Long Life Concrete Pavements (LLCP) – Consideration of Design & Construction Features

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Presentation Outline

- LLCP Background
- LLCP Requirements
- LLCP Design & Construction Features
  - Thickness
  - Dowels
  - Base Type - lean concrete base typical in CA
  - Smoothness (best practice for constructing smooth pavements)
- Summary/Recommendations

Common PCCP Types (US)

- JPCP
  - 4.3 to 5.5 m joint spacing
  - t = 150 to 200 mm (streets); 200 to 250 mm (secondary roads); 300 to 350 mm (primary and interstate systems)
  - Dowels & stabilized base for medium/heavy volume of truck traffic
- CRCP
  - Steel: 0.65 to 0.80%
  - Cracking at 0.8 to 2 m, tight cracks
  - Terminal joints at structures

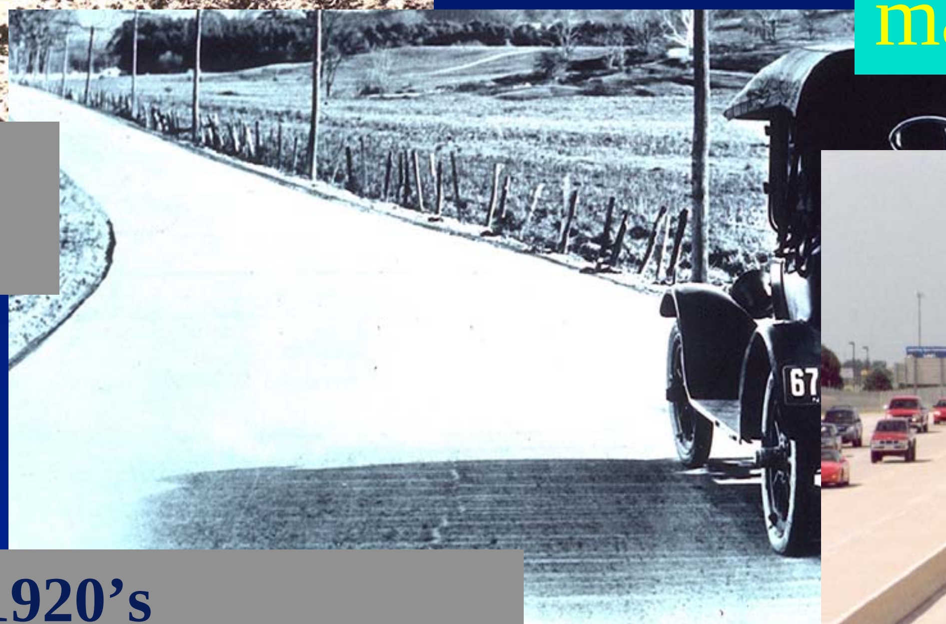
Widened Slab/Tied Shoulder

- Widened Lane
  - Slab paved 0.6 m wider than usual
  - Lane striped at normal 3.65 m width
  - Reduces edge and corner stress/deflections

- Tied cement concrete shoulder
  - Reduces edge stress/deflections
  - Reduces moisture infiltration
  - Emergency/future traffic lane

PCC P Evolution – A Long Journey

1900's
Life – 1 season



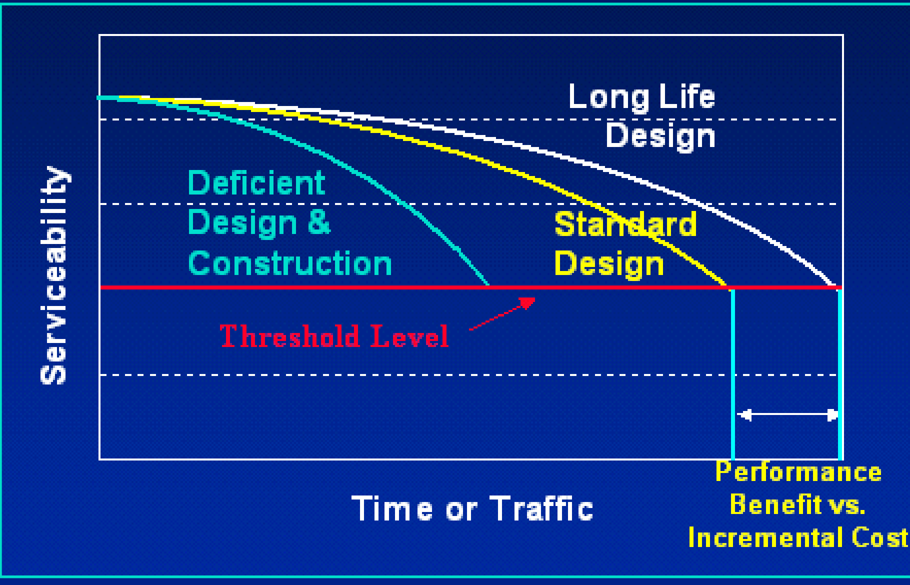
1920's
Life – 10+ years (?)

