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Flexible Pavement Recycling Techniques: A Summary of Activities

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16. Abstract

Cold in-place recycling (CIR) involves the recycling of the asphalt portions (including hot-mix asphalt and chip, slurry, and cape seals, as well as others) of a flexible or composite pavement with asphalt emulsion or foamed asphalt as the binding agent. Full-depth reclamation (FDR) includes the recycling of the entire depth of the pavement and, in some cases, a portion of the subgrade with asphalt, cement, or lime products as binding agents. Both processes are extensively utilized in Illinois. This project reviewed CIR and FDR projects identified by the Illinois Department of Transportation (IDOT) from the Transportation Bulletin and provided comments on pavement designs and special provisions. The researchers evaluated the performance of existing CIR/FDR projects through pavement condition surveys and analysis of falling weight deflectometer data collected by IDOT. They also reviewed CIR/FDR literature and updated/modified (as appropriate) previously provided inputs concerning mix design, testing procedures, thickness design, construction, and performance as well as cold central plant recycling (CCPR) literature related to design and construction. The team monitored the performance of test sections at the National Center for Asphalt Technology and Virginia Department of Transportation. The researchers assisted IDOT in the development of a CCPR special provision as well as responded to IDOT inquiries and questions concerning issues related to CIR, FDR, and CCPR. They attended meetings of IDOT's FDR with the Cement Working Group and provided input in the development of a special provision for FDR with cement. The project's activities confirmed that CIR, FDR, and CCPR techniques are successfully utilized in Illinois. Recommendations for improving the above-discussed techniques are provided.

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Members of the Technical Review Panel (TRP) were the following:

- Charles Wienrank, TRP Chair, Illinois Department of Transportation
- Dennis Bachman, Federal Highway Administration, Illinois Division
- Mike Brand, Illinois Department of Transportation
- Kevin Burke, Illinois Asphalt Pavement Association
- Brian Hill, Illinois Department of Transportation
- Tim Peters, Illinois Department of Transportation
- LaDonna Rowden, Illinois Department of Transportation
- John Senger, Illinois Department of Transportation
- Heather Shoup, Illinois Department of Transportation

EXECUTIVE SUMMARY

Cold in-place recycling (CIR) involves the recycling of the asphalt portion of flexible or composite pavements. This includes recycling of both hot-mix asphalt (HMA) layers and surface treatments, including chip, slurry, and cape seals of flexible pavements, mixed with asphalt emulsion or foamed asphalt. Full-depth reclamation (FDR) includes the recycling of the entire depth of the flexible pavement and, in some cases, a portion of the subgrade with asphalt, cement, or lime products. Both processes are extensively utilized in Illinois. In general, the most common processes are recycling the asphalt layers of a composite pavement (CIR application) or FDR.

Project activities included the following tasks:

- Task 1: Review CIR and FDR projects identified by the Illinois Department of Transportation (IDOT) from the Transportation Bulletin and provide comments on pavement designs and special provisions.
- Task 2: Evaluate performance of existing CIR and FDR projects through pavement condition surveys and analysis of falling weight deflectometer data collected by IDOT.
- Task 3: Review CIR and FDR literature and update or modify (as appropriate) previously provided inputs concerning mix design, testing procedures, thickness design, construction, and performance.
- Task 4: Review cold central plant recycling (CCPR) literature related to design and construction as well as monitor the performance of National Center for Asphalt Technology test sections and Virginia Department of Transportation high-volume test sections.
- Task 5: Assist IDOT in the development of a special provision for CCPR.
- Task 6: Respond to IDOT inquiries and questions concerning issues related to CIR, FDR, and CCPR.
- Task 7: Attend meetings of IDOT’s FDR with the Cement Working Group and provide input in the development of a special provision for FDR with cement.

Chapters 2–8 include inputs from the project’s team to IDOT concerning the various tasks. Overall, the project’s activities confirmed that CIR, FDR, and CCPR techniques are successfully utilized in Illinois. Chapter 9 provides recommendations concerning some particularly relevant issues:

- Provide guidance and policy concerning the types of surfaces to utilize for CIR and FDR with asphalt pavement sections.
- Closely monitor the performance of previously constructed CIR (with asphalt) and HMA overlay of existing composite (HMA overlaid Portland cement concrete) pavements. The issue

of most concern is the reflective/transverse cracking of the HMA overlay. Rutting does not appear to be an issue.

