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Continuously Reinforced Concrete Pavement Performance and Best Practices

INTRODUCTION

Continuously reinforced concrete pavement (CRCP) is enjoying a renaissance across the United States and around the world. CRCP has the potential to provide a long-term, "zero-maintenance," service life under heavy traffic loadings and challenging environmental conditions, provided proper design and quality construction practices are utilized. (An example of CRCP construction is shown in figure 1.) This TechBrief provides an overview of the CRCP technology and the major developments that have led to what are referred to herein as

FIGURE 1. A continuously reinforced concrete pavement under construction.

the "best practices" for CRCP design and construction.

CRCP DESIGN

CRCP differs from other concrete pavements as follows:

1. CRCP has no active transverse contraction joints, except at ends.
2. Continuous longitudinal reinforcement is provided that results in tight cracks in the concrete at about 2-ft to 8-ft (0.6 m to 2.4 m) spacing. Sufficient reinforcement is necessary to keep the cracks tight.
3. CRCP can extend, joint free, for many miles with breaks provided only at structures, such as bridges.

CRCP design focuses on managing the cracking that develops so as to reduce the structural distress that may develop as a result of traffic and environmental loadings. These distresses include punchouts, steel rupture, and crack spalling.

CRCP design involves determining the proper combination of slab thickness, concrete mixture constituents and properties, and steel reinforcement content and location; providing for sufficient slab edge support; strengthening or treating the existing soils; providing non-erodible bases that also provide friction that leads to desirable transverse cracking patterns. While most of these features are common to all good pavement designs, reinforcement and edge support are particularly critical to a CRC pavement.

Several highway agencies have implemented the new mechanistic-empirical pavement design procedure and the associated Pavement ME Design software (formerly DARWin-ME™) for design of CRC pavements (available from the American Association of State Highway and Transportation Officials (AASHTO)). However, several other highway agencies continue to use AASHTO's 1993 Pavement Design Guide for design of CRC pavements.

Reinforcement

CRCP is a unique rigid pavement in that it has no constructed transverse contraction or expansion joints except at bridges or at pavement ends. The use of longitudinal steel reinforcement, typically Grade 60 bars (see figure 2), results in a series of closely spaced transverse cracks. The steel reinforcement is used to control the crack spacing and the amount of opening at the cracks and to maintain high levels of load transfer across them. Modern CRCP is built with longitudinal reinforcing steel percentages in the range of 0.65 to 0.80 percent (lower in milder climates, higher in harsher). Equally important as the percentage of steel content is the bond area between the concrete and the bars, which the Federal Highway Administration (FHWA) recommends at a minimum of 0.030 square inch per cubic inch of concrete (FHWA 1990).

FIGURE 2. View of concrete reinforcement using Grade 60 bars.

Most transverse cracks form at very early ages before a pavement is open to traffic, and cracking may continue for several years after concrete placement. Transverse cracks occur when and where the tensile stress, due to the restrained volume changes in the concrete, exceeds the concrete's developing tensile strength. New transverse cracks occur roughly at the midpoint between two previously formed cracks, where the maximum concrete stress occurs. Crack formation continues until concrete strength exceeds the stresses due to the restrained volume change. Recognizing that the tensile strength of the concrete and the tensile stresses vary along the length of the slab, the transverse crack spacing pattern is never uniform, but the majority of cracks should be spaced within a desired range (typically 2 to 8 ft (0.6 to 2.4 m)). Design steel content provides a balance between crack width (< 0.02-inch at surface over design life), crack spacing, and crack load-transfer capability.

Vertical placement of the bars also affects performance—placed too high, the bars may corrode due to inadequate cover; placed too low, the bars are too far away to keep the cracks tight at the surface. It is common to position the reinforcment between one-third and one-half the slab thickness measured from the pavement surface (CRSI 2009). The chairs or bar supports must be stable and should not sink into the base prior to paving.

In modern CRCP, transverse bars are always used to support longitudinal reinforcement. The transverse bars are placed on bar supports, and the bars also keep tight any longitudinal cracking that may develop.

Edge Support / Shoulders

Proper edge support (tied concrete shoulder) adjacent to mainline CRCP reduces wheel load stresses and deflections, reducing the occurrence of punchouts; reduces longitudinal joint maintenance issues; reduces shoulder maintenance needs; and provides support for traffic detours.

