Concrete Pavement Intersections

Presented By:

National **R**eady **M**ixed **C**oncrete **A**ssociation

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- HQ in Alexandria, VA
- 400+ Member Companies
- NRMCA Represents ~75% of North American Ready Mixed Production
- Mission - Serve Industry and Partners Through:
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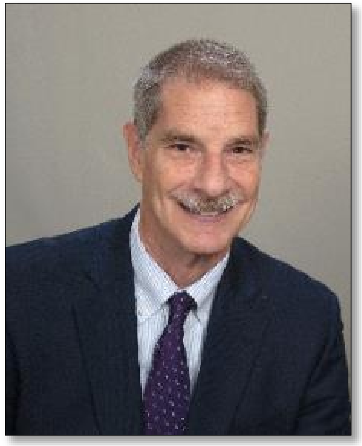

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NRMCA Disclaimer

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Instructions

- Everyone is muted.
- Webinar is being recorded and posted at paveahead.com/education/.
- Type questions in the question box.
- Download the handouts in the GoToWebinar control panel.
- Credit for course:
  - Based on attendance.
  - Attendance Certificate – In follow-up e-mail 1 hour after webinar.
  - AIA members – Attendance registered with AIA-CES if AIA number provided.

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About the Course

Learning Units

- AIA-CES 1.0 LU | Elective or 1.0 PDH
- **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
  - Understand how decorative concrete can enhance safety and improve streetscapes at intersections

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References for Course

CONCRETE PAVING Technology

ACPA — AMERICAN CONCRETE PAVEMENT ASSOCIATION

Concrete Intersections

A Guide for Design and Construction

Introduction

Traffic causes damage to pavement of at-grade street and road intersections perhaps more than any other location. Heavy vehicle stopping and turning can stress the pavement surface severely along the approaches to an intersection. The pavement within the junction (physical area) of an intersection also may receive nearly twice the traffic as the pavement on the approaching roadways.

An intersection reconstructed with concrete.

At busy intersections, the added load and stress from heavy vehicles often cause asphalt pavements to deteriorate quickly. Asphalt surfaces tend to rut and shove under the stress or load of busses and trucks stopping and turning. These deformed surfaces become a safety concern for drivers and costly maintenance problems for roadway agencies.

Concrete pavements better withstand the loading and turning movements of heavy vehicles. As a result, city, county and state roadway agencies have begun rebuilding deteriorated asphalt intersections with concrete pavement. These agencies are extending road and street system maintenance funds by eliminating the expense of intersections that require frequent maintenance.

At-grade intersections along business, industrial, and arterial corridor routes are some of the busiest and most vital pavements in an urban roadway network. Closing these roads and intersections for pavement repair creates costly traffic delays and disruption to local businesses. Concrete pavements provide a long service life for these major corridors and intersections.

Concrete pavements also offer other advantages for intersections, including:

1. A long-term pavement solution.
2. Low maintenance costs.
3. No softening or deterioration caused by oil and/or fuel drippings.
4. Better light reflectivity than asphalt, enhancing pedestrian and vehicle safety at night and in inclement weather.
5. A durable and skid resistant surface.

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Intersection Joint Layout

Designers and contractors should outline an intersection joint layout while developing project plans. The initial plan view of an intersection provides the best birds-eye view for seeing the entire intersection. During construction it is difficult to visualize an intersection because of construction staging.

A good jointing plan will ease construction by providing clear guidance. It is common practice for some designers to leave intersection joint layout to the field engineer and contractor. These designers often justify this practice by citing the many field adjustments that occur during construction, which they contend negates the usefulness of a jointing plan. However, it is not desirable to eliminate the jointing plan except for very simple intersections. A jointing plan and appropriate field adjustments are both necessary for more complex intersections, because islands, medians and turning lanes complicate joint layout and require some forethought before construction. The plan will also enable contractors to more accurately bid the project.

During construction it is likely that location changes will be necessary for some joints within an intersection. The primary reason is to ensure that joints pass through fixtures embedded in the pavement like manholes or drainage inlets. It is common for the actual location of these fixtures to vary from the location shown on the plans. As a result, it will be desirable for the construction crew to adjust the location of some joints so that they coincide with the actual location of a nearby manhole or inlet. The designer should consider placing a note on the plan to give the field engineer and contractor the latitude to make appropriate adjustments.

The transverse and longitudinal joints in concrete pavement are necessary primarily to control cracking. The desirable transverse joint spacing depends on the slab thickness and subbase, but is usually about 15 ft (4.5 m). On typical roadway pavements, longitudinal joints divide lanes of traffic and in most cases are no more than about 12 ft (4 m) apart. Because the transverse and longitudinal joint spacing are usually not identical, it is difficult to maintain an even spacing on either roadway through an intersection.

The ten-step method in this publication provides intersection joint layout fundamentals. The examples show a right-angle and a skewed T-intersection. The detail diagrams show preferable alternates, but there may be certain intersections with unique geometry that the methodology does not fully address. This publication does not address dowel and reinforcing requirements for joints.

A primary goal of this method is to minimize or eliminate joints that intersect another joint or the pavement edge at an acute angle. Experience shows that cracks often occur near acute angles, especially angles less than 60°. For most intersections it is possible to eliminate all angles less than 90° from the roadway slabs — there may be some acute angles in the curb and gutter. For skewed intersections it is likely that some joints will intersect at angles less than 90°. However, even for skewed intersections it is preferable to avoid angles less than 60°.

The method works equally well for integral curb and gutter, as well as for separate curb and gutter. The diagrams show how to place joints through curb and gutter and along curves between the intersecting roadways. The method also helps produce a plan that is easier to construct by avoiding width changes along the edge of the mainline or primary paving lane(s).

Joint Layout Terminology

Doglegs: Construction block-outs at points where the pavement changes width. (See page 5 for details.)

Circumference-Return Line: A lightly drawn line 1.5-3.0 ft (0.5-1.0 m) from the face of the gutter along the curve between the edges of the intersecting roads. For obtuse angles, the line is 1/2 the nominal lane width from the gutter. Any joint that meets the circumference-return line is brought along the curve's radius to the back of the curb and gutter. Older publications use the term "off-set points" to refer to the points where joints return to the back of the curb.

Taper-Return Line: A lightly drawn line 1.5 ft (0.5 m) from the face of the gutter at the start of a turn lane taper. Any longitudinal joint that meets a taper-return line defines a location for a dogleg in the gutter.

Cross-Road Return Line: A lightly drawn line 1.5 ft (0.5 m) from the edge of a the mainline roadway at a skewed intersection. Any cross-road longitudinal joint will meet a transverse joint for the mainline roadway at the cross-road return line.

Intersection Box: The box formed by the edge of the mainline and intersecting paving lanes (including turning lanes).

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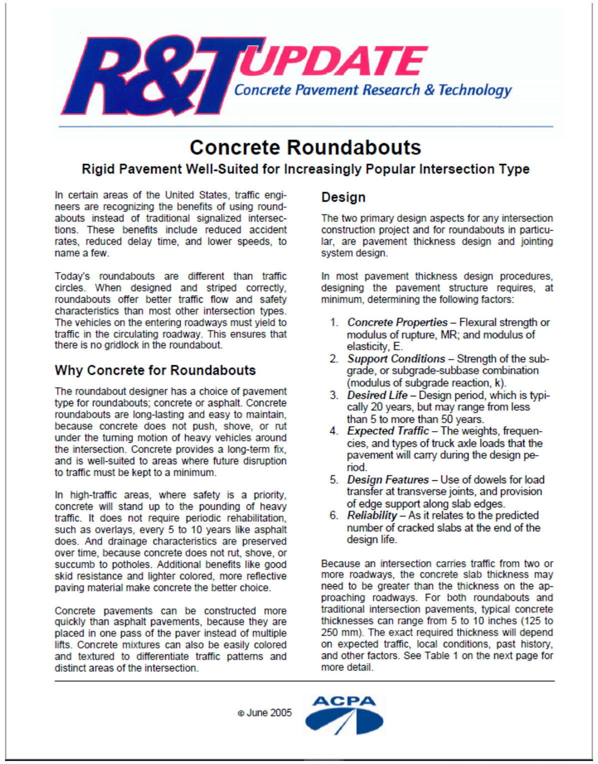

R&T UPDATE — Concrete Pavement Research & Technology

Concrete Roundabouts

Rigid Pavement Well-Suited for Increasingly Popular Intersection Type

In certain areas of the United States, traffic engineers are recognizing the benefits of using roundabouts instead of traditional signalized intersections. These benefits include reduced accident rates, reduced delay time, and lower speeds, to name a few.

Today's roundabouts are different than traffic circles. When designed and striped correctly, roundabouts offer better traffic flow and safety characteristics than most other intersection types. The vehicles on the entering roadways must yield to traffic in the circulating roadway. This ensures that there is no gridlock in the roundabout.

Why Concrete for Roundabouts

The roundabout designer has a choice of pavement type for roundabouts; concrete or asphalt. Concrete roundabouts are long-lasting and easy to maintain, because concrete does not push, shove, or rut under the turning motion of heavy vehicles around the intersection. Concrete provides a long-term fix, and is well-suited to areas where future disruption to traffic must be kept to a minimum.

In high-traffic areas, where safety is a priority, concrete will stand up to the pounding of heavy traffic. It does not require periodic rehabilitation, such as overlays, every 5 to 10 years like asphalt does. And drainage characteristics are preserved over time, because concrete does not rut, shove, or succumb to potholes. Additional benefits like good skid resistance and lighter colored, more reflective paving material make concrete the better choice.

Concrete pavements can be constructed more quickly than asphalt pavements, because they are placed in one pass of the paver instead of multiple lifts. Concrete mixtures can also be easily colored and textured to differentiate traffic patterns and distinct areas of the intersection.

Design

The two primary design aspects for any intersection construction project and for roundabouts in particular, are pavement thickness design and jointing system design.

In most pavement thickness design procedures, designing the pavement structure requires, at minimum, determining the following factors:

1. *Concrete Properties* – Flexural strength or modulus of rupture, MR; and modulus of elasticity, E.
2. *Support Conditions* – Strength of the subgrade, or subgrade-subbase combination (modulus of subgrade reaction, k).
3. *Desired Life* – Design period, which is typically 20 years, but may range from less than 5 to more than 50 years.
4. *Expected Traffic* – The weights, frequencies, and types of truck axle loads that the pavement will carry during the design period.
5. *Design Features* – Use of dowels for load transfer at transverse joints, and provision of edge support along slab edges.
6. *Reliability* – As it relates to the predicted number of cracked slabs at the end of the design life.

Because an intersection carries traffic from two or more roadways, the concrete slab thickness may need to be greater than the thickness on the approaching roadways. For both roundabouts and traditional intersection pavements, typical concrete thicknesses can range from 5 to 10 inches (125 to 250 mm). The exact required thickness will depend on expected traffic, local conditions, past history, and other factors. See Table 1 on the next page for more detail.

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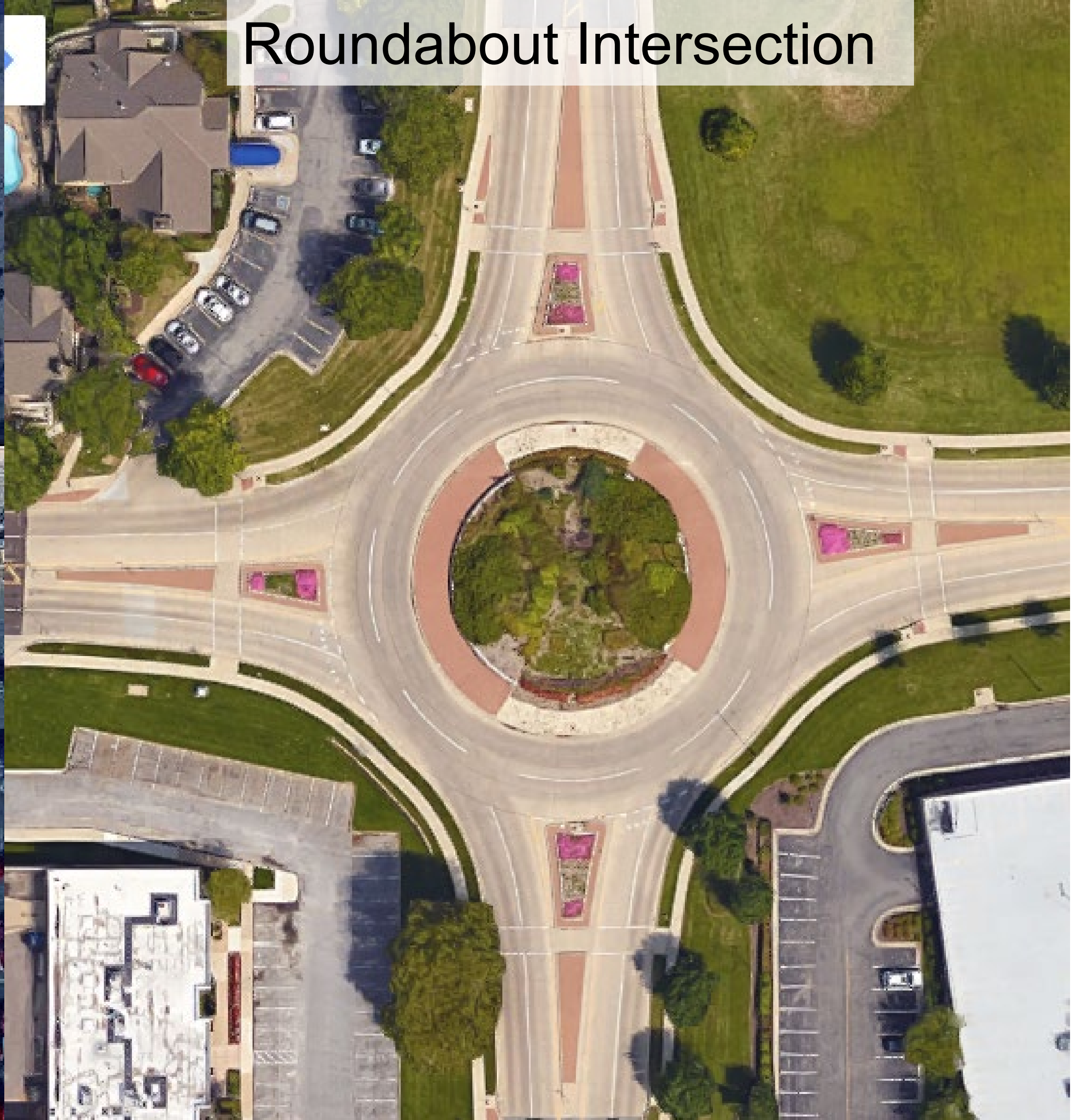
Typical 4-Way Intersection


Roundabout Intersection

Common Problems at Intersections…

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Intersections and Roundabouts

- Pavement Concerns:
  - Starting and stopping
  - Slow & heavy loads
  - Turning movements
  - High shear stresses
  - Repeated repairs

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Utilizing Concrete For Intersections: Options

- Build New at Time of Initial Construction
- Reconstruct Existing Intersection
- Overlay (or Inlay) Existing Intersection

