CONCRETE PAVEMENT

The Right Solution for Florida

March 2009
Florida Pavement System

Concrete and Asphalt Pavement Initial Costs

Concrete and Asphalt Pavement Life Cycle Costs

Traffic and Truck Weights

What if?

MythBusters
FDOT maintains over 42,400 lane-miles of roads & highways.

- **Total System = 42,400 Lane Miles**
  - 960 (2.3%) Lane Miles Concrete
  - 41,440 (97.7%) Lane Miles Asphalt

- **Florida Interstate/Turnpike Highways = 9,500 Lane Miles**
  - 600 (6.3%) Lane Miles Concrete
  - 8,900 (93.7%) Lane Miles Asphalt

- **Florida State Roads = 32,800 Lane Miles**
  - 362 (1.1%) Lane Miles Concrete
  - 32,441 (98.9%) Lane Miles Asphalt

MAJORITY OF ROADS IN THE STATE ARE ASPHALT, REQUIRING PERPETUAL REHABILITATION WORK
FL IS INVESTING MORE RESOURCES INTO MAINTAINING EXISTING ROADS RATHER THAN BUILDING NEW ONES

While resurfacing expenditures have increased more than 9%, the total lane miles have increased by less than 1%.

1. Florida Department of Transportation, Program and Resource Plan Summary Fiscal Years 1979/80 to 2007/08
   Resurfacing & Maintenance are summation of "Program I-Product J (resurfacing)" and "Program III-O&M (Routine Maintenance)"

2. Florida Department of Transportation, Florida Highway Mileage Reports - State Highway System
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HISTORICALLY ASPHALT HAD THE INITIAL COST ADVANTAGE WITH CONCRETE RANGING FROM 10-40% MORE THAN ASPHALT
Depends on design specifics

As a result, asphalt was considered to be the right choice

1. Initial costs for 10 miles, 2 lanes & Shoulders. Costs include Pavement, base, and subgrade stabilization materials and labor
   Asphalt from FDOT 2004 Price Trends Annual Average = Asphalt PFC = $74.8/ton (delivered), Asphalt Base = $62.33/ton (delivered), Concrete = $81.05 ($76.05 + $5/CY for delivery) (Regional Average Range is $71.60 - $76.05)
2. LBR = Limerock Bearing Ratio (a measure of strength on a scale from 0 to 100 (strongest))
2. Initial costs for 10 miles, 2 lanes & Shoulders
2004: Asphalt PFC = $74.8 / ton (delivered), Asphalt Base = $62.33/ ton (delivered), Concrete = $81.05 ($76.05 + $5/CY for delivery)
2008: Asphalt PFC = $115.00 / ton (delivered), Asphalt Base = $85.00/ ton (delivered), Concrete = $104.62 ($94.62 + $10/CY for delivery)

NOTWITHSTANDING THE RECENT ASPHALT PRICE DECLINES,
Price between concrete and asphalt pavements has narrowed

Asphalt mix prices have increased 96% since 2000\(^1\)

Concrete initial cost gap has decreased, but still remains 23% higher

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2. Initial costs for 10 miles, 2 lanes & Shoulders
2004: Asphalt PFC = $74.8 / ton (delivered), Asphalt Base = $62.33/ ton (delivered), Concrete = $81.05 ($76.05 + $5/CY for delivery)
2008: Asphalt PFC = $115.00 / ton (delivered), Asphalt Base = $85.00/ ton (delivered), Concrete = $104.62 ($94.62 + $10/CY for delivery)
ADDITIONALLY, THERE HAVE BEEN TECHNOLOGICAL ADVANCES IN CONCRETE PAVEMENT DESIGN  
New design procedure based on advanced models & actual field data collected across the US

Mechanistic Empirical Pavement Design Guide (MEPDG)

