CRCP FORENSIC INVESTIGATIONS AND REMEDIAL ACTIONS IN VIRGINIA

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The key to attaining a long lasting, safe, and economical Continuously Reinforced Concrete Pavement (CRCP) or any other pavement is learning from its performance. Pavement performance is dependent on the characteristics of the materials, the pavement design, and the construction practice used. Therefore, it makes good sense to trace the impact of these elements to identify issues and then to develop a plan of action leading to a high-performing CRCP. Virginia’s plan of action was formulated using all the available talent in several areas, including pavement design, materials selection and testing, research, and the construction practices. The close cooperation with the concrete industry was essential for success. The collective effort resulted in a better understanding of the failure mechanisms, good performance and the interaction among the several factors involved in constructing long-lasting CRCP with minimal maintenance. This paper highlights forensic investigations and lessons learned from CRCP projects in the past and how the findings are applied to recently constructed CRCP pavements.
INTRODUCTION
Continuously Reinforced Concrete Pavements (CRCP) has been used in the United States for more than 50 years. The first continuously reinforced concrete pavement built by Virginia Department of Transportation (VDOT) was in late 1966 and early 1967 on I-64 around Richmond area (1, 2). Virginia has in excess of 500 lane miles of CRCP, predominately on interstate highways (1). Despite potential higher initial cost, constructing highways using CRCP could provide a number of benefits such as lower long-term life cycle cost, low maintenance, reduced water penetration because of fewer joints and tighter transverse cracks, smoother pavements over time, ability to handle heavier truck loading and volumes, easier to rehab and can become a successful composite pavement because of the absence of joints.

CRCP is designed to control transverse cracks through continuous longitudinal steel reinforcement, which hold the transverse cracks tightly together to ensure the integrity of the aggregate interlock and load transfers at the crack face. The desired spacing for cracks in the pavement is 3 to 6 ft apart, since cracks spaced closer together lead to inadequate resistance to loads, leading to punch outs. If spacing is longer them wider cracks are expected. Cracks wider than 1 mm have crack edge raveling or spall that gets progressively worse with traffic leading to maintenance problems. Slab thickness, setting temperature, coefficient of thermal expansion (CTE), drying shrinkage of concrete and longitudinal steel characteristics affect the widths of transverse cracks.

The most commonly employed structural design method for CRCP currently is the AASHTO 93 Guide for Design of Pavement Structures. However, there are a number of serious limitations. These are; being completely empirical and based on performance equations from one test location, one environment, one set of materials, no sub-drainage consideration, and limited traffic with axle configuration and tire types representing the late 1950’s. The perceived deficiencies of the empirical design approach were the motivation for the mechanistic-empirical methodology developed in NCHRP Project 1-37A. The interim MEPDG is currently being evaluated for possible adoption by several states.

The key to attaining a long lasting, safe, and economical CRCP or any other pavement is learning from its performance. Pavement performance is dependent on the characteristics of the materials, the pavement design, and the construction practice used. Therefore, it makes good sense to trace the impact of these elements to identify deficiencies as well as the good performing characteristics and then to develop a plan of action leading to a high-performing CRCP.

PURPOSE AND SCOPE
This paper summarizes common distresses and failure mechanisms in CRCP in Virginia. The distresses addressed are map cracking, localized areas of broken concrete, edge punchouts, and sags. The issues with material selection and construction practices that lead to durable pavements are explained. The lessons learned have resulted in changes to specifications which are listed. These changes were incorporated into recent CRCP. The most recent one was the CRCP project on I-64 Battlefield Blvd which is explained in some detail in this paper.
DISTRESS IDENTIFICATION AND FAILURE MECHANISMS

Distress identification was based on extensive field visits and consistent concrete pavement condition surveys. Failure mechanisms were established based on pavement condition surveys, coring, shoulder trenching, laboratory testing, and historical data.