Resulting from improvements in design, construction & material technologies

2004
Life – 30 to 40+ years

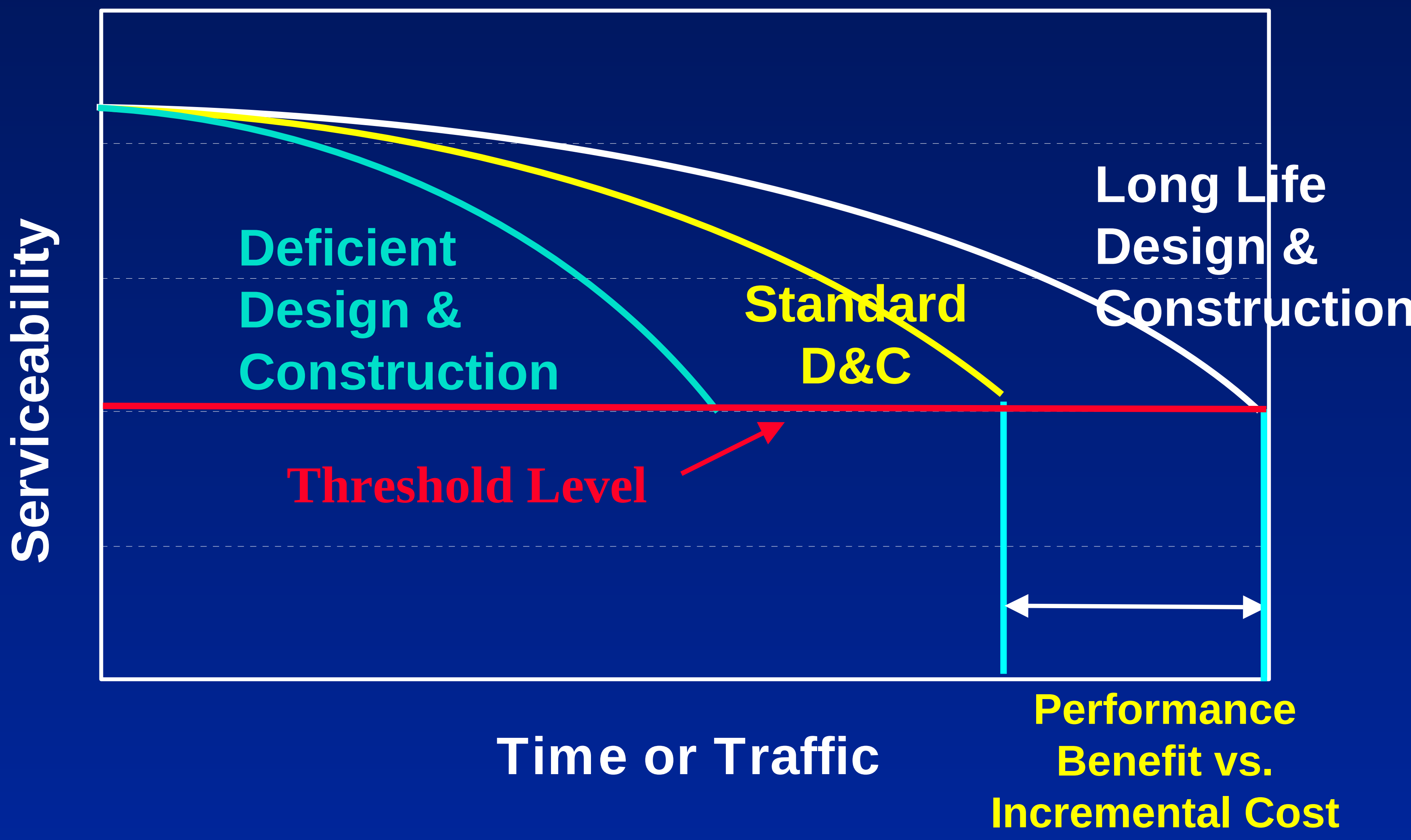
LLCP Performance Requirements

- Structural performance
  - Long life - no major distresses
  - Routine M&R only
- Functional performance
  - Safety – no wet weather accidents
  - Smoothness – good ride
- Lower life cycle cost
  - Lower agency costs
  - Lower user operating costs
  - Very few delays & accidents



(Long Life Requires Optimization of Design Features, Construction Techniques & Materials)

Pavement Performance



Pavement Design Considerations

- Minimize failure conditions & costs
- Understand typical failure mechanisms
  - How does a concrete pavement crack?
  - How does a concrete pavement fault?
  - How does a concrete pavement get rough?
  - Are there other local failure conditions that need to be addressed?
- Understand impact of design features
  - Minimize costs by optimizing design features

How do Concrete Pavements Fail?

Transverse Cracking

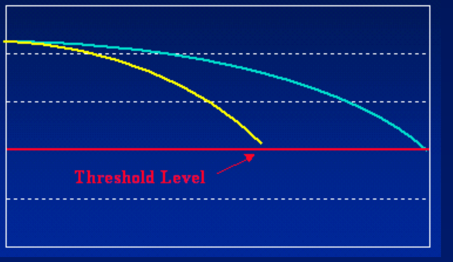
Smoothness (IRI)

Faulting

And, localized distresses (<u>spalling</u>) and materials related distresses (ASR, etc.)

Allowable Distress/Performance

- At end of service life
  - 40 years for primary system
  - 20+ years for secondary system



Distress	Value
Cracked Slabs, %	10 - 15
Faulting, mm	6 – 7
Smoothness (IRI), m/km	2.5 to 3.0
Spalling (length, severity)	Minimal?
Materials Related Distress	None

LLCP Premise

