Design, Construction, & Sustainable Advantages of Portland Cement Concrete Pavements

Presented By:
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www.ConcreteParkingLots.com
FL. CONCRETE & PRODUCTS ASSOCIATION
HOT MIX ASPHALT

• “Sticky tape-like” adhesive for binder
  • Requires pressure (compaction)
  • Petroleum-based organic adhesive – breaks down due to heat, water, & UV rays
    • Becomes weaker over time
• Requires regular maintenance cycles
  • Periodic seal coats and overlays needed to rejuvenate pavement
• Creates a flexible pavement
  • Strength and durability highly reliant on quantity and quality of base material
PORTLAND CEMENT CONCRETE

• Industrial strength glue as binder
  • Inorganic
  • Gains strength over time
• Creates a rigid pavement
  • Able to evenly carry loads
• Low maintenance
HISTORICALLY ASPHALT HAS BEEN LOWER ON INITIAL COST
(2004 Data)

<table>
<thead>
<tr>
<th>Asphalt Paving Design</th>
<th>USD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pavement Costs</td>
<td>$67,750</td>
</tr>
<tr>
<td>• AC Layer¹</td>
<td>$17,750</td>
</tr>
<tr>
<td>• Gran. Layer²</td>
<td>$50,000</td>
</tr>
<tr>
<td>Labor Costs</td>
<td>(Included)</td>
</tr>
<tr>
<td>Curb &amp; Gutter Cost⁴</td>
<td>$8,500</td>
</tr>
<tr>
<td><strong>Total Initial Cost</strong></td>
<td><strong>$76,230</strong></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Conventional Concrete Paving Design</th>
<th>USD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pavement Costs</td>
<td>$93,050</td>
</tr>
<tr>
<td>• Concrete³</td>
<td>$43,050</td>
</tr>
<tr>
<td>• Gran Layer²</td>
<td>$50,000</td>
</tr>
<tr>
<td>Labor Costs</td>
<td>$45,000</td>
</tr>
<tr>
<td>Monolithic Curb &amp; Gutter Cost⁴</td>
<td>$3,400</td>
</tr>
<tr>
<td><strong>Total Initial Cost</strong></td>
<td><strong>$141,450</strong></td>
</tr>
</tbody>
</table>

Concrete paving traditionally been over-designed, having a significant impact on initial costs

(1) AC Price = $45/ton ($13.55/SY Total Installed)
(2) Granular Base = $10/SY
(3) Concrete = $62/CY($27.61/SY Total Installed))
(4) Additional Curb and Gutter =$10/LF asphalt , Concrete Monolithic = $4/LF
Note: 5000 SY Parking Lot
HOWEVER, ASPHALT MIX PRICES HAVE BEEN INCREASING, RAISING THE COST OF ASPHALT PAVEMENTS

Asphalt mix prices have increased 145% since 2000¹

Asphalt rising prices have reduced the initial cost gap to within 2-4% 

(1) Bureau of Labor Statistics, Producer Price Index based on year 2000
HOWEVER, ASPHALT MIX PRICES HAVE BEEN INCREASING, RAISING THE COST OF ASPHALT PAVEMENTS

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Asphalt rising prices have reduced the initial cost gap to within 2-4%

(1) Bureau of Labor Statistics, Producer Price Index based on year 2000
• ACI has developed recommended design procedure specifically for parking lots

**Given:**
- Soil Strength
- Concrete Strength
- Traffic Demand

<table>
<thead>
<tr>
<th><strong>Determines:</strong></th>
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<tbody>
<tr>
<td>• Thickness</td>
</tr>
<tr>
<td>• Jointing</td>
</tr>
<tr>
<td>• Reinforcing (opt.)</td>
</tr>
<tr>
<td>• Subbase (opt.)</td>
</tr>
</tbody>
</table>

• Recognizes construction integrity of rigid pavement materials. Recommends reduction or elimination of granular base:
  • Potential Savings = 25-35% of total cost.

• ACI 330 recognizes parking lots are different than a street/roadway.
  • Load is in the Interior
  • Primary purpose is to store & move vehicles
  • Lot may be a water collector
  • May need to accommodate lighting, islands, landscaping
HOW CONCRETE AND ASPHALT PAVEMENTS ARE DIFFERENT

Concrete Pavements are rigid

- Loads are distributed over a large area through slab action.
- Minor deflections.
- Low subgrade contact pressures.
- Subgrade uniformity is more important than strength.

