

SHRP 2 Renewal Project R21

**R21 Composite Pavements:
Proposed Revisions to
MEDPG/DARWin-ME Manual of
Practice**

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TRANSPORTATION RESEARCH BOARD

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This document includes the SHRP 2 Project R21 recommendations for revision of the AASHTO “Mechanistic-Empirical Pavement Design Guide, Interim Edition: A Manual of Practice” (AASHTO MOP) dated July 2008 for the DARWin-ME design procedure to include newly constructed composite pavements. The existing version of DARWin-ME only includes new HMA and PCC pavements and HMA overlays of PCC and PCC overlays of PCC pavements but not new composite pavements. The program was found to have some limitations for “new” composite pavements but in general was very effective in modeling and predicting distresses and IRI of these pavements. The following revisions are recommended for the AASHTO MOP so that composite pavement can be included as a “new” type of pavement similar to flexible and rigid pavements.

1. Introduction

No revisions needed.

2. Referenced Documents and Standards

No revisions needed.

3. Significance and Use of the MEPDG

p. 16: Add another bullet

- Composite Pavements
 - HMA/JPC or CRC Rut Depth
 - HMA/JPC Mean Joint Faulting (of bare JPCP only without HMA)
 - HMA/JPC Load-Related Transverse Slab Cracking (includes both bottom and surface initiated cracking)
 - HMA/JPC or CRC Smoothness (IRI)
 - HMA/CRC Crack Spacing, Crack Width, and Crack LTE
 - HMA/CRC Punchouts
 - PCC/JPC Mean Joint Faulting (of bare JPCP only)
 - PCC/JPC Load-Related Transverse Slab Cracking (includes both bottom and surface initiated cracking)
 - PCC/JPC or CRC Smoothness (IRI)
 - PCC/CRC Punchouts

p. 18: Add the following bullet

- Semi-Rigid Pavements—delete the following: “This type of pavement is also referred to as composite pavements in the MEPDG.”
- Composite Pavements—Two different types are defined:
 - HMA placed over new JPC, CRC, or jointed RCC.
 - PCC placed wet-on-wet (bonded) to new JPC or CRC.

Composite pavement distress and IRI models were nationally validated under SHRP2 R21 “Composite Pavement Systems” project.

4. Terminology and Definition of Terms

p. 28: Add the following to the bullet item **Structural Response Model**: “...., while for rigid pavements and composite pavements, the ISLAB2000 program is used.”

p. 31: Add the following bullet items under Section 4.5:

- **Total Cracking (Reflection + Alligator) (%) (HMA/JPC Only)**—Reflection cracking portion is JPC transverse joint reflection cracking plus transverse mid-panel fatigue reflection cracking (see Section 4.6 definitions for Bottom-Up and Top-Down Transverse Cracking). Alligator cracking in the HMA surface portion is nearly always zero due to the JPC slab directly below the HMA surface layer.

- **Total Cracking (Reflection + Alligator) (%) (HMA/CRC Only)**—Reflection cracking portion is CRC punchout reflection cracking (see Section 4.6 definitions for CRCP Punchouts). Alligator cracking in the HMA surface portion is nearly always zero due to the CRC slab directly below the HMA surface layer.

5. Performance Indicator Prediction Methodologies—An Overview

Add Section 5.4 DISTRESS PREDICTION EQUATIONS FOR COMPOSITE PAVEMENTS

5.4 DISTRESS PREDICTION EQUATIONS FOR COMPOSITE PAVEMENTS

The damage and distress transverse functions for HMA/JPC, HMA/CRC, HMA/RCC, PCC/JPC, and PCC/CRC were evaluated and validated under SHRP2 R21. It was determined that the transverse fatigue cracking and punchouts fit reasonably into the previous calibrations for bare JPCP and CRCP. It was also determined that the rutting of the thin HMA surfacing (which was typically very low) was predicted reasonably by the models in Section 5.2.2. The top down wheelpath HMA cracking was not evaluated since none of this distress existed in the field HMA/PCC sections. In addition, the Section 5.2.4 Non-Load Related Cracking—Transverse Cracking (low temperature cracking) was also not found on any of the HMA/PCC field sections. Thus, it is recommended to not include either of these distress types in the design of composite pavements.

Table 5.4 was prepared so show the distress and IRI models that are used with each type of composite pavement.