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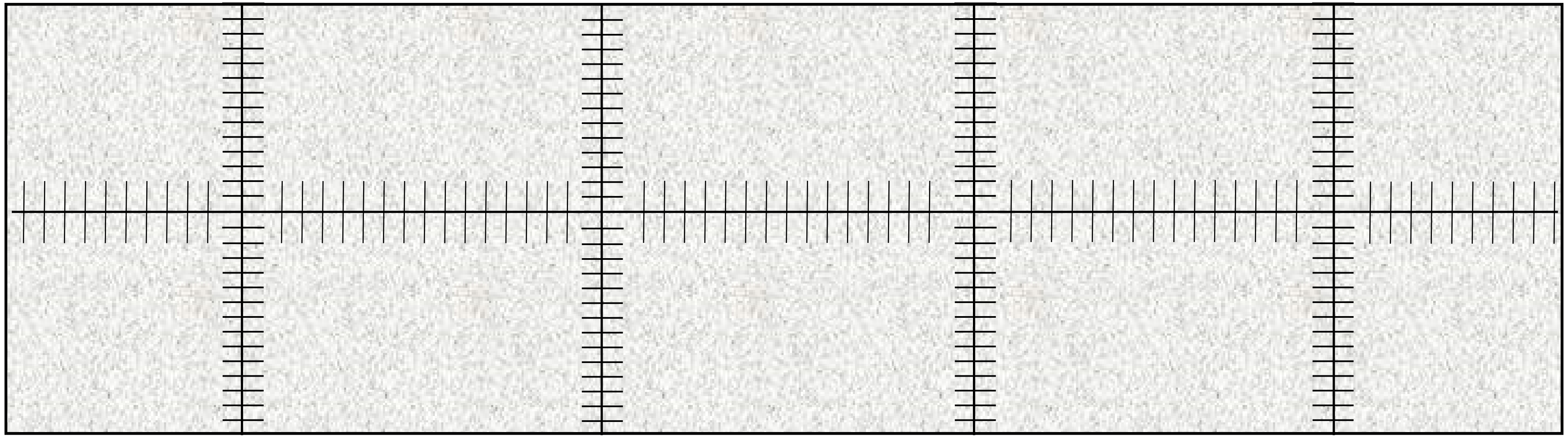
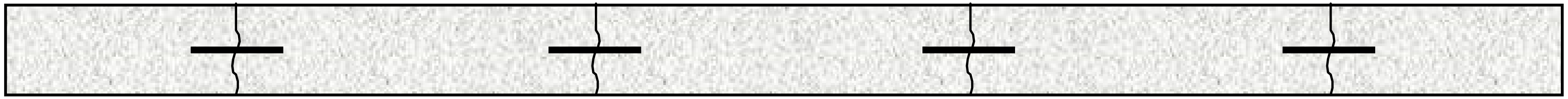
What Kind of Concrete Pavement is Recommended?
Jointed – Unreinforced Pavement

Plan



Profile



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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

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Concrete Intersections

Why The Need For Durable Surfaces?


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Courtney Park and Kennedy Road
Mississauga, Ontario

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Life Cycle Costs Analysis for Intersections Washington State (with user costs)

40 Year Annualized Cost					
SR	**Intersection**	**Concrete**	**AC with 4 yr Inlay**	**AC with 6 year Inlay**	**AC with 8 year Inlay**
27	Sprague Ave.	$33,000	$46,800	$39,500	$35,800
90	Thierman St.	$54,300	$66,400	$57,600	$53,100
2	Francis Ave.	$73,500	$100,900	$87,000	$79,900
291	Maple & Ash St.	$33,900	$50,800	$42,100	$37,600
27	Broadway Ave.	$36,100	$51,000	$42,600	$38,300
395	19th Ave.	$29,700	$45,800	$37,800	$33,700
2	Third Ave.	$15,200	$18,700	$16,500	$15,400

www.wsdot.wa.gov

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Concrete Intersections

For Existing Intersections: Rehabilitation or Reconstruction?


Pre-Design Data Gathering*

- 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
  - ft^2, in., ft, etc.

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Destructive Testing Options

Coring

Trenching

Dynamic Cone Penetrometer (DCP)

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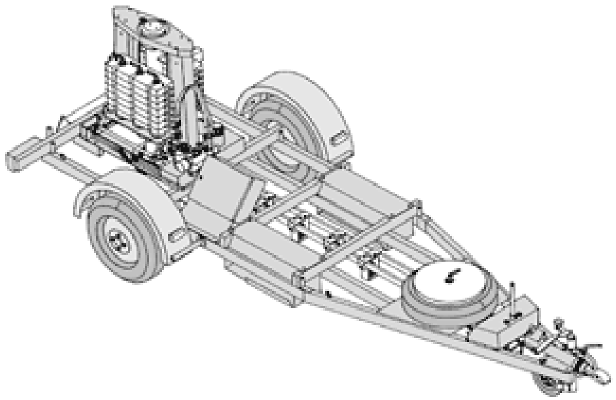
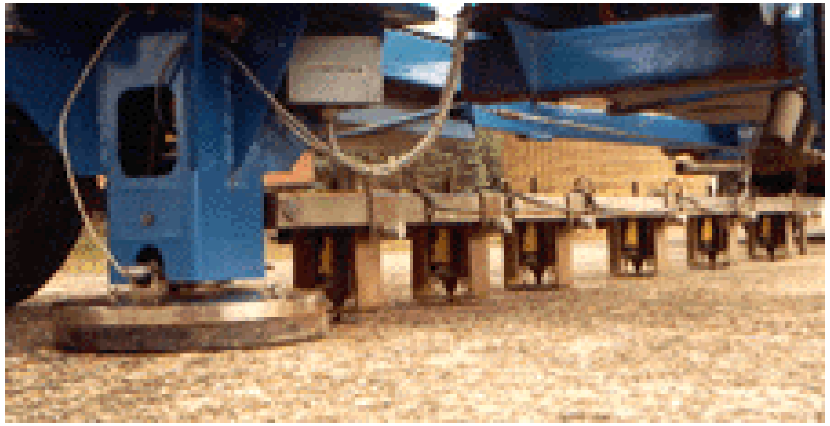
Coring

- 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)





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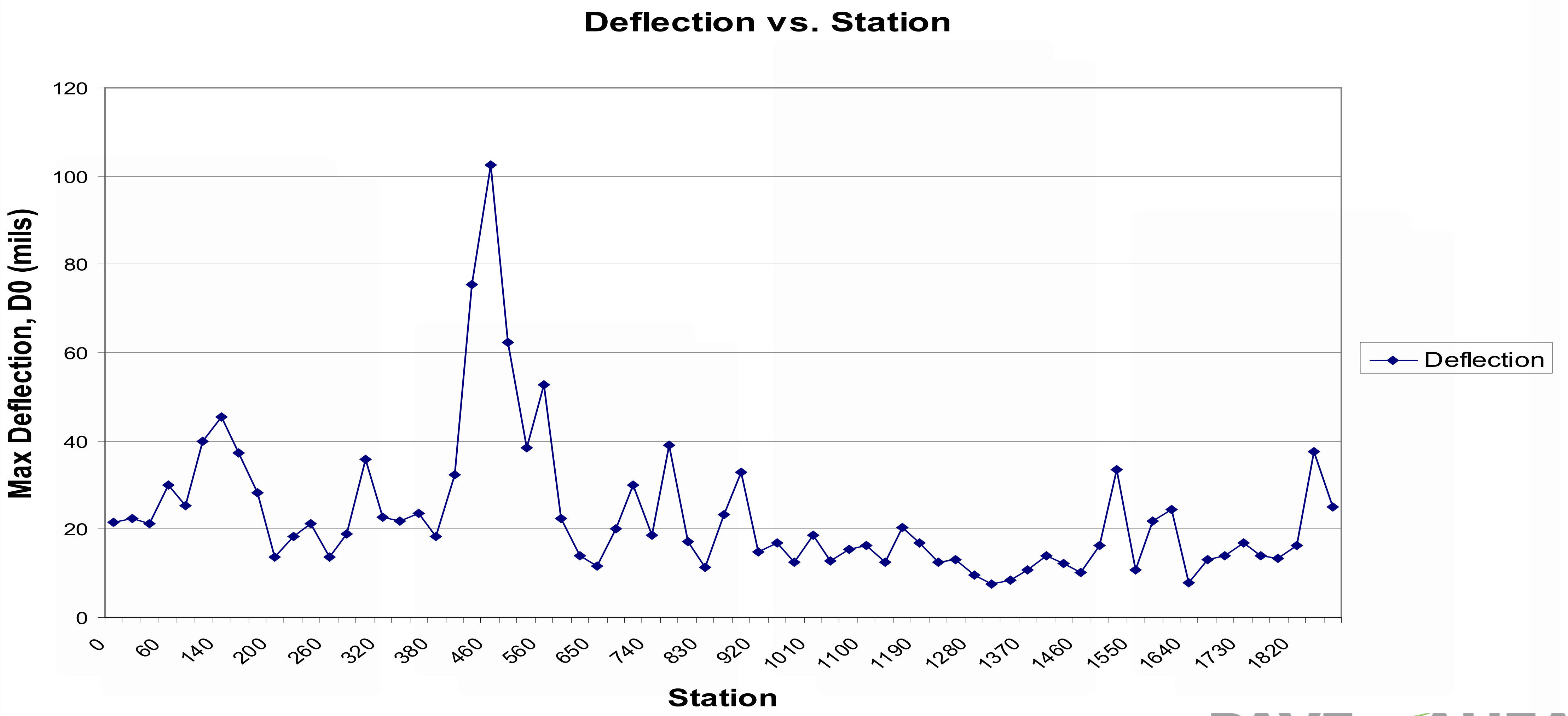
Pavement Structural Capacity



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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?

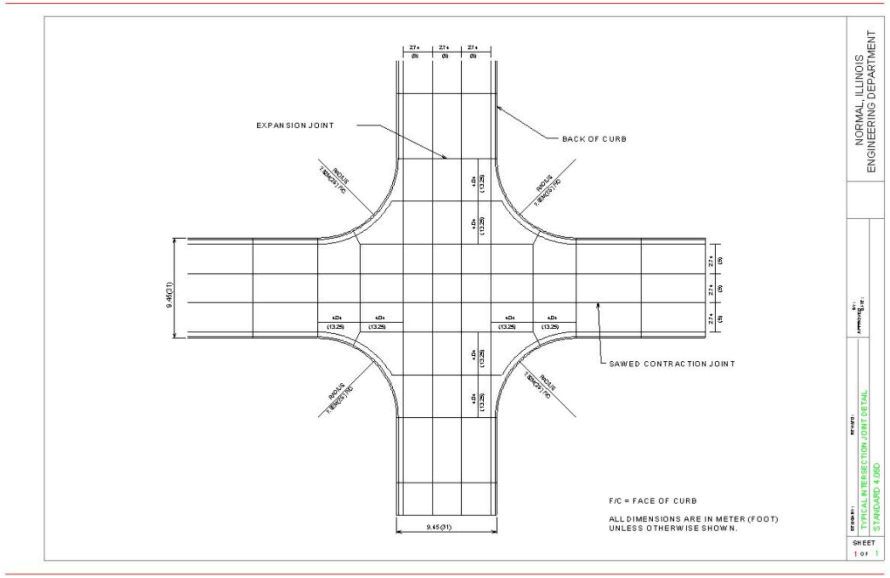


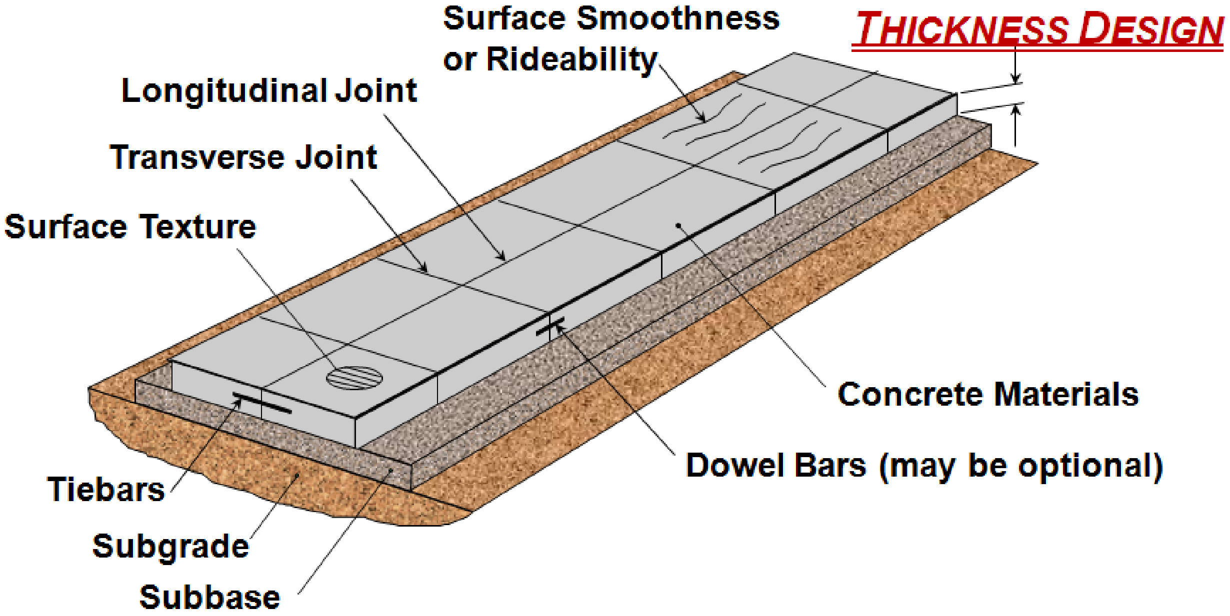
Concrete Intersections

Pavement Thickness Design Methods


Primary Information Needed For Thickness Design

- Traffic Information
- Underlying Support Condition
- Concrete Strength





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Define The Traffic Streams Through The Intersection

Subgrade Soil Characterization

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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

Soil Strength for Design: Modulus of Subgrade Reaction (k-value)

