Impact of Existing Pavement on
Jointed Plain Concrete Overlay Design and Performance

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ABSTRACT

Concrete overlays are increasingly being constructed over deteriorated existing asphalt and concrete pavements. Designers struggle to consider the extent of deterioration of the existing pavement in the design of the concrete overlay. This paper addresses the impact of the level of condition of the existing pavement on the performance of the concrete overlay. Use is made of the new AASHTO Interim Mechanistic-Empirical Pavement Design Guide to simulate two case studies over a range of conditions and designs. Significant findings were obtained to help guide designers to better consider the condition of the existing pavement in their design.

1.0 INTRODUCTION

Existing pavements that are candidates for concrete overlays vary widely in design and condition. Many engineers believe that these factors have an effect on the subsequent performance of concrete overlays. This paper presents some results using the new AASHTO Interim Mechanistic-Empirical Pavement Design Guide (MEPDG) on how different designs and conditions affect the performance and consequently the design of concrete overlays. Existing designs include various types of asphalt pavements, concrete pavements, and composite pavements. These pavements can range in condition from fair to very poor or severe.

Thus, there is a wide matrix of designs and conditions facing designers of concrete overlays. In addition, site conditions including climate, subgrade, and traffic level also contribute to the challenge of providing an economical and reliable concrete overlay design over a future design period. This paper develops a matrix of designs and conditions of existing pavements and then demonstrates the impact of the existing pavement conditions on the performance of jointed plain concrete pavement (JPCP) overlays using the AASHTO Interim (MEPDG models. Based on the results obtained, recommendations are prepared for assisting designers to provide more reliable concrete overlay designs for widely varying existing pavement conditions.

This paper first describes the capabilities of the MEPDG to model concrete overlays, outlines the various design considerations for concrete overlays, and describes two case studies: one for JPCP overlay of an existing hot-mix asphalt (HMA) pavement and another for JPCP overlay over an existing JPCP. The paper concludes with a summary of findings and recommendations for design based on the MEPDG results.

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2.0 CAPABILITIES OF THE AASHTO INTERIM MEPDG TO MODEL CONCRETE OVERLAYS

The MEPDG was developed to model JPCP and continuously reinforced concrete pavement (CRCP) overlays of existing concrete pavements, asphalt pavements, and asphalt over concrete pavements. The ISLAB2000 finite element structural model includes layers for the concrete overlay, a separation layer, the existing HMA layer or a concrete slab, existing base and sub-base layers of any type, the embankment and or subgrade, and finally bedrock. The MEPDG models the condition of the existing concrete or HMA pavement through its effective “modulus,” which has been adjusted to reflect existing crack damage. The concrete overlay can directly consider all of the normal features of a new concrete JPCP or CRCP including such features as thickness, transverse joint spacing, slab width, joint load transfer, tied shoulders, portland cement concrete (PCC) material properties, friction between slab and HMA, and many other factors. The key distress types that are predicted by ME-based models include joint faulting, slab transverse cracking, and International Roughness Index (IRI) for JPCP. For CRCP, crack width, crack load transfer efficiency (LTE), punchouts, and IRI are predicted.

The calibration of the MEPDG for both JPCP and CRCP included a number of field sections across North America. The global cracking and faulting calibration models completed under NCHRP 1-40D are shown in Figures 1 and 2. The calibration shows very good prediction of these key performance indicators for a wide variety of concrete overlays. The mechanistic basis and the field validation give some confidence that the MEPDG can reasonably model concrete overlays that are 6-in. (152 mm) or thicker.

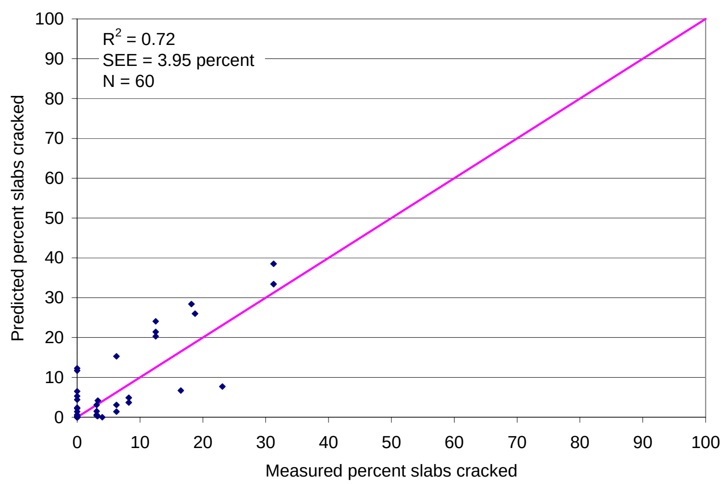

Figure 1. National calibration plot for transverse cracking of unbonded JPCP overlays.