Table 5.4. Summary of distress and IRI models used in the design of composite pavements.

Composite Type	Transverse Fatigue Cracking	Transverse Reflection Joints	Transverse Joint Faulting	HMA Rutting	Punchout	IRI
HMA/PCC	HMA/JPC (5-16 to 5-19)	HMA/JPC or Jointed RCC (5-13 to 5-14)	Analyzed w/bare JPCP (5-20 to 5-25)	HMA (5-1 to 5-3)	CRCP (5-26 to 5-31)	HMA/JPC & CRC (5-15C)
PCC/PCC	PCC/JPC (5-16 to 5-19)	N/A	PCC/JPC (5-20 to 5-25)	N/A	PCC/CRC (5-26 to 5-31)	PCC/JPC (5-32 to 5-34) PCC/CRC (5-35 to 5-36)

6. Hierarchical Input Levels—Deciding on the Input Level

No revisions needed.

7. General Project Information

No revisions needed.

8. Selecting Design Criteria and Reliability Level

p. 74: Add following to Table 8.1. Design Criteria or Threshold Values Recommended for Use in Judging the Acceptability of a Trial Design.

Pavement Type	Performance Criteria	Maximum Value at End of Design Life
Composite Pavement	IRI (All types)	Interstate: 160 in/mile Primary: 200 in/mile Secondary: 200 in/mile
HMA/JPC or CRC	Rutting HMA	Interstate: 0.40 in. Primary: 0.50 in Secondary: 0.65
	Transverse cracking (HMA/JPC)	Interstate: 10% Primary: 15% Secondary: 20%
	Mean joint faulting (Bare JPCP)	Interstate: 0.15 in Primary: 0.20 in Secondary: 0.20 in
	Punchouts (HMA/CRC) Crack Width: < 0.020 in. Crack LTE:	Interstate: 10/mile Primary: 12/mile Secondary: 15/mile
PCC/JPC or CRC	Transverse cracking (PCC/JPC)	Interstate: 10% Primary: 15% Secondary: 20%
	Punchouts (PCC/CRC) Crack Width: < 0.020 in. Crack LTE:	Interstate: 10/mile Primary: 12/mile Secondary: 15/mile
	Mean joint faulting	Interstate: 0.15 in Primary: 0.20 in Secondary: 0.20 in

9. Determining Site Conditions and Factors

Section 9.1: Add Truck Wheel Base

- Truck wheel base length (distance from steering axle to next first axle) is used in the calculation of top-down and bottom-up cracking of JPC slabs. The wheel base is divided into three lengths: Short (10-13.5 ft), Medium (13.5-16.5 ft), and Long (16.5-20 ft). The percentages of trucks of Class 8 through 13 are included in the fatigue analysis. The percentage breakdown can vary from site to site. A national study of 26 SPS sites provided the following to be used as defaults: Short (17%), Medium (22%), and Long (61%).

10. Performance Evaluation for Rehabilitation Design

No revisions needed.

11. Determination of Material Properties for New Paving Materials

No revisions needed.

12. Pavement Design strategies

p. 129: First paragraph, modify the third sentence as follows: “This section provides guidance to the designer in developing the initial pavement design strategy for the site conditions and describes new or reconstructed pavement design strategies for flexible, rigid, and composite pavements.”

p. 142: Add the following major Section 12.3 on composite pavements:

12.3 NEW COMPOSITE PAVEMENT DESIGN STRATEGIES—DEVELOPING THE INITIAL TRIAL DESIGN

The DARWin-ME design procedure provides for two major types of new composite pavements.

- HMA surface bonded to JPC (including jointed RCC and jointed LCB) and CRC.
- PCC surface bonded to JPC or CRC.

A description of and various alternatives for each of these two types of new composite pavements are described along with design strategies.

i. **HMA type surface bonded to JPC (including jointed Roller Compacted Concrete (RCC) and jointed Lean Concrete Base (LCB)) and CRC.**

This type of composite pavement has been constructed in the United States and in other countries often as part of a widening strategy to maintain similar structure, as a major pavement type for urban streets, and also as a low-noise surface that can be rapidly replaced yet includes a sufficient PCC structure for long life. The main design strategy has been to provide a two-layer composite pavement where each layer has specific purposes.

