State of Florida

Department of Transportation

Portland Cement Concrete Pavement Specifications: State of the Practice

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TABLE OF CONTENTS

LIST OF TABLES

1 DISCLAIMER

The information presented herein encompasses mainly the “State of the Practice” of the following seven states: Florida (FL), Texas (TX), Kansas (KS), Missouri (MO), Minnesota (MN), Michigan (MI), Wisconsin (WI), and Indiana (IN). The information summarized in this report is based on a variety of sources that were made available to the authors. A number of discrepancies were encountered in the process of synthesizing the information, including inconsistencies within the same source documents. The FDOT staff responsible for gathering, summarizing and reporting this information has reconciled these discrepancies to the best of their abilities but cannot attest to the accuracy of all the information provided herein. Comments and questions arising from any misinterpretation may be submitted to the authors for corrective actions and/or further clarification. However, the Florida Department of Transportation and the authors assume no liability for the contents of this report or use thereof.

The reader is cautioned that in some instances, the terminology used in Florida may differ from the terminology used by other states. For instance, “Embankment” is the term used in Florida for the natural soil, which in other states is referred to as “Subgrade”. In Florida, the term “subgrade” refers to the layer below the base which has, in most cases, been specially treated.

2 Executive Summary

Specifications and practices from States considered to have strong concrete pavement programs were reviewed and compared to Florida methods. Methods and techniques that were thought to strengthen Florida specifications were noted for further consideration. Overall, Florida specifications are generally in line with those of the states that lead concrete pavement construction.

3 Objective

The objective of this effort was to conduct a critical review, analysis, and provide recommendations on the State-of-the Practice for Concrete Pavement Specifications for Florida conditions. The specifications and/or recommended practices from State Highway Agencies (SHA) considered to have a strong concrete pavement program such as Texas (TX), Minnesota (MN), Kansas (KS), Missouri (MO), and Wisconsin (WI) as well as the Federal Highway Administration (FHWA) were reviewed and compared to Florida Methods. .

4 Findings

The following is a summary of key findings by practice area:

4.1 PAVEMENT DESIGN

1. Florida is among the majority of states using the 1993 AASHTO Guide. Florida currently allows the use of the Mechanistic-Empirical Pavement Design Guide (MEPDG) as an alternate design method.
2. Florida is in line with the other states for design considerations such as rigid pavement type, joint spacing, structural requirements, design life, and design inputs.
3. Florida uses a 20-year design life; the other States use a 20 to 45 year design life.
4. Florida uses lower Initial Serviceability and Design Reliability compared to other States, excluding WI.
5. Florida uses 40-year as input to Life Cycle Cost Analysis; the other States use 21 to 50-year.
6. Considerations
   i) Re-assess design life and design inputs.
   ii) Continue effort to implement MEPDG.
   iii) Optimize project specific designs based on local conditions as opposed to boiler-plate approach.
   iv) Investigate the feasibility of continuously reinforced concrete pavement (CRCP) for extremely heavy load/high traffic facilities.

v) Use sleeper slabs at Portland cement concrete (PCC)/hot mix asphalt (HMA) interfaces to prevent asphalt concrete (AC) drop off.
vi) Limit slab width to 14 feet to minimize cracking.
vii) Review use of non-standard terminology (ex: Embankment) and revise as appropriate.

4.2 CONCRETE MIX DESIGN

1. Florida specification for minimum cementitious material content and minimum compressive strength is on the low side.
2. Considerations
   i) Consider allowing a higher compressive strength but limit total cementitious material in an effort to reduce potential cracking (i.e. allow contractors to optimize their mix designs).

4.3 SUBGRADE AND BASE PREPARATION

1. Unlike Florida, most of the other states also allow the use of an unbound aggregate base option.
2. States have similar subgrade moisture and surface condition requirements at the time of concrete placement.
3. Florida does not specify permeability requirement for the permeable base, except for the special select option.
4. Florida does not allow use of lime or fly ash as embankment modifier. Most others allow one or both.
5. Considerations
   i) Unbound aggregate base as an optional base. State of the practice for a drainable base is 200 to 300 ft/day.
   ii) Use of lime and/or fly ash as embankment modifier.
   iii) Specify a range of permeability for permeable base.
   iv) Treat top of Asphalt-Treated Permeable Base (ATPB) with lime solution before paving to keep base temperature low and prevent flash set of concrete mixture.

4.4 CONCRETE PRODUCTION

1. Florida allows up to 22% fly ash per percent cement weight; other states allow up to 30%.
2. Florida allows up to 70% slag per percent cement weight; others allow up to 50%.
3. Florida does not allow use of blended cement types; most other states allow it.
4. Considerations
   i) Increase fly ash content up to 30% with contingency for longer curing time.

4.5 DOWEL BARS

1. Florida has similar dowel bar spacing, placement, diameter and alignment tolerances as the other States, which are within the FHWA/National Cooperative Highway Research Program (NCHRP) recommended limits (see NCHRP 637).
2. Florida uses secured dowel bar baskets but does not prohibit inserters.
3. Considerations
   i) Allow Contractor to demonstrate dowel placement technique for Department approval to account for innovative methods.
   ii) Develop post-construction dowel tolerance requirements (see NCHRP 637).
   iii) Verify post-construction dowel alignment using technologies like MIT Scan.

