CRCP
Performance
Measuring CRCP Performance

Fun Times!!
Long-Term Performance

• On average, CRC pavement:
  – Lasts over 30 years & carry millions of ESALs, longer than any other pavement type
  – Requires minimal maintenance & repair
  – Causes minimal disruption to traffic once constructed
  – Built smooth stays smooth
  – Offers long-lived rehabilitation options
Long-Term Performance KEYS

• “Design” CRC pavement
  – Understand coarse aggregate influence on performance
  – Understand concrete-reinforcing steel interrelationships

• Approach monolithic slab behavior/achieve maximum load transfer

• Aim for uniformity
  – concrete, support conditions, construction methods to minimize construction-related distress

• Avoid edge problems; provide non-erodible bases
Long-Term Performance KEYS

• “Sweat” the details
  – Details of rebar layout are important
• Tie construction to design assumptions
• Recognize effects of changes in ambient conditions
• Educate construction & inspection personnel

Use FHWA “Hiperpav” or CRSI “PowerPave” to evaluate changes in conditions, materials
Long-Term Performance
Defining & Solving Failures

• Concrete material defects: D-cracking, ASR
• Transverse crack deterioration
• Localized distress at construction joints, end terminals
• Horizontal cracking
• Punch-outs
Eliminating Problems

- Adequate thickness & tight cracks
- Proper steel amount & placement
- Good non-erodible subbase
- Drainage design
- Shoulder design, widened lanes

Punch-Out Prevention
Performance – Loads (Maximum US Truck Weights)

<table>
<thead>
<tr>
<th>Weight Limit (lbs)</th>
<th>Pre-Interstate</th>
<th>1956</th>
<th>1975</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>73,280</td>
<td>80,000</td>
</tr>
<tr>
<td></td>
<td>58,420</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>88,000? 97,000?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

All pavements saw truck weights higher than design loads.
States Experiences & Performance
California CRCP Test Section
Close view of transverse cracks in passing lane in 2005, 1949 CRCP, Interstate 80, California
State Performance – Virginia

• 1966-67: first CRCP on I-64 through Richmond, about 15 miles
• ASR hits IH-64 (also Delaware CRCP)
• Poor performance seen on tube-feeding
  – VDOT mandates manual placement method
• “Smart Road” near Blacksburg contains CRCP test section, with asphalt & JPCP
• 2000: First use of high-performance concrete on CRCP on IH-64, VA-288, US-29
Oklahoma

% of original interstate highways that were reconstructed, rehabilitated or preserved only. Urban sections excluded.

- 1969: first projects
- 110 lane miles placed by 1972
- Soil conditions & traffic dictate CRCP
- Several projects this year, I-44 Tulsa
- I-40 Oklahoma City
  - Raised steel above midpoint, moist cure for 36 hrs after placement, strength requirement to 5000 psi & steel 0.8%
Recent Projects

- **I-35 in Oklahoma City**
  - AADT = 113,800
  - 10” CRCP, 4” OG Bit Base, 12 Agg Base, 8” Lime Subbase

- **I-40 in McIntosh County**
  - AADT = 14,400 (35% trucks)
  - 9” CRCP unbonded overlay
  - 1 ½” HMA over 9” JRCP built in 1964
Georgia

- **I-95 (1972-1975)**
  - Between Savannah and Florida Line
  - 8.5-9 inches reconstructed

- **I-75 (1974)**
  - Cobb and Monroe Counties
  - ~ 65 lane miles

- **I-20**
  - ~63 lane miles

Original Interstates w/CRCP
128 lane miles still in service
I-75 Cobb Co (1974)

