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Considerations for Sustainable Long-Life Concrete Pavements

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ACPT ADVANCED CONCRETE PAVEMENT TECHNOLOGY

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

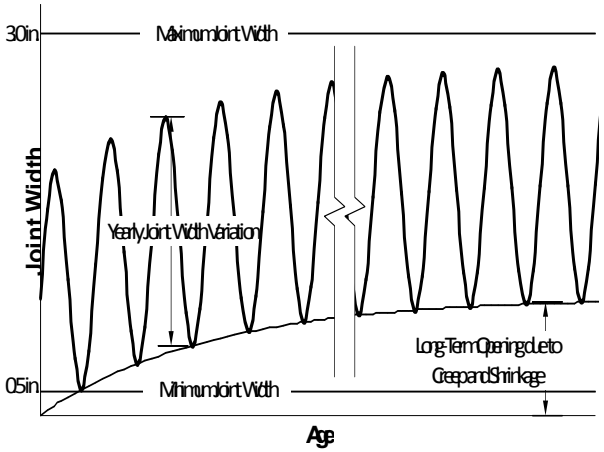
2015 (?) on
Life – 40+ years

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**



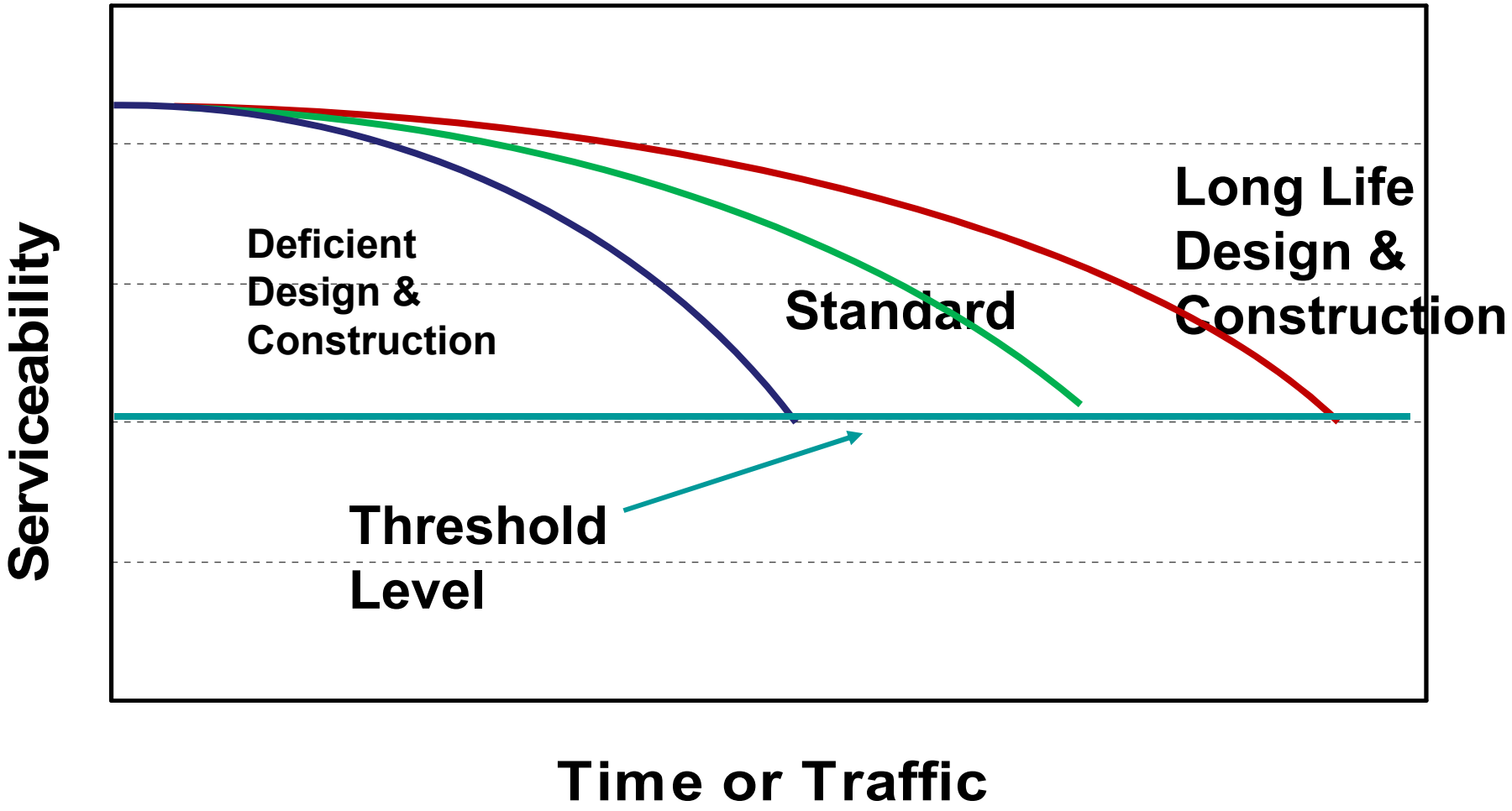
What Are Our Expectations of Our Concrete Pavements?