- A thin (typically 1-3 in) asphaltic surface course consists of several alternatives including dense-graded HMA, SMA alone or in combination with HMA binder layer, porous HMA, asphalt rubber friction course (ARFC), WMA, rubber-modified HMA (RHMA) and Nova chip surface that have generally provided excellent surface characteristics including low noise, increased smoothness, lower splash and spray, and non-polishing aggregates. These types of surface material have typically shown service lives from 10 to 16 years and can be renewed rapidly when needed.
- A thicker lower layer of concrete that is typically less expensive but has sufficient durability and strength. This layer may include high proportions of supplemental materials (e.g. fly ash), recycled concrete coarse aggregates, RAP materials, and local aggregates that may not be suitable for use in a surface layer. This lower PCC layer is the primary structural load carrying layer in the pavement and is expected to provide a durable and strong base which is economical to construct and promotes the ideals of sustainability and energy efficiency.

Applications of this type of HMA/PCC composite pavements have been growing in recent years.

- **HMA/JPC and HMA/CRC for widening of an existing PCC pavement.** The most widely used application of HMA/PCC is for widening of an existing PCC pavement or an existing HMA/PCC pavement, and it is desired to match layer types across the new traffic lanes. Many States have designed and built widening composite pavements, and these have performed well.
- **A thin 1-in ARFC over JPCP and CRCP to reduce tire/pavement noise levels in urban areas.** Arizona uses a thin 1-in ARFC over JPC and CRC to reduce tire-pavement noise levels in urban areas. The entire Phoenix freeway system was surfaced with ARFC beginning in 2003, and many of these were also new JPC segments. There are a number of ARFC/JPC sections on rural Interstate highways that have been constructed since the early 1990's. This composite design has performed very well in Arizona.

- **New HMA/JPC and HMA/jointed LCB composite pavements for heavily trafficked highways.** Starting in the 1970's some US States and Canadian Provinces built this type of composite projects on major freeways. Some are now considering this type of composite pavement for sustainability benefits where the PCC layer can utilize recycled concrete aggregate (RCA) from nearby sources or aggregates with a polishing characteristics that could not be used for surfacing PCC.
- **Urban areas have built HMA/Jointed RCC, HMA/Jointed LCB, or HMA/JPC composite pavements** on residential, collector, and arterial streets. The use of short joint spacing plus saw and seal of joints in the HMA layer directly above the joints to control transverse reflection cracking has been critical to their success. Use of PCC with RCA or local aggregates for sustainability benefits is also considered a benefit.
- **Several European countries (e.g., Netherlands) have built porous HMA/CRC composite pavements on heavily trafficked freeways and highways.** The strategy is to provide for low noise and splash/spray surfacing that has no reflection cracking and can be periodically removed and replaced but have a long structural life CRC layer to carry very heavily traffic for 40 or more years.
- **A number of States and European countries have built HMA over LCB and RCC.** Here the use of short joint spacing (e.g. 10 ft) to reduce reflection cracking is critical as many of these pavements without joints have failed early from large transverse cracks spaced at 40 to 100 ft. The use of more standard joint spacing (e.g., 15 ft) with saw and seal of the HMA directly over transverse joints in the HMA layer has been highly successful.

While the performance of these pavements has been very good, few agencies consider them routinely in their pavement selection procedures. This may be due to the perception that they are more expensive to build than conventional HMA or PCC pavements. However, given the need to consider pavement alternatives that not only have long-term structural load carrying capacity, have excellent surface characteristics, and can be rapidly rehabilitated in the future, the interest in and use of HMA/PCC composite pavements may increase at both State and local highway agencies.

New information and technology has been developed and assembled under the SHRP2 R21 project to give highway agencies additional information about HMA/PCC composite pavements as follows:

1. Performance of composite pavement on Interstate and other heavily trafficked highways.
2. Performance of composite pavement on lower traffic volume urban streets.
3. Validation of a rational mechanistic based design procedure (e.g., the AASHTO DARWin-ME).
4. Construction guidelines and recommendations for building quality composite pavements.

