Implementation of Performance Specifications for Concrete at the Illinois Tollway

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Illinois Tollway System

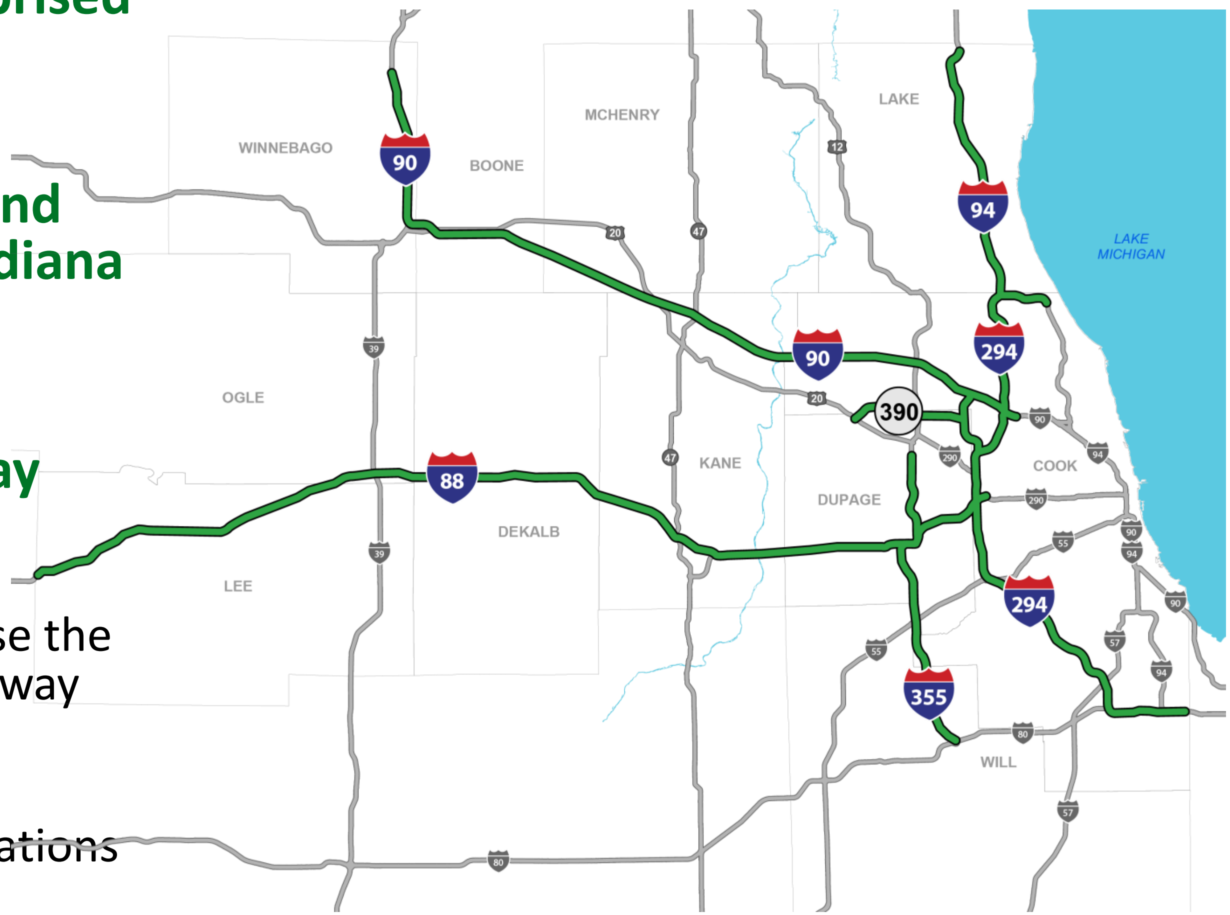
292-mile system comprised of five tollways

Opened in 1958 as a bypass around Chicago to connect Indiana and Wisconsin

Carries more than 1.6 million vehicles per day

User-fee system

- Only customers who use the Tollway pay for the Tollway
- No state or federal tax dollars used for maintenance and operations



