IMPROVING PAVEMENT RESILIENCY & DISASTER RECOVERY
Flooding Impacts

Jim Mack, P.E.
Director of Market Development – Infrastructure

February 2020

TOPICS COVERED

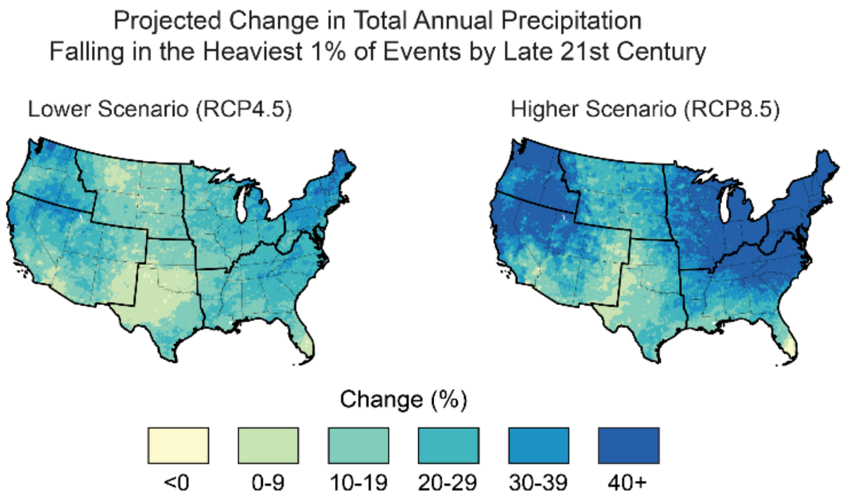
The Need for Resilient Pavements

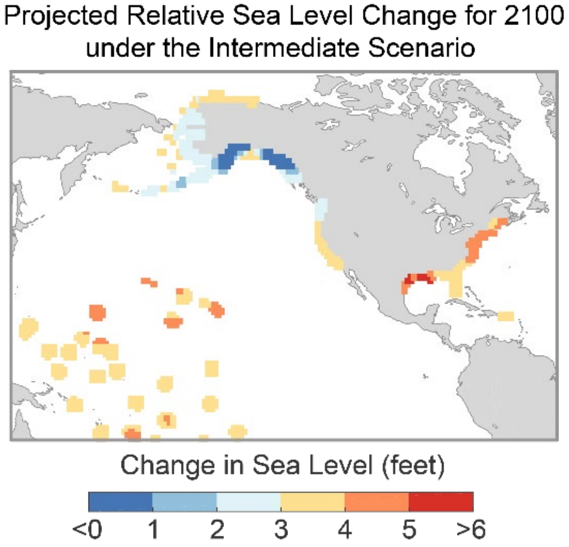
Defining Resiliency

Improving a Pavement’s Flood Resiliency

FUTURE CLIMATE CONDITIONS WILL NOT RESEMBLE THE PAST

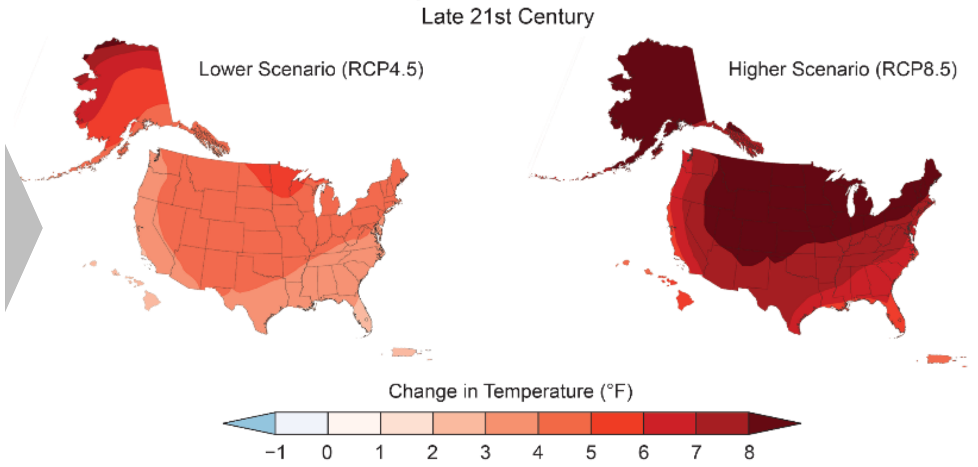
U.S. severe storms, heavy precipitation events:
Greater intensity *and* frequency
Continued increases expected





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

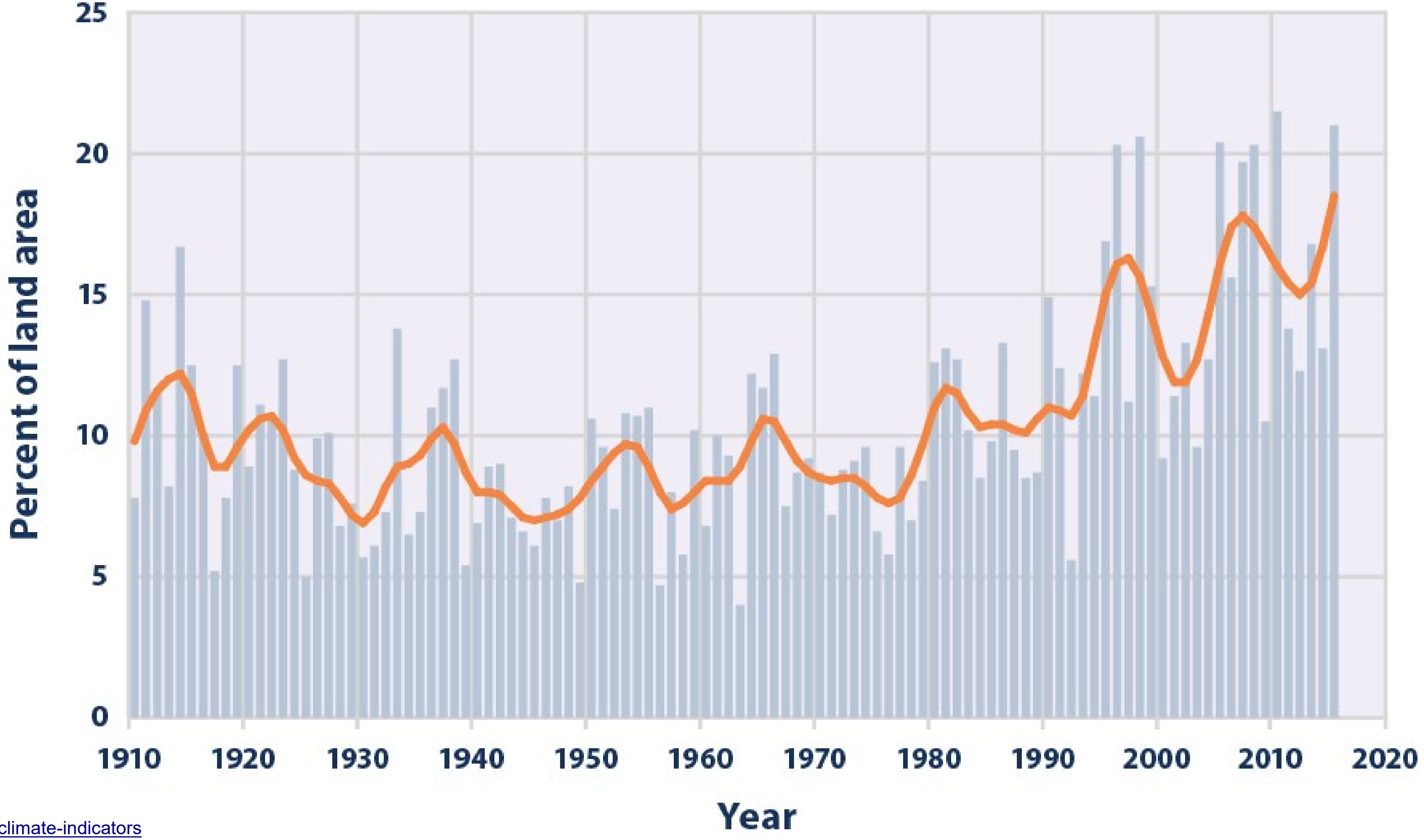
Increased Extreme heat events and drought:
Increased incidence of large forest fires



USGCRP, 2018: Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II: Report-in-Brief [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, 186 pp.