Asphalt pavements are flexible

- Loads are more concentrated.
- Deflections are higher.
- Subgrade, base and subbase strength are very important.
- Usually require more layers and greater thickness for optimally transmitting load to the subgrade.

Concrete’s Rigidity spreads the load over a large area and keeps pressures on the subgrade low.
DISTRICTED REINFORCEMENT
(Is it necessary?)

- Steel reinforcement has no significant effect on a pavement’s load-carrying capacity
- Does NOT add strength
- Greater load-carrying capacities are best achieved from adding thickness or specifying higher $f_c'$
- It is rarely placed in the correct location to help

“Shorter unreinforced panels are generally more economical and provide better performance” – ACI 330R-08 3.8.1
STEEL REINFORCEMENT IS NOT MANDATORY FOR CONCRETE PAVEMENTS

- Steel reinforcement does NOT have a significant effect on a pavement’s load-carrying capacity or thickness
  - It does effect the joint design of the pavement
  - Joints are placed according to the system selected and identifies the “concrete pavement type”
- For all paving applications, industry does not recommend using mesh reinforcing steel
  - Not enough mesh to add strength
  - It is rarely placed at the correct depth
- Greater load-carrying capacities are best achieved from adding thickness or specifying higher fc’

“Shorter unreinforced panels are generally more economical and provide better performance” – ACI 330R-08 3.8.1
WHY ARE JOINTS NECESSARY?

- The concrete will crack after placement
  - Joints tell the concrete where to crack
- Why does concrete crack after placement?
  - Concrete drying shrinkage
  - Changes in temperature and moisture
    - Ambient (contraction)
    - Gradient (curling)
  - Subbase restraint (friction or bond)
  - First applied loads

Proper jointing provides a series of saw cuts (joints) spaced to control crack formation

Erratic crack patterns due to no joints

<table>
<thead>
<tr>
<th>Pavement thickness, in.</th>
<th>Spacing range, ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 to 4.5</td>
<td>6-10</td>
</tr>
<tr>
<td>5 to 5.5</td>
<td>7.5 -12.5</td>
</tr>
<tr>
<td>6 or greater</td>
<td>10-15</td>
</tr>
</tbody>
</table>
DO I NEED DOWELS?

Dowels are used to improve Load Transfer

A slabs ability to share its load with neighboring slabs
1. Dowels

2. Aggregate Interlock
   • Shear between aggregate particles below the initial saw cut

3. Concrete shoulders, extended lane, & curb and gutter aid load transfer

Trucks Control Thickness and Deflections

• Include dowels if:
  • Slab thickness > 8.0 inches
• Exclude dowels if:
  • Slab thickness < 7.0 inches

Other issues:
Speed of Traffic (Speeds >~30 mph more apt to need dowels)
Channelized traffic (more apt to need dowels)
Direction (single direction more apt to need dowels)
IMPLEMENTING THESE INDUSTRY RECOGNIZED PRACTICES, WILL MAKE CONCRETE MORE COMPETITIVE

<table>
<thead>
<tr>
<th>Element</th>
<th>Objective</th>
<th>Recommendation</th>
<th>Cost Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pavement Thickness$^1$</td>
<td>• Design thickness to match expected traffic</td>
<td>• Do not use artificial minimums</td>
<td>10-20%/inch</td>
</tr>
<tr>
<td></td>
<td>• ACI 330 Guide</td>
<td>• ACI 330 Guide</td>
<td></td>
</tr>
<tr>
<td>Granular Base$^2$</td>
<td>• Used to prevent pumping</td>
<td>• Only use in high truck traffic areas (&gt;200/day)</td>
<td>25-35%</td>
</tr>
<tr>
<td></td>
<td>• Used as construction platform</td>
<td>• Appropriate compaction of subgrade</td>
<td></td>
</tr>
<tr>
<td>Welded Wire Mesh</td>
<td>• To hold cracks that may occur together</td>
<td>• Use proper joint spacing</td>
<td>7-12%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Eliminate welded wire mesh</td>
<td></td>
</tr>
</tbody>
</table>