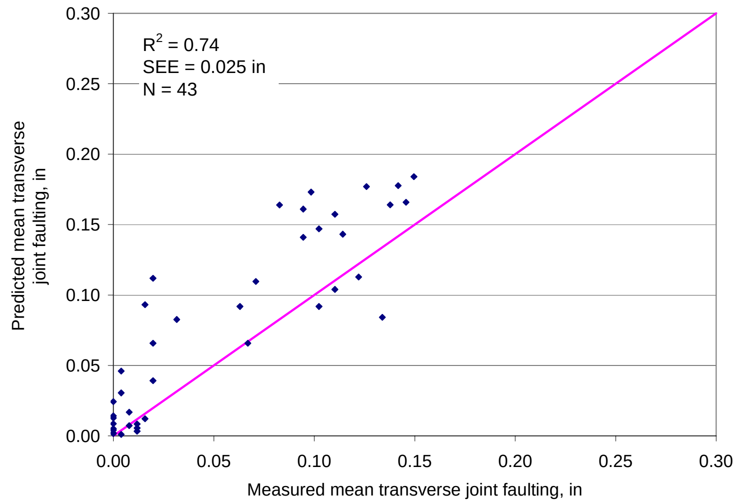

Figure 2. National calibration plot for joint faulting of unbonded JPCP overlays.

3.0 DESIGN CONSIDERATIONS RELATED TO THE EXISTING PAVEMENT

Design considerations include many different factors that are included in the design and construction specifications of concrete overlays. A brief summary of these considerations is provided.

- Design features of the existing pavement. The type of pavement, the layer thicknesses, other design aspects such as joints and shoulders are critical factors that must be considered. The appropriate modulus and thickness of each layer must be estimated for overlay design.
- Material types and their appropriate modulus for each layer in the existing pavement.
- Treatment to the existing surface for unevenness, if any, is another consideration. Significant unevenness of this surface must be corrected prior to concrete paving through milling or a level-up HMA layer. Correcting an uneven surface should not be left to the paver to adjust thickness of the concrete overlay.
- Friction/Bonding of the concrete overlay to the underlying HMA layer. Full friction is beneficial to provide for joint formation, reduction in erosion, and improved structural capacity. The existing HMA surface may need to be milled to provide long-term friction.

4.0 DESIGN CONSIDERATION OF THE CONCRETE OVERLAYS

There are several critical design features that must be specified to have a successful construction and performance of a JPCP overlay. This section summarizes these factors, most of which are considered directly in the MEPDG.

- Dimensions of the overlay slab. Required dimensions include thickness, transverse joint spacing, longitudinal joint spacing, and shoulder edge support (tied concrete, widened slab, non-supportive).

- Joint design of overlay: load transfer details (bar size, spacing, embedment) and tie bar spacing and size.

- Overlay slab materials. Strength, modulus of elasticity, coefficient of thermal expansion, and shrinkage of the concrete are critical.

- Interface friction between the slab and HMA layer below the slab is critical.

- Climate and subdrainage considerations.

- Subgrade support.

- Traffic loadings that the overlay must support over the design period. There are many aspects of traffic related to volume of each type of truck, growth rate, lane distribution, axle types, axle load distribution, and other factors.

- Construction, including month during which the concrete overlay will be placed, time between placement and opening to traffic, and curing of the concrete to avoid built in temperature gradient.

5.0 CASE STUDY A: ILLUSTRATION OF JPCP CONCRETE OVERLAY OVER EXISTING HMA PAVEMENT CONDITION

Case Study A is located near Topeka, Kansas, on I-44 where a many times overlaid HMA pavement was considered for a concrete overlay. The following are defined for the existing pavement condition and thickness, concrete overlay design, and friction between the concrete overlay and HMA layer.

- Existing HMA pavement: milled HMA layer thickness (4 in. [102 mm] after milling), 10-in. (254-mm) granular base course, 10-in. (254-mm) gravel sand subbase.

- Friction between the concrete slab and existing HMA: full friction (milled surface) over the 30-year analysis period due to the milling of the HMA.

- Existing HMA condition: "Fair" (15-35 percent), "Poor" (35-50 percent), "Very Poor" (>50 percent) alligator cracking for all severity levels. As fatigue cracking increases, the dynamic modulus (E*) of the HMA layer decreases resulting in a decrease in structural capacity of the overlaid pavement. The mean E* computed by the MEPDG over the entire year for each level of fatigue damage is given in Table 1.

- Overlay design: thickness and joint spacing (6.5 in. [165 mm] with 12 ft [3.7 m] and 8.0 in. [203 mm] with 15 ft [4.6 m]), slab width (12-ft [3.7-m] slab), transverse joint load transfer (both dowels and no dowels).

- Site conditions: Topeka, Kansas, climate, A-6 subgrade soil, and I-44 traffic (two-way truck traffic is 1,350 with a 2.3 percent linear growth rate results in 8.4 million trucks (14 million equivalent single-axle loads [ESALs]) in the design lane over 30 years). Slab placed in September and opened to traffic in 1 month after placement.

