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Considerations for Sustainable Long-Life Concrete Pavements

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Presentation Outline

- Introductory

- Top 3 Design Considerations
  - Focus on Design Features
  - Joint Load Transfer
  - PCCP Support Condition/Drainage

- Top 3 Construction Considerations
  - Construction Quality
  - Concrete Management – from Plant to Curing
  - Contractor Process Control

- Top M&R Consideration
  - Timely M&R
Concrete Pavements
– A Mature Technology in the Year 2013

Resulting from improvements in design, construction, material & restoration technologies

1920’s Life – 10+ years (?)

1960’s Life – 20+ years

2000’s Life – 40+ years

2015 (?) on Life – 40+ years
Current US Expanded Definition of Long-Life Concrete Pavements

- Original PCC surface service life – 40+ years
  - The next frontier – 60+ years service life
- Pavement will not exhibit premature failures and materials related distress
  - Pavement failure should be a result of traffic loading
- Pavement will have reduced potential for cracking, faulting & spalling, and
- Pavement will maintain desirable ride and surface texture characteristics with minimal intervention activities to correct for ride & texture, for joint resealing, and minor repairs
So, What Are the Design Targets?

- Pavements need to accommodate
  - 40 to 60+ annual seasonal changes
  - 15,000 to 20,000 daily temperature variations in the slab (curling)
    - And, joint openings/closings
  - 100 to 300 million truck loadings
    - Peak slab stresses & corner/joint deflections
  - 200 to 600 million axle loadings at joints
    - Same no. of corner deflections
    - Same no. of the loads transferred by the critical dowel bars
  - And, little or no maintenance & restoration activities
What Are Our Expectations of Our Concrete Pavements?

- At end of 40 year service life
  - Or, 60+ years service life – the next frontier

<table>
<thead>
<tr>
<th>Distress</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Cracked Slabs, %</td>
<td>10 - 15</td>
</tr>
<tr>
<td>Faulting, in.</td>
<td>0.125 (?)</td>
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<tr>
<td>(Consider grinding when threshold is reached)</td>
<td></td>
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<tr>
<td>Smoothness (IRI), in./mile</td>
<td>&lt;120</td>
</tr>
<tr>
<td>(Consider grinding when threshold is reached)</td>
<td></td>
</tr>
<tr>
<td>Spalling</td>
<td>Minimal</td>
</tr>
<tr>
<td>Materials Related Distress</td>
<td>None</td>
</tr>
</tbody>
</table>

Many agencies now routinely grind concrete pavements every 12 to 15 years
Pavement Performance Expectation

- Time or Traffic
- Serviceability

- Deficient Design & Construction
- Standard
- Long Life Design & Construction

Threshold Level
Top 3 Design Considerations

1. Focus on Design Features
2. Load Transfer at joints
3. PCCP Support Condition/Drainage
1 - Comprehensive Long-Life Concrete Pavement Design

- More than just slab thickness
- Incorporation of appropriate design features to enhance performance (e.g., improved base, dowel bars, etc.)
  - Reduce stresses/deflections/curling
- Must design pavement as a system
  - Consider interactive effects of all design elements
  - Consider overall cost effectiveness
  - Consider use of locally available & recycled materials (sustainable approach)
1 - Comprehensive Long-Life Concrete Pavement Design

- New Mechanistic-Empirical Pavement Design Guide (MEPDG) allows **optimization** of many key design features to develop LLCP designs
  - Joint spacing
  - Base type (& drainage?)
  - Edge support
  - Load transfer at joints
  - Concrete thickness/strength

- End result
  - More cost-effective & reliable designs
  - More sustainable designs

No more excuses to make design errors!
1 - Comprehensive Long-Life Concrete Pavement Design

