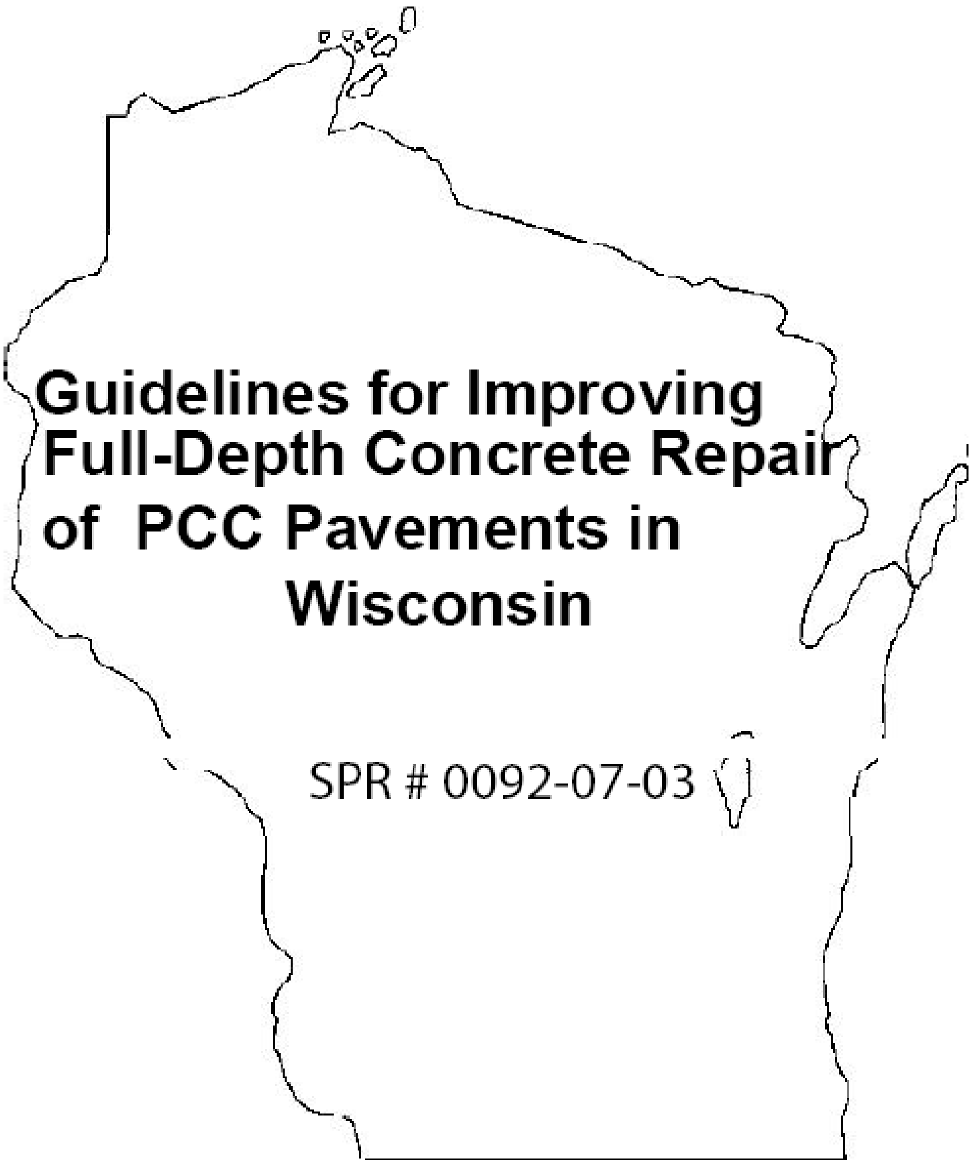
Wisconsin Highway Research Program



Guidelines for Improving Full-Depth Concrete Repair of PCC Pavements in Wisconsin

SPR # 0092-07-03

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Applied Research Associates, Inc.

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16. Abstract

This document presents recommendations for improving full-depth repair of portland cement concrete (PCC) pavements in Wisconsin. It is not intended to be used as a standard by itself, but rather as a supplement to current specifications for PCC pavement repair throughout the state.

These recommendations were developed using information available from existing Wisconsin Department of Transportation (WisDOT) guidelines, research conducted or sponsored by transportation agencies in Wisconsin, and published national and regional literature pertaining to the design, construction, and field surveys of PCC pavement full-depth repair projects in Wisconsin.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
(none)	mil	25.4	micrometers	µm
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
NOTE: volumes greater than 1000 shall be shown in m^3				
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (metric tons)	Mg (or t)
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lb	pounds	4.45	Newtons	N
lb/in^2 (psi)	pounds per square inch	6.89	kiloPascals	kPa
k/in^2 (ksi)	kips per square inch	6.89	megaPascals	MPa
		DENSITY		
lb/ft^3 (pcf)	pounds per cubic foot	16.02	kilograms per cubic meter	kg/m^3

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
µm	micrometers	0.039	mil	(none)
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.71	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or t)	megagrams (metric tons)	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	Newtons	0.225	pounds	lb
kPa	kiloPascals	0.145	pounds per square inch	lb/in^2 (psi)
MPa	megaPascals	0.145	kips per square inch	k/in^2 (ksi)
		DENSITY		
kg/m^3	pounds per cubic foot	0.062	kilograms per cubic meter	lb/ft^3 (pcf)

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised September 1993)

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CHAPTER 1. INTRODUCTION

History of PCC Pavement Construction and Rehabilitation in Wisconsin

The use of portland cement concrete (PCC) for highway construction in Wisconsin began in the 1920's with the construction of both local roads and, over time, high-type (interstate/freeway) pavement facilities. The PCC pavement types that have been constructed historically are jointed plain concrete pavement (JPCP) with or without dowels, jointed reinforced concrete pavement (JRCP) with dowels, and some continuously reinforced concrete pavements (CRCP).(1) Currently, only JPCP with dowels is constructed in Wisconsin. A full description of these PCC pavement types is presented in table 1.

PCC pavements in Wisconsin are designed for 20 to 25 years of service, after which they typically, experience one or two significant rehabilitation events prior to reconstruction. The typical PCC pavement life cycle is presented in figure 1.(1)

- The first significant rehabilitation typically involves full-depth repair concurrent with activities such as dowel retrofit and shoulder replacement. The repairs sometimes are followed immediately by either diamond grinding, to restore pavement ride quality, or the placement of a hot mix asphalt (HMA) overlay.(1) The first significant rehabilitation typically is designed to last for 12 to 15 years.

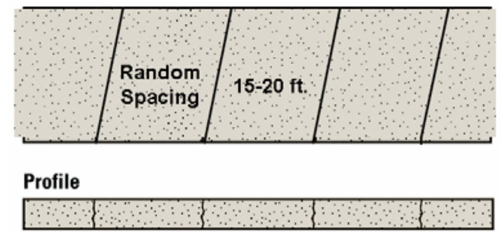
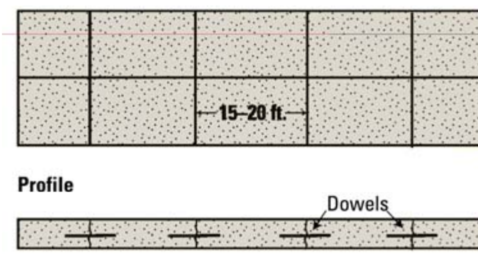
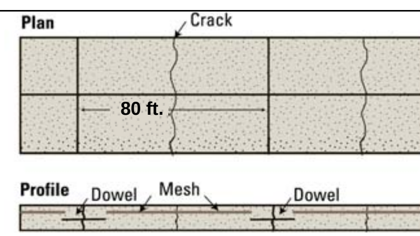
- A second significant rehabilitation consisting of the following may be performed after the deterioration of the first rehabilitation:

    - For pavements receiving the HMA overlay during the first significant rehabilitation, the second significant rehabilitation consists of milling off all or part of the first HMA overlay for recycling, performing full-depth repairs, and placing another HMA overlay.

    - For pavements subjected to full-depth repairs and diamond grinding as part of the first significant rehabilitation, the second significant rehabilitation consists of additional full-depth repairs and concurrent repairs activities, followed immediately by either another diamond grinding or the placement of an HMA overlay.

  The second significant rehabilitation is designed to last 8 to 10 years.

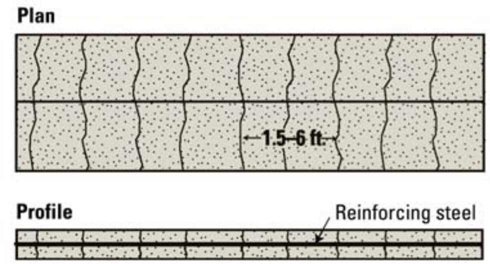
Table 1. Description of PCC pavement types constructed in Wisconsin.(2, 3, 4)

Pavement Type*	Description	Plan and Profile
New JPCP (undoweled)	This pavement type was constructed from the mid 1970's to late 1980's in Wisconsin. Typical design features include (1) load transfer through aggregate interlock, (2) unreinforced slab panels, (3) random spacing (13-19-18-12 ft), and (4) skewed joints. Due to inadequate load transfer at the transverse joints, these pavements experienced significant amounts of pumping and faulting within a relatively short period of time after initial construction. The construction of this pavement type has been discontinued since the late 1980's. The existing pavements are increasingly being subjected to rehabilitation which includes full-depth repair of cracks and deteriorated joints and dowel-bar retrofit.	
New JPCP (doweled)**	JPCP with dowels has been the favored PCC pavement type constructed in Wisconsin since the late 1980's. Typical design features include (1) dowels at the transverse joints to provide load transfer, (2) unreinforced PCC slabs, (3) widened slabs, (4) dense-graded aggregate base/subbase (crushed stone, crushed gravel, or crushed "recycled" PCC, reclaimed HMA pavement, or any other recycled or reprocessed material), (5) joint spacing less than 20 ft (typically 15 ft), (6) asphalt shoulders, and (7) PCC thickness (9.5-in for rural highways with 15-ft joint spacings and 8- to 9.5-in for urban highways). The final JPCP design is selected based on anticipated traffic volumes, speed, terrain/location, etc. (e.g., 4-lane divided Interstate or Freeway highway with annual average daily traffic (AADT) ranging from 8700 to 60000, a design speed of 70 mph, and on level terrain). Because the construction of this pavement type began recently, a vast majority are yet to be subjected to significant rehabilitation. In the future, however, this pavement type will be the most common in Wisconsin and thus will be the main candidate for full-depth repairs.	
JRCP	This pavement type was constructed from the 1950's to early 1970's. Typical design features were (1) a wire mesh reinforced PCC slab, (2) doweled joints, and (3) 80-foot joint spacings. The most commonly occurring distresses are deteriorated joints and midpanel cracking that deteriorates with time. Faulting is not generally a problem at joints but can occur at cracks and is influenced by the age and loading on the pavement as well as the condition of the base and subgrade materials. The existing pavements are increasing being subjected to significant rehabilitation which includes full-depth repair of cracks and joints.	

*Typical JPCP, JRCP, and CRCP designs are available form the WisDOT Standard Specifications, WisDOT Facilities Development Manual, and other publications. These documents provide recommended layer types that make up the pavement structure along with minimum and maximum planned thicknesses for the PCC layer, base/subbase layers, and subgrade.(2,3,4)

**Note that current WisDOT policy establishes JPCP with dowels as the standard type of PCC pavement utilized in Wisconsin.