9” CRCP – 1” H Mix – 5” Cement Stabilized GAB

241,600 ADT now
## Recent Projects
**LET 2005-2007**

<table>
<thead>
<tr>
<th>State Route</th>
<th>P.I. No.</th>
<th>CL Miles</th>
<th>Lane Miles</th>
</tr>
</thead>
<tbody>
<tr>
<td>I-75</td>
<td>410520 Cook</td>
<td>9.8</td>
<td>60</td>
</tr>
<tr>
<td>I-75</td>
<td>410530 Cook-Tift</td>
<td>9.7</td>
<td>59</td>
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<tr>
<td>I-20</td>
<td>M002966 Carroll-Haralson</td>
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<tr>
<td>I-20</td>
<td>210810 Newton</td>
<td>1.75</td>
<td>10.5</td>
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<td>I-85</td>
<td>M002434 Coweta</td>
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<td>38</td>
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<tr>
<td>I-85</td>
<td>003161 Coweta</td>
<td>14</td>
<td>84</td>
</tr>
<tr>
<td>I-85</td>
<td>M003480 Fulton</td>
<td>4</td>
<td>16</td>
</tr>
<tr>
<td>I-95</td>
<td>511100 Glynn-McIntosh</td>
<td>7.5</td>
<td>45</td>
</tr>
<tr>
<td>I-95</td>
<td>005088 Glynn</td>
<td>4.7</td>
<td>29</td>
</tr>
<tr>
<td>6 /US 278</td>
<td>M003158 Cobb-Douglas</td>
<td>6</td>
<td>25</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>~80</td>
<td>~413</td>
</tr>
</tbody>
</table>
State Performance – Oregon

• 1963: first built 9.5 miles of 4 lane CRCP on IH-5 between Medford & Ashland in Jackson County
  – 8” with 0.6% longitudinal steel on aggregate base
  – ESALs: 3.6 million design; 22.6 million actual (thru 2000)

• 2005: electrical heating wires installed along EB lanes of IH-84 at Ladd Canyon, extremely challenging section E of La Grande
Oregon CRCP Performance

560 +/- Miles Constructed

- Still In-Service: 59%
- Rut Repair: 22% (2” overlay)
- Thick Overlay (>=4”): 16%
- Rubblize/Reconstruct: 3%

CRCP Age

- 1-44 Years; Av’g: 23 yrs
- 25-45 Years: Av’g: 35 yrs. Overlays placed at 17 to 44 yrs due to rutting.
- Overlays placed at 30-42 yrs due to punchouts and cracking.
- Projects were > 37 yrs and considered too far gone for overlay.
Age IRI Versus
State Performance – Texas

[Diagram showing the history of THD Design Standards in Texas, starting with Illinois in the 1940s, leading to Texas in 1951 with 2 projects in Ft. Worth, followed by Ft. Worth (1957), Houston (1957), San Antonio (1958), and Dallas (1959), and ending with the THD Design Standard (1959).]
Long-Life CRCP in Texas

• **Dallas:** IH 635 was built in mid-late 1960s, 8 inch CRCP, still in service today.

• **Dallas:** IH 45 southbound was built in late 1960s, 15 miles of 8 inch CRCP, still in service today.

• **Dallas:** North Central Expressway, built in late 1940s and early 1950s, in service until reconstruction in late 1990s.

• **Houston:** IH 610 Loop, portions of 6” CRCP frontage road built in 1961 still in service today.
Concrete Pavement in Texas

![Graph showing PMIS Lane Miles from 2006 to 2010 for CRCP and JCP.

TxDOT PMIS Annual Report]
State Performance – Illinois

• 1947: first experimental CRCP on US-40
• 1960 CRC used extensively thru 2000s
• 1981: first completely rebuilt freeway Edens Expressway
  – 10" CRCP reached design traffic life in 1996
  – No major rehabilitation in 25 years
  – AC overlay in 2008
• 2001: CRCP accelerated study at Advanced Transportation Research and Engineering Laboratory
• 2002: first use of “Long-Life Pavement” on IH-70 with 30 year design life
  – 13” CRCP, 6”bituminous base, 12” aggregate
• 2007: 14” CRCP used to rebuild IH-90/94 thru Chicago
Summary of Pavement Life (No DC) – Cumulative ESALs

![Diagram showing pavement life summary with ESALs for different materials and designs.](image)
Actual vs. Design ESAL – No DC

40-90 MESALs

50th Percentile ESAL, million  Design ESALs, million

Cumulative Million ESALs

Design ESAL varies
Dan Ryan Expressway
I-94 Chicago 500 million ESALs

2007
LTPP – Smoothness

“CRCP pavement appear to maintain relatively constant roughness values over time.” . . . “In fact, there are many sections that are more than 15 years old, but are still very smooth.”