4.6 TEXTURING

1. Florida requires longitudinal diamond grinding for entire project; others spot grind as required.
2. Florida is the only State that does not use transverse or longitudinal tinning.
3. The majority of states use longitudinal burlap or turf drag (for micro texture) followed by transverse or longitudinal tinning (for macro texture).
4. Considerations
   i) Limited spot grinding as needed to attain ride quality without affecting overall appearance.
   ii) Transverse tinning for friction, safety, and surface drainage as appropriate.

4.7 CURING

1. Florida is similar to other States in curing requirements except that Florida is the only State that tests all curing compounds prior to application.
2. Considerations
   i) Given the inconsistencies of curing compounds, continue testing all compounds used.
   ii) Clarify curing requirements for special circumstances (i.e., rain, cold, wind, etc.).
   iii) Use of evaporation retarders.

4.8 JOINTS AND JOINT SAWING

1. Florida is similar to the other states regarding initial joint cutting requirement except for the minimum time required to saw certain type of joints.
2. The final joint width specified by the States studied ranged from 1/8 inch to 3/8 inch depending on sealant type and if sealant is required. Florida specifies a final joint width of 1/4 inch for contraction and longitudinal joints.
3. Florida has transverse expansion joint requirements while most others do not.
4. Considerations
   i) Smaller joint width.
   ii) Isolation expansion joints around manholes.
   iii) Use of string line to guide longitudinal joints and reducing the 72 hour sawing time limit.

4.9 JOINT CLEANING

1. Florida is similar to other states.
2. Considerations
   i) Ensure air-blowing equipment is capable of filtering surplus oil and water.

4.10 JOINT SEALING

1. Florida has time limits, temperature restrictions and, in general, has more specific requirements than others.
2. Considerations
   i) Refill hot-poured sealant if the level drops significantly.
   ii) Shorter time periods before cutting and sealing joints.

4.11 SMOOTHNESS

1. States use a variety of different requirements from California Profilograph with various blanking bands to high-speed laser profilers. Florida is one of the few remaining States still using a profilograph with a 0.2 inch blanking band.
2. While Florida only specifies an incentive, most others specify both an incentive and a disincentive.
3. Considerations:
   i) Transition from 0.2 inch to zero blanking band for California Profilograph or implement inertial profiler acceptance with International Roughness Index (IRI) for smoothness acceptance.
   ii) Specify an incentive and a disincentive.

4.12 DEFICIENT PAVEMENT/ACCEPTANCE

1. Florida along with the others, assess some pay adjustment based on thickness and smoothness; Florida along with some of the States also adjusts pay due to strength.
2. MI also specifies acceptance based on steel embedment and position; KS and WI specify acceptance based on deficient slabs (e.g., spalling and cracking). FHWA recommends a pay factor / percent within limits (PWL) method incorporating strength, thickness, air content, ride and dowel alignment (STAR-D).

Table 1 Surveyed States with Deficient Pavement and Incentive/Disincentive Provisions

Deficient Criteria	Incentive/Disincentive Provision(s)			
	Incentive & Disincentive	Disincentive Only	Incentive Only	Neither
Other States				
Thickness	2	4	0	0
Strength	3	1	0	2
Smoothness	5	0	0	1
Other	0	2	0	1
Florida				
Thickness	√			
Strength		√		
Smoothness			√	
Other				

5 State Highway Agency Practices

This section summarizes standard practices for the State Highway Agencies (SHA) considered. To synthesize the information, only practice in key areas have been identified, namely Pavement design, Mix design, Subgrade and Base Preparation, Paving, Finishing, Texturing, Curing, and Smoothness.

5.1 PAVEMENT DESIGN

The 1993 AASHTO Guide is the most commonly used design procedure. The MEPDG, which has many advantages over the 1993 AASHTO Guide, has been implemented in MO and is being considered an alternate method in FL.

5.1.1 Florida

1. Design Methodology
   i) 1993 AASHTO Design Guide.
   ii) MEPDG as alternate to 1993 AASHTO Guide.
2. Rigid Pavement Types
   i) Jointed Plain Concrete Pavement (JPCP).
3. Joint Spacing
   i) 15 feet or 24 times the slab thickness, whichever is smaller.
4. Structural Requirements
   i) 12 inch stabilized subgrade with an LBR of 40.
   ii) Base layer: treated permeable base, AC base, or special select soil.
   iii) Design slab thickness 8 inches minimum.
5. Design Life
   i) 20 years.
6. Typical Design Input Values (See Table 2).

5.1.2 Other States

1. Design Methodology
   i) Mostly 1993 AASHTO Design Guide.
   ii) 1972/1981 AASHTO (WI), 1981 AAASHTO Guide (MN).

iii) MEPDG (MO, IN).

2. Rigid Pavement Types
   i) JPCP and JRCP: KS and MI.
   ii) JPCP only: MO, MN, IN.
   iii) JPCP, JRCP, and CRCP: TX and WI.

   Note: TX policy requires utilizing CRCPs on all their new and re-construction projects. Jointed concrete pavements are allowed for use only if specific conditions are met (e.g., for railroad crossings, approaches to structures or to widen existing jointed pavement).

