Highlights of the Long Life Concrete Pavements Conference – DOT Directions

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Presentation Outline

- Correct errors in Danny's Presentation ☺
- LLCP Background
- LLCP Conference Highlights
  - DOT LLCP Practices
- Future Directions

Common PCCP Types (US)

- JPCP
  - 15 ft joint spacing
  - Thickness
    - 6 to 8 in. (streets)
    - 8 to 10 in. (secondary roads)
    - 12 to 14 in. (primary and interstate systems)
  - Dowels & stabilized base for medium/heavy volume of truck traffic
- CRCP
  - Steel: 0.65 to 0.80%
  - Cracking at 2 to 5 ft, tight cracks
  - Terminal joints at structures

Widened Slab/Tied Shoulder

- Widened Lane
  - Slab paved 2 ft wider
  - Lane striped at normal 12 ft width
  - Reduces edge and corner stress/deflections
- Tied cement concrete shoulder
  - Reduces edge stress/deflections
  - Reduces moisture infiltration
  - Emergency/future traffic lane

Concrete Pavement Evolution

Resulting from improvements in design, construction & material technologies

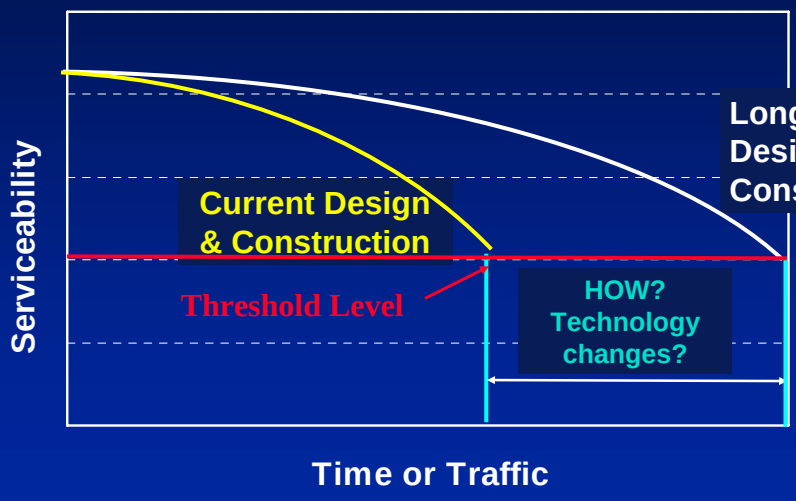
1900's
Life – 1 season

1920's
Life – 10+ years

1960's
Life – 20+ years

2007
Life – 40+ years

Pavement Performance



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Warrants for Long Life Pavements

- Public Demand For Longer Life Pavements
  - Improved performance – less lane closures
    - Less construction traffic congestion
    - Safer highways
- Environmental/Sustainability Issues
  - Scarce aggregate sources
  - Reduced greenhouse gases
  - Higher construction costs
- Lower incremental cost ==> But, significant improvement in performance

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How do Concrete Pavements Fail?

Transverse Cracking

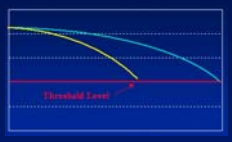
Poor Ride
Poor Texture

Faulting

And, localized distresses (spalling) and materials related distresses (ASR, etc.)

Allowable Distress/Performance

- At end of service life
  - 40+ years for primary systems



Distress	Value
Cracked Slabs, %	10 - 15
Faulting, in.	0.25
Spalling (length, severity)	Minimal?
Materials Related Distress	None
Smoothness (IRI), in./mile	150 - 180
Texture Loss	Minimal/Per Design

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Defining Long-Life Concrete Pavements

- Australia (Vorobief) – 40-year design life when a pavement is "consumed"
- Belgium – well designed and well constructed CRCP – 30+ years initial service life

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US Definition of Long-Life Concrete Pavements

- Original PCC surface service life – 40+ years
- Pavement will not exhibit premature failures and materials related distress
- 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 CPR

