Concrete Innovations

North Carolina Concrete Conference

November 28, 2023

IOWA STATE UNIVERSITY
Institute for Transportation

National Concrete Pavement Technology Center

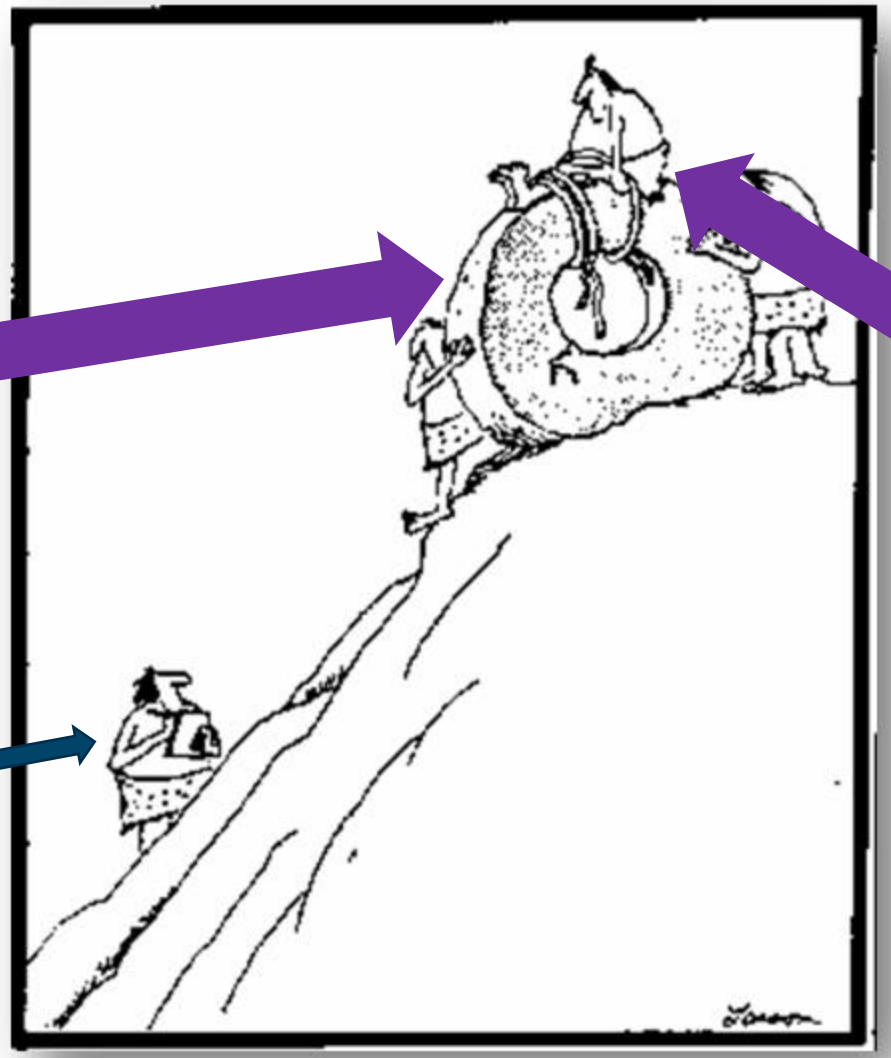
Leif G. Wathne, P.E.

Tech Center

Innovation….

Innovation

Data Collection



Commitment!

Examples of NCDOT Embrace of Innovation…

Geotextile fabric as replacement for PADL

Images: Greg Dean

Examples of NCDOT Embrace of Innovation…

RCC for shoulder and ramp paving

Images: Greg Dean

Examples of NCDOT Embrace of Innovation…

- 7 inch think concrete overlay on asphalt demo (on interstate ramp)
- Leader in unbonded overlays on concrete

Images: Greg Dean

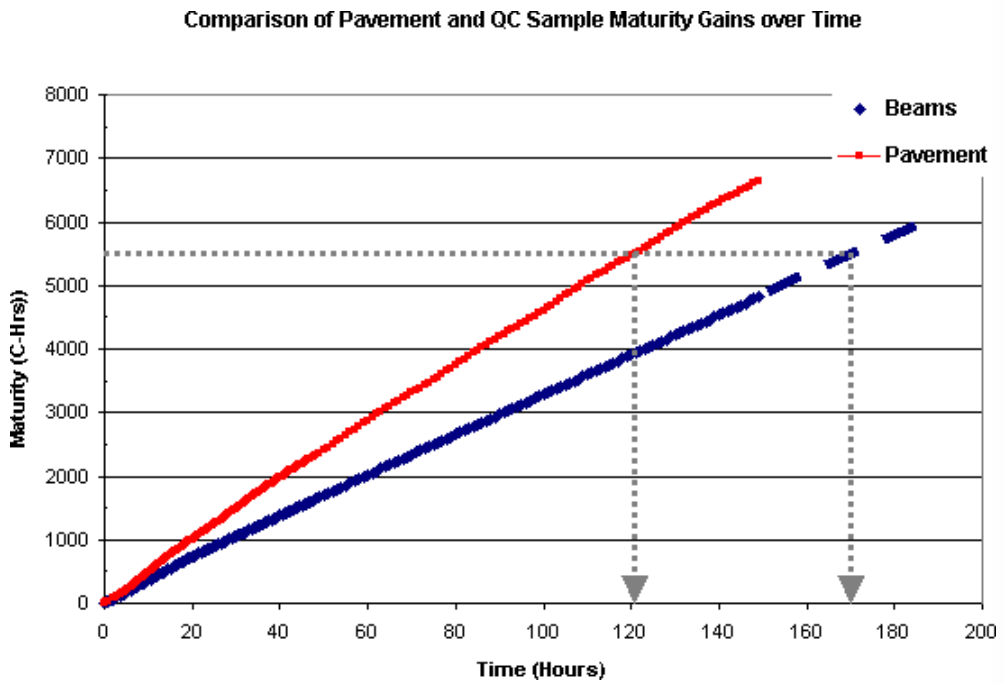
Examples of NCDOT Embrace of Innovation…