Source: Tech Brief, FHWA-RD-98-148, LTPP
# Nationwide Load Transfer Efficiency Study

## Summary Statistics of CV Associated with Average LTE

<table>
<thead>
<tr>
<th>Statistical Parameters</th>
<th>Plain-Jointed Pavements</th>
<th>Dowelled-Jointed Pavements</th>
<th>CRC Pavements</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Avg. Section LTE, %</td>
<td>Avg. Section LTE, %</td>
<td>Avg. Section LTE, %</td>
</tr>
<tr>
<td>Mean</td>
<td>67.9</td>
<td>80.2</td>
<td><strong>91.1</strong></td>
</tr>
<tr>
<td>Maximum</td>
<td>96.8</td>
<td>97.9</td>
<td>100.4</td>
</tr>
<tr>
<td>Minimum</td>
<td>11.3</td>
<td>8.9</td>
<td>77.4</td>
</tr>
<tr>
<td>75 Percent. Point</td>
<td>&gt; 42.8</td>
<td>&gt; 73.6</td>
<td>&gt; 89.6</td>
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<tr>
<td>95% Conf. Interval for</td>
<td>± 3.7</td>
<td>± 1.1</td>
<td>± 0.4</td>
</tr>
<tr>
<td>Mean</td>
<td>± 1.2</td>
<td>± 0.5</td>
<td>± 0.2</td>
</tr>
<tr>
<td>No. of Data Sets</td>
<td>182</td>
<td>653</td>
<td>187</td>
</tr>
</tbody>
</table>

International Performance – Belgium

- Life-Cycle Cost Analysis
- Walloon Ministry of Infrastructure and Transport
- CRCP use since 1960s
- Historical data available
- Comparisons
  - 4 CRCP with different shoulders
  - 2 full-depth asphalts
Belgium Pavement Life-Cycle Cost

Source: Walloon Ministry of Infrastructure & Transport, Genl Directorate of Motorways & Roads, 2006
International Performance – UK

- 1978: first project (experimental) on M180 from Sandtoft to Trent
  - Dual 3-lane motorway, unreinforced concrete shoulder
  - Slab thickness 210mm; 230mm base material; 0.60% steel at various levels
- 1987: DoT analysis enabled thickness reduction of reinf. concrete pavement.
  - Combined with falling reinforcement prices, saw use increase
- 2001: M6 first UK toll motorway & first privately-financed motorway
  - One-half of 43km, 4 lane Birmingham Northern Relief Road (M6) built with CRC
  - 220mm thick with 35mm thin wearing course using site-won aggregates
  - Concrete train laid full 14.3m wide pavement in single pass
  - Steel reinforcement sits at mid-depth
CRCP for Tunnels
CRCP for Airports
CRCP for Intermodal Facilities
Performance Summary

• Slab thickness, %steel, & foundation layers have highest effect on CRCP performance
• CRCP can be designed for 40+ years based on traffic loads
• CRCP failures are well known & “designed” out
• CRCP causes minimal disruption to users since little maintenance & repair is required
• CRCP stays smooth
• Ideal base for concrete overlays as well as asphalt overlays
Whole Life Costs Talking Points

• Intangibles – Does a matrix make sense
• Background on state projections
• Economic or Financial analysis
• Example
• Summary
• Predictions
Intangibles