- LLCP is not a “gimmick” or a “Cadillac” design, but a necessity for high volume highways
- LLCP is a serious on-going effort by DOTs, engineers, contractors, and materials suppliers to design & construct the best concrete pavements for long term service keeping LCC in mind
- LLCP includes the optimization of all components of design, materials & construction to produce cost-effective long-lasting (40+ years) concrete pavements

LLCP – FHWA/DOT LLCP Goals

- Increased service life - 40 to 60 years
- Lower life cycle cost
- Decreased construction time
- Fewer maintenance closures
- Construction of better initial ride
- Use of efficient construction equipment & procedures (Get in & Get Out AQAP; sustainability)
- Use of improved QA/QC procedures
  - To monitor quality as paving progresses, not days or weeks later

LLCP - Caltrans Directions

- New -- Corridors with 20-year traffic > 150,000 vpd
  or > 15,000 tpd
- Rehab -- Corridors with current traffic > 150,000 vpd
  or > 15,000 tpd

  (Rehab policy under review)

- Added initial cost ~ 3 to 5 % ($25K to $50K/lane-mile)

Caltrans Concrete Pavement Policy
(Highway Design Manual – Chapter 600)

- Structural design
  - Base – stabilized (LCB or ATB) if TI >10
  - Other bases – free draining ATPB/CTPB or aggregate base
  - No bonding between PCC & LCB
  - PCC thickness = 300 mm (max shown in tables for TI > 14)
  - Tied-concrete shoulder or widened lane with AC shoulder
- Drainage design guidelines
- Cross-section design guidelines
- Pavement selection process guidelines