3. Joint Spacing
   i) 15 feet standard (all States).
   ii) 20 feet maximum (TX).

4. Structural Requirements
   i) Base Types
      (1) 4 inch treated (asphalt or cement) or granular base (KS).
      (2) Granular base with a wide range of thickness (MI/10 inch, MN/18 to 2 inch, MO/ 4 inch, WI/ 18 inch).
      (3) 4 inch thick asphalt (or asphalt treated) base or a minimum of 1 inch asphalt bond breaker over a 6 inch cement-stabilized base (TX).
      (4) 3 inch open graded coarse aggregate on top of 6 inch dense graded coarse aggregate, both unstabilized (IN).
   ii) Slab thickness
      (1) Minimum: 8 inch (KS, MO, TX), 6 inch (WI), 7 inch (MN), 9 inch (MI), 8 inch (IN).
      (2) Maximum: 15 inch (TX, IN).

5. Design Life
   i) 20 years (KS, MI,WI); 30 years (TX, IN); 35 years (MN); 45 years (MO).

6. Typical design input values (See Table 2).

Table 2 Rigid Pavement Design Inputs

State	Typical Values for Rigid Pavement Design Inputs (Based on AASHTO Guide)								
	PCC Modulus of Elasticity (ksi)	**Concrete Modulus of Rupture (psi)**	**Drainage Factor**	**Joint Transfer Factor**	**Initial Service ability**	**Terminal Serviceability**	**∆ PSI**	**Design Reliability (New Constructio n)**	**Subgrade k-Value (psi/in)**
FL	4,000	635	1.0	3.2	4.2	2.5	1.7	75% to 95%	200
MI	4,200	670	1.0 to 1.05	2.7 to 3.2	4.5	2.5	2.0	95%	50 to 200
MN	4,200	650	Not found		4.5	2.5	2.0	Not found	
MO	Currently using MEPDG. The values shown below are for the old 1993 design guide.								
	3,600	690	1.0	2.8	4.5	2.5	2.0	90% to 95%	100 to 150
TX	5,000	620	0.91 to 1.16	2.9 to 4.2	4.5	2.5	2.0	95%	300
WI	4,200	Not found	1.0	2.7 to 3.4	4.0	2.5	1.5	Not found	

Note 1: Typical design inputs for **KS** could not be found at this time; **WI** is still using 1972/81 AASHTO Design Guide; **MN** is using the 1981 AASHTO Guide; **IN** is using MEPDG.

5.1.3 Considerations

1. Most of FL's typical design inputs are similar to those of the other States. However, a couple of input variables were found to be unique to FL. First, FL uses an initial serviceability value of 4.2 (hence a lower ∆PSI), while others use mostly 4.5 (except WI using 4.0). Second, FL allows a design reliability ranging from 75% to 95% for new-construction; the other States use a fixed value of 90% or 95%. It may be worthwhile to study the effects of these design parameters in the final design.
2. More utilization of MEPDG, especially for heavy truck traffic roads. MO has obtained more realistic (i.e.; thinner) designs since moving away from the 1993 AASHTO Guide. MEPDG designs have not been implemented long enough to compare long-term performance with 1993 AASHTO based designs.
3. Look at optimizing project specific designs based on sound engineering and economic judgment, as opposed to specifying default pavement thickness.
4. Optimize the use of recycled materials.
5. Include the omitted Table 5.2 referenced in section 5.2.2 of the Florida Rigid Pavement Design Manual.

6. Florida's Rigid Pavement Design Manual (Section 2.1) specifies a minimum slab thickness of 8 inches. However, Section 5.2.2 specifies a maximum joint spacing of either 15 ft or <u>24 times the slab thickness</u>, whichever is smaller. The underlined criterion should be removed since all combinations of thickness and calculated joint spacing are larger than the 15 ft specified maximum.
7. Use of CRCP for heavy load/heavy traffic facilities.
8. Use sleeper slab at PCC/HMA interface to prevent asphalt drop-off and/or cracking.
9. Limit slab width to 14 ft to minimize longitudinal cracking.

5.2 MIX DESIGN

5.2.1 Florida

1. Cement Type(s)
   i) I, IP, IS II, and III.
2. Coarse Aggregate Gradations (per ASTM C 33)
   i) No. 57 (Nominal size 25.0 to 4.75 mm).
   ii) No. 67 (Nominal size 19.0 to 4.75 mm).
   iii) No. 78.
   iv) No. 8 and No. 89 can be used alone or as a blend with other sizes with approval.
3. Design Requirements
   i) Minimum 28-day compressive strength: 3,000 psi.
   ii) Total cementitious material content: 470 lb/yd3 minimum.
   iii) Maximum water/cement ratio: 0.5.
   iv) Design air content: 1.0 to 6.0 %.
   v) Target slump: 2 inches.

5.2.2 Other States

1. Cement Type(s)
   i) KS, MI, MO: Types I(PM) and I(SM) allowed; Type III not allowed.
   ii) IN: Types I, II, and III allowed.
2. Coarse Aggregate Gradations (should be 2. And not 3.)
   i) Texas
      (1) No. 7, 57, 67, and 467 gradations (per ASTM C-33).