• How to account for items that are not in current economic models
  – Bias in specifications
    • Bid items – sq yd vs ton
    • Pay factors – plan width times length vs actual weight total
  – Long-life infrastructure credit
    • Real discount rate penalizes long life
    • No way to capture increasing benefits
  – Purchasing power of the dollar
• And items that are not quantified…..
  – Fuel Consumption, Reflectance & Heat Island, Sustainability, Work Zone Safety, Surface Characteristics, etc.
## Decision Matrix - Georgia

<table>
<thead>
<tr>
<th>Decision Factor</th>
<th>Relative Importance</th>
<th>1. HMA full-depth</th>
<th>2. CRCP full-depth</th>
<th>3. JPCP full-depth</th>
<th>4. CRCP UBO</th>
<th>5. CRCP full-depth w/o struct shdrs</th>
<th>6. JPCP full-depth w/o struct shdrs</th>
<th>7. CRCP UBO w/o struct shdrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Construction Agency Costs</td>
<td>40%</td>
<td>1.00</td>
<td>0.50</td>
<td>0.65</td>
<td>0.60</td>
<td>0.62</td>
<td>0.75</td>
<td>0.77</td>
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<tr>
<td>Maintenance Costs</td>
<td>20%</td>
<td>0.14</td>
<td>0.88</td>
<td>0.48</td>
<td>0.88</td>
<td>1.00</td>
<td>0.54</td>
<td>0.91</td>
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<tr>
<td>Annualized Agency Costs</td>
<td>5%</td>
<td>0.93</td>
<td>0.66</td>
<td>0.81</td>
<td>0.78</td>
<td>0.81</td>
<td>0.94</td>
<td>1.00</td>
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<tr>
<td>Annualized User Costs</td>
<td>15%</td>
<td>0.35</td>
<td>0.75</td>
<td>0.62</td>
<td>0.75</td>
<td>1.00</td>
<td>0.83</td>
<td>1.00</td>
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<tr>
<td>Salvage Value</td>
<td>2%</td>
<td>0.00</td>
<td>1.00</td>
<td>0.00</td>
<td>1.00</td>
<td>0.88</td>
<td>0.00</td>
<td>0.96</td>
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<tr>
<td>Expected Life</td>
<td>2%</td>
<td>0.40</td>
<td>1.00</td>
<td>0.80</td>
<td>1.00</td>
<td>1.00</td>
<td>0.80</td>
<td>1.00</td>
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</tbody>
</table>
# Decision Matrix – Georgia cont

<table>
<thead>
<tr>
<th>Decision Factor</th>
<th>Relative Importance</th>
<th>1. HMA full-depth</th>
<th>2. CRCP full-depth</th>
<th>3. JPCP full-depth</th>
<th>4. CRCP UBO</th>
<th>5. CRCP full-depth w/o struct shdres</th>
<th>6. JPCP full-depth w/o struct shdres</th>
<th>7. CRCP UBO w/o struct shdres</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction</td>
<td>2%</td>
<td>1.00</td>
<td>0.69</td>
<td>0.69</td>
<td>0.69</td>
<td>0.97</td>
<td>0.97</td>
<td>0.97</td>
</tr>
<tr>
<td>Ease of Repairing/Maintaining</td>
<td>2%</td>
<td>0.15</td>
<td>0.80</td>
<td>0.44</td>
<td>0.80</td>
<td>1.00</td>
<td>0.57</td>
<td>1.00</td>
</tr>
<tr>
<td>Construction Traffic Control</td>
<td>2%</td>
<td>0.33</td>
<td>0.67</td>
<td>0.67</td>
<td>1.00</td>
<td>0.67</td>
<td>0.67</td>
<td>1.00</td>
</tr>
<tr>
<td>Proven Design in Agency</td>
<td>10%</td>
<td>0.93</td>
<td>0.90</td>
<td>1.00</td>
<td>0.87</td>
<td>0.84</td>
<td>0.89</td>
<td>0.81</td>
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<tr>
<td>Total Score</td>
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<td>65.7</td>
<td>69.6</td>
<td>64.1</td>
<td>74.3</td>
<td>81.2</td>
<td>72.8</td>
<td>87.0</td>
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<td>Rank</td>
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<td>5</td>
<td>7</td>
<td>3</td>
<td>2</td>
<td>4</td>
<td>1</td>
</tr>
</tbody>
</table>
‘Economic analysis helps answer the questions "Why do it at all?" "Why do it this way?" "Why do it now?" Financial analysis helps answer the questions "Can it be financed?" "Who will bear the burden?“’ p. 21