Map Cracking

Map cracking was identified in at least two interstate projects (I-64 and I-295). On I-64, map cracking totaling 10,241 m² (12,248 yd²) was found in a 1989 VDOT survey of a 14.5 km (9 miles) section with four lanes. The CRCP was constructed in 1971, had a thickness of 200 mm (8 in), and was supported on 150 mm (6 in) of a cement treated aggregate base without edgdrains. The crack pattern had a predominant longitudinal direction and was interconnected by finer transverse or random cracks. The cracks in the wheel path were the first to crumble, as shown in Figure 1(a). On I-64 westbound lanes near Charlottesville, VDOT replaced 9.6 km (6 miles) of CRCP because of severe cracking beyond repair. On I-64 in New Kent County and on I-295 near Richmond a total of 37 km (23 miles) were overlaid. All pavements were beyond their 20-year service life but with different levels of distress. Map cracking with white gel (Figure 1(b)) was attributed to alkali-silica reaction (ASR). This failure mechanism was challenging since it required an understanding of cement production after the implementation of particular environmental regulations, leading to higher alkalinity in the cement. The chemical reaction between the reactive aggregate and the high alkalinity cement in the presence of water was the cause of the problem. The cracks stay tight even after the formation of the gel around the aggregates; the presence of water then leads to the expansion of the gel, cracks form, and the concrete breaks into pieces.

FIGURE 1(a) Map cracking as a result of ASR.
Localized Areas of Broken Concrete

Figure 2 (a) shows cluster of closely spaced transverse cracks 200 to 450 mm (8 to 18 in). The distress was more evident where the cracks intersected, creating a Y shape. The concrete was broken into pieces mainly at the wheel paths, as shown in Figure 2(b). On I-64, in the 14.5 km (9 mile) section, there was 13,830 m$^2$ (16,540 yd$^2$) of spalling and potholes with broken concrete and edge punchouts.
Cracks and spalls as a result of the delamination are shown in Figures 3(a) and 3(b). Delamination occurred at mid depth of the pavement at the level of the reinforcing steel. The shear stress in slabs has a parabolic distribution, with the highest stress at mid slab, which could explain the delamination. The CRCP in Virginia did not show the large amount of distress until the early 1980s, shortly after radial tires increased the concentration of the load on CRCP and the legal axle loading increased (from 18000 lbs to 20,000 lbs). The delamination was not observed in the 225 mm thick (9in) jointed reinforced concrete pavement. It became a real problem with the 200 mm thick (8in) CRCP. The value of the maximum shear stress is reduced with increased slab thickness. Merritt et al. [3] described similar delamination in CRCP 350 mm (14 in) thick. Thickness may not be the only issue. The curling action of the concrete because of drying and temperature changes is another contributing factor. The selection of ingredients and their proportioning affect the shrinkage and curling. The dissimilarity between the reinforcing steel and the concrete because of thermal and drying shrinkage may cause the delamination to be located at the level of the steel. Also, some of the delamination in Virginia was attributed to early slip forming paving in which the concrete was allowed to dry or set before the top layer was placed. The strength of the bond would be low because of the creation of a cold joint. After the concrete slab has delaminated, it separates into two layers at the reinforcing steel. Now the axle loading is carried by the upper layer making it easy to break mainly in the wheel path of truck. The presence of closely spaced cracks and large entrapped air resulting from inadequate consolidation causes the concrete to break into pieces without evidence of pumping or staining. Water then infiltrates to the bottom layer causing it to fail in a similar fashion to punchouts.
FIGURE 3(a) Separation at the steel as a result of delamination.

FIGURE 3(b) Broken concrete attributable to traffic loading and advanced delamination.

**Edge Punchouts**

This distress is similar to the localized area of broken concrete except that punchouts occur between two transverse cracks spaced at about 450 to 750 mm (18 to 30 in) near edge joint. These cracks typically start as faulting and slight spalling followed by a short longitudinal crack at the wheelpaths. Eventually, these cracks break down further and pieces of the concrete punch downward into the subbase and subgrade. Pumping and staining are always present near the edge punchouts. Edge punchouts occur under variety of conditions including a lack of subbase, edge support, or drainage. This is attributable to the presence of voids and water under the pavement. On the other hand, punchouts can be from the top down because
of the delamination. Staining and pumping are generally associated with edge punchouts. The seriousness of this failure is that it can expand to adjoining pavement and develop into a very large area if not repaired.