Table 1. Description of PCC pavement types constructed in Wisconsin, continued.(2, 3, 4)

Pavement Type	Description	Plan and Profile
CRCP	CRCP's were mostly constructed from the early 1960's to the late 1980's in Wisconsin. The presence of the continuous reinforcement in this type of pavement resulted in high quality ride even at elevated levels of distress. However, as these pavement approaches the end of their service life, an increase in the rate of deterioration can be expected. With increasing rate of deterioration it is expected that the CRCP's in Wisconsin will soon require extensive rehabilitation including full-depth repair.(2)	
Composite (HMA overlaid JPCP, JRCP, and CRCP)	WisDOT has been placing HMA overlays over existing PCC pavements since the late 1970's as part of first or second significant rehabilitation. The HMA overlays are typically placed after extensive repairs of the existing PCC (including full-depth repairs). The main form of deterioration for the composite pavement is the occurrence of reflection cracking that deteriorates with truck traffic applications. Depending on the condition of the existing underlying PCC pavement, HMA overlaid PCC can be subjected to further rehabilitation or completely reconstructed.	

*Typical JPCP, JRCP, and CRCP designs are available form the WisDOT Standard Specifications, WisDOT Facilities Development Manual, and other publications. These documents provide recommended layer types that make up the pavement structure along with minimum and maximum planned thicknesses for the PCC layer, base/subbase layers, and subgrade.(2,3,4)

**Note that current WisDOT policy establishes JPCP with dowels as the standard type of PCC pavement utilized in Wisconsin.

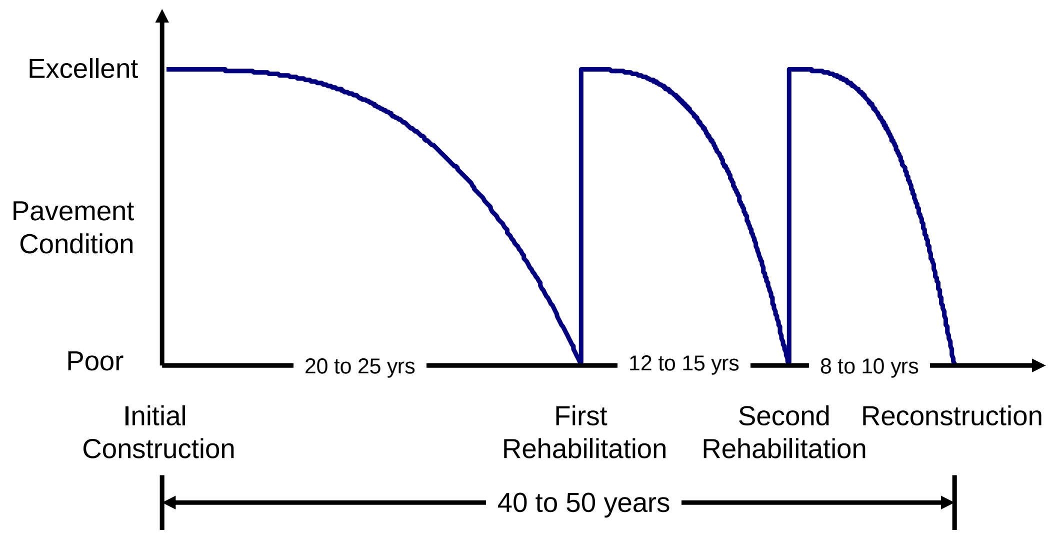


Figure 1. Typical PCC pavement life cycle.[1]

Need for Full-Depth Repair

Full-depth repair is a very important maintenance and rehabilitation technique in Wisconsin, as it can remedy numerous PCC pavement distresses (see table 2). [5, 6, 7] Detailed descriptions of these distresses are presented in table 3. The extent and severity of the distresses listed in tables 2 and 3 are key in determining the feasibility of full-depth repair or single/multiple slab replacements as a rehabilitation option. Distress extent and severity are determined through visual distress survey and limited coring and laboratory examination of cores. There is also a need for full-depth PCC repairs of existing overlaid PCC pavements.

Table 2. Description of WisDOT PCC pavement rehabilitation strategies involving full-depth repairs.

Distress Type	**Pavement Type**					
	JPCP	**JRCP**	**CRCP**	**HMA overlaid JPCP**	**HMA overlaid JRCP**	**HMA overlaid CRCP**
Linear (transverse and longitudinal) cracking and corner breaks	X	X	X			
Reflection cracking				X	X	X
Punchout			X			X
"D" cracking and alkali-silica reaction (ASR)	X	X	X	X	X	X
Joint spalling	X	X				
Blowup	X	X	X			

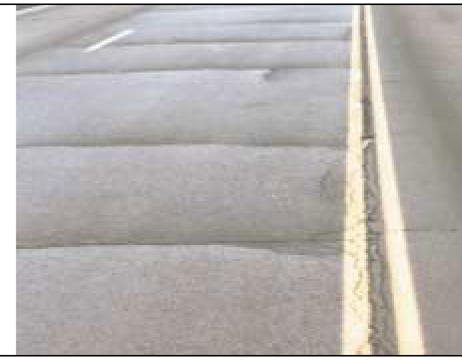
Table 3. Detailed description PCC pavement distresses that require full-depth repairs.[5, 8]

Distress Type	Description	Photo
Joint spalling	Spalling at the joint or crack is caused by the combination of infiltration of incompressibles into the joint and horizontal joint or crack movements which leads to the disintegration of PCC at the joint or crack. PCC disintegration at the joint or crack is more severe for large horizontal joint movements that occurs predominantly in long JRCP (40-100 ft) or for short span JPCP with extensive infiltration of incompressibles. PCC disintegration at the joint or crack is not always initially visible at the pavement surface although it eventually develops into a spall that can be seen at the surface.	
Blowup	Blowups are caused by compressive stress buildup in the PCC slab (due to infiltration of incompressibles, or alkali aggregate reaction). A blowup may occur as a shattering of the PCC for several feet on both sides of the joint, or an upward buckling of the slabs.	
"D" cracking and aggregate alkali reaction	"D" cracking is a pattern of cracks caused by freeze-thaw expansion of aggregates in PCC. Alkali-aggregate reaction includes alkali-silica reaction (ASR) and alkali-carbonate reaction (ACR) and is caused by compressive stress building up in the PCC slab, due to swelling of gel produced from reaction of certain siliceous and carbonate aggregates with alkalies in cement. The disintegration and spalling associated with these distresses normally begins near the joints.	

Table 3. Detailed description PCC pavement distresses that may require full-depth repairs, continued.(5, 8)

Distress Type	Description	Photo
Cracking	Transverse and longitudinal cracking, and corner breaks, typically are caused by repeated heavy truck loads and loss of support from beneath the slab due to pumping. Another cause is movement of the foundation from frost heave or swelling soils. If slab cracking occurs only in the lane with the heaviest truck traffic, fatigue damage is the likely cause, otherwise foundation problems are more likely the cause.	
CRCP punchouts	Punchouts usually occur between closely spaced transverse cracks. Loss of aggregate interlock at the transverse cracks, a function of crack width and traffic loads, can cause the slab to act as a cantilever beam, inducing high transverse (perpendicular to the direction of traffic) tensile stresses at the PCC surface. Depending on the magnitude of the tensile stresses, strength and fatigue characteristics of the PCC, and traffic load applications, a longitudinal crack may eventually form between transverse cracks. The result is a punchout. Progression of the punchout distress continues with traffic loads and climate cycles that induce spalling at the cracks, further loss of support, pumping, reduced subgrade support, and increased severity of the punchout distress.	

Table 3. Detailed description PCC pavement distresses that may require full-depth repairs, continued.[5, 8]

Composite (HMA overlaid PCC) pavement reflection cracking	Reflection cracking are cracks in HMA-overlaid PCC pavement that occur directly over the underlying PCC pavement joints, cracks, or punchouts. They are caused by movement of the PCC layer beneath the HMA surface because of thermal and moisture changes and wheel load applications. Application of heavy truck wheel loads can hasten progression and deterioration of reflection cracking. Reflection cracking allows moisture infiltration into the existing pavement base/subbase leading to pavement foundation weakness and additional pavement deterioration.	

Guidance for Determining Need for Full-Depth Repair

- The feasibility of full-depth repair depends on several factors, such as the extent and severity of the distress and the rate of deterioration. In general, medium-severity distresses that are likely to deteriorate into high-severity distress in a relatively short timeframe are prime candidates for full-depth repairs. The severity level, extent, and rate of deterioration of a given pavement distress are best determined through detailed pavement evaluation (visual distress survey, coring and lab examination, etc.).

- As a general rule:[(5)]

    - JPCP requires a structural improvement when 10 to 20 percent of the slabs in the outer traffic lane are cracked. Linear cracking (transverse, longitudinal, diagonal, and corner breaking) of all severities is considered structural distress.
    - JRCP requires a structural improvement when 50 percent of the joints in the outer lane have medium- or high-severity joint deterioration, and/or when there are about 75 or more medium- or high-severity transverse cracks per mile in the outer traffic lane. Low-severity transverse cracks are part of the design and are not structural distress.
    - CRCP requires a structural improvement when 10 or more punchouts, steel ruptures, and/or failed full-depth repairs per mile are present in the outer traffic lane.

- It is recommended that full-depth repair be performed concurrently with diamond grinding as needed to restored pavement rideability or with the placement of an HMA overlay.[(2)]

Scope

This document presents recommendations for improving full-depth repair of PCC pavements in Wisconsin. It is intended to be used not as a standard by itself, but rather as a supplement to current specifications for PCC pavement repair throughout the state.

These recommendations were developed using information available from existing Wisconsin Department of Transportation (WisDOT) guidelines, research conducted or sponsored by transportation agencies in Wisconsin, and published national and regional literature pertaining to the design, construction, and performance data from full-depth repair projects in Wisconsin.

Organization and Use

This document is a compilation of good design practices, materials selection, construction, and inspection methods that should reduce the risk of early cracking, pumping, faulting, and rocking of full-depth repairs. It is anticipated that this, in turn, will help rehabilitated PCC pavement in Wisconsin to realize its long-term performance goals. In addition to highlighting the best practices to avoid early failures, this document presents a discussion of design, materials selection, and construction practices that are known to cause early failures.

This document is divided into four chapters. This introductory chapter provides some background and general guidance when designing and construction full-depth repairs.

Chapter 2 presents the design of full-depth repairs (i.e., general considerations, selection of full-depth repair boundaries, joint design, load transfer, dimensions, and sealing, and PCC thickness).

Chapter 3 presents the construction of full-depth repairs—PCC mixture design, saw cutting of repair boundaries, removal of existing PCC (including large area removal), placement of load transfer devices (round bar dowels), PCC placement and finishing, joint forming, curing, and opening to traffic.

Finally, chapter 4 provides a checklist of activities for the design and construction engineer and inspection team.

This document is neither a construction guidance specification nor a design procedure. It does not provide detailed instructions on conducting specific design or construction-related activities. It does not constitute a standard, specification, or regulation. This manual should not be used in lieu of a project specification. The specific requirements of plans and specifications for a project have precedence.

CHAPTER 2. FULL-DEPTH REPAIR DESIGN

Issues that are considered key to the design of full-depth repair include:

- General considerations.
- Determination of full-depth repair boundaries.
- Joint design (load transfer mechanism, sizing, layout, and dimensions).
- Repair PCC thickness.