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

Distress	Value
Cracked Slabs, %	10 - 15
Faulting, in. (Consider grinding when threshold is reached)	0.125 (?)
Smoothness (IRI), in./mile (Consider grinding when threshold is reached)	<120
Spalling	**Minimal**
Materials Related Distress	**None**

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

Pavement Performance Expectation



Top 3 Design Considerations

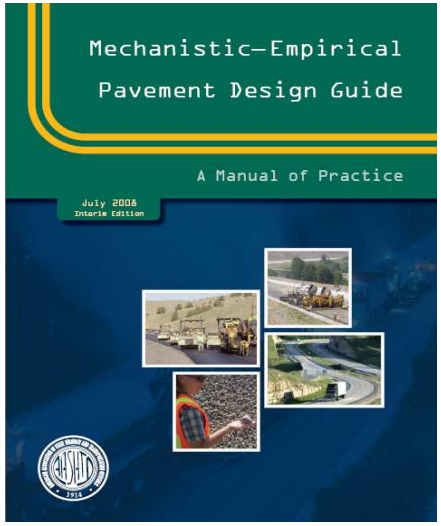
1. *Focus on Design Features*
2. *Load Transfer at joints*
3. *PCCP Support Condition/Drainage*

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 <u>without compromising performance</u>
  - 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