<table>
<thead>
<tr>
<th>Description</th>
<th>Process</th>
<th>Validation</th>
</tr>
</thead>
</table>
| ▪ A new mechanistic design procedure based on most advanced pavement performance models  
▪ Comprehensive methodology that incorporates layer thicknesses, material properties, climate, and traffic loadings  
▪ It uses mechanistic-empirical numerical models to analyze traffic, climate, materials, and proposed structure to estimate accumulated damage of the analysis period  
 | ▪ Provides predicted performance of a given structure during analysis period  
▪ AASHTO 93 only provides thickness (no performance)  
▪ Concrete Criteria = cracking, faulting, IRI, cumulative damage, and load transfer  
 | ▪ Adopted by AASHTO in 2007 as the Interim Pavement Design Guide  
▪ Most states are currently in the process of calibrating and validating the design procedure with actual field performance data  
▪ Improves accuracy of performance prediction for each pavement type  
▪ Provides “true” performance of each pavement type  

Limited adoption by FDOT as a supplement to the Concrete Pavement Design Manual
### MEPDG ALLOWS FOR DESIGN OPTIMIZATION
Making Concrete’s Initial Cost More Attractive

<table>
<thead>
<tr>
<th>Asphalt Design</th>
<th>FDOT Concrete Design</th>
<th>Optimized Concrete</th>
<th>Initial Cost Comparison</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.75-1.5” Fric. Course</td>
<td>12.0” PCC Jointed w/ Dowels</td>
<td>10.0” PCC Jointed w/ Dowels</td>
<td>$36.3</td>
</tr>
<tr>
<td>5.5” Asphalt Ty-SP</td>
<td>4” ATPB non-structural</td>
<td>1.5” Asph. Structural Layer</td>
<td>23%</td>
</tr>
<tr>
<td>12” Limerock Base Course (LBR = 100)</td>
<td>12” Type-B Stabilized Subgrade (LBR=40)</td>
<td>12” Limerock Stabilized Base (LBR=70)</td>
<td></td>
</tr>
<tr>
<td>12” Type-B Stabilized Subgrade (LBR=40)</td>
<td>Subgrade</td>
<td>Subgrade</td>
<td></td>
</tr>
</tbody>
</table>

**Initial cost gap is significantly reduced when using MEPDG**

Initial costs for 10 miles, 2 lanes & Shoulders. Costs include Pavement, base, and subgrade stabilization materials and labor
Asphalt = $85.00 / ton, Concrete CY Price = $104.62 ($94.62/CY + $10/CY for delivery)
DIFFERENT FACTORS HAVE MADE CONCRETE’S CURRENT INITIAL COST COMPARABLE TO ASPHALT

Initial Cost Difference between Asphalt and Concrete

- Initial Gap: 32.2% (New Gap = 32.2% - 9.4% = 22.8%)
- Inflation Effect: 22.8% (New Gap = 32.8% - 19.7% = 3.2%)

MEPDG Redesign
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Mythbusters
MOREOVER, CONCRETE DELIVERS SUBSTANTIAL SAVINGS THROUGHOUT THE LIFE CYCLE OF THE ASSET

Nominal Expenditures by Pavement Type for 10 Miles

Concrete Rehab: Patch & diamond grind at years 30 and 45
Asphalt Rehab: 4” AC Overlay in years 14 & 28
2” Mill / 4” AC Overlay in year 42

Discount Rate = 8%

Total Cost Net Present Value

Asphalt is 49% more expensive than concrete throughout the life cycle of the road

Design – Asphalt: 6.5” AC (inc 1.5” PFC) / 12” Limerock (LBR=100) / 12” Limerock (LBR=40); Concrete: 10” JPCP / 1.5” AC / 12” Limerock (LBR=70)
Initial costs - Pavement, base, and subgrade stabilization materials and labor (Asphalt = $85.00 / ton, Concrete = $94.62 / CY)
Rehabilitation - Concrete activities based on MEPDG, Asphalt Activities based on standard FDOT Standards

Current year costs are inflated at 4%
Rehab costs also include other Incidental Costs (striping, mob, etc) - Assumed to be 40% of Material Costs and Traffic Control - 5% of material cost, Engineering & Inspection - 5% of material cost
RECENT DATA SHOWS THE AVERAGE ASPHALT INTERSTATE LAST 10 YEARS BEFORE NEEDING RESURFACING

Weighted Average Life of Resurfacing (Interstate System)