State Road Construction (SRC) Revenues and Future SRC Buying Power

Source: Mn/DOT Office of Investment Management

Minnesota Statewide Transportation Policy Plan: 2009-2028

1.2% annual funding increase
3.0% construction cost increase
Texas Income vs Purchasing Power

Transportation Finance Challenges, Delisi, Deirdre, Texas Transportation Commission, Testimony before the House Committee on Transportation and the Senate Committee on Transportation Homeland Security, February 1, 2010.

Projecting 1% increase in Deposits thru 2020
Recession helped purchasing power in 2009
Texas Income vs Purchasing Power

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Projecting 1% increase in Deposits thru 2020
Recession helped purchasing power in 2009
FIGURE 3
Projected Construction Needs vs. Projected Construction Revenues
Program Period 2009-2028
(Does not include maintenance or administrative needs)


$ 27.5 Billion Needed Revenue by 2028
$ 16.9 Billion Shortfall
$ 10.6 Billion Projected Revenue By 2028

Needs are not met by anticipated revenue
Agency LCCA used today do not consider revenue

$ 12.3 Billion in Existing Inadequate Needs

20-YEAR PROJECTED
CONSTRUCTION NEEDS

20-YEAR PROJECTED
CONSTRUCTION REVENUES

FY 2009   FY 2016  FY 2028
Since 1993, the last year of a federal gas tax increase, receipts rose at a rate of 2.4%
Constant Dollars

“Constant dollars, often called real dollars, reflect dollars with the same or constant purchasing power over time.

In such cases, the cost of performing an activity would not change as a function of the future year in which it would be accomplished.

For example, if hot-mix asphalt concrete (HMAC) costs $20/ton today, then $20/ton would be used for future year HMAC cost estimates.”
Indexing Constant Dollars

AASHTO Survey on the Use of Price Adjustment Clauses

www.fhwa.dot.gov/programadmin/contracts/aashto.cfm

Oxymoron – we just stated $20 today is $20 in the future
“… Revenues, in the past, increased as fuel consumption increased and, at relatively low inflation rates, funding pretty well kept pace with costs. However, with the 1973 oil embargo a very pronounced change occurred. … costs increased sharply due to rapidly rising inflation rates. While future rates may be tempered somewhat, there is every reason to believe that this trend will continue.”  p. 631

BLS Inflation Indexes


- Paving Asphalt (CAGR=7.2%)
- Steel Mill Products (CAGR=4.7%)
- Concrete Products (CAGR=4.3%)
- Aggregate (CAGR=4.6%)
- Cement (CAGR=4.3%)
- CPI (CAGR=4.4%)

67% difference in CAGR between Concrete Products and Paving Asphalt
Not your father's global economy

Contributions to global GDP growth

Data: International Monetary Fund, April 2010

Forecast

Advanced economies (U.S., Euro area, Japan)

Rest of the world

China

Advanced economies no longer leading ~ 70% GDP to 20%
Economic downturn has had little long-term effect on the price of oil.
Nominal Discount Rate accounts for inflation

- “The essential time to consider inflation is when the project budget is being prepared, after economic analysis has shown the project to be economically viable.

- Future year or multiyear project budgets are appropriated in future year dollars rather than base year dollars.

- Failure to account for inflation in project budgets will almost always result in too few future year dollars being set aside to complete the projects…”

  - Economic Analysis Primer, FHWA IF-03-032
Kansas Viewpoint

• “…With the spiraling costs of single product one needs to consider what ramifications a decision made today based on costs will have in the future. Once a pavement type is selected the subsequent actions are tied to that pavement type as are the costs.”