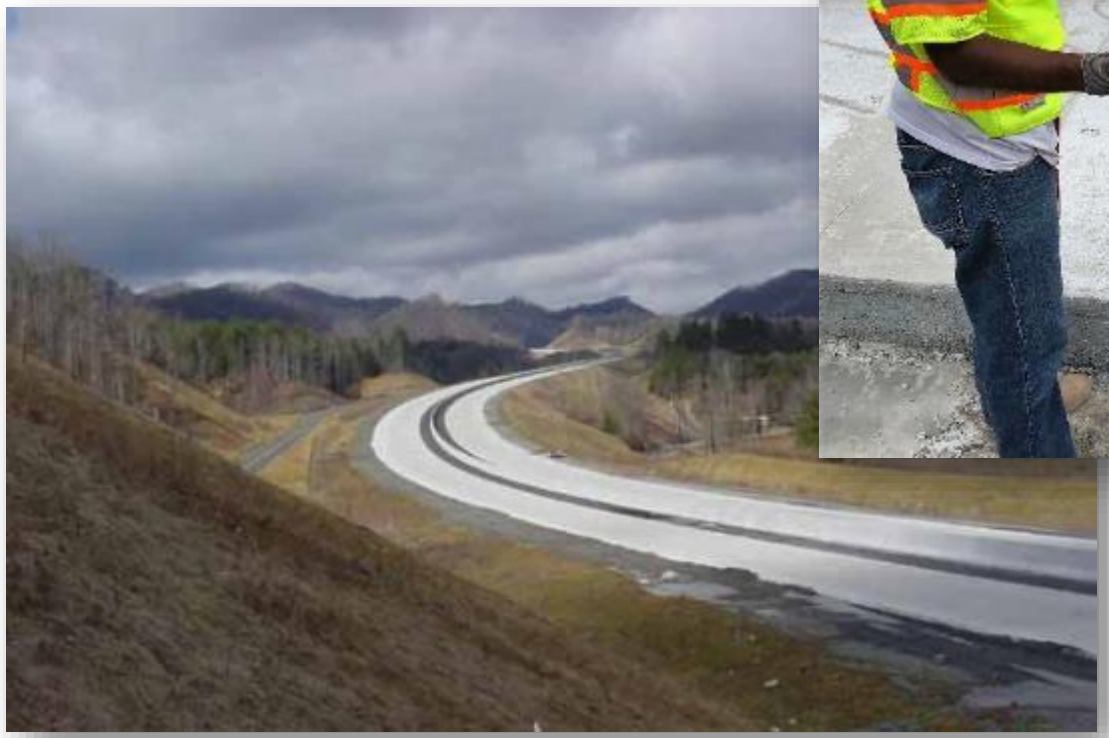
Concrete roundabouts

Images: Greg Dean

Examples of NCDOT Embrace of Innovation…

Use of Maturity to assess in-place pavement strength…





Images: Leif Wathne and Greg Dean

Talking Points…

- P3C
- Hardening with Overlays
- Early Opening

Performance Centered Concrete Construction

P3C – Performance Centered Concrete Construction

PEM pooled fund:

Specify, measure, and deliver concrete paving mixtures that perform as intended for their design lifetime

Link to sustainability is undeniable…

Summary of PEM requirements

- **Strength**
- **Reducing shrinkage**
- **Freeze-thaw durability**
- **Transport properties (permeability)**
- **Aggregate stability**
- **Workability**

Performance Engineered Mixtures

- Successful effort in accelerated time frame:
- Culminated in development of AASHTO R101.
- Changing practice!
- Only up to point of delivery… but what happens then…?

Steps to Long Life

Target performance

Workability
Durability
Strength

Design Levers

Gradation
Paste Volume
Cementitious
Admixtures

Batching

Uniformity – Water
– Cementitious system
– Aggregates
Mixing – Time
– Energy

P3C

Transportation

Mixing
Workability
– Time and weather
– Added water / admixtures
Uniformity

Placement

Handling / Vibration
- Bleeding
- Segregation
- Air void system
- Water movement

Finishing

Surface finish
Curing
Sawing

P3C – Performance Centered Concrete Construction

- **Fundamental philosophy remains unchanged!**
- PEM consistently produce reliable high performing mixtures at the plant…. but what happens during:
  - **Transport**
  - **Placement**
  - **Finishing**
  - **Sawing**
  - **Curing, etc**.