<table>
<thead>
<tr>
<th>Interstate</th>
<th>Asphalt Miles</th>
<th>Weighted Average Life</th>
</tr>
</thead>
<tbody>
<tr>
<td>I-95</td>
<td>339.2</td>
<td>8.9</td>
</tr>
<tr>
<td>I-75</td>
<td>426.8</td>
<td>11.3</td>
</tr>
<tr>
<td>I-10</td>
<td>229.8</td>
<td>8.5</td>
</tr>
<tr>
<td>I-4</td>
<td>86.2</td>
<td>10.6</td>
</tr>
<tr>
<td>Statewide</td>
<td>1084.0</td>
<td>9.9</td>
</tr>
</tbody>
</table>

Source
2003 Florida DOT Data, FDOT Pavement management records
Analysis by Dr. Jamshid Armaghani, Ph.D., P.E., Florida Concrete & Products Association
Using FDOT History, Asphalt's Cost of Ownership is 91% more than Concrete

Design - Asphalt: 6.5" AC (inc 1.5" PFC) / 12" Limerock (LBR=100) / 12" Limerock (LBR=40); Concrete: 10" JPCP / 1.5" AC / 12" Limerock (LBR=70)

Initial costs - Pavement, base, and subgrade stabilization materials and labor (Asphalt = $85.00 / ton, Concrete = $94.62 / CY)

Rehabilitation - Concrete activities based on MEPDG, Asphalt Activities based on 2003 FDOT Pavement management records for interstates.

Current year costs are inflated at 4%

Rehab costs also include other Incidental Costs (striping, mob, etc) - Assumed to be 40% of Material Costs and Traffic Control - 5% of material cost, Engineering & Inspection - 5% of material cost
UP TO THIS POINT, ALL COMPARISONS HAVE BEEN MADE WITH THE SAME INFLATION RATES
However, asphalt prices are much more volatile...

Asphalt's higher inflation rate implies more expensive rehabilitation work in the future

Source: U.S. Department of Labor, Bureau of Labor Statistics
http://www.bls.gov/ppi/home.htm
Paving Asphalt Series ID = wpu13940113
Cement Series ID = wdu13220131 and wpu13220161
Concrete Products Series ID = wpu1333
Using data from 2000, asphalt’s inflation is even higher.

Inflation Rates since Jan 2000

- Paving Asphalt
- Cement
- Concrete Products

Asphalt CAGR = 8.5%
Cement CAGR = 3.8%
Concrete Product CAGR = 4.5%

Month-to-Month Change in PPI since Jan 2000

- Paving Asphalt
- Concrete Products

Max Asphalt Change = 12.2%
Max Concrete Change = 3.8%

Since 2000, asphalt’s inflation rate is double cement & concrete’s inflation rate

Source: U.S. Department of Labor, Bureau of Labor Statistics
http://www.bls.gov/ppi/home.htm
Paving Asphalt Series ID = wpu139401113
Cement Series ID = wdu13220131 and wpu13220161
Concrete Products Series ID = wpu133
ASPHALT’S HISTORICAL 5.9% INFLATION GREATLY INCREASES THE ASPHALT COST OF OWNERSHIP

Nominal Expenditures by Pavement Type for 10 Miles

Concrete Rehab: Patch & diamond grind at years 30 and 45
Asphalt Rehab: 4” AC Overlay in years 14 & 28
2” Mill / 4” AC Overlay in year 42

Discount Rate = 8%

Asphalt is 84% more expensive when using historical inflation rates

Design – Asphalt: 6.5” AC (inc 1.5” PFC) / 12” Limerock (LBR=100) / 12” Limerock (LBR=40); Concrete: 10” PCC / 1.5” AC / 12” Limerock (LBR=70)
Initial costs - Pavement, base, and subgrade stabilization materials and labor (Asphalt = $85.00 / ton, Concrete = $94.62 / CY)
Rehabilitation - Concrete activities based on MEPDG, Asphalt Activities based on standard FDOT Standards

Current year costs for asphalt are inflated at 5.9% and concrete at 4%
Rehab costs also include other Incidental Costs (striping, mob, etc) - Assumed to be 40% of Material Costs and Traffic Control - 5% of material cost, Engineering & Inspection - 5% of material cost
**Concrete Rehab:** Patch & diamond grind at years 30 and 45  
**Asphalt Rehab:** 4” AC Overlay in years 10 & 20  
2” Mill / 4” AC Overlay in years 30, 40, and 50