Special Experimental Project (SEP-14)  
Alternate Surfacing Bidding

Report No. FHWA-KS-09-1
LCCA/Budget

• Determine action – program item in budget
  – Estimate time of action - yes
  – Estimate cost of action
    • Base on today’s cost - yes
    • Inflate to account for cost adjustments
      – Nominal rate – yes
      – Real rate - no

• Estimate future cost
  – If use nominal rate - yes
  – If use real rate - no
What does it really cost?

“The present situation in funding of highway maintenance and improvements, described earlier in this paper, involves rising costs and reduced revenues. Both are reflections of inflationary pressures. If this scenario is indicative of future trends, then these factors should be taken into account in engineering economic evaluations of alternative maintenance, rehabilitation, and replacement strategies for highway facilities. The real cost of providing essential future services in terms of the value of expendable future income is” p. 633

\[ F' = F \left( \frac{1+f}{1+q} \right)^n \]

- \( F' \) = present worth of future services
- \( F \) = present cost of services (products)
- \( q \) = rate of increase in funding
- \( f \) = rate of inflation for service
- \( n \) = time of expenditure in years

3 Designs for Freeway Construction 2 lanes, one mile, 75 years

<table>
<thead>
<tr>
<th>Activity</th>
<th>Today’s Cost</th>
<th>Inflated Cost</th>
<th>Real Discount Rate (per Caltrans)</th>
<th>Nominal Discount Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>DR = 4.0%</td>
<td></td>
</tr>
<tr>
<td>15” Hot Mix -Initial Rehab costs (5)</td>
<td>$1,631,997</td>
<td>$1,631,997</td>
<td>$1,631,997</td>
<td>$1,631,997</td>
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<tr>
<td>Total</td>
<td>$1,425,573</td>
<td>$43,424,690</td>
<td>$377,786</td>
<td>$4,860,935</td>
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<tr>
<td></td>
<td>$3,057,570</td>
<td>$45,056,687</td>
<td>$2,009,783</td>
<td>$6,492,933</td>
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<tr>
<td>12” JPCP - Initial Rehab costs (3)</td>
<td>$1,512,362</td>
<td>$1,512,362</td>
<td>$1,512,362</td>
<td>$1,512,362</td>
</tr>
<tr>
<td>Total</td>
<td>$449,758</td>
<td>$4,622,918</td>
<td>$96,375</td>
<td>$497,758</td>
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<tr>
<td></td>
<td>$2,012,120</td>
<td>$6,135,280</td>
<td>$1,608,738</td>
<td>$2,012,120</td>
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<tr>
<td>10.2”CRCP - Initial Rehab costs (2)</td>
<td>$1,621,238</td>
<td>$1,621,238</td>
<td>$1,621,238</td>
<td>$1,621,238</td>
</tr>
<tr>
<td>Total</td>
<td>$193,650</td>
<td>$1,119,242</td>
<td>$50,440</td>
<td>$193,650</td>
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<tr>
<td></td>
<td>$1,814,888</td>
<td>$2,740,479</td>
<td>$1,671,678</td>
<td>$2,025,486</td>
</tr>
</tbody>
</table>

Initial construction: total cost sq yd price/pavement sq yd price
Hot Mix  $72.48/$67.93  JPCP $67.17/$37.49  CRCP $72/$42.33
STATE INFLATION DATA FOLLOWS THE SAME TREND AS NATIONAL INFLATION DATA.