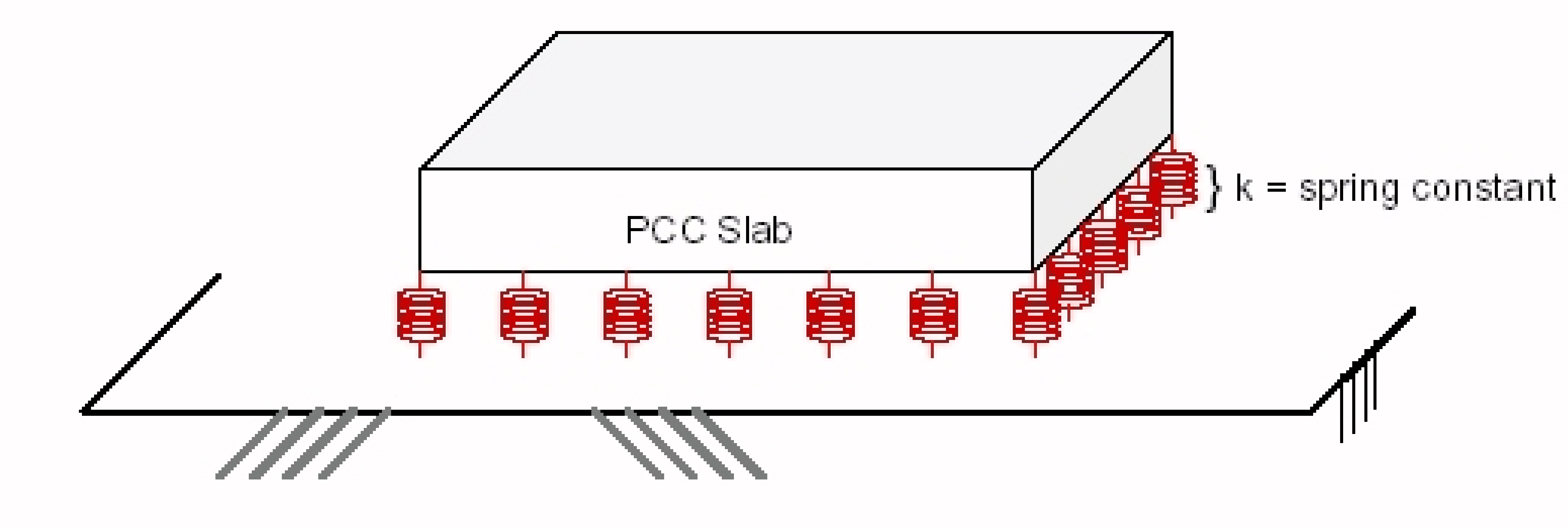
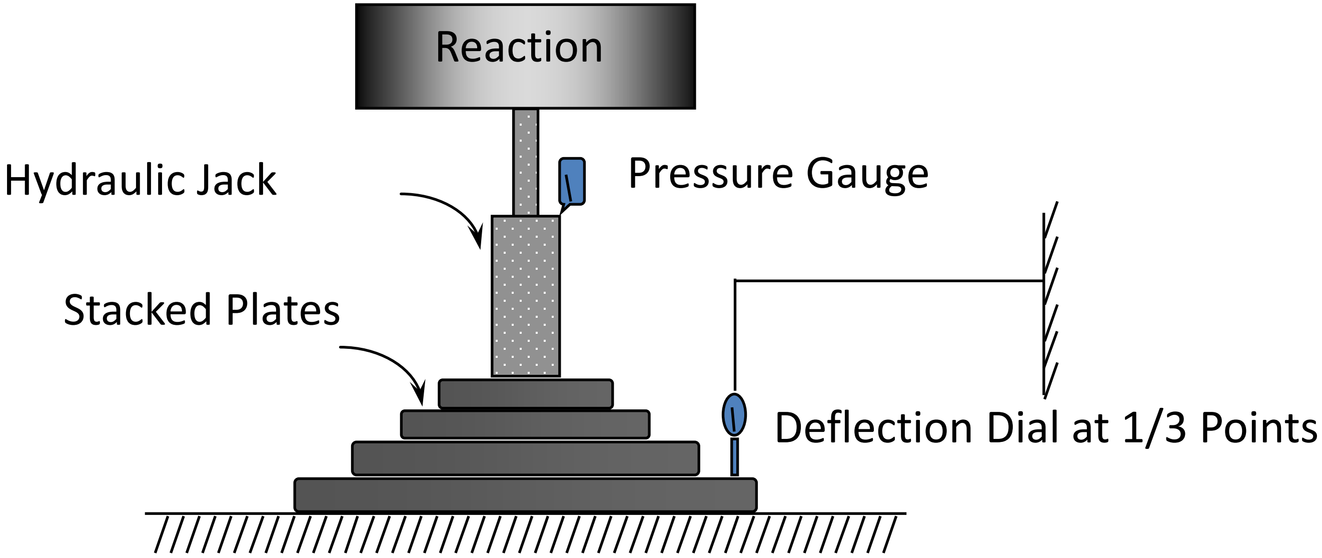


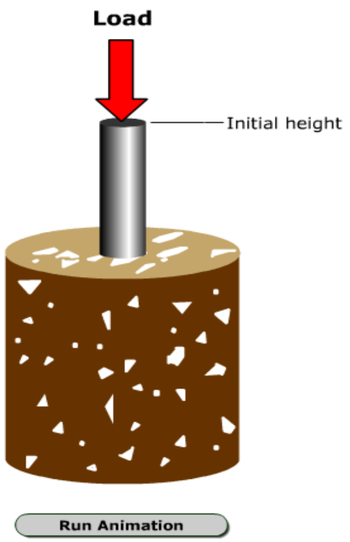
Plate Load Bearing Test (k-value)

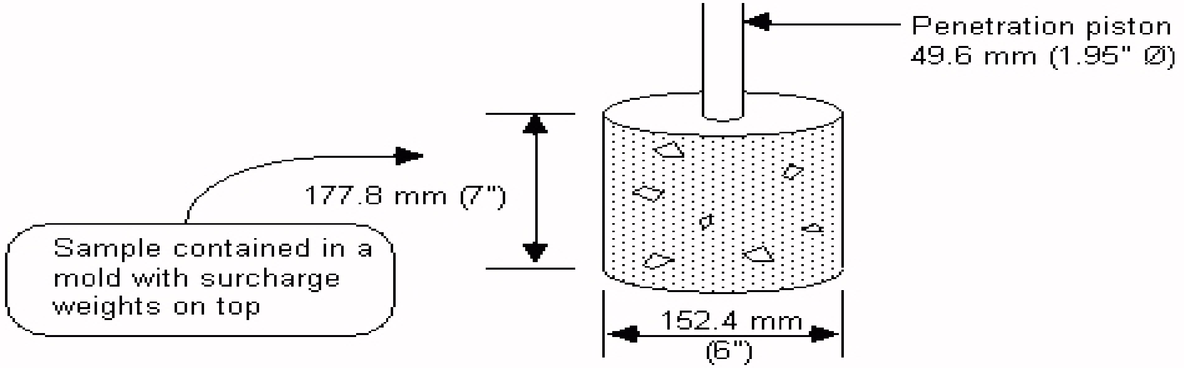


k (psi/in) = unit load on plate / plate deflection

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.

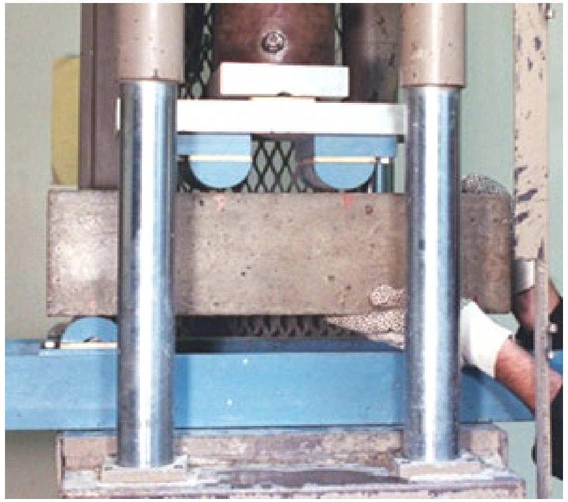




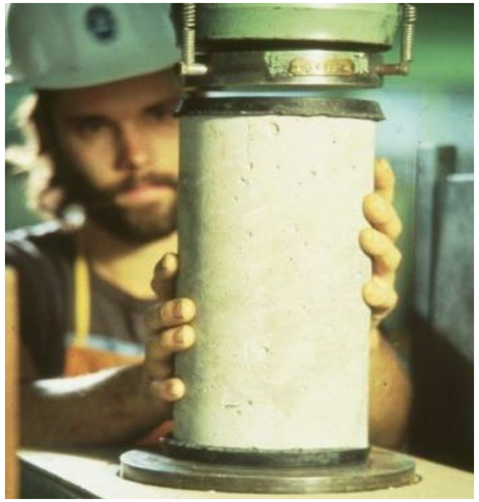
Concrete Strength

- Design = Modulus of Rupture (MOR)
  - Sometimes referred to as Flexural Strength
- Construction = Compressive Strength (*f'*c)
- MOR = 8 to 10 * √*f'*c
  - MOR ~ *f'*c
  - 500 psi ~ 3,500 psi
  - 550 psi ~ 4,000 psi
  - 600 psi ~ 4,500 psi
  - 650 psi ~ 5,000 psi

MOR



*f'*c



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

PavementDesigner.org

Inputs:

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

Outputs:

- Concrete Thickness
- Joint Spacing
- Doweling

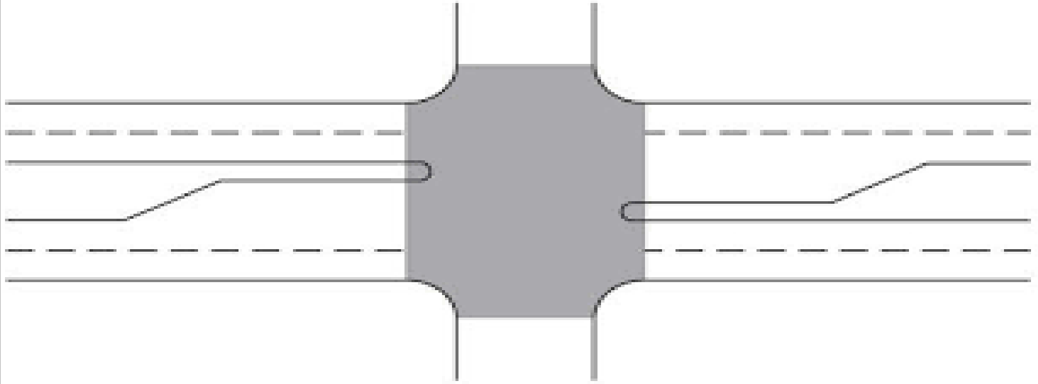
Typical Design Inputs: Concrete Overlay

- 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

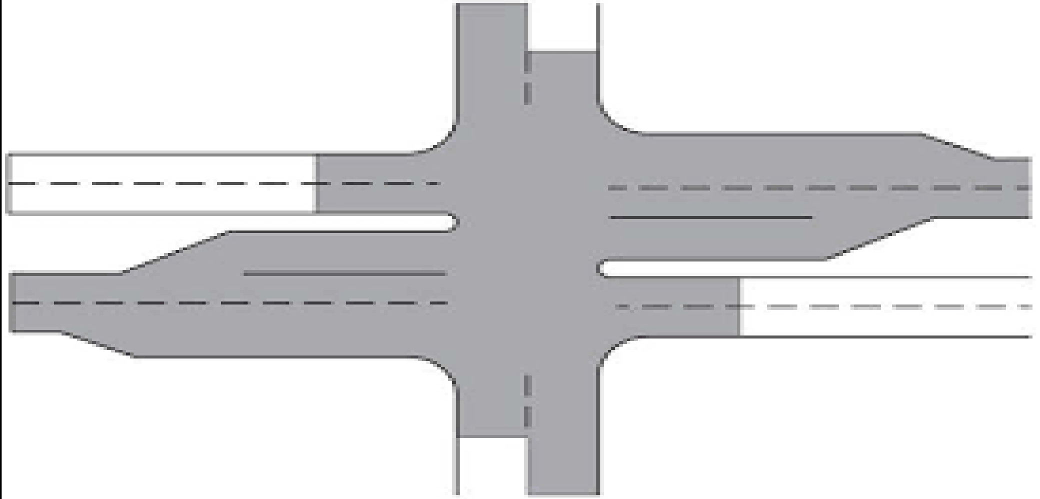
Paving Limits: Functional Limits

- Stopping Distance
- Average Queue Length
- Limits of Pavement Distress
- Consider Placement and Compaction of Adjacent Asphalt
- Radius Return Minimum

Intersection: Physical Area



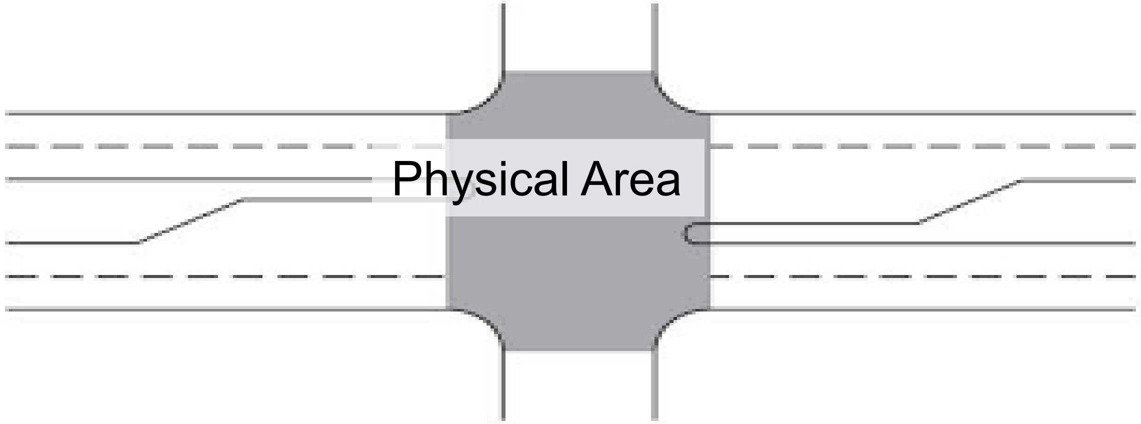
Intersection: Functional Area

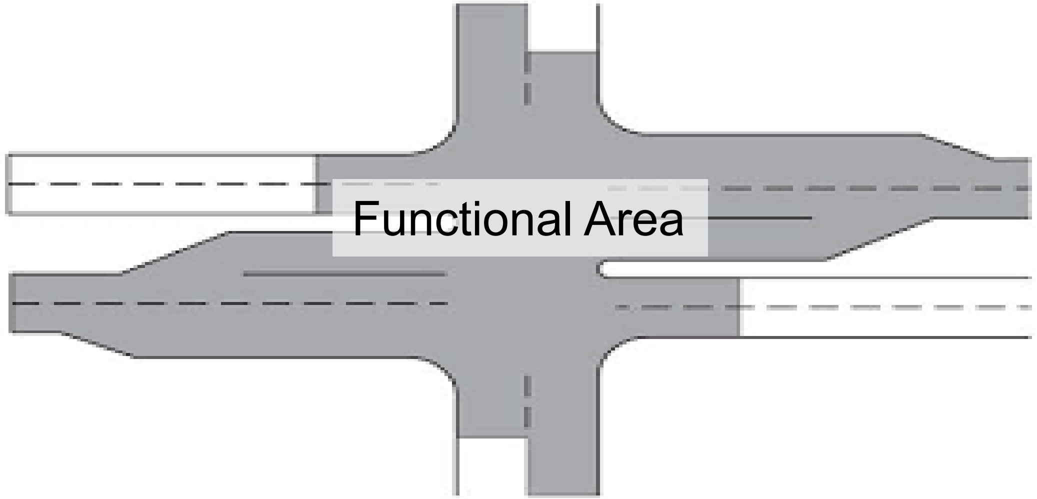


Note 1: Physical area carries the combined traffic from both roadways. Therefore, thickness design must account for both.