Table 1
HMA Pavement Condition and Mean E* Over the Entire Year From MEPDG

Existing HMA Condition	Percent Alligator Cracking Lane Area	Mean HMA E* Over the Entire Year (lbf/in^2)
Fair	15 to 35	1,094,000
Poor	35 to 50	537,000
Very Poor	>50	314,000

The MEPDG was run for these specific conditions over a 30-year analysis period. The predicted performance at the end of the 30-year analysis period is given in Table 2. Additional MEPDG solutions were run for other conditions including wider slab, increased HMA thickness, and reduction in friction between the slab and HMA layer, with results in Table 3.

Table 2
Impact of JPCP Overlay Design Features and HMA Pavement Condition (Fair, Poor, Very Poor) on Performance of Concrete Overlay 30 Years, 4-in. HMA, Full Friction Between Slab/HMA, 12-ft-wide Lane

	PCC Slab: 6.5-in., 12-ft Joint Spacing		PCC slab: 8-in., 15-ft Joint Spacing	
Existing HMA Pavement Condition	**Nondoweled Joint**	**Doweled Joint (1-in. diameter)**	**Nondoweled Joint**	**Doweled Joint (1-in. diameter)**
"Fair" Condition (15–35% alligator cracking)	C = 8 % slabs F = 0.19-in IRI = 221 in/mi	C = 8 F = 0.04 IRI = 123	C = 6 F = 0.19 IRI = 189	C = 6 F = 0.12 IRI = 154
"Poor" Condition (35–50% alligator cracking)	C = 53 F = 0.19 IRI = 260	C = 53 F = 0.04 IRI = 160	C = 29 F = 0.19 IRI = 208	C = 29 F = 0.12 IRI = 173
"Very Poor" Condition (>50% alligator cracking)	C = 78 F = 0.19 IRI = 280	C = 78 F = 0.04 IRI =180	C = 49 F = 0.19 IRI = 225	C = 49 F = 0.12 IRI = 190

C = percent slab transverse cracks at 30 years and 8.4 million trucks
F = mean joint faulting, inches at 30 years and 8.4 million trucks
IRI = International Roughness Index, in/mile at 30 years and 8.4 million trucks

Table 3
Impact of JPCP Overlay Design Features and HMA Pavement Condition of Concrete Overlay Over 30 Years, 4-to-6-in. HMA Thickness Variation, Slab/HMA Friction Variation, 13-ft-wide Traffic Lane Slab

	PCC Slab 6.5-in 12-ft Joint Spacing		PCC slab 8-in 15-ft Joint Spacing	
Existing HMA Pavement Condition	**Nondoweled Joint**	**Doweled Joint (1-in. diameter)**	**Nondoweled Joint**	**Doweled Joint (1-in. diameter)**
Special Case: Poor HMA Condition with 6-in. HMA existing thickness	C = 9 F = 0.19 IRI = 217	C = 9 F = 0.04 IRI = 121	C = 8 F = 0.18 IRI = 187	C = 8 F = 0.12 IRI = 153
Special Case: Poor HMA Condition with zero friction between JPCP and HMA existing thickness after 60 months	C = 88 F = 0.19 IRI = 288	C = 88 F = 0.04 IRI = 188	C = 58 F = 0.19 IRI = 232	C = 58 F = 0.12 IRI = 197
Special Case: Poor HMA Condition with 13-ft slab width outer lane	C = 1 F = 0.13 IRI = 178	C = 1 F = 0 IRI = 89	C = 1 F = 0.13 IRI = 161	C = 1 F = 0 IRI = 87

C = percent slab transverse cracks at 30 years and 8.4 million trucks
F = mean joint faulting, inches at 30 years and 8.4 million trucks
IRI = International Roughness Index, in/mile at 30 years and 8.4 million trucks

The following results were obtained from these analyses of Case Study A.

- As existing HMA pavement condition varies from "Fair" to "Poor" to "Very Poor," the performance of the JPCP overlay is greatly affected as shown in Table 2 and Figure 3 for the 6.5-in. (165-mm) JPCP. A similar effect occurs for the 8-in. (203-mm) JPCP overlay. The reason for this increase in slab fatigue cracking of the overlay is the loss in structural capacity of the pavement structure that includes the existing HMA layer. The damaged E* of the HMA layer is reduced as in Table 1. The slab and HMA layer were assumed to have full friction over the 30 years analysis period, and thus the equivalent slab would be a function of the E* of the HMA as well as the E of the concrete.

- The thickness of the existing milled HMA layer was varied from 4 in. (102 mm) to 6 in. (152 mm) for a "Poor" HMA pavement condition and dowel bars in the overlay to see if it had a significant effect on performance. The MEPDG prediction shows a major impact on cracking and IRI for the 6.5-in. (165-mm) JPCP (cracking decreased from 53 to 9 percent slabs cracked) and for the 8-in. (203-mm) JPCP (29 to 8 percent) as shown in Figure 4. The IRI was also reduced as shown in Figure 4. This effect again shows the significant impact of the existing HMA layer on performance of the concrete overlay.