- Encourage implementation/use of the CCPR process. Some states have utilized CCPR on lower traffic volume as well as higher-volume pavements (particularly interstates in Virginia).
- Support studies and projects concerning the mixture and thickness designs of CCPR pavements. This issue is very important to the judicious utilization of CCPR in high traffic volume applications. The South African Bitumen Association (Sabita) manual (2020) provides a comprehensive perspective.
- Develop guidance and policy as well as a thickness design procedure for FDR with cement pavement sections. The process is widely used by local road agencies. Current practice (mixture and thickness designs) varies widely. However, good performance has been achieved, with the exception of transverse shrinkage cracking.

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CHAPTER 1: INTRODUCTION

Cold in-place recycling (CIR) involves the recycling of the asphalt portion (including hot-mix asphalt [HMA] as well as chip, slurry, and cape seals) of a flexible or composite pavement with asphalt emulsion or foamed asphalt as the binding agent. Full-depth reclamation (FDR) includes recycling of the entire depth of the flexible pavement and, in some cases, a portion of the subgrade using asphalt, Portland cement, or lime products as binders. Both processes are extensively utilized in Illinois. The most common processes are recycling the asphalt in a composite pavement (CIR application) or FDR.

Project activities included the following tasks:

- Task 1: Review CIR and FDR projects identified by the Illinois Department of Transportation (IDOT) from the Transportation Bulletin and provide comments on pavement designs and special provisions.
- Task 2: Evaluate performance of existing CIR and FDR projects through pavement condition surveys and analysis of falling weight deflectometer data collected by IDOT.
- Task 3: Review CIR and FDR literature as well as update or modify (as appropriate) previously provided inputs concerning mix design, testing procedures, thickness design, construction, and performance.
- Task 4: Review cold central plant recycling (CCPR) literature related to design and construction as well as monitor the performance of National Center for Asphalt Technology test sections and Virginia Department of Transportation high-volume test sections.
- Task 5: Assist IDOT in the development of a special provision for CCPR.
- Task 6: Respond to IDOT inquiries and questions concerning issues related to CIR, FDR, and CCPR.
- Task 7: Attend meetings of IDOT’s FDR with the Cement Working Group and provide input in the development of a special provision for FDR with cement.

Major activities pertaining to the various tasks are presented in the following chapters of this report.

CHAPTER 2: REVIEW COMMENTS (COLD IN-PLACE RECYCLING AND FULL-DEPTH RECLAMATION)

The work proposed in Task 1 was to review CIR and FDR projects identified by IDOT from the Transportation Bulletin and provide comments on pavement designs and special provisions. The current IDOT specification commonly used for cement-treated base pavements is Section 352 (Soil-Cement Base Course) of IDOT's *Standard Specifications for Road and Bridge Construction* (2016). Full-depth reclamation with cement (FDRC) is covered by this specification. However, several recent projects have utilized Section 302 (Soil Modification) or various combinations of Section 352 and Section 302. Section 352 requires a 7-day cured compressive strength of 500 psi. The stability requirement in Section 302 is a minimum Illinois bearing value (IBV) of 10 "measured within 10 calendar days prior to pavement construction." A recent project utilized Section 302 with a 7-day compressive strength requirement of 350 psi. Section 352 requirements are considerably more stringent than Section 302. However, Section 352 projects have also been constructed with 350 psi strength requirements. Based on the principal investigator's (Marshall Thompson) review of many projects (mostly local roads and streets), projects constructed with all the various combinations of specifications are showing acceptable performance. The only distress typically noted is transverse shrinkage cracking.

CHAPTER 3: COLD IN-PLACE RECYCLING AND FULL-DEPTH RECLAMATION PERFORMANCE

The work proposed in Task 2 was to evaluate the performance of existing CIR and FDR projects through pavement condition surveys and analysis of falling weight deflectometer (FWD) data collected by IDOT. The FWD is a nondestructive device used to determine the structural capacity of a flexible pavement. In short, the FWD applies a pulse load to the pavement surface and measures the resulting deflection using sensors. The deflection data can then be used to back-calculate the modulus of the pavement layers and the subgrade. During the project, IDOT FWD testing was conducted on the county highway (CH) projects noted in Table 1.