P3C – Performance Centered Concrete Construction

- Continue to assist state agencies on specification improvements and procedures to enhance performance
- Continue shadow and pilot projects
- Continue to offer program training
- Explore operational **innovations** to further advance reliability of concrete pavements

Transportation Pooled Fund - Study Detail

Performance Centered Concrete Construction

Print

General Information

Study Number:	TPF-5(517)
Former Study Number:	TPF-5(368)
Lead Organization:	Iowa Department of Transportation
Solicitation Number:	1582
Partners:	CO, IADOT, ID, KS, MI, MO, ND, PADOT, WI
Status:	Cleared by FHWA
Est. Completion Date:	
Contract/Other Number:	
Last Updated:	May 31, 2023
Contract End Date:	

$20k/yr for 5 years

Financial Summary

Contract Amount:	
Total Commitments Received:	$705,000.00
100% SP&R Approval:	Approved

Contact Information

Lead Study Contact(s):	Khyle Clute Khyle.Clute@iowadot.us Phone: 515-239-1646
FHWA Technical Liaison(s):	Michelle Cooper michelle.helsel.ctr@dot.gov Phone: 2024933691
Study Champion(s):	Todd Hanson todd.hanson@iowadot.us

Continue the work of PEM through **P3C** – Performance Centered Concrete Construction

Establish a sound understanding of concrete properties and how they are affected by workmanship, develop / select appropriate test methods for evaluation at or behind the paver, and provide tools for contractors to ensure compliance

Join agency and industry to innovate and further advance concrete as a sustainable and durable product.

See Pooled Fund details at ➔➔➔

Hardening with Overlays

Starting point…

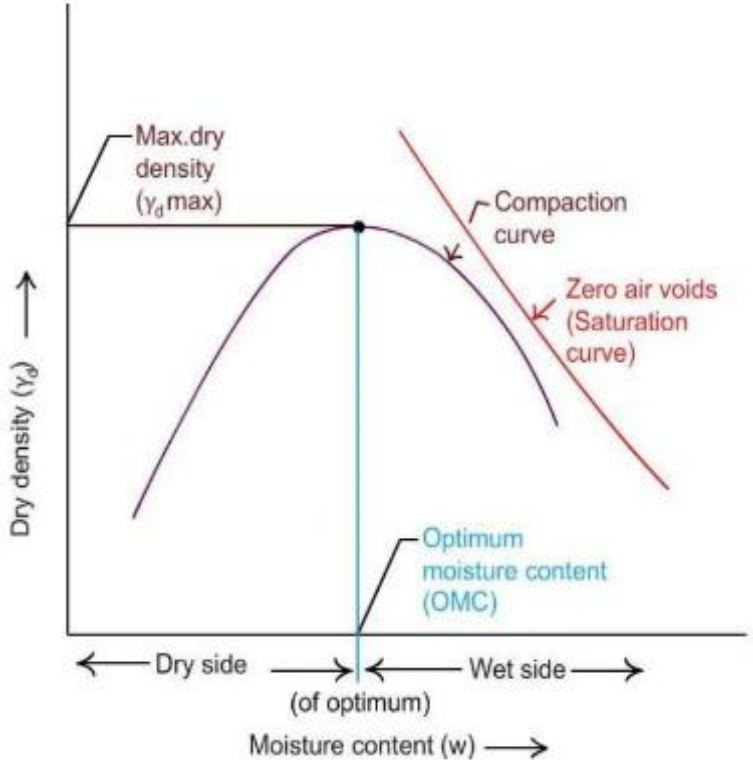
- *"Engineers…design...structures…and materials to fulfill functional objectives and requirements while considering the limitations imposed by practicality, regulation, safety and cost."*

  [BLS September 2006]

- For **pavements**, this means designing cost effective solutions to function **in the environment** and loading regime it is expected to be exposed to during its lifetime…

It all starts with geotechnical engineering…

- Sample in-place soils
- Classify (LL, PL, sieve, etc.).
- Proctor curve (moisture and MDD)
- CBR test? Correlation? Soaked?
- K-Value, Mr
- Design pavement section