EXTREME FLOOD EVENTS ARE INCREASING IN BOTH FREQUENCY AND MAGNITUDE

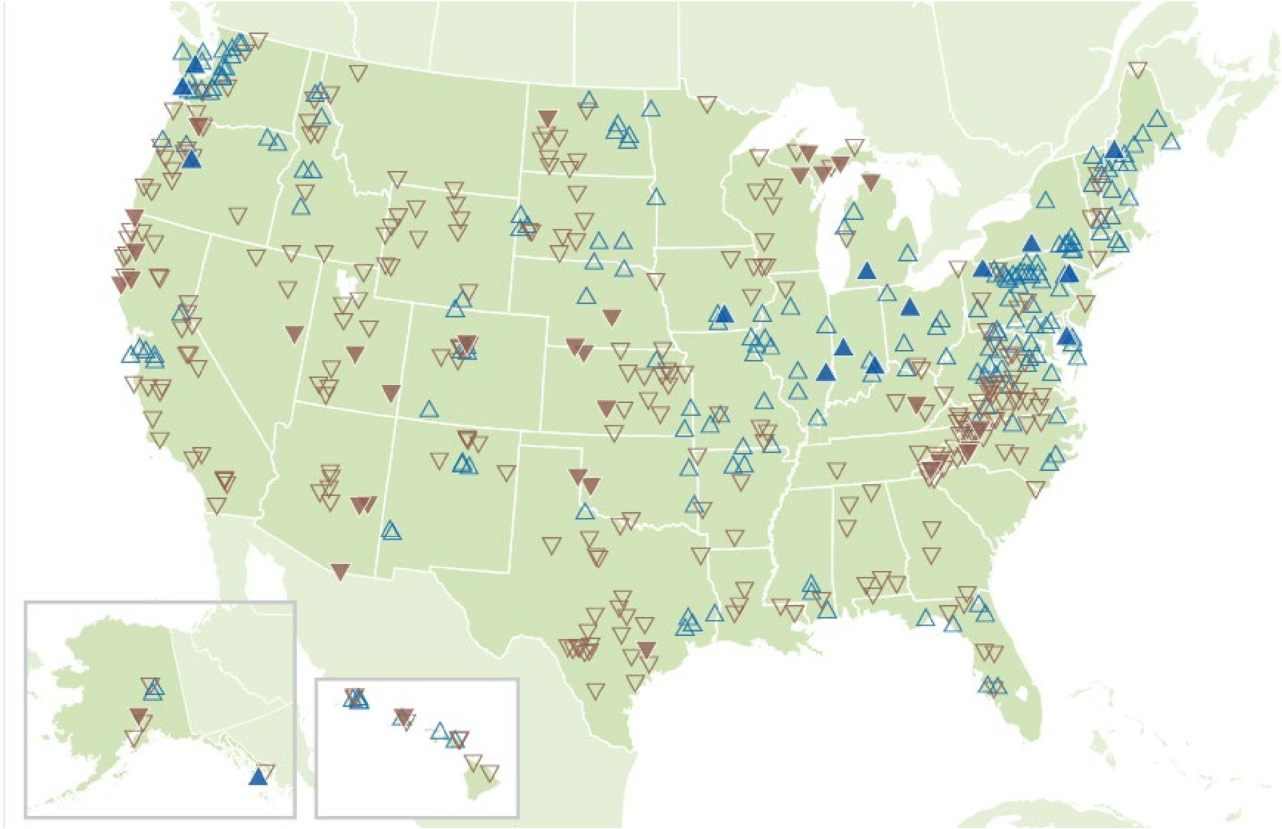
Extreme One-Day Precipitation Events in the Contiguous 48 States, 1910–2015



