Why Joint Concrete Pavements?

- Control natural cracking caused by internal slab stresses.

  - Stresses from:
    - Shrinkage from cement hydration
    - Temperature gradient (curling)
    - Moisture loss (drying shrinkage/warping)
    - Restraint to contraction (subbase friction/bond)
Why Joint Concrete Pavements?

- Control natural transverse & longitudinal cracking from internal slab stresses.

40-80 ft \rightarrow 15-20 ft
Types of Joints

Joint types:
- Contraction
- Construction
- Isolation (and, if necessary, expansion)

Each can occur in either the transverse or longitudinal directions.

Also specialty joints (e.g., transitions, terminal joints in continuously reinforced, etc.).
Types of Joints

Transverse Contraction:

Undoweled – Transverse (Type A-1)

Smooth dowel

Doweled – Transverse (Type A-2)

1 in. (25 mm) max.

T/4 – T/3

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Types of Joints

Longitudinal Contraction:

- Untied – Longitudinal (Type A-3)
  - Deformed tie bar
  - $1/8 - 3/8 \text{ in.} = (3 - 9 \text{ mm})$ typ.

- Tied – Longitudinal (Type A-4)
  - $T/2$
  - $T/3$

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Types of Joints

Transverse Construction:

Doweled butt – Transverse (Type B-1)

Deformed tie bar

Tied – Transverse (Type C-1)
(Keyway optional)

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Types of Joints

Longitudinal Construction:

1/8 – 3/8 in. (3 – 9 mm) typ. Tied butt – Longitudinal (Type B-2)

Deformed tie bar

T/2

T

Deformed tie bar

Keyed – Longitudinal (Type C-2)
(Deformed tie bar optional)
Types of Joints

Isolation:

Thickened edge – Transverse (Type D-1)

Doweled – Transverse (Type D-2)

Sleeper slab – Transverse (Type D-3)

Undoweled – Longitudinal (Type D-4)
**Formula for Maximum Joint Spacing**

\[ ML = T \times C_s \]

- \( ML \) = Maximum length between joints (in.)
- \( T \) = Slab thickness (in.)
- \( C_s \) = Support constant

- Use 24 for subgrades or unstabilized [granular] subbases;
- Use 21 for stabilized subbases (ATB, CTB, lean concrete) or existing concrete or asphalt pavement;
- Use 12 to 15 for thin bonded overlays on asphalt
Effects of Joint Spacing

![Graph showing the effects of joint spacing on percent slab cracking with traffic, million ESALs.]

- 20 ft
- 18 ft
- 17 ft
- 15 ft

Traffic, million ESALs

Percent slab cracking

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Joint Spacing Recommendations

For Streets, Roads, and Highways:

- Use $ML = T \times C_s$
- Keep ratio of transverse to longitudinal spacing at less than 1.5
- Keep maximum spacing of transverse joints to 15 ft for plain concrete unless local history shows longer panels work (e.g., low CTE aggregate)
Examples of Locations
Examples of Locations
Adjust to Meet Utilities!

- Blockout with perimeter isolation joint
- Optional reinforcement
- Adjust joint to meet inlet
- Adjust joint
- Telescoping manhole no boxout
Proper Boxouts

- **Square Manhole Boxout**: Reinforcing bars recommended to hold cracks tight. Isolation joint.
- **Diagonal Manhole Boxout**: Isolation joint.
- **Circular Manhole Boxout**: Isolation joint.
- **Square Inlet (no 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...
Concrete Pavement Joint Construction

TIMING & DEPTH
Crack Control Window

- Too Early: Raveling
- Sawing Window
- Too Late: Cracking

Internal Stress Equals Concrete Strength

Minimum Strength to Avert Excessive Saw Cut Raveling

Concrete Strength

Internal Stress

Time
IMPORTANCE OF CURING!

![Graph showing the importance of curing in concrete]

- Longer Sawing Window
- Concrete Strength
- Internal Stress
- Time

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Levels of Raveling

Unacceptable:

Moderate: www.hiperpav.com

None:
How to Test the Window...