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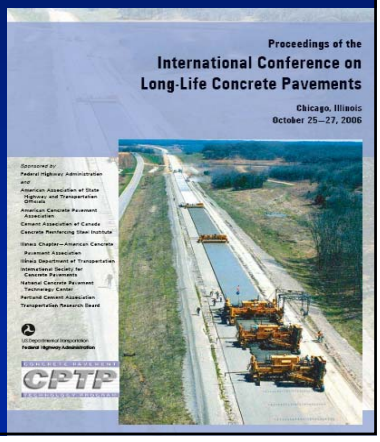
LLCP Conference

- International Conference on Long-Life Concrete Pavements, Chicago, Oct. 25-27
  - 12 countries
  - ~30 states plus DC
  - ~180 attendees
  - 10 State DOT presentations on Best Practices



Highway Agencies Represented

California	Minnesota
Colorado	Texas
Florida	Virginia
Illinois	Washington State
Iowa	Province of Ontario

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California Highlights

- Philosophy – small incremental costs to improve various features can lead to exponential improvement in performance (life)
- LLCP warrants
  - Reduced congestion
  - Reduced green-house gases
  - Reduced construction related accidents/loss of life
  - Sustainable construction

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LLCP - Caltrans Directions

(Proposed in mid-1990's)

- 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
- Added initial cost ~ 3 to 5 % ($25K to $50K/lane-mile)
  - **Primarily due to incremental improvements in quality of materials & construction**

Caltrans Concrete Pavement Policy

- Structural design (catalog developed)
  - PCC thickness upto 13.5 in. for highest expected traffic; doweled joints
  - Tied-concrete shoulder or widened lane with AC shoulder
  - Base – stabilized (LCB or ATB) for high truck traffic
  - Other bases – free draining ATPB/CTPB or aggregate base – low truck traffic
- Drainage design guidelines
- Focus on durable concrete & construction quality

California US 40/I 80 CRCP Excellent Performance

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California Study Results

- Evidence of long life concrete pavements
- Excellent performance of concrete pavements to date
- M-E Guide predictions match field performance
- All factors have contributed to extended life
  - o Design, Materials, Construction
- Recommended CRCP designs developed for California conditions
  - o 40-year design with 200 million trucks

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Recommended CRCP Designs for CA – 40 year, 200 million trucks

Layer	Material and thickness	Design features or properties	Construction issues
1	CRCP – 10 to 12 in. depending on climate and subgrade	0.70 %; Tied shoulder PCC 28-day strength > 675 psi CTE below $6x10^{-6}$ in/in/deg F	Well cured and paved during low to moderate ambient temperatures
2	CTB OR ATB – 4 in.	Non erodible properties CTB modulus > 2 million psi ATB binder content > 10 %	Construct to provide adequate friction
3	Granular base – 6 in.	Strong base material with low fines	Well compacted; adequate drainage
4	Existing subgrade		Treated as required

Colorado Highlights
(Incremental Changes)

- DOT implementations for LLCP (incremental changes)
  - Longitudinal tining
  - Widened slabs
  - Single-cut joints
  - Preventing early-age cracking

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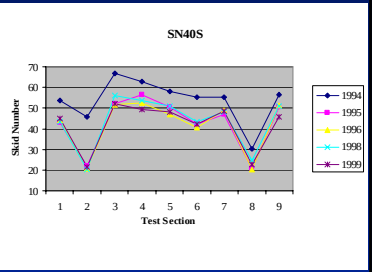
Colorado LLCP Directions – Spec Changes

- Longitudinal Tining
  - Adopted since 1997 – based on in-state studies
  - ¾ in. spacing, 3 by 3 mm groove
  - Best long-term performance for friction
- Widened slabs
  - 2 ft widening adequate – based on LTPP SPS-2 and in-state studies
  - Lowers corner deflections & slab stresses (field instrumentation)