1) Concrete = $85/CY  
2) Granular Base = $15.30/SY  
3) Concrete w/ Fibers = plus $3/CY  
Note: 5000 SY Parking Lot
RISING ASPHALT COST AND INCORPORATING INDUSTRY STANDARDS HAVE REDUCED THE INITIAL COST GAP…
(2010 Data)

<table>
<thead>
<tr>
<th>Asphalt Paving Design</th>
<th>ACI Concrete Paving Design</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pavement Costs</strong></td>
<td><strong>Pavement Costs</strong></td>
</tr>
<tr>
<td>1.5” HMAC</td>
<td>5” Concrete</td>
</tr>
<tr>
<td>6” Granular Base</td>
<td></td>
</tr>
<tr>
<td>Subgrade</td>
<td>Subgrade</td>
</tr>
<tr>
<td><strong>USD</strong></td>
<td><strong>USD</strong></td>
</tr>
<tr>
<td>Pavement Costs</td>
<td>Pavement Costs</td>
</tr>
<tr>
<td>$108,000</td>
<td>$59,030</td>
</tr>
<tr>
<td>• AC Layer¹</td>
<td>• Concrete³</td>
</tr>
<tr>
<td>$31,500</td>
<td>$59,030</td>
</tr>
<tr>
<td>• Gran. Layer²</td>
<td>• Monolithic Curb &amp; Gutter Cost⁴</td>
</tr>
<tr>
<td>$76,500</td>
<td>$5,100</td>
</tr>
<tr>
<td>Labor Costs (Included)</td>
<td>Labor Costs</td>
</tr>
<tr>
<td>$10,200</td>
<td>$56,250</td>
</tr>
<tr>
<td>Curb &amp; Gutter Cost</td>
<td>Monolithic Curb &amp; Gutter Cost⁴</td>
</tr>
<tr>
<td>$10,200</td>
<td>$5,100</td>
</tr>
<tr>
<td><strong>Total Initial Cost</strong></td>
<td><strong>Total Initial Cost</strong></td>
</tr>
<tr>
<td>$118,200</td>
<td>$120,380</td>
</tr>
</tbody>
</table>

Concrete paving with proper design now has an initial cost gap of 2%
LONGEVITY AND DURABILITY LEAD TO SUSTAINABILITY

Less Maintenance/ Reconstruction (Typical 20+ yr design life)

Less Consumption of Materials/Energy

Overall Less Resource Intensive
VERY LITTLE CONCRETE MAINTENANCE IS EXPECTED

Clean and Striping

- Surface needs to be degreased and restriped
- Every 10 years, cost $0.50/SY - $2,500/application

Crack Seal

- Concrete surface maintains structural capacity
- Cracks can be sealed to avoid moisture penetration
- Every 20 years, cost $2/LF - $1,800/application

Note: 5000 SY Parking Lot

$4,300

<table>
<thead>
<tr>
<th>Parking Lot Age</th>
<th>$2,500</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stripe</td>
<td>$4,300</td>
</tr>
</tbody>
</table>

$2,500

<table>
<thead>
<tr>
<th>Maintenance Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cleaning and striping</td>
</tr>
<tr>
<td>- Surface needs to be degreased and restriped</td>
</tr>
<tr>
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Crack Seal

- Concrete surface maintains structural capacity
- Cracks can be sealed to avoid moisture penetration
- Every 20 years, cost $2/LF - $1,800/application
### ASPHALT MAINTENANCE IS REQUIRED OFTEN

**Seal Coat**

- Seal coat fills cracks and rejuvenates surface
- Apply every 3 to 5 years
- Recommended by Asphalt Institute
- Expected cost $1.50/SY - $7,500/application
- Expected 20 year cost - $30,000 to $50,000

**Pavement Striping**

Note: 5000 SY Parking Lot

<table>
<thead>
<tr>
<th>Parking Lot Age</th>
<th>Seal Coat &amp; Stripe</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>$7,500</td>
</tr>
<tr>
<td>5</td>
<td>$7,500</td>
</tr>
<tr>
<td>10</td>
<td>$7,500</td>
</tr>
<tr>
<td>15</td>
<td>$7,500</td>
</tr>
<tr>
<td>20</td>
<td>$7,500</td>
</tr>
</tbody>
</table>