Trial Design: Select all design inputs for a trial design. Nearly all of the recommendations provided in section 12.1 for flexible pavement and 12.2 for rigid pavement are valid for HMA/PCC composite pavement and is not repeated here. Guidelines on some unique inputs for a HMA/PCC composite pavement are as follows:

1. **Design life:** Select desired life of structural design until major rehabilitation is needed. Composite pavements are very appropriate to a long structural “perpetual” life exhibiting little structural deterioration over many years. DARWin-ME can design pavements for a design life of up to 100 years. To design a “perpetual” pavement, select a longer life of 40+ years. The HMA surface can be

replaced as needed, but the PCC slab will remain over the long design life with little structural fatigue damage or joint load transfer efficiency loss.

2. **Traffic levels:** An HMA/PCC composite pavement can be designed to carry any level of truck traffic. This ranges from a residential street to heavy industrial highway.
3. **Initial IRI:** The initial IRI for HMA/PCC composite pavements can be very low due to the multiple layering of the pavement. Initial IRI values as low as 40 in/mile have been achieved, with routine values of less than 50 in/mile.
4. **Type and thickness of asphaltic surface layer:** There exist many types but the most appropriate depends on the design objectives. If reducing noise levels to a minimum are required, then some type of porous asphalt surface can be used. Thickness should be the minimum possible to provide durability and surface characteristics desired for a given truck traffic and climate. In warmer weather locations, a thinner surfacing have performed well, such as the 1-in asphalt rubber friction courses in Arizona, but for colder weather and heavier traffic, up to 3 in total may be required. Typical surface life ranges from 10 to 18 years. Note that thicknesses of 1 to 3 in are sufficient to provide thermal and hygral (moisture) insulation of the PCC layer and thus reduced stresses in the PCC (resulting in reduced PCC thickness required as compared to a bare PCC pavement). Greater HMA thickness can also result in increased rutting as was observed in SHRP2 R21 project.
5. **Type (JPC, RCC, or CRC) and thickness of the PCC layer:** This is the load carrying capacity layer for the composite pavement. The trial design should start with a typical thickness used for bare pavement. Depending on the thickness of the HMA surface, the slab thickness may be reduced by 1 to 3 inches of concrete as determined by the AASHTO DARWin-ME software.
6. **Joint design for JPCP:** Joint design includes joint spacing and joint load transfer.
 - a. Joint spacing is considered directly in the DARWin-ME analysis and impacts transverse fatigue cracking as well as joint faulting. A shorter slab has two distinct advantages:
 - i. Requires a thinner slab to control transverse fatigue cracking.
 - ii. Less joint reflection cracking and deterioration through the HMA surface. For nondoweled joints, the shorter the joint spacing (e.g. 10 ft) the higher the joint LTE reducing the deterioration of the reflection crack. For conventional joint spacing (e.g., 15 ft) the use of sawing and sealing of the HMA surface is highly recommended.
 - b. Joint load transfer requirement is similar to bare JPCP design in that dowels of sufficient size are required to prevent erosion and faulting for any significant level of truck traffic. The greater the dowel diameter the higher the joint LTE and the more truck loadings the pavement can carry to the terminal level of faulting.
 - i. Simplified dowel design: the dowel diameter should be at least 1/8 the slab thickness. For example, a slab thickness of 12 in requires a dowel diameter of at

least $12/8 = 1.5$ in. For exceptionally heavy truck traffic highways, it may be necessary to add 0.25-in diameter.

- ii. Use of DARWin-ME: DARWin-ME can be run with all the same inputs but without the HMA surface to calculate joint faulting. In this case, joint faulting should be limited to no more than 0.15 to 0.20 in at the design reliability level to ensure sufficient joint LTE.
 - iii. Low volume roadways where dowels would not normally be used for bare JPCP do not require dowels for composite pavement. This is true for residential or farm to market streets where JPC or RCC is used as the lower layer. When dowels are not used, it is highly recommended to reduce the joint spacing to 10 ft to reduce reflection cracking and increase joint LTE.
7. **Joint design for RCC or LCB:** Joints should always be provided for RCC or LCB at spacings even shorter than JPC for reasons described previously (e.g. 10 ft is recommended). These joints will not have dowels and can be formed with a single saw cut or formed with a knife edge and do not require sealing or filling.
 8. **Tied shoulders:** Tied PCC shoulders provide improved edge support and are recommended.
 9. **Widened slab:** Widened slab traffic lane provides improved edge support. A maximum of 1 ft widened slab is recommended.
 10. **Reinforcement design for CRC:** The reinforcement content should be similar to bare CRCP. All of the same crack spacing, long term width, and long term LTE are applicable. The reinforcement design is provided in the DARWin-ME. If these recommendations are followed, HMA /CRC pavements have shown no reflection cracking over many years and very heavy traffic.
 11. **Concrete slab recommendations:** The formed concrete or roller compacted concrete to be used for the lower layer of an HMA/PCC composite pavement can vary widely as described below:
 - a. Conventional concrete used in bare JPCP or CRCP can be used.
 - b. Lower cost concrete achieved by use of local aggregates, recycled concrete from local projects, and higher amounts of fly ash or other supplemental materials. The strength, modulus of elasticity, CTE, and drying shrinkage of the concrete can be varied as it is a direct input to the DARWin-ME software.
 - c. Both of these alternatives provide for substantial sustainability and energy advantages as well as cost savings but yet provide adequate durability.
 12. **Base layer and other sublayers:** These sublayers should be selected similar to bare JPCP or CRCP designs based on minimizing erosion, construction ease, subdrainage, and cost effectiveness. No attempts should be made to reduce the friction between the slab and the base because good friction is required to form joints in JPC/RCC and cracks in CRC. Good friction also helps control erosion and pumping and reduces stresses in the PCC slab.

