Design and Construction of Highway Pavement Joint Systems

Complex Joint Layouts: Roundabouts & DDI

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Technical Services Engineer
Why Concrete?

CONSIDERATIONS FOR INTERSECTIONS
Where are Concrete Pavements Historically Used?

Answers:

- High traffic areas
- Areas with lots of turning movements
- Situations where we need a “long-term fix”
- Situations where future maintenance must be kept to an absolute minimum
- Areas where future disruption to traffic must be kept to a minimum
- Economical over long-term – Life-Cycle Cost (LCC)
- Areas where safety is a priority – surface characteristics
Things to Consider for all Intersections

- Thickness
- Jointing
  - Spacing
  - Type
  - Layout
- Traffic management (phasing)
- Fast track mixtures
- Other considerations (i.e., reconstruction versus inlay, subgrade and subbase requirements, concrete materials, traffic detection systems, construction processes, etc.)
Pavement Thickness Design

- AASHTO
  - 1993 Pavement Design Guide
    - Most commonly used by state DOTs
  - Pavement ME Design (MEPDG)
    - Under calibration/implementation in many states

- Concrete Pavement Industry Method
  - PavementDesigner pavementdesigner.org (Coming Soon)

MUST CONSIDER CUMULATIVE TRAFFIC!!
**Thickness Impacts Jointing!**

Design may be based on AASHTO, PavementDesigner, etc.

<table>
<thead>
<tr>
<th>Class</th>
<th>ADT</th>
<th>ADTT</th>
<th>Thickness</th>
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<tbody>
<tr>
<td>Light residential</td>
<td>&lt; 200</td>
<td>2-4</td>
<td>4.0-5.0 in.</td>
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<tr>
<td>Residential</td>
<td>200-1,000</td>
<td>10-50</td>
<td>5.0-6.0 in.</td>
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<tr>
<td>Collector</td>
<td>1,000-8,000</td>
<td>50-500</td>
<td>5.5-8.0 in.</td>
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<tr>
<td>Business</td>
<td>11,000-17,000</td>
<td>400-700</td>
<td>6.0-8.0 in.</td>
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<tr>
<td>Industrial</td>
<td>2,000-4,000</td>
<td>300-800</td>
<td>6.5-9.5 in.</td>
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<tr>
<td>Arterial (minor)</td>
<td>4,000-15,000</td>
<td>300-600</td>
<td>6.5-9.5 in.</td>
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<tr>
<td>Arterial (major)</td>
<td>4,000-30,000</td>
<td>700-1,500</td>
<td>7.0-10.0 in.</td>
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Concrete Intersections: Thickness

Physical Area

Functional Area
# Concrete Intersections: Thickness

<table>
<thead>
<tr>
<th>Roadway 1</th>
<th>Roadway 2</th>
<th>Physical Area Thickness</th>
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<tbody>
<tr>
<td>Low ADTT (T1)</td>
<td>Low ADTT (T2)</td>
<td>T2</td>
</tr>
<tr>
<td>Low ADTT (T1)</td>
<td>High ADTT (T3)</td>
<td>T3</td>
</tr>
<tr>
<td>High ADTT (T3)</td>
<td>High ADTT (T3)</td>
<td>T3 + 0.5 to 1 in.</td>
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</table>

**T3 > T2 > T1**
Joint Spacing “Best Practices” Summary

- Keep it Short!
- Keep it Uniform!
- Keep it Perpendicular!
- Keep it Simple!
- Keep it Practical!
Joint Spacing and Placement Considerations

JOINT LAYOUT
Rules for Joint Layout

Things to Do

- Match existing joints or cracks – location AND type!
- Cut joints at the proper time and to the proper depth
- Place joints to meet in-pavement structures
- Remember maximum joint spacing
- Place isolation joints where needed
- **Understand that joint locations can be adjusted in the field!**
- Be Practical
Rules for Joint Layout

Things to Avoid:
- Slabs < 2 ft wide
- Slabs > 15 ft wide
- Angles > 60º (90º is best)
  - Use “dog-leg” joints through curve radius points
- Creating interior corners
- “Odd” shapes
  - Keep slabs nearly square or rectangular, when possible
Solving the Intersection Dilemma with the 10-Step Method of Jointing
Concrete Intersections: Jointing

The Ten-Step Method for Intersections

**Step 1:** Draw all pavement edge and back-of-curb lines to scale in the plan view.
Concrete Intersections: Jointing

The Ten-Step Method for Intersections

Step 2: Lightly draw circumference-return, taper-return, and crossroad-return lines as offsets of 1.5 – 3.0 ft
Concrete Intersections: Jointing

The Ten-Step Method for Intersections

**Step 3:** Draw all lane lines on the mainline roadway and crossroad. Do not extend through return lines (offsets).
Concrete Intersections: Jointing

