Improving a Pavement’s Resiliency
Part II
Concrete Pavement Solutions

Greg Dean
Executive Director
Carolinas Concrete Paving Association

VA Concrete Conference
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Topics Covered
Improving Pavement Resiliency & (Flood) Disaster Recovery

1. The Need for Resilient Pavements (9am)

2. Defining Resiliency (9am)

3. Improving a Pavement’s Flood Resiliency (9am)
   a. Concrete Pavement Solutions (Part II – Starts Now)
   b. How to Implement Resiliency into your pavement policies?
Pavement (Flooding) Resiliency
GOOD resources can be found...

Articles & New Polling

How Severe Weather Damages our Roadways (August 2019)
Extreme Weather and Climate Adaptation (June 2019)
Federally Funded Infrastructure Must Be Flood Ready (PEW, April 2019)
Public Roads - Boosting Pavement Resilience (Autumn 2018)
Texas Roadways Proven Resilient After Hurricane Flooding (May 2018)
PEW Charitable Trusts Flood Infrastructure Survey (Feb 2020)

Reports and Publications

LTPP Tech Brief - Impact of Environmental Factors on Pavement Performance
FHWA - Climate Change Adaptation For Pavements (August 2015)
INCREASED FLOODING IS IMPACTING OUR PAVEMENT STRUCTURES

Need to distinguish between Inundation and Washout Impacts

**Inundation**

The rise of water that submerges the pavement.
No rapid flow or current that erodes base

**Washout**

Rapid flow of flood water / high current that scours and washes out the pavement structure

Pavement type does have an impact on long-term performance

Pavement type has little impact
FLOODING CAUSES THE SUBGRADE TO BECOME SUPERSATURATED
Moisture infiltrates base, pushes the subgrade particles apart and weakens the system

Asphalt Pavements are Flexible
- Lowered subgrade strength & reduced modulus
  - Reduced load carrying capacity
  - Takes ~1 year to regain strength
- Loading during this time accelerates pavement damage / deterioration
  - Reduced pavement life

Concrete Pavements are Rigid
- Maintains high level of strength / stiffness
- Subgrade is weak, but still uniform
- Spreading of the load means subgrade is not overstressed
- Little impact on the serviceability / life

Flooding does not impact the concrete’s load carrying capacity to the same degree as asphalt’s
There are ways to improve a highway’s / pavement’s resilience.

Time to Full Recovery

Time

Lost Performance

Performance

Modifications before disruptive events that improve system performance

Repairs after disruptive event to restore system functionality

Adapted from Bruneau, 2003 and McDaniels, 2008

Actions to consider when dealing with flood prone pavements:

Hardening Activities
- Stiffen the system
- Improve Designs by using soaked subgrade strength values

Adaptive resilience – Capacity to learn and make decisions to avoid future loss based on the type of disturbance

Adapted from Bruneau, 2003 and McDaniels, 2008
SOME RESILIENT CEMENT-BASED PAVEMENT SOLUTIONS THAT CAN BE USED AS HARDENING TECHNIQUES

- Conventional Concrete Pavement
- Thin Concrete Pavement
- Concrete Overlays
- Roller Compacted Concrete (RCC)
- Full Depth Reclamation (FDR) w/ Cement
- Pervious Concrete
Expanded Use of Conventional Concrete Pavements
How are your Roundabouts performing?

Project Details

• New CSX Facility under construction in vicinity
• Pavement design changed in the 11th hour
  ➢ 9.5-inch doweled PCCP upon Agg Base
• Project bid without a jointing detail
• Contractor required to submit jointing plan for approval prior to starting
• ACPA Tech Bulletin was referenced as part of bidding documents

NCDOT's First Use of Concrete Roundabout
CONCRETE OVERLAYS OF ASPHALT HAVE UNTIL RECENTLY BEEN CALLED “WHITETOPPING OVERLAYS”

Bonded Concrete Overlays of Asphalt Pavements (BCOA)
- Small square panels reduce curling, warping, & shear stresses.
- if necessary, mill to correct crown, remove surface distresses, improve bond
- Need a 3-inch minimum of asphalt after milling.