**Longitudinal Cracking**

Longitudinal cracking are typically parallel with the centerline of the pavement, mainly on ramps wider than 4.5 m (15 ft). They start as hairline cracks and eventually develop into spalling and faulting, as shown in Figure 4. In the 14.5 km (9 miles) of CRCP on I-64, 1,700 m (5578 ft) of longitudinal cracking was found during the survey. Longitudinal cracking was investigated in two cases, which resulted from improper construction of longitudinal joints. In one case crack is within a normal lane width of 3.6 meters (12 feet) in a 7.2 meter (24 ft) wide concrete placement. In this case either the plastic tape at the centerline joint did not perform its intended function, or was missing during construction, or the sawing of the center joint was delayed, causing the concrete to crack randomly in the longitudinal direction. The second case occurs on ramps with width greater than 4.5 meters (>15 ft), without longitudinal joint, so concrete creates its own joint by cracking randomly. The observed distresses are the same in both cases, which include spalling, eventual faulting, and infiltration of water causing further damage to the sub-layers. Also combination of heavy load repetition, loss of support, and curling and warping stresses can cause this distress.

**FIGURE 4** Longitudinal cracking near outer edge.

**Sags**

Sags are depressions up to 100 mm (4 in) varying in length from about 10 to 30 m (30 to 100 ft); where the concrete surface is lower than that of the surrounding pavement as shown in Figure 5. Sags develop because of inadequate compaction, the continuing consolidation of the sub-layers, or lack of drainage in the area. In severe cases, all three factors are present. Water ponding after rain is usually present in these areas. Eventually, severe cracking and settlement of the pavement occur. These conditions are mostly located near culverts and bridge approach slabs, especially at high fill embankments. For example, on I-295, near
Chickahominy swamp, sag occurred and CRCP was replaced on both sides of the culvert on Route 60 near Sandston, VA, while on I-295 south of Route 60 a fill settlement resulted in sag.

**FIGURE 5** Pavement depression measurement as a result of sag on I-295.

Small vibrating plates shown in Figure 6 can be used to compact the backfills in bridges. Similarly proper densification of fills in CRCP is needed to avoid the sags. As the roughness due to sag increases, bounce increases by the heavily loaded trucks, causing severe cracking.

**FIGURE 6** Construction of backfill behind the backwall of bridges.
MATERIALS SELECTION AND TESTING

Aggregate Maximum Size and Grading
VDOT is interested in minimizing the crack width and increasing the spacing of cracks in the CRCP. Moisture loss causes shrinkage and temperature drop contraction, which, when restrained by the base and the reinforcing steel, result in cracking. CRCP paving projects in Richmond and Lynchburg district used larger nominal maximum size aggregate of 50 mm (2 in). With larger size aggregate, a reduction in the water and paste contents is expected, which will lead to reduced shrinkage. However, in these projects, the use of maximum size aggregate did not result in large water reductions because the aggregate was not well graded (4). Present VDOT specification separate the aggregate into coarse and fine and require that each meet a certain grading requirement. When such aggregates are combined, a lack of intermediate sizes is evident. In present CRCP projects, an attempt is being made to look at the combined aggregate grading. The goal is to achieve a uniform grading that enables the use of a large amount of aggregate with minimal paste content, reducing the shrinkage potential. In the Lynchburg project, to encourage the use of a uniform grading, the contractor was given the option of reducing the cementitious material content to 318 kg/m$^3$ (535 lb/yd$^3$) rather than the usual 335 kg/m$^3$ (564 lb/yd$^3$). Larger aggregate is also expected to provide better aggregate interlock. If cracks form, a vertical movement between two sides is not expected because of the bridging of the larger aggregates. Old pavements in Virginia with 50 mm (2 in) NMSA have performed well, which supports the soundness of the increasing the aggregate top size.

Pozzolans/Mineral Admixtures
Since early 1990s, VDOT has been specifying pozzolans (Class F fly ash) and slag to inhibit ASR. Pozzolans also reduce the permeability of concrete. Concrete exposed outdoors is subjected to severe conditions because of the intrusion of harmful solutions: either just water, or chloride, or sulfate solutions. Concrete with low permeability resist such intrusion. CRCP naturally has cracks that may facilitate the intrusion of solutions. However, if the crack width is narrow or does not exist near the reinforcement, corrosion concerns are diminished. Even if corrosion occurs, it is expected to be in isolated small anode locations at the cracks. Corrosion of CRCP has not been an issue in Virginia unless the reinforcing steel has been very close (within couple of inches) to the surface due to misplacement.

Alkali Silica Reaction
Factors required to get ASR are reactive aggregate, alkalies, and moisture. The 9.6 km (6 mi) of pavement on I-64 was replaced because of reactive aggregate, even though the aggregates met the specifications at that time, which are unacceptable by current limits. Since most of the aggregate in Virginia have some of the reactive components, VDOT decided to arbitrarily declare all aggregate reactive.