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

EXTREME FLOOD EVENTS ARE INCREASING IN BOTH FREQUENCY AND MAGNITUDE

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



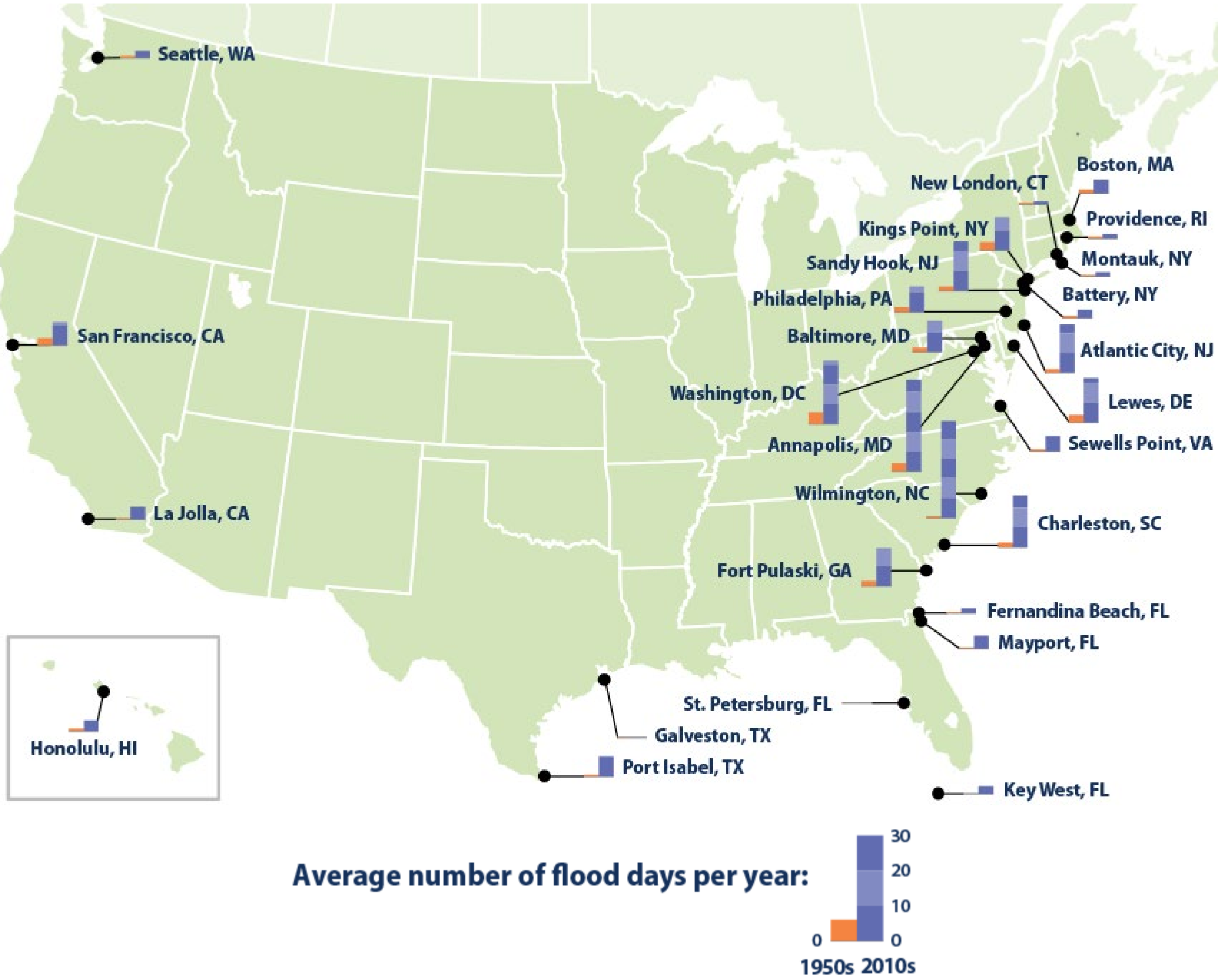
Significant decrease

Insignificant decrease

Insignificant increase

Significant increase

Frequency of Flooding Along U.S. Coasts, 2010–2015 vs 1950–1959

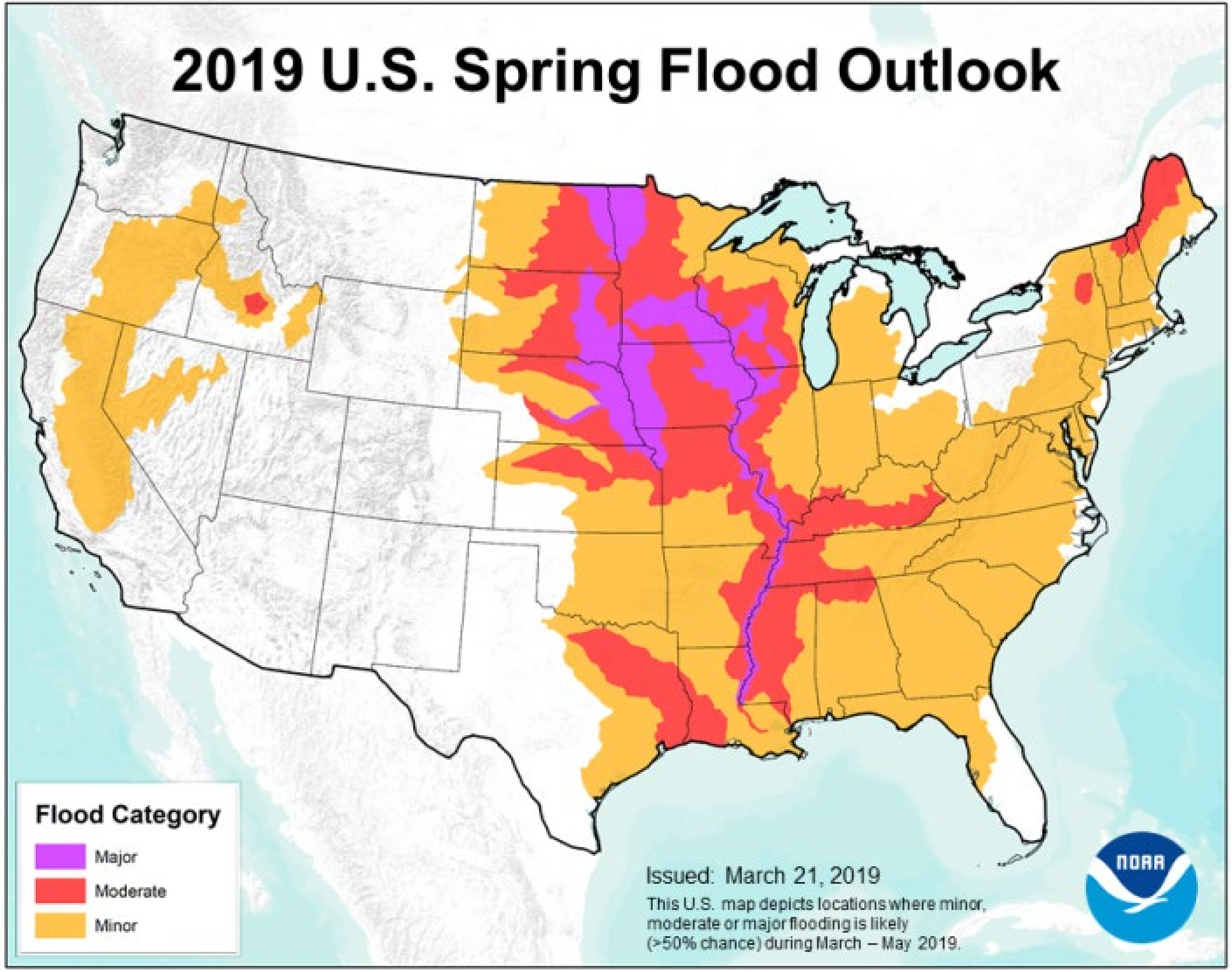


Source: https://www.epa.gov/climate-indicators

CEMEX

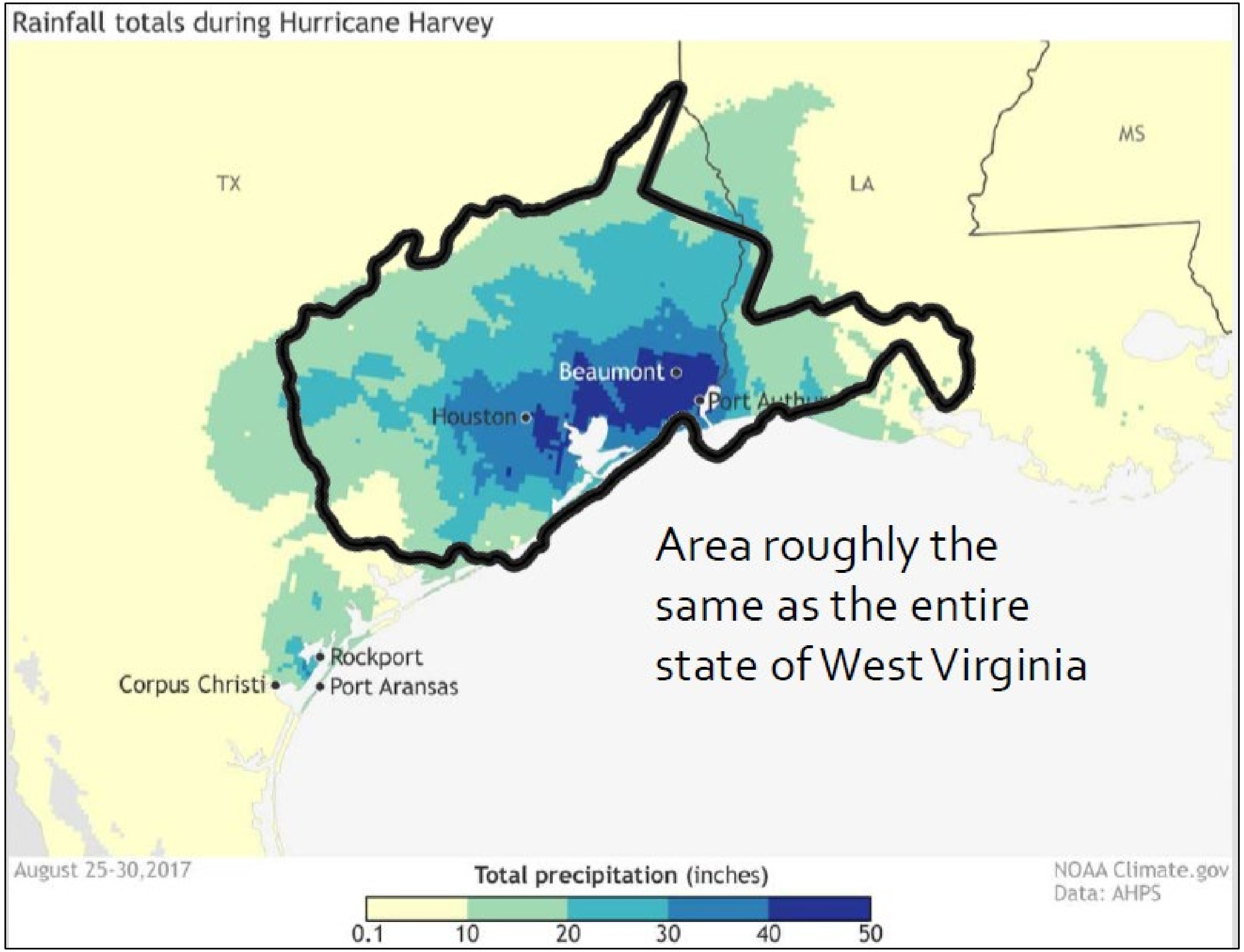
FLOODING IN THE PLAIN STATES WAS SEVERE THIS PAST YEAR

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

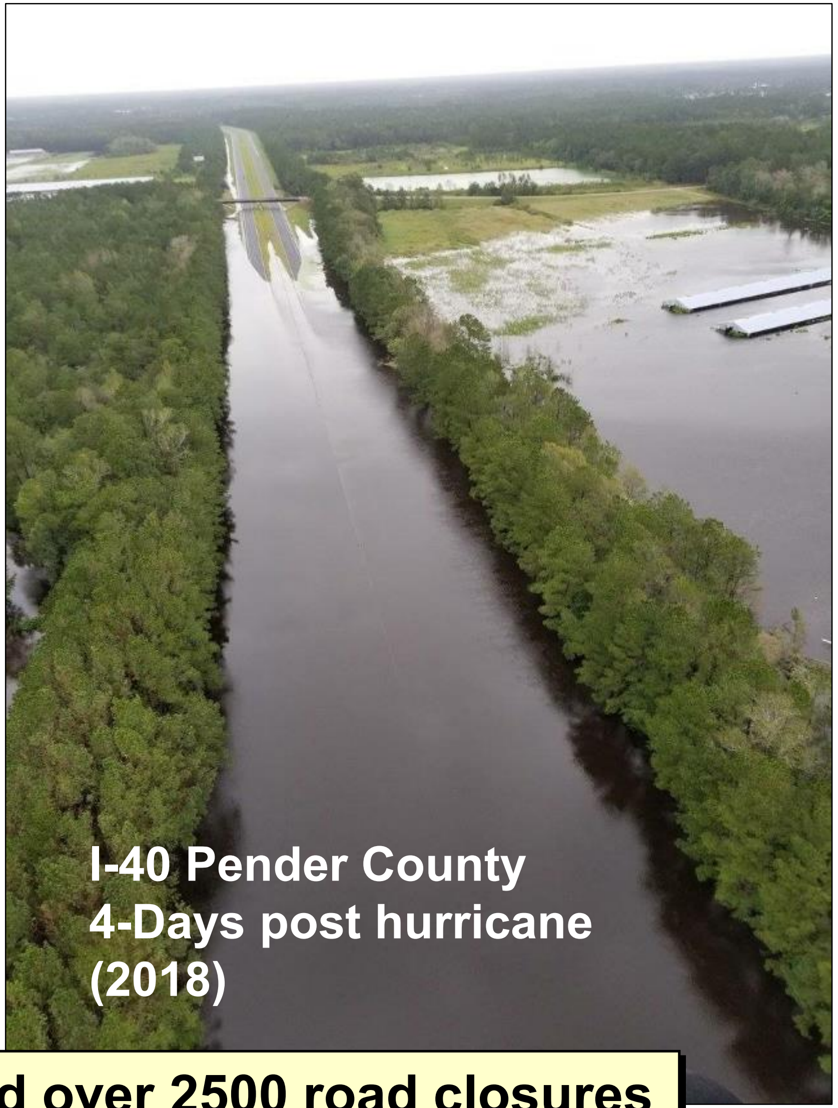


NORTH CAROLINA HAS BEEN HIT BY TWO 500 YEAR FLOOD EVENTS

Hurricane Matthew (2016) & Hurricane Florence (2018)

I-95 Lumberton, NC (2016)

I-95 Lumberton, NC (2016)



I-40 Pender County 4-Days post hurricane (2018)

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

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

Pavement type does have an impact

Washout

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

Pavement type has little impact

TOPICS COVERED

The Need for Resilient Pavements

Defining Resiliency

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 [1]**

Resiliency Planning Fundamentals [2]

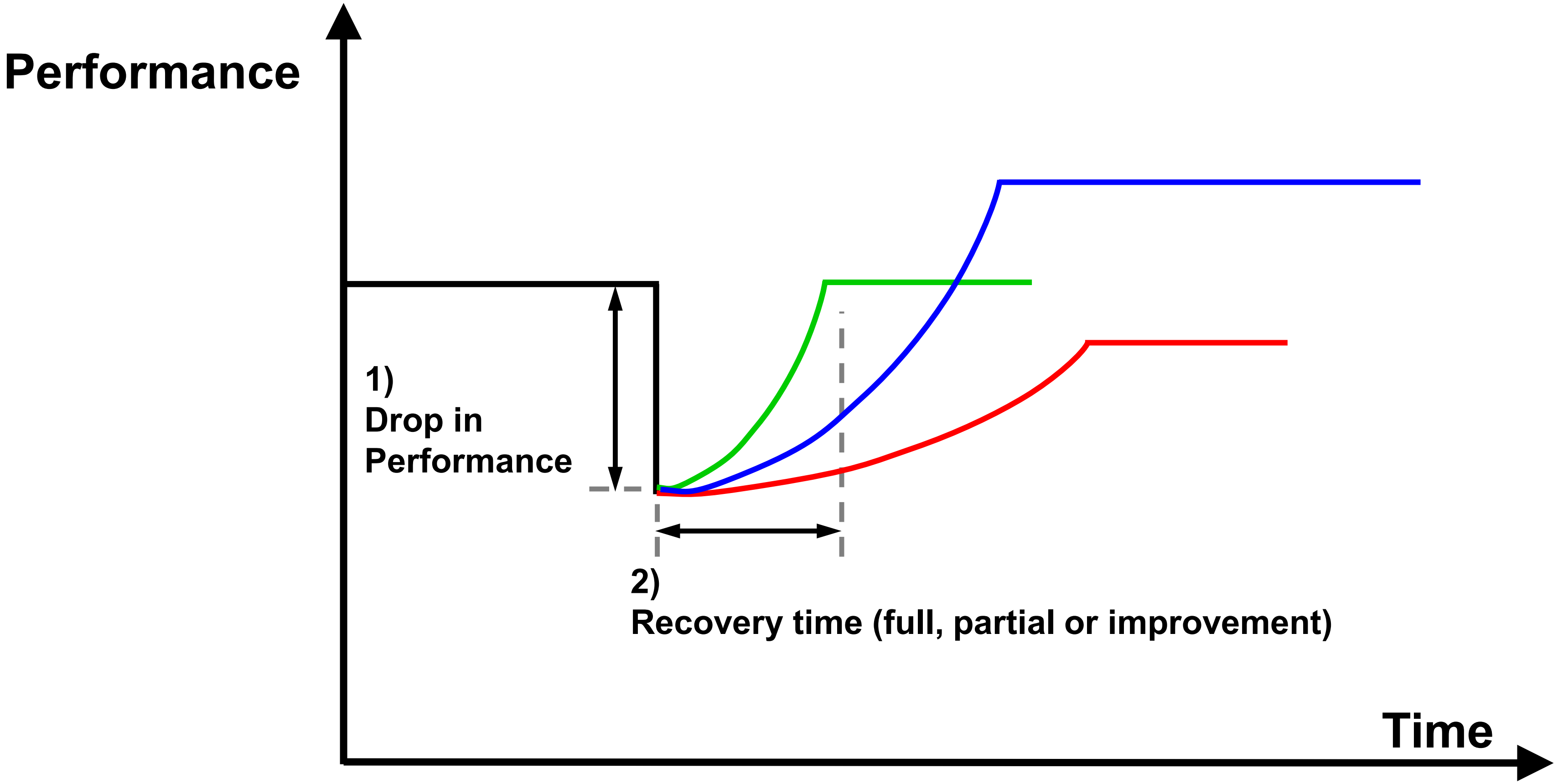
1. **Prevention: stop a … manmade or natural disasters**
2. **Protection: secure against …manmade or natural disasters**
3. **Mitigation: reduce …. by lessening the impact of disasters**
4. **Response: … meet basic human needs after an incident**
5. **Recovery: …assist communities affected by an incident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



Green is more resilient than Red

- **faster recovery time**
- **Higher level of service**

Blue is a hardened [2] system as it has a higher final performance level

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.