(2) Gradations with nominal sizes of 2 inch, 1-1/5 inch, and 3/8 inch.

ii) Wisconsin

(1) AASHTO No. 4 and 67 gradations.

iii) Minnesota

(1) 1.5 inch maximum, MnDOT gradations.

iv) Missouri

(1) 2 inch or 3/8 inch maximum aggregate size.

v) Kansas

(1) 3/4 inch or 1/2 inch maximum aggregate gradations.

vi) Indiana

(1) Minimum of 20% retained on No. 4 sieve, Class AP, Size No. 8.

vii) Michigan

(1) Class 4AA, 6A, 6AA, 6AAA, 17A and 26 A coarse aggregate.

3. Design requirements

i) Minimum 28-day compressive strength: 3,000 psi to 4,400 psi

ii) Minimum total cementitious material content: 451 to 790 lb/yd^3

iii) Maximum water/cement ratio: 0.42 to 0.53

iv) Typical air content: 6.0 %

v) Target slump: 1.5 to 4.0 inch.

5.2.3 Considerations

FL specifies a minimum concrete strength of 3,000 psi. However, the actual strength achieved may be much higher which could cause cracking in the future. More realistic strengths should be considered or use in design.

5.3 BASE AND SUBGRADE

5.3.1 Florida

1. Unbonded rigid subbase (e.g., cement stabilized subbase) is generally not recommended.

2. Treated permeable base is generally the preferred sub drainage design.

   i) 4 inch Asphalt Treated Permeable Base (ATPB) or Cement Treated Permeable Base (CTPB) built on 2 inch Type SP Structural Course over 12 inch Type B Stabilization (LBR 40).

ii) Edge drains (CTPB or draincrete) required.

3. Special select soil option should only be used when there is a history of successful construction and performance with concrete pavements:

   i) Placed in top 60 inches of embankment

   ii) Average permeability of 5 x 10-5cm/sec with no individual test less than 1 x 10-5cm/sec.

   iii) Permeability based on FHWA-TS-80-224.

   iv) Non-plastic A-3 with less than 12% passing #200.

   v) Day lighting (i.e.; extending special select soil to shoulder slope) is recommended.

   vi) 3 inches of #89 or #57 mixed into the top 6 inches of special select soil.

   vii) Edge drains and draincrete required.

5.3.2 Other States

A summary of slab thickness, type of base and subgrade used by the various SHA considered is given in Table 3.

Table 3 Slab Thickness, Base and Subgrade Type

State	Design Slab Thickness		Base Type	Subgrade Type
	Minimum (inch)	Maximum (inch)		
Florida	8	N/A	4 inch treated permeable base over 2 inch asphalt structural course (separator layer)	12 inches Type B stabilized subgrade (LBR 40) for the 4 inch treated permeable base design option only.
			6 inch special stabilized sub base over 60 inch special select embankment (atypical)	
Kansas	8		4 inch asphalt concrete, cement treated base or granular base	12 inch of cement treated subgrade if recommended in the soils report

Michigan	9		10 inch dense graded granular base	
Minnesota	7		18 to 24 inch dense or open graded granular (rock) base	
Missouri	8		4 inch dense graded granular	
Texas	8	15	4inch asphalt concrete or asphalt stabilized base Min. 1inch asphalt concrete bond breaker over 6 inch cement stabilized base	
Wisconsin	6		18 inch dense graded granular	
Indiana	8	15	3 inch open graded on 6 inch dense graded (unstabilized)	14 inch lime stabilized subgrade

1. Construction

   i) All States require a time or distance separation between the paving operation and the subgrade construction: FL (500ft), KS (3 hours), WI (300ft).

2. Moisture

   i) All States, except MI, require maintaining the subgrade at or close to optimum moisture content until concrete placement; FL specifies ± 2 percent of optimum.

3. Sub-drainage

   i) All States allow some form of drainable base, either an unbound granular or treated permeable base.

   ii) Most States require edge drains when using a drainable base option.

4. Rolling and Compaction

   i) All States require maintaining the finished subgrade in a smooth compacted condition prior to placing the concrete. Only TX specific roller requirements for embankment, sub base and base.

5. Planner

   i) Of the States studied, only FL and MN require the use of a planer.

5.3.3 Considerations

1. Option to use a graded granular base.
2. Specify a permeability range for permeable base.
3. Specify edge drain testing/maintenance requirement.

5.4 DOWEL BARS

5.4.1 Florida

1. Similar dowel spacing, diameter and alignment tolerances as other States using secured baskets; use of dowel inserters is optional.
2. Alignment tolerances
   i) Longitudinal translation: may not exceed 2 inch.
   ii) Vertical translation: may not exceed 1 inch.
   iii) Rotation component (horizontal skew and vertical tilt): may not exceed 0.5 inch.