Detailed descriptions of these issues are presented in the following sections.

General Considerations

Full-depth repairs should be designed for specific project conditions. The desired life of the repair and anticipated future traffic loadings mostly dictate design details. The longer the design life, the greater the truck volumes, and the more critical the structural design of the repair becomes.

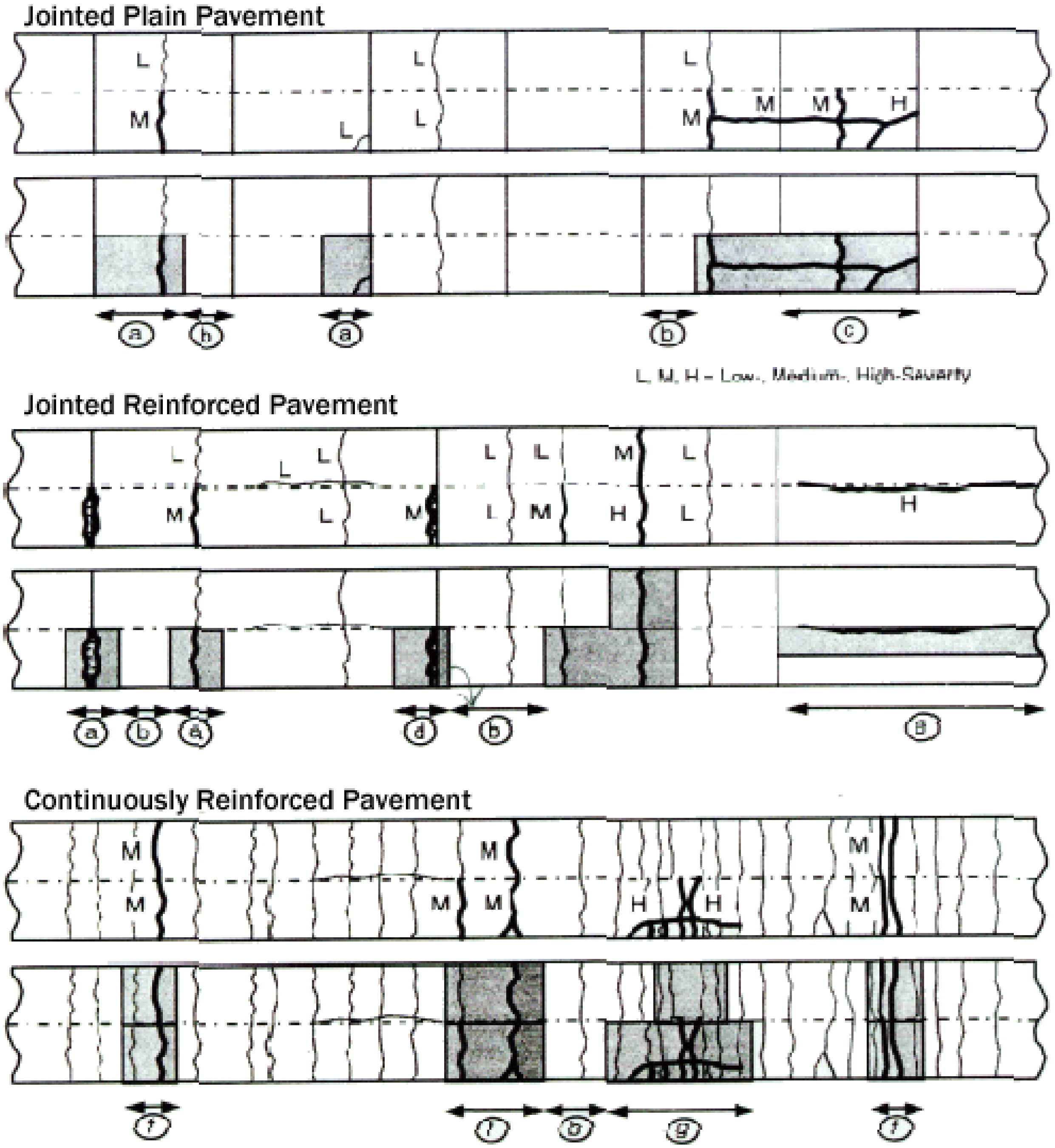
> Sometimes, full-depth repair is effective only if done concurrently with activities such as drainage retrofit and diamond grinding.

Many full-depth repairs have not performed as desired because the effect of heavy truck traffic and climate were not fully considered, especially in the joint design of the repairs. Other issues that must be considered in the design of full-depth repairs are (1) available lane closure time, (2) environmental (temperature and moisture) conditions, (3) subgrade drainability, and (4) design features of existing pavement.

Determination of Full-Depth Repair Boundaries

It is important that full-depth repair boundaries be determined to ensure that all significant deterioration in the existing PCC slab or joint is removed and replaced. For PCC durability-related distresses, the full-depth repair boundaries should extend at least 6 inches into what appears to be durable PCC. Identification of distress and deteriorated PCC in most cases requires both surface and subsurface evaluation of the pavement. Pavement evaluation typically is done using visual distress surveys. Additional evaluation from coring and laboratory examinations may be useful to assess underlying PCC deterioration. Examples of full-depth repair layouts for distressed JPCP, JRCP, and CRCP are presented in figure 2. It may be tempting to minimize repair quantities, but this practice nearly always results in early failures around the new repair.

> Deterioration near joints and cracks may occupy a greater area at the bottom of the slab than at the top. Special attention should be paid to PCC material durability-related distresses such as "D" cracking or aggregate alkali reaction, as it is difficult to determine the full extent of such distresses at the pavement subsurface (the PCC slab).



a. End at existing transverse joint if existing transverse joint is not doweled, otherwise extend the full-depth repair beyond transverse joint by a minimum of 1-ft to include dowels even if there is not any deterioration on the adjacent slab. Minimum length is 6-ft, transverse joints should be doweled.
b. Minimum length of remaining slab must be at least 6-ft.
c. Replace the entire slab if there are multiple intersecting cracks.
d. Extend perimeter beyond nearby cracks to get solid PCC even if nearby cracks do not need repair.
e. Remove the full length of any deteriorated longitudinal cracks, remove all punchouts.

Figure 2. Full-depth repair recommendations for JPCP (< 20-ft joint spacing), JRCP (joint spacing typically 80-ft), and CRCP.

Key Points for Determining Full-Depth Repair Boundaries

- If full-depth repairs are too long, they can cause transverse cracking mid-panel. If too short, they can cause longitudinal cracking, or the full-depth repair panel may rock with repeated loadings. Slab replacement is the best option for slabs with multiple types of cracks.

- The repair dimensions must fully encompass the extent of existing deterioration, including what is not visible at the surface.

- Minimum repair dimensions of 6 by 12 ft (i.e., lane width) are recommended to provide stability under heavy traffic and to prevent longitudinal cracking within the full-depth repair. For the same reason, the minimum dimensions of the remaining slab between repairs should also be at least 6 ft long.

- The length of the full-depth repair panel must not exceed 15 ft. If the repair must be longer than 15 ft, one or more properly designed and constructed intermediate transverse joints must be placed. For extremely long repairs, multiple slab replacement must be considered.

Full-Depth Repair Layout and Joint Design

Load Transfer Mechanism Selection

Proper selection and layout joint design details are extremely important aspects of full-depth repair design. There are three joint types of interest for full-depth repairs, namely (1) transverse joint between the full-depth repair and existing PCC, ((2) lane-to-lane longitudinal joint, and (3) lane-to-shoulder longitudinal joint (for existing pavements with tied PCC shoulders).

Key aspects of repair joint design are:

- Load transfer mechanism selection
- Sizing and layout of load transfer mechanism
- Joint dimensions

The following is guidance for selecting the proper joint load transfer mechanism:

- For JPCP and JRCP transverse joints, round dowel bars are recommended. Round dowels bars are made out of mild steel and must be epoxy coated to prevent corrosion. The dowels bars can also be coated with stainless steel for the same reasons.

- Providing tie bars at the lane-to-lane longitudinal joint of JPCP and JRCP is always desirable. However, research has shown that full-depth repairs can perform adequately without tie bars at the lane-to-lane longitudinal joint if the repair length is less than 15 ft. For repairs longer than 15 ft, tie bars must always be provided. Tie bars should be provided at the lane-to-shoulder joint if the shoulder type is PCC and the existing PCC slabs are tied to the shoulder.

- For CRCP transverse and lane-to lane longitudinal joints, full-depth repair longitudinal/transverse steel reinforcement must be tied or welded at the transverse/longitudinal joints to the steel in the adjacent slabs with an intermediate lap splice to allow expansion prior to PCC placement.

- For the CRCP lane-to-lane shoulder joint, tie bars should be provided if the shoulder type is PCC and the existing PCC slabs are tied to the shoulder.

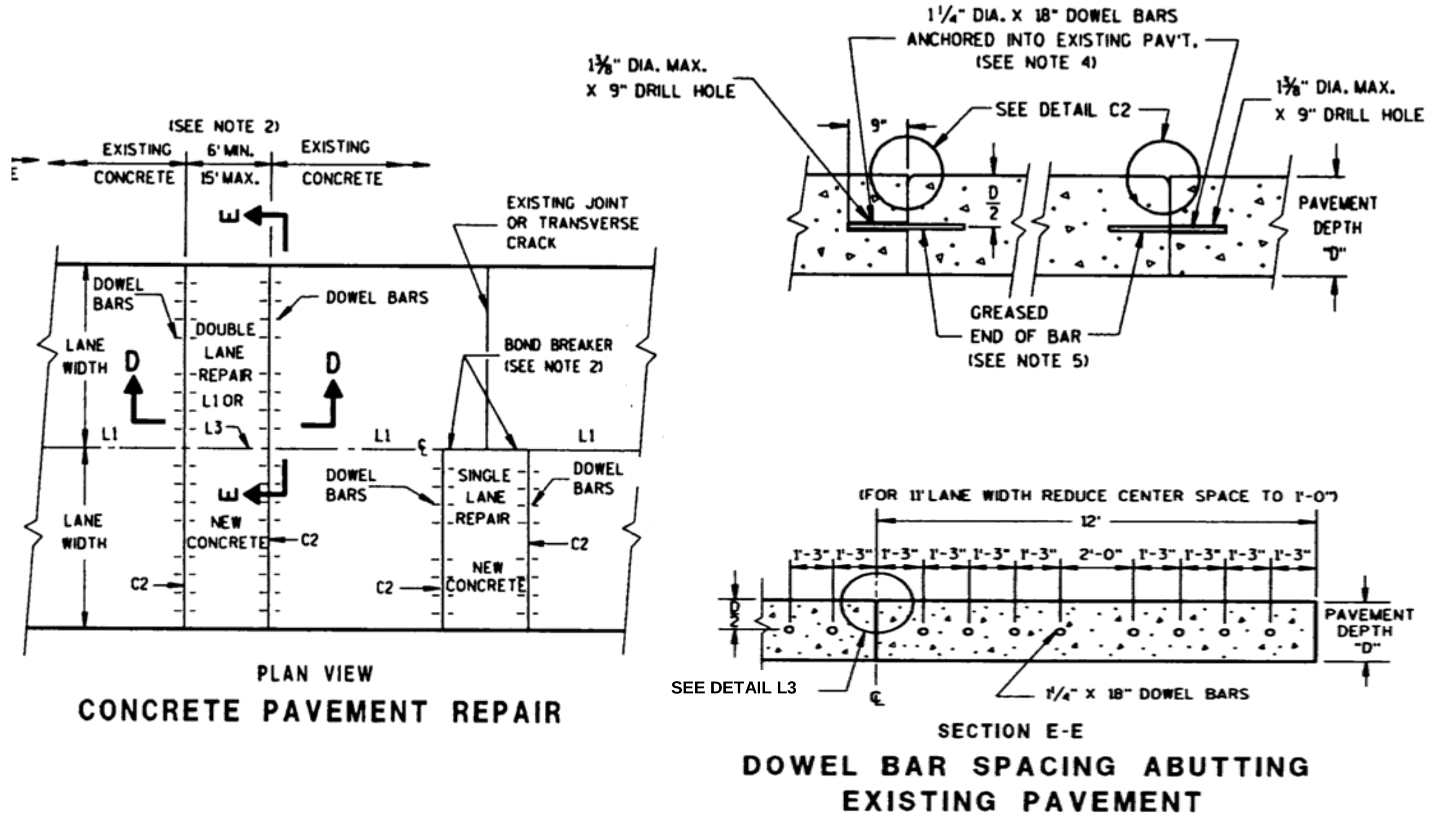
Sizing and Layout of Load Transfer Mechanism