Note 2: Functional area must account for stopping distances and turning/accelerating movements.

Concrete Intersections: Thickness





Roadway 1	Roadway 2	Physical Area Thickness
Low AADT (T1)	Medium AADT (T2)	T2
Low ADTT (T1)	High AADT (T3)	T3
High AADT (T3)	High AADT (T3)	T3 + 0.5 to 1.0 in.

Note: T3 > T2 > T1

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Source: ACPA



Concrete Intersections

Construction Details and Jointing


Concrete Materials & Mix Design

- Conventional Concrete Mixes Used for <u>Reconstruction</u> or <u>Overlay</u>
  - 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)
  - Maximum Top Size ¾" 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

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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.

Steel

Structural Synthetic

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

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Considerations: Intersection Overlay/Inlay

- Place concrete when surface temperature is **<120° 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

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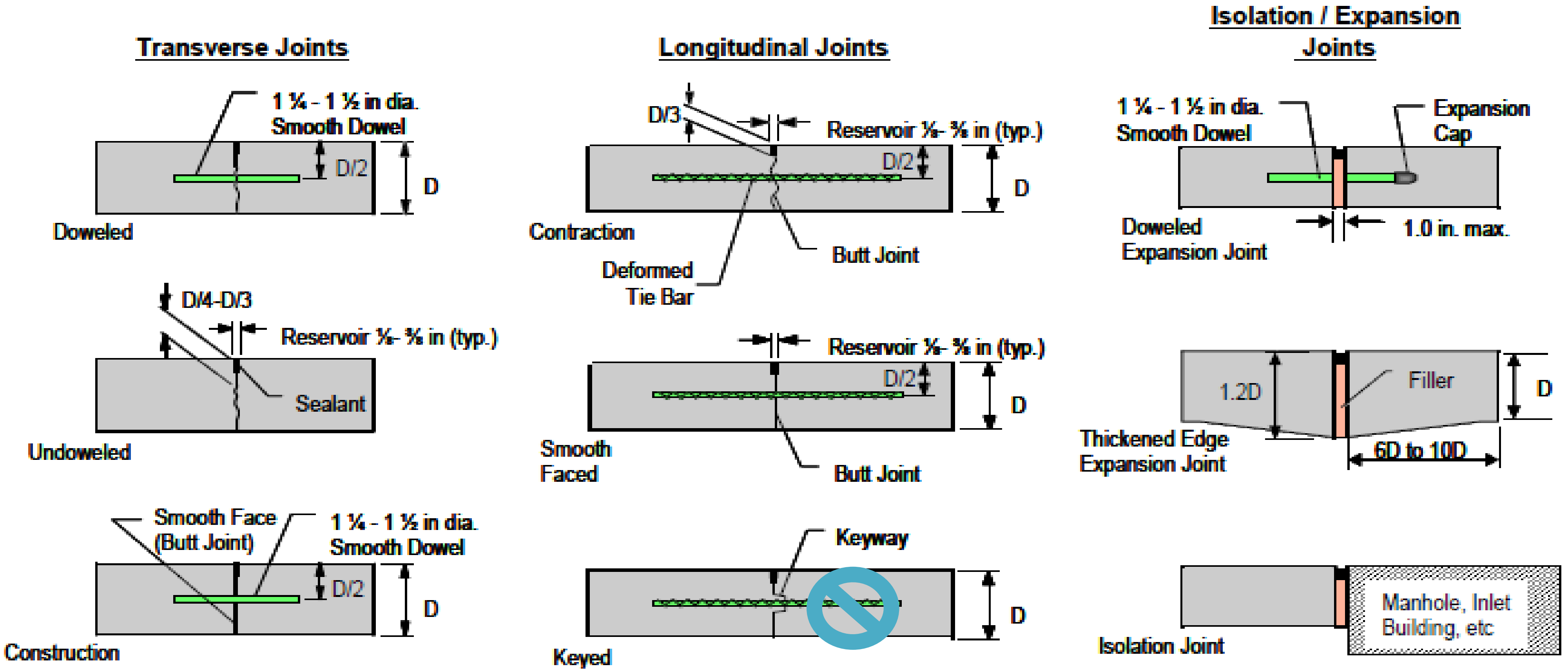
Jointing: Joint Types

Source: ACPA



≥ 8 in.

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Jointing: Common Intersections

- Things 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.

- Things 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

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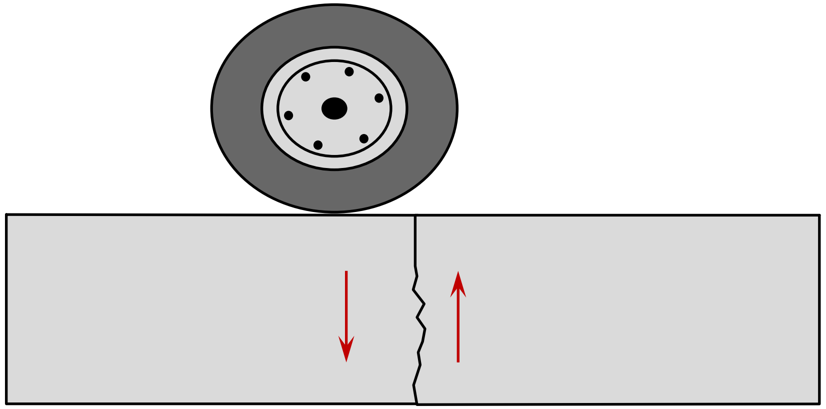
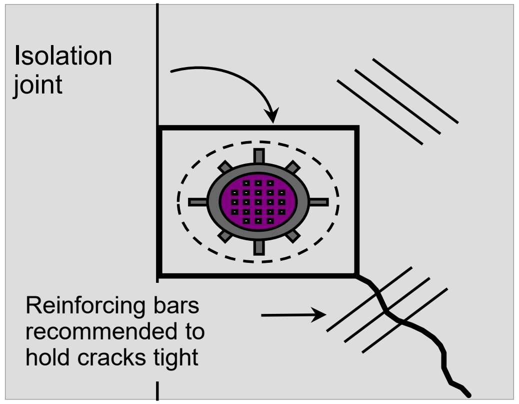
Forming Contraction Joints by Saw Cutting



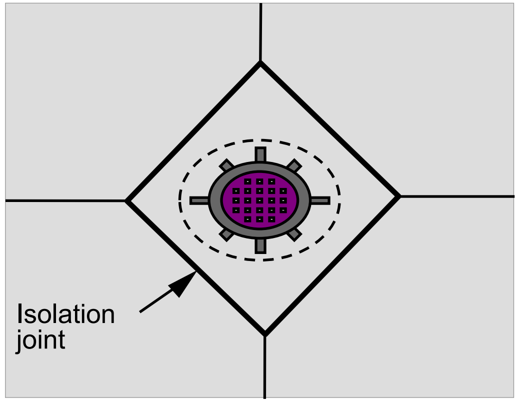
Conventional Sawcut
¼ to ⅓ of thickness

Early Entry Sawcut
~1 inch

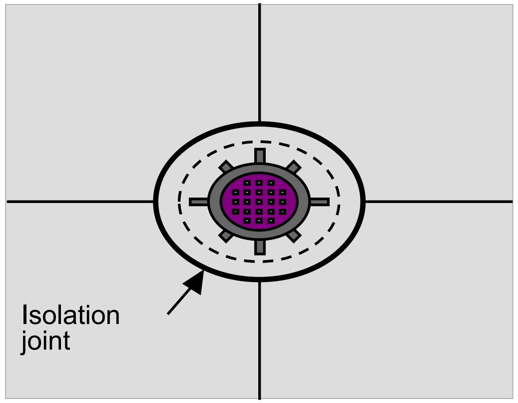
Common Details for Isolation of Fixtures



Square

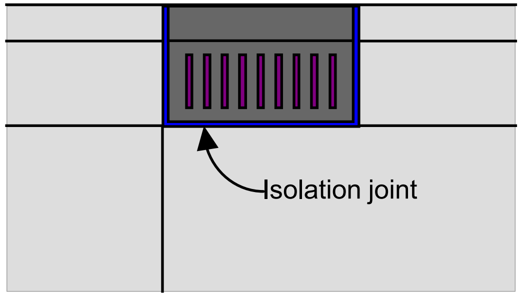


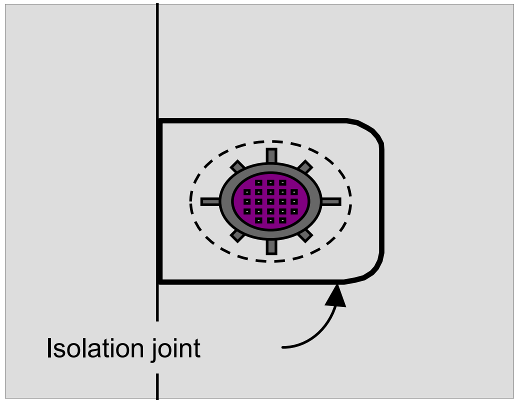
Diagonal



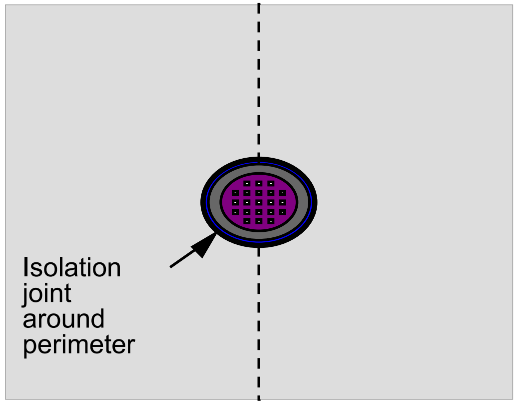
Circular

Inlet

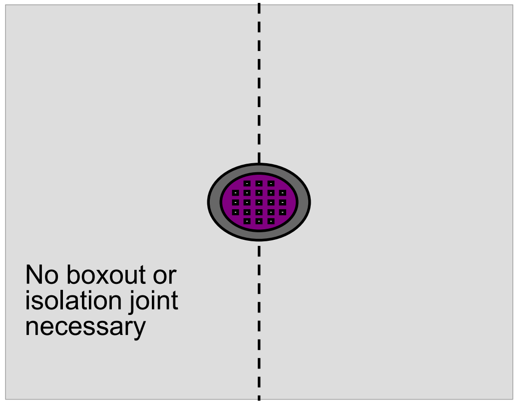




Square with Fillets

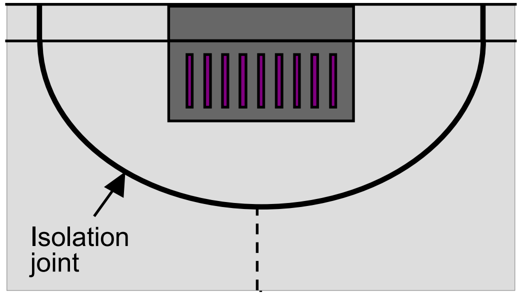


None

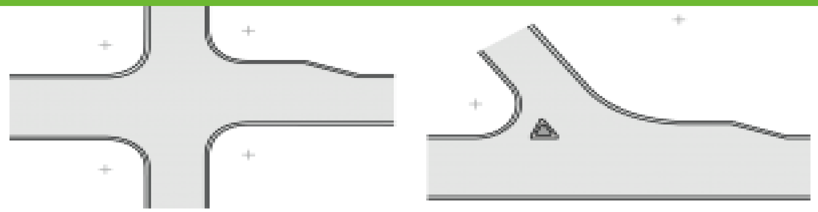


Telescoping Manhole

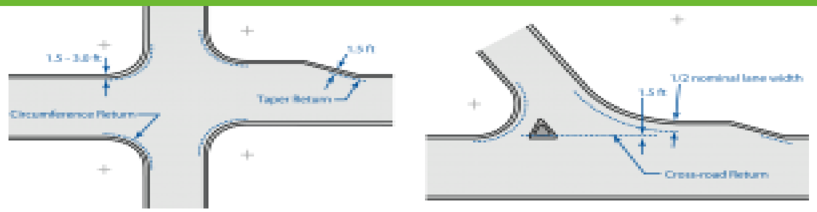
Inlet - Round



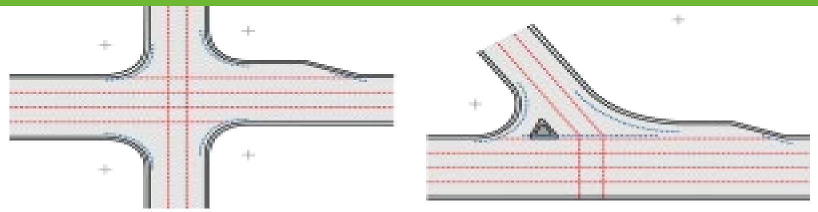
Jointing: Common Intersection – 10 Step Process