Most of the available alkalis come from the cement. The amount of alkali has increased over the years because of environmental restrictions. The amount of alkali that VDOT found to cause an excessive expansion is 0.45 %. ASTM C 150 recognizes 0.60% as dividing line for low-alkali cement. The difference is probably attributable to the changes in fineness over the years. Others have also found that an alkali limit of 0.60 % does not provide protection in all cases (5, 6).
Another way to prevent ASR is to use supplementary cementitious materials, such as Class F fly ash, slag, silica fume, metakaolin, or similar types of products (6). In Virginia, because of the difficulty of eliminating aggregate sources or finding low-alkali cements, VDOT have opted for the use of supplemental cementitious material, which is highly effective and improves the overall durability of concrete.

The amount of supplementary cementitious material is determined by the amount necessary to limit the expansion of the mortar bars in accordance with ASTM C 441, which uses pyrex glass as the reactive aggregate. VDOT has data that show the expected expansion for particular types of materials at different concentrations and through interpolation, have maximum alkali levels that can be used with certain percentages of cement replacement (6). Table 1 shows the pavement mix proportions used for recently completed CRC projects, which highlights the use of Fly ash and Slag.

**Strength Tests**
The flexural strength of concrete is used in design of the pavement. However, flexural strengths are seldom determined in actual concrete pavements. Beams are bulky and exhibit a lot of variability. Currently, VDOT is establishing a relationship between compressive strength and flexural strength before the beginning of a project. The acceptance tests are then based on the compressive strength of the concrete. Table 1 also shows the material characterization of recently completed CRCP projects.

**CONSTRUCTION ISSUES**
One concern has been with the availability of slipform pavers to place a 50 mm (2 in) NMSA. VDOT present projects have shown that slipform pavers can satisfactorily place concrete with large aggregate. Test results show that satisfactory strength and durability are obtained (7).

Construction issues of concrete placement, consolidation, and curing are important for satisfactory performance. Adequate concrete consolidation is essential to attain the strength and durability desired. The frequency of the vibrators needs to be continuously monitored. Cores can be tested for air void system to determine the adequacy of consolidation. Prompt and proper curing ensures that the desired properties are achieved and that the volumetric changes that result in cracking are minimized.

Proper location of steel is maintained in recent projects by placing the longitudinal reinforcing steel on continuous runner chairs with clips attached at planned widths. The feed-tube system is not permitted. The chairs provide the proper positioning of the steel in the slab, and serve as the horizontal reinforcement. It also allows for the slab to be poured monolithically, which reduces the probability for cold joint at the reinforcing steel, that have resulted from pouring two layers in the feed tube system. Figure 7 shows failure occurred because of high steel due to feed tube installation which has lead to corrosion, cracking, and spalling.
TABLE 1 Pavement Mixture Proportions Used for Recent Projects

<table>
<thead>
<tr>
<th>Materials</th>
<th>IS-64</th>
<th>SR 288 Mix Design 2003</th>
<th>US 29 Bypass Phase 1</th>
<th>US 29 Bypass Phase 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Type</td>
<td>Amount lb/yd²</td>
<td>Type</td>
<td>Amount lb/yd³</td>
</tr>
<tr>
<td>Cement</td>
<td>Type II cement</td>
<td>472</td>
<td>Type II</td>
<td>405</td>
</tr>
<tr>
<td>Fine Aggregate</td>
<td>Natural sand</td>
<td>1220</td>
<td>Natural sand</td>
<td>1144</td>
</tr>
<tr>
<td>Coarse Aggregate</td>
<td>#57 Biotite gneiss and granite</td>
<td>1763</td>
<td>#57 amphibole gneiss and metamorphosed granite</td>
<td>1901</td>
</tr>
<tr>
<td>Class F fly ash</td>
<td>Class F</td>
<td>118</td>
<td>Class F</td>
<td>135</td>
</tr>
<tr>
<td>Water</td>
<td>250</td>
<td>242</td>
<td>275</td>
<td>290</td>
</tr>
<tr>
<td>Max w/cm</td>
<td>0.42</td>
<td>0.45</td>
<td>0.49</td>
<td>0.49</td>
</tr>
</tbody>
</table>