- Some simple changes in approach to reduce concrete volume & amount of other materials without compromising performance
  - Reduce slab thickness
    - Improve foundation/base (European approach)
    - Use widened lane & shorter joint spacing
  - Reduce materials
    - Reduce no. of dowel bars (9 or 10 vs. 12 per lane)
    - Reduce joint sealant material (single cut sawing)

- Other changes
  - Consider two-lift design & construction to allow use of local/marginal & recycled materials in the lower lift.
2 - Joint Load Transfer

Joint spacing – Typical practice
- 15 ft (4.6 m) max for most highway applications
- Uniform spacing & perpendicular joints

Load transfer (40/60+ year design)
- Corrosion protection a must
  - Epoxy-coated (not long-lasting)
  - Clad bars (steel/zinc)
  - Microcomposite steel (MMFX)
  - Fiber-reinforced polymer (FRP)
2 - Joint Load Transfer

- Dowels for truck-loaded highways, typically for:
  - Slab \( t \geq 8 \) in or ESALs \( \geq 5 \) million
  - Minimum 1.25 in (32 mm) diameter
- Round dowels meet needs & are economical
- Need to maintain LTE at joints - > 70%
- **NO NEED FOR MIDDLE 2 to 3 BARS IN EACH LANE**
2 - Joint Load Transfer

- For corner loading, outer 3 to 4 dowels critical
- Dowel size can be adjusted for widened lanes
3 – Support Condition/Drainage

- US Approach – Do the best we can?
- European approach – Start with a good (standard) foundation
- We must construct better support – cannot undo poor support in future R&R
- Non-erodible base - prevention of pumping
- Stiffer support - reduction in slab stresses & deflections; less rolling resistance (MIT study)
- Provide stable and uniform construction platform – achieve better concrete surface finish

*Mentality switch – Refer to a base as a base & not as a subbase*
3 – Support Condition/Drainage Base Type Selection

- Provide for stiff/stable support
- Provide for needed base-slab friction
- Provide for needed frost heave protection
- Provide for needed subsurface drainage
- Untreated granular (aggregate) bases should be reserved for low traffic

- **Stabilized (treated) bases preferred for LLCP (40+ years)**
  - Asphalt-treated/Cement-treated
  - Lean concrete bases (Caltrans use)
  - Permeable bases – treated
3 – Support Condition/Drainage Pavement

Subsurface Drainage

➢ Need to pay more attention
➢ Rapidly remove water from beneath pavement structure
   ○ Stability vs. porosity: use lower permeability material
     ~300 - 500 ft/day
➢ Drainable Pavement System
   ○ Daylighted permeable base 🙂
   ○ Permeable base with edge drainage system 😞
**Top 3 Construction Considerations**

1. Construction Quality
2. Concrete Management – from plant to joint sawing
3. Contractor Process Control

*GOOD CONSTRUCTION STARTS WITH GOOD SPECS, PREFERABLY END RESULT SPEC*
1 - Construction Quality?

- For construction projects, achieving quality equates to conformance to requirements
  - Requirements need to be well defined, can be measured, and are not arbitrary
- Quality must be built into a project. It is not a hit or miss proposition.

- Owner should not expect more than what is specified
- Contractor may not deliver more than what is specified
1 - Construction Quality?

**Poor Design/Quality Construction vs. Good Design/Poor Construction**

A poorly designed pavement but well constructed will outlast a well designed pavement but poorly constructed

Ray Rollings  
Retired, Corps of Engineers
2 – Concrete Management
Typical US Paving Concrete Mixture

- Minimum 28-day flexural strength ~ 650 psi
  - Minimum fc ~ 4,000 psi
- Maximum w/cm ratio < 0.50 (<0.45 freeze areas)
- Well-graded aggregates (3+ bins) (Shilstone)
- Greener cementitious materials
- Advanced admixtures (future of concrete)
2 – Concrete Management
Ideal Paving Concrete Mixture

- **US vs. European approach (Freeways)**
  - **US**: \(~650\) psi MR \& slab \(t = 12\) to \(14\) in.
  - **European**: \(750+\) psi \& slab \(t = 10\) in.