Table 1. FDR with Cement Pavement Sections

Location	Construction Date	FDR Thickness (in.)	Cement Treatment Level (%)	Surface
Cumberland Co. CH 1 / Neoga Rd.	2019	12	~7	2.5 in. HMA
Cumberland Co. CH 3	2016	12	~7	3.5 in. HMA
Marion Co. Kinoka Rd.—Westbound	2019	10	8	3.0 in. HMA
Marion Co. Kinoka Rd.—Eastbound	2019	10	8	3.0 in. HMA

Table 2 summarizes the pertinent structural response parameters. Field-compacted and laboratory-cured 7- and 28-day compressive strength data for the Marion County project are presented in Table 3. Of particular note are the significant strength increases from 7- to 28-day curing.

Table 2. FDR with Cement FWD Data

Location	Max Deflection (mils)	Area Under Pavement Profile (AUPP)	Flexural Modulus (ksi)	Estimated Compressive Strength (psi)
Cumberland Co. CH 1 / Neoga Rd.	4.9*/1.2**/23***	3.35/1.58/47	~1100	880
Cumberland Co. CH 3	4.6/1.3/28	2.77/1.82/66	~1500	1200
Marion Co. Kinoka Rd.—Westbound	5.1/0.45/9	3.2/0.33/10.4	~1500	1200
Marion Co. Kinoka Rd.—Eastbound	5.5/0.7/13	3.6/0.33/19	~1150	920

*Average

**Standard deviation

***Coefficient of variation (%)

Table 3. Marion County FDRC Compressive Strengths

Construction Date	7-Day Strength (psi)	28-Day Strength (psi)	Strength Increase from 7- to 28-Day Curing (%)
7/25/19	285	411	44%
7/26/19	247	365	48%
7/31/19	231	306	32%

The projects were visited during the fall of 2020. The Kinoka Road sections and Cumberland CH 1 show very limited (nil) transverse cracking. Average transverse crack spacings on Cumberland Co.—CH 3 for three separate 500 ft long segments were 66 ft, 62 ft, and 59 ft. The cracked section is shown in Figure 1.

A 2016 Champaign Co. FDRC project (Compromise Township) was a 12 in. depth, ~6% cement, with an A-2 surface treatment. Transverse shrinkage cracking was initially observed in 2018. The average crack spacing was 59 ft. The spacing in 2020 was 61 ft.

Figure 1. Photo. Transverse shrinkage crack on CH3 in Cumberland Co.

All older sections of FDR with cement pavement sections considered in recent years show significant transverse cracking regardless of surface type (HMA or surface treatments). Fatigue cracking has not been detected on any of the FDRC projects observed during this project. Traffic factors for most FDRC projects are typically less than 0.2.

A Grundy County FDRC project (Livingston Road—CH3) constructed in 2017 included a microcracking requirement. The original pavement section was a 4 in. HMA surface with a 15 in. crushed stone base. The FDRC mix design was 6% cement. The 7-day compressive strength of the mix was about 550 psi. In the microcracking process, a steel-wheeled vibratory roller is utilized to "pre-crack" the FDRC layer after about two days of curing. The goal of the process is to reduce the segment size of the FDRC layer and decrease the propensity to develop transverse cracking. Following the microcracking, the section was profile milled, and an A-2 surface treatment was applied. FWD testing of the FDRC layer before microcracking indicated a modulus of approximately 430 ksi. Following microcracking, the modulus decreased to about 230 ksi, indicating the effectiveness of the microcracking process. However, after 7 days of curing, the modulus had increased to approximately 400 ksi. A crack survey in 2018 indicated a transverse crack spacing of 68 ft. Overall, the microcracking process was not effective.

CIR REHABILITATION OF EXISTING COMPOSITE PAVEMENTS (HMA OVERLAID PCCP)

IDOT's first use of CIR for rehabilitating a Portland cement concrete pavement (PCCP) with an existing HMA overlay was in 2010 on US 24 west of Summum, Illinois. The existing pavement was a 9-6-9 in. concrete slab with variable thickness of HMA overlay. The CIR emulsion thickness was 3 in. to 5 in., and the HMA overlay was 3 in. Based on IDOT 2020 data, the International Roughness Index (IRI) was 76, the rut depth was 0.12 in., and the condition rating survey (CRS) value was 6.5. The project has performed well but has developed some low-level alligator cracking, transverse/joint reflective cracking, and centerline deterioration.