LLCP Directions - Other DOTs

- MinnDOT -- 60 year design - Jointed (Twin Cities)
  - Durable concrete aggregate (D-cracking concerns)
  - Higher specified air – 8.5 +/- 1.5 % (75% entrained air)
  - 35% GGBF Slag; w/cm < 0.40
  - 1.5 in. diam. stainless steel clad dowels from UK (cost > $12/bar)
  - Slab thickness – 34 mm (vs. standard of 32 mm)
  - Cost: placement - $6/sy; concrete - $75/cy; clad dowels - $12/bar
- Illinois DOT -- 30+ year CRCP (I-70 demo & Chicago area)
  - Higher steel content
  - 33 to 36 mm thickness
  - 150 mm ATB over 300 mm aggregate subbase
  - Durable concrete aggregate (D-cracking concerns)
  - Epoxy-coated steel & tie-bars

LLCP Elements – Structural Design

- Design features
  - Thickness
  - Widened lane and/or tied concrete shoulder
  - Joint layout (spacing)
  - Base type & drainage considerations
  - Load transfer mechanism (dowels)
- Design details
- Plans & specifications
  - Clearly defined requirements
  - Requirements must support design objectives
  - May require supplementary provisional specs

Eliminate Early Age Distress

LLCP Elements - Materials

- Concrete
  - Durable – no MRD; Low shrinkage
  - Desired structural properties (f, E, α)
- Joint system
  - Dowel bars – corrosion resistant
  - Sealant – 12 to 15 + years service life; minimize no. of re-sealing (re-facing) intervals
- Base/Subbase
  - Non-erodible (moisture insensitive system)
  - Desired structural properties (f, E, a)
- Subgrade
  - Need for a “solid” foundation & construction platform
  - Protection from swelling & freezing

> Eliminate Early Age Distress

LLCP Elements - Construction

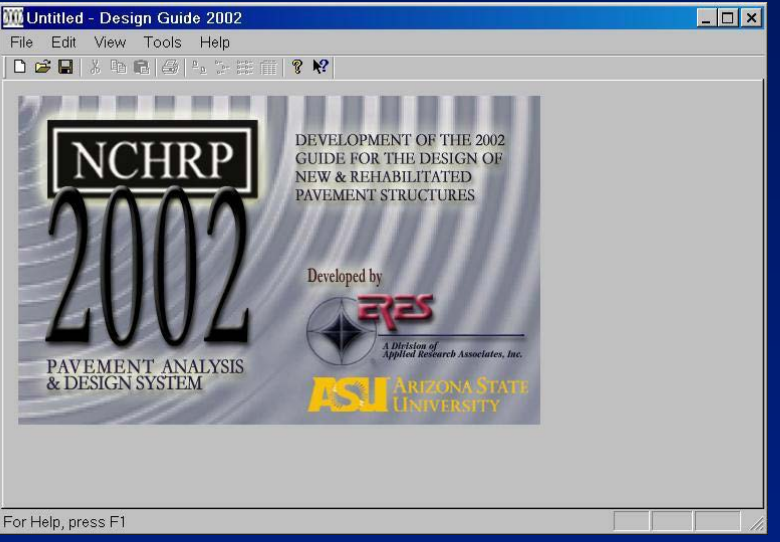
- Concrete production & delivery
  - Uniform production & consistency
- Concrete placement & consolidation
  - Dowel bar/tie-bar placement
  - Consolidation monitoring
- Concrete finishing, texturing & curing
  - Minimal manual finishing
  - Durable/low-noise texture
- Concrete sawing & sealing
  - Single vs. double cut
  - Longer re-sealing intervals
- QA/QC features - continuous monitoring

Eliminate Early Age Distress

LLCP Structural Design Issues

- Needed improvements
  - o Improved understanding of failure modes
    - Cracking, faulting, spalling
  - o Optimization of key design features
  - o Possible “out-of-the-box” design concepts for LLCP