13. **Reflection cracking through HMA surface:** This type of distress often results in reduced life for HMA overlays of existing concrete pavements. However, for HMA/PCC composite pavements, this mode of distress can be reduced as follows:

- a. **Typical freeway and highway construction with JPC doweled joints:** Cut and saw and seal joints immediately above transverse and longitudinal joints. This is a highly successful strategy used for decades in the US to greatly reduce the negative impact of reflection cracks.
 - b. **Typical freeway and highway construction with CRC:** No reflection cracks were observed for HMA/CRC when the surface was 1 in or more in thickness.
 - c. **Typical urban or rural area street/highway construction with jointed RCC or LCB with no dowel bars:** form transverse and longitudinal joints in the RCC or LCB immediately after placement or saw joints after sufficient hardening at a short spacing of no more than 10 ft.
- ii. **HMA type surface bonded to JPC (including jointed Roller Compacted Concrete (RCC) and jointed Lean Concrete Base (LCB)) and CRC.**

This type of composite pavement has been constructed in the United States on several experimental projects but has been built on major freeways and highways for 30 years in several European countries. The main design strategy has been to provide a two-layer concrete pavement where each layer has specific purposes.

- A relatively thin surface wearing course consisting of high quality concrete with non-polishing aggregates placed immediately on top of a thicker plastic lower cost concrete layer. The placement process is termed “wet on wet” construction and generally requires two closely-spaced pavers.
- The thin (typically 2-3 in) surface course is specially textured to have excellent surface characteristics including low noise, increased smoothness, non-polishing aggregates, and high durability. This surface material has traditionally been designed and processed to achieve an Exposed Aggregate Concrete (EAC) wearing surface in Europe and in several US projects. However, a successful and simpler alternative to construct involves diamond grinding of the surface that also provides excellent surface characteristics and simplifies its construction. This alternative has been termed DGC/PCC. Conventional surface textures such as tining and turf or burlap drags can also be used.
- A thicker lower layer of concrete that is typically less expensive but has sufficient durability and strength. This layer may include high proportions of supplementary materials (e.g. fly ash), recycled concrete coarse aggregates, RAP materials, and local aggregates that may not be suitable for use in a surface layer (e.g. aggregates susceptible to polishing). The lower PCC layer is the primary load carrying layer in the pavement and is expected to provide a durable and strong base which is economical to construct and promotes the ideals of sustainability and energy efficiency.

The use of this type of composite pavement is on the rise as summarized below.

- Several European countries have built two-layer, wet on wet, concrete pavements beginning in the late 1980's. The thin surface has typically been EAC and the thicker lower layer regular concrete or special more sustainable concrete composite pavements on heavily trafficked freeways. The strategy is to provide for excellent surface characteristics along with a structural second layer to carry heavy loadings for a long structural life of 40 or more years.
- A few States have built PCC/JPC (Florida, Kansas) composite pavement and more recently EAC/JPC (Michigan, Kansas) that have performed well.