Move Illinois Program

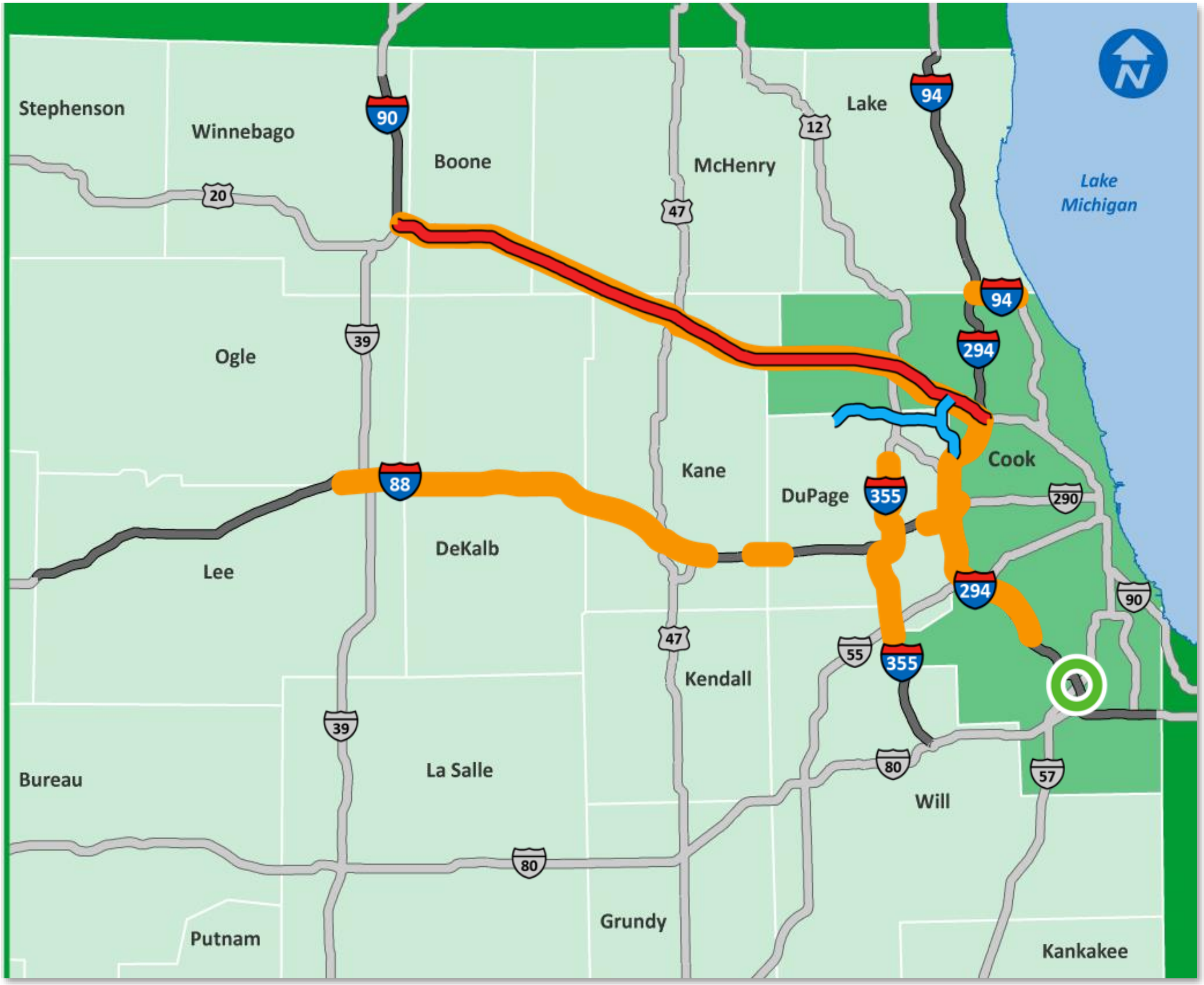
ADDRESS EXISTING SYSTEM NEEDS

JANE ADDAMS MEMORIAL TOLLWAY
$2.5 billion

ELGIN O'HARE WESTERN ACCESS
$3.4 billion

I-294/I-57 INTERCHANGE
$719 million

INTERCHANGES AND OTHER EMERGING PROJECTS



Performance-Engineered Mix (PEM) Design Specifications

Goals For PEM Designs

Strength

- Adequate, but not excessively over-designed

Durability

- Freeze/thaw
- Shrinkage
- Chloride penetration resistance
- Alkali-silica reaction (ASR)

