Concrete Pavement Intersections

Presented By:
National Ready Mixed Concrete Association
Your Instructor Today...

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  – 34 Years in Practice
  – Civil Site Design – Airfield Emphasis
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More information at paveahead.com/experts/
About the Course

• **Learning Objectives:**
  – Understand the benefits of concrete intersections
  – Identify the special pavement design considerations for intersections
  – Learn the importance of properly jointing different intersection types including roundabouts
  – Recognize how decorative concrete can enhance safety and improve streetscapes at intersections
NRMCA Disclaimer

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National Ready Mixed Concrete Association

- National Trade Association – Established in 1930
- HQ in Alexandria, VA
- 400+ Member Companies
- NRMCA Represents ~75% of North American Ready Mixed Production
- Mission - Serve Industry and Partners Through:
  - Compliance and Operations
  - Engineering
  - Government Affairs
  - Local Paving: Pave Ahead™ Initiative
  - Structures and Sustainability: Build With Strength™ Initiative

Interested in becoming a member?
Visit: www.nrmca.org/membership/
The National Ready Mixed Concrete Association promotes the use of concrete products for pavement due to their safety, resilience, and long-term value.
Local Paving: Market Areas

- Parking Lots
- Streets
- Roller Compacted Concrete
- Conventional Concrete
- Pervious Concrete
- Concrete Overlays
- Full Depth Reclamation
Local Paving: Market Areas

- Parking Lots
- Streets
- Full Depth Reclamation
- Concrete Overlays
- Roller Compacted Concrete
- Conventional Concrete
- Pervious Concrete
Other Reasons

• My client wants asphalt pavements

• Asphalt pavements are cheaper

• Concrete pavements can’t handle freezing temps

• I can’t wait 28 days to open the pavement to traffic

• We just don’t do that up here
Source – Minnesota Concrete Association
Route 20 Westbound - Charlton, MA
Concrete Intersections

Why The Need?
Common Problems at Intersections...
Ideal for Concrete!

Concrete…

– is **Durable**
– is **Functional**
– is **Sustainable**
– has a **Long Life**
– has **Low Maintenance**
– is **Cost Effective**
– **Saves $$$$** for other repairs, maintenance, and other projects
CONCRETE PAVING Technology

Concrete Intersections
A Guide for Design and Construction

Introduction
Traffic can be a major annoyance for many people, and traffic intersections are some of the worst culprits. Not only do they cause delays and frustration, but they also present a significant safety hazard. This guide is designed to help engineers and architects design safe and efficient intersections that meet the needs of both drivers and pedestrians.

Intersection Joint Layout

Designing and constructing effective intersection joint designs is crucial for ensuring long-term performance and durability. This section provides guidelines for selecting and configuring joint types to accommodate various traffic and environmental conditions.

Concrete Roundabouts

Rigid Pavement Well-Suited for Increasingly Popular Intersection Type

In recent years, roundabouts have become increasingly popular as an alternative to traditional intersection designs. This section explores the benefits of using concrete roundabouts and provides guidance on their design and implementation.

References for Course

For more information, please visit the following resources:
1. American Concrete Pavement Association
2. National Association of Concrete Countertop Contractors
3. American Society of Civil Engineers
4. American Concrete Institute

Design

The three primary factors for any intersection are geometry, drainage, and sustainability. These factors must be considered during the design process to ensure the safety and functionality of the intersection.
Intersections and Roundabouts
What Kind of Concrete Pavement is Recommended?
Jointed – Unreinforced Pavement

Plan

Profile
Define the Traffic Streams Through the Intersection
Intersection: Physical Area

Intersection: Functional Area

North Pines Road and East Broadway Ave
Spokane Valley, WA
Concrete Intersections: Thickness

<table>
<thead>
<tr>
<th>Roadway 1</th>
<th>Roadway 2</th>
<th>Physical Area Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low AADT (T1)</td>
<td>Medium AADT (T2)</td>
<td>T2</td>
</tr>
<tr>
<td>Low ADTT (T1)</td>
<td>High AADT (T3)</td>
<td>T3</td>
</tr>
<tr>
<td>High AADT (T3)</td>
<td>High AADT (T3)</td>
<td>T3 + 0.5 to 1.0 in.</td>
</tr>
</tbody>
</table>