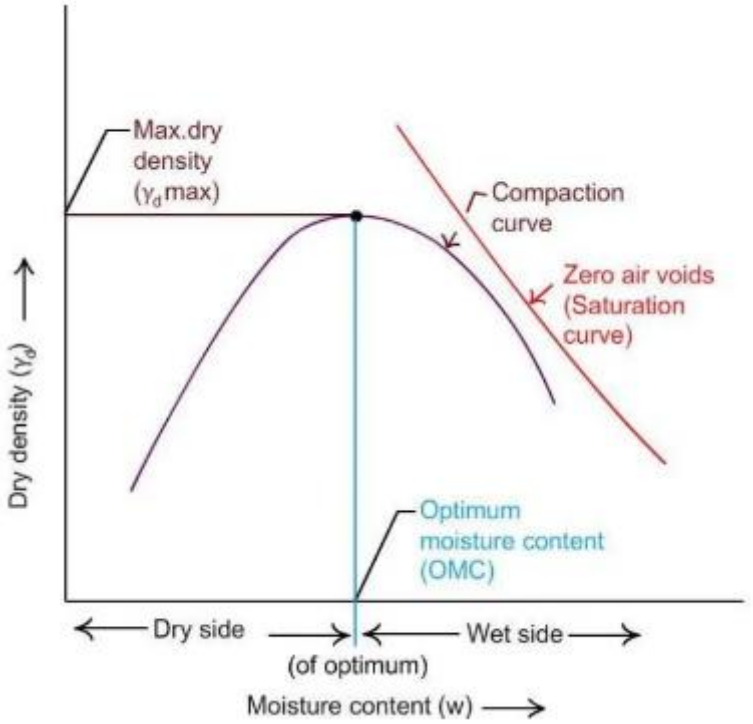
[Images: Grainger.com, IndiaMart.com]

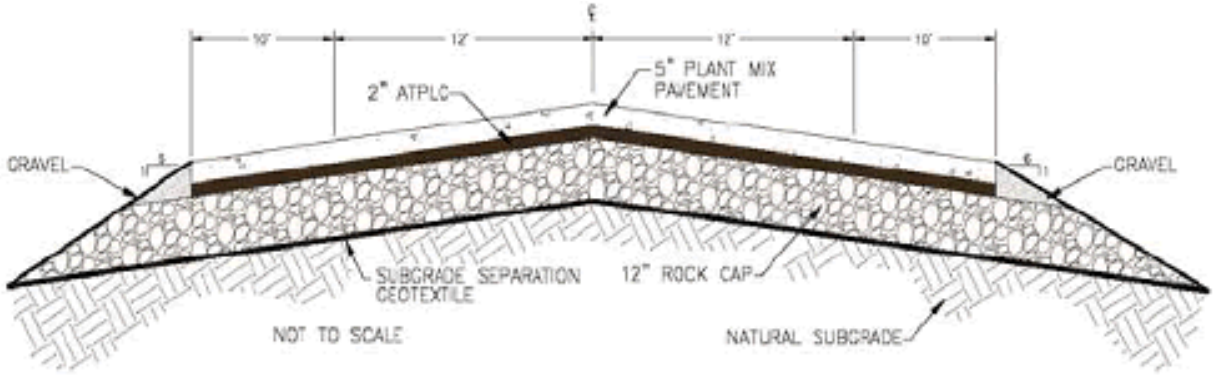
Site work…

- Work the in-place soils (scarify, dry, wet, etc.)
- Compact to some percentage of MDD at optimum in required number of lifts…
- Similar for subbase, base…
- Place pavement surface (concrete or asphalt)
- Crown, super, ditches, drainage structures, etc. to direct and keep water away
- Of course… **don’t build in floodplains**

Fundamental assumption of this process…

- Pavement layers will **REMAIN** at or near optimum… system was specifically designed to direct and keep water away.
- May have been reasonable when road network was developed… but the **context has changed**, in some cases substantially!





- Not designed to perform in an **inundated** condition
- Is BAU good engineering…?

Carolinas have been hit by TWO 500-year flood events

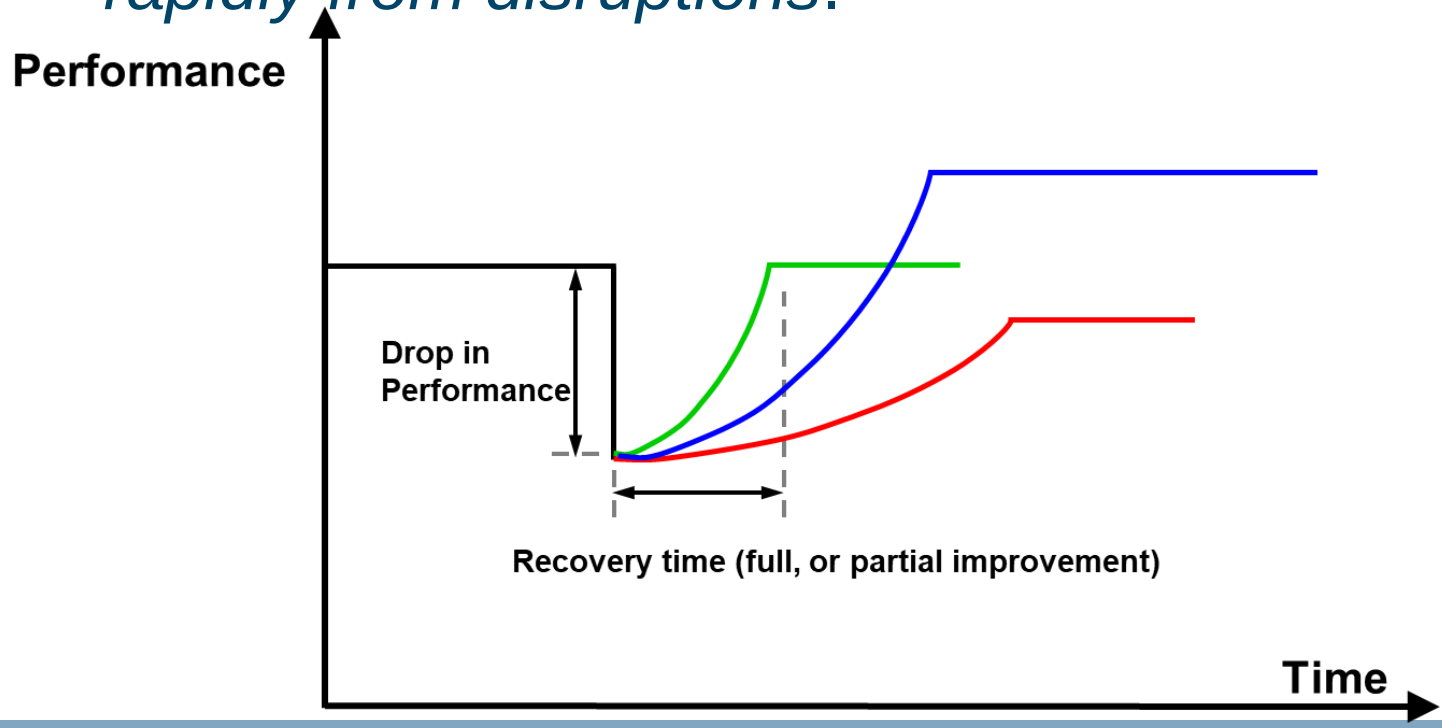
Hurricane Matthew (2016) & Hurricane Florence (2018)