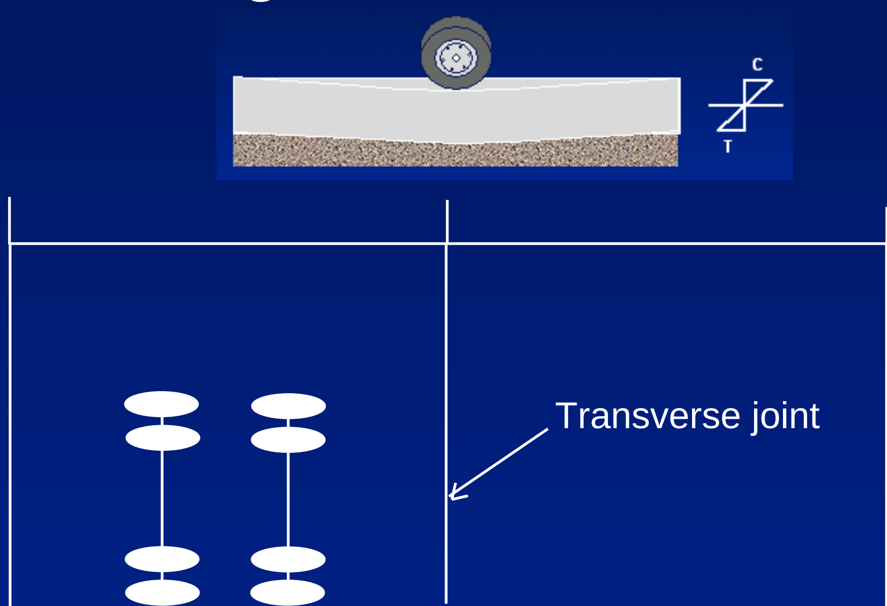
    -- provide smoother , safer, longer-lasting CP at lower LCC



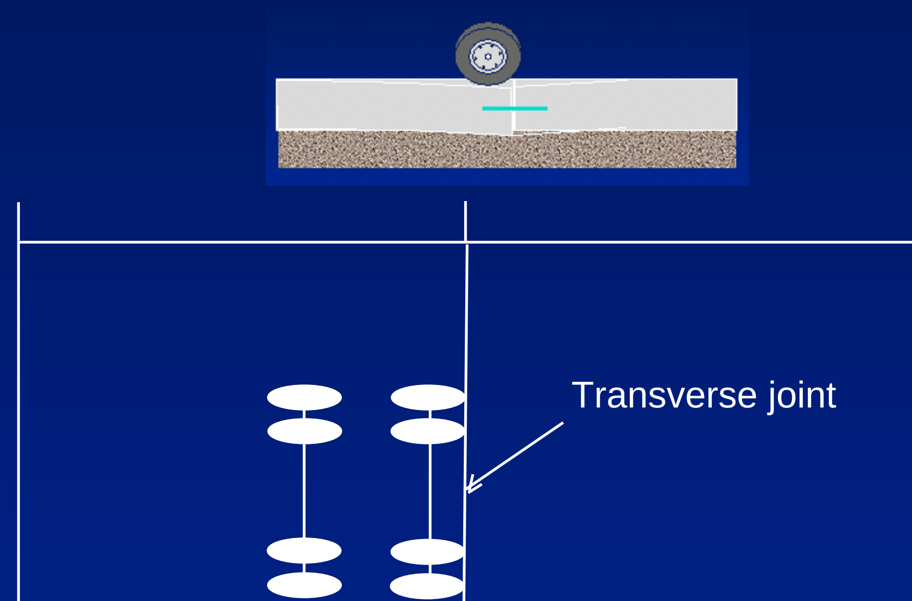
Implementation time period - Next 10 to 15 years