The next IDOT project was IL 130 (Philo Road) south of Urbana, Illinois (2015 construction). The existing jointed (100 ft joint spacing) PCC slab was 8 in. thick with HMA overlay thickness of approximately 3.75 in. The CIR emulsion treatment was 3.5 in. with a 2.5 in. to 3 in. HMA overlay. A June 2016 project survey indicated there was no cracking or rutting and the project was in excellent condition. A summer 2018 survey indicated there was practically "no rutting," but 40% to 60% of the PCCP joints had developed reflective cracking of low to medium severity. A 2020 site visit indicated the continuing deterioration of some of the reflective cracks. Per IDOT District 5, the current (February 2021) pavement condition is as follows: CRS was 8, IRI was 75 in/mi, and rut depth was 0.07 in. Ride quality is still good, and the performance is quite satisfactory. While other distresses have been very limited, the US 24 and IL 130 projects demonstrated that transverse/reflective cracking has not been eliminated by the CIR with the HMA overlay rehabilitation technique.

CIR and FDR with asphalt projects in Illinois have utilized various surface courses. For lower traffic volumes, surface treatments and cape seals are popular. For higher traffic volumes, HMA surfaces are normally employed. The WIRTGEN (2012) and Sabita (2020) manuals suggest that surface treatments (including cape seals) can be used for less than 3 MESALs (three million equivalent single axle loads). Suggested HMA surface thicknesses for MESALs greater than 3 are 1.25 in. to 2.00 in.

Subsequent to 2015, several projects have been constructed by IDOT, particularly in District 4. The performance of all the IDOT projects should be closely monitored. It appears that rutting is not a problem, but transverse/reflective cracking is a concern.

CHAPTER 4: LITERATURE REVIEW INPUTS

The work proposed in Task 3 was to review CIR and FDR literature and update or modify (as appropriate) previously provided inputs concerning mix design, testing procedures, thickness design, construction, and performance. The principal investigator monitored the technical literature relevant to recycling with asphalt and cement. Some particularly relevant items are discussed in the following sections.

The final report for NCHRP 09-62 (Rapid Tests and Specifications for Construction of Asphalt-treated Cold Recycled Pavements) has been published and reviewed (Diefenderfer et al., 2021). The report recommended "to use the shear and raveling properties of recycled materials in an effort to quantify the time to surfacing and time to opening, respectively. Specifically, the number of blows and torque values from a long-pin shear test and a short-pin raveling test were recommended. By use of a statistical approach, suggested threshold values for each test were developed. Draft guide specifications and preliminary draft standard practice documents were developed to assist agencies with using these new tests." The NCHRP 09-62 findings and recommendations should be helpful in the conduct of Illinois Center for Transportation project R27-227: Moisture Content and In-Place Density of Cold Recycle Treatments.

In line with continued efforts to develop/refine a thickness design approach for soil cement and FDR with cement pavements, a helpful Austroads report by Grenfell et al. (2020) has been reviewed. The report shows 28-day cured compressive strengths between ~150 and ~300 psi. Several Illinois local roads agencies are currently utilizing FDR cement contents that produce cured compressive strengths in the "lightly bound" range. Austroads does not use "fatigue" as a failure criterion in their thickness design procedure. The material is assigned a "cracked phase" modulus for use in the Austroads flexible pavement design procedure. The "cracked phase" modulus values vary between approximately 40 ksi and 85 ksi.

A report by Issam et al. (2018) from the Colorado Department of Transportation (CDOT) contains a good data set of dynamic modulus values for CIR project cores from 10 projects. Performance data were also collected. CDOT has constructed 37 CIR projects since 2000. The moduli at 75°F ranged from 1,040 ksi to 290 ksi. Of particular interest is that three of the coring projects were for interstate pavements. The CIR thicknesses ranged from 4 in. to 8 in. with HMA overlay thicknesses from 3 in. to 4.25 in. The study concluded that the CIR materials investigated behaved similarly to a CDOT HMA (SX [75] PG 58-28).

Sabita's *Technical Guideline* (2020) is a comprehensive treatment of the use of bitumen-stabilized materials (BSM). Two BSM classes (BSM1 and BSM2) are considered. Jenkins and Johns (2021) recently published a paper that summarizes the South African Technical Guideline (TG2) approach.

