Design and Construction of Highway Pavement Joint Systems

Joint Placement and Spacing Considerations

Mark B. Snyder, Ph.D., P.E.
Engineering Consultant to the American Concrete Pavement Association
The Principal Factors of Concrete (Overlay) Pavement Design

- Geometrics
- Thickness
- Joint Systems
- Materials
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Most Often Influence Cost & Selection of Projects
The Principal Factors of Concrete (Overlay) Pavement Design

- Geometrics
- Thickness
- Joint Systems
- Materials

Most Often Influence Real-world Performance
## MnROAD Whitetopping Distress
(Mainline – 5 yrs service)

<table>
<thead>
<tr>
<th>Cell</th>
<th>% Cracked Panels</th>
<th>Crack Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>4”-4’x4’ (93)</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>3”-4’x4’ (94)</td>
<td>40</td>
<td>165</td>
</tr>
<tr>
<td>3”-5’x6’*(95)</td>
<td>8</td>
<td>17</td>
</tr>
<tr>
<td>6”-5’x6’ (96)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>6”-10’x12’(97U)</td>
<td>13</td>
<td>0</td>
</tr>
<tr>
<td>6”-10’x12’ (92D)</td>
<td>3</td>
<td>0</td>
</tr>
</tbody>
</table>

4’x4’ Panels - Corner Breaks due to Wheel Loadings
Source: Burnham (MnDOT)
Source: Burnham (MnDOT)
Longitudinal Joint Layout

2 ft x 2 ft

3 ft x 3 ft

4 ft x 4 ft

6 ft x 6 ft

Outer Shoulder

Traffic

12 ft
Conclusion: Good Jointing is a Key to Good Performance
Joint Spacing and Placement Considerations

PANEL LENGTH AND ASPECT RATIO
Effects of Panel Length: Shrinkage and Curl/Warp Stresses

Effect of Slab Length on Shrinkage Force

- Curling & warping is produced by the shrinkage force at the slab surface.
- Due to drying and thermal differential shrinkage on the surface of the concrete.
- The magnitude of this force is dependent on the length of the surface.
- Shorter slabs have less length, which means that shorter slabs have reduced curling

Effect of Slab Length on Curling/Warping

- All concrete slabs curl / warp so that approximately 1/4 of the slab length is lifted of the subgrade / subbase support
- By reducing slab length, the amount lifted, and the height of the lift is greatly reduced

Cantilever = 1/4 L

Length 12 to 15 ft., cantilever = 3 to 3.75 ft

Cantilever = 1/4 L

Length 6 ft., cantilever = 1.5 ft
Combined load and curl-warp stress for longer panels
Combined load and curl-warp stress for shorter panels
Effects of Joint Spacing on Slab Cracking

An MEPDG example for a specific pavement thickness and design conditions
Simple Formula for **JPCP**

**Maximum Panel Dimension (Joint Spacing)**

\[ L_{\text{max}}^* = T \times C_s \]

- \( L_{\text{max}} \) = Maximum distance between joints (in.)
- \( T \) = Slab thickness (in.)
- \( C_s \) = Support constant
  - = 24 for subgrades or unstabilized [granular] subbases
  - = 21 for ATB, CTB, lean concrete [econocrete], or existing concrete or asphalt;
  - = 12 to 15 for bonded concrete overlays on asphalt (BCOA)

*\( L_{\text{max}} \) should be capped at 15 ft for slabs less than 10 in. thick unless local history shows longer panels work (e.g., low CTE of aggregate, granular base, light traffic, etc.)

Keep aspect ratio (i.e., longer panel dimension/shorter panel dimension) \( \leq 1.5 \)
There’s an app for this ...

Maximum Joint Spacing Calculator

Description

For jointed plain (unreinforced) concrete pavement (JPCP), the maximum allowable joint spacing or slab length depends on variables such as slab thickness, concrete aggregate used, cement content, subgrade/subbase used, and climate. In most areas, the typical maximum transverse joint spacing for JPCP used in applications such as streets, roads, and highways is about 15 ft (4.5 m); a longer maximum transverse joint spacing may be used, however, based on local experience. Longitudinal joint spacing on two-lane and multilane concrete pavements typically is about 10 to 13 ft (3.0 to 4.2 m). This tool provides an estimate of the maximum allowable joint spacing based on the slab thickness and the subgrade/subbase used; two of the variables with the most prominent effect on joint spacing requirements. Slabs kept to dimensions shorter than those calculated by this tool will have curling and warping stresses within safe limits to ensure minimal risk of random cracking.