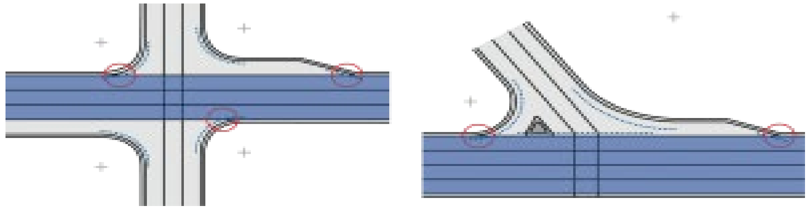
Step 1



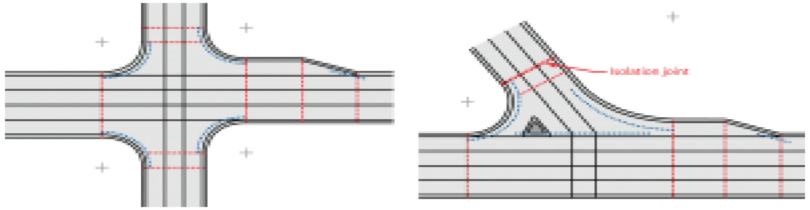
Step 2



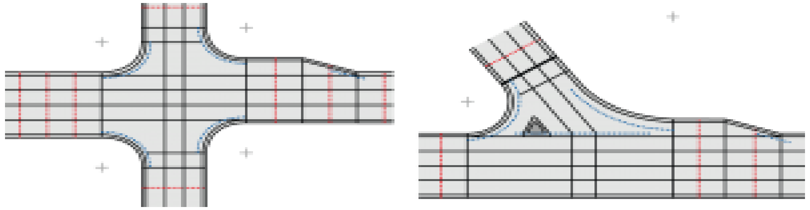
Step 3



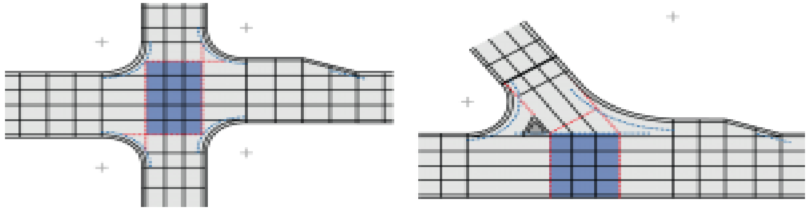
Step 4



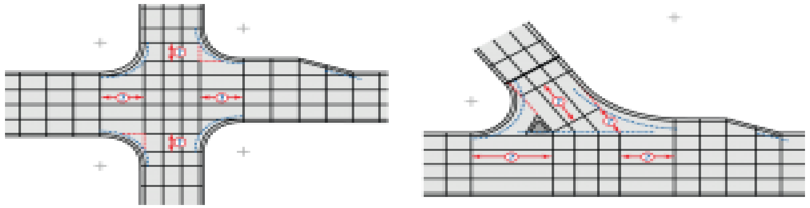
Step 5



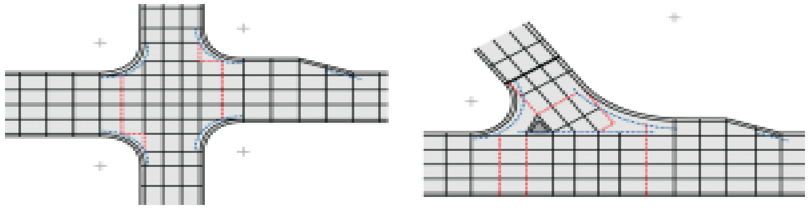
Step 6



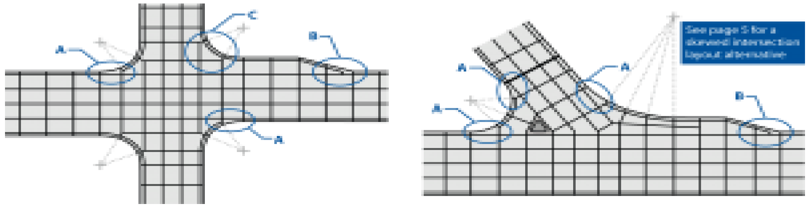
Step 7



Step 8



Step 9



Step 10

Source: ACPA

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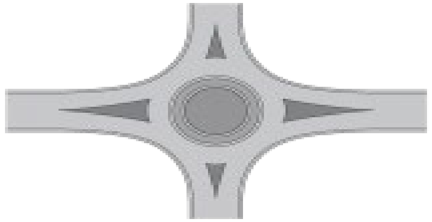
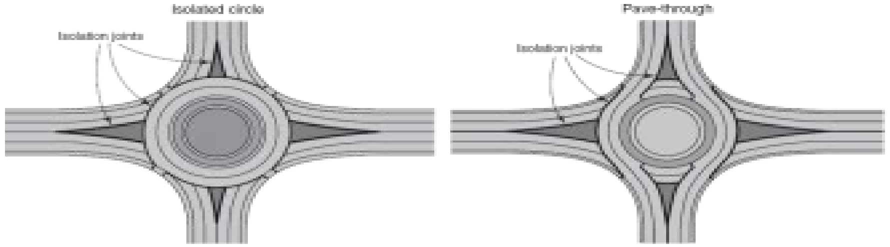
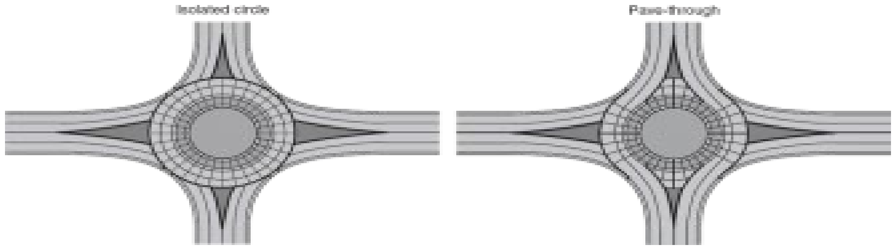
Jointing: Roundabouts – 6 Step Process



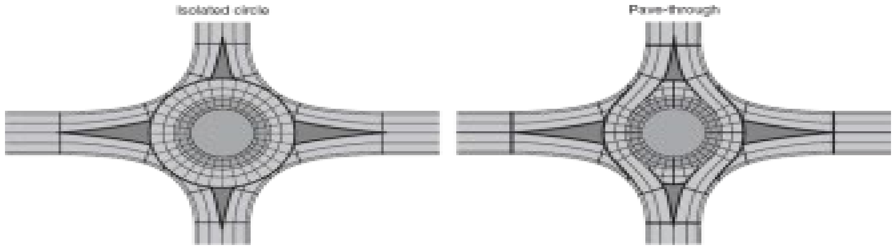
Step 1



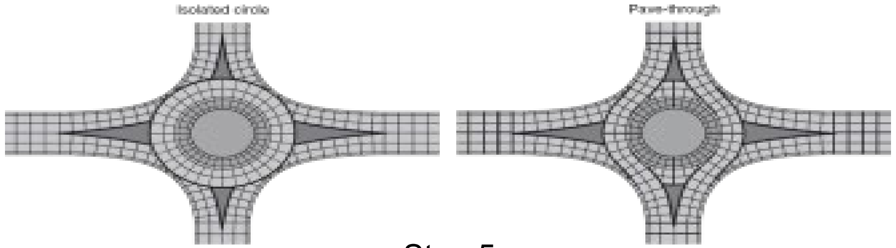
Step 2



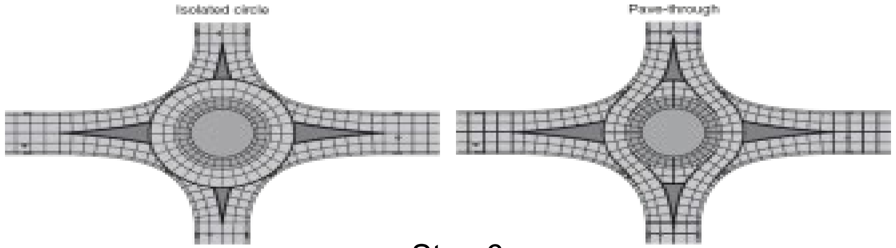
Step 3



Step 4



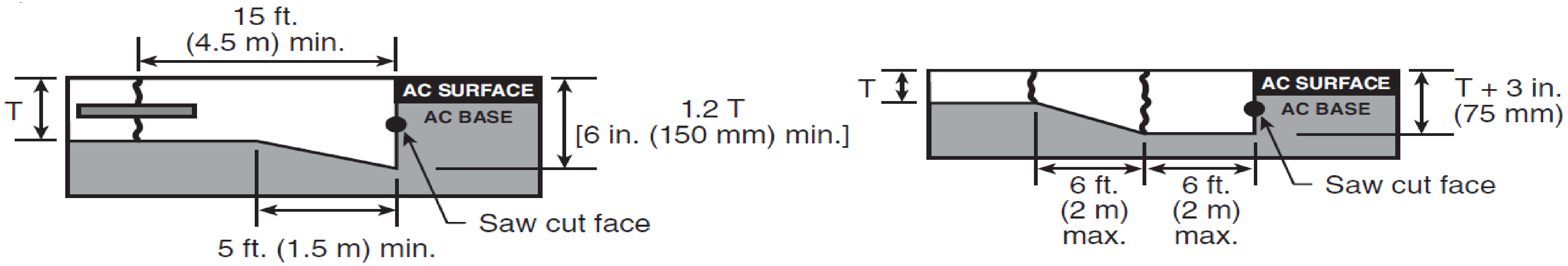
Step 5



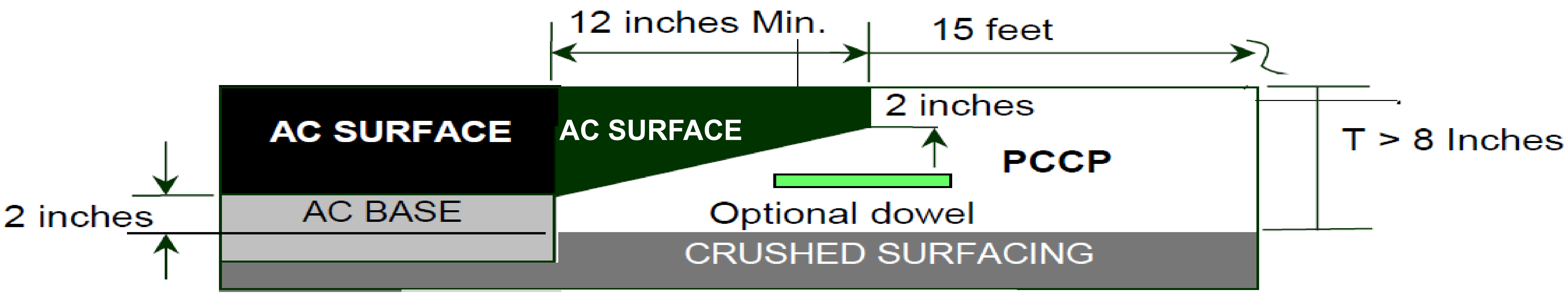
Step 6

Source: ACPA

Asphalt to Concrete Transitions



Thickened Edge Transition (Doweled or Undoweled)



Impact Slab Transition for New Pavement

Detail Courtesy of ACPA

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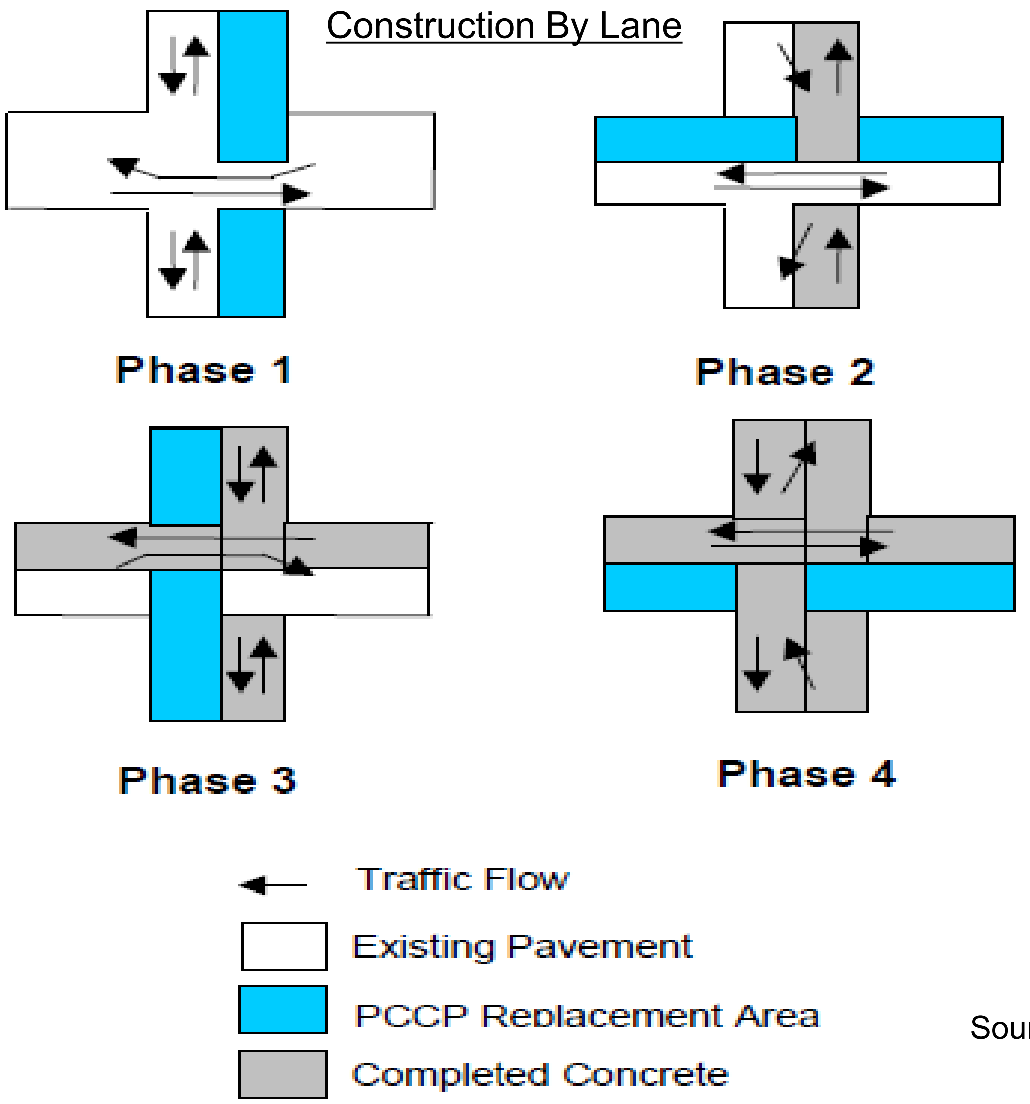
Concrete Intersections

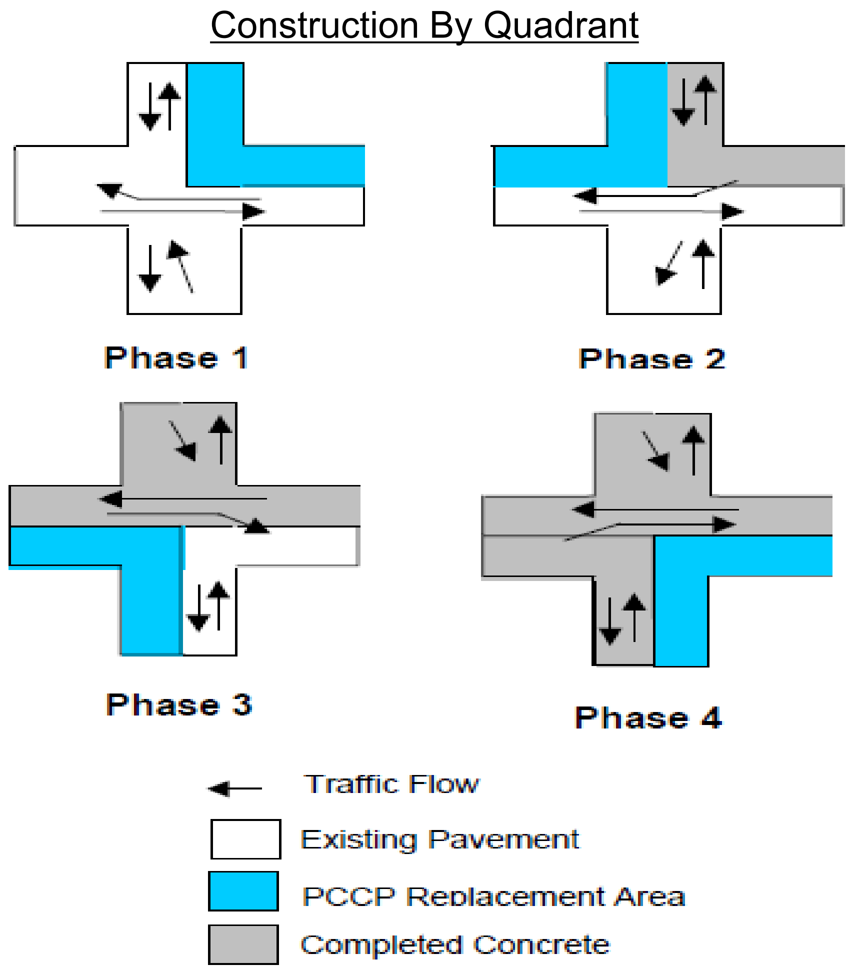
Maintenance of Traffic (Staging)