JPCP and JRCP

The number, spacing, and size of dowel bars at JPCP and JRCP transverse joints will determine the amount of future faulting and rocking that occurs at the joints. Detailed layouts of dowel bars at JPCP and JRCP transverse joints are presented in figures 3 and 4. The layout shown in figure 3 places the dowels where they are needed the most (in the wheel paths) and provides adequate load transfer. Placing the dowels bars uniformly across the joint (as done in new design, figure 4) also provides an adequate level of load transfer. Transverse joint forming details are presented in figure 5.

Recommendations for Selecting Transverse Joint Dowel Bars Sizes and Spacings

- Material type:
  - Epoxy or stainless steel coated mild steel.
- Dowel size:
  - Diameter range from 1.25- to 1.5-in (preferable).
  - Dowel size must be selected based on anticipated future traffic levels and existing PCC thickness.
- Dowel length: 18-in
- Dowel spacing (see figures 3 and 4).



GENERAL NOTES

1. DOWEL BARS SHALL BE INSTALLED PARALLEL TO THE PAVEMENT CENTERLINE AND SURFACE
2. FULL-DEPTH REPAIR SIZES AND LAYOUT ARE SHOWN ELSEWHERE IN THIS DOCUMENT
3. PREPARATION OF BASE/SUBBASE WILL BE AS RECOMMENDED ELSEWHERE IN THIS DOCUMENT
4. DOWEL BARS SHALL BE ANCHORED INTO DRILL HOLES WITH AN APPROVED EPOXY.
5. THE FREE END OF DOWEL BARS SHALL RECEIVE A THIN UNIFORM COATING OF BOND BREAKER
6. JOINT SHALL NOT BE SEALED OR FILLED

Figure 3. Plan and profile details for transverse (dowels in wheel path) and longitudinal joints for full-depth repairs.[2,3]

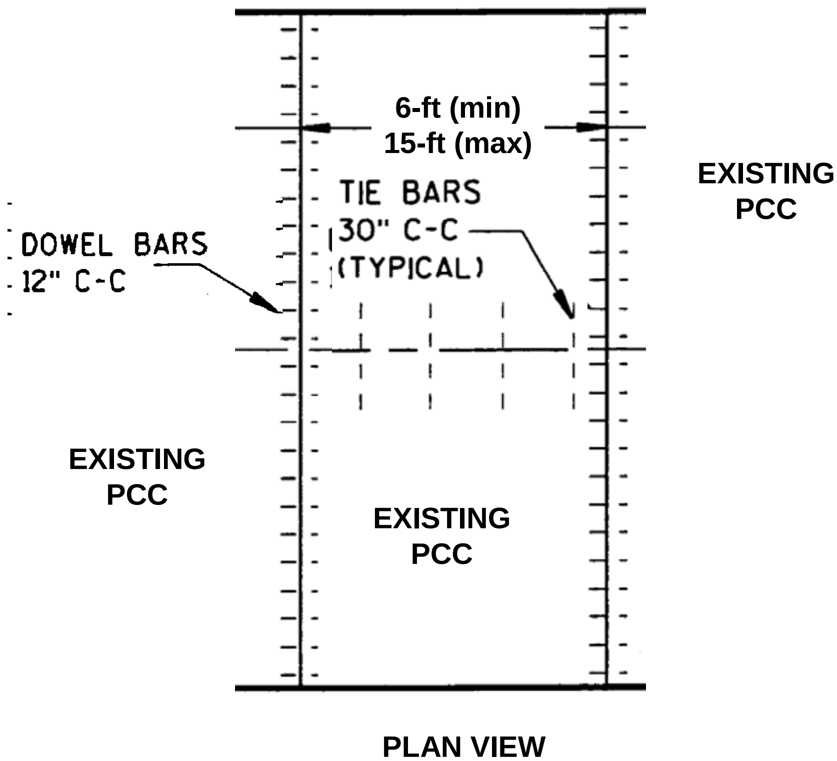


Figure 4. Plan details for transverse (dowels uniformly spaced) and longitudinal joints for full-depth repairs.(2,3)

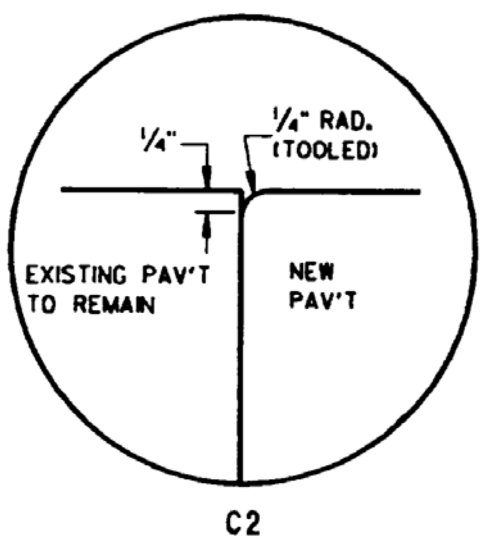


Figure 5. Additional dimension details for full-depth repairs transverse joints.(2,3)

Although tie bars are desirable for all full-depth repairs, they are specifically recommended for repairs longer than 15 ft. Additional recommendations are as follows:

- The No. 6 bar is recommended for use as tie bars. The mild steel bar should be coated with epoxy to prevent corrosion and chemical reaction.
- Tie bar length: 12-in.
- Tie bar spacing: 30 to 36-in.
- The tie bar should be installed on 6:1 skew horizontally. The direction of skew will alternate after one or two bars.
- Tie bar should be installed at mid-depth of the PCC.
- Detailed layout of longitudinal joint tie bar placement and dimensions is presented in figures 6 and 7.

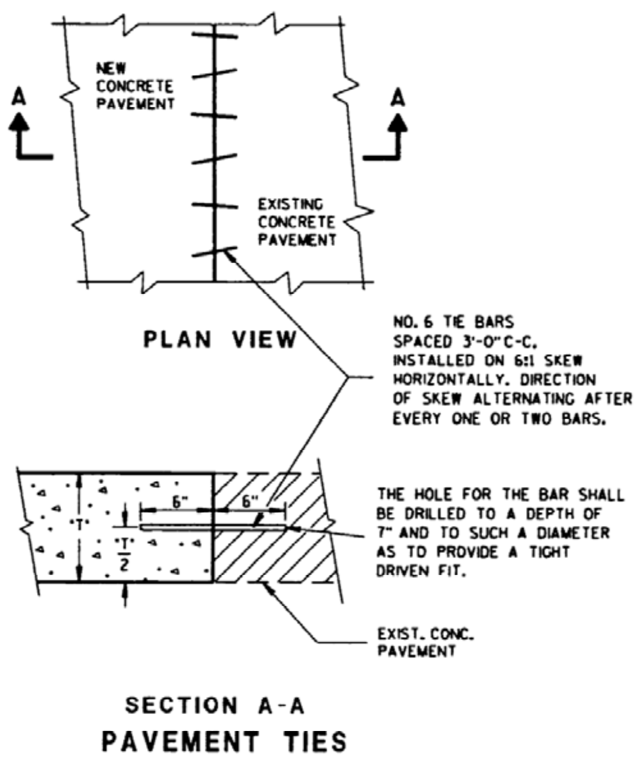
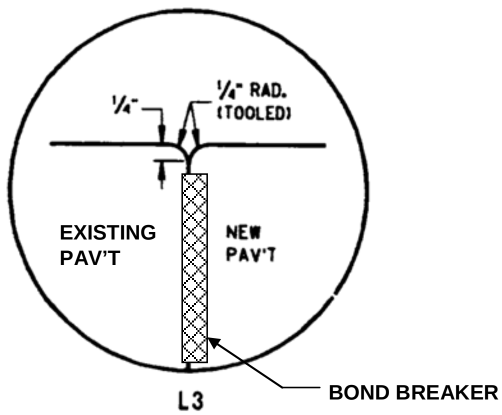


Figure 6. Longitudinal joint tie bar plan layout and profile.(2,3)



Note that for full-depth repair placed across two adjacent lanes in one operation, the longitudinal joint should be sawed according to current WisDOT specifications. Also a bond breaker (felt material) must be placed at the longitudinal joints).

Figure 7. Additional dimension details for full-depth repairs longitudinal joints.[2,3]

Intermediate Transverse Joints

Intermediate transverse joints must be placed mid-panel for full-depth repair panels (without reinforcement) longer than 15 ft. The design of the intermediate transverse joints is the same as that for new JPCP. Details are available in WisDOT standards.

CRCP

The continuity of the longitudinal reinforcing bars must be maintained throughout the repair. The reinforcing bars keep the transverse joints tight and provide load transfer. This is accomplished by full-depth cutting and removal of a center section where the punchout or other deterioration exists and then partial-depth cutting (above the steel) in end sections. The concrete is then removed in the end sections from around the existing reinforcement. See figure 8 for illustration of the center and end sections. The end sections must have sufficient length for lapping with the new reinforcement placed across the center section. The new reinforcement bars in the full-depth repair can be attached to the existing reinforcement in the end sections by tying or welding.

Detailed layouts of full-depth repair for CRCP showing details of reinforcement bar spacing, size, etc., are presented in figure 9. Also shown are the details of tied splices used to tie existing and new longitudinal reinforcement (figure 10). Details of welded splices are available in figure 11. Also, reinforcement bars in the full-depth repairs should rest on supporting chairs to avoid bending, sagging, or stressing the splices. The full-depth repair transverse reinforcement should be tied to the longitudinal reinforcement. There is no need to tie the full-depth repair transverse reinforcement to the existing PCC transverse reinforcements. Tie bars are desirable if the repair length is greater than 15 ft.