**BLS & State Asphalt Inflation Rates**

- BLS Liquid Asphalt (CAGR=9.8%)
- FDOT AC 20/30 (CAGR=13.6%)
- TDOT Bituminous (CAGR=12.5%)
- SCDOT Asphalt Binder (CAGR=12.4%)
- NCDOT Asphalt Binder (CAGR=12.8%)
- ALDOT Asphalt (CAGR=12.7%)
- AZDOT Bitum. Material (CAGR=13.2%)
- CALTRANS Paving Asph. (CAGR=14.9%)
- BLS Cement (CAGR=2.2%)
- BLS Ready Mix Conc (CAGR=3.3%)

(Data thru July 2011)

**BLS & USGS (State) Cement Inflation Rates**

- BLS Liquid Asphalt (CAGR=9.8%)
- FL Cement (CAGR=2.99%)
- KY, MS, TN Cement (CAGR=2.75%)
- SC Cement (CAGR=2.51%)
- AL Cement (CAGR=1.43%)
- AZ & NM Cement (CAGR=2.15%)
- South CA Cement (CAGR=2.19%)
- North CA Cement (CAGR=3.03%)
- BLS Cement (CAGR=2.2%)
- BLS Ready Mix Conc (CAGR=3.3%)

(Data thru July 2011)

2. Statewide Paving Asphalt Price Indexes are from each State DOT's website
Cost Basis for Decision

ACC inflation factor of 7.2% used for nominal DR OMB & DR prog
PCCP & CRCP inflation factor of 4.3% used for nominal DR OMB & DR prog
Indexes

“The indiscriminate use of indexes of price changes to situations where they do not apply can cause serious distortions in the decision-making process.

Nationwide composite cost indexes should not be used when state or local indexes are available.

Neither should composite indexes be used if component indexes are available.”

p. 34

# Lumber, Steel, Concrete, and Asphalt Escalation Rates

<table>
<thead>
<tr>
<th>Year</th>
<th>Lumber</th>
<th>Steel</th>
<th>Concrete</th>
<th>Asphalt</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>2.12%</td>
<td>2.24%</td>
<td>0.57%</td>
<td>3.84%</td>
</tr>
<tr>
<td>15</td>
<td>1.41%</td>
<td>1.48%</td>
<td>0.40%</td>
<td>3.21%</td>
</tr>
<tr>
<td>20</td>
<td>1.07%</td>
<td>1.14%</td>
<td>0.28%</td>
<td>2.93%</td>
</tr>
<tr>
<td>25</td>
<td>0.72%</td>
<td>0.99%</td>
<td>0.23%</td>
<td>2.82%</td>
</tr>
<tr>
<td>30</td>
<td>0.74%</td>
<td>0.85%</td>
<td>0.15%</td>
<td>2.69%</td>
</tr>
</tbody>
</table>

Life-Cycle Cost Analysis

LCCA uses discounting to convert anticipated future costs to present dollar values so that the lifetime costs of different alternatives can be directly compared. Discounting is an economic method of accounting for the time value of an investment.

FHWA Office of Asset Management
Summary

• CRCP is the best choice for pavements with heavy traffic loads and congestion – level C and above.
• Future LCCA models should consider program dollars if realistic budgets are to be met.
• The “real” discount rate penalizes long life pavements.
• Agencies need to recognize program costs – not discounted costs – and intangibles when determining the best pavement choice.
Summary

- Nominal Discount Rate Rationale
  - Using Real DR assumes Trust Fund increases at same rate as the economy grows - we know this is not realistic
    - Fixed gas tax rate
    - More fuel efficient vehicles
    - Oil price volatility
  - Use local commodity indexes for future costs
  - Use rate of increase in funding to bring back to present value
- Nominal Discount Rate allows us to ascertain what projected revenue stream is needed to accomplish future actions
  - Gives better “financial” picture of expenditures based on pavement choice that can be used by planners
Predictions

• World demand for liquid asphalt will rise in developing countries.
• Price model will follow demand and cost will continue to increase above CPI.
• Fiduciary responsibility will dictate that limited resources be consumed in a prudent manner i.e., asphalt’s primary use will be for maintenance and rehabilitation of existing facilities.
• Nominal discount rates will be based on 20 year individual inflation rates and brought back by future rates of income projections for life cycle programmed pavement costs.
20’ pavement, 20’ joints, 1920’s or early 30’s
Thank you for your time
Eliminating Problems