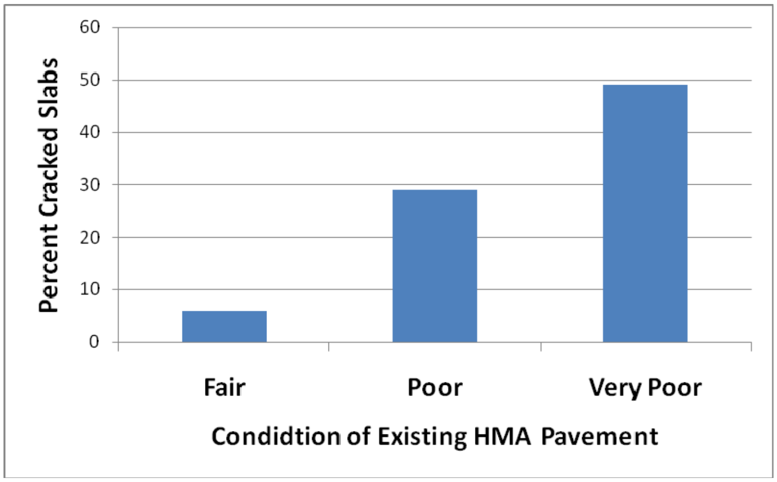

Figure 3. Effect of condition of existing 4-in. (102-mm) HMA pavement alligator cracking on 6.5-in. (165-mm) JPCP concrete overlay slab cracking after 30 years and 8.4 million truck loadings (14 million ESALs).

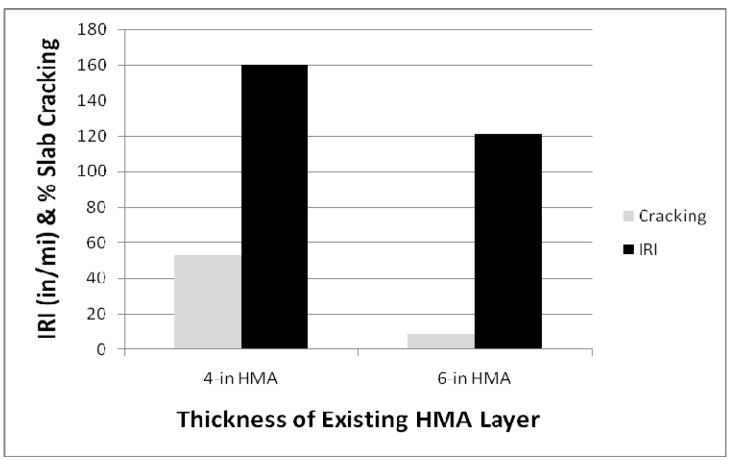

Figure 4. Effect of "Poor" HMA layer thickness on IRI and transverse cracking of the JPCP overlay.

- If the HMA surface is milled, it will have high friction with the JPCP slab. Friction between the concrete overlay and existing HMA would likely be full over the entire analysis period as found in the national calibration. The MEPDG was run for the 8-in. (203-mm) JPCP overlay, assuming no milling, and thus the friction between the two layers would likely be less. The friction was set to zero after 60 months of the analysis period. Figure 5 shows that with zero friction after 60 months there develops twice as much fatigue cracking in the overlay after 30 years. Again, this is caused by a decrease in structural capacity when full friction does not exist between layers.

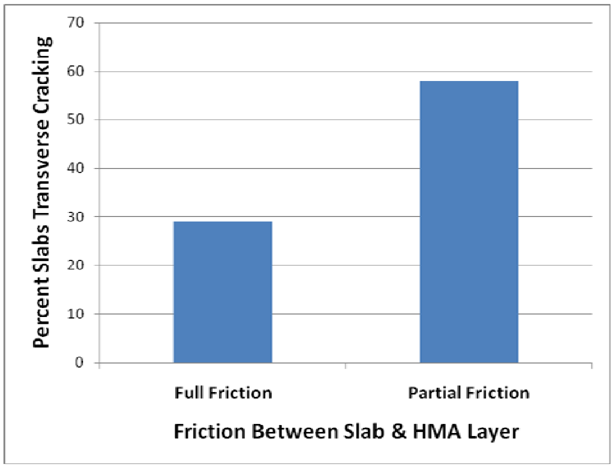

Figure 5. Effect of Slab/HMA friction on slab cracking (partial means no friction after 60 months).

- The thickness and joint spacing of the JPCP overlay are known to have significant effects when changed individually. This analysis was conducted with both changing together (joint spacing increases with increasing slab thickness), which would be typical of practice, but the results are more complex to understand. Table 4 shows the average cracking, faulting, and IRI for "Poor" condition of the existing HMA pavement. The 6.5-in. (165-mm) JPCP overlay with 12-ft (3.7-m) joint spacing does show greater cracking than the 8.0-in. (203-mm) JPCP overlay with 15-ft (4.6-m) joint spacing. However, the longer joint spacing has more effect on slightly increasing faulting due to increased joint opening. The IRI is lower for the slab 8 in. (203 mm) thick with 15-ft (4.6-m) joint spacing.