It is a common practice in the United States to have shoulders be constructed of the same materials as the mainline pavement to facilitate construction, improve performance, and reduce maintenance costs. Another option gaining popularity is to provide a widened outside lane. Research indicates that the slab needs to be a minimum 13 ft (3.9 m) wide (to minimize longitudinal cracking) and be striped to 12 ft (3.7 m) to significantly reduce the stresses and deflections due to heavy truck traffic near the pavement edge. Use of asphalt shoulders was a practice in the past. However, the current best practice to improve the edge support is to use a tied-concrete shoulder or a widened outside lane.

End Treatments

Two types of end treatments, at structures, are used for CRCP:

1. Wide flange beam joint—This treatment serves as an expansion joint and allows the end to move freely as the concrete expands and contracts with changing temperature.
2. Anchor lugs—This treatment, consisting of several lugs below the slab and tied into the slab end, attempts to restrain any movement from taking place at the ends. The use of anchor lugs is not common in current practice due to the difficulty in construction and varied performance.

For short sections of CRCP, use may also be made of conventional doweled expansion joints as part of the approach slabs at a structure.

CRCP CONSTRUCTION

During construction, it is very important to focus on the bar placement, the concrete consolidation, and the concrete curing. Along with actual concrete strength, these are the elements with the largest impact on the transverse crack formation and thus the long-term performance of the CRCP.

FIGURE 3. Reinforcing bar supports.

Reinforcement Placement

Today, all bars are placed using what is called the "manual method," that is, steel placers install the bars by hand prior to paving. The placers ensure that the bars are supported in the specified vertical position, that the lap splices are of sufficient length, that the supports do not impede placing and consolidation of the concrete, and that the completed mat does not move during slip-form paving. The vertical position of the bars is set by the supports and diameters of the transverse and the longitudinal bars, and the tolerance is usually ±0.5 inch (13 mm). Horizontal spacing tolerances are less stringent, but it is important that longitudinal bar placement does not impede placement or consolidation of concrete.

Steel bars normally come in standard lengths of 60 ft (18.3 m) and must be lap-spliced to form a continuous longitudinal mat. In the past it was found that failures have occurred due to inadequate concrete compaction when all laps were located adjacent to each other. The lap-splicing patterns used today are either staggered or skewed.

The development of continuous bar supports, commonly known as transverse bar assemblies or TBAs, has led to speedier placement of the steel mat. A TBA is a transverse bar to which are welded steel supports, which serve as chairs, and U-shaped clips (see figure 3). The spacing of the clips along the bar matches that required of the longitudinal bars. When the longitudinal bars are installed into the clips, the clips hold them in position vertically and keep them from moving transversely, while allowing a bit of longitudinal movement. This system is more expensive than using individual bar supports, but it should decrease installation time significantly.

Concrete Placement

One key to a well-performing CRCP is a steady production rate with a steady supply of a uniform concrete mixture. The more uniform the concrete mixture, the more uniform the crack pattern—and thus the better the CRCP performance. Because the bar mat is in place in front of the paver, concrete delivery is always from one side of the paver (as shown in figure 4). In one method, the concrete is deposited from a truck or a mixer into a hopper, and then the hopper is lifted to place the concrete on a conveyor. The conveyor brings and deposits the concrete in front of the paving machine, where it is then spread, vibrated, and slipped. With a good amount of steel in the bar mat and the very stiff concrete mixtures that are used for

FIGURE 4. Side placement of concrete.

of the base and steel bars just in front of the paver, and whitewashing the asphalt base prior to placement of the reinforcement (as long as it does not reduce bonding and friction with the CRCP, as this will greatly affect crack spacing and width). The use of HIPERPAV® software at the construction site can provide relative information regarding expected CRCP cracking patterns if there are drastic temperature changes, and various remediation measures (changes in concrete mixture, curing techniques, etc.) can be implemented.

slip-form paving, it is very important to make sure the concrete is adequately vibrated and that there is good consolidation. Good consolidation provides the all-important steel–concrete bond; areas of poor consolidation quickly show up with undesirable crack patterns, such as intersecting and cluster cracking, and may lead to premature failure.