Constructability

- Batching
- Workability

Sustainability

- Increased supplementary cementing material (SCM) usage
- Recycled material

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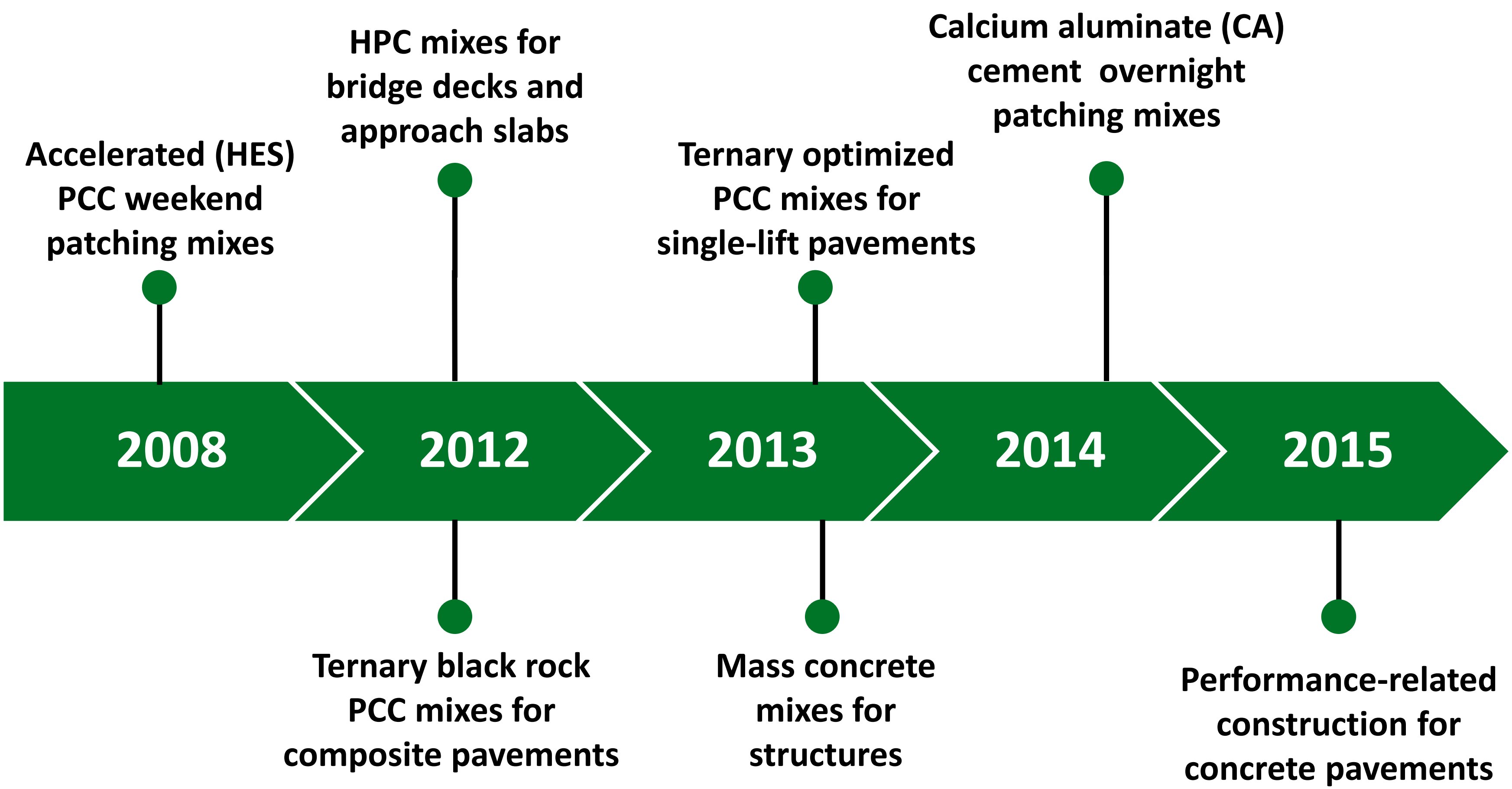
Timeline Of PEM Specifications And Designs At The Tollway