ASTM C Now = “Alright, Start To Make Cut Now”
Not Just Timing...DEPTH!
Joint Depth Recommendations

- **Transverse**
  - T/4 on unstabilized
  - T/3 on stabilized

- **Longitudinal**
  - T/3

- Timing is a factor

[Diagrams showing joint depth recommendations for transverse and longitudinal directions.]
Concrete Pavement  Joint Construction

CONSTRUCTION
Embedded Steel – Pre-Placed
Embedded Steel – Inserter Placed
Location Identification
Joint Formation/Sawing
Common Types of Pavement Saws

Walk-Behind ►

Span Saw ▼

Early Entry ▼
Proper Location, Time & Depth = Joint Activated Over Dowel Bars
Dowel Drilling
Concrete Pavement Joint Construction

TROUBLESHOOTING
Concrete Pavement Joint Construction

STEEL OPTIMIZATION
WHY?

- **Dowel Bars:**
  - Never “designed”; typically selected based on thickness – what if pavement always fails by fatigue and not erosion?
  - Proven dowel bar retrofit uses 50% of the steel of standards.
  - “Non-standard” specs drive up costs.

- **Tie Bars:**
  - Again, never “designed” but requirements must change based on subgrade/subbase, climate, etc.
  - Subgrade drag theory does not adequately define relationships.

Research focusing on optimizing and “greening” design!
Emerging Dowel Geometries
### Potential for Steel Savings

<table>
<thead>
<tr>
<th>Dimensions (in.)</th>
<th>Spacing (in.)</th>
<th>Dowels per 15 ft Joint</th>
<th>Total Steel per Joint (in³)</th>
<th>Steel Reduction per Joint</th>
</tr>
</thead>
<tbody>
<tr>
<td>Round 1¼ x 18</td>
<td>12</td>
<td>15</td>
<td>330</td>
<td>-</td>
</tr>
<tr>
<td>Square 1¼ x 18</td>
<td>14</td>
<td>13</td>
<td>365</td>
<td>-10%</td>
</tr>
<tr>
<td>Rectangle ¾ x 2½ x 12</td>
<td>18</td>
<td>10</td>
<td>225</td>
<td>32%</td>
</tr>
<tr>
<td>Diamond ¾ x 4½ x 4½</td>
<td>20</td>
<td>9</td>
<td>135</td>
<td>59%</td>
</tr>
<tr>
<td>Tapered ¾ x 1.67 to 3.33 x 12</td>
<td>18</td>
<td>10</td>
<td>150</td>
<td>55%</td>
</tr>
</tbody>
</table>

Strategic placement of steel at the joint + Potential for greater dowel spacing = Less steel per joint

Table after ACI 360R-06 and 302.1R-04.
FREE software that predicts pavement behaviors based on different round and elliptical dowel bar spacings and configurations.

Results can help designers significantly decrease embedded steel content (and costs) without compromising performance!

Program based on finite element analyses.

WWW.PAVEMENT.COM/DOWELCAD
Research report is almost completed.

**Will provide a practical design:** Design considers subbase type, number of lanes/shoulders, concrete material properties, climate (location and placement time), concrete thickness, steel yield, etc.
The following sources were used in the development of this Webinar:
- IS006P, Intersection Joint Layout
- IS061P, Design and Construction of Joints for Concrete Streets
- EB237P, Concrete Pavement Field Reference: Prepaving
- TB019P, Concrete Intersections – A Guide to Design and Construction
- TB010P, Design and Construction of Joints for Concrete Highways
- TB012P, Joint and Crack Sealing and Repair for Concrete Pavements
- TB016P, Early Age Cracking of Concrete Pavements: Causes and Repairs

Visit the ACPA Bookstore at [www.pavement.com](http://www.pavement.com)
FHWA References

Some great pertinent (and FREE) FHWA resources available here http://www.fhwa.dot.gov/pavement/pub_listing.cfm?areas=Concrete:
- FHWA-IF-03-003, Pavement Preservation Checklist #06 Joint Sealing Portland Cement Concrete Pavements
- FHWA-IF-02-052, High Performance Concrete Pavements: Alternative Dowel Bars for Load Transfer in Jointed Concrete

... and don’t forget HIPERPAV here http://www.hiperpav.com/!
Thank You!!!

Please contact Michael Ayers or Robert Rodden with questions or comments:

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