Note: T3 > T2 > T1

Source: ACPA
Concrete Intersections

When is the Best Time?
Utilizing Concrete For Intersections

New Construction

Reconstruction

Overlay / Inlay
### 40 Year Annualized Cost

<table>
<thead>
<tr>
<th>SR</th>
<th>Intersection</th>
<th>Concrete</th>
<th>AC with 4 yr Inlay</th>
<th>AC with 6 year Inlay</th>
<th>AC with 8 year Inlay</th>
</tr>
</thead>
<tbody>
<tr>
<td>27</td>
<td>Sprague Ave.</td>
<td>$33,000</td>
<td>$46,800</td>
<td>$39,500</td>
<td>$35,800</td>
</tr>
<tr>
<td>90</td>
<td>Thierman St.</td>
<td>$54,300</td>
<td>$66,400</td>
<td>$57,600</td>
<td>$53,100</td>
</tr>
<tr>
<td>2</td>
<td>Francis Ave.</td>
<td>$73,500</td>
<td>$100,900</td>
<td>$87,000</td>
<td>$79,900</td>
</tr>
<tr>
<td>291</td>
<td>Maple &amp; Ash St.</td>
<td>$33,900</td>
<td>$50,800</td>
<td>$42,100</td>
<td>$37,600</td>
</tr>
<tr>
<td>27</td>
<td>Broadway Ave.</td>
<td>$36,100</td>
<td>$51,000</td>
<td>$42,600</td>
<td>$38,300</td>
</tr>
<tr>
<td>395</td>
<td>19th Ave.</td>
<td>$29,700</td>
<td>$45,800</td>
<td>$37,800</td>
<td>$33,700</td>
</tr>
<tr>
<td>2</td>
<td>Third Ave.</td>
<td>$15,200</td>
<td>$18,700</td>
<td>$16,500</td>
<td>$15,400</td>
</tr>
</tbody>
</table>
Concrete Intersections - Considerations

- For existing pavement: Complete reconstruction or overlay/inlay?
- Concrete intersection construction limits
- Thickness Design
- Subgrade and subbase requirements
- Jointing details
- Pavement profiles
- Concrete materials (early opening strength for fast-track paving?)
- Concrete to asphalt transitions
- Coordination with local businesses
- Incorporating decorative elements
Courtney Park and Kennedy Road
Mississauga, Ontario
Concrete Intersections - Considerations

- For existing pavement: Complete reconstruction or overlay/inlay?
- **Concrete intersection construction limits**
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Concrete Intersections

Pre-Design Information Gathering
What Do We Know?*

- Pavement Condition Evaluation
- Pavement Materials Analysis (Destructive/Non-Destructive Testing)
- Existing Pavement Structural Layers (cores, borings, etc.)
- Subgrade Soils (borings, DCP, etc.)
- Expected Future Traffic and/or Use (Service Life)
- Roughness (Smoothness)
- Drainage Conditions
- Grade & Elevation Restrictions

*Typically requires hiring knowledgeable consulting engineer.
Pavement Condition Evaluation

- **Identify Types of Distress**
  - Fatigue (Alligator) Cracking
  - Rutting
  - Transverse or Longitudinal Cracking
  - Etc.

- **Identify Severity of Distress**
  - Low, Medium, High

- **Identify Quantity of Each Type/Severity**
  - ft², in., ft, etc.
Destructive Testing Options

- Coring
- Trenching
- Dynamic Cone Penetrometer (DCP)
• Layer confirmation
• Layer thicknesses
  – Variability
  – Minimum requirements for thin overlays
• Subsurface conditions
  – Stripping
  – Delamination
• Samples for laboratory testing
  – Material properties
Pavement Structural Capacity

- Falling Weight Deflectometer (FWD)
Pavement Structural Capacity

Deflection vs. Station

Max Deflection, D0 (mils)

Station
Analysis of Evaluation Data

• Combine Information From:
  – Visual Distress Survey
  – FWD
  – Cores, Soils, etc.
  – Drainage Survey and Grade Restrictions