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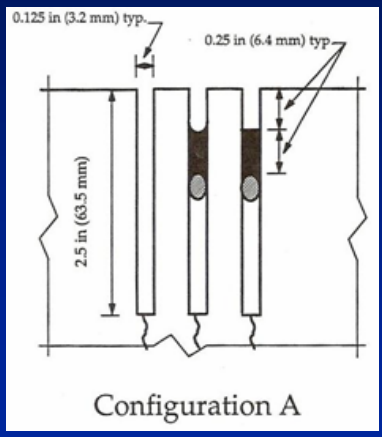
Colorado LLCP Directions – Spec Changes

- Single-Cut Joints – since 1996
  - Based on LTPP SPS-4 & in-state studies
  - 1/8 in. cut adequate
  - Less sealant, less cost, more durable, less noisy
- Prevent early age cracking
  - Inspect joint saw-cut depths
  - Vibrator monitoring devices



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Illinois Highlights

- Long life concrete program started late 1990's
- Studies undertaken at the University of Illinois
  - Accelerated load testing of new CRCP systems
  - High steel content – upto 1.09%
  - 10 in. thick sections failed – punchouts
  - 14 in. thick sections did not fail
- Developed 30-year and 40-year designs for CRCP
- Constructed five LLCP projects – all CRCP
  - Thickness – 11.5 to 14 in.
  - Flyash or slag used in concrete

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Illinois LLCP Directions – Spec Changes

- Design
  - Use of ME design procedure for jointed pavement & modified AASHTO 2003 for CRCP
  - CRCP steel increased from 0.7 to 0.8%
  - Tie bars – No. 8 at 24 in., 30 in. long
  - Subgrade – No lime treatment; now, 12 in. aggregate subbase
  - Base – stabilized; HMAC if under CRCP

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Illinois LLCP Directions – Spec Changes

- Material (Durability Focus)
  - Wet-freeze region; D-cracking susceptible limestone
  - LLCP requires highest quality limestone – Class A
    - Freeze-Thaw Expansion Rating – 0.06% for 20 year life
    - F-T Expansion Rating – 0.04% for 30 year life
    - F-T Expansion Rating – 0.025% for 40 year life
  - ASR – some sands are reactive; mitigation required if ASTM C 1260 expansion > 0.1% at 16 days
  - Blended cements – mortar bar expansion limited to 0.02% at 14 days and 0.06% at 8 weeks

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Illinois LLCP Directions – Spec Changes

- Construction
  - Concrete placement temperature – 50 to 90 F
  - Concrete consolidation by internal vibration
  - Vibration frequency limited by paver speed
    - Approval needed for paver speed < 3 ft/minute
  - Curing application within 10 minutes of tining
  - Skewed transverse tining for speeds > 55 mph
  - Profile – zero blanking band Profile Index
    - Incentive if < 17 ipm
    - Corrective action if > 30 ipm
    - Penalty if > 40 ipm
  - Five year warranty mandatory

Minnesota Highlights

- Started LLCP program in 2000
- LLCP requirements adopted for all high volume highways
  - 60 year service life
  - Based on best practices approach – extrapolating what has worked in the past

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MnDOT's First LLCP

- 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
  - 38 mm diam. stainless steel clad dowels (cost > $12/bar)
  - Slab thickness – 13.5 in. (vs. standard of 12.5 in.)
  - Cost: placement - $6/sy; concrete - $75/cy; clad dowels - $12/bar

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MnDOT's LLCP Directions

- Design
  - Thickness – 11.5 to 13.5 in. (based on traffic)
  - Base – 4 to 6 in. dense-graded granular
  - Subbase – 36 in. select granular (typ.) – frost resistant
  - Joints at 15 ft; 1.5 in. diameter corrosion resistant dowel bars – stainless steel clad or stainless steel (approved list)
  - Texture – Astro-turf or broom drag; 1 mm average depth