Concrete Curing

CRCP has been paved during both daytime and nighttime. Paving at nighttime when daytime temperatures would be very hot has shown to result in better performing CRCP because the development of heat of hydration and high ambient daytime temperatures due to solar radiation do not coincide. Better temperature specifications and temperature management during paving are leading to better performing CRCP. Specifications limit the concrete temperature to a range of 50 °F to 90 °F (10 °C to 32 °C). Other measures to reduce heat may include changing the concrete mixture constituents and proportions for lower heat of hydration, specifying wetting

CRCP PERFORMANCE

A well-performing CRCP can be identified by a reasonably regular transverse cracking pattern with desirable crack spacing (2 to 8 ft (0.6 to 2.4 m)) that in turn keeps the cracks tight and provides a high level of load transfer across the cracks (figure 5). Today's CRCP design details reduce or eliminate punchout occurrence. The slab contains concrete of sufficient strength and durability. The slab thickness is appropriately established for the traffic projections, and reinforcing steel is of proper size and amount and placed at the correct location. The foundation consists of uniform supporting, non-erodible layers and separation layers (typically hot-mix asphalt (HMA) concrete) with friction properties that lead to desirable transverse cracking patterns. The pavement edge is tightly sealed and well supported using a tied concrete shoulder. Or a widened slab may be used to move the critical stresses away from the edge. Table 1 lists historical performance problems, associated distress/failure mechanisms, and measures that can be taken to prevent their occurrence.

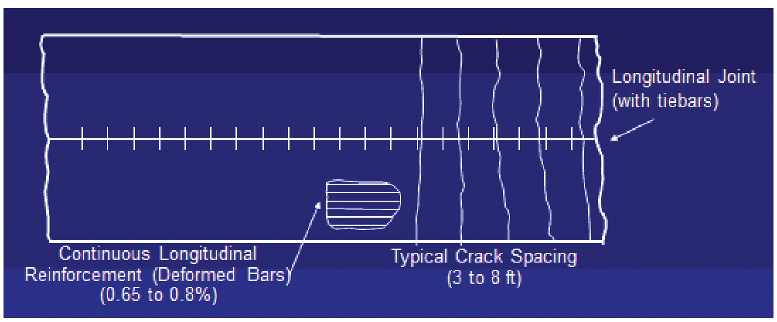

FIGURE 5. Above, CRCP cracking in a 25-year-old pavement, closely spaced and tight, as diagrammed below the photograph.

Experience in the States

Highway agencies in Illinois, Oklahoma, Virginia, North and South Dakota, Texas, and Oregon have used CRCP since the 1960s or 1970s. These are the agencies that, many times in partnership with the FHWA, have studied the technology in detail to learn the best way to build CRCP given the materials and climate and experiences unique to each State. Other highway agencies with significant past or current experience with CRCP are in the States of California, Georgia, and Louisiana. Summaries of the experiences in many of these agencies are included in the following sections.

California—California built its first experimental pavement in 1949, a 1-mi (1.6 km), two-lane westbound section on US-40 near the town of Fairfield. A second CRCP section was built in 1971. Recognition by the California Department of Transportation (DOT) (Caltrans) of the incredible performance of the more than 60- and 30-year-old sections, along with successful CRCP use around the United States, led the agency to adopt CRCP in its specifications, standard drawings, design catalog, and highway design manual starting in the mid 2000s. In a recent presentation, Caltrans pointed out the factors driving their interest in CRCP: smoothness, low maintenance costs, no transverse joints, thinner slab thickness relative to unreinforced concrete pavement, lower life cycle cost despite higher initial cost, and a higher capacity for truck loading and volumes.

Caltrans is expecting CRCP to be selected primarily for new highways, reconstruction of existing highways, and as overlays on projects in high truck-traffic areas, in remote locations where maintenance is difficult, and where long-term performance is important. Nearly a dozen projects have been recently let.

Georgia—The first CRCP projects in Georgia were built in 1969. In the early 2000s, when the Georgia DOT began an interstate highway reconstruction program, the department recognized the success it had had with CRCP performance and minimal maintenance. CRCP was considered a valuable component of the pavement selection process. Currently, the Georgia DOT design is full-depth (12 inches (305 mm)) or overlay (11 inches (280 mm)) CRCP, with 0.70 percent longitudinal steel content placed

TABLE 1. CRCP Historical Performance Concerns and "Modern CRCP" Design and Construction Practices