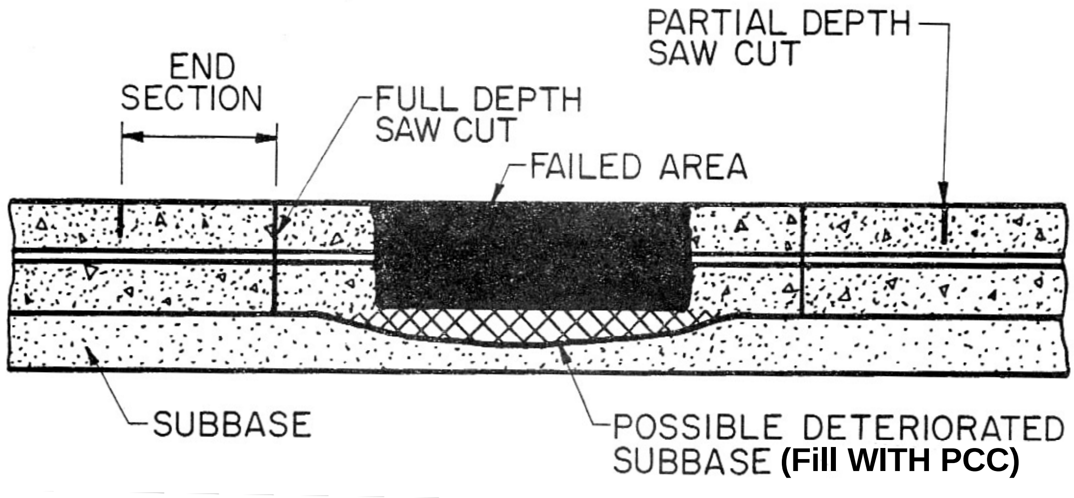


Figure 8. Illustration of the center section (complete removal) and end sections (where concrete around the reinforcement is removed).

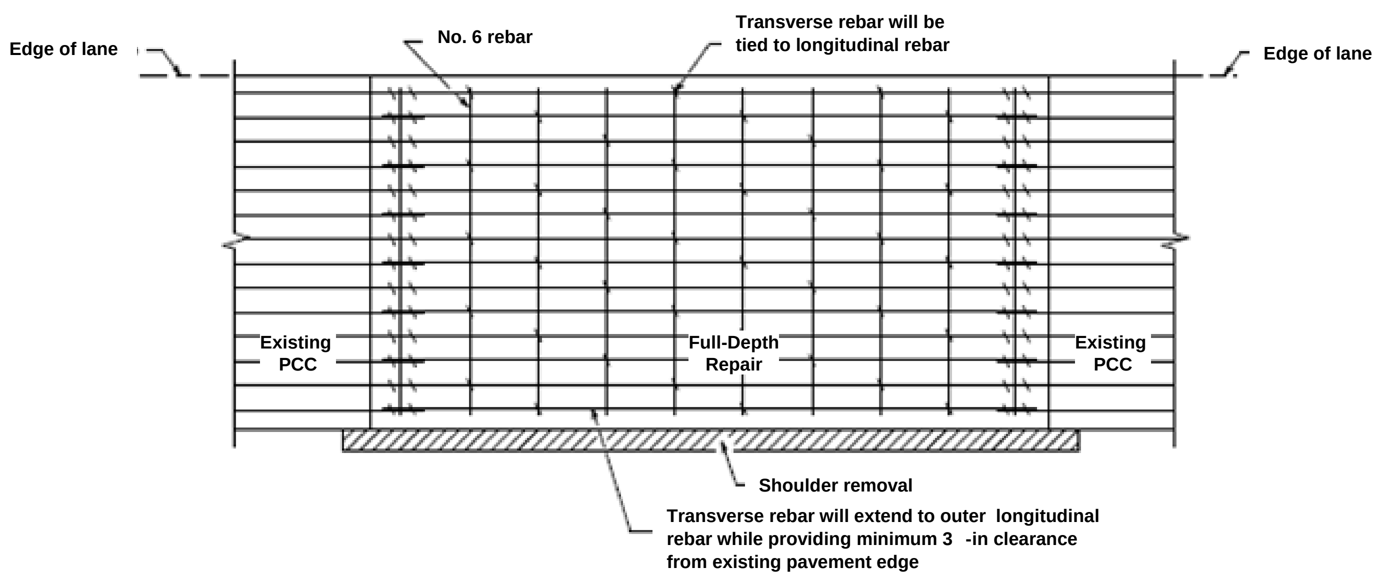


Figure 9. CRCP full-depth repair reinforcement details.

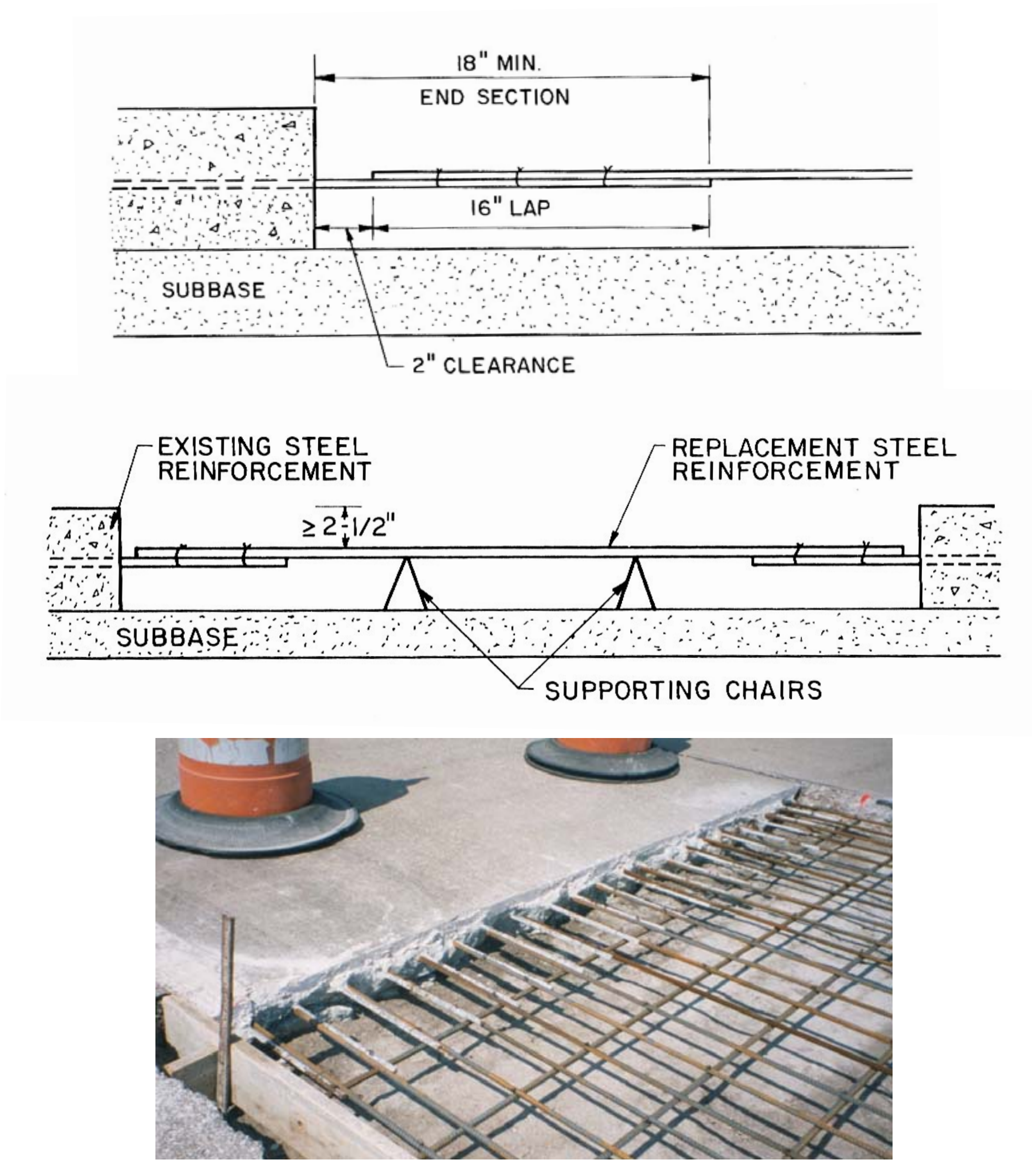


Figure 10. CRCP full-depth repair tied splice details.

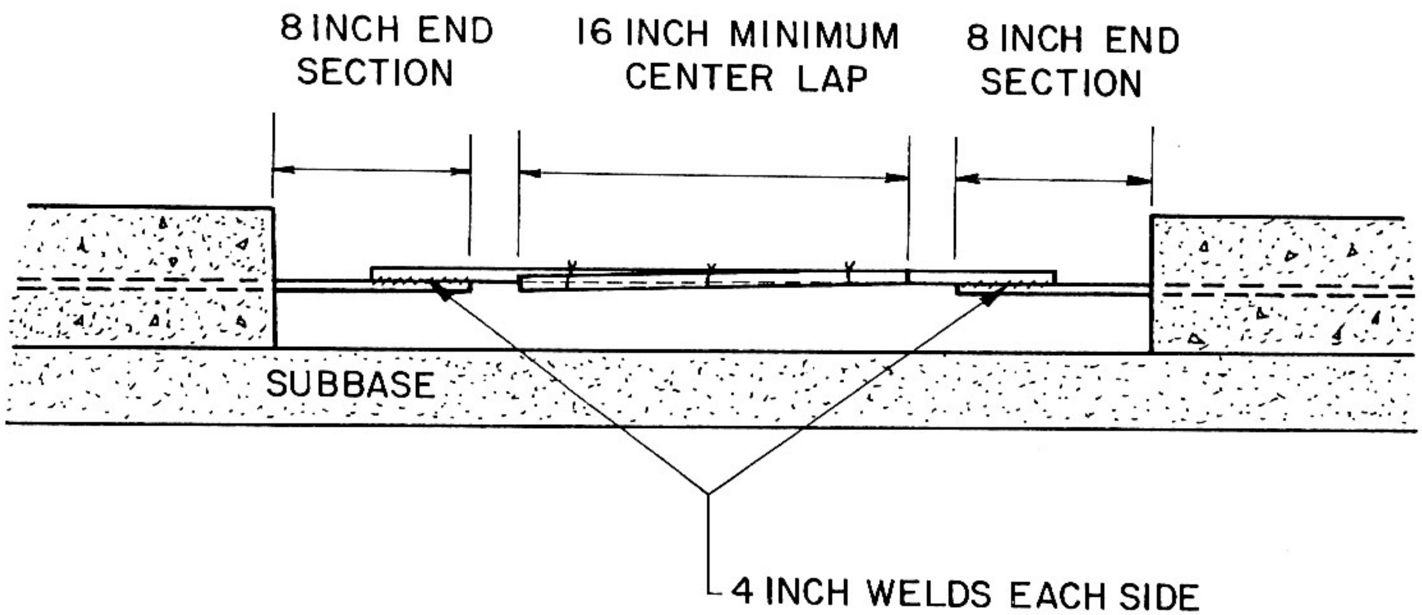


Figure 11. CRCP full-depth repair welded splice details.

PCC Thickness

Typically, the thickness of a full-depth repair is the same as that of the existing slab. If necessary, the thickness of the full-depth repair may be increased 2 to 4 inches thicker than the existing PCC slab. A thicker repair may be warranted in the following circumstances:

- If very heavy truck traffic is anticipated along with early opening.
- If previously constructed full-depth repairs have a history of cracking after a few years in service.
- If the contractor disturbs the base/subbase, the disturbed material should be replaced with PCC during the repair placement.

When the repair is made thicker than the surrounding pavement, there is a risk that subdrainage through the granular base will be blocked, which could result in pumping and/or frost heave problems on adjacent sections.