CHAPTER 5: COLD CENTRAL PLANT RECYCLING ACTIVITIES

The work proposed in Task 4 was to review cold central plant recycling (CCPR) literature related to design and construction as well as monitor the performance of National Center for Asphalt Technology (NCAT) sections and Virginia Department of Transportation (VDOT) high-volume sections. Diefenderfer et al. (2019) documented the performance/response of the NCAT CCPR sections.

Virginia sponsored the construction, trafficking, and testing of three CCPR test sections at the NCAT Test Track from 2012 to 2017. The sections all included a 5 in. CCPR (2% asphalt + 1% cement) foamed base. Sections N4 and S12 received a 4 in. HMA surface course, and N3 was paved with a 6 in. HMA surface. The CCPR layer was placed over a 6 in. aggregate base in sections N3 and N4. In section S12 the existing 6 in. aggregate + 2 in. of subgrade was stabilized with 4% cement. The subgrade was AASHTO A-4 (0). The sections have received approximately 20 MESAL.

The summary of their findings indicates:

> The study found that the performance of the three recycled sections continues to be excellent after 20 million equivalent single axle loads of traffic loading. This was evidenced by the following examples of functional performance: no observable cracking in the pavement surface, rut depths less than 0.3 in, and steady measurements of ride quality. The claim of excellent performance is also supported by the following examples of structural performance: steady or increasing modulus values for the asphalt/CCPR layer and steady or slightly increasing tensile strain at the bottom of the CCPR layer, vertical base pressure, and vertical subgrade pressure.

Note that NCAT staff has indicated "first cracking" was observed in section N4 (4 in. asphalt surface) in January 2021 at 29.6 MESALs.

The study recommends that VDOT continue to sponsor two of the recycled sections for the 2018 track cycle and further recommends that VDOT find ways to identify and fund additional projects to implement the pavement recycling concepts in Virginia.

Diefenderfer et al. (2016) utilized FWD data from the NCAT sections to estimate the AASHTO structural coefficient for the CCPR. The average values were 0.39 for section N3 and 0.36 for section N4. VDOT currently uses a coefficient of 0.35 for CCPR. Note that the IDOT Bureau of Local Roads and Streets assigns an AASHTO structural coefficient of 0.28 to CIR with asphalt products.

CHAPTER 6: COLD CENTRAL PLANT RECYCLING SPECIFICATION

The work proposed in Task 5 was to assist IDOT in the development of a special provision for CCPR. The principal investigator participated in the IDOT CCPR Working Group chaired by John Senger (IDOT Bureau of Research). Relevant inputs concerning typical specifications, mixture design procedures, and construction specifications were provided to the working group. Review comments were provided on various drafts of the special provision.

In 2020, a CCPR project was constructed in District 5 (FAS 509) near Indianola in Vermillion County. The existing 8 in. jointed reinforced concrete pavement (JRCP) (4 in. subbase) was in extremely poor condition. The new pavement section is a 3 in. CCPR with a 1.5 in. HMA surface course. Cross Construction of Urbana, Illinois, was the contractor on the project. The Asphalt Materials mixing plant was utilized in preparing the CCPR mix. The plant is completely automated with two feed bins and two weigh belts. The plant produces about 250 tons per hour. Illinois Center for Transportation project R27-227 (Moisture Content and In-Place Density of Cold Recycle Treatments) conducted considerable testing on the project.

CHAPTER 7: ILLINOIS DEPARTMENT OF TRANSPORTATION INPUTS

The work proposed in Task 6 was to respond to IDOT inquiries and questions concerning issues related to CIR, FDR, and CCPR. The principal investigator provided inputs and recommendations to IDOT activities concerning mixture design, construction specifications, strength and durability requirements, structural behavior, thickness design, and performance. An issue of particular importance that was noted during the review of many project documents is the lack of a realistic IDOT thickness design procedure for FDRC. This issue is addressed in the following section.

CEMENT-TREATED BASE THICKNESS DESIGN

In Illinois, FDRC is a commonly used rehabilitation procedure for low-volume (Class III and IV) local roads and streets. IDOT's *Bureau of Local Roads and Streets Manual (2018*) and *Bureau of Design and Environment (BDE) Manual (2021)* do not currently include thickness design procedures for FDRC layers. Chapter 54: Pavement Design of the *BDE Manual* includes a modified AASHTO design method as a historical reference. This procedure is based on the structural number (SN) approach. The SN is established by multiplying the thickness (in inches) of the FDRC layer by a coefficient of relative strength. The assigned coefficients are dependent on the 7-day compressive strengths (field mixing conditions). Table 4 presents the Chapter 54 compressive strength—coefficient relationships. Note that these are historic values that were not developed specifically for use in FDRC design.