Using FDOT history and historical inflation, asphalt’s is 152% more than concrete

Design – Asphalt: 6.5” AC (inc 1.5” PFC) / 12” Limerock (LBR=100) / 12” Limerock (LBR=40); Concrete: 10” JPCP / 1.5” AC / 12” Limerock (LBR=70)

Initial costs - Pavement, base, and subgrade stabilization materials and labor (Asphalt = $85.00 / ton, Concrete = $94.62 / CY)

Rehabilitation - Concrete activities based on MEPDG, Asphalt Activities based on 2003 FDOT Pavement management records for interstates.

Current year costs are inflated at 4%

Rehab costs also include other Incidental Costs (striping, mob, etc) - Assumed to be 40% of Material Costs and Traffic Control - 5% of material cost, Engineering & Inspection - 5% of material cost
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Mythbusters
ADDITIONAL REHABILITATION TRANSATES INTO HIGHER WORK ZONE ACCIDENTS

Construction Work Zone Fatalities in Florida

<table>
<thead>
<tr>
<th>Year</th>
<th>Fatalities</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>31</td>
</tr>
<tr>
<td>2001</td>
<td>48</td>
</tr>
<tr>
<td>2002</td>
<td>99</td>
</tr>
<tr>
<td>2003</td>
<td>105</td>
</tr>
<tr>
<td>2004</td>
<td>136</td>
</tr>
<tr>
<td>2005</td>
<td>138</td>
</tr>
<tr>
<td>2006</td>
<td>118</td>
</tr>
<tr>
<td>2007</td>
<td>92</td>
</tr>
</tbody>
</table>

Total = 767 (2.97% of motor vehicle fatalities)

Implications

Freeway work zones increase number of traffic accidents on average 28%

Each motor vehicle fatality costs $3 million according to 2002 FHWA motor vehicle cost

Between 2000 and 2007

- Florida work zone fatalities cost $2,301 M
  \( (767 \times $ 3M = $2,301 \text{ M}) \)
- Florida highest Work Zone Fatalities / lane mile of all 50 states
- Florida has ranked #1 in Work Zone Fatalities / lane mile since 2003
  - It has been in the top 10 since 2001

Over a 50 year period, concrete will have 1/3 fewer work zones and 43% less days in a work zone

- Work zone construction days for 10 miles of 2-lane interstate roadway over 50 years
  - Asphalt - 239 days
  - Concrete - 134 days

1) 2000-2007 Fatality Analysis Reporting System (FARS) - Final, NHTSA
3) Treatment of Value of Life and Injuries in Preparing Economic Evaluations, 2002
4) Derived from Source 1) and FHWA Highway Statistics Manual, Table HM-51
5) FDOT Production Rates:
   Concrete Rehab: Patch & diamond grind at years 30 and 45 (DG = 2000 SY / day, Patch = 1192/day) Asphalt
   Rehab: 4” AC Overlay in years 14 & 28 and 2” Mill / 4” AC Overlay in year 42 (880 tons/day)
Florida’s population grows by 1000 people every day

Since April 2000 Florida’s estimated population has grown at a rate 14.2%  
- the United States grew by 7.2%.

Three Florida cities rank among the Top 10 nationwide in percentage growth among cities over 100,000 population

- Port St. Lucie (St. Lucie County) - 70.3%
- Cape Coral (Lee County) - 53.2%
- Miramar (Broward County) - 48.8%

Florida has 3 cities in the Top 20 nationwide of most congested cities

- Orlando - 54 hours in Annual Delay / Traveler
- Miami - 50 hours
- Tampa-St. Petersburg - 45 hours

Congestion and safety concerns continue to rise

1. Floridians for a Sustainable Population (FSP) [http://www.flsuspop.org/docs/florida_population_facts.htm](http://www.flsuspop.org/docs/florida_population_facts.htm)
2. US Census: [http://www.census.gov](http://www.census.gov), Data for April 1, 2000 to July 1, 2007
3. 2007 Annual Urban Mobility Report, Texas Transportation Institute, [http://mobility.tamu.edu/ums/](http://mobility.tamu.edu/ums/)
... AND THE VEHICLES ARE GETTING HEAVIER