Table 4
Performance of the 6.5-in. and 8.0-in. Slabs for "Poor" Condition of Existing HMA Pavement After 30 Years

Slab Thickness & Joint Spacing	Transverse Slab Cracking (%)	Joint Faulting (in.)	IRI (in/mi)
6.5-in. & 12-ft	53	0.11	210
8.0-in. & 15-ft	29	0.15	190

- Use of dowels at transverse joints shows a major impact on joint faulting and IRI and no effect on transverse cracking. Figure 6 shows that with dowels, joint faulting is far lower than without dowels (0.04 versus 0.19-in.) over the 30-year analysis period for slabs either 12 ft (3.7 m) or 13-ft (4.0 m) wide. Note that the truck traffic in the design lane is significant at 8.4 million trucks (or 14 million ESALs), and the project is located in cold climate.

- The widening of the slab from 12 ft (3.7 m) to 13 ft (4.0 m) has a profound effect on the performance of the concrete overlay. Cracking, faulting, and IRI are all greatly reduced with a 1-ft (0.3-m) widening of the traffic lane slab that moves some of the heavy truck wheels away from the free edge. Of course, the paint stripe must be placed at the normal

12-ft (3.7-m) location. Cracking goes essentially to zero. Figure 6 shows the impact on faulting, and Figure 7 the impact on IRI.

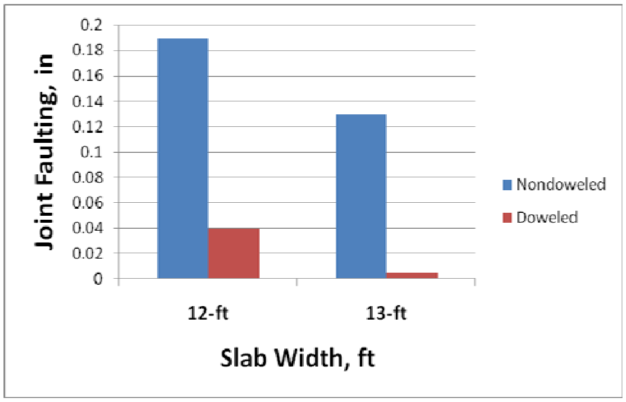

Figure 6. Impact of concrete overlay slab width on doweled and nondoweled joint faulting (for 8-in. JPCP) using the MEPDG.

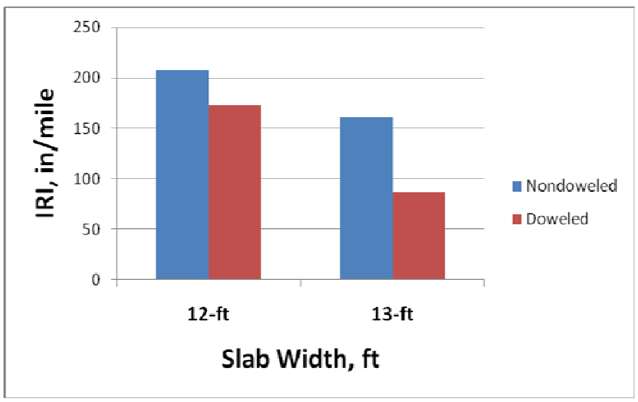

Figure 7. Impact of concrete overlay slab width on doweled and nondoweled IRI (for 8-in. JPCP) using the MEPDG.

6.0 CASE STUDY B: ILLUSTRATION OF JPCP CONCRETE OVERLAY OVER EXISTING CONCRETE PAVEMENT

Case Study B is located near Aurora, Illinois (west of Chicago), on I-88 where an old JPCP with HMA overlay exists. The following conditions were defined for the existing pavement condition and thickness, concrete overlay design, and separation layer.

- Existing HMA overlay: A 4-in. (102-mm) HMA overlay exists that is badly cracked and weathered. It will be removed through milling to minimize the added height of the concrete overlay.
- Existing JPCP: Slab thickness 10 in. (254 mm), 12-in. (305-mm) granular base course, 6-in. (152-mm) gravel sand subbase.

- Existing JPCP Condition: the condition will be varied from “Good” (10 percent slabs cracked), “Moderate” (20 percent), and “Severe” (50 percent) transverse cracking of all severity levels to illustrate the impact on the overlay performance. The effective modulus of the existing slab ($E_{BASE/DESIGN}$) is calculated as follows:

$$E_{BASE/DESIGN} = C_{BD} * E_{TEST}$$

Where: $E_{BASE/DESIGN}$ = Design modulus of elasticity of existing slab, lbf/in^2

C_{BD} = Coefficient reduction factor

0.42 to 0.75 existing pavement in “Good” condition

0.22 to 0.42 existing pavement in “Moderate” condition

0.042 to 0.22 existing pavement in “Severe” condition

E_{TEST} = Modulus of the existing uncracked concrete slab, lbf/in^2.

The modulus of the existing concrete slab (sound material) was estimated by testing of cores to be 5.6 million lbf/in^2 (38,611 MPa)(ASTM C469). The $E_{BASE/DESIGN}$ for each condition that is input to the MEPDG is computed in Table 5. In addition, the alternative of rubblizing the existing JPCP was evaluated.