Typical Thickness = 3 to 6 inches

Unbonded Concrete Overlay of Asphalt Pavements
- No minimum thickness of Asphalt (used only as base)
- Normal to slightly smaller than normal joint spacing. Based on unbonded overlay thickness

Typical Thickness = 5 to 10+ inches

Both systems bond to the underlying asphalt, but bond is not accounted for in the DESIGN for unbonded overlays
Concrete overlay increases both the height and the structural strength of the roadway.

Pressure ~3 - 7 psi at the top of the Asphalt layer
Base & subgrade pressures are even lower

Road Elevation raised the height of the overlay

Concrete overlay increases both the height and the structural strength of the roadway

HOW CONCRETE OVERLAYS IMPROVE ASPHALT PAVEMENT’S RESILIENCE TO FLOODING
NATIONWIDE CONCRETE OVERLAY USAGE IS GROWING

Source: From data submitted by ACPA chapters/state paving associations and other sources, including Oman Systems, Bid Express and DOT websites.
Resiliency of Concrete Recognized

"The rehabilitation will provide aircraft a solid concrete runway that is more RESILIENT than asphalt and will increase the useful life of runway by four times”

Reconstruction of Runway 13L-31R at JFK
Port Authority of NY & NJ Press Release (April 2019)

"Use of Concrete will extend runway’s useful life to 40 years, rather than 8-12 years with asphalt.”
Exit 22 at I-85
Gastonia, NC

7-inch BCOA / Binder Base Coarse, B-25
Constructed in 2010

BCOA = Small Panels
Governors Club - Chapel Hill, NC

7-in Unbonded Concrete Overlay Construction

Governors Club Concrete Overlay
Charleston Executive Airport
Johns Island, SC

11-inch Unbonded Overlay (2010 Construction)

2016 PCI Data from Pavement Management Report

2010 LCD-RW Concrete Overlay range from 93 to 96 (weighted average 94, 1 point per year drop)
2010 LCD-TW Connectors (Tie-Ins) Asphalt range from 77 to 86 (weighted average 82, 3 points per year drop)
2008 LCD – Taxiway A Asphalt = 75 (drop of 3.1 points per year)
Concrete Overlays
South Carolina General Aviation Airports

Airports are commonly found in low elevation (flat) areas, prone to flooding in hurricane events

Grand Strand (N. Myrtle Beach, SC)

<table>
<thead>
<tr>
<th>Airport</th>
<th>Overlay</th>
<th>RW, TW, Apron</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charleston Exec</td>
<td>11-inch UBO</td>
<td>Runway (RW)</td>
</tr>
<tr>
<td>Lancaster Co</td>
<td>7.5-in WT</td>
<td>RW</td>
</tr>
<tr>
<td>Berkeley Co</td>
<td>9-in WT</td>
<td>RW</td>
</tr>
<tr>
<td>Laurens Co</td>
<td>5-in WT</td>
<td>RW, TW, Apron</td>
</tr>
<tr>
<td>Greenwood Co</td>
<td>5-in WT</td>
<td>RW</td>
</tr>
<tr>
<td>Lexington Co</td>
<td>6-in + 6-in CMB</td>
<td>RW</td>
</tr>
<tr>
<td>Grand Strand</td>
<td>7.5-in WT</td>
<td>RW</td>
</tr>
<tr>
<td>Darlington Co</td>
<td>7-in WT</td>
<td>RW, TW Tie-ins</td>
</tr>
</tbody>
</table>

UBO = Unbonded Overlay; WT = Whitetopping; CMB = cement modified base

Grand Strand Airport Concrete Overlay
Lots (100’s) of Lane-Miles of Unbonded Concrete Overlays
Mostly constructed since late 1990’s