Characterization of Recent Concrete Projects

<table>
<thead>
<tr>
<th>Hardened Concrete Properties</th>
<th>I-64 in 2002</th>
<th>SR 288 in 2003</th>
<th>US 29 Bypass Phase 1</th>
<th>US 29 Bypass Phase 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compressive Strength (psi)</td>
<td>5800</td>
<td>4520</td>
<td>4020</td>
<td>3440</td>
</tr>
<tr>
<td>Flexural (psi)</td>
<td>692</td>
<td>665</td>
<td>615</td>
<td>545</td>
</tr>
<tr>
<td>Elastic Modulus (10^6 psi)</td>
<td>4.32</td>
<td>4.62</td>
<td>3.52</td>
<td>3.51</td>
</tr>
<tr>
<td>Permeability (coulombs)</td>
<td>764</td>
<td>694</td>
<td>1672</td>
<td>706</td>
</tr>
<tr>
<td>Shrinkage (microstrain)</td>
<td>370</td>
<td>300</td>
<td>400</td>
<td>320</td>
</tr>
<tr>
<td>Coefficient of Thermal Expansion (10^-6°F)</td>
<td>5.9</td>
<td>6.2</td>
<td>5.8</td>
<td>5.5</td>
</tr>
<tr>
<td>Poisson's Ratio</td>
<td>0.2</td>
<td>0.2</td>
<td>0.24</td>
<td>0.18</td>
</tr>
<tr>
<td>Split Tensile Strength (psi)</td>
<td>515</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
Another construction problem is potential cold joint due to delays in concrete loads and to uneven concrete spreading as shown in Figure 8. This problem is avoided in recent I-64 battlefield blvd project by establishing a batch plant on site.

Another construction problem is the lack of proper consolidation at the header due to steel congestion (50% more steel) in that area. Figure 9 shows header failure at I-64 due to improper consolidation.
FIGURE 9 Header construction failure.

VIRGINIA’S PLAN OF ACTION
Virginia’s plan of action was formulated using all the available talent in several areas, including pavement design, materials selection and testing, research, and construction practices. The collective effort resulted in a better understanding of the failure mechanisms and the good performance and the interaction among the several factors involved in constructing long-lasting CRCP with minimal maintenance. The close cooperation with the concrete industry is essential for success. Preconstruction conference is very important to declare VDOT expectations.

Pavement Changes
Based on the field experience and available technology, several changes listed below were undertaken for constructing durable pavements. The changes address not only to materials and mix design but also to structural design, environment, and construction practices.

(i) Use of wider travel line 4.2m (14 ft) while keeping the delineating white line at 3.6 m (12 ft). This approach provides an economical way to provide edge support equal to a full width tied shoulder without the joint, and it reduces the chances for punchouts.

(ii) Increasing the amount of reinforcing steel from 0.65% to 0.70% to improve the crack spacing and allowing two-layer reinforcement with smaller diameter bars for future consideration. The goal is to have the transverse cracks spaced at 0.9 to 1.8 m (3 to 6 ft) while having tight crack opening less than 0.5 mm (0.02 inch) at the end of service life.

(iii) Using transverse steel spaced at 1.2 m (4ft) to support the longitudinal steel and to keep the longitudinal cracks tight in the event of their occurrence.

(iv) Use of an open graded asphalt layer 75 mm (3 in) thick that provides stability and drainability under the slab. New open graded drainage layer can provide stability which is the most important and then sufficient drainability for a dry condition under the CRCP.
Modifying Virginia’s edgedrain standards to provide an effective drainage system. An edgedrain inspection program was established using the video camera to ensure the system will function during the pavement service life.

Dealing with sags at the bridge approaches, VDOT modified the requirement for constructing the backfill behind the backwall of bridges. The depth of select material used behind the footing must be a minimum 1.8 m (6 ft) under the pavement end of the approach slab. Select material Type 1, with a minimum CBR of 30 is used. In addition, the minimum compacted dry density of the select material must be 100% in the top 0.9 m (3 ft), 98% from 0.9 to 1.8 m (3 to 6 ft), and 95% below 1.8 m (6 ft).

Long sags resulting from inadequate consolidation of a thick and soft subsurface layer is avoided by requiring the primary consolidation of the soft layer to be complete, before the pavement placement.