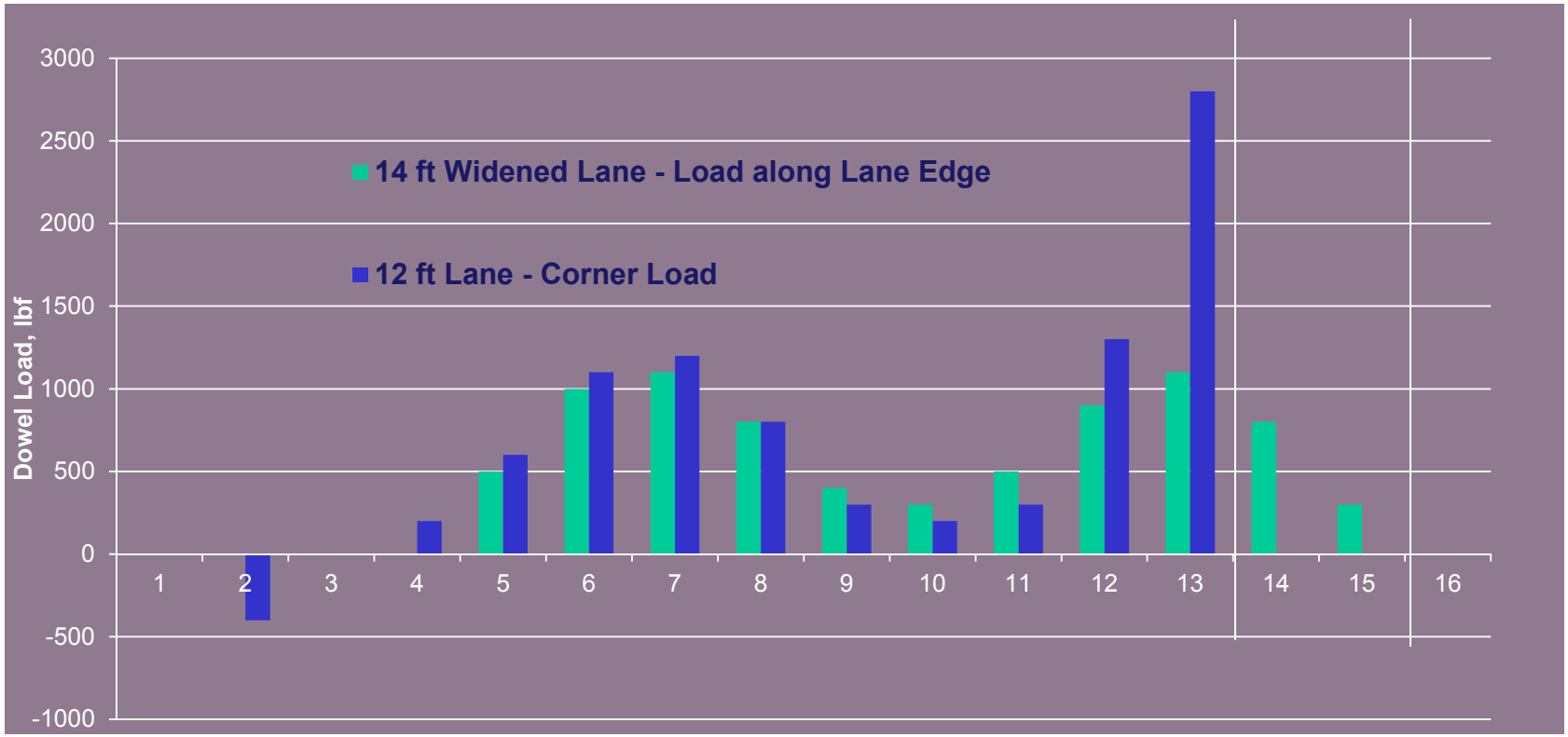
- Load transfer (40/60+ year design)
  - **Corrosion protection a must**
    - Epoxy-coated (not long-lasting)
    - Clad bars (steel/zinc)
    - Microcomposite steel (MMFX)
    - Fiber-reinforced polymer (FRP)

2 - Joint Load Transfer

- Dowels for truck-loaded highways, typically for
  - Slab t ≥ 8 in or ESALs ≥ 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 (sta
  foundation
- We must construct better support – <u>cannot undo poor support in future R&R</u>
- 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

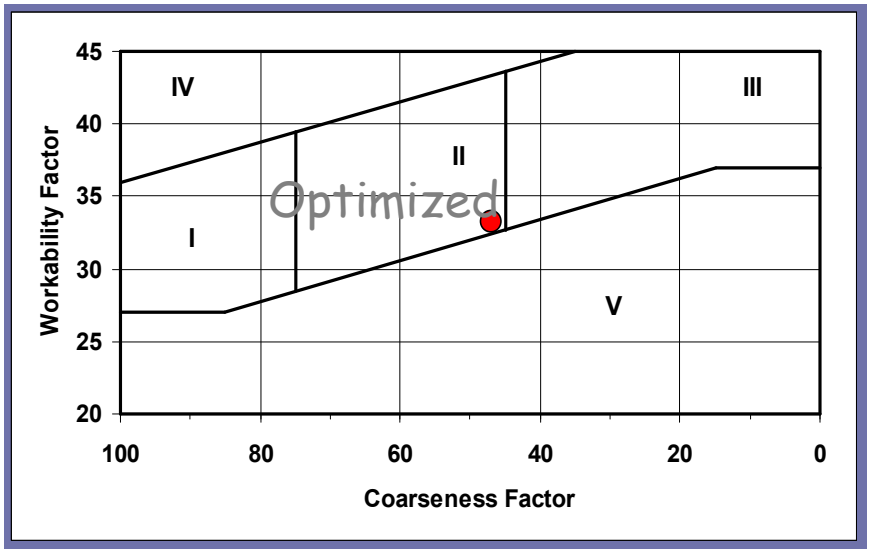
A poorly designed pavement but well constructed will outlast a well designed pavement but poorly constructed

