RESILIENCY
A Concrete Pavement Industry Perspective

Greg Dean
Executive Director
Carolinas Concrete Paving Association

VA Concrete Conference
February 28 2020
The Future of Transportation and the Role of Concrete Pavements

- Blue-Ribbon Panel of 25 Experts
  - Convened in Sept 2017
  - Diverse group (DOT, FHWA, Consultants, Industry)

- What will transportation look like in 2040?
  - Role of Concrete and Cement Based Solutions?
  - Agencies’ needs for pavement solutions?
    - Pavement Adaptability
    - Capitalize on Current Assets
    - Responsible Stewardship of Resources
    - Safety Goals
    - Instilling Competition
    - Need for Resilience
Presentation Subtitle
Improving Pavement Resiliency & (Flood) Disaster Recovery

1. The Need for Resilient Pavements

2. Defining Resiliency

3. Improving a Pavement’s Flood Resiliency
FUTURE CLIMATE CONDITIONS WILL NOT RESEMBLE THE PAST

U.S. severe storms, heavy precipitation events:
Greater intensity and frequency
Continued increases expected

Global mean sea level:
7–8 inches higher since 1900 - about half since 1993
Expected to rise by 1–4 feet by 2100

Increased Extreme heat events and drought:
Increased incidence of large forest fires

EXTREME FLOOD EVENTS ARE INCREASING IN BOTH FREQUENCY AND MAGNITUDE

Source: https://www.epa.gov/climate-indicators

Extreme One-Day Precipitation Events in the Contiguous 48 States, 1910–2015
EXTREME FLOOD EVENTS ARE INCREASING IN BOTH FREQUENCY AND MAGNITUDE

Change in Magnitude of U.S. River Flooding, 1965–2015


Source:  https://www.epa.gov/climate-indicators
FLOODING IN THE PLAIN STATES WAS SEVERE THIS PAST YEAR
And is forecast to be high again in 2020

At one point, the Nebraska DOT reported 1,500 road miles were closed
HOUSTON TEXAS HAS BEEN HIT BY 4 FLOOD EVENTS IN THE LAST SEVERAL YEARS – THE WORST WAS HURRICANE HARVEY

Area roughly the same as the entire state of West Virginia
NORTH CAROLINA HAS BEEN HIT BY TWO 500 YEAR FLOOD EVENTS

With Hurricane Florence, NC had over 2500 road closures
SEA LEVEL RISE IS ALREADY IMPACTING COASTAL ZONES
Sunny sky flooding is becoming a common or daily occurrence

SR54 East of Fenwick, DE

South Bowers Beach, DE

Miami, FL

DE Photos courtesy of Jim Pappas, DELDOT
As we are becoming more sustainable (and green)... shouldn’t we also become more resilient?
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

Pavement type does have an impact on long-term performance

Washout

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

Pavement type has little impact
Topics Covered
Improving Pavement Resiliency & (Flood) Disaster Recovery

1. The Need for Resilient Pavements

2. Defining Resiliency

3. Improving a Pavement’s Flood Resiliency
ADDRESSING RESILIENCY AND THE ENVIRONMENT

Resilience

• The ability … to resist, absorb, accommodate, and recover from the effects of a hazard in a timely and efficient manner

Resiliency Planning Fundamentals

1. Prevention: stop a … manmade or natural disasters
2. Protection: secure against … manmade or natural disasters
3. Mitigation: reduce … by lessening the impact of disasters
4. Response: … meet basic human needs after an incident
5. Recovery: … assist communities affected by an incident to recover effectively

Policies should focus on items 1, 2 and 3 so that they do the job 99% of the time

1. UN-International Strategy for Disaster Reduction
2. AASHTO. Fundamentals of Effective All Hazards Security and Resilience for State DOTs, 2015.
**INTRODUCTION TO PAVEMENT RESILIENCE**

The ability ... to resist, absorb, accommodate, & recover ... in a timely and efficient manner

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**Pavement Resilience** with respect to an event (eg. Flooding) is characterized by two parameters:

1. Drop in performance, induced by the event (eg. reduced ability to carry load).
2. Recovery time to reinstate or improve performance.