Tollway Mix Performance Requirements

Parameter	Test Method	Mix Types
Compressive strength	AASHTO T 22	All
Flexural strength	AASHTO T 97	Pavement only
Slump	AASHTO T 119	All
Plastic air	AASHTO T 152	All
Length change	AASHTO T 160	All except pavement and CA
Ring shrinkage	ASTM C 1581	HES, HPC, CA
ASR	AASHTO T 303	All except CA
Hardened air	ASTM C 457	All except CA
Chloride penetration	AASHTO T 277	HES, HPC

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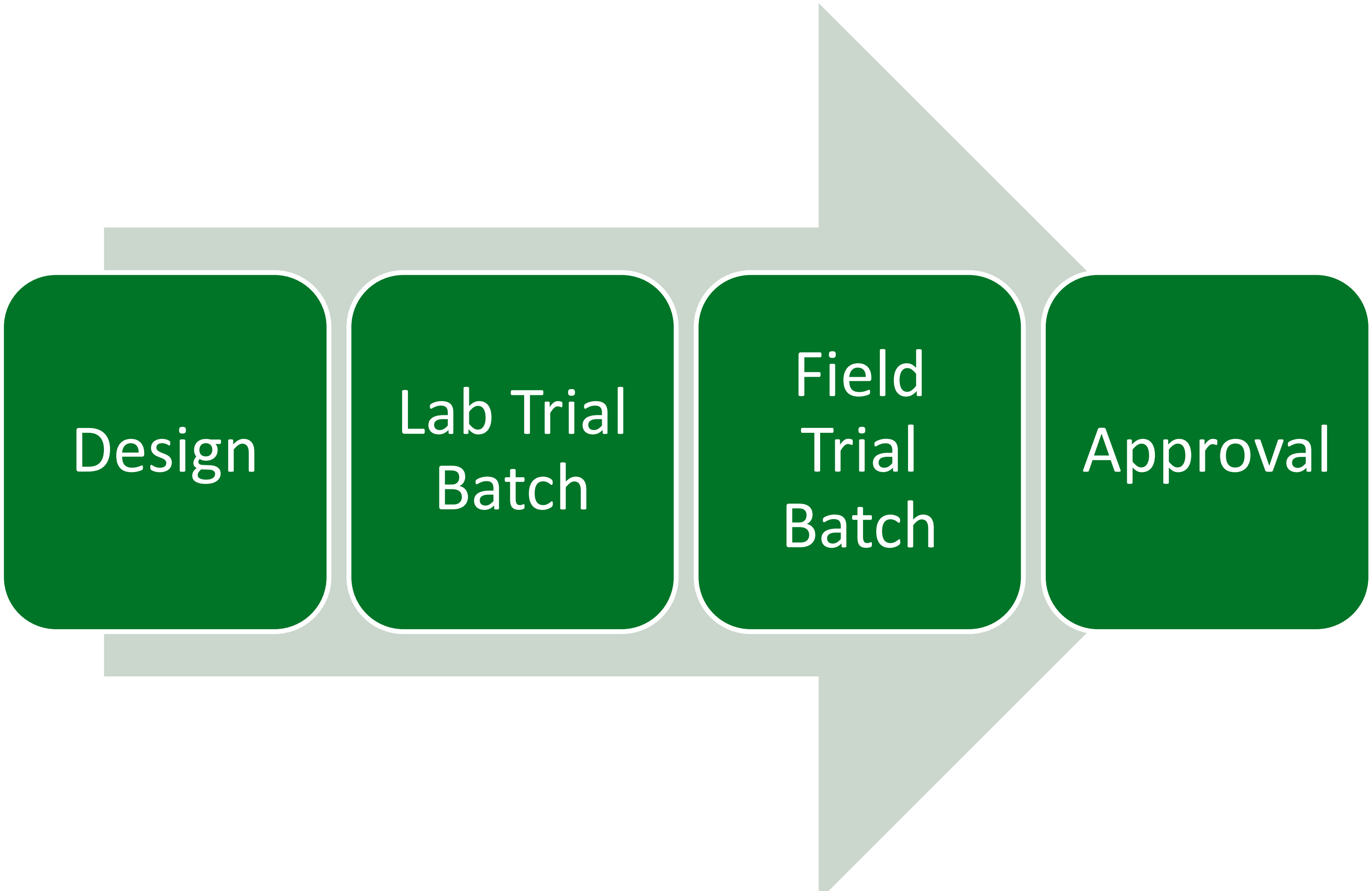
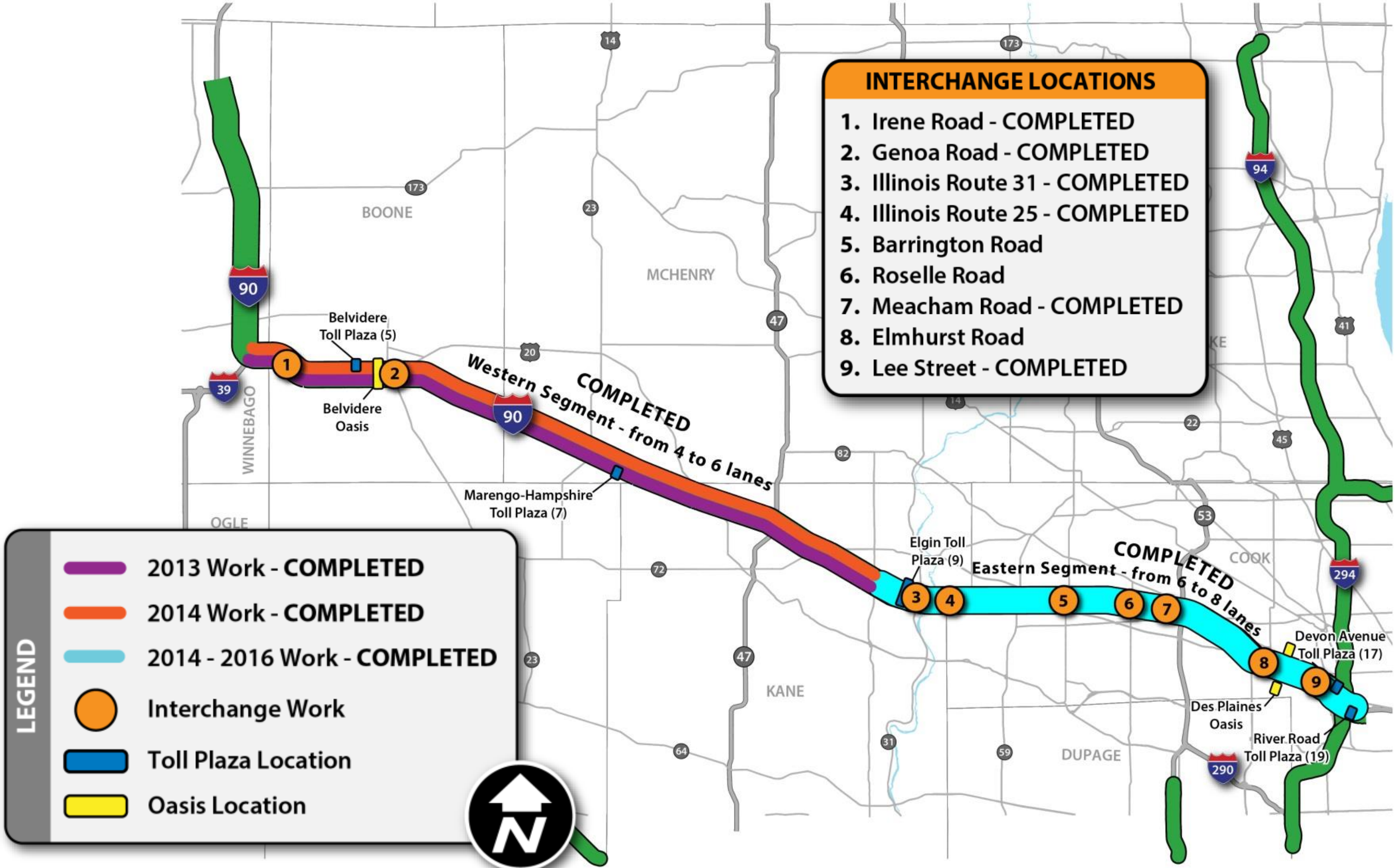
Mixture Design And Approval Process