5.4.2 Other States

1. FHWA
   i) Longitudinal shift: ± 2 inch for 18 inch bar.
   ii) Vertical: mid-depth + 1 inch.
   iii) Horizontal or vertical rotation: 0.6 inch over 18 inch dowel.
2. NCHRP 637 study of projects from 17 States reported the following range of as-constructed dowel misalignment which did not impact pavement performance:
   i) Longitudinal translation: ± 2 inch over 18 inch dowels
   ii) Vertical translation: ± 0.5 inch for pavements 12 inch or less
   iii) Rotation component (horizontal skew and vertical tilt): each less than 0.5 inch over 18 inch dowels
3. Baskets are the most common method of installing dowels although some States allow inserters.

TABLE 4 Dowel Bar Specifications

State	Application Method	Pavement Thickness (Dowel Diam.), in	Dowel Spacing, in	Length, in
FL	Metal dowel bar assembly	8-1/2 (1) 9 to10-1/2 (1-1/4) ≥11 (1-1/2)	12	18
MI	Load transfer assembly or dowel bar inserter	6 to <8 (1) 8 to 11 (1-1/4)	12	18

		> 11 (1-1/2)		
MN	Baskets (approve dowel bar inserters on case-by-case basis)	<10 (1-1/4) 10.5≤t<13 (1-1/2) 13≤t<14 (1-3/4)	12	15
TX	Heavy welded wire baskets	8 (1) 9 (1-1/8) 11 (1-3/8) 15 (1-7/8) Increase diam. by 1/8 inch for each additional inch of thickness	12	18
WI	Baskets or mechanical inserters	7 to 7-1/2 (1) 8 to 9-1/2 (1-1/4) >10 (1-1/2)	12	18
IN	Welded wire assembly	MEPDG (1-11/2)	12	18

5.4.3 Considerations

1. Verify alignment of representative dowel population with MIT Scan.
2. Allow/disallow inserters or just provide tolerances.

5.5 TEXTURING

5.5.1 Florida

1. Burlap drag and diamond grinding to produce longitudinal corduroy type texture.
2. Grinding is an effective texturing option that has been shown to significantly reduce tire-pavement noise and increase friction. The texture produced by grinding is not as deep as that produced by tinning (1/32 inch versus 1/8 to 5/16 inch deep).

5.5.2 Other States

1. Burlap or turf drag followed by longitudinal or transverse tinning is the most common texturing method.

   Missouri allows the option of grinding the entire pavement as the final texture.

TABLE 5 Texturing Techniques

Texturing Technique	Typical Texture	Impact on Friction	Impact on Tire-Pavement Noise
Longitudinal Diamond Grinding	.08 to 0.16 inch deep grooves	Significant increase	Significant reduction
Drag	Longitudinal gritty texture with 1/16 inch to 1/8 inch deep grooves	Sufficient friction particularly for roadways with speeds < 45 mph	Relatively quiet pavements
Longitudinal Tinning	1/8 to 5/16 inch deep grooves	Adequate friction on high speed roadways	Conflicting reports - Occasional significant noise reduction

Transverse Tinning	Sometimes randomly spaced or skewed 1/8 to 5/16 inch deep grooves	Durable, high friction surfaces especially on wet pavements	Undesirable wheel whine noise
Exposed Aggregate	Exposed durable aggregate surface	Improved	Conflicting reports – highly regarded in Europe but results of trial projects in US have been mixed

5.5.3 Considerations

1. There is some debate on whether grinding should be performed on a new pavement and what the effect on the long-term durability of the surface will be. The advantages of grinding are the exceptionally smooth surfaces and reduced pavement-tire noise. A study should be considered to investigate the advantages and disadvantages of grinding versus longitudinal tinning. Some factors in the study should include cost, smoothness, surface drainage, pavement-tire noise, construction aspects, and surface durability.

5.6 CURING

5.6.1 Florida

1. Liquid membrane curing compound or burlap mat.
   i) Liquid membrane curing compound is placed at 1 gal/200 ft^2 for a period of 72 hours exclusive of any period the surface temperature drops below 50°F.
   ii) The weight and condition of the burlap mat is also specified.
2. Florida is the only State that tests all curing compound used prior to construction.
3. Weather restrictions relating to evaporation rate should be added to concrete placement requirements.

5.6.2 Other States

1. Use liquid membrane forming compounds (most common) and curing blankets.
2. Most specify a minimum application rate of 1 gal/ 150 to 200 ft^2 per coat of compound.
3. TX: 2 coats at a minimum rate of 1gal/180 ft^2; MI: 2 coats at 1 gal/ 225 ft^2 for tined surfaces and 1 coat at 1 gal/ 225 ft^2 for other surfaces.
4. ACPA recommends 1 gal/200 ft^2 for normal paving operations, 1 gal/150 ft^2 for fast-track concrete, and 1 gal/100 ft^2 for thin overlays.
5. Curing duration is typically 3 days, except for KS which specifies 4 days. Curing time is often extended to consider periods of unfavorable temperatures.

5.6.3 Considerations

1. Evaluate the effectiveness and benefits of the different curing methods. Curing compounds provide the most efficient means of curing given the speed of the construction operation and the need to use the paved surface. If the concrete is still warm when a burlap mat or plastic sheeting is removed and the ambient temperature is low, thermal shock can occur, which may cause cracking.
2. Clarify the curing requirements for special circumstances (e.g., rain, cold weather, etc.). For instance, plastic sheeting may be appropriate for small projects and pervious concrete. Thermal blankets may be required for lower temperatures. Evaporation retarders may be required during dry, windy days.
3. Evaluate the need to extend curing time for concrete with fly-ash or other pozzolanic substitutions.