IS SUBGRADE AT OR NEAR OPTIMUM MOISTURE?

With Hurricane Florence, NC had over 2500 road closures

What Does Resilience Mean in the Pavement Context?

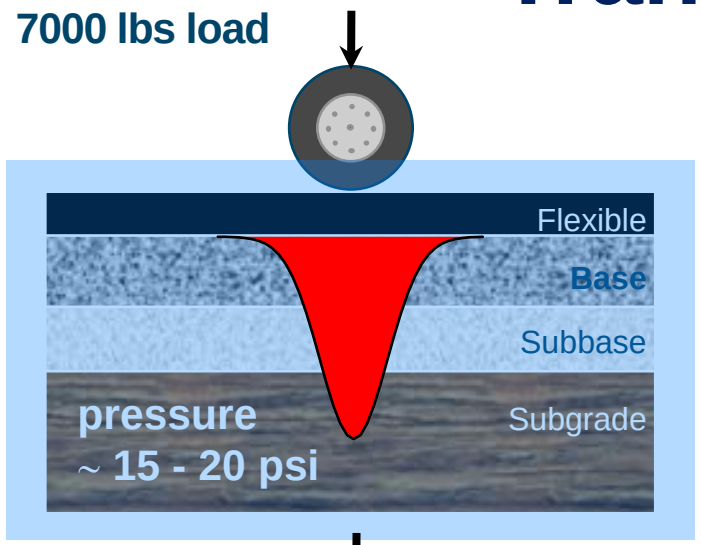
- FHWA Order 5520 - *Transportation System Preparedness and Resilience to Climate Change and Extreme Weather Events* (2014)
  - *Resilience …is the ability to anticipate, prepare for, and **adapt** to changing conditions and **withstand**, respond to, and recover rapidly from disruptions*.



Green is more resilient than Red
- **Faster recovery time**
- **Higher level of service**

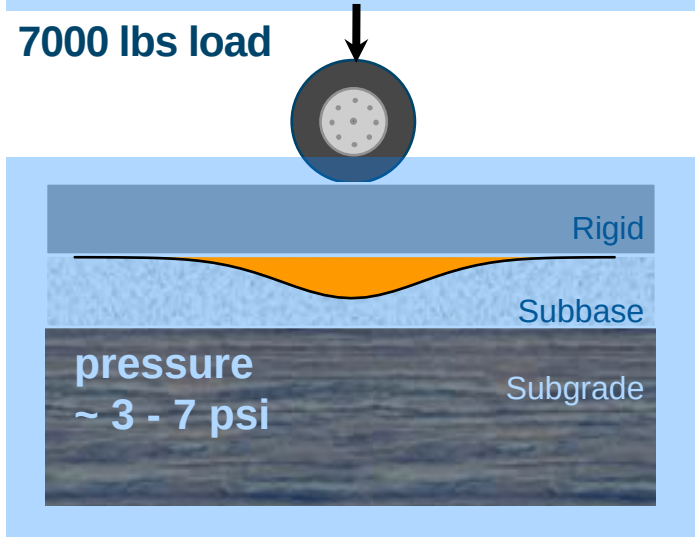
Blue is a hardened system as it has a higher final performance level

Rigid and Flexible Pavement Transmit Loads Differently



Flexible Pavement Structure

- Lowered subgrade strength & reduced modulus
  - Reduced load carrying capacity and >1 year recovery time
- Loading accelerates pavement damage / deterioration
  - Consumes fatigue life faster → Reduced pavement life



Rigid Pavement Structure

- 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 concrete's load carrying capacity to the same degree as asphalt's

Making Pavement Resilient to Inundation….?