Table 4. Modified AASHTO—Predicted Life (8 in. FDRC / IBR = 3)

Compressive Strength* (psi)	Coefficient	Structural Number (SN)	Estimated Life (KESALs**)
500	0.20	1.60	2.0
650	0.23	1.84	5.5
750	0.25	2.00	10.0

*7-day field mixed

**Equivalent single axle loads (thousands)

Typical FDRC layers are 8 in. to 12 in. thick. Jasper County has constructed many miles of 8 in. FDRC sections with surface treatments. The sections have demonstrated good performance for several years. Other Illinois local road agencies have experienced similar FDRC performance. Based on the coefficients shown in Table 4, the estimated design lives of an 8 in. FDRC section were calculated per Chapter 54. The design life estimates are shown in Table 4 for a subgrade IBV of 3. Note that for the 8 in. thickness, the design lives are very low. For an average daily traffic of 400 (the upper limit for a Class IV road), the 20 year Illinois traffic factor is 0.11 (110,000 ESALs). It is apparent that the modified AASHTO SN system does not provide a realistic estimate of FDRC life.

Project efforts have demonstrated that a mechanistic-empirical approach based on flexural fatigue failure of the FDRC layer provides more realistic estimates of pavement life. A prior IDOT-sponsored study (Thompson, 1986) developed a process for conducting a mechanistic-empirical analysis for high-strength stabilized base pavements. The Meyerhof ultimate load-carrying approach (Meyerhof, 1962) also indicates the potential of achieving good performance of FDRC layers.

The initial IDOT FDR with the Cement Working Group (Chaired by Kevin Burke in 2012—Bureau of Local Roads & Streets) recommended a minimum FDRC thickness of 8 in. The principal investigator's FDRC monitoring activities over the past several years indicate 12 in. is a practical upper limit.

FDRC pavement performance as well as the mechanistic-empirical and Meyerhof analysis procedures indicate that for the 8 in. to 12 in. FDRC thickness range, FDRC 7-day mixture compressive strengths in the approximate range of 300–750 psi will provide good performance. Increased thickness and increased compressive strength will provide better performance.

CHAPTER 8: FDRC WORKING GROUP

The work proposed in Task 7 was to attend meetings of IDOT's FDR with the Cement Working Group and provide input in the development of a special provision for FDR with cement. The principal investigator participated in several meetings concerning the development of the special provision. The Working Group Chair was James Krstulovich of the IDOT Central Bureau of Materials. Inputs, particularly concerning strength requirements and freeze-thaw durability, were provided. Several draft versions were reviewed, and review comments were provided. The Bureau of Local Roads and Streets recently published the *Special Provision for Full-Depth Reclamation (FDR) with Cement or Cement Slurry (LR 400-9)*, which is effective May 1, 2021.

CHAPTER 9: SUMMARY AND RECOMMENDATIONS

As indicated in Chapters 2–8, inputs to IDOT concerning the various project tasks have been provided. Recommendations concerning some particularly relevant issues are:

- Provide guidance and policy concerning the types of surfaces to utilize for CIR and FDR with asphalt pavement sections.
- Closely monitor the performance of previously constructed CIR (with asphalt) and HMA overlay of existing composite (HMA overlaid PCCP) pavements. The issue of most concern is the reflective/transverse cracking of the HMA overlay. Rutting does not appear to be an issue.
- Encourage the implementation and use of the cold central plant recycling (CCPR) process. Some states have utilized CCPR on lower traffic volume pavements as well as high-volume pavements (including interstates and particularly in Virginia).
- Support studies and projects concerning the mixture design and thickness design of CCPR pavements. This issue is very important to the judicious utilization of CCPR in high traffic volume applications. Sabita's manual (2020) provides a comprehensive perspective.
- Develop guidance, policy, and a thickness design procedure for FDR with cement (as the binding agent) pavement sections. The process is widely used by local roads agencies. Current practice (mixture and thickness designs) shows a wide variation. However, good performance has been achieved, with the exception of transverse shrinkage cracking.

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