*Note: 5000 SY Parking Lot*
THE 20 YEAR OWNERSHIP COSTS FOR CONCRETE PAVEMENT ARE $12.9 K LESS THAN ASPHALT FOR A 5000 SY PARKING LOT

Nominal cost by pavement type for 5000 SY parking lot ($ K)

<table>
<thead>
<tr>
<th>Year</th>
<th>Concrete</th>
<th>Asphalt</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>$120.4</td>
<td>$118.2</td>
</tr>
<tr>
<td>5</td>
<td>$7.5</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>$2.5</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>$7.5</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>$7.5</td>
<td></td>
</tr>
</tbody>
</table>

Discount Rate = 4.0%
Seal coat and stripe application every 5 years, cost $1.50/SY
Concrete cleaning and re-striping every 10 years, cost $0.50/SY
Concrete crack sealing every 20 years, $2/LF
EARLY ENTRY SAW CUTS CONTROL CRACKING AND IMPROVE PERFORMANCE

- Use single pass, 1/8” wide cut
- 1/3 depth of pavement thickness
- Joints do not necessarily need to be filled/sealed
- When cut at proper time, joints tell the concrete where to crack
- Maintain joint load transfer
- Small joint openings reduce water intrusion
- Small openings reduce “tire slap”
- Cost $0.35 to $0.50/LF
AGENDA

• Factors affecting Costs of Parking Lot Pavements

• Performance and Maintenance of Parking Lot Pavements

• Design Practices for Concrete Parking Lots

• Jointing and Construction Considerations for Concrete Pavements

• Other Important Issues

• Pervious Concrete Pavements
Basic Concrete Pavement
Natural Looking Pavement
Colored to Match Architecture
Stamped Concrete
Concrete and LEED Categories within LEED NC 2.2

1. Sustainable Sites (SS) 14 pts 
2. Water Efficiency (WE) 5 pts 
3. Energy & Atmosphere (EA) 17 pts 
4. Materials Resources (MR) 13 pts 
5. Indoor Air Quality (EQ) 15 pts 
6. Innovation in Design (ID) 5 pts 

Total = 69 pts 


Credits must be submitted in their specific Design or Construction Phase
AND CONCRETE PAVEMENTS LOWER HEAT ISLAND EFFECT PROVIDING 1 LEED POINT

Heat Island

- Concrete’s higher albedo reflects significantly more sunlight than asphalt
- LEED Sustainable Site Credit 7.1
  - Provide 50% of hard surface with Surface Reflectance Index (SRI) of 29 or higher
    - PCC SRI 35 – 80\(^1\) - 1 Credit
    - AC SRI 5 – 20\(^1\) – 0 Credit
- Concrete’s surface temperature is approximately 22\(^\circ\)F lower than asphalt
- Lowering a City’s temperature reduces smog and decreases utility bills
  - Decreases levels of pollution (CO\(_2\), NO\(_x\), SO\(_x\), PM, VOC, smog)

Reduces cooling loads for nearby structures

1) Jay S. Golden, Director Sustainable Systems Program for Urban Climate and Materials, Arizona State University
### Lighting Needs

| Concrete has higher albedo than asphalt in both new & weathered conditions |
| The average luminance of concrete is 1.77 times higher than asphalt |
| Asphalt requires 24-40% more poles for same lumens as concrete |
| e.g. Asphalt requires 400w light compared to 250w light for concrete for same luminance |
| Asphalt parking lots can cost 53% PER YEAR more in electrical energy than concrete parking lots (FL Power & Light) |

### Comments

- Cost to light a one acre lot in Miami ($0.02097/kwh)
- Miami-Dade County Code Sec. 8C-3: Code requirement of 1 foot candle on the parking surface from dusk to dawn
- Lighting uniformity not to exceed 12:1

<table>
<thead>
<tr>
<th>Asphalt: $3,189/yr</th>
<th>Concrete: $1,993/yr</th>
</tr>
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Savings on lighting will address the initial cost delta in 2 yrs