CHAPTER 3. FULL-DEPTH REPAIR CONSTRUCTION

Applying good construction practices is key to obtaining adequate performance. The issues that must be considered are:

- PCC mixture specifications (high early strength and long-term durability).
- Saw cutting of repair boundaries.
- Removal of existing PCC (including large area removal).
- Placement of load transfer devices (dowels and tie bars).
- PCC placement and finishing (including joint forming, curing, and texturing).
- Joint forming.
- Curing and opening to traffic.

Each of these issues is discussed in detail in the following sections.

PCC Mixture Design

PCC mixture used for full-depth repairs must satisfy the following criteria:

- Able to achieve high early strength.
- Workable to facilitate placement, consolidation, and finishing.
- Durable in the long-term.

High early strength PCC is recommended for full-depth repairs. A minimum PCC strength at opening of 3,000 psi is adequate for most typical PCC thicknesses ($\geq$ 10 in). For a relatively thin PCC layer, the minimum strength criteria can be modified as needed (e.g., 3,500 to 4,000 psi).

Regardless of the opening time selected, minimum PCC compressive strength must be at least 3,000 psi. Therefore, opening times must be selected based on the time it takes to achieve a minimum compressive strength of 3,000 psi. Note that ambient conditions could influence the rate of PCC strength gain.

The minimum strength criterion is valid regardless of recommended opening time, which normally is determined by factors such as functional class, traffic volumes, congestion, user delay, and so on.

Finally, the rate of PCC strength gain is highly influenced by site conditions (e.g., ambient temperature, curing). It is therefore very important to factor in the effect of ambient conditions on PCC strength prior to opening the full-depth repair to traffic.

A summary of good practices regarding high early strength PCC mixture design adapted from published literature is presented in below.[9] Note that the best practice is to perform PCC mix design in the laboratory prior to full-depth repair.

- Type I or III and special blended cements (including hydraulic non-portland cements that have rapid strength gain) are the cement types of choice for high early strength PCC. Note that best practice is to determine long term performance of selected cements prior to use.

- Minimum cement content ranges from 650 to 800Ib/yd^3. Increasing cement content does not necessarily increase PCC strength and may adversely influence the durability of high strength PCC mixtures.

- Admixtures such as air entrainers, accelerators, and water reducers commonly are added to high strength PCC mixtures during proportioning or mixing to enhance the properties of freshly mixed and/or hardened PCC. An accelerator is almost a necessity for mixtures that are to be opened within 8 hours. The most common accelerator is calcium chloride ($CaCl_2$). Note that Type III cement and some of the special blends do require additional water to enhance workability. A water reducer is used to reduce this need for excessive water in the mix.

- Because cement/admixture interactions are not well understood, compatibility problems can result in non-durable PCC. Thus, it is essential that both strength and durability testing be conducted on the actual job mixture during mixture design and construction monitoring.

- Water to cementitious materials (w/cm) ratio is typically low (less than 0.40) for high early strength PCC, as early strength and enhanced durability may be achieved effectively by reducing the w/cm ratio while increasing the aggregate volume as long as workability is maintained.

- The rate of PCC strength gain is enhanced by providing thermal insulation during curing (to retain heat of hydration).

- High early strength PCC is prone to durability-related problems (e.g., inadequate entrained air content). Thus, the potential for durability-related distress must be verified as part of mix design and quality assurance/quality control (QA/QC) after placement (e.g., checking air content of high early strength PCC).

- Maturity meters or pulse-velocity devices may be useful for monitoring the strength development of high early strength PCC in the field. Maturity readings from test cylinders, cured in the field alongside the full-depth repair, may be used to provide an indication of actual in-place strength gain of the full-depth repair PCC. This ensures that recommended minimum PCC strength is achieved prior to opening full-depth repair to traffic.

Sawing of Repair Boundaries

The methods used for saw cutting and subsequent removal of existing PCC depend primarily on the type of pavement being rehabilitated. For JPCP and JRCP, a single full-depth saw cut at the repair boundaries with a diamond saw blade is recommended. In JRCP, this will cut through any reinforcement wire present. The result of this process is a smooth cut surface with reduced potential for spalling during removal (see figure 12).(10)

For CRCP, two saw cuts should be made at each end of the repair with a diamond saw blade (at both the longitudinal and transverse boundaries). The first is a partial-depth cut made at the outside edge of the repair area. This cut is followed by a full-depth cut in the interior of the repair at a distance dependent on the lap length requirement (24 in for tied laps and 8 in for mechanical or welded laps).(10)

> The first step in full-depth PCC repair is to identify the extent of deterioration and establish the repair boundaries. The critical factor is to ensure that the entire area of deterioration is removed and that minimum repair length of 6 ft is obtained. If the deteriorated area is longer than 15 ft, the repair must be divided into as many separate panels as needed to keep panel length between 6 and 15 ft. The width of the full-depth repair should always be a full lane width for JCP.

Regardless of PCC pavement type, it is preferable that the saw cuts should not intrude on the adjacent lane if that lane is not slated for repair (see figures 12 through 14).(10) This mostly requires stopping the saw cut short of the lane to lane longitudinal joint and chipping the remaining PCC away introducing unwarranted stresses in the existing PCC leading to deterioration. A minimal intrusion (up to 1-ft) may be warranted in this case.

Figure 12. Sawing of full-depth repair transverse boundaries.(10)

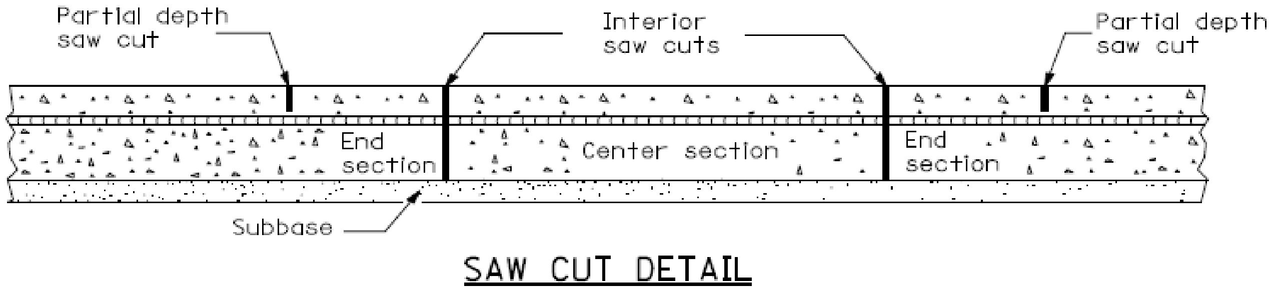


Figure 13. Required saw cuts for CRCP defining the center section (to be completely removed) and the end sections (where concrete around the reinforcing bars is removed).[10]

Figure 14. Partial-depth and full-depth saw cuts for CRCP.[10]

Removal of Existing PCC

Upon completion of the saw cutting, the existing PCC must be removed. Removal procedures must not spall or crack/damage the adjacent PCC. Also, disturbance to the subbase/subgrade must be minimized.

When used correctly, two methods of PCC removal satisfy the conditions outlined: (1) break-up-and-cleanout (see figure 15) or (2) lift-out (see figure 16). The advantages and disadvantages of using each method are presented in table 4.

Figure 15. "Light" drop hammer breaks the deteriorated PCC.

Figure 16. Lift-out operation chain for removing existing slab.

Table 4. Advantages and disadvantages to using break-up-and-cleanout or lift-out methods.

Existing PCC Removal Method	Advantage	Disadvantage
Break-up-and-cleanout	Pavement breakers can efficiently breakup the existing PCC and a backhoe having a bucket with teeth can rapidly remove the PCC and load it onto trucks	Great potential for damaging existing base/subbase. It also has considerable potential to damage adjacent PCC
Lift-out	Does not disturb the base/subbase and does not damage the adjacent slab. It generally permits more rapid removal than the break-up-and-cleanout method	Disposal of large pieces of PCC may be difficult. Heavy lifting equipment is required. The sawed slab may have to be sawed into smaller pieces so they can be lifted with less difficulty by perhaps a front-end loader

Recommendations for Existing PCC Removal

- Heavy drop hammers or large automated jackhammers should not be used as pavement breakers for relatively small full-depth repairs.
- Whenever the ambient temperature is such that the sawed joint closes up, additional saw cuts must be made to relieve pressure and spalling.
- After the existing PCC is removed, the base/subbase must be examined for damage. As it is extremely difficult to recompact base/subbase material back into place within the confines of a relatively small full-depth repair area, it is recommended that loose or damaged base/subbase material be removed and replaced with PCC. Ultimately, the entire base/subbase in the repair area must be prepared carefully to ensure uniformity of support for the full-depth repair.
- Excessive moisture within the repair area should be removed before PCC placement.
- Preparation may require cleaning of loose material before PCC is placed to minimize the potential for settlement.

Load Transfer Mechanism (Dowels and Tie Bar) Placement

Dowel Installation

> Dowel bars must be anchored with epoxy into the existing PCC to provide a secure fit and reduce potential for faulting. A quick-setting, nonshrinking epoxy is recommended for permanently anchoring the dowel bar into the drilled hole. The selected material must be capable of uniformly surrounding the dowel and filling all voids in the drilled hole without running out of the hole during curing. It is extremely important that the material be easy-to-use and capable of producing consistently good results.
>
> While material cost is always a consideration, the prime consideration must be performance, since the success of the entire repair depends largely on the performance of the load transfer system.

1. Drill holes into the edge of the existing PCC pavement to the dimensions specified in design plans (see chapter 2). Hole diameters exceeding bar diameter by 1/16-in or less are recommended to provide clearance for the epoxy and for a strong anchor (see figures 17 through 19).

2. Clean drilling dust, debris, and excess moisture from drill holes (see figure 20).

3. All dowel bars must be anchored with epoxy into the drill hole as follows:

    a. Prepare epoxy. Ensure that it is sufficiently plastic to be pumped or placed at the back of the drill hole and extruded forward to fill small voids.

    b. Insert a sufficient volume of epoxy into the drill hole. There must be enough epoxy to ensure excess material at the face of the PCC after fully inserting the dowel. The epoxy is placed into the back of the hole so that when the dowel is inserted it will force the material forward to cover and support the entire dowel (see figure 21). To further ensure that the dowels are well coated, epoxy also can be placed around the entire half of the dowel that will be inserted into the drill hole. A high level of care must be exercised in anchoring dowels to ensure complete coverage of the bars.

4. Insert dowel bars with **retention disks** against the face of the slab into the drill holes and rotate ½ turn. Do not force drive dowel bars into the drill holes. The dowel bar should be inserted into the hole with a twisting motion so that the material on the bottom of the hole is forced up and around to cover the entire bar (see figures 22 and 23).

Figure 17. Marking out locations in the existing PCC for drilling.

Figure 18. Layout of locations marked for drilling in the existing PCC.

Figure 19. Drilling the existing PCC.

Figure 20. Cleaning drilling dust.