Case Studies

Jane Addams Memorial Tollway (I-90) Rebuilding and Widening Project



High-Performance Concrete (HPC) for Bridge Decks

HPC Concrete Requirements

Proportioning

- Material from approved sources
- ASR
  - Maximum total alkali content contributed by Portland cement ≤ 4 lb/yd^3 or test
- Shrinkage
  - 1.5 gal./cy. SRA and < 605 lbs./cy total cementitious or ring shrinkage
- Water/cementitious ratio during production
  - Design – 0.03, + 0.00

Properties

- Compressive strength
  - 4,000 psi at 14 days
- Plastic air
  - Design ± 1.5 percent, minimum 4.0
- Slump
  - 3 – 8 inches
- Freeze/thaw or hardened air (trial batch)
- Slump loss (trial batch)
- Linear shrinkage (trial batch)
- Chloride penetrability (trial batch)

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Prairie Material Tollway HPC

Material	Quantity
Portland cement	335 lbs./cy.
Fly ash – class C	90 lbs./cy.
Slag cement	150 lbs./cy.
Water	230 lbs./cy.
Coarse aggregate (CM 11)	1700 lbs./cy.
Lightweight fine aggregate	395 lbs./cy.
Fine aggregate (FM 02)	860 lbs./cy.
Water reducer – type A	4 – 6 oz./cwt.
Water reducer – type F	1 – 6 oz./cwt.
Air entrainment	0.4 – 3 oz./cwt.
Retarder	1 – 6 oz./cwt.
Shrinkage reducing admixture	0.5 gal./cy.

w/cm – 0.40

Design air – 6.5 percent

Design slump – 5.0 in.

Ternary Optimized (TL) Concrete for Pavement

Slip-Form Class TL Concrete Requirements

Proportioning

- Material from approved sources
- Ternary
  - 35 to 50 percent SCM
- Optimized gradation
  - 2 coarse aggregates
  - Virgin
- ASR
  - Maximum total alkali content contributed by Portland cement ≤ 5 lb/yd^3
- Water/cementitous ratio during production
  - Design – 0.03, + 0.00

Properties

- Compressive strength
  - 2,500 psi at 3 days
  - 3,500 psi at 14 days
  - 6,500 psi at 28 days (target)
- Flexural strength (trial batch)
  - 650 psi at 14 days
- Hardened air (trial batch)
  - Spacing factor ≤ 0.008 in.
  - Specific surface ≥ 600 in^2/in^3
  - Total air content ≥ 4.0 percent
- Plastic air
  - 5.5-8.0 percent
- Slump
  - ¼” slump edge next to adjacent pavement otherwise ½” slump edge