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





Source: ACPA

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Reconstruction SR 395 Kennewick, WA:

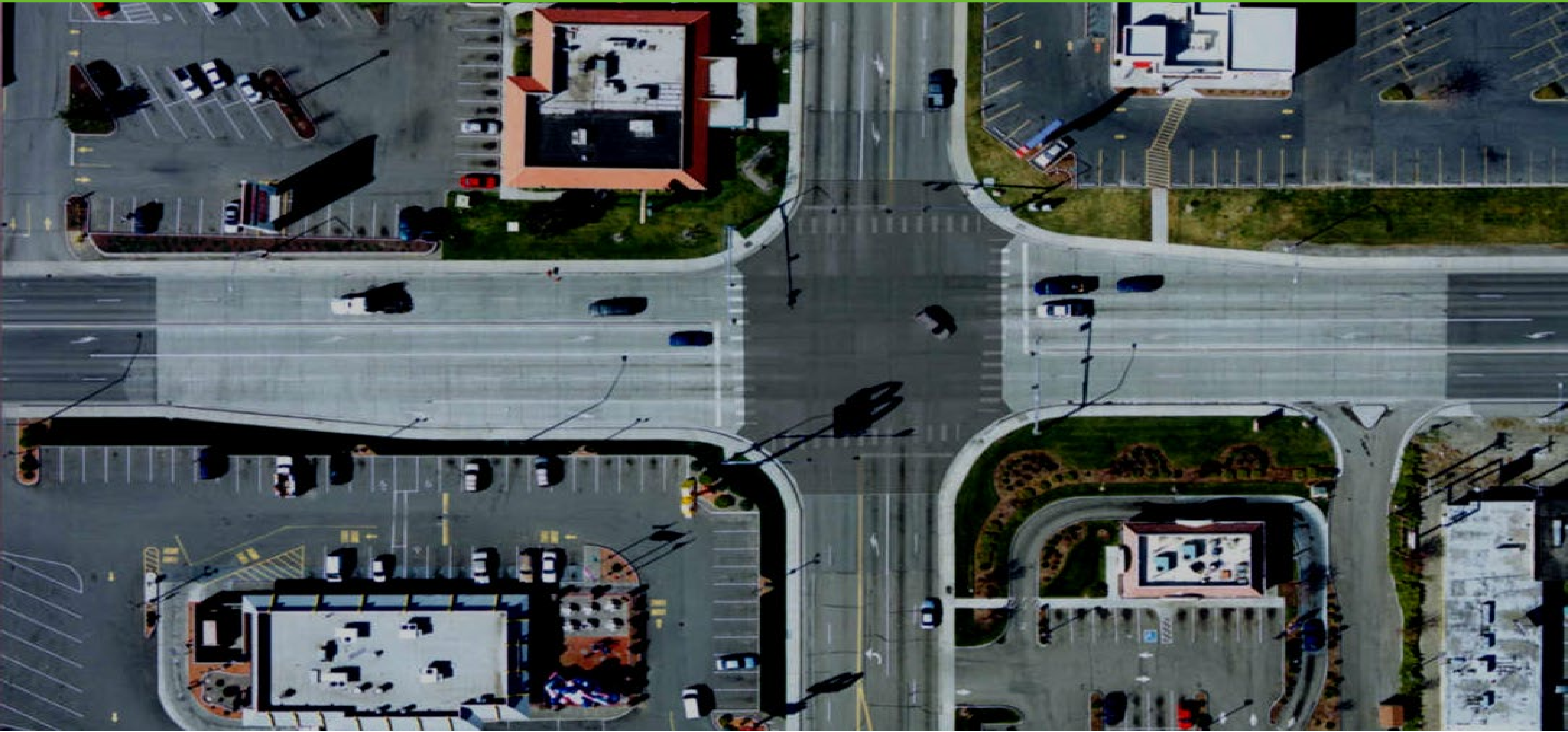
Under Traffic & Full Closure Over 3-Day Weekend

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

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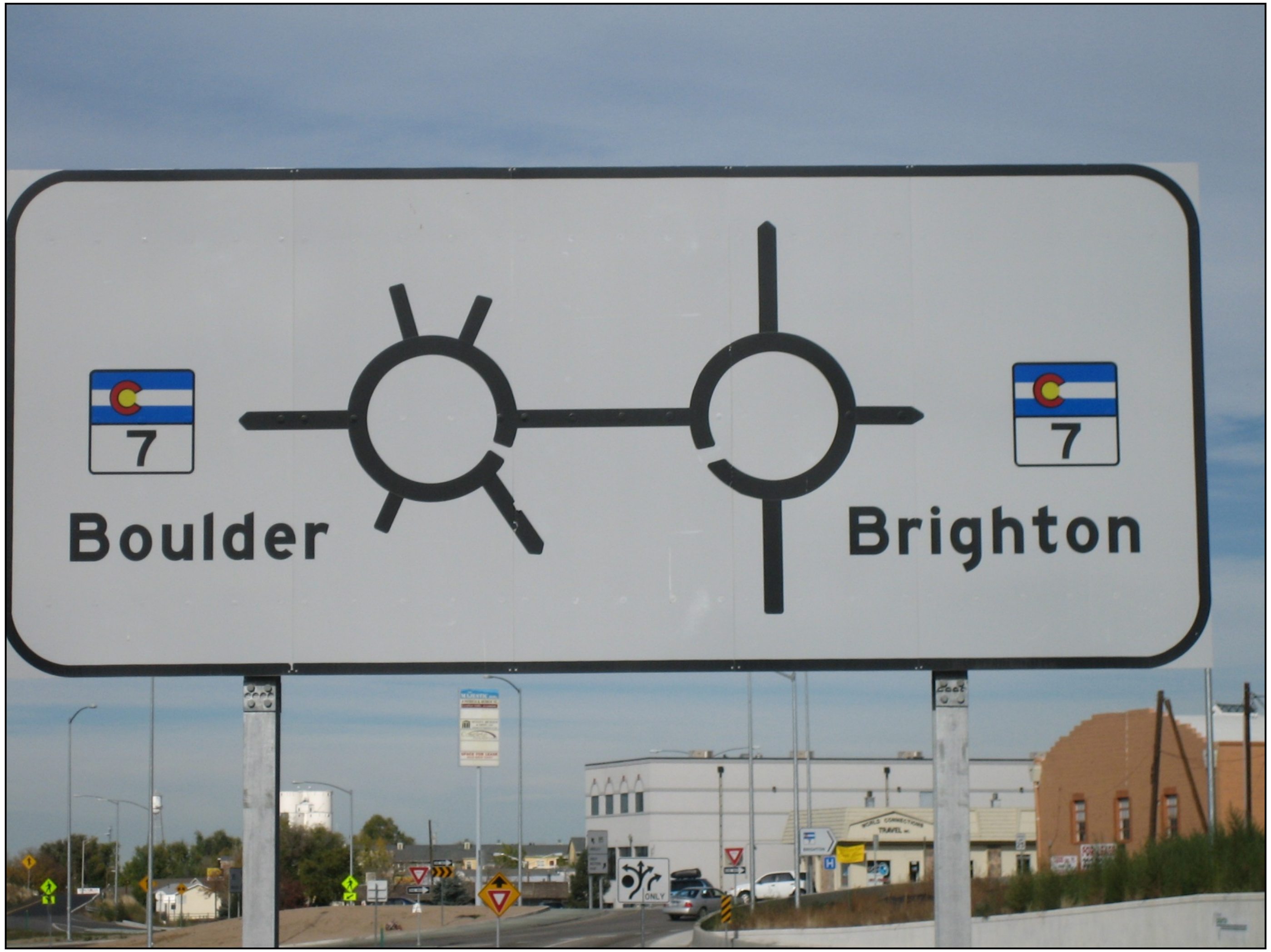
Bend Oregon Roundabout

SIGN OF THE TIMES



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Grand Junction, Colorado

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M-5 and Pontiac Trail - Michigan

Downtown Roseburg streetscape project

- OAK + WASHINGTON CORRIDOR
- CITY OF ROSEBURG
- SUMMER 2015

PRESENTED BY:

ALEX PALM + EMILY BRANDT

i.e. ENGINEERING

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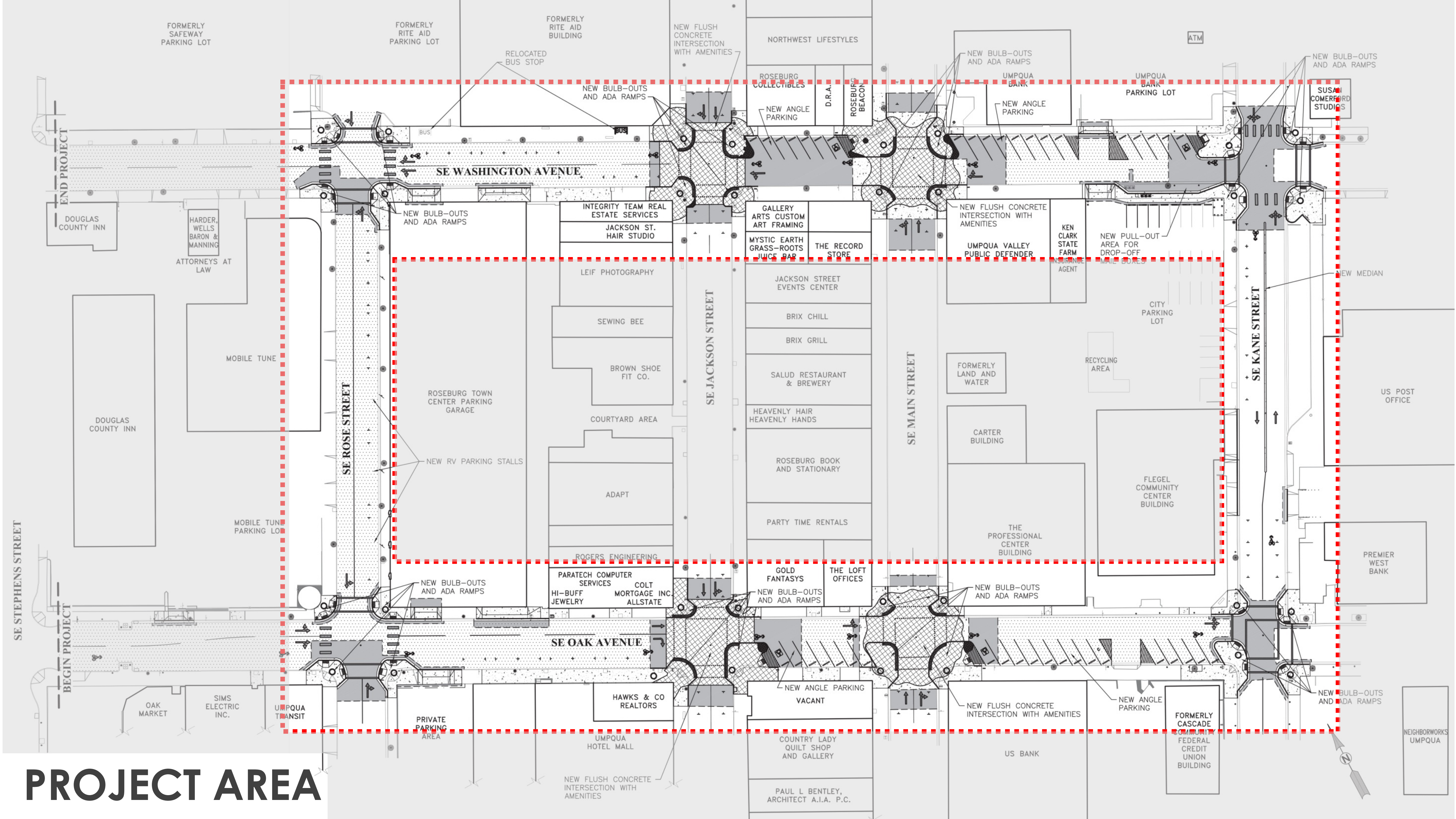
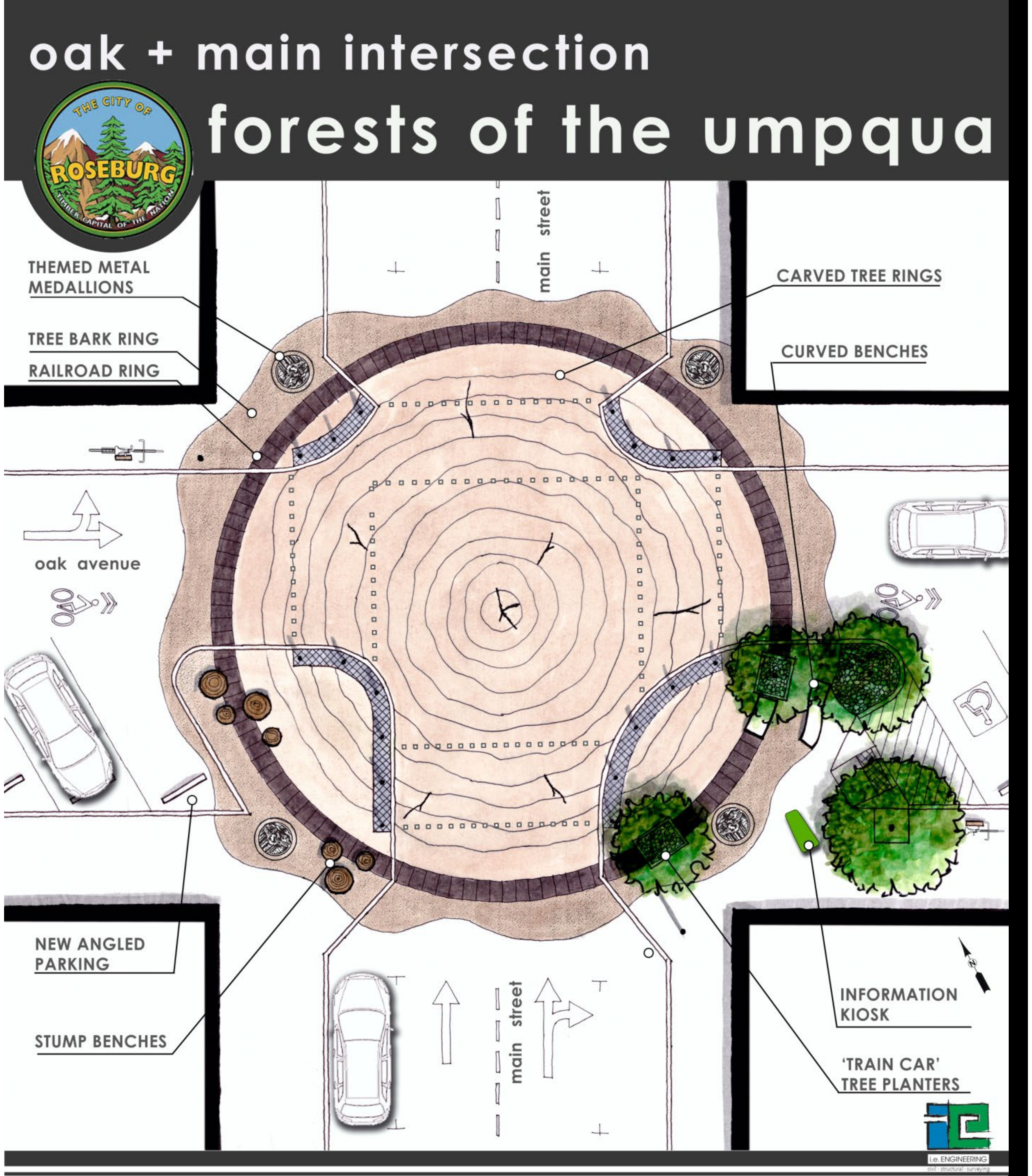
PROJECT AREA