MnDOT's LLCP Directions

- Materials (Concrete)
  - Combined aggregate gradation – incentive-based
  - ASR testing for fine aggregate
  - D-cracking susceptibility check
  - Slag & Flyash required – for durability/low permeability
  - Air – 7.0 +/- 1.5% - 75% to be entrained air
  - Water to cementitious material ratio < 0.40
- Construction
  - Requires vibration monitoring devices
  - Improved curing requirements

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Washington State Highlights

- Manages 2,300 lane miles of concrete pavements – 38% > 35 years, including I-5
- WSDOT goal – 50 year for new pavements
- Past design features
  - 20 year designs (but got 30 to 40 years service)
  - Base – crushed stone, CTB or ATB
  - Joints
    - Pre-1997- skewed and random spacing, single-cut/sealed
    - Since 1997 - doweled, not-skewed, single cut/sealed
  - Concrete – pre-1991 State designed; high quality hard aggregates available
  - Tining – Pre-2000, transverse – 0.5 in. spacing

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WSDOT LLCP Directions – Spec Changes

- Design
  - AASHTO 2003 – 50 year life
    - Seattle I-5 thickness – 13 in., 4 in. HMA, 4 in. subbase
    - Allows for future grinding for studded tires
  - Base
    - Dense-graded HMAC required
    - ATB & CTB & crushed stone not allowed based on past performance
  - Joints
    - 15 ft spacing; single cut (1/3 depth); hot poured sealant
    - Dowels – stainless steel clad or sleeved; MMX steel
    - Widened lane – no shoulder lane dowels
    - 12 ft lane – tied shoulder and doweled shoulder joints

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WSDOT LLCP Directions – Spec Changes

- Material (Durability Focus)
  - Contractor developed concrete mixture
  - End product emphasis in spec
  - Aggregates - gap-graded or combined gradation
  - Flyash Class F and slag allowed
  - Opening to traffic strength – 2,500 psi
  - Studded tire wear is a concern
    - Combined aggregate gradation
    - Higher strength – higher cement & slag content
    - Use of hardner in the concrete mixture

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WSDOT LLCP Directions – Issues

- Studded tire resistant concrete surface
- Durability of dowel bars for 50+ years
- Tire-pavement noise & pavement friction impacts
- Construction contracting
  - Time-based incentives vs. quality-based incentives
  - Quality & long-life may suffer if focus only on time-based incentives
- DOT staff training for LLCP technology

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Ontario Highlights

- Practices similar to US
- Many projects design-build-operate; pavement type is a contractor option
- LCCA procedure use has resulted in may long-life projects going concrete
- Implemented a PWL spec for dowel bar alignment acceptance

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PWL for Dowel Bar Alignment

- The PWL is calculated for vertical alignment, horizontal alignment, longitudinal shift and depth
- If the lot PWL $\geq$ 90%, the lot is acceptable
- If the lot PWL < 90% and $\geq$ 50%, the lot is accepted with a price adjustment
- If the lot PWL < 50%, the lot is rejectable & subject to repair/reassessment

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LLCP - Future Directions

- LONG-LIFE IS NOT JUST THICKER PAVEMENTS
- Lots of incremental improvements necessary in design, materials & construction processes
- Need to perform accelerated structural & durability testing
  - Cannot wait for 30 years to find out if some improvements/innovations will lead to LLCP

LLCP - Future Directions

- M-E procedures will allow optimum designs
  - Will address high levels of truck traffic
  - Design life of 40 to 50+ years more reliable
  - Will consider many design features
- State-based design catalogs will become standard
- BUT, NO RADICAL CHANGES IN DESIGN EXPECTED (Plain Jointed or CRCP)

Can we learn from other DOTs & international practices??

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LLCP - Future Directions

- Equipment changes will be slow – investments require 10+ years to pay off
  - Improvements in concrete production & placement efficiency
- Biggest change – in concrete materials and construction practices
  - Higher strength concretes as in Europe?
  - More emphasis on construction quality & durability
    - Minimizing material & construction variability
  - Emphasis on END PRODUCT REQUIREMENTS

Obtaining LLCP - Simply by Achieving Consistently What We Know is Attainable

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Thank You!