1960 era Concrete

Asphalt Separation Layer

I-85 Vance & Warren Counties (S. of VA Border)

Fast Forward North Carolina - I85 UBO
Bonded Concrete Overlay of Asphalt (BCOA)
Design and Construction Recommendations
based on Caltrans PPRC 4.58B Project

John Harvey, Angel Mateos, Fabian Paniagua, Julio Paniagua, Rongzong Wu
University of California Pavement Research Center

Julie Vandenbossche, John DeSantis
University of Pittsburgh

Deepak Maskey
California Department of Transportation

Charles Stuart
Southwest Concrete Pavement Association
4.58B Project experimental data sources:

1. Laboratory testing of concrete, asphalt, and concrete-asphalt interface
2. Monitoring the response of BCOA to the ambient environment
3. Heavy Vehicle Simulator testing

- 15 BCOA sections were built at Davis UCPRC facilities on Feb-2016
  - Thickness = 4.5 and 6 inches
  - Joint spacing and interface conditions varied
- Response to ambient environment was monitored in 6 of the sections
- 11 of the sections were tested with the Heavy Vehicle Simulator (HVS)
Summary of HVS Testing at UCPRC

11 full-scale BCOA sections tested with the HVS

After testing 10 out of the 11 sections*...

- No cracking at any section, no faulting, no noticeable slabs movements
- To induce cracking, pavement was flooded and loaded - “wet” Loading (140,000 Reps)
- One panel crack after 7.55 M ESALs (8 times the loading for a normal BCOA application)

* One section was for environment studies only
CONCRETE OVERLAYS OF ASPHALT ARE COST EFFECTIVE
State Highway 13 – North of the city of Craig, CO

Project Bid in December 2015 as AD/AB*

Hot Mix Asphalt (HMA) Alternative
- 2-in SX(75) PG 58-34 (surface AC) over 4-in of SX(75) PG 58-28 (Base AC) over 8-in of Full Depth Reclamation
  - Initial Const = $5,385,980.85
  - Rehab & Maint = $2,456,560
  - Users Cost = $596,170
  **Total Life Cycle Cost = $8,438,710.85**

Concrete Alternative
- 6-in Unbonded Concrete Overlay on Asphalt
  - Initial Const = $5,338,308.82
  - Rehab & Maint = $1,674,060
  - Users Costs = $718,490
  **Total Life Cycle Cost = $7,730,858.82**

Concrete overlay was $47k lower in Initial cost & $708k Lower in Life Cycle Costs

* AD/AB = Alternate Design / Alternate Bid: Essentially two pavement designs (1 concrete & 1 Asphalt) are developed and bid competitively against each other in order to increase competition
FULL-DEPTH RECLAMATION (FDR) WITH CEMENT RECYCLES AN EXISTING DETERIORATED ASPHALT PAVEMENT INTO A NEW STABILIZED BASE

The stabilized base can be topped with an asphalt or **concrete** surface

- Utilizes In-Place Materials (reduces cost)
- Saves Energy by Reducing Trucking Requirements
- Increased Rigidity Spreads Loads
- Minimizes Rutting
- Reduced Moisture Susceptibility
Moisture infiltrates base
- Through high water table
- Capillary action
- Causing softening, lower strength, and reduced modulus

Cement stabilization reduces permeability
- Helps keep moisture out
- Maintains high level of strength and stiffness even when saturated

FDR W/ CEMENT INCREASES RIGIDITY TO SPREADS LOADS AND REDUCES PERMEABILITY TO REDUCE MOISTURE SUSCEPTIBILITY
FULL DEPTH RECLAMATION WITH CEMENT REDUCES THE STRAINS UNDER THE ASPHALT PAVEMENT

Asphalt Strain at 68°F

Date of Testing

Tensile Strain at 68°F

* FDR = 6-in aggregate base + 2-in subgrade stabilized in-place with 4% Type II Portland Cement