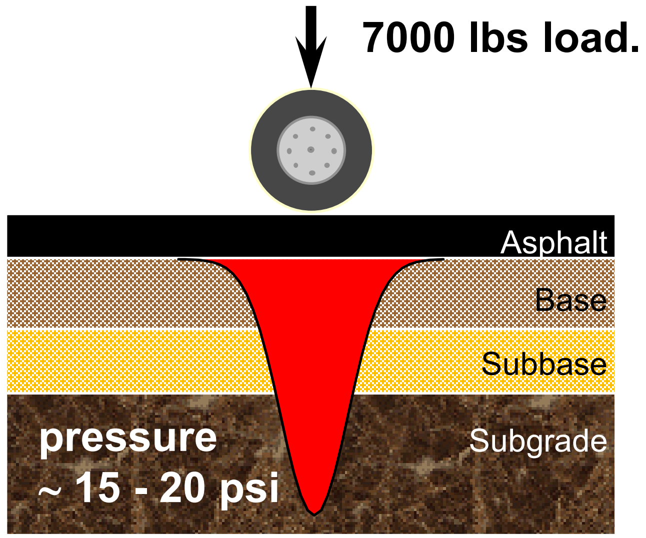
UN-International Strategy for Disaster Reduction

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

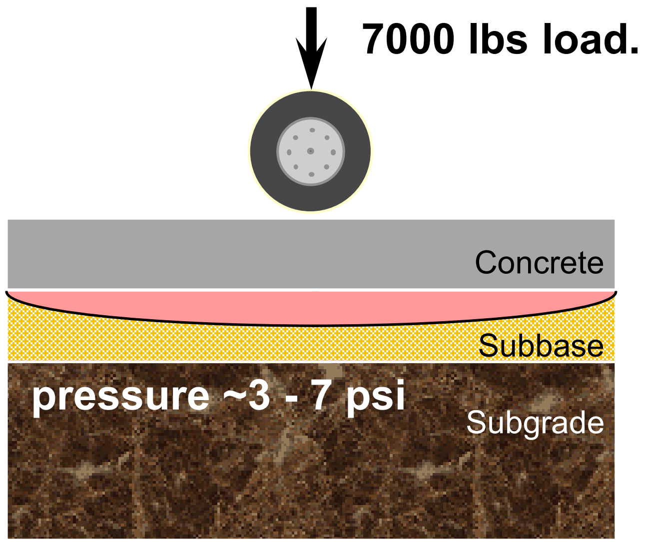
Asphalt Pavements are Flexible

- 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 SUPERSATURATED

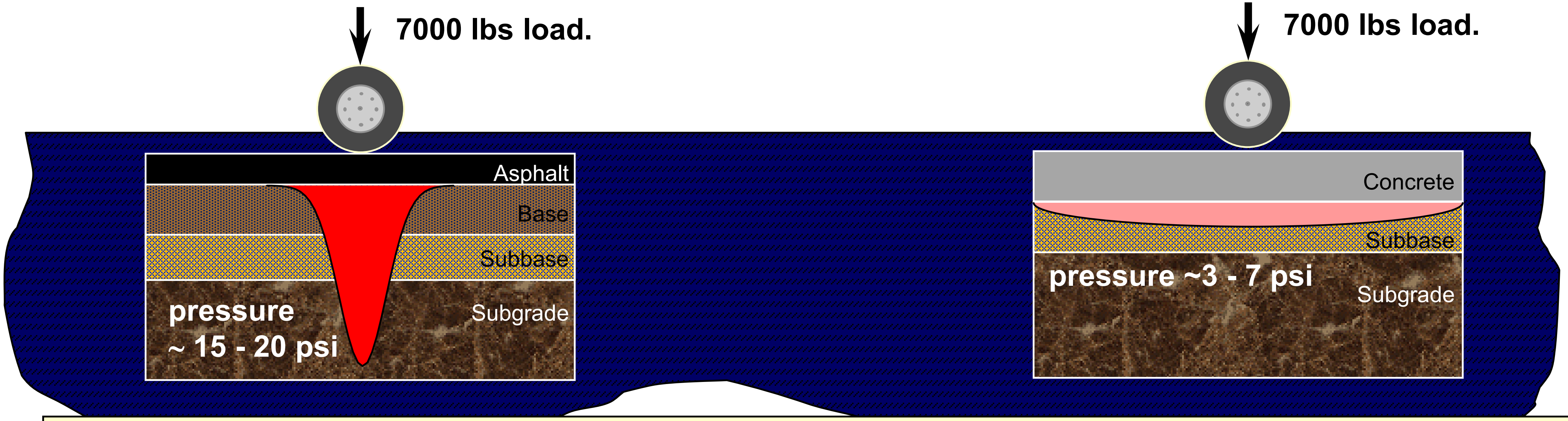
Moisture infiltrates base, pushes the subgrade particles apart and weakens the system

Asphalt Pavements are Flexible

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

Concrete Pavements are Rigid

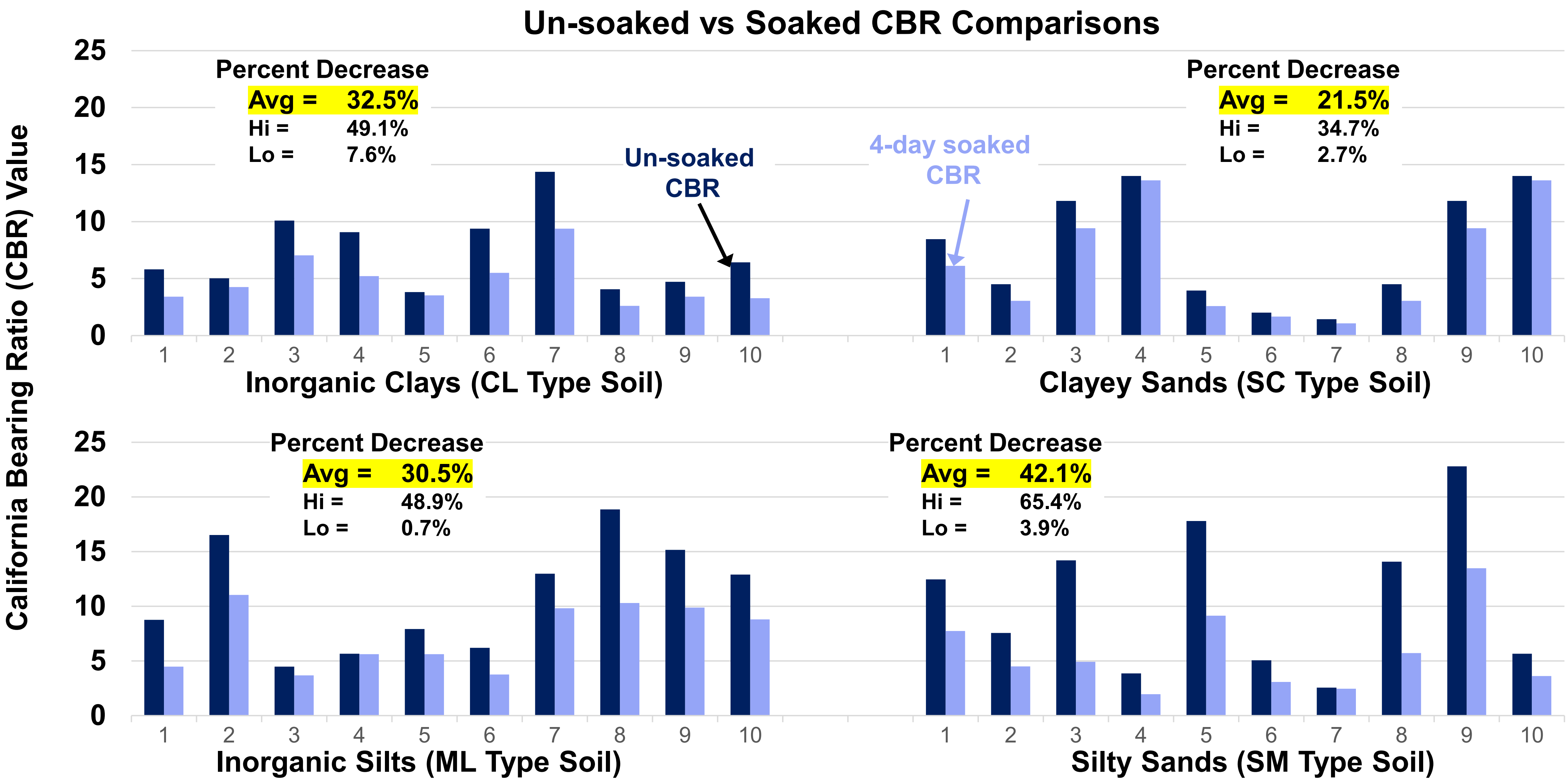
- Maintains high level of strength / stiffness
- Subgrade is weak, but still uniform
- Spreading of the load means subgrade is not overstressed
- Little impact on the serviceability / life