Florida has 14 Deepwater Seaports
Three seaport expansions in development
• Port of Jacksonville
• Port of Tampa
• Port Everglades

In addition the Panama Canal is being widened to allow for bigger ships
• Over the next 20 years, cargo volume will grow at an average of 3% / year
  - Doubling 2005’s tonnage by 2025

More and heavier trucks will degrade the current infrastructure at a faster rate

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2. Proposal for the Expansion of the Panama Canal by the Panama Canal Authority, April 2006 (http://www.acp.gob.pa/eng/plan/documentos/propuesta/acp-expansion-proposal.pdf)
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Mythbusters
SINCE CONCRETE ROADS REQUIRE LESS MAINTENANCE, FL WOULD HAVE MORE FUNDING FOR NEW CONSTRUCTION

Impact of Pavement Choice on State System

- Assume a constant $1.0 B budget per year for 50 years with no inflation (Total Cumulative Budget = $50 B)
  - All funds are initially used for new construction
  - When rehabilitation is required, funds are first used for rehabilitation and the remainder for new construction

- After 50 years, Pavement choice has a great impact on number of Lane Miles constructed in the system

In 2059 Florida could have 61% more lane miles using MEPDG designed concrete than with current FDOT asphalt design.

Traditional Concrete: Initial Life = 40 years
Asphalt: initial Life = 14 year
MEPDG Concrete: initial Life = 30 year
USING FDOT 2003 DATA SHOWING REHABILITATION CYCLES OF 10 YRS, AND HISTORICAL 5.9% ASPHALT INFLATION RATE

Impact of Pavement Choice on State System

- Assume a constant $1.0 B budget per year for 50 years with no inflation (Total Cumulative Budget = $50 B)
  - All funds are initially used for new construction
  - When rehabilitation is required, funds are first used for rehabilitation and the remainder for new construction
- After 50 years, Pavement choice has a great impact on number of Lane Miles constructed in the system

In 2059 Florida could have 221% more lane miles using MEPDG designed concrete than with current FDOT asphalt design.

Traditional Concrete: Initial Life = 40 years
Asphalt: Initial Life = 10 years
MEPDG Concrete: Initial Life = 30 years

Data in graph equals 1.9% inflation for asphalt based on the delta between asphalt and concrete’s true inflation rate of 5.9% and 4% respectively.
Asphalt Inflation = 5.9%
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MythBusters
I-10 Premature Distress

I-10 across the Panhandle was built in the late 1970s to early 1980s.
The premature distress in the pavement was caused by improper design.
The major design flaw was the lack of reinforcement across the adjoining slabs (commonly referred to as dowel bars). Lack of dowels bars increased stresses in the vicinity of slab joints. The compounding design flaw was the use of non permeable and stabilized clay layer to support the concrete pavement which prevented free draining of water beneath the pavement.

With no side drains, that water got trapped and was under-pressure which caused erosion of the base, thus undermining the concrete slabs. Absence of water drainage and dowel bars in the design caused the distresses in the pavement.

Former FDOT District 3 Secretary Edward Prescott mentioned on many occasions that the I-10 problems had nothing to do with the concrete pavement, but was rather cause by base layer problems.

Since the mid 1980s the FDOT modified their design standards to include dowel bars and provisions for proper drainage.

No concrete pavement built since 1985 has had any premature failures.
Concrete Pavement Noise is caused by:

1. Faulting
   - Difference in elevation between slabs due to slab deflections
     - Modern concrete pavements use dowels to minimize deflections
       (Note I-10 in the Panhandle was built in the late 1970s to early 1980s without dowels and is the primary cause of its problems)

2. Wheel Slap
   - Wide joints (>5/8 in) create air compression in gap (wheel slap)
     - Modern concrete pavements have narrow joints (some are only ¼” wide or less).

Pavements using dowels and narrow joints are absolutely quiet
   - Concrete Pavements built in the 1940s to 1960s were designed with wide gaps > 1 inch, and no dowels
     - In 2009 many of these pavements are still in service and performing well without the need for major repairs.
     - However as vehicle tires cross the wide joint gaps they generate “slap” noise.