Design and Construction of Long-Life (High-Performance) Concrete Pavements: Current Practices and Needs

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Prepared for the National Concrete Consortium Meeting
Savannah, GA – April 6, 2010

What is High-Performance Concrete Pavement?

- What it's not: "high-strength" concrete pavement
- What it is: A combination of materials, mix design, structural design, and construction activities selected and implemented to ensure acceptable long-term pavement performance.

It's A System!

U.S. Definition of Long-Life Concrete Pavements

- Service life of original PCC surface = 40+ years
- No premature failures or materials-related distress
- Reduced potential for cracking, faulting, spalling, etc.
- Maintain desirable ride and surface texture characteristics with minimal M&R

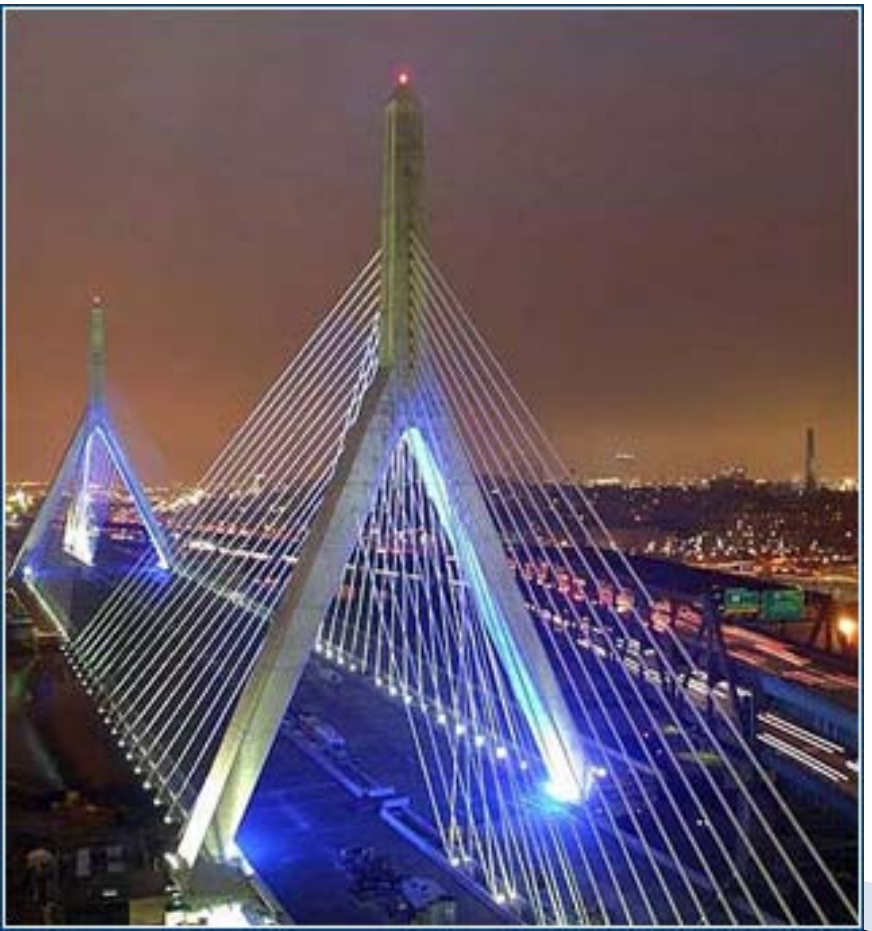
Design and Build it Right

&

Stay Out As Long As Possible

Why Build Long-Life (High-Performance) Concrete Pavements?

- Match Performance of other Transportation System Components to Minimize Future Congestion



75- and 100-year bridge design lives are becoming increasingly common

Why Build Long-Life (High-Performance) Concrete Pavements?

- Match Performance of other Transportation System Components

- Economic Justifications
  - MnDOT example: increase design life to 60 years (from 35)
    - increased pavement cost by 16.5%
    - Increased overall project cost by 3.4%
    - reduced estimated LCC by 5%.

Why Build Long-Life (High-Performance) Concrete Pavements?

- Match Performance of other Transportation System Components (75-100 year bridge designs)
- Economic Justifications (MnDOT example)
- Sustainability (the new driving force for everything!)

Longevity means…

Less-frequent reconstruction

- Lower consumption of raw materials
  - Cement, aggregates, steel
- Lower energy consumption
  - Raw material processing
  - Rehab and reconstruction
  - Congestion

Longevity means… (cont.)