• Determine Structural Adequacy of Existing Pavement

• Make Decision: Reconstruct, or Concrete Overlay?
Concrete Intersections

Pavement Thickness Design Methods
Primary Information Needed For Thickness Design

- Traffic Information
- Underlying Support Condition
- Concrete Strength
Subgrade Soil Characterization
Suitability of Subgrade Soils

- Classification (Gradation, Atterberg Limits, etc.)
- Depth to Bedrock
- Depth to Water Table
- Potential for Compaction
- Presence of Weak or Soft Layers or Organics
- Susceptibility to Frost Action or Excessive Swell
- Soil Strength Characteristics
  - Modulus of Subgrade Reaction (k value)
  - Easily related to CBR
  - CBR usually cheaper and easier to run
  - Soil strength more important for flexible pavements
California Bearing Ratio (CBR)

- Load a piston at a constant rate (0.05 in/min)
- Record Load every 0.1 in penetration
- Total penetration not to exceed 0.5 in.
- Draw Load-Penetration Curve.
- Determine CBR from Curve.
Concrete Strength

- Design = Modulus of Rupture (MOR)
  - Sometimes referred to as Flexural Strength
- Construction = Compressive Strength ($f'c$)
- $\text{MOR} = 8 \text{ to } 10 \times \sqrt{f'c}$
  - $\text{MOR} \sim f'c$
    - 500 psi $\sim$ 3,500 psi
    - 550 psi $\sim$ 4,000 psi
    - 600 psi $\sim$ 4,500 psi
    - 650 psi $\sim$ 5,000 psi
Source of Much of What We Know About Pavement Design

- AASHO Road Test (1958-1960)
- Ottawa, Illinois - 1.1 Mil Reps
- Wholly empirical
- 368 concrete and 468 asphalt sections
- Focus was *highway pavement*
Test Sections or Guessed Sections

Necessary Thickness was Guessed!

**TYPICAL SECTIONS**

**ASPHALT**

- Surface
- Base
- Subbase

**CONCRETE**

- Concrete
- Subbase

**Subgrade = Clay Soil**

Source: Ferrebee ACPA
1986-93 JPCP AASHTO 93 Equation

\[ \log(ESAL) = Z_R * s_o + 7.35 * \log(D+1) - 0.06 + \left[ \log \left( \frac{\Delta PSI}{4.5 - 1.5} \right) \right] \]

\[ \left( \frac{1}{1 + \frac{1.624 \times 10^7}{(D+1)^{8.46}}} \right) \]

Standard Normal Deviate
Overall Standard Deviation
**Thickness**
Change in Serviceability

\[ \pm (4.22 - 0.32 * p_t) * \log \]

Terminal Serviceability
Traffic

\[ S_c' * C_d * (D^{0.75} - 1.132) \]

Modulus of Rupture
Drainage Coefficient

\[ 215.63 * J * \left[ D^{0.75} - \frac{18.42}{(E_c / k)^{0.25}} \right] \]

Load Transfer
Modulus of Elasticity
Modulus of Subgrade Reaction

WHAT DO DESIGNERS FOCUS ON?

Source: ACPA
New Construction or Reconstruction: Pavement Thickness Design Software (JPCP)

Inputs:
- Design Life
- Traffic
- Soil Strength
- Concrete Strength
- Base Properties (if used)
- Reliability (Factor of Safety)

Outputs:
- Concrete Thickness
- Joint Spacing
- Doweling
Typical Design Inputs: Concrete Overlay

- Current and Future Traffic Loading
- Soil Strength
- Concrete Strength
- Location (For Temperature Thermal Gradient Calculation)
- Reliability
- Fibers (Residual Strength Ratio)
- Underlying (Existing) Pavement Thickness/Strength
- Slab Dimensions
- Bond Condition
- Output: Required Overlay Thickness
Concrete Intersections