Ray Rollings

Retired, Corps of Engineers

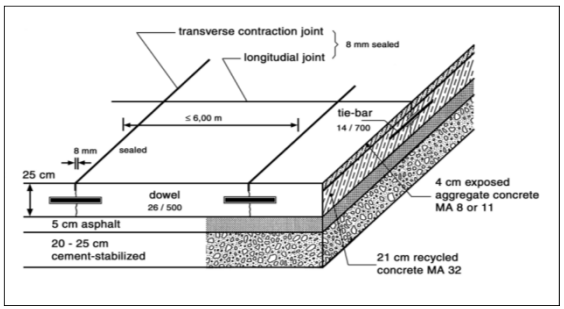
2 – Concrete Management
Typical US Paving Concrete Mixture

- 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)



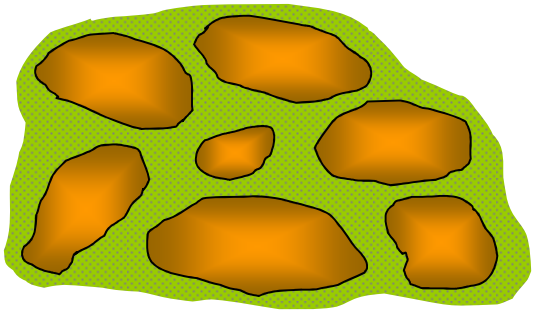
2 – Concrete Management
Ideal Paving Concrete Mixture

- 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(-)



2 – Concrete Management
Cement Reduction for Paving Concrete

- 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 – **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

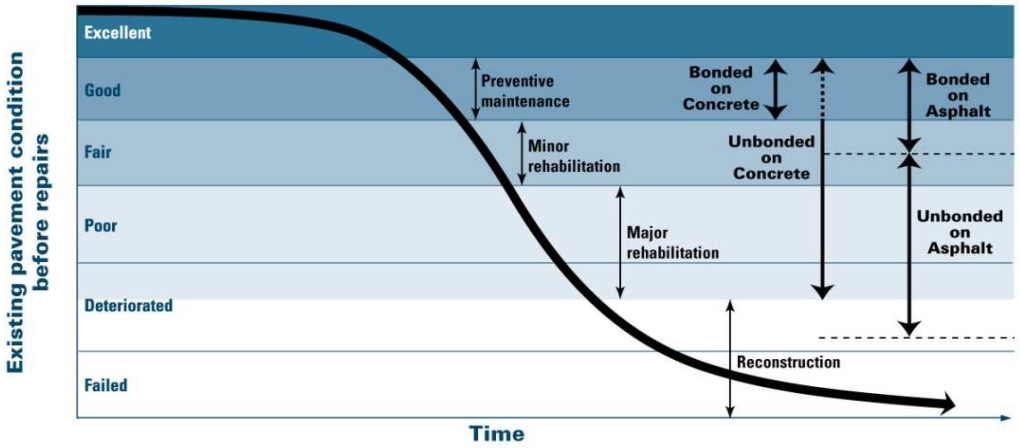
- Ideal contractor process control
  - Material is rejected or process is stopped when the testing indicates that end product requirements are not being met
  - Minimizes placement of marginal or non-acceptable concrete

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

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THANK YOU!
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