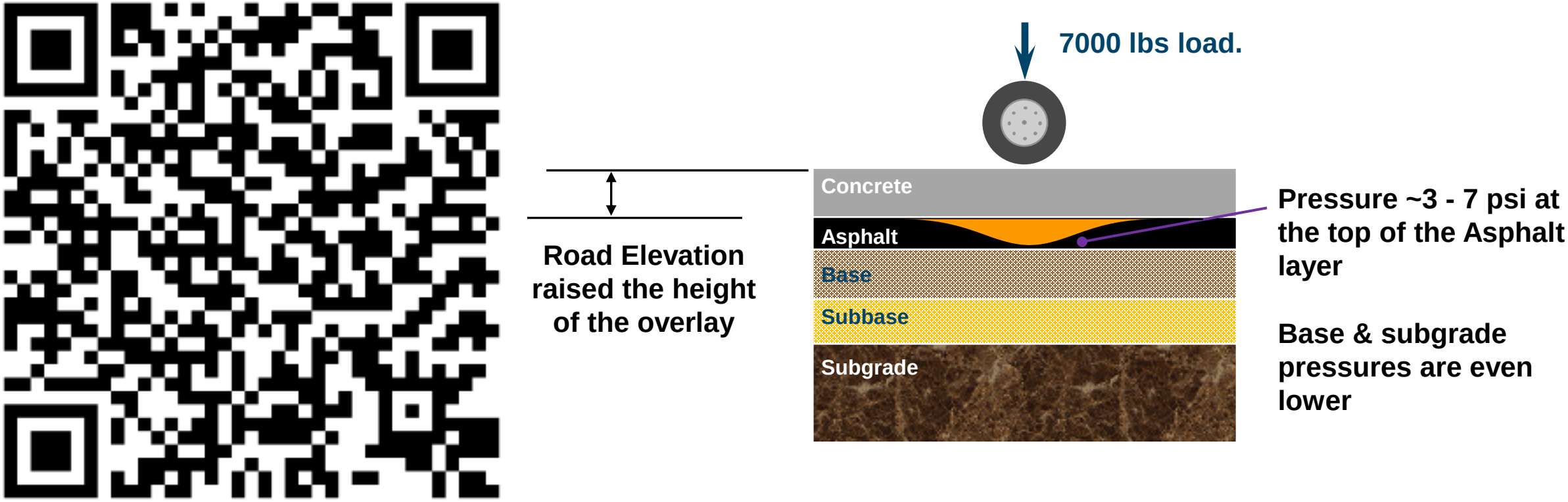
[Image: Google Images]

“Hardening” techniques for existing roadways…

(Concrete) Overlays

Full Depth Reclamation (FDR)

Concrete Overlay as a Resilient Hardening Solution



Rigid overlays increase both the height and the structural strength of the roadway ALSO… a technology under FHWA's EDC6 TOPS program…

Concrete Overlays to Improve Resilience

- Testing at the University of California's Pavement Research Center demonstrated excellent performance from COA overlays under loading from a heavy vehicle simulator

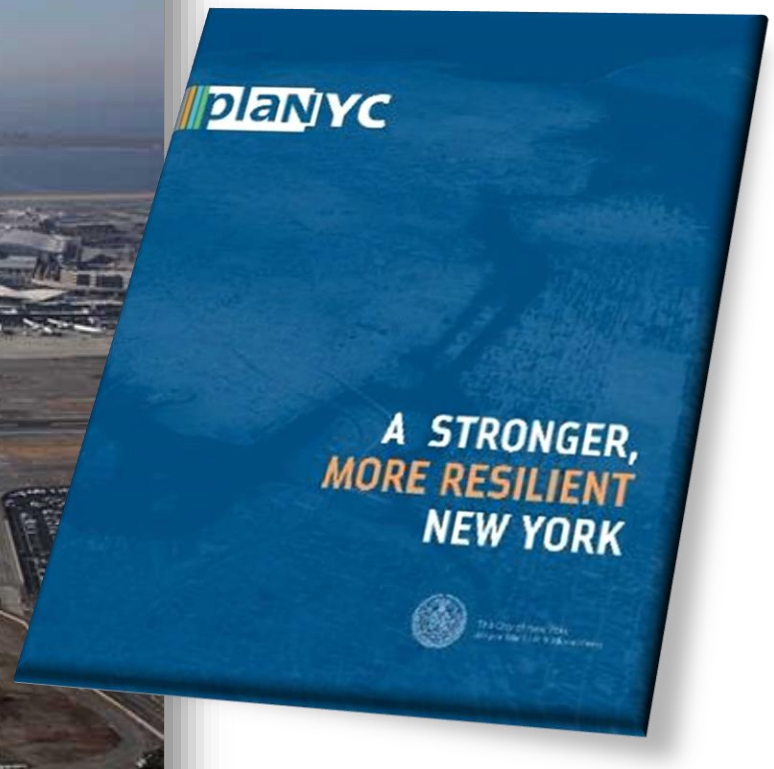
Continuous water supply during the flooded HVS testing

Source: Mateos et al. 2021

Concrete Overlays as an Airfield Resilience Solution

Reconstruction and Rehabilitation of Runways at JFK

*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"*



[Source: Port Authority of NY & NJ Press Release, April 3, 2019]

So… what to do? Where do we start?