Table 5
Existing JPCP Condition and Estimated Effective Modulus of Elasticity

Condition	**% Slabs Transverse Cracked**	**Effective Modulus of Existing Slab** (lbf/in^2) $\mathbf{E_{BASE/DESIGN}}$
Good	10 %, 0.5 = C_{BD}	2,800,000 (2 to 5 million)*
Moderate	20 %, 0.3 = C_{BD}	1,680,000 (1.0 to 1.6 million)*
Severe	50 %, 0.1 = C_{BD}	580,000 (160,000 to 935,000)*
Rubblized	NA	50,000

*Range of existing slab moduli obtained from the national calibration effort.

- Separation layer: A 1-in. (25-mm) HMA interlayer is placed to separate the existing and new concrete layers. The new HMA layer will have friction with the new concrete overlay to provide for proper joint formation and to minimize erosion.

- Overlay design: Thickness will vary from 8 in. to 9 in. (203 mm to 229 mm) with a constant joint spacing of 15 ft (4.6 m), slab width of 12 ft (3.7 m), and doweled joint load transfer. Traffic is too high to not include dowels, as high faulting is predicted.

- Site conditions: Aurora, Illinois, climate, A-6 subgrade soil, and I-88 traffic (two-way truck traffic is 10,000 with a 3 percent linear growth rate results in 55 million trucks (93 million ESALs) in the design lane over 30 years). Slab placed in June, opening to traffic in 1 month after placement.

The MEPDG was run for these specific conditions over a 30-year analysis period. The predicted performance at the end of the 30-year analysis period is given in Table 6. Additional MEPDG solutions were run for other conditions, including wider slab and increased HMA separation layer thickness, as shown in Table 7.

Table 6
Impact of JPCP Overlay Design Features and Existing JPCP Condition on Performance of Concrete Overlay Over 30 Years and 12-ft-wide Lanes (Case Study B) From MEPDG

Existing JPCP Condition	PCC Slab 8-in. Doweled Joint	PCC Slab 9 in. Doweled Joint
"Good" Condition (10% slab transverse cracking)	C = 10% slabs F = 0.04-in IRI = 118-in/mi	C = 1 F = 0.05 IRI = 116
"Moderate" Condition (10-50% slab transverse cracking)	C = 16 F = 0.05 IRI = 129	C = 2 F = 0.06 IRI = 122
"Severe" Condition (>50% slab transverse cracking)	C = 29 F = 0.07 IRI = 150	C = 5 F = 0.08 IRI = 134

Table 7
Impact of Special JPCP Overlay Design Features and Existing JPCP Condition on Performance of Concrete Overlay Over 30 Years (Case Study B) From MEPDG

Existing JPCP Condition	PCC Slab 8-in. Doweled Joint
Special Case: Rubblize Existing JPCP	C = 46 F = 0.09 IRI = 172
Special Case: Severe Existing JPCP Condition with 13-ft slab width outer lane	C = 2 F = 0.001 IRI = 90
Special Case: Severe Existing JPCP Condition with Increased HMA separation layer from 1 to 3-in.	C = 23 F = 0.07 IRI = 145

- As existing JPCP condition varies from "Good" to "Moderate" to "Severe," the performance of the JPCP overlay is significantly reduced, as shown in Figure 8. The JPCP overlay over the existing JPCP in "Severe" condition shows more cracking over time than the existing JPCP in "Good" condition. This is due to the composite slab effect when the existing JPCP is combined with that of the JPCP overlay to form a composite modulus.

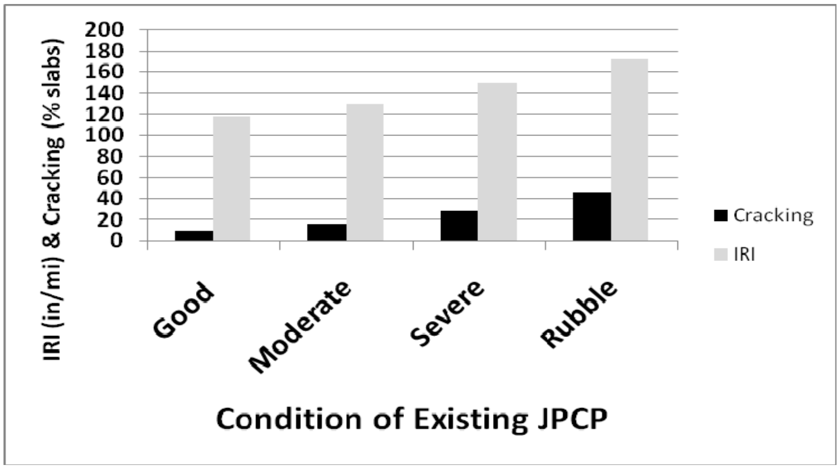

Figure 8. **Effect of condition of existing JPCP on IRI and transverse cracking of JPCP overlay after 30 years and 55 million trucks (93 million ESALs).**

- The thickness of the JPCP overlay has a significant effect on performance. The 8-in. (203-mm) JPCP overlay shows much greater cracking and IRI than the 9.0-in. (229-mm) JPCP overlay after 30 years and 55 million trucks. Figure 9 shows the trends.