Construction Details and Jointing
Concrete Materials & Mix Design

- Conventional Concrete Mixes Used for Reconstruction or Overlay
  - 4,000 psi Compressive (600 - 650 psi Flexural)
    - Type I/II Cement (Type III Cement for High Early Strength When Quick Opening is Required)
    - High Cement Content/Low Water Content Desired (max. w/cm~0.45)
    - Add SCMs to improve durability
  - Maximum Top Size 3/4” for Thin Overlays
    - Coefficient of Thermal Expansion Must Be Considered
  - Admixtures for air, etc.
    - Reduce Water
    - Accelerate Set/Strength
  - Fibers May be Used (Micro or Macro Synthetic, Steel, or Blend)
    - Improve Toughness
    - Improve Post-Cracking Behavior
    - Reduce Plastic Shrinkage Cracking
Fiber-Reinforced Concrete

• Fiber reinforcement should be considered in any of the following situations:
  – The project has specific vertical restrictions
  – The asphalt lift is very thin (and thus may not readily bond with the concrete)
  – The base thickness and/or condition is inadequate
  – The design thickness makes conventional reinforcement for load transfer difficult to use.
Considerations: New Construction/Reconstruction of Intersection

- Removal of existing pavement (reconstruction)
- Preparing the grade
- Setting forms or slip form paver
- Placing in-pavement structures
- Other details prior to placing concrete
- Placing, finishing, and texturing the concrete
- Curing the concrete
- Saw cutting the pavement
- Sealing/Filling joints
- Opening to traffic
Considerations: Intersection Overlay/Inlay

- Place concrete when surface temperature is $<120^\circ$ F.
- Conventional fixed-form or slip form placement used.
- Shotblast or mill (if needed) and clean surface thoroughly.
- Grout or epoxy bonding agents are not required.
- Texture pavement for friction.
- Curing material must be placed as soon as possible (<30 minutes). Full coverage is essential.
- Begin sawing as soon as possible (use of early entry saw is recommended).
Pre-Overlay Preparation (Asphalt)

• Spot repairs as needed.

• Mill for grade correction and drainage transition.

• Sweep or wash clean to maximize bond.

• Address rutting if present.

• If needed, fill expansion cracks and any other deep cracks in asphalt to prevent keying of concrete into cracks.
Overlay: Typical Concrete Overlay Construction Sequence

1-Mill
2-Clean
3-Place
4-Texture
5-Cure
6-Joint
Jointing: Joint Types

Source: ACPA
Jointing: Common Intersections

• To Do:
  – Crack due to severe acute angle
  – Match existing joints or cracks.
  – Place joints to meet in-pavement structures.
  – Be mindful of the maximum joint spacing.
  – Place isolation joints where needed.
  – Allow necessary adjustments to joint locations in the field.
  – Be practical.

• To Avoid:
  – Slabs < 2 ft (0.6 m) wide.
  – Slabs > 15 ft (4.5 m) wide, unless local experience dictates otherwise.
  – Angles < 60° (~90° is best); do this by dog-legging joints through curve radius points.
  – Creating interior corners.
  – Odd shapes (keep slabs near-square or pie-shaped).

Source: ACPA
Forming Contraction Joints by Saw Cutting

- **Conventional Sawcut**: $\frac{1}{4}$ to $\frac{1}{3}$ of thickness
- **Early Entry Sawcut**: ~1 inch
Common Details for Isolation of Fixtures

- **Square**
  - Isolation joint
  - Reinforcing bars recommended to hold cracks tight
- **Diagonal**
  - Isolation joint
- **Circular**
  - Isolation joint
- **Square with Fillets**
  - Isolation joint
  - Reinforcing bars recommended to hold cracks tight
- **None**
  - Isolation joint around perimeter
- **Telescoping Manhole**
  - No boxout or isolation joint necessary
- **Inlet**
  - Isolation joint
- **Inlet - Round**
  - Isolation joint
Jointing: Common Intersection – 10 Step Process

Step 1

Step 2

Step 3

Step 4

Step 5

Step 6

Step 7

Step 8

Step 9

Step 10

Source: ACPA
Jointing: Roundabouts – 6 Step Process

Step 1

Step 2

Step 3

Step 4

Step 5

Step 6

Source: ACPA
Asphalt to Concrete Transitions

Thickened Edge Transition (Doweled or Undoweled)