Historical Concern	Distress/Failure Mechanism	Preventative Solution
Pumping and loss of support due to permeable erodible bases, inconsistent soil stabilization, weak base	Localized cracking and failures and ultimately punchouts (can cause failure across multiple lanes)	Proper subsurface drainage systems, non-erodible bases (such as hot-mix asphalt concrete bases), proper stabilization of the base
Poor detailing, poor construction of transverse construction joints and transitions/end terminals	Localized cracking and failures	Revised specifications and plan details
Timing and depth of longitudinal saw cut, foundation movement	Longitudinal cracking	Proper saw-cut timing; proper saw-cut depth (1/3 of slab thickness); use of transverse steel to keep cracks tight, should they develop
Poorly consolidated concrete	Poor crack patterns, localized cracking and failures	Revised concrete specifications; monitoring of vibrator frequency; observation and test cores for air void system to determine the adequacy of consolidation; concrete delivered must be workable with adequate set time; staggered or skewed lap-splicing patterns
Poor finishing, poor curing, aggregate issues	Crack spalling	Better aggregates, enhanced curing, no over-finishing, and proper air entrainment in the concrete for projects in cold climates
Poor maintenance of pavement edge at shoulder	Edge punchouts	Tied concrete shoulders or widened slab (lane)
Horizontal cracking, delamination at the steel level	Localized cracking and crack deterioration failures and, ultimately, some type of structural punchouts	Appropriate bar size, amount and spacing; lower coefficient of thermal expansion concrete; adequate curing; reduced volumetric changes

no less than 3.5 inches (89 mm) or no more than 4.25 inches (108 mm) below the top of the slab, with a 3-inch (76 mm) HMA layer on a 12-inch (305 mm) aggregate base. Different shoulder configurations have been used: CRCP shoulders (intended as future travel lanes) and widened slab (lane) with asphalt or roller-compacted concrete shoulders. Georgia has also constructed several CRC overlays.

Illinois—Illinois has a long history of CRCP use. One of the first States to experiment with CRCP technology, in 1947, Illinois now has the second-largest inventory of CRCP in the United States, behind Texas. The Illinois DOT has built CRCP throughout the State, including most of the freeways in the Chicago area. CRCP is typically selected for projects with traffic levels of over 60 million equivalent single-axle loads. Recently, building on the DOT's successful use, the Illinois State Toll Highway Authority used CRCP on several large projects on I-294.

Dozens of CRCP research reports have been produced through the Illinois DOT's Bureau of Materials and Physical Research. Many research projects have been conducted in cooperation with FHWA, under the Illinois Cooperative Highway Research Program (Illinois DOT, FHWA, University of Illinois at Urbana–Champaign) or, most recently, in cooperation with the Illinois Center for Transportation at the University of Illinois at Urbana. Illinois' first CRCP report, "A Ten-Year Report on the Illinois Continuously-Reinforced Pavement," Highway Research Board Bulletin, was produced in 1959. Subsequent reports on the performance of the State's rigid pavement were issued about once a decade, in 1968, 1978, and 1997, and most recently, in 2002 (Garaibeh and Darter 2002). CRCP built since the early 1990s has exhibited limited punchout failures.

In 2002, the Illinois DOT began its Extended Life Pavement Program, building several large CRCP projects through the mid-2000s that increased design life to 30 or 40 years with slab thickness up to 14 inches (356 mm), 0.70 percent to 0.80 percent longitudinal steel, HMA-stabilized base 4 to 6 inches thick (102 to 152 mm), aggregate subbase 12 inches thick (305 mm), and lime-treated subgrade.

Illinois has also built several CRC overlays, ranging from 8 to 12 inches (203 to 305 mm) on major highways. When the need for rehabilitation occurs, Illinois properly repairs the existing CRCP and overlays with HMA. This composite structure performs over many years with no reflection cracks or new punchouts through the overlay.

Louisiana—The Louisiana Department of Transportation and Development built many miles of 8-inch-thick (203 mm) CRCP between 1966 and 1974. Premature problems, including wide crack widths, excessive deflection, and base erosion (leading to punchout failures) developed on several projects, mostly due to poor foundations. However, bare sections of I-20 and I-10 are still in service, and some sections of I-10 only received their first asphalt overlay in 2009. All sections were built with asphalt shoulders. These problems led to a CRCP moratorium in 1975 that was not to be lifted until better designs could be developed. Subsequent State research identified the causes of punchout failures: insufficient slab thickness, poor base and subgrade conditions, poor construction practice, and the use of rounded aggregate.

North and South Dakota—Both North and South Dakota have been building "nonurban" CRCP sections since the 1960s. North Dakota has built close to 300 mi (483 km) of CRCP. Over the years, more than half of the State's inventory has been overlaid with an asphalt wearing surface. South Dakota's first two experimental CRCP sections (0.5-mi long (0.8 km)), built in 1962 near Sioux Falls, are still in service, reportedly without significant maintenance. South Dakota subsequently adopted CRCP for initial interstate highway construction (I-29, I-229, I-90, and I-190), which ended in 1974. The CRCP details were an 8-inch-thick slab (203 mm) with 0.60 percent longitudinal steel and granular and lime-treated gravel cushion bases. Only one project was slip-formed.