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

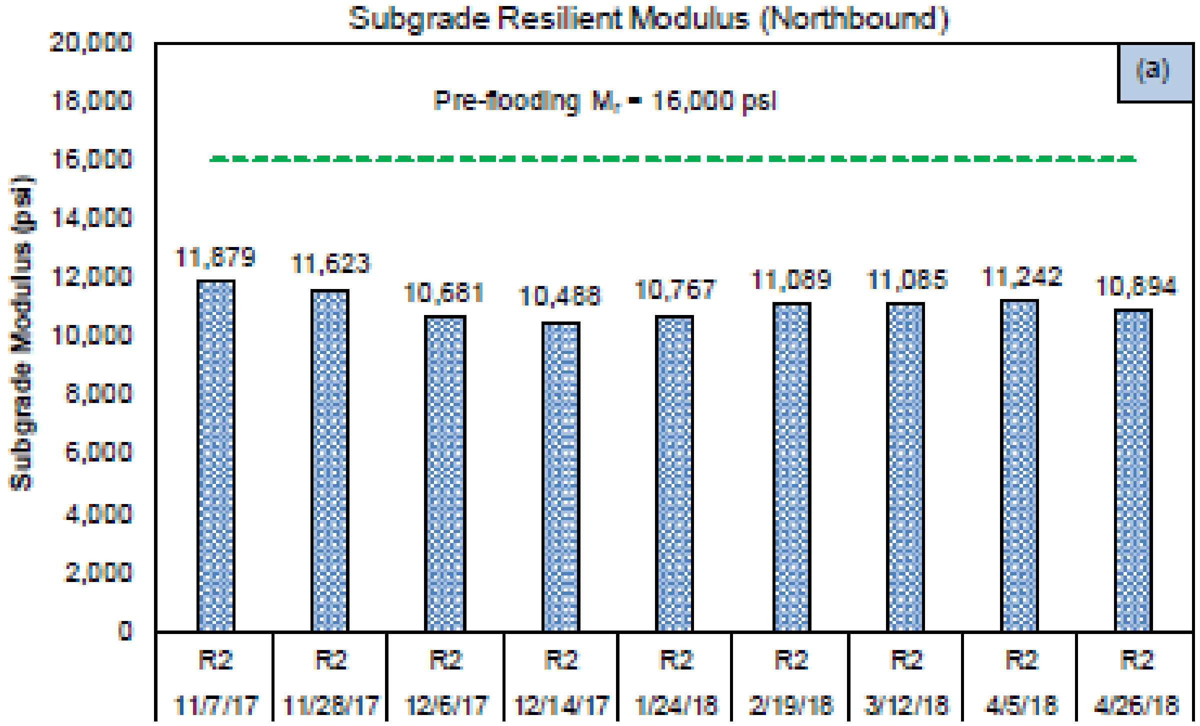


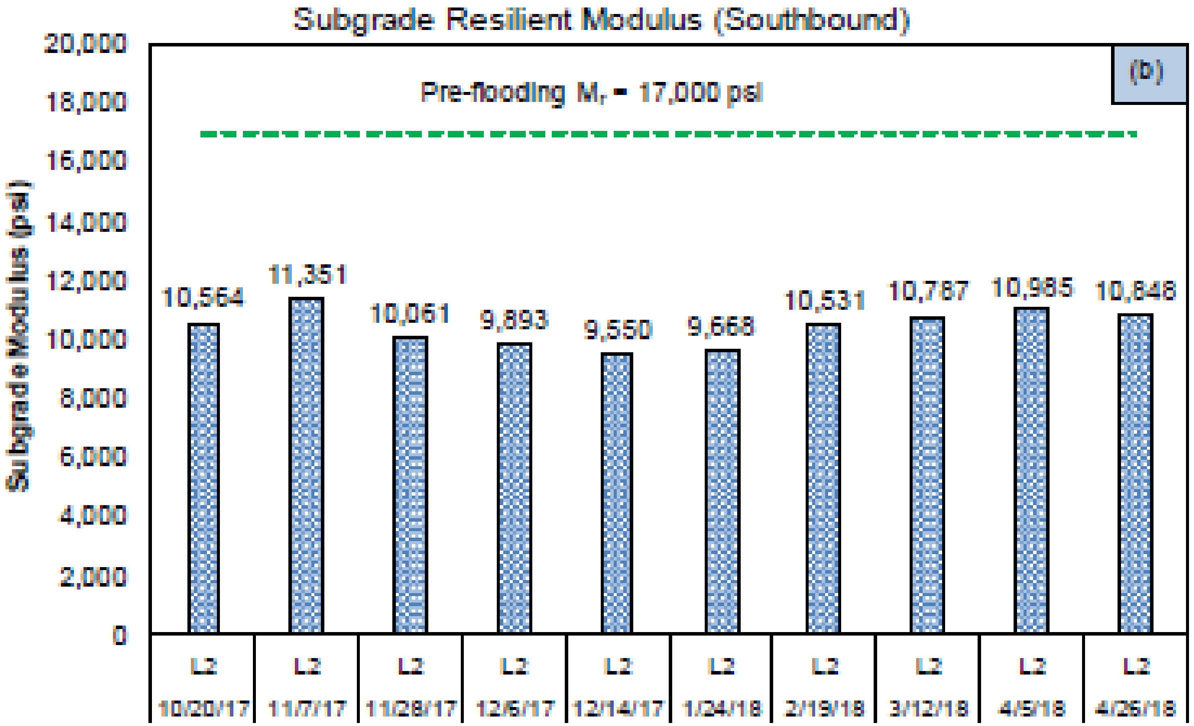
Source: *Comparison Between Soaked and Unsoaked CBR*, Sathawara Jigar K & Prof. A.K.Patel; International Journal of Advanced Engineering Research and Studies E-ISSN2249–8974

RELIEF AND RESCUE EFFORTS WILL TAKE PLACE
Loading weakened Pavements will shorten their lives

ALSO NEED TO ACCOUNT FOR LONG TERM LATENT EFFECTS WHEN DISCUSSING RESILIENCE TO FLOODING

After the flood waters recede, the pavements are structurally vulnerable





US 441 in Alachua County, Florida between MP 7.960 to MP 9.680

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

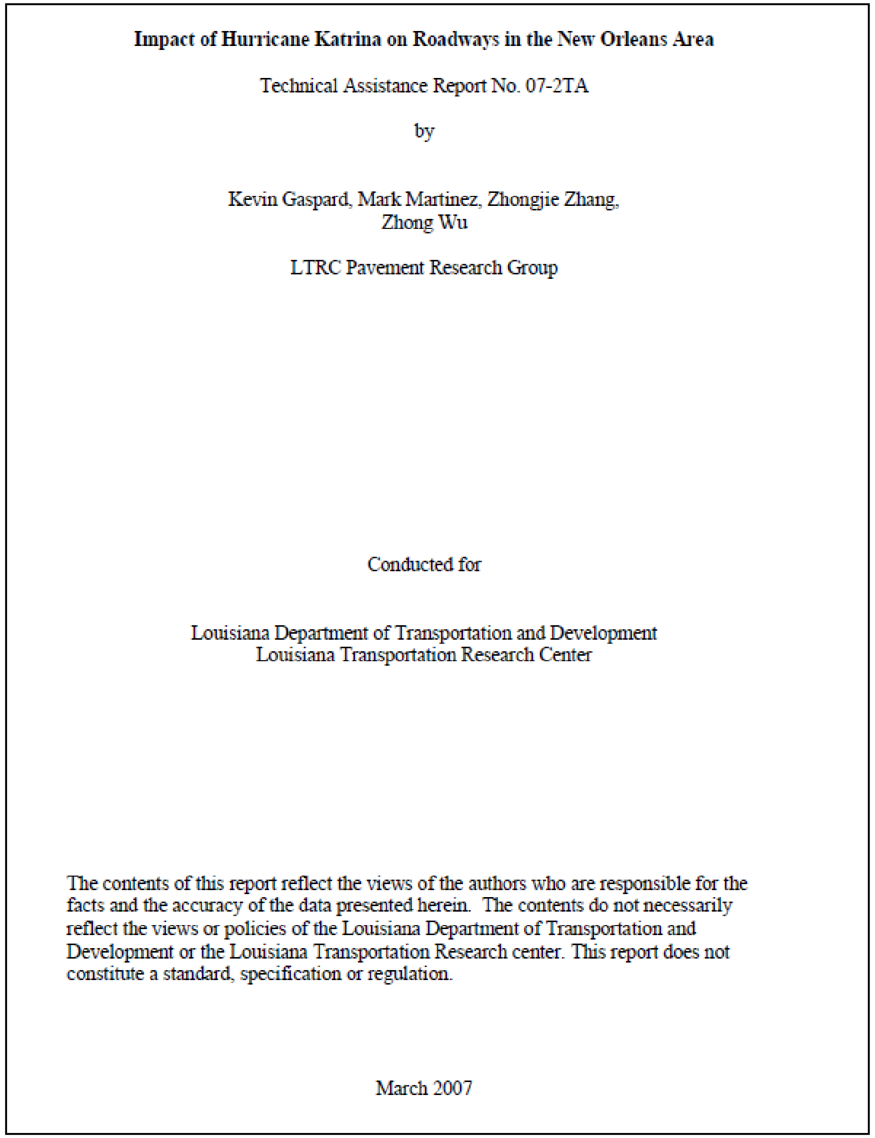
Sources:

1. Decision Support Criteria for Flood Inundated Roadways: A Case Study, A. Gundla, Ph.D., E. Offei, Ph.D. G. Wang, Ph.D., P.E. C.Holzschuher, P.E. and B>Choubane, Ph.D., P.E., Presented at the 2020 TRB Annual Mtg
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**



Impact of Hurricane Katrina on Roadways in the New Orleans Area

Technical Assistance Report No. 07-2TA

by

Kevin Gaspard, Mark Martinez, Zhongjie Zhang,
Zhong Wu

LTRC Pavement Research Group

Conducted for

Louisiana Department of Transportation and Development
Louisiana Transportation Research Center

The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the views or policies of the Louisiana Department of Transportation and Development or the Louisiana Transportation Research center. This report does not constitute a standard, specification or regulation.