The Ten-Step Method for Intersections

**Step 4:** Define mainline lanes for paving. Extend *only* these lane lines through return lines (offsets) to allow for slipform paving. Blockouts & doglegs will occur in the gutter pan at these locations.
Concrete Intersections: Jointing

The Ten-Step Method for Intersections

**Step 5:** Add transverse joints locations where a width change occurs in the pavement (begin & end of tapers, tangents, curves, curb returns, etc.) and extend these joints through the curb & gutter.
Concrete Intersections: Jointing

The Ten-Step Method for Intersections

**Step 6:** Add transverse joints between and beyond the joints defined in Step 5, but not to the center of the intersection. Attempt to keep the distance between joints less than $L_{\text{max}}$. 
Concrete Intersections: Jointing

The Ten-Step Method for Intersections

**Step 7:** Define the intersection box by extending the edges of pavement lines for the cross road and any turning lanes.
Concrete Intersections: Jointing

The Ten-Step Method for Intersections

**Step 8:** Check the distances between the "intersection box" and the surrounding joints.
The Ten-Step Method for Intersections

**Step 9:** If the distance is more than the maximum desirable joint spacing, add transverse joints at an equal spacing. Do not extend these joints through return lines.
Concrete Intersections: Jointing

The Ten-Step Method for Intersections

**Step 10:** Extend lines from center of curb return radii to corners of intersection box panels. Draw joints along these “diagonal” lines. Make adjustments to eliminate doglegs in pavement edges.
Concrete Intersections: Jointing

Details A, B, and C

A. Width change and dogleg in gutter near point of curvature

B. Width change and dogleg in gutter near start of a taper

C. Width change and dogleg in paving lane for hand-pours
What If I Have to Dead-end a Joint?

Saw transverse joint deeper and reinforce slab to prevent sympathy crack.

Optional core hole (or formed hole) to prevent sympathy cracking.
What If I Have to Dead-end a Joint?
What If I Have to Dead-end a Joint?
Concrete Intersections: Jointing

Adjust joints that are within 5 ft of a utility!

- Blockout with perimeter isolation joint
- Optional reinforcement
- Adjust joint to meet inlet
- Adjust joint
- Telescoping manhole no boxout
Concrete Intersections: Jointing

Box Out Fixture Details

Square Manhole Boxout
- Reinforcing bars recommended to hold cracks tight
- Isolation joint

Diagonal Manhole Boxout
- Isolation joint

Circular Manhole Boxout
- Isolation joint

Square Boxout with Fillets
- Isolation joint

Manhole (No Boxout)
- Isolation joint/bond breaker around perimeter

Telescoping Manhole
- No boxout or isolation joint necessary

Round Inlet Boxout
- Isolation joint
If You DO Box Out Properly...
If You DON’T Box Out Properly...
Where there’s a will, there’s a way…

… visibly old, but no cracks!
Good Practice...
It works for other areas too.
It works for other areas too.
Where to Place Isolation Joints

Where do you put isolation joints?

- 90° T
- 90° T/Apron
- Divided highway (non-concrete median)
- Skewed T
- 90° Skew
- Skew/Skew
Contractor’s Involvement is Crucial!

NOTICE: NO EXPANSION JOINTS!
Joint Summary

<table>
<thead>
<tr>
<th>Transverse Contraction Joints</th>
<th>Transverse Construction Joints</th>
<th>Transverse Isolation Jts</th>
<th>Longitudinal Construction Joints</th>
<th>Longitudinal Contraction Joints</th>
<th>Isolation Jts @ Drainage</th>
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<td>45</td>
<td>70</td>
<td>300</td>
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<tr>
<td>1@60= 60</td>
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<td>195</td>
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<td>10</td>
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<tr>
<td>4@65= 260</td>
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<td></td>
<td>300</td>
<td></td>
<td>10</td>
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<td>4@55= 220</td>
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<td></td>
<td>190</td>
<td></td>
<td>10</td>
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<tr>
<td>3@45= 135</td>
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<td>10</td>
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<tr>
<td>4@45= 180</td>
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<td>1,063</td>
<td>48</td>
<td>90</td>
<td>1,000</td>
<td>300</td>
<td>60</td>
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...This is the basis of the bill of materials.
Design and Jointing of Concrete Roundabouts

ROUNDABOUTS
Why a Roundabout?