Structural Study of Cold Central Plant Recycling Sections at the National Center for Asphalt Technology (NCAT) Test Track,
AGENCIES SHOULD MODIFY “DESIGN STANDARDS” TO BE BASED ON WEAKENED SUBGRADE CONDITION

Almost All Pavement Designs in Australia are based on soaked subgrade conditions

5.6.2 Determination of Moisture Conditions for Laboratory Testing

Fine-grained materials wet up through capillary action in high rainfall areas. For this reason, use a soaked CBR for design in these areas with a 10-day soaked period in accordance with test method T117 for cohesive soils, unless the rainfall and testing conditions shown in Table 7 support 4-day soaking.

For dry inland regions of NSW prepare the sample at the field moisture content (or the equilibrium moisture content (EMC) where applicable) and test with no soaking period unless the road is subject to inundation or located adjacent to irrigation channels. This approach is to be used in lieu of Table 7.

<table>
<thead>
<tr>
<th>Median annual rainfall (mm)</th>
<th>Specimen compaction moisture content</th>
<th>Excellent to good drainage</th>
<th>Testing condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 600</td>
<td>OMC</td>
<td>Unsoaked</td>
<td>4-day soak</td>
</tr>
<tr>
<td>600 – 800</td>
<td>OMC</td>
<td>4-day soak</td>
<td>10-day soak</td>
</tr>
<tr>
<td>&gt; 800</td>
<td>OMC</td>
<td>10-day soak</td>
<td>10-day soak</td>
</tr>
</tbody>
</table>

Does not require any changes to current design practices other than changing the subgrade input (Especially important in flood prone areas)
CONCLUSIONS

1. Everyone recognizes the need to make our infrastructure “Flood Ready”
   - Need to define specific actions that agencies should consider when dealing with flooded pavements

2. In areas where pavements have a history of flooding (or in flood prone areas), or in areas of danger due to climatic changes,
   - Use Stiffer or stiffen the existing pavement
   - Require pavement designs be based on Lowered subgrade strength

3. Concrete pavement / cement based solutions have shown a remarkable resiliency to flooding
   - There are many solutions that are viable that are low costs, such as concrete overlays that can be used as mitigation / hardening strategies
Utilities Industry has promoted their resiliency for years...

- Their ability to prepare (minimize outages)
  - Resist & Absorb
- Their ability to quickly inform and restore power
  - Accommodate & Recover

2017 Duke Energy Sustainability Report

Invest $25B during 2017-2026 to create a smarter, greener energy grid that also will be even more reliable and RESILIENT during severe weather events
It’s time for our Concrete Industry to partner with our agencies…
One last idea…

CASE STUDY
PARKLAND OF FLOYDS FORK TRAILS
JEFFERSON COUNTY, KY
8 Miles in flood plain

Concrete Trails Design Guide & Case Studies
Thank you

Comments & Questions?

Greg Dean

gdean@pavementse.com
ONE LAST ITEM – PLEASE SUPPORT PAVEMENT FLOODING RESEARCH

Proposal for AASHTO Research Advisory Committee (RAC)

Problem Number: 2021-C-16

Problem Title: Impact of Flooding and Inundation on the Performance of Pavements

Recommended Funding: $1,000,000

Research Period: 36 months

Project selection takes place at the end of this Month
Concrete and asphalt pavements are different due to how they transmit loads to the subgrade.

Asphalt Pavements are Flexible
- Load - more concentrated & transferred to the underlying layers
- Higher deflection
- Subgrade & base strength are important
- Requires more layers / greater thickness to protect the subgrade

Concrete Pavements are Rigid
- Load – Carried by concrete and distributed over a large area
- Minor deflection
- Low subgrade contact pressure
- Subgrade uniformity is more important than strength

Concrete’s rigidity spreads the load over a large area & keeps pressures on the subgrade low.