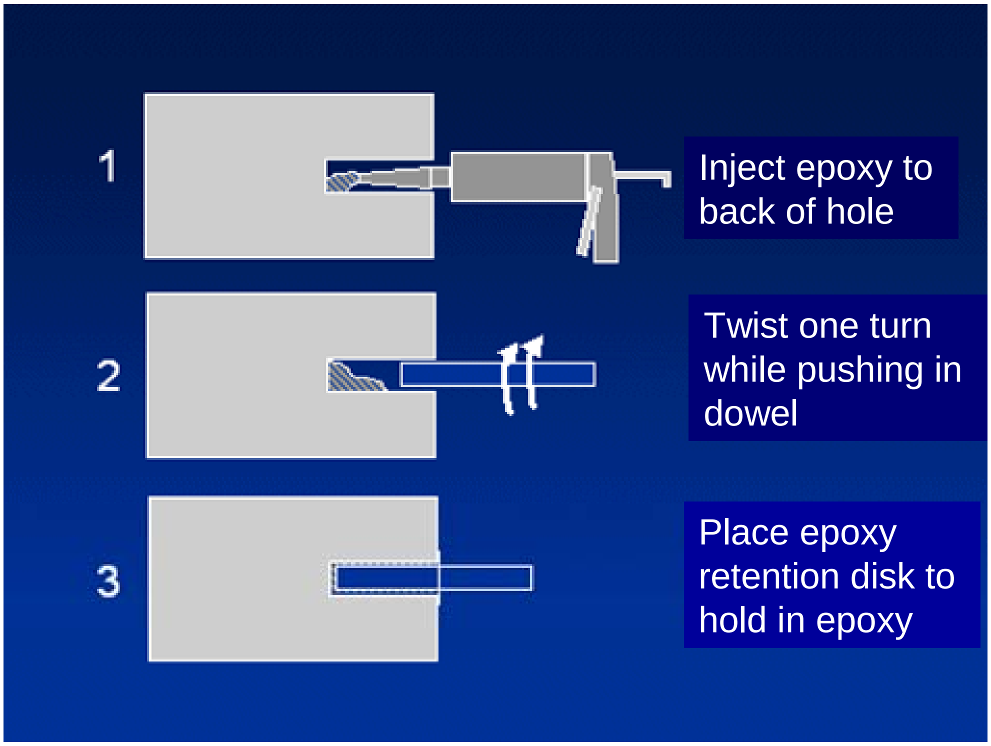


Figure 21. Schematic depicting the injection of epoxy along with the installation of dowels (note the use of the retention disk which are essential to anchoring the dowels properly).

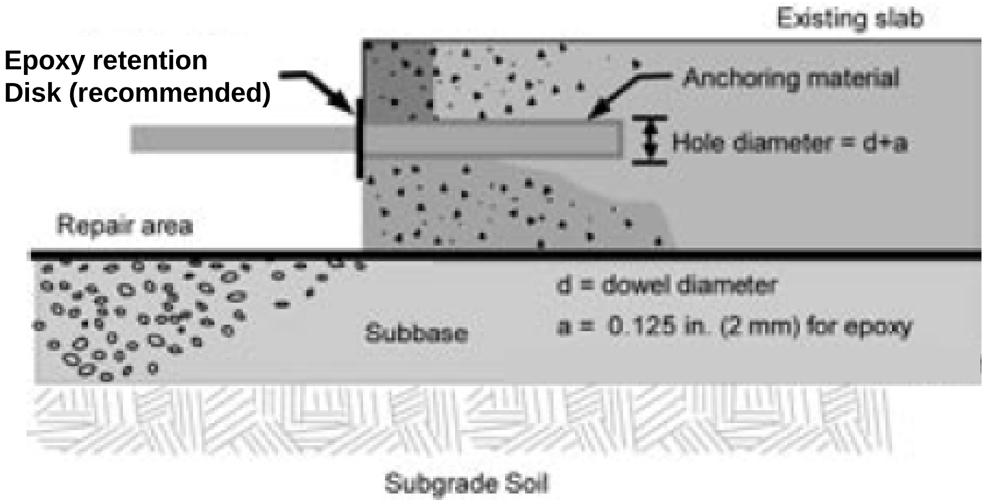
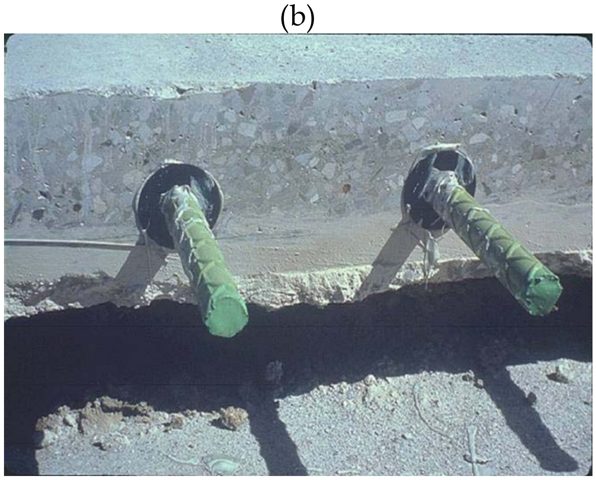


Figure 22. Schematic depicting installed dowel with retention disk.

(a)

(b)



(c)

Figure 23. Installing dowels and tie bars (note: retention disks are required for this project, also there is the need to check for dowel bar misalignment as part of quality assurance/quality control).

5. **A plastic or nylon epoxy retention disk that fits tightly over the dowel and effectively seals the gap around the hole is required to prevent flowable epoxy from running out of the hole.** THIS DISK IS ESSENTIAL TO SUCCESSFUL ANCHORING OF A DOWEL BAR. This disk may be about 2 inches larger in diameter than the dowel being used and should be manufactured to fit snugly over the bar and slide up against the face of the slab when the bar is being inserted into the hole. The retaining disk is inserted over the dowel bar and pushed to flush against the PCC surface to retain the epoxy. The disk will keep most of the material in the dowel hole and provide an excellent bearing surface at the face of the slab.

6. The free end of the dowel bar that extends into the repair area should be lightly greased with a thin, uniform layer of bond breaking lubricant to provide ease in movement. Thick coats of grease or oil may result in loose dowel installations.

Tie Bar Installation

Tie bars must be anchored with epoxy into the existing PCC slab or force driven. The following is recommended:

- Force Driven
    - Drill a suitably sized hole into the existing PCC. Typically, the diameter of the hole is not be more than 1/16-in larger than the bar diameter. Note that the drilled hole diameter is critical, too small and the tie may not penetrate, too large and the tie will fit loosely. Engineers may want to try out different drilled hole sizes to determine the most appropriate sized hole prior to construction. The hole must have a depth of 7 inches.
    - Force-drive the tie bar to a depth of 6 inches into the drilled hole.

- Epoxied
    - Drill a suitably sized hole into the existing PCC. The hole must have a depth of 7 inches. Hole diameters exceeding bar diameter by 1/16-in or less are recommended.
    - Follow steps 2 through 6 for dowel bar installation outlined in the preceding sections. Note that a retention disk similar to that provided for dowels would enhance epoxy surrounding the tie bar at the face of the PCC.

PCC Placement and Finishing

Critical aspects of PCC placement and finishing include:

- Ambient climate conditions (good ambient temperature and moisture conditions both during placement and in the immediate aftermath, i.e., no cold fronts).
- Consolidation (avoid a mix that is either too stiff or has too high a slump).

- Finishing and texturing.
- Curing and opening to traffic.
- Joint forming.

Ambient Climate

Paying particular attention to ambient air and PCC temperatures at the time of PCC placement is key to avoiding early cracking and excessive built-in temperature gradients, and to long-term durability of the PCC.

PCC should not be placed when the temperature of the surrounding air is expected to be below 40ºF within 24 hours after placement. The temperature of the plastic PCC as placed should be above 50ºF. Because high early strength PCC may contain higher amounts of cementitious materials than normal PCC, it may be necessary to lower the upper placement temperature to limit the maximum hydration temperature (to not more than 150 to 170ºF). High hydration temperatures can be detrimental to the PCC.

Consolidation

Except for self-consolidating PCC, the PCC should be placed as near as possible to the final location. For self-consolidating PCC, the PCC should be placed in accordance with approved procedures. In any progressive PCC placement operation, the time between successive placements onto previously placed PCC should not exceed 20 minutes, unless the previously placed PCC has not yet stiffened, as evidenced by the continued effective use of vibration.

High early strength PCC is dependent on proper consolidation to ensure durability. Poor consolidation may result in PCC with high permeability. This situation can lead to dowel steel corrosion and damage from the freezing of moisture that enters the PCC pores.

The PCC should be consolidated around the edges of the repair (especially at the corners) and internally. The PCC mixture should have a slump of approximately 2 to 4 inches at the repair site for best placement. However, this may vary depending on admixtures used and construction conditions. A mix that is too stiff or too fluid could cause serious placement problems. The use of a superplasticizer will help in providing a workable mixture. Work crews should not add excessive water to get a highly flowable mix because this will weaken the PCC and cause higher shrinkage.

Finishing and Texturing

The repair must be finished level with the adjacent PCC. This can be accomplished by screeding in a transverse direction (to follow any ruts in existing pavement), a double strike-off of the surface, followed by further transverse finishing with a straight edge.[4] The surface should then be textured similarly to the existing slab surface (if an overlay will not be placed and diamond grinding will not soon follow). Note that diamond grinding is highly recommended when full-depth repairs are performed without HMA overlay. A summary of texturing options is shown in table 5.

The texture of a PCC surface affects skid resistance and noise. Texture usually is applied while the PCC is still plastic (unless diamond grinding will soon follow). It is important to apply texture uniformly but not deeper than the existing surrounding pavement.

Joint Forming

Transverse and longitudinal joints of full-depth repairs should be formed or "tooled in" as part of finishing. Formed joints are made by depressing an approved tool or device into the plastic PCC to form grooves. The tool or device remains in-place until the PCC has attained its initial set and then it is removed without disturbing the adjacent PCC. Some devices are designed to remain in the joint. Note that a bond breaker is required at the lane-to-lane longitudinal joint and lane-to-shoulder longitudinal joint if the shoulder is PCC. A saw cut longitudinal joint is required only if a full-depth repair is placed in one operation across two adjacent lanes. The saw cut must be done in accordance with WisDOT specifications for new PCC pavement construction.

Curing and Opening to Traffic

Curing is the protection provided to new PCC to maximize the desirable characteristics of the PCC (high strength, low shrinkage, high durability). Proper curing provides proper temperature and moisture conditions to maximize the hydration of the cementitious materials. Thorough hydration provides many enhancements to PCC properties, including improved strength gain, reduced permeability, improved freeze-thaw resistance, and reduced plastic shrinkage cracking. Proper curing also reduces the risk of introducing high built-in temperature gradients that could significantly influence full-depth repair panel cracking.

Common methods of curing include:

- Curing compounds
- Curing covers
  - Burlap
  - Plastics and papers

PCC that cures at the proper temperature will have better performance properties than PCC cured at very high or very low temperatures. The consequences of curing at too high a temperature include reduction in ultimate strength, increased chance of shrinkage cracking, and increased built-in temperature gradients. The importance of timely and proper curing cannot be overemphasized. A summary of curing options is in table 6.