CRCP construction resumed in 1995, with the rebuilding of sections of the Interstate Highway System, including replacement of 10 percent of the asphalt pavements. These CRC pavements were from 8 to 12 inches thick (203 to 305 mm) and contained 0.66 to 0.69 percent longitudinal steel, on a nominal 5-inch (127 mm) granular base (rubblized concrete from the existing project was used where feasible). All totaled, South Dakota's CRCP comprises about 40 percent of the State's Interstate Highway System and about 6 percent of the DOT's entire road network. Unfortunately, the South Dakota DOT has experienced undesirable cracking patterns on some projects built in the 2000s and is evaluating the causes of the undesirable cracking patterns through laboratory work and experimental sections with varying features built in 2004–05 on I-29 and I-90.

Oklahoma—The Oklahoma DOT believes CRCP is an outstanding pavement and builds on average several projects per year. CRCP has been used on all interstate highway routes and on several U.S. routes. Oklahoma built its first CRCP project in 1969. For the DOT, a project's traffic levels and soil conditions dictate CRCP selection. Typical modern CRCP design consists of a slab 8 to 12 inches thick (203 to 305 mm) with 0.70 percent longitudinal steel placed at mid-depth. Oklahoma DOT uses this CRCP for full-depth reconstruction and unbonded overlay construction. Through 2010, the DOT's Interstate Highway Pavement Management System showed zero percent of the original CRCP sections reconstructed and only 25 percent requiring rehabilitation, compared to 6 percent reconstructed and 84 percent rehabilitated for the total pavement inventory. Seventy-five percent of the CRCP miles have required pavement preservation treatment.

Oregon—The Oregon DOT has built about 560 mi (901 km) of CRCP with the average age being 23 years. The first section (built in 1963) was an 8-inch-thick (203 mm) slab containing 0.60 percent longitudinal steel placed 3 inches (76 mm) from the top of the slab, built on an aggregate base. It received an asphalt overlay in 2004. Since the late 1970s, thicknesses from 8 to 11 inches (203 to 279 mm) have been used and the steel content has been increased to 0.70 percent.

At that time, the outside-lane pavement width (widened slab/lane) was increased to 14 ft (4.3 m), combined with an asphalt shoulder. As of 2010, 59 percent of Oregon's CRCP miles still had concrete surface; 22 percent had received a thin (2 inch (51 mm)) asphalt overlay to repair rutting due to studded tire damage; 16 percent had received a thick (> 4 inches (102 mm)) overlay; and 3 percent had either been rubblized or reconstructed. Today, ODOT uses CRCP on major rehabilitation or reconstruction projects with a high volume of heavy trucks, primarily on the Interstate Highway System. CRCP has also been used as an inlay in the truck lane of I-84 in several locations.

Texas—Texas began using CRCP in 1951, before its long and extensive testing and research programs were initiated. Through the 1960s and 1970s and continuing to the present, the Texas DOT initiated extensive research to investigate ways to improve the performance of CRCP. Research teams in conjunction with the Center for Transportation Research at the University of Texas at Austin, Texas Transportation

Institute at Texas A&M University at College Station, and, recently, Center for Multidisciplinary Research in Transportation at Texas Tech have been studying the many aspects of the CRC pavement structure.

As of 2010, Texas had an inventory of nearly 12,500 lane-miles (20,117 km) of CRCP. Texas DOT has been increasing its CRCP use as it expands its roadway network and as it replaces jointed pavement taken out of service. CRCP in the State has performed exceedingly well. According to FY 2010 figures presented by the State, the failure rates for CRCP are 1 punchout per 8.8 lane-miles, 1 concrete patch per 4.6 lane-miles, and 1 asphalt patch per 88 lane-miles.

For all rigid pavements, the initial pavement structure is to be designed and analyzed for a performance period of 30 years. The Texas DOT's current policy allows CRCP in the thickness range of 6 to 13 inches (152 to 330 mm), with 0.5-inch (13 mm) increments. The sheer volume of CRCP work in Texas (averaging over 1 million yd^2 per year), combined with the local paving industry's knowledge and competition, typically results in the lowest cost for CRCP found anywhere in the United States. The Texas DOT has also constructed several CRC overlays.