Impact Slab Transition for New Pavement

Detail Courtesy of ACPA
Concrete Intersections

Maintenance of Traffic (Staging)
Maintenance of Traffic

• Options:
  – Complete closures with detours,
  – Partial closures with detours,
  – Construction under traffic,
  – Complete closures during limited time periods,
  – Combinations of the above.
Staging: Intersection Under Traffic

Construction By Lane

Phase 1

Phase 2

Phase 3

Phase 4

Construction By Quadrant

Phase 1

Phase 2

Phase 3

Phase 4

Source: ACPA
Reconstruction SR 395 Kennewick, WA: Under Traffic & Full Closure Over 3-Day Weekend
Concrete Intersections – Staging (Start)
Concrete Intersections – Staging
(Stage 1 Under Traffic)
Concrete Intersections – Staging
(Stage 2 Under Traffic)
Concrete Intersections – Staging (Stage 3 Under Traffic)
Concrete Intersections – Staging
(Stage 4 Under Closure 3-Day Weekend)
3-Day Weekend Closure

- **Thursday evening to Friday morning**
  - 8:00 pm to 3:30 am – Remove existing surfacing
  - 3:30 am to 7:30 am – Grade, prep base

- **Friday Morning to Friday Evening**
  - 7:30 am to 9:00 pm – Form and pour concrete
  - 3:00 pm – Start joint sawing

- **Saturday Morning to Saturday Evening**
  - 6:30 am – Finish joint sawing
  - 8:00 am to 4:15 pm – Form and pour concrete
  - 4:30 pm to 8:00 pm – Asphalt approaches
  - 6:00 pm to 11:30 pm – Sawcut

- **Sunday Morning to Sunday Afternoon Evening**
  - 5:00 am to 9:00 am – Clean joints/blow dry
  - 9:00 am to 1:00 pm – Joint seal
  - 1:00 pm to 2:00 pm – Clean roadway
  - 2:00 pm to 4:45 pm – Prep roadway (striping)
  - 4:45 pm – Open to traffic
Downtown Roseburg streetscape project

- Oak + Washington Corridor
- City of Roseburg
- Summer 2015

Presented by:
Alex Palm + Emily Brandt
OAK + MAIN
FORESTS OF THE UMPQUA

- Exposed aggregate finish for tree bark (outer ring)
- Black integral colored concrete for the railroad track ring, scored lines for track detail
- Brown integral colored concrete for the inside rings, rings scored and dyed black
- Concrete curved benches
- Decorative concrete ‘stump’ benches
- Inlaid decorative stainless steel
‘STUMP’ CONCRETE BENCHES
OAK + JACKSON
FISH OF THE UMPQUA

- EACH SCALE INDIVIDUALLY POURED
- BLACK INTEGRAL COLORED CONCRETE FOR THE FISH HEAD
- SANDBLASTED “RIPPLES”
- CONCRETE CURVED BENCHES
- SCORE MARKS FOR FIN LINES
WASHINGTON + MAIN
RECREATION IN THE VALLEY

- REAL LEAF IMPRESSIONS
- BLACK INTEGRAL COLORED CONCRETE FOR THE BICYCLE WHEEL
- CURVED CONCRETE BENCHES
- SCORE LINES FOR BICYCLE SPOKES
WASHINGTON + JACKSON
UMPQUA RIVER

- BLUE CONCRETE, 4” OF BLUE ON 4” OF GRAY
- STAMPED RIVER WITH SLATE DESIGN AND CLEAR RELEASE
- EXPOSED AGGREGATE FOR “RIVER SAND BARS”
- CONCRETE FISH LADDER BENCH
- INLAYED FISH
- Poured concrete around boulder benches
Additional Resources

• http://safety.fhwa.dot.gov/intersection/innovative/roundabouts/

• www.Roundaboutsusa.com

• www.ACPA.org

• https://www.wsdot.wa.gov/research/reports/fullreports/503.2.pdf
NRMCA Resources

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- Specification review
- Ready mixed products:
  - Conventional concrete (full depth and overlays)
  - Pervious concrete
  - Roller compacted concrete
  - Cement slurry for full depth reclamation (FDR)
Thank You!

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Questions???