According to FHWA:

- Up to 90% reduction in fatalities
- 76% reduction in injury crashes
- 30-40% reduction in pedestrian crashes
- 75% fewer conflict points than 4-way intersections
- 30-50% increase in traffic capacity
- No signal equipment to install/maintain
- No left-turn lane and reduced need for storage lanes
JOINTING ROUNDABOUTS
Layout Joints as Normal Intersection

Good for small roundabouts or traffic circles?
Jointing

- Decide on joint layout philosophy
  - Like normal intersection
  - Isolate circle from legs
  - Pave-through, isolate two legs
  - Other philosophy, based on experience

- Follow 6-step method

- Joints in circular portion radiate from center
- Joints in legs are normal (perpendicular)
Proper Jointing of Roundabouts

Isolated circle

Pave-through
Concrete Roundabout Design And Construction

6-STEP METHOD FOR JOINTING ROUNDABOUTS
Jointing a Roundabout

Step 1: Draw all pavement edges and back-of-curb lines in plan view.
Step 2: Draw all lane lines on the legs and in the circular portion, accounting for roundabout type.
Jointing a Roundabout

Step 3: Add “transverse” joints in the circle, being mindful of the maximum joint spacing.
Jointing a Roundabout

Step 4: On the legs, add transverse joints where width changes occur.
Step 5: Add transverse joints between those added in Step 4, minding the maximum joint spacing.
Doglegs

A. Width change and dogleg in gutter near point of curvature

B. Width change and dogleg in gutter near start of a taper

C. Width change and dogleg in paving lane for hand-pours
Layout Joints as Normal

Good for small roundabouts or traffic circles?
Jointing a Roundabout

**Step 5:** Add transverse joints between those added in Step 4, minding the maximum joint spacing.
Jointing a Roundabout

Step 6: Make adjustments for in-pavement objects, fixtures, and to eliminate odd shaped slabs.
What If I Have to Dead-end a Joint?

Notes:
1. Maximum joint spacing = 15 feet
2. Expansion joint filler per standard specification 415
3. Truck apron transverse joints should not be doweled or tied

Constructions:
- Concrete curb and gutter (typ.) tied to pavement
- Back of curb (typ.)
- Flange of curb (typ.)
- Concrete curb tied to circulatory roadway not tied to truck apron
- Concrete curb tied to truck apron
What If I Have to Dead-end a Joint?
Properly Jointed Roundabout
Another Kansas Example...
More Information?

- “Concrete Roundabouts: Rigid Pavement Well-Suited to Increasingly Popular Intersection Type,” R&T Update #6.03, ACPA, June 2005.
- Various agency standards…KS, WI, IA, OH, etc…
JOINTING DIVERGING DIAMOND INTERCHANGES
Diverging Diamond Interchanges
Navigating a DDI

- crossover approach
- crossover intersection
- crossover storage area
- crossover departure
- ramp islands
- center median
- off-ramp
- on-ramp
- auxiliary lane
- eyebrow
DDI – Reduced Conflict Points

Diamond interchange

DDI interchange

SPUI interchange

Conflict Points

<table>
<thead>
<tr>
<th>Type</th>
<th>Diverging</th>
<th>Merging</th>
<th>Crossing</th>
<th>Total</th>
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</thead>
<tbody>
<tr>
<td>Diverging</td>
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<td></td>
<td>10</td>
<td>18</td>
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<tr>
<td>Merging</td>
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<td></td>
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<td>16</td>
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<tr>
<td>Crossing</td>
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<tr>
<td>Total</td>
<td>26</td>
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DDI vs Conventional Comparison

SR-201 & Bangerter (2009)

SR-201 & Bangerter (2012) - DDI retrofit
The Challenge - Jointing
Jointing a DDI

Step 1: Draw all pavement edges and back-of-curb lines in plan view.
Jointing a DDI

Step 2: Divide the interchange into four quadrants.
Jointing a DDI

Step 3: Place a joint in each quadrant when the pavement width changes as you work your way out from the center. Make sure the joint is perpendicular to the direction of travel.
Jointing a DDI

Step 4: Lightly draw the circumference-return and taper-return line(s) outside of the central portion defined in Step 3.
Jointing a DDI

Step 5: Lightly draw cross road return lines on each side of the central bisecting joint.
Step 6: Define paving lanes on the mainline approaches. Do not cross the cross road return lines defined in Step 5.
Jointing a DDI

Step 7: Place transverse joints on the mainline approaches.
Jointing a DDI

Step 8: Lightly draw cross road return lines for each of the on/off ramps.
Jointing a DDI

Step 9: Add longitudinal joints to the on/off ramps.
Jointing a DDI

Step 10: Add transverse joints to the on/off ramps.
Jointing a DDI

Step 11: Address doglegs and odd shaped panels as possible.
Jointing a DDI
Jointing a DDI – An Alternate Method
Jointing a DDI – An Alternate Method
Jointing a DDI
Jointing a DDI
Jointing a DDI
Jointing a DDI

- load transfer dowell joint
- tie bar joint
- other typical joints
Next up:

Interactive Joint Layout Workshop