5.7 JOINT SAWING

5.7.1 Transverse Contraction Joints

Florida

1. Maximum spacing is 15 feet.
2. Initial joint cut is same as for other States. Final joint width is typically 1/4 inch.
3. Joints sawed no later than 12 hours after placement.
4. Final joint cutting to take place just before sealing.
5. Early entry saws are not prohibited but are not mentioned in the specification.
6. Uncontrolled cracks repaired at no expense to the Department by removing and replacing full width.

Other States

1. Typical maximum transverse joint spacing is 15 feet.
2. Initial saw depths are typically 1/8 inch wide by 1/4 to 1/3 the slab depth.
3. Most States do not specify a specific time to saw cut joints other than requiring the concrete has to have hardened sufficiently to permit sawing without excess raveling.

Considerations

1. Continue existing practice but look for improvements (e.g., nondestructive methods to determine dowel bar location and orientation).
2. Smaller joint width to reduce noise and enhance smoothness.

5.7.2 Transverse Construction Joints

Florida

1. Form transverse construction joint bulkheads and install dowel bars in construction joint.
2. Construct at the end of all pours and at locations where paving has stopped for 30 minutes or longer.
3. Do not place within 10 feet of any other transverse joint or within 10 feet of a section end.
4. Saw or form joints in same manner as contraction joints.

Other States

1. Fresh concrete to replace the concrete in the spreader for the last few meters to ensure that only production quality concrete is used.
2. Most States specify that the construction joint should be placed at a planned contraction joint or at 15 feet from the last contraction joint.

5.7.3 Transverse Expansion Joints

Florida

1. Limited to bridge approaches and where two pavements intersect at an angle.
2. Uses preformed joint filler and provides dowels.
3. Form and protect joint with bulkhead and metal strips at bottom and side edges.

Other States

1. Expansion joints are typically limited to bridge approaches.
2. Most States do not have specifications specific to expansion joints.

Considerations

1. Limited specification/construction information was found on expansion joints since they are limited in application. The FL practice appears to be as complete as any other state studied.
2. Use of isolation expansion joint around street manholes to prevent cracking.

5.7.4 Longitudinal Lane-Tie Joint

Florida

1. Complete sawing as soon as possible but within 72 hours.
2. May insert or secure tie-bars to subgrade.
3. Initial cut 1/8 inch wide and at least 1/3 the slab depth. Final joint width is typically 1/4 inch.

Other States

1. Saw longitudinal joints within 36 hours.
2. Align longitudinal joint with string line along centerline.
3. Some States do not expand the joint width from 1/8 inch and do not seal. Since these joints are not meant to deal with expansion there is no need to keep out incompressible material or transfer loads. A properly designed graded base should drain any water infiltration.

Considerations

1. Use string line to guide longitudinal joint saw cuts. Florida does not specify an alignment tolerance for longitudinal saw cuts.
2. Consider a shorter time period for cutting joints. They are typically cut later than transverse joints and they are all required to be sealed within 72 hours.

5.8 JOINT SEALING

5.8.1 Florida

1. All joints should be sealed.
2. Complete sealing within 72 hours.

3. Temperature should be greater than 50°F for hot-poured sealant and greater than 40°F for silicone sealant.

5.8.2 Other States

1. Traffic not allowed on joints prior to sealing.
2. Preformed material should not be spliced when used for transverse joints.
3. Refill hot-poured sealant if level drops 3 mm below surface.
4. Some States do not seal all joints.

5.8.3 Consideration(s)

1. Refill hot-poured sealant if level drops significantly.
2. A shorter time period before cutting and sealing joints.

5.9 SMOOTHNESS

TABLE 6 Smoothness Specifications

State	Index	Blanking Band, inch	Incentive/Disincentive	Localized Roughness Provision	Testing Device*
FL	PI	0.2	Incentive/Must Correct	Yes	P
TX	IRI	N/A	Both	Yes	HSP or LWP
MN	PI	0.2	Both	Yes	P or LWP
KS	PI	0.0	Both	Yes	P
MI	IRI	N/A	Must Correct	Yes	HSP
MO	IRI	N/A	Incentive/Must Correct	Yes	HSP
WI	IRI	N/A	Both	Yes	HSP
IN	PI	0	Must Correct	Yes	P

***P= Profilograph; HSP= High Speed Profiler; LWP= Light Weight Profiler; SE= Straight Edge**

5.9.1 Consideration(s)

1. FDOT certified inertial profiler and operator for smoothness quality control and acceptance by contractor.
2. IRI and localized roughness or smoothness acceptance.

5.10 DEFECTIVE PAVEMENT/ACCEPTANCE

5.10.1 Florida

1. Criteria for Thickness (Incentive & Disincentive), Strength (Disincentive only), and Smoothness (Incentive only).

5.10.2 Others

1. Deficient Pavement/Acceptance criteria (Table 7).
2. Most states have acceptance criteria for thickness, strength and smoothness.
3. MI has criteria for reinforcing steel, cover depth and deviation from design range.
4. KS has acceptance criteria for spalling and cracking.
5. WI has deficiency threshold criteria for cracking.