March 2007

Impact of Hurricane Katrina on Roadways in the New Orleans Area, Technical Assistance Report No. 07-2TA
Kevin Gaspard, Mark Martinez, Zhongjie Zhang, and Zhong Wu; LTRC Pavement Research Group, March 2007

FLOODED PAVEMENTS RESEARCH IN AUSTRALIA FOUND SIMILAR RESULTS

Road authorities may want 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)

Estimating Pavement's Flood Resilience

Misbah U. Khan, CPEng.[1]; Mahmoud Mesbah, Ph.D.[2]; Luis Ferreira, Ph.D.[3]; and David J. Williams, Ph.D.[4]

Abstract: Although several studies observed pavement responses after flooding, no detailed quantification has been done to date. This paper has estimated different pavements' performances with flooding to identify flood-resilient roads. This was shown through (1) new roughness and rutting-based road deterioration (RD) models, (2) the relationship between changes in roughness [International Roughness Index (IRI)] versus time and modulus of resilience (Mr) loss at granular and subgrade layers versus time, and (3) flood consequence results. The comparative analysis on different pavement performances shows that a rigid and strong pavement built to a high standard is the most flood-resilient, which may be adopted as a preflood strategy. Results obtained using two proposed new gradients of IRI (incremental change in IRI, ΔIRI) in Year 1 over probability of flooding ($\Delta IRI/Pr$) and ΔIRI in Year 1 over loss in Mr ($\Delta IRI/MrL$) as well as flood consequences provided similar results. Road authorities should consider changing their roads to flood-resilient pavements in the future. It is recommended to investigate after flood roads' structural conditions and performances to validate the new ratio values of $\Delta IRI/Pr$ and $\Delta IRI/MrL$. **DOI:** 10.1061/JPEODX.0000007.

Author keywords: Road deterioration; Modulus of resilience; Flooding; Flood-resilient pavement.

Introduction

Pavement performance shows deterioration of roads with time in its service life, which is dependent on traffic loading, material properties (pavement type, structure, strength, and subgrade strength), climate and environment, drainage, initial road condition, and maintenance activities (Hunt and Bunker 2001). It is generally expressed by roughness versus time. Roughness is related to pavement structural and functional conditions, traffic loading, and environmental factors, and it has a direct relationship with vehicle operating costs, accidents, and driver comfort (Gopinath et al. 1994; Odoki and Kerali 2000; Prozzi 2001). Therefore, it is the most representative index for evaluating a pavement performance. AASHTO also uses roughness for pavement design.

A pavement shows an abrupt change in road condition, e.g., roughness and rutting, after a disaster such as flooding. As a result, higher pavement deterioration is observed, for example, significant roughness [denoted by International Roughness Index (IRI)] increase is found due to flooding. Studies reveal that the incremental change in IRI (ΔIRI) due to a flood depends on loss in pavement modulus of resilience (Mr) and the probability of flooding.

Several studies have identified that the Mrs of granular and subgrade layers are reduced due to moisture intrusion (Brown and Dawson 1987; Drumm et al. 1997; Yuan and Nazarian 2003). Both Monismith (1992) and Huang (1993) found an increase in pavement deflection due to a lower Mr, and consequently a reduced pavement life. There are no studies that can address pavement performance with flooding.

Recently, Khan et al. (2014a, 2017c) and Khan (2017) developed project and network levels roughness and rutting-based road deterioration (RD) models at different probabilities of flooding. Additionally, Khan (2017) and Khan et al. (2017a) determined pavement responses during flooding using the Mr loss values in granular and subgrade layers. Using the roughness prediction model of AASHTO (2008) (based on AASHTO's pavement design guide of 2008) and the Highway Development and Management Model (HDM-4) (Odoki and Kerali 2000), they observed poor pavement performance after a flood when Mr was reduced. The impact of pavement performance due to different probabilities of flooding was shown in Khan et al. (2014a). Both these studies (Khan et al. 2014a; Khan 2017) provided IRI versus time and rutting versus time because of a flood. An after-flood effect on pavement roughness was estimated while assessing flood risk for the road network (Khan 2017; Khan et al. 2017b), which gives ΔIRI due to a flood.

The current paper has aimed to measure pavement performances with flooding in order to obtain strong pavements that can better sustain flooding in their lifecycle, which was determined using the pavement performances with flooding scenarios, that is, (1) performance at different probabilities of flooding, (2) performance at different Mr loss values in Year 1, and (3) change in IRI due to a flood. The newly derived RD models are valid for a short period up to 2–3 years (Khan 2017; Khan et al. 2017c). The RD models with flooding, ΔIRI in Year 1 divided by the percent of probability of flooding ($\Delta IRI/Pr$) and ΔIRI in Year 1 divided by the percent of Mr loss at subgrade and granular layers ($\Delta IRI/MrL$) for different road groups and flood consequence results provide valuable information in this regard.

The current paper has proposed two new gradients: (1) $\Delta IRI/Pr$, and (2) $\Delta IRI/MrL$ using the IRI versus percent probability of flooding and IRI versus percent Mr loss relationships, respectively. The consequence of a flood for a road group using ΔIRI also gives useful information. The gradient of rutting (ΔRutting) versus the percent probability of flooding provides similar relationships; hence, the ΔRutting in Year 1 over probability of

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[4]Professor, School of Civil Engineering, Univ. of Queensland, Brisbane,

2016; approved on … ussion period open … be submitted for … f Transportation Engineering, Part B: Pavements, © ASCE, ISSN 2573-5438.

Estimating Pavement's Flood Resilience; Misbah U. Khan, CPEng; Mahmoud Mesbah, Ph.D.; Luis Ferreira, Ph.D.; and David J. Williams, Ph.D.; American Society of Civil Engineer's Journal of Transportation Engineering, Part B Pavements, 2017

PAVEMENTS IN HOUSTON HAVE BEEN FLOODED SEVERAL TIMES

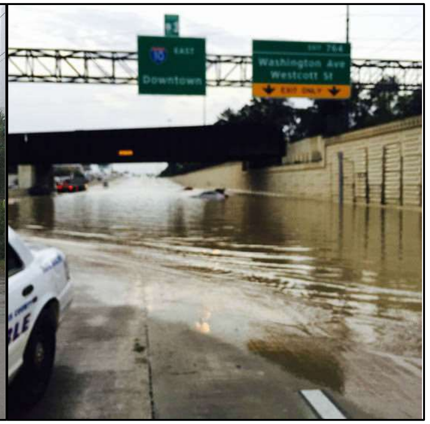
But roadways are opened as soon as water has receded

I-10 from I-610 to I-45

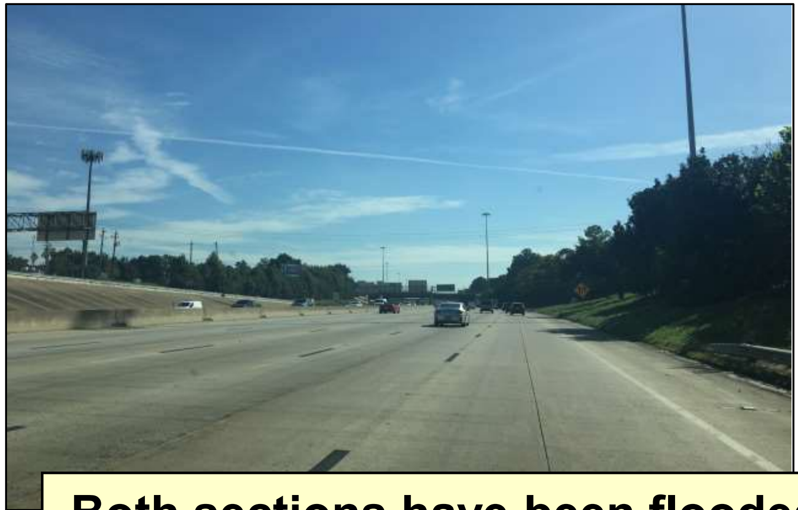
11” CRCP UBOL & 14” CRCP (Const = 1995-2000)
Design= 43M ESALS, Carried = 92M ESALS

SH 288 from Southmore to Yellowstone –

9” CRCP (Const = 1983 & 1984)
Design = 7M ESALS, Carried = 22M ESALS



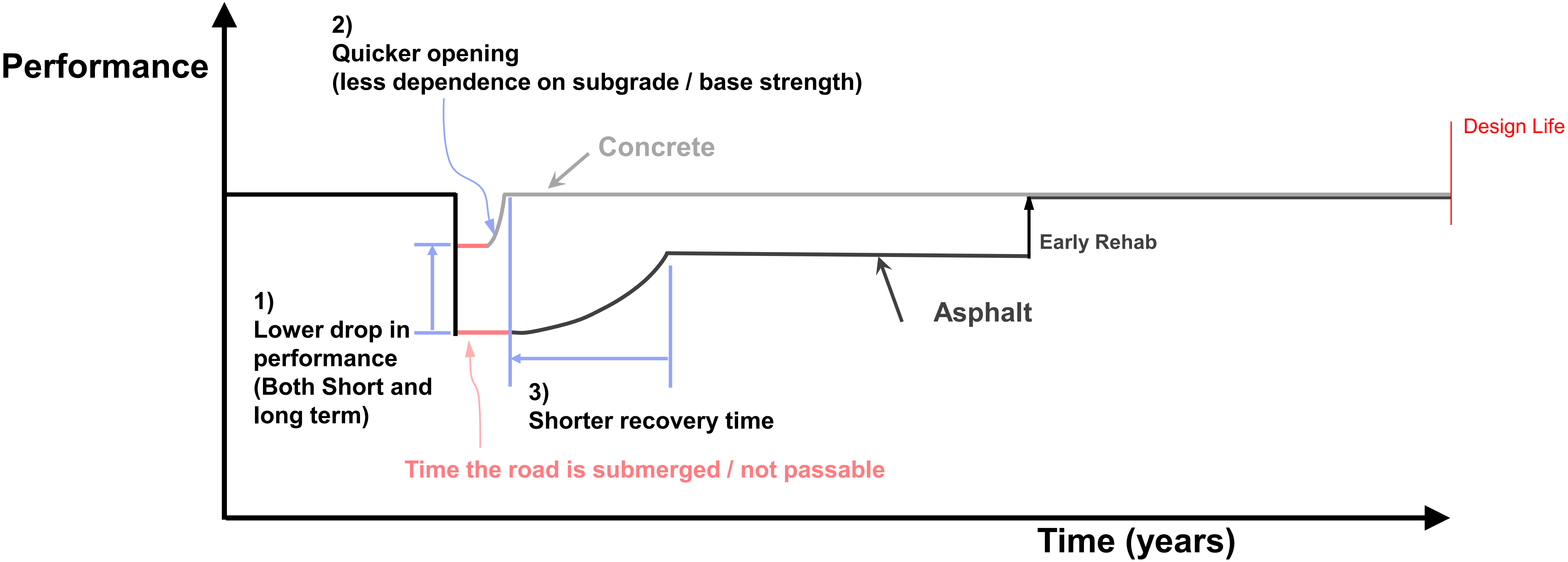
Opened roadway shortly after Hurricane Harvey