Virginia—The first CRCP built by the Virginia DOT was in 1966–67 on I-64 through Richmond. All CRCP slabs from the 1960s through the 1980s were 8 inches (203 mm) thick with 0.60 percent longitudinal steel located 3.5 inches (89 mm) below the top of the slab. The concrete slab was placed on 4 to 6 inches (102 to 152 mm) of cement-treated base. Asphalt shoulders were generally used. By 2010, there were more than 500 lane-miles (805 km) of CRCP in the State. Virginia DOT philosophy has been that CRCP lasts long and is very competitive for roadways with high traffic levels. Today, the DOT uses a combination of life cycle cost analysis and engineering judgment to select the pavement type. At the end of its initial service life, CRCP is overlaid with asphalt concrete to provide for many more years of service.

Long-Term Pavement Performance Program Data

The best source for a national overview of CRCP performance is the Long-Term Pavement Performance (LTPP) Program. When General Pavement Study (GPS) 5, which studied CRCP over various base layers, began, it included 85 CRCP experimental sections in 29 States and all 4 LTPP climatic regions. Over the years, sections dropped out or, when overlaid with asphalt, were transferred to GPS-7 (study of asphalt concrete overlay over portland cement concrete).

LTPP GPS-5 data for CRCP test sections were analyzed in 1999 and 2000. These analyses showed the following (Tayabji et al. 1999, 2001):

- CRCP test section ages ranging from 5 to 34 years (as of 1999) were observed.
- Very limited amounts of localized failures were observed (at only 16 sections as of 1995), with only little high-severity cracking observed at these 16 sections.
- Nine sections were overlaid as of 1995, most due to resurfacing of adjacent sections.
- Most CRCP sections were performing well with ≥ 15 years (some ≥ 20 years) of service life.
- Very little distress was reported.
- Little degradation in ride quality over time was observed, indicating that a CRCP built smooth remains smooth for many years.

A partial analysis as of March 2012 indicated that 34 of the original 85 sections in GPS-5 remain active in the study. Their average age is

31 years, with the oldest constructed in 1969 in Virginia and the newest constructed in 1990 in Oklahoma. The average age of the 51 sections removed from GPS-5 was 26 years when removed, and at least 30 of those sections were added to GPS-7 after receiving asphalt overlays. Other than the Virginia section mentioned above, the oldest were a section in Texas (0.50 percent longitudinal steel and CRCP shoulders) that lasted from 1965 to 2006 and a section in South Dakota (0.65 percent longitudinal steel and asphalt shoulders) that lasted from 1963 to 2008.

States with the best-performing CRCP sections, based on longevity in the GPS-5 database, are Texas (13 of 17 still included, 3 removed in 2000s when overlaid); South Carolina (3 of 3, average age 36 years); Virginia (3 of 4, 1 removed in 2000s); Oklahoma (3 of 3); and Oregon (4 of 6, 2 removed when overlaid in 2003).

International CRCP Use

Road agencies around the rest of the world have been using CRCP almost as long as agencies in the United States. CRC pavements have now been built on every continent except Antarctica. Belgium, the Netherlands, South Africa, the United Kingdom, and Australia are perhaps the largest users. More recently, Germany and China have begun experimenting with CRCP.

Perhaps the most important recent development in technology concerning CRCP can be found on the M7 Motorway (Westlink), which was opened in 2005 in the western suburbs of Sydney, NSW, Australia. Technological innovation comes by connecting the CRCP longitudinal reinforcement directly into the bridge deck reinforcement, with additional pavement reinforcement provided in the transition zones, eliminating anchorages and joints to create a “seamless pavement.”

SUMMARY

CRC pavements have a long history of good performance in the United States and other countries when designed and constructed well. Many U.S. highway agencies consider CRC pavements their pavement of choice for implementing long-life pavement strategies that have lower life cycle costs and require fewer lane closures for routine maintenance and repair/rehabilitation.

CRC pavements have also been used on local roads, intersections, and roundabouts and at airports, freight terminals, warehouses, and racetracks.

As discussed in this TechBrief, well-performing CRCP and CRC overlays require consideration of the following best practices:

1. Adequate amount of longitudinal reinforcement.
2. Control over depth of steel placement.
3. Well-drained and stable support. For heavy truck traffic projects, use of an alphalt base or a cement-treated base with an asphalt concrete interlayer is recommended.
4. Use of a 13-ft-wide (4.0 m) outside lane.
5. Use of slab thickness appropriate for the long-term design traffic.

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