TABLE 7 Acceptance and Incentives/Disincentives Criteria

State	Criteria for Deficient Pavement		Incentives and/or Disincentives	Corrective action
FL	Thickness	Yes	Both	Remove/Replace if the deficiency is enough to seriously impair the anticipated service life
	Strength	Yes	Disincentives	
	Smoothness	Yes	Incentives	Remove/replace if any area, after grinding, still shows a deviation in excess of the allowable tolerance
KS	Thickness	Yes	Both	Based on Engineer's judgment
	Strength	Yes	Both	
	Smoothness	Yes	Both	Contractor's decision to elect remove/replace. DOT will pay for smoothness based on the PI after replacement
	Defective Slab	Yes	Neither	Contractor's responsibility to repair or remove/replace slabs with spalling, longitudinal and transverse cracking
MI	Thickness	Yes	Disincentives	Removal required if the thickness deficiency exceeds 1.0 inch
	Strength	Yes	Both	Contractor can remove/replace or get pay adjusted
	Smoothness	Yes	Neither	Corrective action required if IRI > 125
	Steel location	Yes	Disincentives	Remove/Replace if depth of Steel Deviation (from pavement surface and from design range) is beyond limiting criteria.
MN	Thickness	Yes	Disincentives	Remove/replace or get pay adjustments
	Strength	No	Neither	
	Smoothness	Yes	Both	Remove/replace or diamond grinding required for 0.1-mile sections/subsections
MO	Thickness	Yes	Both	Remove/Replace if thickness deficiency exceeds 10 percent of plan thickness
	Strength	Yes	Both	Removal required if compressive strength is less than 3,500 psi
	Smoothness	Yes	Both	Diamond Grinding required for corrected areas (min. 20% deduction of contract price applied) or entire section of at least 0.1-mile long. Contractor has an option to remove/replace segments
TX	Thickness	Yes	Disincentives	Remove/Replace or leave in place without pay if the thickness deficiency is more than 0.75 inch but less than 1 inch . Remove/Replace if thickness deficiency is more than 1.0 inch
	Strength	No	Neither	
	Smoothness	Yes	Both	Corrective action (typically grinding) is required.
WI	Thickness	Yes	Disincentives	Remove/Replace if the thickness deficiency is more than 1.0 inch or Leave in Place with no pay
	Strength	No	Disincentives	Remove/Replace or Leave in Place and receive 50 % of the contract price unit
	Smoothness	Yes	Both	Remove/Replace if the departure from correct cross section or profile exceeds 1/2 inch in 10 feet
	Defective Slab	Yes	Disincentives	Repair cracked concrete as the engineer directs

IN	Thickness	Yes	Disincentives	Remove/Replace or Leave in place with reduced or no payment
	Strength		Disincentives	Remove/Replace or Leave in place with reduced or no payment
	Smoothness	Yes	Disincentives	Smoothness variance outside specified tolerance shall be corrected by grinding or by replacement. Pay factor applied depending on PI.

5.11 RECOMMENDED PRACTICES

5.11.1 Florida: Results from 2007 tour of PCC projects in Districts 2, 3, 5 and 7.

1. Cracking is minimized when slabs are <= 14 ft wide and <= 15 ft long.
2. Placing a longitudinal joint in the middle of ramps eliminates cracking in curves/super-elevations.
3. Ensure proper marking and maintenance of drainage weep holes.
4. Consider a smaller joint spacing to reduce noise and enhance smoothness.
5. Experienced contractor is critical to the project success, in terms of performance and aesthetics.
6. Localized grinding gives a marred finish to a pavement surface and may affect vehicle handling.
7. Use of isolation expansion joint around street manholes prevents cracking.
8. Use a sleeper slab at PCC/HMA pavement interface to prevent asphalt drop off and/or cracking.

5.11.2 Kansas and FHWA Recommendations (Better Roads, March 2003)

1. Have precise string lines.
   i) String lines have the greatest effect on pavement smoothness. Place them carefully, keep them safe, and use aircraft cable instead of rope; it can be tensioned to eliminate sag without breaking.
   ii) Conventional supports are placed 50 feet apart, but Kansas contractors place them 25 ft apart, which increases labor and material costs.
2. Build from the ground, up.
   i) Without a solid, stable, smooth foundation, it is not possible to get a smooth driving surface.
3. Watch paving speed and delivery rate.
   i) The paving train should move at a consistent speed without stops.

    ii) Having a constantly producing batch plant helps, and so does having adequate delivery vehicles. Also, delivery vehicles need to have unfettered movement to the paving area and back to the plant.