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 recover faster
(stiffer = concrete, cement stabilized bases, increased asphalt thickness)

TOPICS COVERED

The Need for Resilient Pavements

Defining Resiliency

Improving a Pavement's Flood Resiliency

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

A fact sheet from THE PEW CHARITABLE TRUSTS | April 2019

Federally Funded Infrastructure Must Be Flood Ready

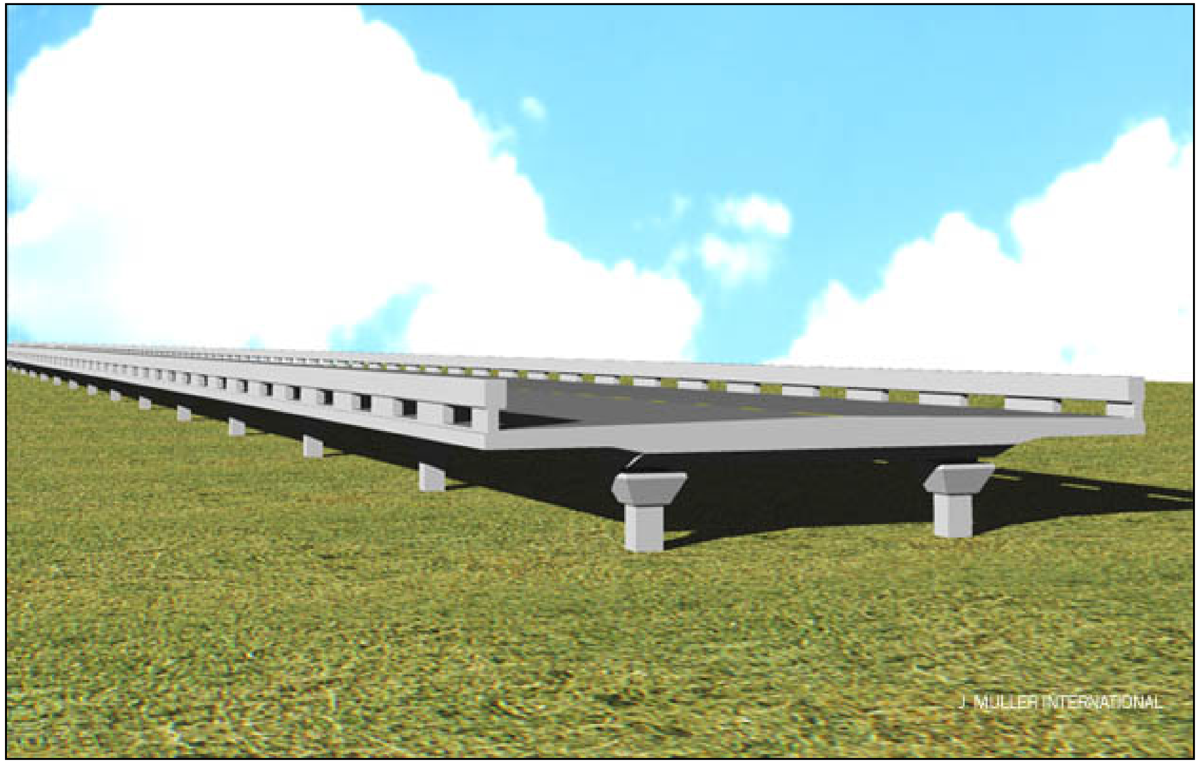
Incorporating future flood risk into projects would reduce losses, recovery costs

Overview

Flooding is the most common[1] and costly[2] natural disaster in the United States, causing more than $830 billion in estimated losses since 2000.[3] In addition to private property damage, deluges from hurricanes and other storms have washed out roads and bridges and flooded schools, hospitals, and utilities.

Much of this infrastructure is vulnerable to flooding because it's decades old and in poor condition, reflected by a failing grade by the American Society of Civil Engineers in its 2017 report card.[4] And as floods have become more frequent and intense, exposing more areas to a deluge, federal policies haven't evolved to address this growing threat. As Congress considers new investments in infrastructure, it must account for present and future risk to ensure that every dollar spent makes communities more resilient in the face of increasingly costly storms.

ONE OFTEN DISCUSSED APPROACH IS ELEVATING THE ROAD ABOVE FLOODING ELEVATION



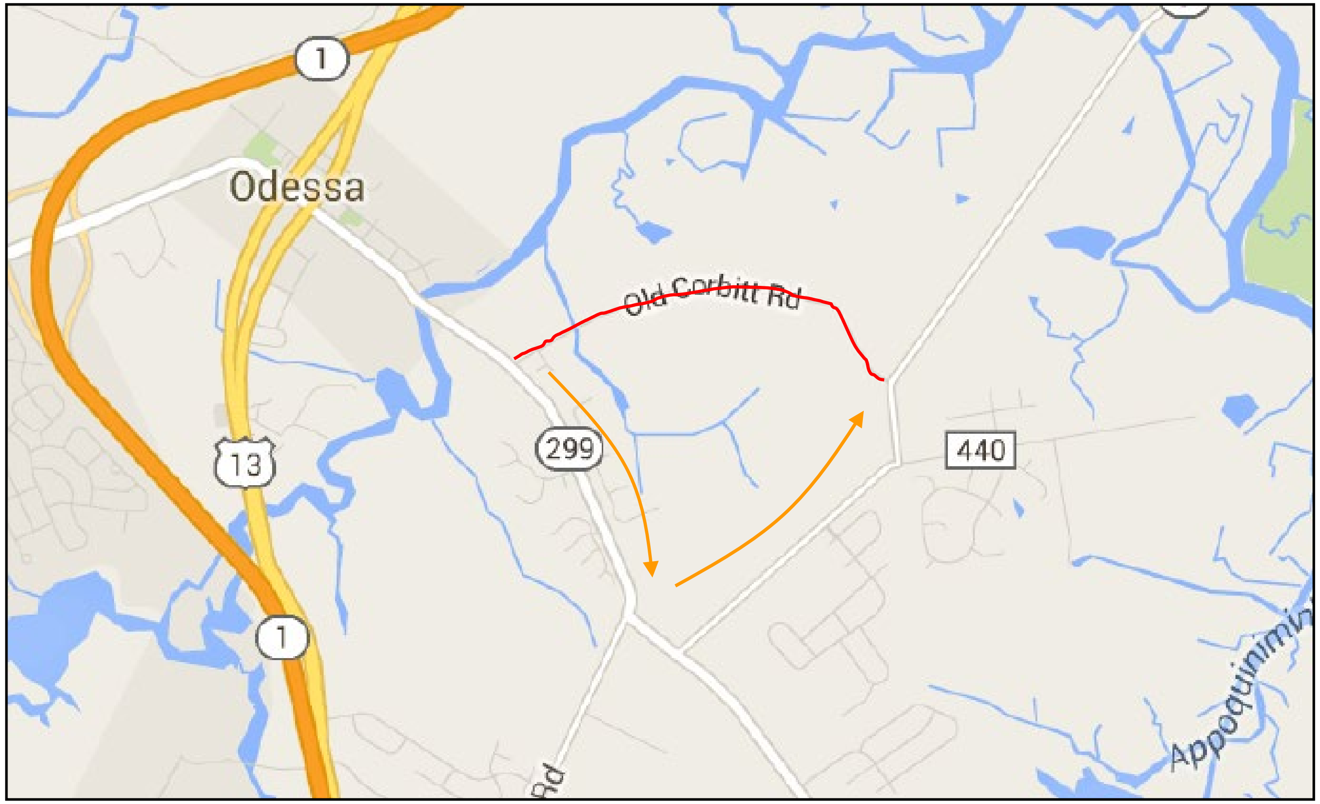
Elevation View of SR54 Viaduct From Old SR54 Alignment, Fenwick DE
Cost = $16 M in 2001