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Terrell Materials Class TL

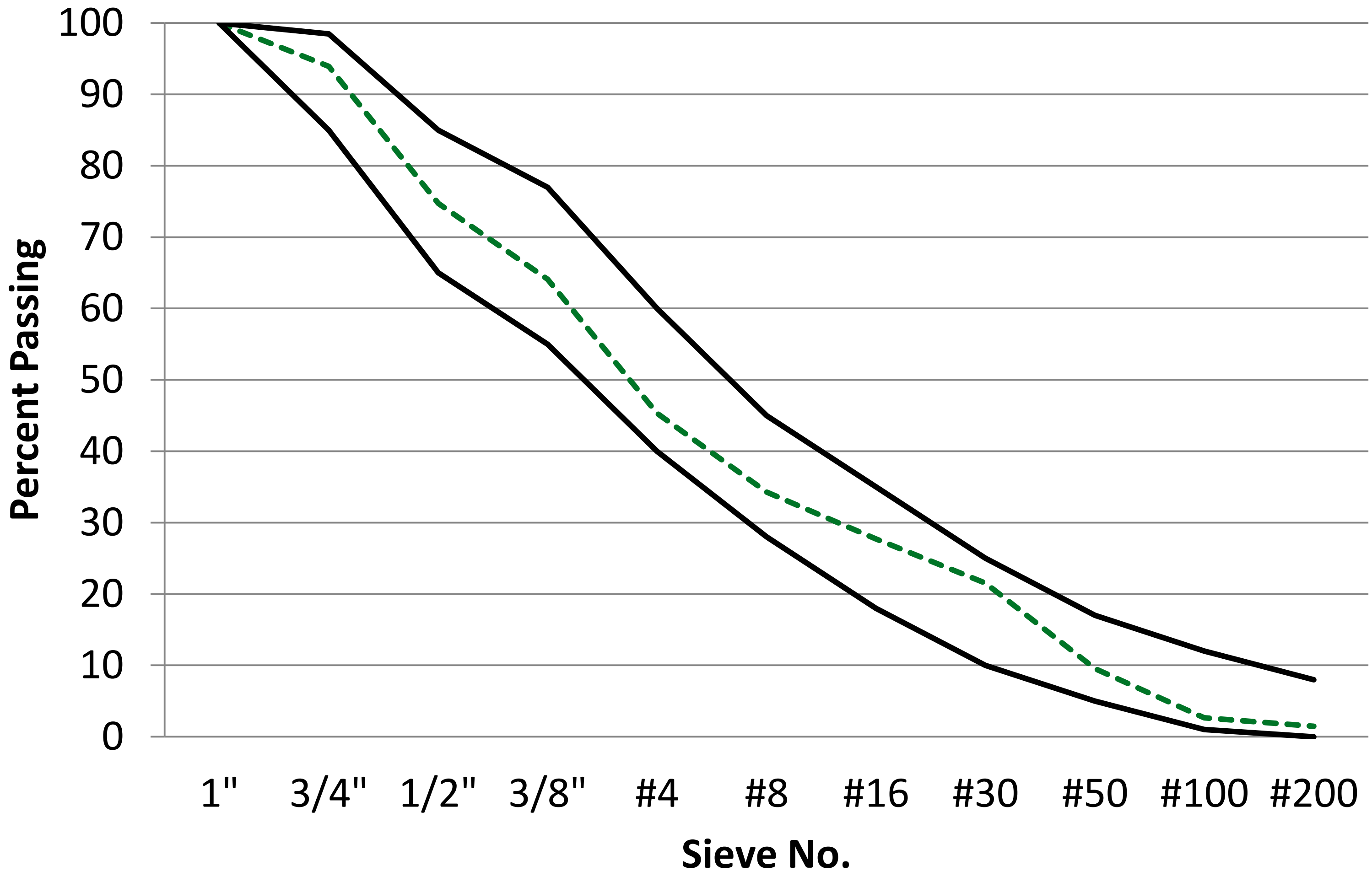
Material	Quantity
Portland cement	303 lbs./cy.
Fly ash – class F	98 lbs./cy.
Slag cement	99 lbs./cy.
Water	210 lbs./cy.
Coarse aggregate (CM 11)	1650 lbs./cy.
Intermediate aggregate (CM 16)	428 lbs./cy.
Fine aggregate (FM 02)	1186 lbs./cy.
Water reducer – type A	3 – 5 oz./cwt.
Air entrainment	0.5 – 3 oz./cwt.
Retarder	2 – 5 oz./cwt.