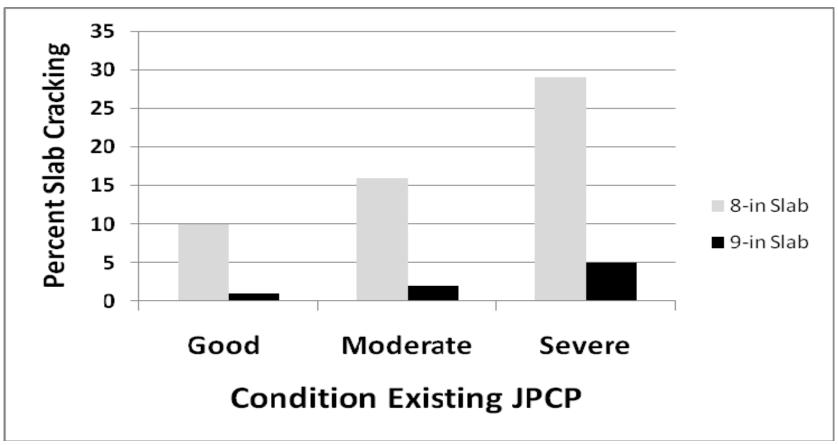

Figure 9. Effects of condition of existing JPCP and slab thickness on percentage of slab cracking after 30 years and 55 million trucks.

- The thickness of the HMA interlayer was varied from 1 in. (25 mm) to 3 in. (76 mm) for a “Severe” pavement condition to see if it had a significant effect on performance. The prediction shown in Table 7 indicates that percent slab cracking decreases only moderately from 29 to 23 percent and IRI decreases from 150 to 145 in/mi (2.4 to 2.3 m/km).

- The 13-ft (4.0-m) traffic lane slab has a significant effect on reduction of slab cracking and IRI as compared to the 12-ft (3.7-m) conventional lane, as shown in Table 7 and Figure 10. There is also a very significant difference in joint faulting, reducing the mean faulting from 0.07 in. (1.8 mm) to zero.

Figure 10. Effect of traffic lane slab width on slab cracking and IRI after 30 years and 55 million trucks.

- Joint faulting is also affected by the condition of the existing pavement. Figure 11 shows the results for joint faulting after 30 years and 55 million trucks for the different levels of pavement condition including rubblizing the existing JPCP. As the effective modulus of the existing pavement decreases, the amount of joint faulting increases.

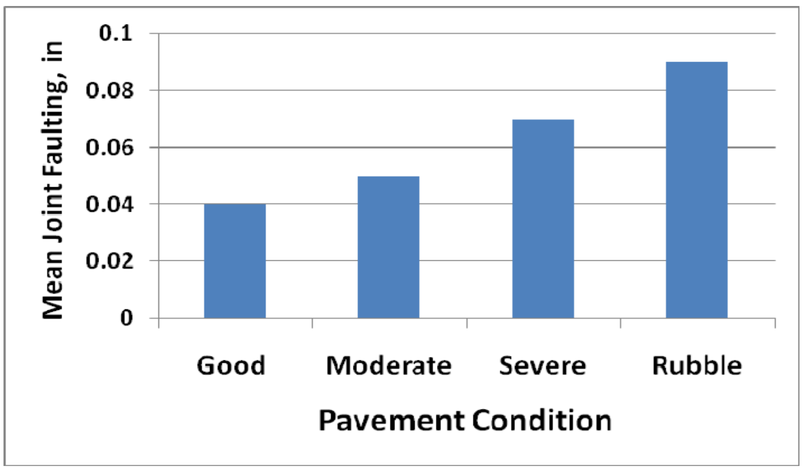

Figure 11. Effect of existing JPCP condition on transverse mean joint faulting after 30 years and 55 million trucks.

7.0 IMPACT OF EXISTING CONDITION ON JPCP OVERLAY THICKNESS

The previous analyses focused on showing the impact of the condition of the existing HMA or JPCP on cracking, faulting, and IRI of the concrete overlay over time. This section briefly shows the impact on thickness of the overlay when the condition of the existing pavement is varied from good to very poor or severe. Table 8 shows the summary of results achieved from this analysis using the MEPDG and typical design criteria, including 0.12-in. (3.0 mm) joint faulting, 15 percent transverse cracking, and 170 in/mi (2.7 m/km) IRI all at 90 percent design reliability.

Case Study A JPCP/HMA results show the following:

- Slab thickness required increases from 7 in. (178 mm) to 8 in. (203 mm) as HMA pavement condition changes from "Fair" to "Very Poor."
- Dowel bar diameter required increases from 1.00 in. (25 mm) to 1.25 in. (32 mm) as HMA pavement condition changes from "Fair" to "Very Poor."