Critical Loading Positions

<u>Fatigue</u>



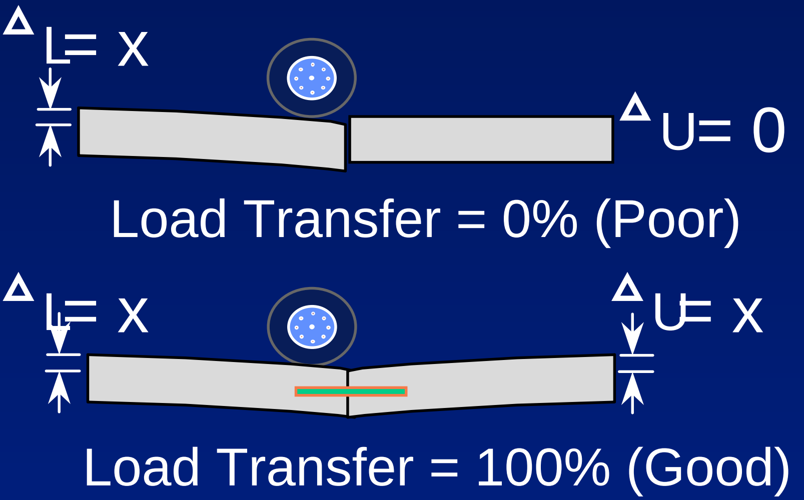
<u>Erosion/faulting</u>



- Midslab loading away from transverse joint produces critical edge <u>stresses</u>
- Corner loading produces critical pavement <u>deflections</u>

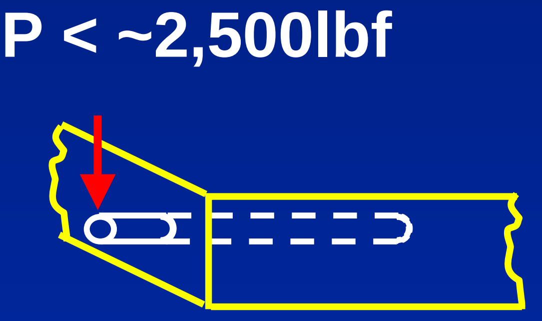
Load Transfer for LLCP

- Load-transfer is a slab's ability to transfer part of its load to the adjacent slab
- Poor load transfer leads to:
  - o Pumping & Faulting



Load transfer (dowels) essential for LLCP

- Also, need to consider dowel bearing stresses
  - o Dowel looseness over time
  - o Dowel size important



LLCP – Slab Thickness

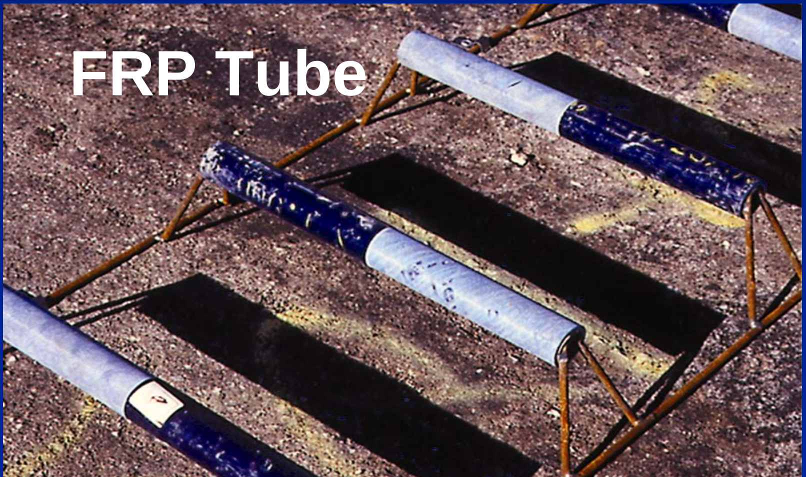
- Thickness, edge treatment (widened lane/tied shoulder), base type & load transfer at joints are inter-related
- For LLCP, consider
  - Slab thickness > 300 mm (f(truck traffic))
  - Shorter joint spacing ~ 4.5 m works well
  - Widened outside lane and possible tied shoulder
  - Corrosion resistant dowel bars
    - May use 9 (5&4) or 10 (5&5) to reduce cost
  - Stabilized base

LLCP – Load Transfer (Dowels)

- Corrosion resistant dowels a must
  - o Stainless steel clad (~$10 to $12)
  - o FRP – but effectiveness not proven yet
  - o Epoxy coated (low cost option) (~$4 to $5)
- 38 mm diameter minimum for t = or > 300 mm
- Can reduce no. of dowels – middle 2 to 3 dowels not necessary
  - o May use 9 (5&4) or 10 (5&5) to reduce cost
- Length = 450 mm

Alternative Dowel Bars
(FHWA, DOTs, Canada, HITEC, etc)

- A number of dowel types are under study
  - Solid stainless steel; stainless steel clad; solid FRP; FRP tubes filled with concrete, elliptical shaped dowels, etc
- How do we extrapolate short-term test results to 40+ year service life?



