (3 mm) [10].

VI. SAWING THE JOINTS

Sawed contraction joints for controlling random cracking are not required in RCC pavements due to the fact that RCC has lower water and cement contents than conventional concrete, and thus shrinkage is reduced. Random shrinkage cracks typically occur at 20- to 60-ft intervals, depending on the RCC properties and pavement thickness.

The primary reason for sawing joints in RCC pavements (Fig.1) is to reduce or prevent random cracking. On certain projects where efficiency of aggregate interlock or increased load transfer at the joints is critical, joints are sawed to minimize crack openings through reduced saw joint spacing, compared to longer spacing of random cracks. Widely spaced random cracks can have wider than desired crack width. The improved aggregate interlock increases load transfer across the joint. Furthermore, reducing random cracking is sometimes desired for aesthetic reasons.

When used, transverse sawed joints are typically spaced at intervals of 15 to 20 ft for pavements less than 8 in. thick, and 3 to 4 times (in ft) the pavement thickness (in inch) for pavements 8 in. thick or greater.

Fig.1 Cutting joint with early-entry saw

As with conventional concrete, the timing of saw cuts is based on the prevention of raveling and random cracking. Sawing should begin as soon as the concrete is hard enough to withstand spilling damage caused by sawing operations. For increased load transfer through aggregate interlock, the depth of the saw cuts should not exceed 1/4 of the pavement depth. Thin early-entry saws are being used more frequently because of the speed and convenience they offer. Sawing can begin within one to four hours after final compaction. The saw cut depth for early-entry sawing ranges from 1 to 1.25 in. regardless of the pavement thickness[11].
VII. CONCLUSION

Roller-compacted concrete (RCC) is one of jointed plain concrete pavements that is a zero-slump concrete consisting of dense-graded aggregate and sand, Portland cement, and water. Because it contains a relatively small amount of water, it cannot be placed by the same methods used for conventional Portland cement concrete (PCC). When adjacent lanes are to be constructed in stages it is important to plan the joints before any pavement is placed.

The placement of pavement joints can greatly affect the overall performance of a concrete pavement. This is especially true for jointed concrete pavements. If the joint layout is not properly designed, uncontrolled cracking can occur. Thus for reasons such as control random cracking, prevent concrete structures from damage caused by plastic shrinkage, thermal shrinkage, settlement, movement, improving appearance and providing mechanism for regularly spaced thin crack for improving of aggregate interlock, the jointing seems to be necessary.

Joint spacing for RCC pavements should follow similar concepts as used for conventional concrete pavement. Because RCC has less shrinkage than conventional concrete, the control joints can be spaced further apart. Proper joint spacing depends on pavement thickness, concrete and sub base properties, aggregate type and climatic conditions. In general, transverse joint spacing should not exceed 125% to 150% of the longitudinal joint spacing.

Joints should be sawn as soon as the concrete has obtained adequate strength to resist raveling of the joint edges.

REFERENCES