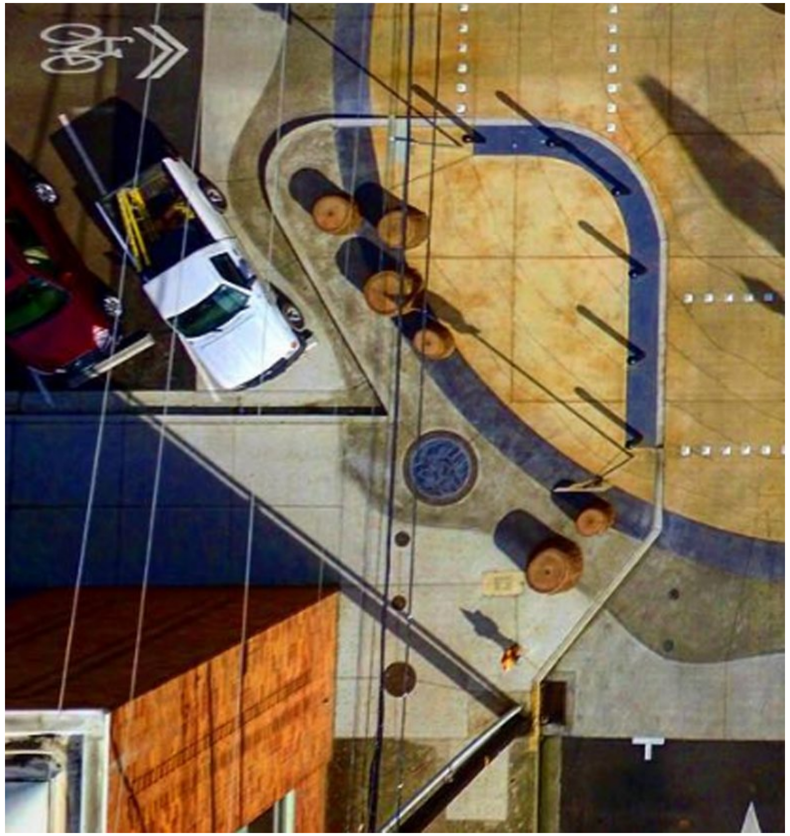
OAK + MAIN

FORESTS OF THE UMPQUA

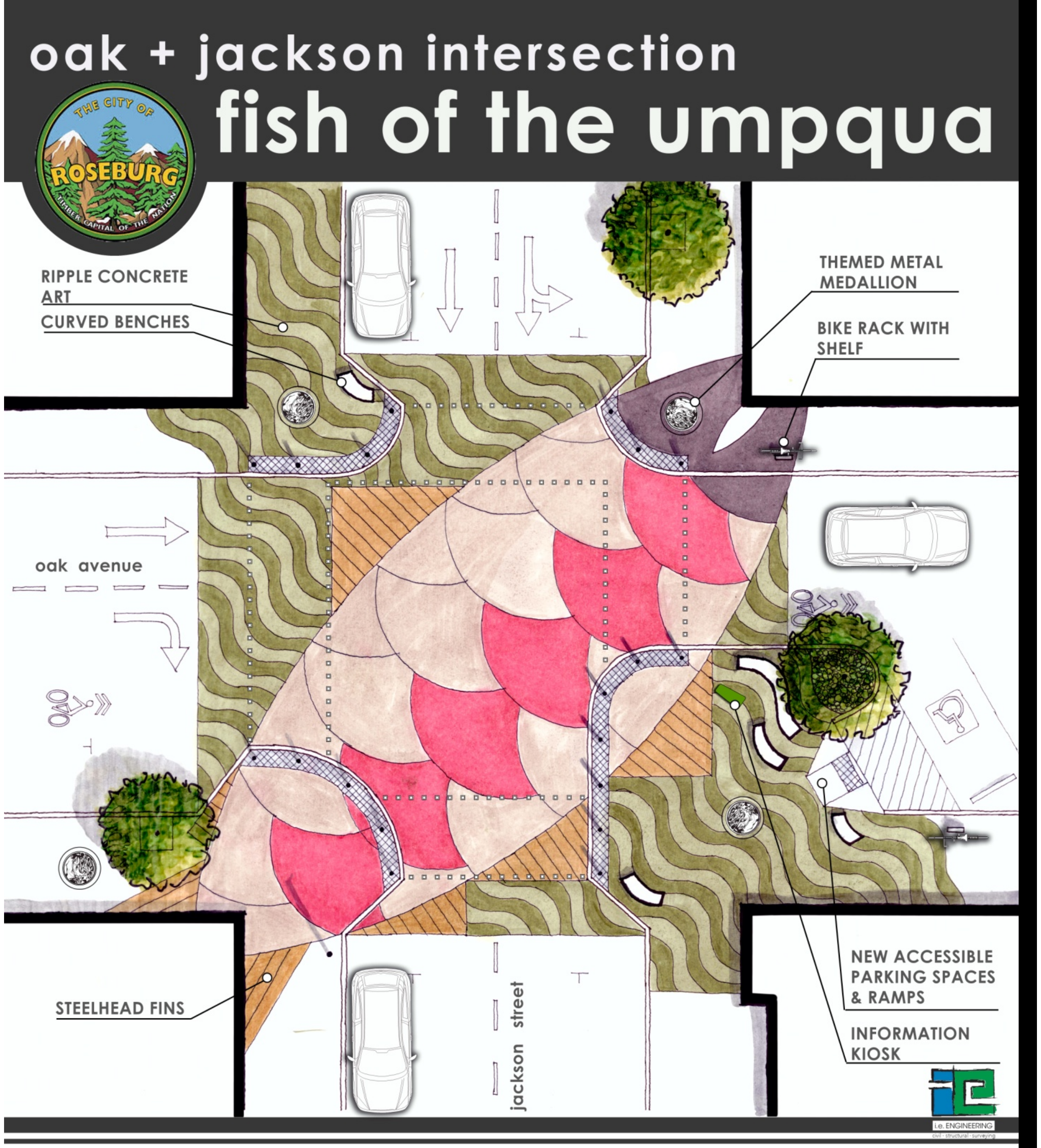
- EXPOSED AGGREGATE FINISH FOR TREE BARK (OUTER RING)
- BLACK INTEGRAL COLORED CONCRETE FOR THE RAILROAD TRACK RING, SCORED LINES FOR TRACK DETAIL
- BROWN INTEGRAL COLORED CONCRETE FOR THE INSIDE RINGS, RINGS SCORED AND DYED BLACK
- CONCRETE CURVED BENCHES
- DECORATIVE CONCRETE 'STUMP' BENCHES
- INLAYED DECORATIVE STAINLESS STEEL