- Reduction in pollutants
  - Manufacturing, construction, congestion
- Lives saved
  - Rigid structure, profile durability
  - Infrequent construction zones
- All these translate into real economic benefits…

Longevity is a crucial element of sustainability!

Why Build Long-Life (High-Performance) Concrete Pavements?

- Match Performance of other Transportation System Components (75-100 year bridge designs)
- Economic Justifications (MnDOT example)
- Sustainability
- Public Demand
  - Traditional design: service life = 20-30 years
  - Congestion has lead to public demand for M&R-free highways

HPCP General Design Concepts

- Address each potential failure mechanism
  - Structural (layer materials and thicknesses, panel dimensions, dowel size and spacing, etc.)
  - Materials
    - Concrete (mix proportions, air void system, permeability, aggregate durability, etc.)
    - Steel (corrosion protection)
    - Foundation (drainage, erosion-resistance, etc.)
  - Construction (compaction, curing techniques/materials and timing, sawing, surface texture design/construction, dowel alignment, etc.)

Example: Minnesota HPCP

- Used on all urban interstate-type pavements

- Original design features included:
  - Increase structural design life (60+ years).
  - Design maintenance-free drainage system.
  - Use more durable concrete (aggregate and paste)
  - Improve dowel bars (w.r.t. corrosion resistance).

Structural Modifications

- Increase design life from 57 M to 100 M ESALS (approximately 60 years)
  - Resulting increase in pavement thickness: 1 inch!
  - Design thickness increased from 315mm to 340mm
- Use 4.6-m (15-ft) panel length
  - (now Mn/DOT standard)
- No open graded base and edge drains!!
  - Eliminate the need for maintenance
- Used 600 mm of clean granular material
  - Limit material passing #10 sieve to having less than 10% retained on the #200

Concrete Material Modifications

- Require use of only the most durable aggregate sources.
  - Limit limestone content of gravels to 20%, with incentives to reduce to 10%
  - Incentives for use of Class A aggregate (quarried igneous, metamorphic, e.g., granite, basalt)
- Require use of well-graded aggregate (without incentive)
  - Reduced paste (more economical), improved workability without using excessive amounts of water reducer

Concrete Material Modifications

- Increase plastic air content
  - Standard: 6.5% +/- 1.5%
  - HPCP: 8.5% +/- 1.5%.
- Require 28-day RCP of <2500 coulombs.
- W/(C + P) < 0.40
  - Now standard Mn/DOT spec requirement, with incentives to 0.35
- Require poly-alpha-methyl-styrene (PAMS) cure compound

Design and Materials Modifications - Joints

- Increase dowel length from 15 in to 18 in
- Required solid or clad stainless steel (316LN) dowels
  - Current MnDOT HPCP Specification allows several additional dowel types, including:
    - Zinc alloy-clad
    - Hollow 316L stainless steel pipe (Sched 40, 1.25-in)

So … who is building HPCP?

Minnesota, Wisconsin, Michigan, California, Washington and …???

Why not more?!?

Why not more?

Many lack guidance and experience for developing HPCP design and construction specs

Current spec development approaches:

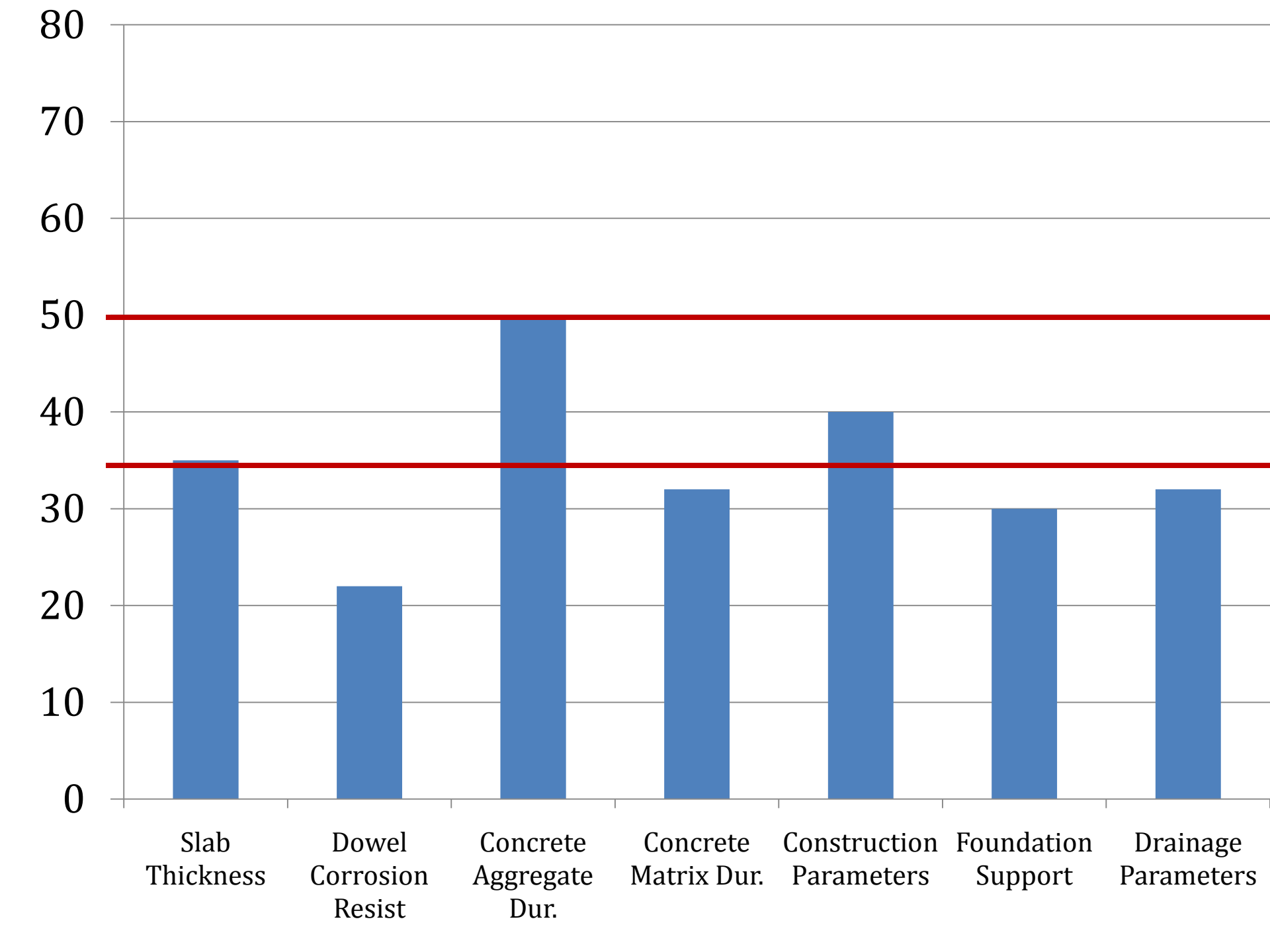
- "Cafeteria approach" based on limited knowledge, shared experiences, budget restrictions, etc.
- Possible results:
  - HPCP
  - "HPCP" that isn't.
    - Additional investment without significantly extended life
    - Retreat from HPCP

There is a need for guidance in developing designs and specs that result in HPCP systems.

HPCP General Design Concepts

- Address each potential failure mechanism
- Matched design performance for design components (optimized design)