VDOT has already implemented many of these changes on Route 288 project in Chesterfield County, with 250 mm (10 in) CRCP, Madison heights Bypass in Lynchburg, where a 300 mm (12 in) CRCP, and recently on I-64 battlefield blvd project with 325 mm (13 inch) thick CRC pavement. The following section discusses the I-64 project in some detail.

I-64 BATTLEFIELD BLVD CRCP PROJECT

The project is located on I-64 in the Chesapeake, Virginia. It consists of replacing the Battlefield Boulevard interchange on I-64 and widens one mile of the interstate from six lanes to fourteen lanes to help improve traffic and to reduce congestion. Ten of the fourteen lanes are mainline lanes and are constructed as CRCP. The CRCP lanes are approximately 1.1 miles long. The new pavement is designed for 60 million Equivalent Single Axle Loads (ESALs) using 1993 AASHTO Guide for Design of Pavement Structure. The existing JRCP pavement was recycled and cement treated to construct the base layer for the CRCP lanes. 3” Open Graded asphalt Drainage Layer (OGDL) was paved above the cement treated recycled concrete. The CRCP placed on top of the OGDL was 325 mm (13” thick) and #7 rebar was used as reinforcement in the longitudinal direction. The project site was barricaded from traffic. An on-site batch plant within the barricades provided a steady supply of concrete, uninterrupted by traffic.

In this project wide outside lanes, high reinforcement ratio (0.7%), stable, and drainable base were used. The total cementitious material was 564 lb/yd3 including 50% slag by weight. The maximum water-cementitious materials ratio (w/cm) was 0.45. The minimum design flexural strength at 28 days was 650 psi. The contractor chose to test for flexural strength rather than the compressive strength due to the need for a correlation if compressive strength is used. Compressive strength is preferred because it is easier to conduct than the flexural test and shows less variability. The flexural strengths from 8 batches averaged 864 psi with an 18 percent coefficient of variation which is considered high. Cylinders were made by VDOT for compressive strength, split tensile, and permeability tests. Permeability specimens were subjected to accelerated curing (1 week at 73°F and 3 weeks at 100°F). The results displayed in Figure 10 indicate satisfactory strengths exceeding 4,000 psi and low permeability. The compressive strength variability was also high with a coefficient of variation of 9% but is still lower than the coefficient of variation for the flexural tests. To minimize variability and obtain a uniform product, VDOT
is currently considering developing an End Result Specification (ERS). ERS is expected to
be practical with innovations and higher quality uniform concrete in the finished product that,
in turn, would result in longer lasting pavements with minimal maintenance.

![Battlefield Blvd. VDOT Data](image)

**FIGURE 10** Concrete strength results for I-64 Battlefield Blvd.

After opening to traffic, crack surveys were conducted in 1000 ft lengths in both the east
bound (EBL) and the west bound lanes (WBL). Figure 11 (a) and 11 (b) shows the crack
spacing distribution for the EBL of this project after 2 and 9 months of construction. At 2
months the cracks were few. At 9 months of construction which included the first winter,
more cracks have occurred as expected. The average crack spacing was 1.08 meter (3.6 feet)
and average crack width is 0.45 mm, which indicates satisfactory performance. The WBL
had similar crack width (0.48 mm) and same spacing 1.08 meter (3.6 ft). VDOT plans to
continue surveying crack spacing and width for next 3-5 years where the complete cracking
system is developed.
FIGURE 11 (a) Crack spacing distributions on east bound lane (After 2 months of construction).

FIGURE 11 (b) Crack spacing distributions on east bound lane (After 9 months of construction).
CONCLUSIONS AND RECOMMENDATIONS

1. Use an analytical approach and benefit from the lessons learned to extend the service life of CRCP with minimal maintenance.
2. Use consistent pavement condition surveys that aid VDOT in identifying critical distresses and good performing pavements.
3. Establish the failure mechanism for each distress before starting pavement rehabilitation or making any changes to improve CRCP performance.
4. Reach the most logical failure mechanism by understanding pavement design, concrete mix design, the factors affecting concrete production, the interaction between the concrete components and environmental conditions, and construction practices.
5. Adopt and implement changes to improve CRCP.
6. Monitor and provide feedback to measure the effectiveness of the changes made.
7. Establish cooperation among pavement design engineers, materials engineers, researchers, and the industry to implement changes.
8. Utilize pre-paving conferences to establish VDOT expectations and sharing lessons learned.

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