The Mark V


Grill & Bar
BREAKFAST



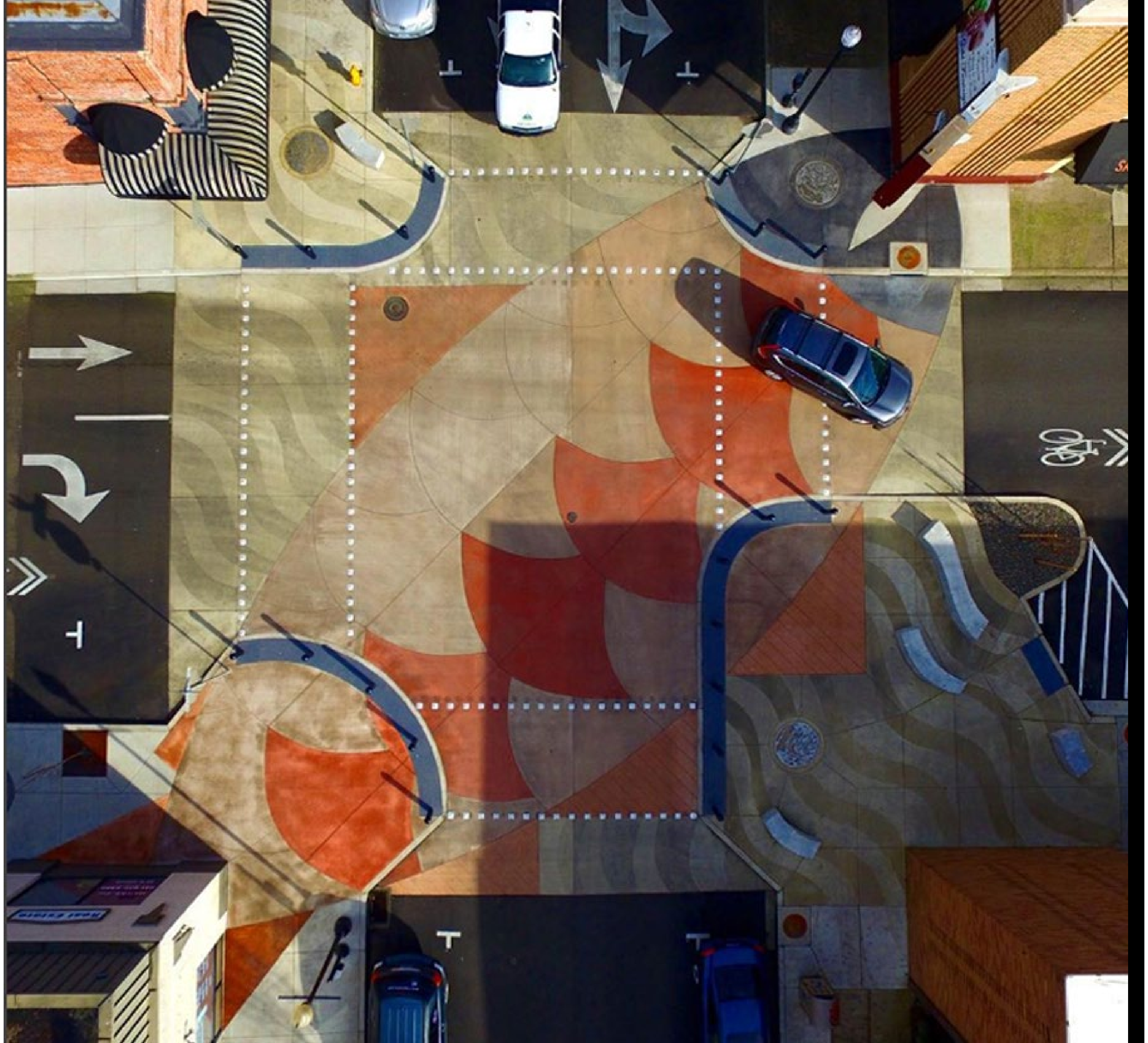
‘STUMP’ CONCRETE BENCHES



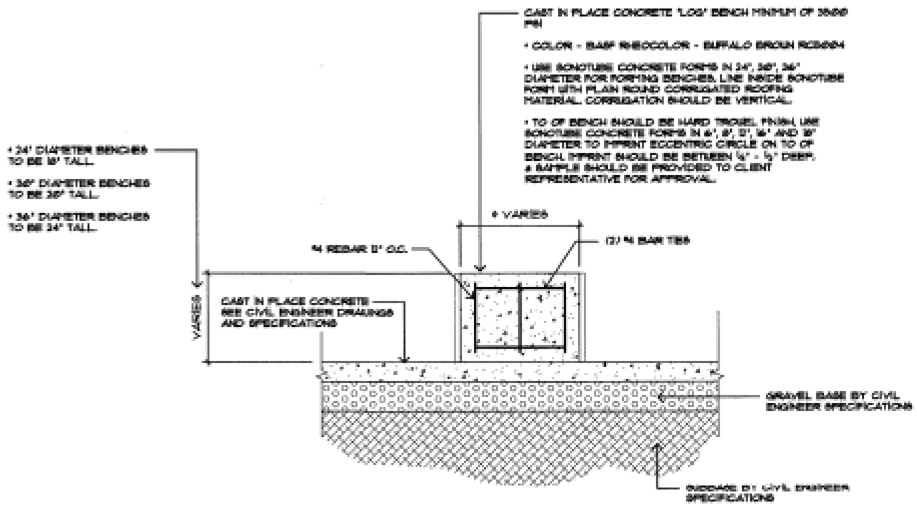
OAK + JACKSON

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




SALON VOLTA



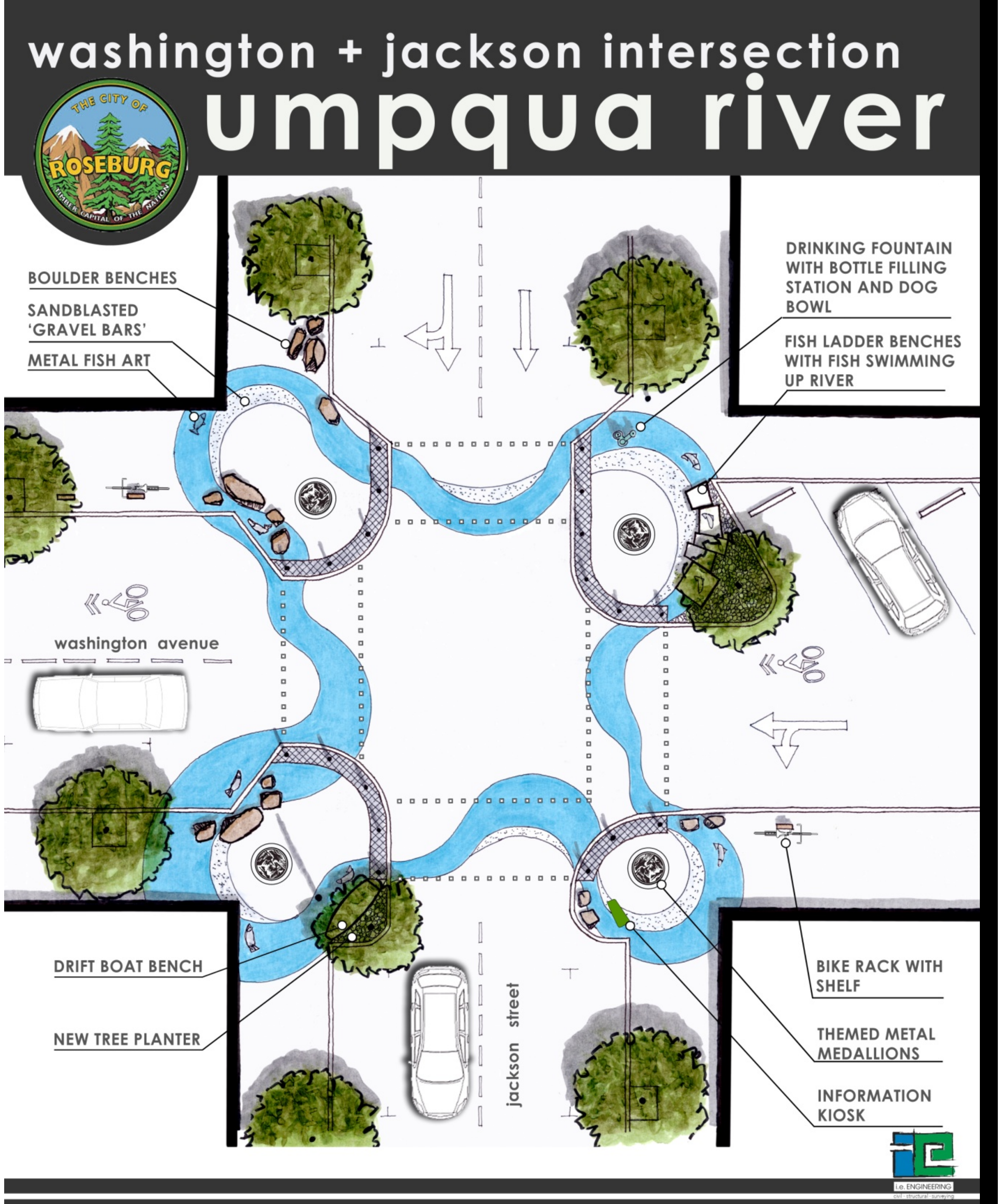
1 VARIED CURVE CONCRETE BENCH

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

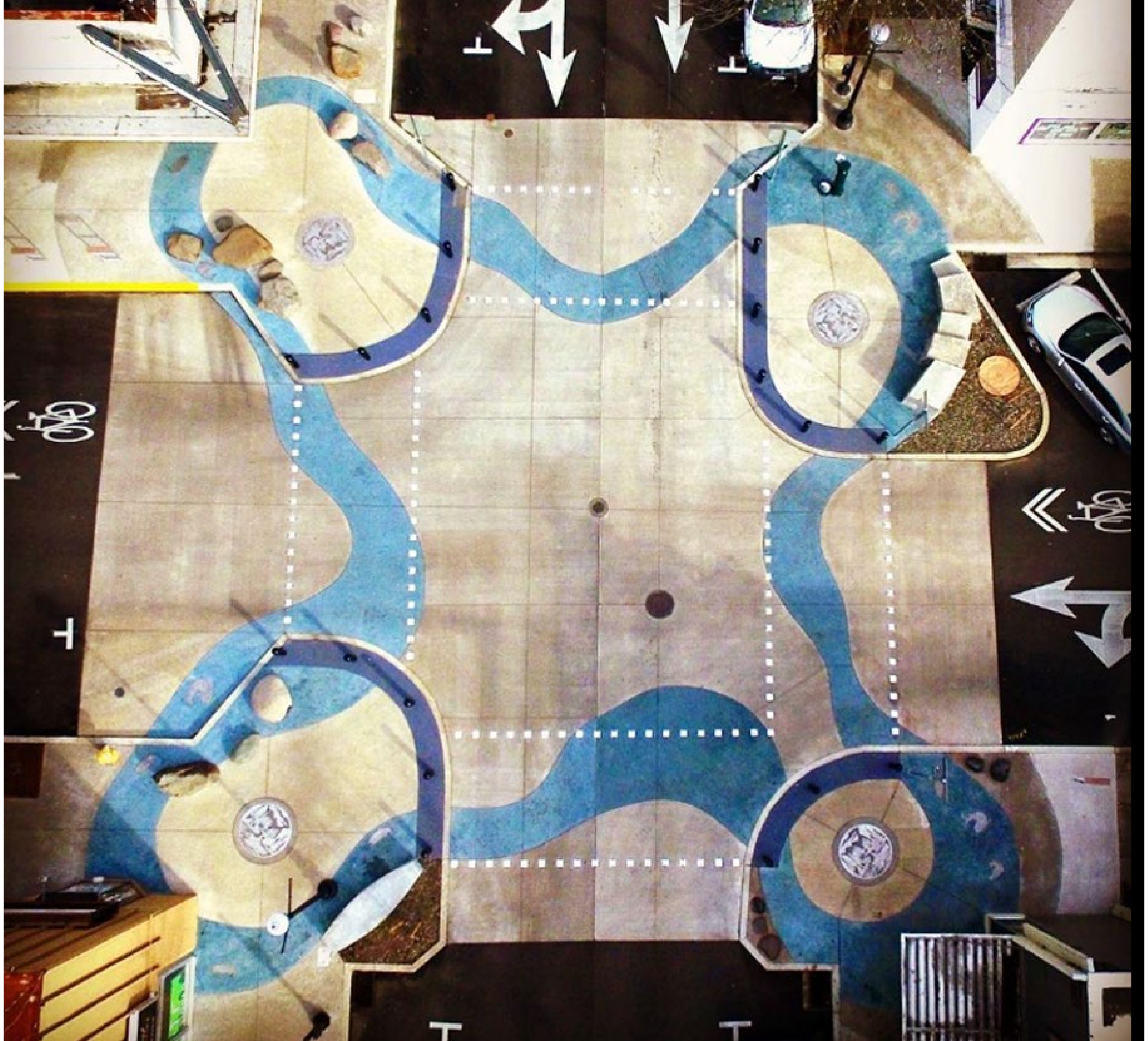


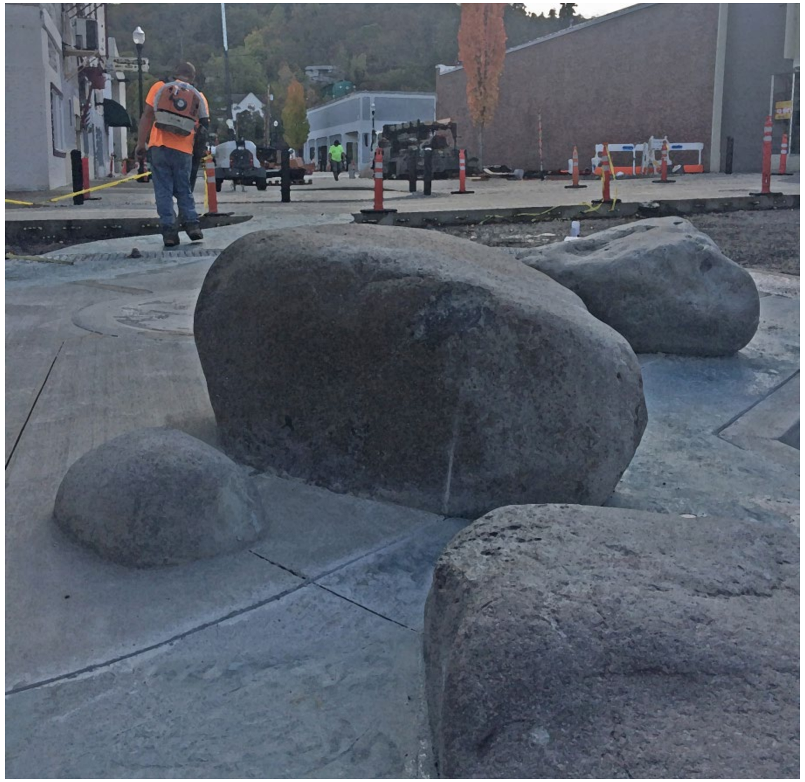


WASHINGTON + JACKSON

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/
- Roundaboutsusa.com
- www.ACPA.org
- https://www.wsdot.wa.gov/research/reports/fullreports/503.2.pdf

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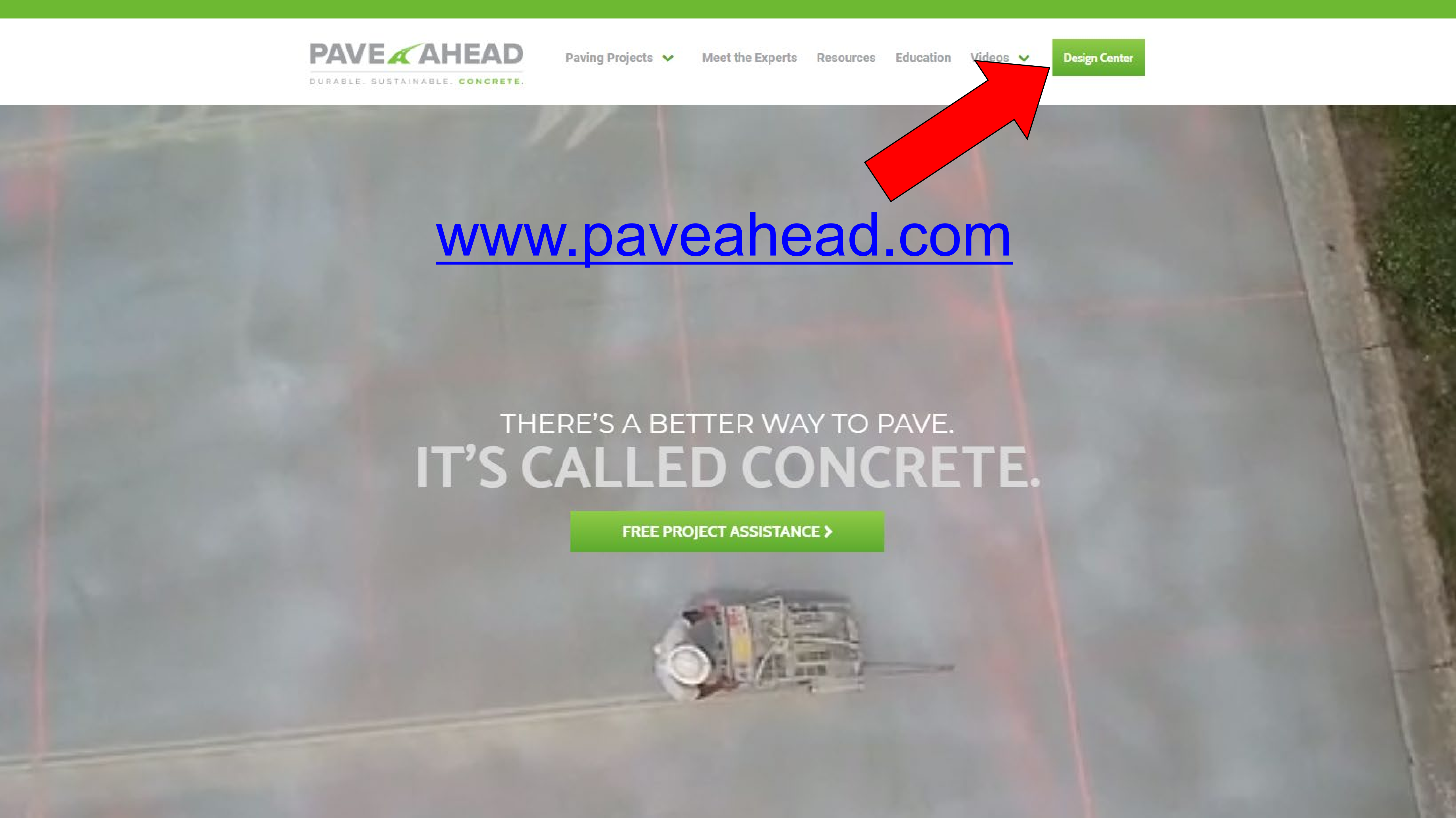
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- Cost comparisons including life cycle costs
- Specification review
- Ready mixed products:
  - Conventional concrete (full depth and overlays)
  - Pervious concrete
  - Roller compacted concrete
  - Cement slurry for full depth reclamation (FDR)

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CONCRETE PAVEMENT WEBINAR SERIES

2021 SERIES

Addressing Myths About Concrete Pavement | Thursday, May 20, 2021 2:00 – 3:00 p.m. ET

Some of the more common myths about concrete pavements will be reviewed and discredited. Myths that will be addressed include: is more cement better? Is steel in concrete pavement necessary? Does adding steel increase the load carrying capacity? Are dowels required at all joints? Is a thick aggregate base required to support heavy loads? When can concrete be opened to traffic? Does cracked pavement mean it has failed? Is concrete more expensive than asphalt? ...and more.

click here to register

Concrete Pavement Innovations | Thursday, May 27, 2021 2:00 – 3:00 p.m. ET

Early forms of concrete were used by the ancient Egyptians and a few millennia later by the Romans. Modern concrete has been in existence since 1824 and the first concrete street in American was built in Bellefontaine, Ohio in 1891. While the basic components of concrete (rock, sand, water, and cement) have not changed, there have been many material, design, and construction innovations that allow us to optimize its use. This webinar will focus on pavement innovations that positively impact the cost, environment, opening time, and ease of construction.

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NRMCA Pave Ahead Webinar Series:

More **Concrete Pavement** professional development:

- paveahead.com/education/
- Each Thursday beginning at 2:00 pm ET
- May 20th Addressing Myths About Concrete Pavement
- May 27th Concrete Pavement Innovations
- Jun 03rd Characterizing Traffic Streams for Pavement Design
- Jun 10th Ready-Mixed Products for Municipal Airport Runways and Taxiways
- Jun 17th Concrete Pavement Intersections
- Jun 24th Controlled Low Strength Material (CLSM) in Transportation Projects

Recordings available for all webinars!

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Portland Cement Association Webinar Series:

- www.cement.org/events/pca-infrastructure-webinar-series
  - Each Wednesday beginning at 11:00 am ET
  - Apr 28th Integrated Pavement Solutions with Portland Cement
  - May 5th Cement Modification and Stabilization of Soils
  - May 12th Sustainable Pavements with Full-Depth Reclamation
  - May 19th Design of Cement-Stabilized Bases
  - May 26th Roller-Compacted Concrete for Pavements

  Geotechnical Solutions with:
  - Jun 2nd Lightweight Cellular Concrete
  - Jun 16th Sustainability of Cement and Concrete
  - Jun 30th Cement-Based Water Resources Applications
  - Jul 7th Applications of Roller-Compacted Concrete for Dams
  - Jul 14th Design and Testing of Roller-Compacted Concrete

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ACPA & CP Technology Center Webinar Series:

- cptechcenter.org/events/upcoming-cp-tech-webinars/
- Monthly on Tuesdays beginning at 1:00 pm ET
- May 11th An Introduction to Recycled Concrete Aggregate (RCA)
- Jun 15th Advancement in DOT Uses for Roller Compacted Concrete
- Jul 13th Innovation with Concrete Overlays for DOT's and Municipalities
- Aug 10th Resiliency–Proper Planning Prevents Disaster and Aids in Crisis Management–Concrete Perspective
- Sep 14th Advancements in Performance Engineered Mixtures (PEM's)
- Oct 12th Sustainability, Recycle and Bicycle

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Thank You!

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