Specific HPCP requirements can be project-specific!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Slab Thickness
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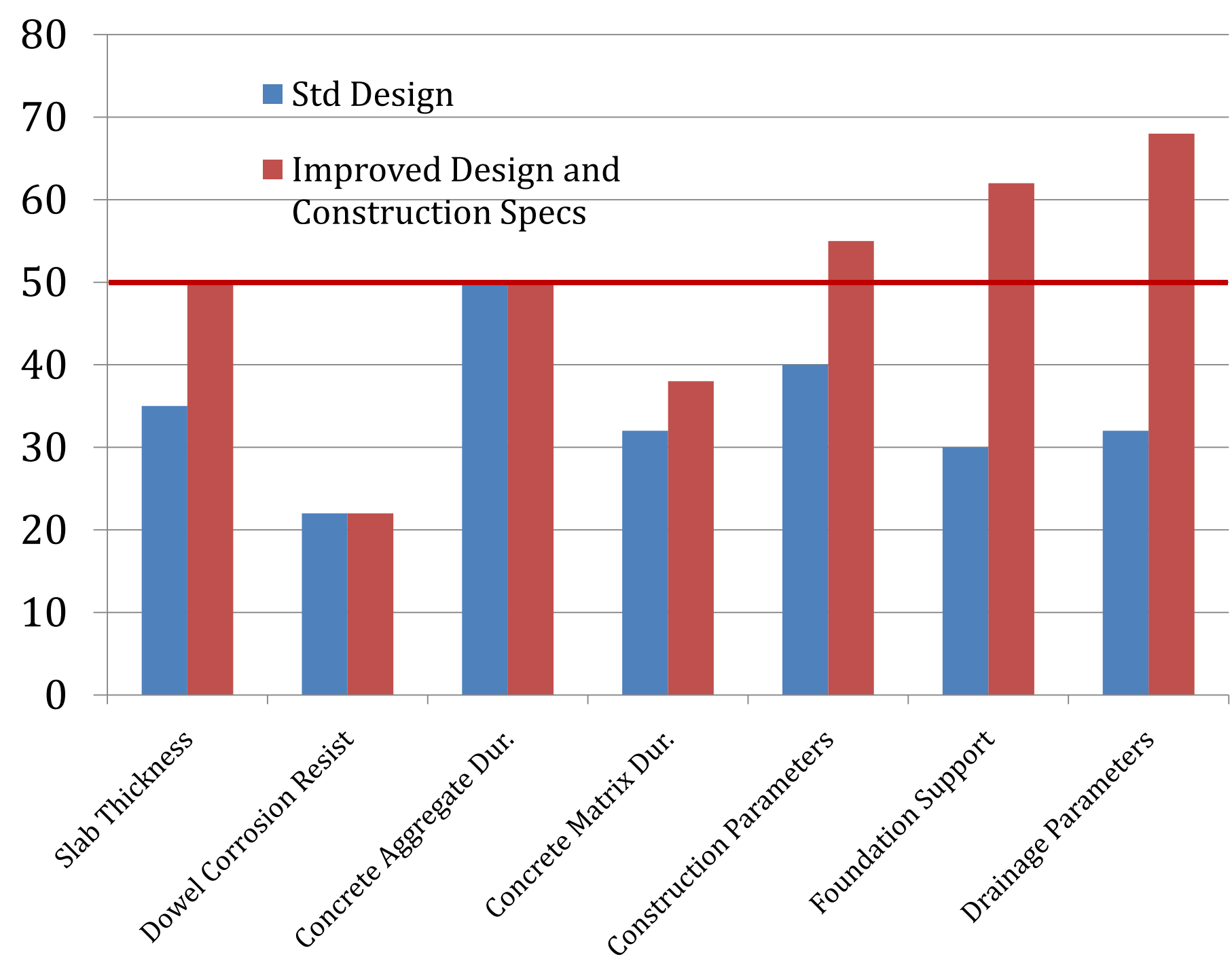
Concrete Matrix Dur.
Construction Parameters
Foundation Support
Drainage Parameters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Foundation Support
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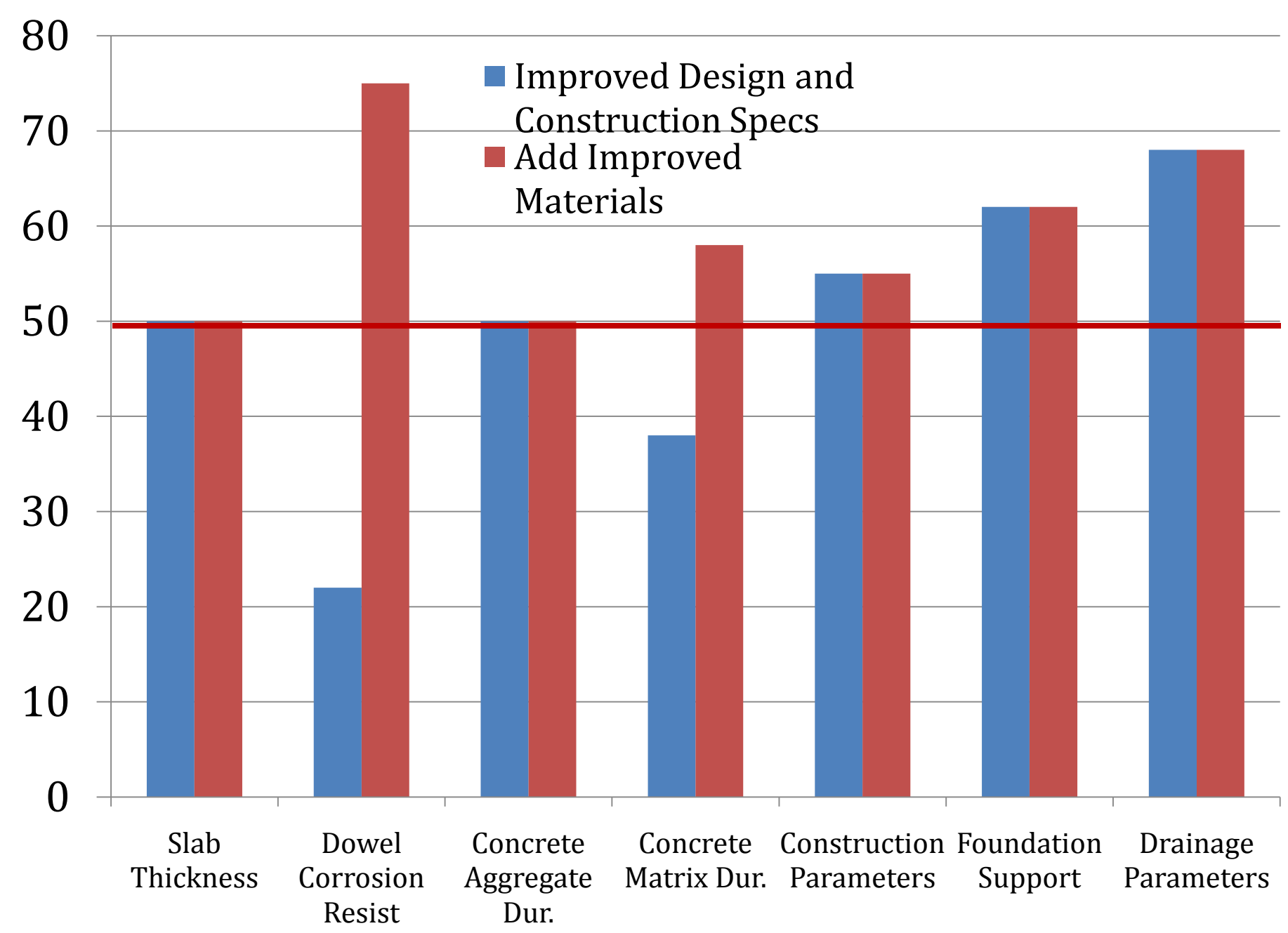
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Improved Design and Construction Specs
Add Improved Materials
Slab Thickness
Dowel Corrosion Resist
Concrete Aggregate Dur.
Concrete Matrix Dur.
Construction Parameters
Foundation Support
Drainage Parameters