Table 5. PCC texturing techniques.[11]

Texture Type	Description	Macro-texture Depth[a]
Broom Drag (longitudinal or transverse)	A long-bristled broom is mechanically or manually dragged over the concrete surface in either the longitudinal or transverse direction. Texture properties are controlled by adjusting the broom angle, bristle properties (length, strength, density), and delay behind the paver. Uniform striations approximately 0.06 to 0.12 in deep are produced by this method.	Typically ranges from 0.008 to 0.016 in.
Artificial Turf Drag (longitudinal)	An inverted section of artificial turf is dragged longitudinally over a concrete surface following placement. Texture properties are controlled by raising/lowering the support boom, adding weight to the turf, and delaying application to allow surface hardening. This method produces uniform 0.06 to 0.12 in deep surface striations.	Typically ranges from 0.008 to 0.016 in, but a deep texture (min depth of 0.04 in) has been specified[b].
Burlap Drag (longitudinal)	One or two layers of moistened coarse burlap sheeting are dragged over the concrete surface following placement. Texture properties are controlled by raising/lowering the support boom and adjusting the delay following concrete placement. This method produces uniform 0.06 to 0.12 in deep striations in the surface.	Typically ranges from 0.008 to 0.016 in.
Longitudinal Tine	A mechanical assembly drags a wire comb of tines (~ 5 in long and 10 ft wide) behind the paver (and usually following a burlap or turf drag). Texture properties are controlled by the tine angle, tine length, tine spacing, and delay for surface curing. Grooves from 0.12 to 0.25 in deep and 0.12 in wide are produced by this method, typically spaced at 0.75 in.	Typically ranges from 0.015 to 0.04 in.
Transverse Tine	Accomplished using methods similar to longitudinal tining, however, the mechanical assembly drags the wire comb perpendicular to the paving direction. Variations include skewing the tines 9 to 14° from perpendicular and using random or uniform tine spacing from 0.5 to 1.5 in.	Typically ranges from 0.015 to 0.04 in.

Table 6. PCC curing techniques.(2, 3, 4)

Curing Techniques	Description
Curing compound.	Liquid membrane curing compounds provide another means of curing. These are most efficient when applied under reasonable ambient conditions (not cold or hot weather conditions). These products are effective when properly applied. It is imperative that curing compounds be applied immediately after finishing and before the PCC surface dries. Curing compound should be applied at the rate recommended by the manufacturer, as a minimum. It should form a uniform, continuous, adherent film that shall not check, crack, or peel and should be free from pinholes or other imperfections. Application rates, generally of 200 ft^2/gal or the manufacturers recommended rates (whichever is greater) must be maintained for acceptable curing of full-depth repairs with high early strength PCC (and for fast track paving). Often application rates are not maintained or material is not uniformly applied in one coat and a second coating, applied at right angles to the first coat is necessary.
Insulation covers (plastic sheeting)	Appropriate for cold weather concreting only. Covers may consist of plastic sheeting, impervious paper, or plastic coated fiber blankets. These materials prevent both heat and moisture from escaping. Care in applying these materials is necessary since they can cause damage to the surface of plastic PCC. In most cases it is more important to commence curing than to be concerned with any aesthetic imperfections on the PCC surface. Covers need to be protected from displacement to remain effective during the curing period. Overlapping the edges of covers and anchoring in place is necessary.
Wet burlap	Appropriate for hot weather concreting. Wet burlap prevents rapid loss of moisture, and maintains reasonable levels of PCC temperature during hydration. Wet burlap significantly decreases the potential for built-in temperature gradients (daytime or nighttime placements).
Sprinklers and fogging	The purpose of fogging is to retain high humidity levels over the fresh PCC in order to avoid water loss until the wet burlap can be placed. Fogging should not be perceived as a "safety factor" that allows for delaying the placement of burlap. Fogging may be impractical on windy days. Exposed PCC surfaces should be kept continuously wet for the duration of the specified curing period. Sprinklers on the other hand are usually used in conjunction with blankets or burlap for continuous wetting that can be easily established. Both fogging and sprinklers require a continuous supply of water and runoff may need to be controlled.

CHAPTER 4. FULL-DEPTH REPAIR OF PCC PAVEMENTS CHECKLIST

This checklist for Wisconsin full-depth repair design and construction practices was adapted from the Federal Highway Administration (FHWA) and the Foundation for Pavement Preservation (FP2).

Preliminary Responsibilities

- ☐ Verify that pavement conditions have not significantly changed since the project was designed and that full-depth repair is appropriate for the pavement.

- ☐ Agree on quantities to be placed, but allow flexibility if additional deterioration is found below the surface.

Materials Checks

- ☐ Verify that the mix design for the material being supplied meets the criteria of the contract documents.

- ☐ Verify that full-depth repair material has been sampled and tested prior to installation, and is not contaminated.

- ☐ Verify that dowel bars and tied bars meet specifications and are properly coated with epoxy (or any other approved material). The surface must be free of any surface damage.

- ☐ Verify that epoxy meets specifications.

- ☐ Verify that bond-breaking board (typically asphalt-impregnated fiberboard) meets specifications.

- ☐ Verify that sufficient quantities of materials are on hand for completion of the project.

Equipment Inspections

PCC Removal Equipment

- [ ] Verify that PCC saws and blades are in good condition and of sufficient diameter and horsepower to adequately cut the required full-depth repair boundaries.

- [ ] Verify that all the equipment required for existing PCC removal is on-site and in proper working order and of sufficient size, weight, and horsepower to accomplish the removal process.

Full-Depth Repair Area Preparation Equipment

- [ ] Verify that the plate compactor is working properly and capable of compacting subbase material.

- [ ] Verify that gang drills are calibrated, aligned, and sufficiently heavy and powerful enough to drill multiple holes for dowel bars.

- [ ] Verify that air compressors are properly functioning.

- [ ] Verify the epoxy retention disks that fits tightly around the dowel bars and tie bars are available.

PCC Placement and Finishing Equipment

- [ ] Verify that handheld PCC vibrators are the proper diameter and operating correctly.

- [ ] Verify that all floats and screeds are straight, free of defects, and capable of producing the desired finish.

- [ ] Verify that sufficient polyethylene sheeting is readily available on-site for immediate deployment as rain protection of freshly placed PCC, should it be required.

Weather Requirements

- [ ] Verify that ambient air and PCC surface temperatures are within recommended range for PCC placement.

- [ ] Full-depth repairs should not proceed if rain is imminent. Full-depth repair that have been completed should be covered with polyethylene sheeting to prevent rain damage.

Project Inspection Responsibilities

PCC Removal and Cleanup

- ☐ Verify that the boundaries of the removal areas are clearly marked on the pavement surface and the cumulative area of the pavement to be removed is consistent with quantities in the contract documents.
- ☐ Verify that the full-depth repair size is large enough to accommodate a gang-mounted dowel drilling rig, if one is being used. Note: The minimum length (longitudinal direction) of full-depth repair is 6 ft.
- ☐ Verify that full-depth repair boundaries are sawed vertically the full thickness of the pavement.
- ☐ Verify that existing PCC is removed using either the break-up or lift-out method, minimizing disturbance to the base or subbase as much as possible. Note: The Saw cut and lift method is preferred to jackhammer removal.
- ☐ Verify that after existing PCC removal, disturbed base or subbase is recompacted, or preferably replaced entirely with PCC.
- ☐ Verify that PCC adjoining the full-depth repair is not damaged or undercut by the existing PCC removal operation.

Full-Depth Repair Preparation

- ☐ Verify that dowel holes are drilled perpendicular to the vertical edge of the existing PCC using a gang mounted drill rig.
- ☐ Verify that drilled holes are thoroughly cleaned using compressed air.
- ☐ Verify that approved epoxy is placed in dowel holes, from back to front.
- ☐ Verify that proper epoxy-retention disks are available for the dowel bars. These must fit reasonably tightly around the dowel bars. It is absolutely essential that these be used to anchor dowel bars.
- ☐ Verify that dowels are inserted with a twisting motion, spreading the epoxy along the bar inside the hole. An epoxy-retention disk must be used to keep the epoxy from seeping out of the hole. Ensure that the disks are placed against the face of the bar as the bar is inserted with a twisting motion. This will guarantee that the epoxy surrounds the face of the PCC slab tightly.

☐ Verify that dowels are installed in transverse joints to the proper depth of insertion and at the proper orientation (parallel to the centerline and perpendicular to the vertical face of the saw cut excavation) in accordance with specifications. Typical tolerances measured perpendicularly to the sawed faced are ¼-in misalignment per 12-in of dowel bar length.

☐ Verify that tie bars are installed at the proper location and to the proper depth of insertion in accordance with contract documents. When the length of the longitudinal joint is 15-ft or greater, tie bars are typically installed in the manner used for dowels. When the length of the longitudinal joint is less than 15-ft, a bond-breaker board is placed along the length of the full-depth repair to isolate it from the adjacent slab.

☐ Ensure that tie bars are checked for location, depth of insertion, and orientation (perpendicular to centerline and parallel to slab surface).

Placing, Finishing, and Curing PCC

☐ Verify that the fresh PCC is properly consolidated using several vertical penetrations of the PCC surface with a handheld PCC vibrator.

☐ Verify that the surface of the full-depth repair is level with the adjacent slab using a straightedge or vibratory screed in accordance with contract documents.

☐ Verify that the surface of the fresh full-depth repair is finished and textured to match adjacent surfaces.

☐ Verify that adequate curing compound is applied to the surface of the fresh PCC immediately following finishing and texturing in accordance with contract documents. Best practice suggests that two applications of curing compound be applied to the finished and textured surface, one perpendicular to the other.

☐ Ensure that insulation blankets are used when ambient temperatures are expected to fall below 40°F. Maintain blanket cover until PCC attains the minimum strength required. Wet burlap must be used when PCC is placed in hot temperatures. Other curing techniques such as fogging can be used to maintain a moist/wet surface.

Common Problems and Solutions

☐ Undercut spalling (deterioration on bottom of slab) is evident after removal of PCC from full-depth repair area:

1. Saw back into adjacent slab until sound PCC is encountered.
2. Make double saw cuts, 6 inches apart, around full-depth repair area to reduce damage to adjacent slabs during PCC removal.
3. Use a carbide-tipped wheel saw to make pressure-relief cuts 4 inches wide inside the area to be removed.

Lifting out existing PCC damages adjacent slab:

☐

1. Adjust lifting cables and re-position lifting device to assure a vertical pull.
2. Re-saw and remove broken section of adjacent slab.
3. Use a forklift or crane instead of a frontend loader.

Slab disintegrates when attempts are made to lift it out:

☐

1. Complete removal of full-depth repair area with backhoe or shovels.
2. Angle the lift pins and position the cables so that fragmented pieces are bound together during liftout.
3. Keep lift height to an absolute minimum on fragmented slabs.

Full-depth repair area become filled with rainwater or groundwater seepage, saturating the subbase:

☐

1. Pump the water from the full-depth repair area, or drain it through a trench cut into the shoulder.
2. Re-compact subbase to a density consistent with contract documents, adding material as necessary.
3. Allow small depressions in subbase to be filled with aggregate dust or fine sand before full-depth repair PCC material is placed. Permit the use of aggregate dust or fine sand to level small surface irregularities (1/2 in or less) in surface of subbase before full-depth repair PCC is placed.

Epoxy around dowel bars flows back out of the holes after dowels are inserted:

☐

1. Pump epoxy to the back of the hole first.
2. Use a twisting motion when inserting the dowel.
3. Add a epoxy retention disk around the bar to prevent epoxy from leaking out.

Dowels appear to be misaligned once they are inserted into holes:

☐

1. If misalignment is less than 1/4 in per 12 in of dowel bar length, do nothing.
2. If misalignment is greater than 1/4 in per 12 in of dowel bar length on more than three bars, re-saw full-depth repair boundaries beyond dowels and redrill holes.
3. Use a gang-mounted drill rig referenced off the slab surface to drill dowel holes.

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