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(1) Pictures taken in Springfield, IL in February at 9:00 pm, within 5 minutes of each other on the same camera settings. Lots are same size & have the same number of light poles.
AGENDA

- Factors affecting Costs of Parking Lot Pavements
- Performance and Maintenance of Parking Lot Pavements
- Design Practices for Concrete Parking Lots
- Jointing and Construction Considerations for Concrete Pavements
- Other Important Issues
  - Pervious Concrete Pavements
Increased runoff volume and discharge rates contribute to flooding and erosion
Pollutants in urban runoff contaminate receiving water bodies

- Oils and Greases
- Metals
- Sediments
- Fertilizers and Nutrients
Quantity Volume is attenuated via outlet structure
Quality Volume is infiltrated through soil
LOW IMPACT DEVELOPMENT
(NON-STRUCTURAL BMPs)

Pre-Development

Post-Development

Low-Impact Development
WHAT IS PERVIOUS CONCRETE?

- A conventional concrete mixture w/ little or no sand and a controlled amount of water
- 15% - 25% air void content
- Rough in surface texture
- Hi variance in color
- No slump mix
Texture Comparison
• Drainage rate = 3-5 gal/min/ft²
• Equivalent of 275” to 450” of rain per hour!
  • More than half of all rainfall is precipitated in rain events that total one-half inch or less.
• 6” section with 20% voids holds 1 – 1 ¼” of rain water
• Higher infiltration rate than subgrade
• Recommend coarse aggregate reservoir base
Subgrade permeability should be at least 1.5 inches per hour
Tree Protection

- Pave within the drip line
- Water & Air filter to roots
South Florida Water Management District is accepting the use of pervious pavements.

Credit given for stormwater attenuation (quantity) and stormwater treatment (quality).

Systems should adhere to permitting guidelines.

Special Conditions and Considerations:
- Recovery Analysis
- Certified Contractors
- Installation of Infiltrometers
- Post Construction Testing
- Maintenance and Remediation Plans

The intent of this memorandum is to provide guidance for staff in reviewing Environmental Resource Permit (ERP) applications that include the proposed use of pervious pavement systems. In the past, the water quality or quantity performance of these systems has not been incorporated into the permit application calculations because there were not sufficient reasonable assurances to address issues pertaining to parent soil compaction, proper construction specifications and maintenance concerns. As a result their efficacy in Florida and the potential benefits were historically not well established. However, during the last few years, independent research and analysis of these systems has better quantified the ability of these systems to percolate stormwater and identified practices and specifications to address the previous concerns.

The use of pervious pavement systems is proposed to be a quantifiable component of the proposed Unified Statewide Stormwater Rule. This rule is anticipated to be in the rulemaking process until mid-2020 or later. Given recent research, sufficient information exists so that the water resource benefits of pervious pavement systems can currently be quantified and incorporated in the design of surface water management systems. This memorandum is designed to provide guidance on the current review of applications proposing the use of pervious pavement systems. This document is not to be considered a rule, and other alternative forms of reasonable assurances to those set forth below may be considered by the District.

Pervious pavement systems can include several types of materials or designed systems including but not limited to pervious concrete, pervious paver systems, modular paver systems and pervious aggregate/binder products. Several recent studies of these systems are available on the University of Central Florida (UCF) Stormwater Management Academy’s website http://stormwater.ucf.edu/

Studies at the UCF Stormwater Management Academy have not provided sufficient reasonable assurances to justify the use in the permitting context of pervious asphalt and pervious pavements.
Permitting Rules

- City of Green Cove Springs (100%)
- Pasco County (Big Box – Min. 10%)
- City of Hialeah Gardens (80%)
- City of Titusville (75%)
- City of Winter Park (Residential 65%)
- City of Stuart (50%)
- City of Lauderhill (50%)
- Statewide Stormwater Rule Coming Soon!
Applications for Pervious Concrete

YES

• Parking Lots
• Driveways
• Residential Streets
• Roadway Base

NO

• Dumpster Pads
• Heavy traffic areas
• Tight turning radius
• Industrial Facilities
Proper Installation!

6 - 8 People
Proper Mix
Keep Pavement Grade High
No Drainage off Landscaping
Thank You

& Any Questions?