- ASR
- D-cracking: aggregate freeze-thaw durability
- Use of cementitious materials (fly ash) – Affect on strength gain
- Aggregate size, shape, CTE

Concrete Materials

<table>
<thead>
<tr>
<th>Crack Spacing (ft)</th>
<th>Distribution Frequency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LS</td>
<td>SRG</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Graph showing distribution frequency against crack spacing.
Eliminating Problems – Corrosion

• In UK Study when corrosion occurred in CRCP:
  – Corrosion level was much less & more localized on longitudinal reinforcement than on transverse bars, & coincided with transverse cracks
  – As longitudinal bars have greater influence on structural performance of pavements than transverse bars, good performance could still be achieved even with significant corrosion
  – The probability of corrosion during the service life is high
  – The consequences of corrosion on the structural performance of CRCP are very low

• Overall, the risk of corrosion affecting the service life of CRCP is low (IF CRACKS ARE TIGHT, MNP)

• Added safeguard may be epoxy coatings

Source: New Continuously Reinforced Concrete Pavement Designs, TRL30, UK, 2005
Performance Studies

• States experiences
  – Individual state studies/experiences/research
  – Pooled fund studies

• National studies
  – LTPP GPS-5 Data Summary

• International studies
  – Europe: Belgium, France, The Netherlands, United Kingdom,
  – Australia, South Africa

• FHWA SCAN Tours
Reflectance & Heat Island

• Lower number of light fixtures required for concrete pavement – up to 30%
• Fewer fixtures is directly related to less energy costs as well as installation and maintenance

Gaza and VanGeem

• Concrete temperature can be 20 degrees F cooler
• Lower temperatures can reduce smog formation

Pomerantz et al.
Fuel Consumption

• Fuel consumption is impacted by rolling resistance and pavement deflection

• Fully loaded tractor-trailers can reduce consumption 1% to 6% when traveling on concrete

National Research Council of Canada (NRC)

• Concrete pavement construction takes less fuel to build the road than asphalt pavement

FHWA Technical Advisory No. T 5980.3
Sustainability

• Paving mixtures incorporate industrial byproducts (i.e., fly ash and slag cement)
• Concrete is recyclable, steel is recyclable
• Concrete pavements exhibit a lower energy footprint associated with their production, delivery and maintenance
• Noise pollution can be reduced by optimizing a long lasting surface texture
Work Zone Safety

- Work zone fatalities in 2010 were 576 – 1.75% of all roadway fatalities – 41 in CA
- More than 40,000 people are injured each year as a result of motor vehicle crashes in work zones

- In 2010 there were a total of 5,419,000 crashes

- For all crashes in CA “In addition to the lives saved and injuries averted, over $17 billion in adverse economic impacts were avoided from 2009 to 2010”

http://safety.fhwa.dot.gov/wz/facts_stats/

Traffic Safety Facts 2010 DOT HS 811 552

OTS 2011 Annual Performance Report
Surface Characteristics

- Long lasting
- Excellent friction resistance
- Quiet
- Smooth
- No rutting
- Less spray
Cost Escalation due to Inflation in years

- 2% Inflation
- 3% Inflation
- 4% Inflation
- 5% Inflation

$208,000 (Overlay Costs in Today's Dollars)
FHWA
Risk Based Cost Estimate Reviews

2010 Capacity Building Workshop
Minneapolis, MN

FHWA-Resource Center
Construction & Project Management Team

Craig M. Actis PE
August 11-13, 2010
Cost Estimating Key Principles

• Process must be transparent
• Should include all project costs
  – Ex: NEPA work, design, right of way, public outreach, project management, construction
    – Include soft costs
• Expressed in Year of Expenditure Dollars
  – Assign a realistic inflation rate per year
    – Usually 3-4% per year
Issues/Lessons Learned

- Inflation/Escalation
  - Inconsistent Application
  - What is included? ie. CPI/PPI, Market Conditions, Number of Bidders, Short Term Material & Labor Prices, etc.
  - Recommend that DOTs keep a cost index
  - Document Assumptions