What do we need?

- Guidance in developing LLCP specifications for design, materials and construction – a standard or recommended approach
  - Recommendations based on MEPDG + accumulated performance and cost experience of states, provinces, and other countries
  - Guidance on matching design of components for overall system performance
  - Documentation of cost-effectiveness of overall design
    - Evaluate increased initial costs (in context of pavement, project costs) vs. benefits of reduced M&R, lower user costs, increased performance levels

Discussion Questions:

- Isn't it time to move HPCP/LLCP to the front burner?
  - (Answer: Yes! HPCP is a tool that every highway agency should have at their disposal, especially with increased and continuing emphasis on sustainability and green construction. Many agencies haven't accessed this tool because they don't know which tool to buy.)

Discussion Questions:

- What is the best strategy for developing standard guidance concerning HPCP/LLCP?
  - NCC?
  - AASHTO?
  - NCPTC Track 8 (currently dormant)?
- How do we start?
  - Survey/evaluation of current practices (including FHWA LLCP Conference Proceedings)?
  - Scan previous studies on cost-effectiveness of various design features, lab studies of various materials, etc.?
  - New research/analyses?

Acknowledgments

The following individuals and companies provided information and other material used in the preparation of this presentation:

- Federal Highway Administration
- Leif Wathne, the American Concrete Pavement Association
- Shiraz Tayabji, Fugro Consultants, Inc.
- Jarden Zinc Products, Inc.
- Tom Burnham and other staff at the Minnesota Department of Transportation
- David Rettner, American Engineering Testing, Inc.

Thank you

Let’s Talk and Get Things Started!