LLCP - Base

- Non-erodible base if rainfall > ~400 mm/year
- Stabilized base – LCB/CTB or ATB for medium to heavy truck traffic
  - Very high strength LCB/CTB not necessary
- Drainable base – stability more important than high porosity – 150 to 300 m/day permeability fine
- PCC/LCB interface treatment (early age concerns)
  - Bonded/monolithic most effective, but not practical
  - Debonding treatment – 2 coats of curing, asphalt emulsion, 1 in. HMAC, or plastic/geotextile membrane
  - Joint spacing & timing of sawing critical

PCC/LCB Interface Treatment

Plastic Membrane – Indian National highways, 2004

Geotextile – Denver Airport, 2002

LLCP - Smoothness

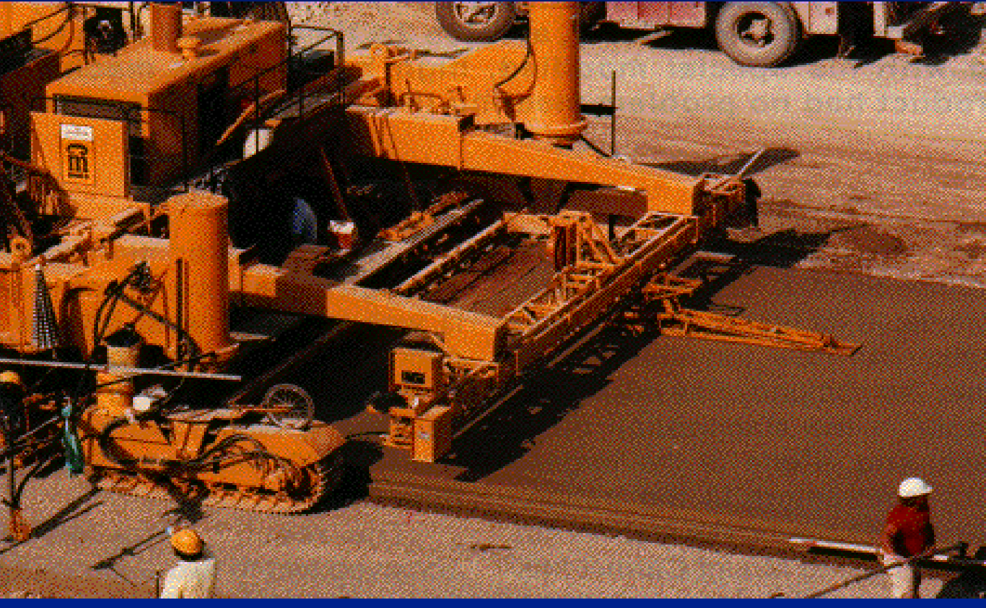
- PCCP constructed smooth remains smoother
- Measures of smoothness for acceptance
  - IRI - < ~1.2 m/km (How to measure?)
  - PI – zero band
- Smoothness over service life ~ 2 to 3.0 m/km
  - "Low" rate of degradation in ride quality over time
    - IRI increase/year < ~ 0.05 m/km (av. Over 40 years)

Factors Affecting Initial Smoothness

- Base/subbase track-line support
  - Extend Track-line by 1m
  - Stable materials
  - Trim to grade
  - Keep track clean
- Horizontal & vertical alignment
  - String-line management
- Embedded reinforcement and fixtures

Factors Affecting Initial Smoothness Construction Operations

- Avoid stop & go operation
- Maintain uniform speed
  - > 1.5 m/minute
- Maintain uniform head
- Manage/monitor vibration
  - Check for vibrator trails
  - Use Smart Vibrator System
- Maintain steady concrete delivery