- **Design for low paste - most concrete durability concerns are due to paste issues**
  - Results in better slipform paving \& better finishing

- **2-lift paving – Top: PCC\(^+(+)\); Bottom: PCC\(^(-)\)**
Some simple changes to reduce cement use

- Reduce paste content (most problematic component)
  - Use of optimized gradation & use larger maximum aggregate size
  - Reconsider minimum cementitious materials requirement (current: typically, 540 pcy); consider end product spec

- Increase use of SCMs (flyash & slag)
  - Results in more durable concrete
  - Efficient use of waste products/by-products

- Use Greener cements
  - Blended cements (ASTM C595)
  - Performance-based cements (ASTM C1157), including portland limestone cement
  - Non-portland cements – under development
2 – Concrete Management
The Joint Rot Issue

- Some joints are deteriorating faster than we would like (Peter Taylor)

- Some key findings
  - Paste saturation is a main culprit (f(freeze/thaw))
  - Need better quality concrete – \( \text{w/cm} < 0.40 \) & good in-situ air system & dense concrete & well-draining pavement, especially at the joint
2 – Concrete Management
From Placement to Curing

- Proper consolidation
  - Use of smart vibrator system
  - Check cores for proper consolidation

- Minimize tendency to over-finish surface
  - Brings more paste to the surface
  - Surface does not have to be super-smooth

- Timely curing
  - A concern on many projects during hot weather

- Timely & proper joint sawing
  - Not an issue for transverse sawing, but delay in longitudinal sawing can result in premature cracking
3 – Contractor Process Control

- Ideal contractor process control (QC) limits or eliminates placement of marginal concrete & use of marginal construction processes
  - Do not produce concrete if aggregate grad. not met
  - Reject concrete loads if requirements not met
  - Stop paving process if placement (edge slump) or consolidation issues

- Process control tests
  - Aggregate gradation & concrete mixture
  - Slab thickness
  - Concrete “slump” & air & density/consolidation
  - Profile (behind paver) & texture
  - Dowel bar alignment
3 – Contractor Process Control

➢ Ideal contractor process control
  o Material is rejected or process is stopped when the testing indicates that end product requirements are not being met
  o Minimizes placement of marginal or non-acceptable concrete

We accept that problems develop during construction, but it cannot be all day long, every day

Contractor must have his process under control!
Top 2 M&R Considerations

1. Timely Maintenance & CPR
**M&R Overview**

- We expect that current & future new concrete pavements will provide a low maintenance service life.

- However, we still have to manage concrete pavements constructed more than 20 years ago & designed for ~20+ years. Many of these pavements have been in place for 40+ years.

- With timely & **IMPROVED** M&R strategies, we can continue to extend the service life of many of these older & **FUTURE** concrete pavements without resorting to “fracturing” & reconstruction.
  - Economical & sustainability benefits
1 – Timely M&CPR
Extend service Life of Existing Pavements

- With minimal effort and lower costs, we can extend service life of most concrete pavements without fracturing, resurfacing & reconstruction
- Well-performing CPR techniques are available – to maintain ride/texture/structural capacity
  - FDR, DBR, grinding, concrete shoulder retrofit
  - Joint resealing? – topic of debate
- But, M&CPR must be done in a timely manner & done well (LIMIT FIXING THE FIX)
Achieving LLCP (60+ years)

Many Small Steps => Big Gains (LLCPs)
One Small Misstep => Premature Failure (PPCPs)

- Optimizing long-life pavement designs
  - Thickness reduction; fewer dowel bars
  - Single cut joints; better bases/foundation
- Managing the construction processes & materials
- Effectively extending service life of existing pavements by timely M&CPR

ACPT ADVANCED CONCRETE PAVEMENT TECHNOLOGY
Greetings from Washington

THANK YOU!

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