Concrete Pavement Structure Details

Concrete Pavement Thickness (in.): 8

Layer Immediately Below Concrete Surface Course:

- Subgrade
- Unstabilized (Granular) Subbase
- Stabilized Subbase
- Existing Asphalt Pavement
- Existing Concrete Pavement

Calculate

Joint Spacing Recommendation

Maximum Joint Spacing: 14

Note: The ratio of transverse joint spacing to longitudinal joint spacing should not exceed 1.5.
Criteria:

L/\ell < 4.5 for stabilized base
L/\ell < 5.0 for unstabilized base

where:
L = maximum panel dimension;
\ell = radius of relative stiffness (slab-foundation)

= \left(\frac{E_{C}h^{3}}{12k(1 – \mu^{2})}\right)^{0.25}

There’s an app for this, too!
apps.acpca.org
Other JPCP Joint Spacing Considerations

“Optimize” Joint Spacing
- Avoid midpanel cracking
- Limit number of joints (more cost effective)
- Limit movement of undoweled joints to 0.03 in

Use of “Randomized” Spacing (15.5’ effective or 12’, 13’, 18’, 19’)
- Reduce potential for resonant vehicle responses
- Max. jt spacing in “random” sequence should still be selected to avoid cracking (18-19 ft almost always exhibit cracking)
- Typically used with skewed joints (1:6, right ahead)
- Popular in late ‘70s and ‘80s, not common now (corner cracking problems, more complex joint repairs)
Influence of slab geometry on stresses

<table>
<thead>
<tr>
<th>4.5m x 1m</th>
<th>2.25 m x 1 m</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Diagram" /></td>
<td><img src="image2.png" alt="Diagram" /></td>
</tr>
<tr>
<td><img src="image3.png" alt="Diagram" /></td>
<td><img src="image4.png" alt="Diagram" /></td>
</tr>
</tbody>
</table>

**Principal stresses on the top of the slab, Red is tensile strength**

Maximun tensile stress = 24.65 Kg/cm²  
Maximun tensile stress = 5.22 Kg/cm²

**Deformation of the slab**
Slab sizes and thicknesses for same top stress (2.5MPa)

Thickness: 10 inches Concrete
Slabs 14.8 ft x 11.8

Thickness: 6.3 inches Concrete
Slabs 5.9 ft x 5.9 ft
Hundreds of lane-miles have been constructed in South and Central America over the last 10 years.
Summary of Best Overlay Jointing Practices

- Joint spacing (max = 18-to-24 x thickness)
  - For <3 in. overlay, use 3 by 3 ft
  - For 3 to 6 in. overlay, use 6 by 6 ft
  - For > 6 in. use full width and conventional spacing

- Adjust depth of saw cut for actual slab thickness
  - Full depth plus ½” for bonded over concrete
  - T/3 for unbonded, bonded on asphalt

- Dowel & tie bar use
  - Dowels not necessary for overlay thickness < 8 in.
  - For unbonded overlays > 4 in., may use tie bars at longitudinal joints
Joint Spacing “Best Practices” Summary

- Keep it Short!
- Keep it Uniform!
- Keep it Perpendicular!
- Keep it Simple!
- Keep it Practical!
Joint Layout and Design

FINAL THOUGHTS
How Many Joint Types?

- We have longitudinal and transverse construction, contraction and isolation joints – 6 total (5 if you don’t have longitudinal isolation joints).
- Does designer dictate construction joint location?
- *Does joint layout really discern between longitudinal and transverse contraction joint differences?*
- Location is the key – really only concerned with isolation and crack control – 2 total!!
Next up: Florida’s Standard Jointing Details

**Dowels (Length 18")**

<table>
<thead>
<tr>
<th>Pavement Thickness (&quot;P&quot;)</th>
<th>Diameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>6”–6½&quot;</td>
<td>⅜&quot;</td>
</tr>
<tr>
<td>7”–8½&quot;</td>
<td>⅜&quot;</td>
</tr>
<tr>
<td>9”–10½&quot;</td>
<td>1½&quot;</td>
</tr>
<tr>
<td>≥11”</td>
<td>⅝&quot;</td>
</tr>
</tbody>
</table>

**Dowel Bar Layout**

- Tied Longitudinal Joints
- Transverse Doweled Expansion Joint
- Transverse Doweled Contraction Joint
- Untied Keyed Joint

**Resources**
- acpa.org
- wikipave.org
- apps.acpa.org
- PavementDesigner.org
- resources.acpa.org
- ondemand.acpa.org
- webinars.acpa.org
- local.acpa.org