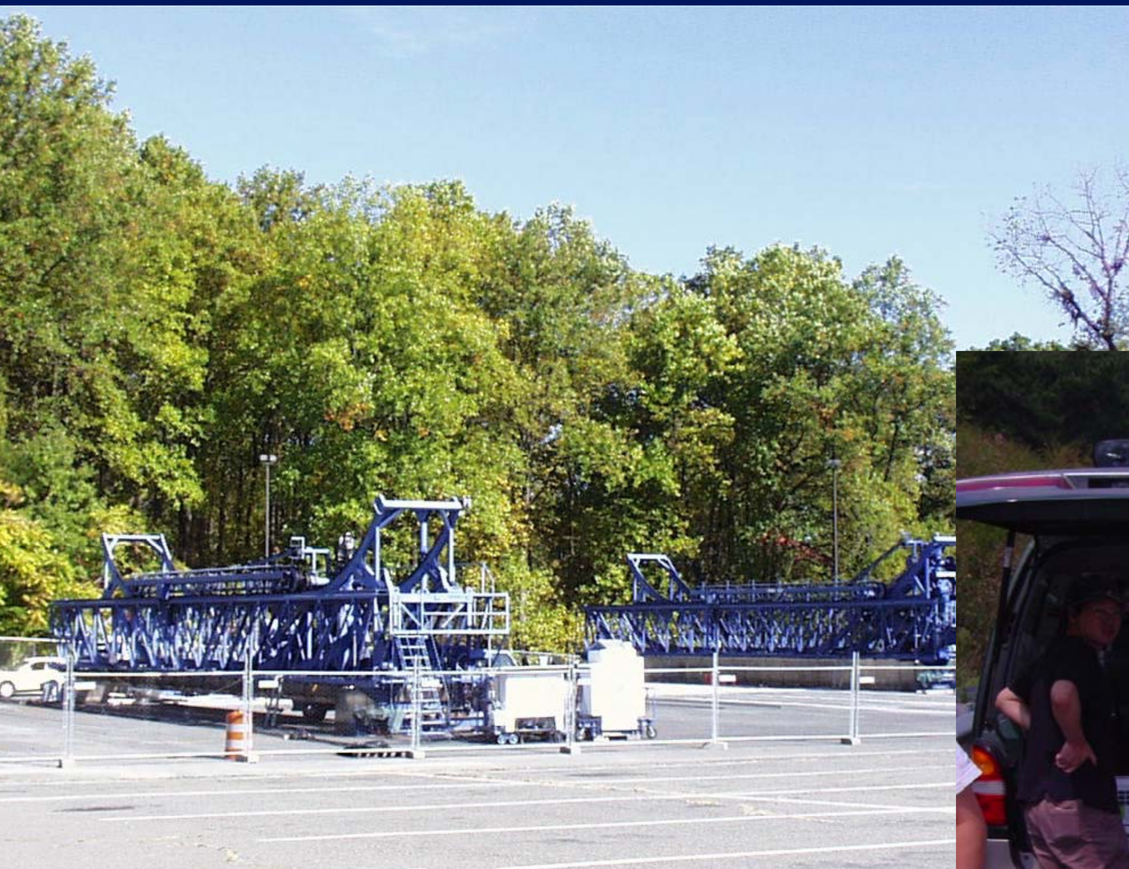
Finishing Operations

- Minimal finishing – do not over-finish – pavement does NOT have to be super-smooth
- Longer straight edges produce smoother ride
  - Kansas projects – 5 to 6 m straightedge
- Do not add water to facilitate finishing or texturing
- Finishers have final say on PCCP smoothness

LLCP - Future Directions

- Continue to improve
  - Understanding of pavement behavior
  - Design feature optimization
  - Concrete mixture optimization
  - Construction practices
- Need to perform accelerated structural & durability testing under simulated conditions
  - Cannot wait for 30 years to find out if some innovations will lead to LLCP
- End result – Well-designed & well-constructed PCCP can provide 40 to 50 year low maintenance service life with low life cycle cost!!!!

Accelerated Testing/ Instrumented Test Highways



<<Accelerated testing to validate design features

Instrumented Test Sections to calibrate/validate analysis models >>

Summary

- Future M-E procedures will allow more optimum designs
  - Will address high levels of truck traffic
  - Design life of 40 to 50+ years more reliable
  - Will consider many design features
- Also, major materials related improvements and construction innovations are expected in near future
- And, instead of “hoping for” long life, we will be designing for long life with 90+% reliability


Thank You!