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Green is more resilient than Red

- faster recovery time
- Higher level of service

Blue is a hardened system as it has a higher final performance level

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*UN-International Strategy for Disaster Reduction*

*Hardening Infrastructure* – Elevating, upgrading, relocating assets, flood walls, berms and levees, etc.
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
FLOODING CAUSES THE SUBGRADE TO BECOME SUPERSATURATIONED
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
SOAKING REDUCES STRENGTH OF SOILS BY 20 TO 40%
Different Soils (clays, silts, sands, clay sands, etc) all react differently but all decrease

Un-soaked vs Soaked CBR Comparisons

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Percent Decrease</th>
<th>Avg</th>
<th>Hi</th>
<th>Lo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inorganic Clays (CL Type Soil)</td>
<td></td>
<td>32.5%</td>
<td>49.1%</td>
<td>7.6%</td>
</tr>
<tr>
<td>Un-soaked</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4-day soaked</td>
<td></td>
<td>21.5%</td>
<td>34.7%</td>
<td>2.7%</td>
</tr>
<tr>
<td>Clayey Sands (SC Type Soil)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inorganic Silts (ML Type Soil)</td>
<td></td>
<td>30.5%</td>
<td>48.9%</td>
<td>0.7%</td>
</tr>
<tr>
<td>Silty Sands (SM Type Soil)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Comparison Between Soaked and Unsoaked CBR, Sathawara Jigar K & Prof. A.K.Patel; International Journal of Advanced Engineering Research and Studies E-ISSN2249–8974
RELIEF AND RESCUE EFFORTS WILL TAKE PLACE
Loading weakened Pavements will shorten their lives

With Hurricane Florence, NC had over 2500 road closures

Meals that Matter
#MtMFlorence Update

(New) Location 1
98 S Trade Way
Rocky Point, NC

Location 2
7701 S Raeford Rd
Fayetteville, NC
ALSO NEED TO ACCOUNT FOR LONG TERM LATENT EFFECTS WHEN DISCUSSING RESILIENCE TO FLOODING

After the flood waters recede, the pavements are structurally vulnerable

Research Findings indicate it takes up to 1 year for the subgrade strength to recover

For this case, this strength loss is a 40 to 60% reduction load carrying capacity and about 3 years of life

Sources:
2. Western Iowa Missouri River Flooding— Geo-Infrastructure Damage Assessment, Repair, and Mitigation Strategies; Center for Earthworks Engineering Research, Iowa State University, Report No. IHRB Project TR-638
KEY FINDINGS FOR PAVEMENTS THAT WERE SUBMERGED BY HURRICANE KATRINA

Submerged pavements were weaker than non-submerged pavements

- **Asphalt pavements**
  - Overall strength loss ≈ two inches of new asphalt concrete
  - Damage occurred regardless of the length of time the pavement was submerged
  - Cost: $50 million to rehabilitate 200 miles of submerged asphalt roads

- **Concrete Pavements**
  - Little relative loss of strength due to flooded conditions
  - Resilient modulus (Mr) is similar for submerged and non-submerged pavements
  - No information given on repairs or repair costs
FLOODED PAVEMENTS RESEARCH IN AUSTRALIA FOUND SIMILAR RESULTS

Road authorities may want to consider changing their roads into flood-resilient pavements.

A rigid pavement performs better than composite and flexible road groups

- Composite and flexible road groups show similar performance up to 2–3 years.
- Rigid pavement performs the best at any probability of flooding, and flooding effect is not critical

A pavement’s strength may be enhanced by:

- Strengthening with an overlay
- Layer stabilization.
- Converting the road into a rigid or composite pavement through granular layers’ stabilization.

“It is settled that a rigid pavement is the more flood-resilient.” (p. 5)
AGENCIES SHOULD MODIFY “DESIGN STANDARDS” TO BE BASED ON WEAKENED SUBGRADE CONDITION

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

Does not require any changes to current design practices other than changing the subgrade input
(Especially important in flood prone areas)
CRCP IN HOUSTON HAVE BEEN FLOODED SEVERAL TIMES
But roadways are opened as soon as water has receded

I-10 from I-610 to I-45
11” CRCP UBOL & 14” CRCP (Const = 1995-2000)
Design= 43M ESALS, Carried = 92M ESALS

SH 288 from Southmore to Yellowstone –
9” CRCP (Const = 1983 & 1984)
Design = 7M ESALS, Carried = 22M ESALS

Opened roadway shortly after Hurricane Harvey

Both sections have been flooded at least three times since original construction

ESALS – Equivalent Single Axle Loads. It is how pavement engineering defines traffic
STIFFER PAVEMENTS ARE MORE RESILIENT TO INUNDATION FLOODING