Case Study B JPCP/HMA/JPCP results show the following:

- Slab thickness required increases from 9 in. (229 mm) to 10 in. (254 mm) as the existing JPCP condition changes from "Good" to "Severe."
- Dowel bar diameter required increases from 1.25 in. (32 mm) to 1.50 in. (38 mm) as JPCP condition changes from "Good" to "Severe."

Table 8
Effect of Existing Pavement Condition on JPCP Overlay Design (MEPDG: Designs Meet Specified Distress, IRI, and Reliability Criteria Over 30 Years With Full Friction Assumed)

Condition of Existing Pavement	Case Study A: HMA Existing Pavement (30 years, 8 million trucks)	Case Study B: JPCP Existing Pavement (30 years, 55 million trucks)
Fair (HMA) or Good (JPCP)	7.0-in., 1.00-in. dowels, 12-ft joint space	9-in., 1.25-in. dowels, 15-ft joint space
Poor (HMA) or Moderate (JPCP)	7.5-in., 1.25-in. dowels, 12-ft joint space	9.5-in., 1.25-in. dowels, 15-ft joint space
Very Poor (HMA) or Severe (JPCP)	8-in., 1.25-in. dowels, 12-ft joint space	10-in., 1.50-in. dowels, 15-ft joint space

8.0 FINDINGS AND RECOMMENDATIONS FOR CONSIDERATION OF EXISTING PAVEMENT IN CONCRETE OVERLAY DESIGN

The following findings and recommendations are based on the previous analyses of JPCP overlays over existing HMA and JPCP pavements using the MEPDG to predict performance for two case studies.

- The amount of deterioration of the existing HMA and JPCP pavements affects the performance of the JPCP overlay. This is caused by the loss of structural capacity of the existing pavement (concrete's modulus of elasticity and HMA dynamic modulus) on the resulting composite structure of overlay and existing pavement.
- The increased slab thickness required for both existing HMA and JPCP case studies was 1 in. (25 mm) when the existing pavement ranged from "Good" to "Poor" condition. The increased dowel bar diameter required for both case studies was 0.25 in. (6 mm) over the same condition range.
- Thus, the condition of the existing pavement must be quantified and used in overlay design. The MEPDG provides practical definitions of the condition of the existing pave-

ment in terms of percent area of alligator cracking for HMA pavement and percent slabs transverse cracked for JPCP.

- The existing pavement can be repaired through full-depth repair or slab replacement. The amount of repair would affect the percentage of alligator cracked area for HMA and the percentage of transverse cracked slabs for JPCP. The required thickness of the JPCP overlay would decrease with increased repair of the existing pavement. The MEPDG provides the data to conduct a cost comparison between more repair and a thinner JPCP overlay with larger dowel bars to establish an optimum balance.

- The thickness of the existing HMA layer beneath the concrete overlay contributes to the performance of the concrete overlay. The thicker this HMA layer the lower cracking and IRI of the overlay. This will affect the thickness design.

- The HMA separation layer thickness change (from 1 in. [25 mm] to 3 in. [76 mm]) has only a moderate effect in mitigating the impact of cracking of the existing JPCP. The impact on overlay slab thickness is small.

- Rubblizing the existing concrete pavement results in a much reduced elastic modulus of the pavement. This reduction will require at least an additional 2-in. (51-mm) concrete overlay thickness over that required for the "Good" condition as illustrated in Case Study B.

The following results were obtained based on MEPDG predictions related to the effect of design features of the JPCP overlay.

- As JPCP overlay slab thickness increases, the impact of the condition of the existing pavement decreases for both HMA and JPCP existing pavement.

- The transverse joint spacing of the JPCP overlay has a major effect on the performance of the overlay. The shorter the joint spacing the lower faulting and cracking. However, jointing costs increase and this must be balanced with thickness requirements. Typically, for slabs from 6 in. (152 mm) to 7 in. (178 mm) thick, the joint spacing should be about 12 ft (3.7 m). For slabs 8 in. (203 mm) or thicker, the joint spacing should be about 15 ft (4.6 m).

- The widening of the slab by 1 ft (0.3 m) has a very beneficial effect on reducing joint faulting and transverse cracking. Only 1 ft (0.3 m) is needed; thus a slab 12 ft (3.7 m) wide would be built 13 ft (14.0 m) wide with the paint strip placed at 12 ft (3.7 m). This feature will also likely require a thinner overlay slab in the order of 1 in. (25 mm).

- Dowel bars in the transverse joints are not always needed and depend in particular on the climate and the level of traffic. Cold climates and high truck traffic loadings were demonstrated for Case Study A and Case Study B overlays. Both required dowels to control joint faulting. Lower traffic and warmer climates may not require dowels. The need for dowels can be determined using the MEPDG for specific projects.

These results shown in this paper are only as good as the MEPDG models' predictions. How accurately can the MEPDG predict the performance of JPCP overlays? The national calibration for slab cracking and joint faulting provided in Figures 1 and 2 indicate reasonably good predictions. The sensitivity results shown in this paper appear to agree with the general trends of the performance of JPCP overlays.

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