Can't address it all…

- **New roadways**:
  - Assess inundation potential (updated maps)
  - Design stiffer pavement sections (soils, bases, pavement)
- **Existing roadways**:
  - **When rehab is needed**… re-assess inundation potential
  - Use resilient hardening solutions (overlay, FDR)
  - Start with evacuation routes, STRAHNET, NHS…

[Image: Google Images]

Fundamentally…

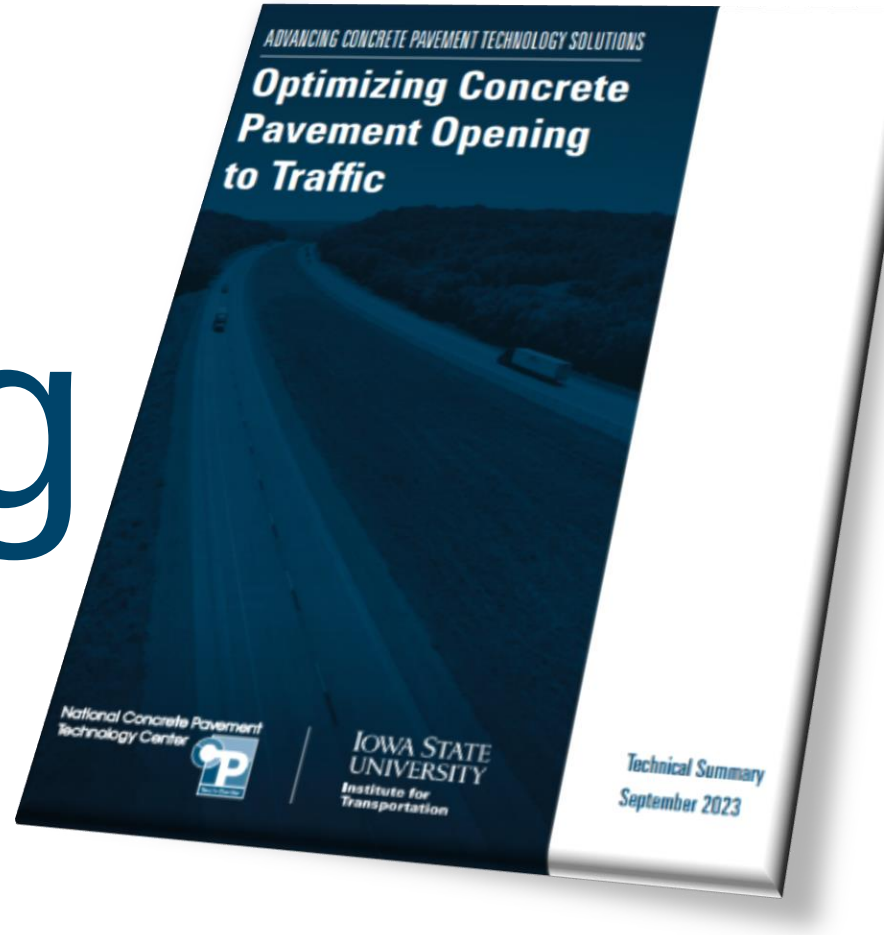
Resilience is about good engineering…

- Recognizing that the service environment of our pavements is changing…
- Adapting our designs to accommodate
  - Stiffer and/or less moisture sensitive pavement structures…
  - **Overlays are uniquely adapted hardening solutions for existing roadways**
- Starting with our most critical pavement assets

Business as Usual is NOT Sustainable!

[Image: Affinite.com]

Early Opening



Optimizing Concrete Pavement Opening to Traffic

- Reviews the science and strategy behind current practices related to open new pavement surfaces to traffic and how opening to traffic can be accelerated when necessary.
- Includes discussion of non-destructive testing (e.g. maturity)
- Case studies from Iowa, Georgia, Ohio, California, Virginia, and Indiana.
- Conclusion: **Current agency strength requirements for opening concrete pavements to traffic may be overly conservative**

Table 1. Results of 2000 and 2020 surveys on opening strength

Survey Year	Opening Time (Hours)	Traffic	Compressive (psi)		Flexural (psi)		Time (Hours)	
2000	6–8	—	1,200	3,500	260	400	4	12
	20–24	—	2,500	3,500	300	600	—	—
2020	—	Construction	2,200	3,500	500	650	—	—
	—	Regular	3,000	4,500	500	650	—	—

Executive Summary

- Excessive strength requirements lead to concrete mixtures that may not be durable in the long term.
- Instances of significant pavement fatigue damage due to early opening were **not reported in the case studies or the literature**.
- Strategic Highway Research Program (SHRP) recommends a **minimum flexural strength of 300 psi** with third-point bending and/or a minimum compressive strength of 2,000 psi.
- MnROAD study in 2017 (Khazanovich)
  - Deliberate early loading of concrete pavement test sections 2 to 10 hours after placement
  - No indication of structural problems after 5+ years of service
  - No damage occurred at estimated flex strength of 73 psi…