4. Control concrete head.
    i) Monitor the size of the head of concrete at the paver; it should be neither too high nor too low. The paver is supposed to finish the surface of the concrete, not act as a bulldozer.
    ii) Because fresh concrete is a plastic fluid mass, hydraulic forces can be set up in the concrete head that can cause the finished concrete to surge and swell, creating permanent defects. A spreader/placer in front of the paver can maximize production while optimizing smoothness.
5. Strive for mix consistency.
    i) The design should be proportioned for correct consolidation without excessive vibration, which can cause segregation and vibrator trails with accompanying rougher surface and lower strength concrete. Test samples often in order to track slump and air content.
6. Use minimal hand finishing.
    i) If quality controls and pavements are used, hand finishing should be needed only for surface sealing, edging, and checking with straightedges. Use restraint. Know the correct texture or tinning to reduce pavement noise (or whine) while keeping surfaces safe for drivers.
7. Use good equipment.
    i) Clean equipment in top working order is necessary.
    ii) Equipment is an investment, the benefits of which are realized in the field.
8. Motivate your workforce.

The workforce is the contractor's most important resource. Unique steps can be taken to motivate employees and create a sense of ownership and consistent self-improvement, including education in smoothness specifications, pride programs, and distribution of part of earned smoothness incentives back to employees as end-of-year bonus.

6 References

6.1 FL

Section 350 Cement Concrete Pavement

ftp://ftp.dot.state.fl.us/LTS/CO/Specifications/SpecBook/2010Book/350.pdf

Index 305 Concrete Pavement Joints

http://www.dot.state.fl.us/rddesign/rd/rtds/10/305.pdf

Rigid Pavement Design Manual

http://www.dot.state.fl.us/pavementmanagement/pcs/RigidPavementManualJanuary12009.pdf

Index 505 Embankment Utilization

http://www.dot.state.fl.us/rddesign/rd/rtds/10/505.pdf

Index 287 Concrete Pavement Sub drainage

http://www.dot.state.fl.us/rddesign/rd/rtds/10/287.pdf

Section 287 Asphalt Treated Permeable Base

ftp://ftp.dot.state.fl.us/LTS/CO/Specifications/SpecBook/2010Book/287.pdf

Section 288 Cement Treated Permeable Base

ftp://ftp.dot.state.fl.us/LTS/CO/Specifications/SpecBook/2010Book/288.pdf

6.2 KS

Section 154 Concrete Pavement Equipment

http://www.ksdot.org/burconsmain/specprov/2007/154.pdf

6.3 MI

Section 602 Concrete Pavement Construction

http://mdotwas1.mdot.state.mi.us/public/specbook/

Road Design Manual

http://mdotwas1.mdot.state.mi.us/public/design/englishroadmanual/

Standard Plan R-40-G Load Transfer Assemblies for Transverse Joints

http://mdotwas1.mdot.state.mi.us/public/design/englishstandardplans/index.htm

6.4 MN

Section 2301 Concrete Pavement

http://www.dot.state.mn.us/pre-letting/spec/2005/div-ii.pdf

Concrete Manual

http://www.dot.state.mn.us/materials/manuals/concrete/Chapter6.pdf

Pavement Design Manual

http://www.dot.state.mn.us/materials/pvmtdesign/docs/Chapter_5-3.pdf

Standard Sheet No. 5-297.221 Pavement Joints: Contraction and Expansion

http://dotapp7.dot.state.mn.us/edms/download?docId=914097

Standard Sheet No. 5-297.221 Pavement Joints: Longitudinal http://dotapp7.dot.state.mn.us/edms/download?docId=914098

6.5 MO

Section 502 Concrete Base and Pavement

http://www.modot.mo.gov/business/standards_and_specs/Sec0502.pdf

Missouri DOT Research Investigation 96-025 Diamond Grinding Newly Placed Pavement

http://www.igga.net/File/Diamond-Grinding-Newly-Placed-PCCP-_2005.pdf

6.6 TX

Pavement Design Guide

http://onlinemanuals.txdot.gov/txdotmanuals/pdm/index.htm

Section 360 Concrete Pavement

ftp://ftp.dot.state.tx.us/pub/txdot-info/des/specs/specbook.pdf

CPCD-94 Concrete Pavement Details Contraction Design

ftp://ftp.dot.state.tx.us/pub/txdot-info/cmd/cserve/standard/roadway/cpcd94.pdf

6.7 WI

Concrete Pavement Design

http://roadwaystandards.dot.wi.gov/standards/fdm/14-10.pdf

Section 415 Concrete Pavement Construction

http://roadwaystandards.dot.wi.gov/standards/stndspec/Sect415.pdf

Standard Detail Drawing 13C13-7 Urban Doweled Concrete Pavement

http://roadwaystandards.dot.wi.gov/standards/fdm/SDD/13c13-7.pdf

6.8 IN

Section 500 Standard Specifications

http://www.in.gov/dot/div/contracts/standards/book/sep09/5-2010.pdf

6.9 OTHER SOURCES

Integrated Materials and Construction Practices for Concrete Pavement: A State-of-the-Practice Manual

http://www.cptechcenter.org/publications/imcp/imcp_frontmatter.pdf

National Highway Specifications Home (FHWA)

http://fhwapap04.fhwa.dot.gov/nhswp/index.jsp

NCHRP 637 Guidelines for Dowel Alignment in Concrete Pavements

http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_637.pdf

FHWA Best Practices for Dowel Alignment 2007

http://www.fhwa.dot.gov/pavement/concrete/pubs/07021/07021.pdf

State Highway Agencies Smoothness Specifications

http://www.smoothpavements.com/