Stiffer Pavements are less impacted by subgrade strength loss and recovers faster (stiffer = concrete, cement stabilized bases, increased asphalt thickness)

Performance

Time (years)

Design Life

Concrete

Asphalt

1) Lower drop in performance (Both Short and long term)

2) Quicker opening (less dependence on subgrade / base strength)

3) Shorter recovery time

Time the road is submerged / not passable
Topics Covered
Improving Pavement Resiliency & (Flood) Disaster Recovery

1. The Need for Resilient Pavements

2. Defining Resiliency

3. Improving a Pavement’s Flood Resiliency
   a. Concrete Pavement Solutions (Part II – come back 11am)
   b. How to Implement Resiliency into your pavement policies?
THERE ARE MANY ARTICLES BEING PUBLISHED ON THE NEED FOR CREATING FLOOD RESISTANCE INFRASTRUCTURE

This recent PEW article recognized the need to make our infrastructure “Flood Ready”

• Existing policies fall short
• Costs due to flooding are increasing, and will likely continue to increase
  - Rebuild the same asset multiple times
  - Higher population density / more damage
• Flood-ready investments are cost-effective

Did not specifically touch on the WAYS to increase the resilience of pavements and roadway infrastructure
ONE OFTEN DISCUSSED APPROACH IS ELEVATING THE ROAD ABOVE FLOODING ELEVATION

Elevating the roadway is not cheap and it is not possible to raise all roadways

Schematic and Photo courtesy of Jim Pappas, DELDOT
ANOTHER APPROACH IS ROAD ABANDONMENT
Old Corbitt Road – Odessa, Delaware

- Overtops daily due to tides
- 340 Avg Daily Traffic (ADT)
- Traveling time will be slightly increased by approximately 2 to 3.5 minutes.

- Alternate - 250’ long concrete structure.
  Estimated cost = $2.5M

Schematic and Photo courtesy of Jim Pappas, DELDOT
THERE ARE WAYS TO IMPROVE A HIGHWAY’S / PAVEMENTS RESILIENCE

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
Thank you

Comments & Questions?

Greg Dean
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Improving a Pavement’s Resiliency

Part II

Concrete Pavement Solutions

Greg Dean
Executive Director
Carolinas Concrete Paving Association

VA Concrete Conference
February 28 2020
Topics Covered
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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.
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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
HOW CONCRETE OVERLAYS IMPROVE ASPHALT PAVEMENT’S RESILIENCE TO FLOODING

Concrete overlay increases both the height and the structural strength of the roadway.
NATIONWIDE CONCRETE OVERLAY USAGE IS GROWING

<table>
<thead>
<tr>
<th>Period</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prior to 2000</td>
<td>2.00%</td>
</tr>
<tr>
<td>2000-2004</td>
<td>2.00%</td>
</tr>
<tr>
<td>2005-2009</td>
<td>4.33%</td>
</tr>
<tr>
<td>2010-2014</td>
<td>11.27%</td>
</tr>
<tr>
<td>2015-2019</td>
<td>12.42%</td>
</tr>
</tbody>
</table>

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

BCOA Examples

Marion Street, Oak Park, Illinois

Colorado SH-121, Wadsworth Ave
Constructed in 2001
Photo in 2013
Resiliency of Concrete Recognized

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

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

1960 era Concrete

Asphalt Separation Layer

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
Introduction

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

<table>
<thead>
<tr>
<th>Project Bid in December 2015 as AD/AB*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot Mix Asphalt (HMA) Alternative</td>
</tr>
<tr>
<td>• 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</td>
</tr>
<tr>
<td>• Initial Const = $5,385,980.85</td>
</tr>
<tr>
<td>• Rehab &amp; Maint = $2,456,560</td>
</tr>
<tr>
<td>• Users Cost = $596,170</td>
</tr>
<tr>
<td>Total Life Cycle Cost = $8,438,710.85</td>
</tr>
</tbody>
</table>

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
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 7: Typical moisture conditions for laboratory CBR testing

<table>
<thead>
<tr>
<th>Median annual rainfall (mm)</th>
<th>Specimen compaction moisture content</th>
<th>Testing condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 600</td>
<td>OMC</td>
<td>Unsoaked</td>
</tr>
<tr>
<td>600 – 800</td>
<td>OMC</td>
<td>4-day soak</td>
</tr>
<tr>
<td>&gt; 800</td>
<td>OMC</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
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
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Concrete’s rigidity spreads the load over a large area & keeps pressures on the subgrade low.