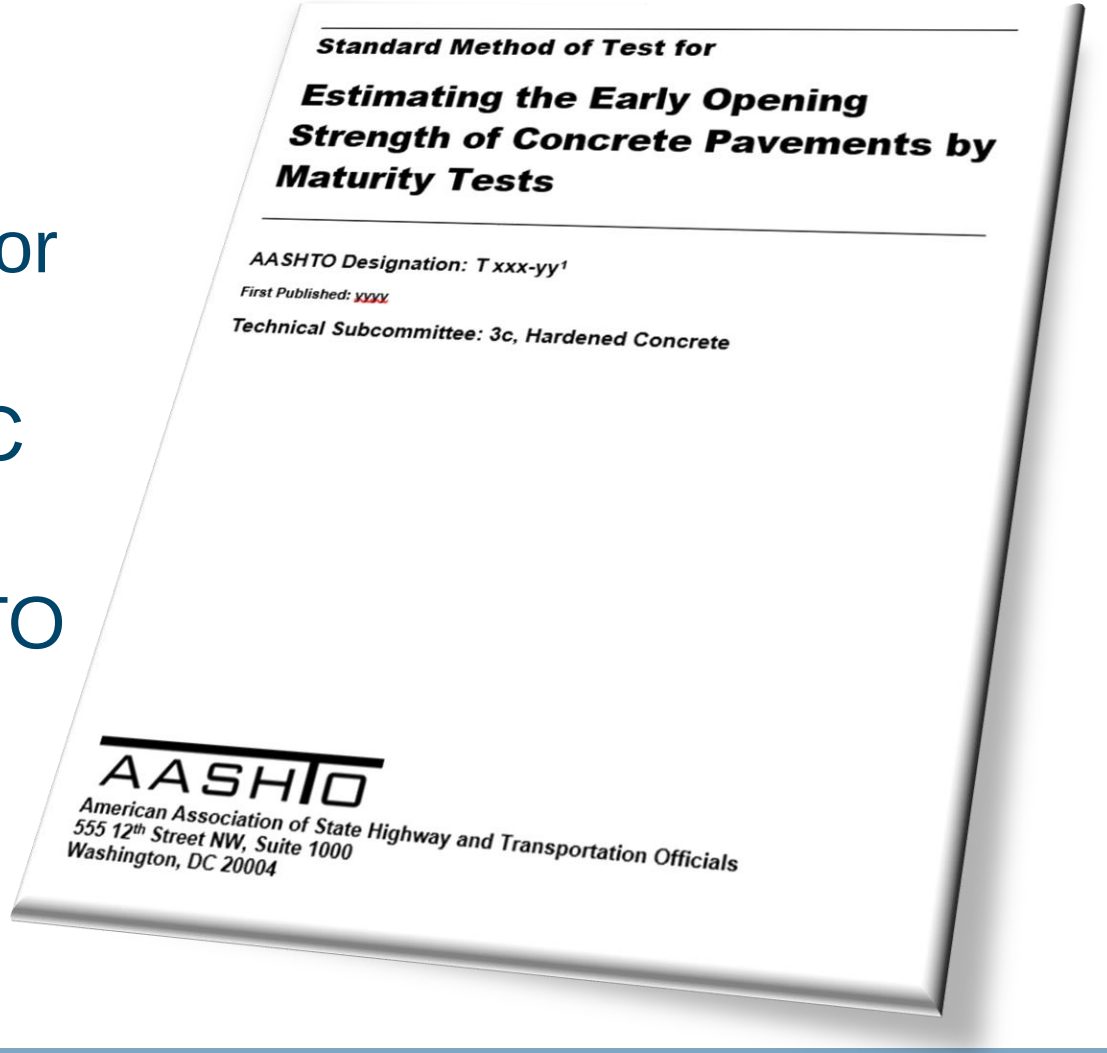
Executive Summary (cont.)

- 24th Street, Ames
  - Paved in 1982
  - Tire tracks have held up well for 40+ years
  - Later diamond grinding did not impact tracks

- In SHRP C-206 testing showed that even when full-depth patches were opened with strengths as low as 900 psi compressive and 155 psi flexural, the fatigue life of the pavement was **not** compromised.
- No difference in fatigue performance was evident between sections that were opened to traffic very early and those opened later.

Use of NDT to Estimate Pavement Strength

- Nondestructive technologies, in particular the maturity method, have proven effective at verifying strength for opening to traffic
- Not widely used… discussions at NCC suggest ASTM C1074 is too onerous.
- Developed new and simplified AASHTO test method for early age opening specifically.
- Passed ballot, publish in 2024


Standard Method of Test for

Estimating the Early Opening Strength of Concrete Pavements by Maturity Tests

AASHTO Designation: T xxx-yy[1]

First Published: yyyy

Technical Subcommittee: 3c, Hardened Concrete

AASHTO

American Association of State Highway and Transportation Officials
555 12th Street NW, Suite 1000
Washington, DC 20004

Covered a lot of ground…

- P3C
- Hardening with Overlays
- Early Opening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