While the performance of the PCC/PCC composite pavement has been very successful both in Europe and the United States, few highway agencies today consider it routinely in their pavement selection procedures. This may be due to the perception that they are more expensive to build than conventional concrete pavements. But given the need to consider pavement alternatives that not only have long-term structural load carrying capacity (e.g., perpetual load carrying capacity), but also have excellent surface characteristics, and are more sustainable through use of RCA or more local aggregates in the lower PCC layer, the interest in and use of PCC/PCC composite pavements is increasing among highway agencies in the US.

New information and technology has been developed and assembled under the SHRP2 R21 project to give highway agencies the required tools with regards to PCC/PCC composite pavements as follows:

- Performance of composite pavement on Interstate and other heavily trafficked highways.
- Validation of a rational mechanistic based design procedure (e.g., the AASHTO DARWin-ME).
- Construction guidelines and recommendations for building quality PCC/JPC or CRC composite pavements.

Trial Design for PCC/PCC: Select all design inputs for a trial design. Nearly all of the recommendations provided in section 12.2 for rigid pavement are valid for PCC/PCC composite pavements and is not repeated here. Guidelines on some unique inputs for a PCC/PCC composite pavement are as follows:

1. **Design life:** Select desired life of structural design until major rehabilitation of the PCC slab is desired. Composite pavements are very appropriate to a long structural “perpetual” life design exhibiting little structural deterioration over many years. The DARWin-ME can design PCC/JPC and PCC/CRC for up to 100 years. To design a “perpetual” pavement, select a longer life of 40+ years. The high quality surface can be diamond ground as needed, but the lower PCC slab will remain over the long design life with little structural fatigue damage or joint LTE loss.
2. **Traffic levels:** A PCC/PCC composite pavement can be designed to carry any level of truck traffic. This ranges from a lower volume highway to the heaviest industrial highway.
3. **Initial IRI:** The initial IRI for PCC/PCC composite pavements can be very similar to conventional concrete paving (e.g., 50-70 in/mile). If the surface is diamond ground, the initial IRI may be even lower.
4. **Type and thickness of PCC surface layer:** The conventional EAC consists of a high quality non-polishing aggregate, gap graded, to produce a low noise level surface. The noise level of EAC

surfaces are equivalent to dense-graded HMA. An alternative to the EAC surface is to use a high quality non-polishing aggregate densely-graded and then diamond grind the surface.

Layer thickness should be approximately 3 in for constructability and durability. Surface life should well exceed conventional PCC texturing especially for maintaining friction. Diamond grinding can be used to retexture and smooth the surface as needed.

5. **Type (JPC or CRC) and thickness of the lower PCC layer:** This is the load carrying capacity layer for the composite pavement. The trial design should start with a typical thickness used for bare pavement.
6. **Joint design for PCC/JPC:** Joint design includes joint spacing and joint load transfer.
 - a. Joint spacing is considered directly in the DARWin-ME analysis and impacts transverse fatigue cracking as well as joint faulting. A shorter slab has the advantage of requiring a thinner slab to control transverse fatigue cracking.
 - b. Joint load transfer requirement is considered directly in the DARWin-ME analysis to provide dowels of sufficient size required to prevent erosion and faulting for any significant level of truck traffic.
 - c. Depth of transverse and longitudinal joint sawcut should be greater of $1/3^{\text{rd}}$ the total PCC thickness and the thickness of the upper PCC layer plus $1/2$ inch.
7. **Reinforcement design for CRC:** The reinforcement content should be similar to conventional CRCP using the full thickness of the two layers to compute percent steel. All of the same crack spacing, long term width, and long term LTE are applicable. The reinforcement design is provided in the DARWin-ME.
8. **Concrete slab recommendations:** The concrete to be used for the lower layer of a PCC/PCC composite pavement can vary widely as described below:
 - a. Conventional concrete used in bare JPCP or CRCP can be used.
 - b. Lower cost concrete achieved by use of local aggregates, recycled concrete from local projects, and higher amounts of fly ash or other supplemental materials. The strength, modulus of elasticity, CTE, and drying shrinkage of the concrete can be varied as it is a direct input to the DARWin-ME software.
 - c. Both of these alternatives provide for substantial sustainability and energy advantages as well as cost savings but yet provide adequate durability.
9. **Base layer and other sublayers:** These sublayers should be selected similar to bare JPCP or CRCP designs based on minimizing erosion, construction ease, subdrainage, and cost effectiveness. No attempts should be made to reduce the friction between the slab and the base because good friction is required to form joints in JPC and cracks in CRC. Good friction also helps control erosion and pumping and reduces stress in the slab.