w/cm – 0.42

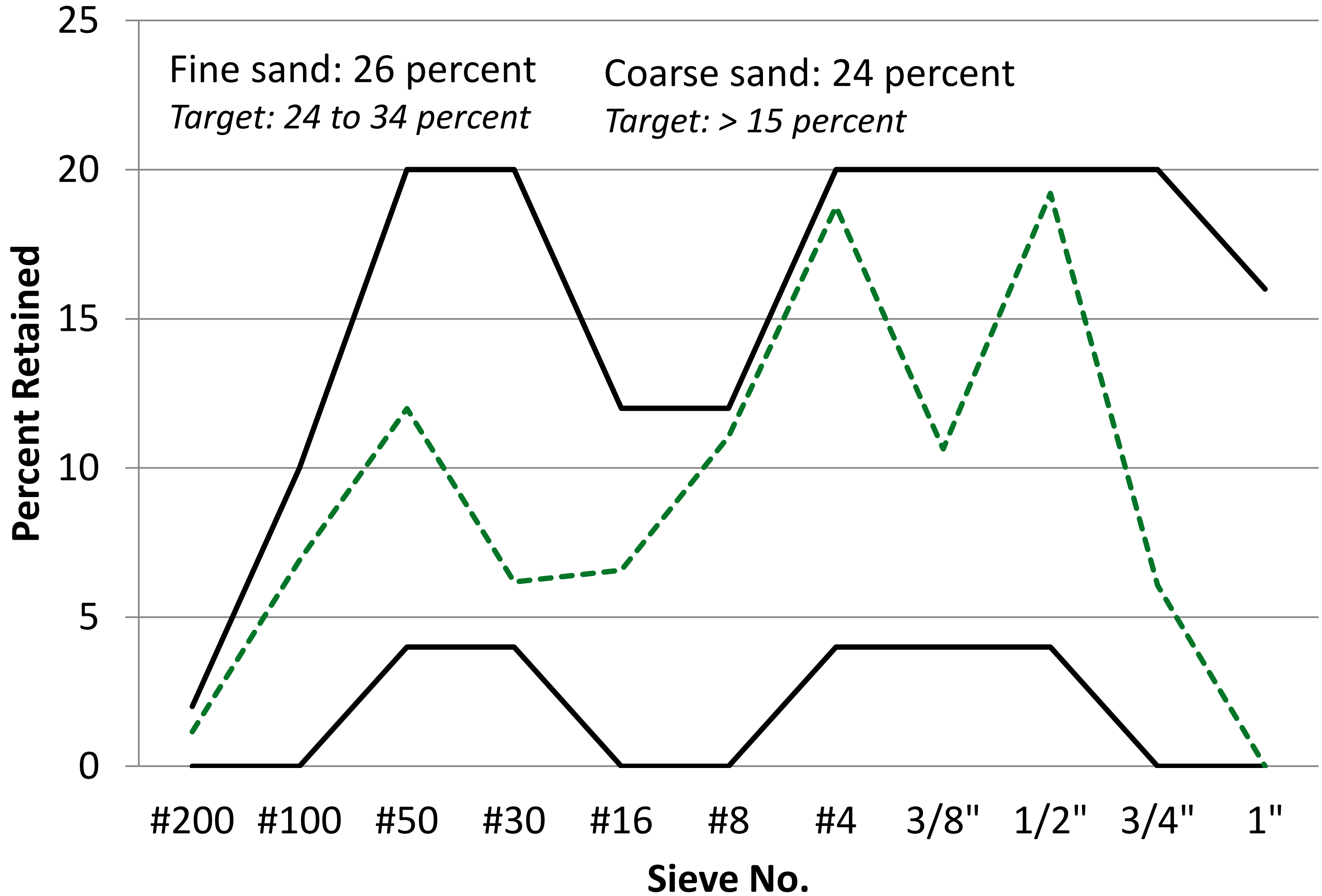
Design air – 6.5 percent

Design slump – 1.5 in.

Class TL Combined Gradation



Tarantula Curve



Summary And Future Changes

Performance Vs. Prescriptive

Reduced cement content

- Bridge deck
- Pavement

Increased SCM usage

- More ternary mixtures
- Higher replacement percentages

Focus on durability

- Chloride penetration resistance
- Shrinkage
- Workability

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Successes To Date With Performance Specifications

Ternary black rock mixes for composite pavement

- 2013/2014
- Approximately 200,000 cubic yards

Ternary optimized pavement mixes

- 2015/2016
- Approximately 500,000 cubic yards
- Most for performance-related construction specifications

HPC for bridge decks

- Used since 2013 for more than 100 bridge decks
- No placement or finishing issues
- Significantly reduced early age cracking in bridge decks

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Lessons Learned

Stakeholder buy-in

- Agency
- Contractor
- Concrete producer

Material source changes

- Portland cement
- Fly ash
- Aggregate

Constructability

- Contractor risk/reward

New PCC Performance Measures Possibly Coming

Resistivity (bulk) measurements for formation factor

- To replace the chloride penetration test (AASHTO T 277)
- To be a general measure of durability

Super air meter or rapid/easier, hardened air tests

- To replace current hardened air test (ASTM C 457)
- Possibly to replace plastic air tests as well

Box or V-Kelly test for workability (only for designs)

- Box test currently used for trial batches

Service life for bridge decks

- Use chloride penetration resistance or corrosion inhibitor while maintaining crack-resistance to achieve 50-year service life with epoxy coated reinforcement

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Questions?

Thank You