END Section 12.3

13. Rehabilitation Design Strategies

No revisions needed.

14. Interpretation and Analysis of the Results of the Trial Design

p. 182: Add third bullet:

- For the HMA/JPC composite example (see Table 14-3), the Terminal IRI, Transverse Cracking, and HMA Rutting met the reliability criterion (>95%) but the joint faulting did not. This trial design is not acceptable at the 95% reliability level and needs to be revised. Increase in dowel diameter may be tried in the next iteration.

p. 182: Modify title of Table 14-2: “Reliability Summary for JPCP and PCC/JPC Trial Design Example.”

p. 182: Add Table 14-3.

Table 14-3. Reliability Summary for HMA/JPC or HMA/RCC or LCB or HMA/CRC

Project		I-100			
Reliability Summary					
Performance Criteria	Distress Target	Reliability Target	Distress Predicted	Reliability Predicted	Acceptable?
Terminal IRI (in/mile)	172	95	110	97.32	Pass
Transverse Crack (JPC) % Slabs	10 Major highways, 15 Others	95	2	99.23	Pass
Mean Joint Faulting, in	0.15 in calc. bare JPCP	95	0.08	93.20	Fail
Mean Wheel Path Rutting, in	0.25 in	95	0.12	95.50	Pass

14.4 PREDICTED PERFORMANCE VALUES

P. 185: Add two new bullet items:

- **HMA/PCC Composite Pavement**
 - **Joint faulting (Bare JPCP)**— The mean joint faulting is calculated using the identical design as the HMA/JPC but without the HMA surface. Faulting criteria is exactly the same as for bare JPCP. Controlling joint faulting is critical to minimize the deterioration of HMA reflection crack as well as erosion and pumping beneath the slab.
 - **Percent slabs cracked (HMA/JPC)**— Fatigue damage in HMA/JPC forms similarly to that of bare JPCP but often the damage at the top of the JPC slab is reduced. Transverse (mid-panel) fatigue cracking is the primary structural deterioration mode of HMA/JPC. It should be minimized for long-term low fatigue cracking service life (e.g., perpetual pavement). The HMA surface

however significantly changes the thermal and moisture gradients through the slab and thus reduces fatigue damage resulting in a thinner slab requirement than a similar bare JPCP. The HMA also contributes additional equivalent slab thickness thereby reducing fatigue damage. The HMA surface does not develop typical fatigue alligator cracking if it remains bonded securely to the slab which is the design assumption.

- **Punchouts (HMA/CRC)**— Repeated load punchouts are caused by the same mechanisms as bare CRCP. The HMA layer reduces the thermal and moisture gradients significantly and thus the top of slab fatigue damage that leads to a punchout. The HMA also contributes additional equivalent slab thickness thereby reducing fatigue damage. The HMA surface does not develop typical fatigue alligator cracking if it remains bonded securely to the slab which is the design assumption.
 - **Crack spacing (HMA/CRC) and Crack LTE (HMA/CRC)**— These are formed similarly to that for bare CRCP since the HMA surface is not often placed for one or more months. The requirements are the same however as these two factors control the development of punchouts.
 - **IRI (HMA/JPC and CRC)**— The IRI of the HMA surface is controlled by the initial IRI, development of JPC transverse cracking, CRC punchouts, rutting of the HMA, and site factors such as precipitation, subgrade, and age.
Reflection Cracking (HMA/JPC and CRC)— Although reflection cracking is output by the software, the models are totally empirical and are not reliable for use in design. The results should be ignored and not used to design this type of pavement until the models are updated.
- **PCC/PCC Composite Pavement**
Note that all of these predicted performance values are the same as for single slab layer JPCP and CRCP as provided in Section 14.4.

Appendix: Getting Started With the MEPDG

This appendix needs to be completely rewritten for the DARWin-ME software (since MEPDG has been replaced by DARWin-ME).

Abbreviations And Terms

Add the following abbreviations:

RCC	Roller compacted concrete
RCA	Recycled concrete aggregate
SMA	Stone Matrix Asphalt
ARFC	Asphalt rubber friction course
EAC	Exposed aggregate concrete
WMA	Warm Mix Asphalt
RHMA	Rubber-Modified HMA

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Add additional entries as included in these modifications.