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



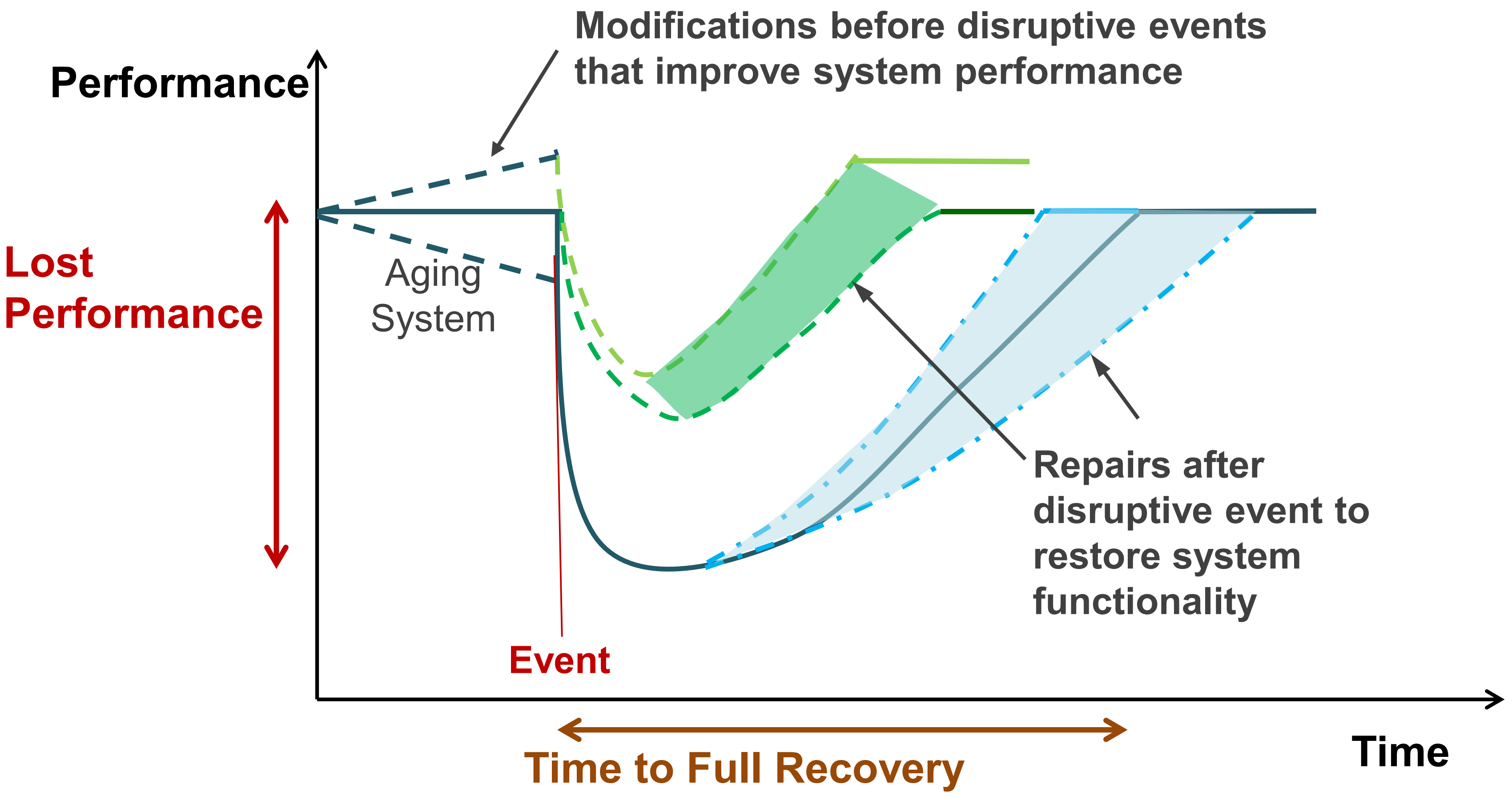
- **Overtops daily due to tides**
- **340 Avg Daily Traffic (ADT)**
- **Traveling time will be slightly increased by approximately 2 to 3.5 minutes.**

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

Abandoning the roadway is not always possible

Schematic and Photo courtesy of Jim Pappas, DELDOT

THERE ARE WAYS TO IMPROVES A HIGHWAY'S / PAVEMENTS RESILIENCE



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

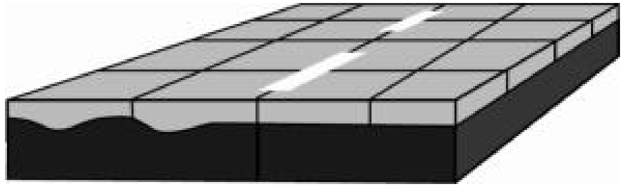
Thin Concrete Pavement

Concrete Overlays

Roller Compacted Concrete (RCC)

Full Depth Reclamation (FDR) w/ Cement

CONCRETE OVERLAYS OF ASPHALT HAVE UNTIL RECENTLY BEEN CALLED "WHITETOPPING OVERLAYS"

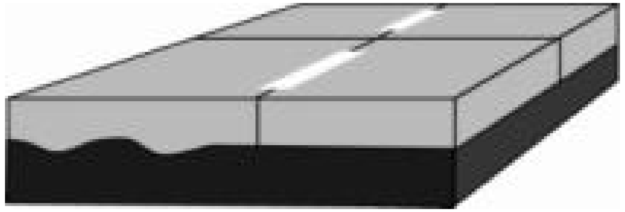


Used since 1998

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



Used since 1919

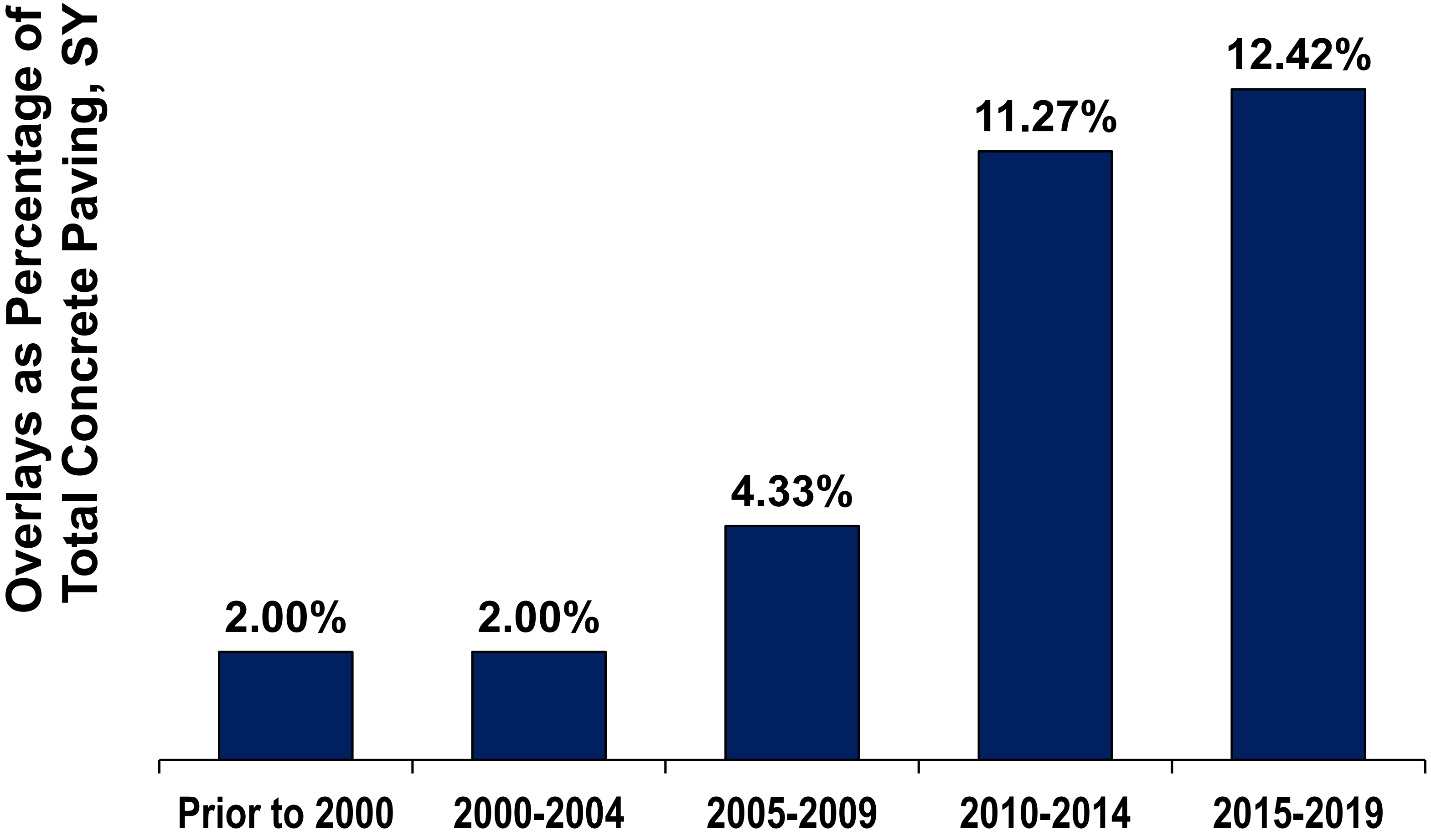
Unbonded Concrete Overlay of Asphalt Pavements

- 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

NATIONWIDE CONCRETE OVERLAY USAGE IS GROWING

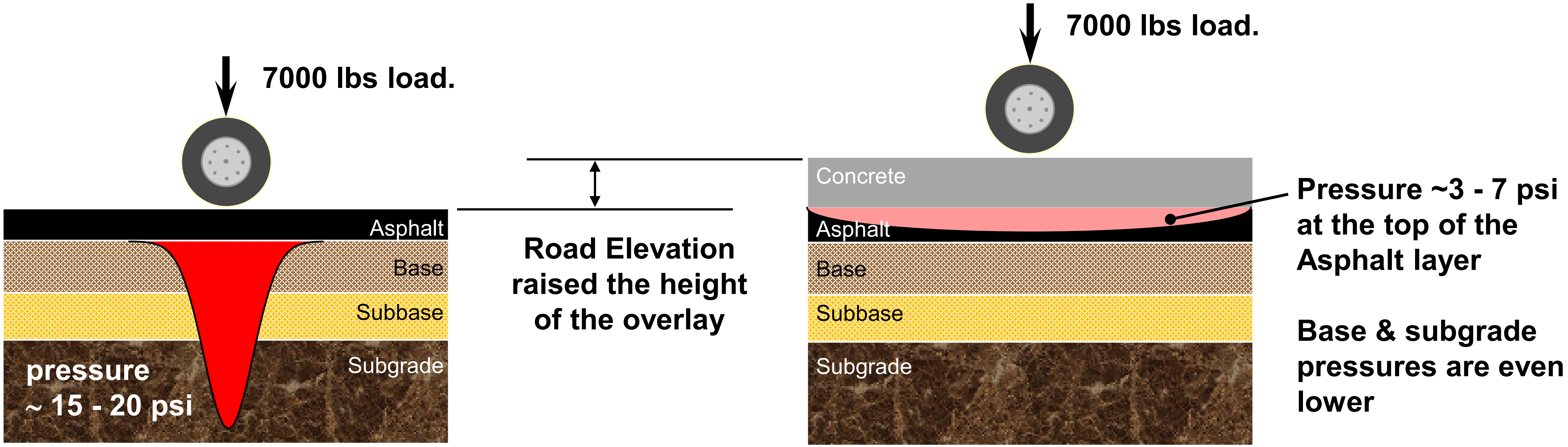


BCOA Examples

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

CEMEX

HOW CONCRETE OVERLAYS IMPROVE ASPHALT PAVEMENT'S RESILIENCE TO FLOODING



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

Bonded Concrete Overlay of Asphalt (BCOA) Design and Construction Recommendations based on Caltrans PPRC 4.58B Project

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California Department of Transportation

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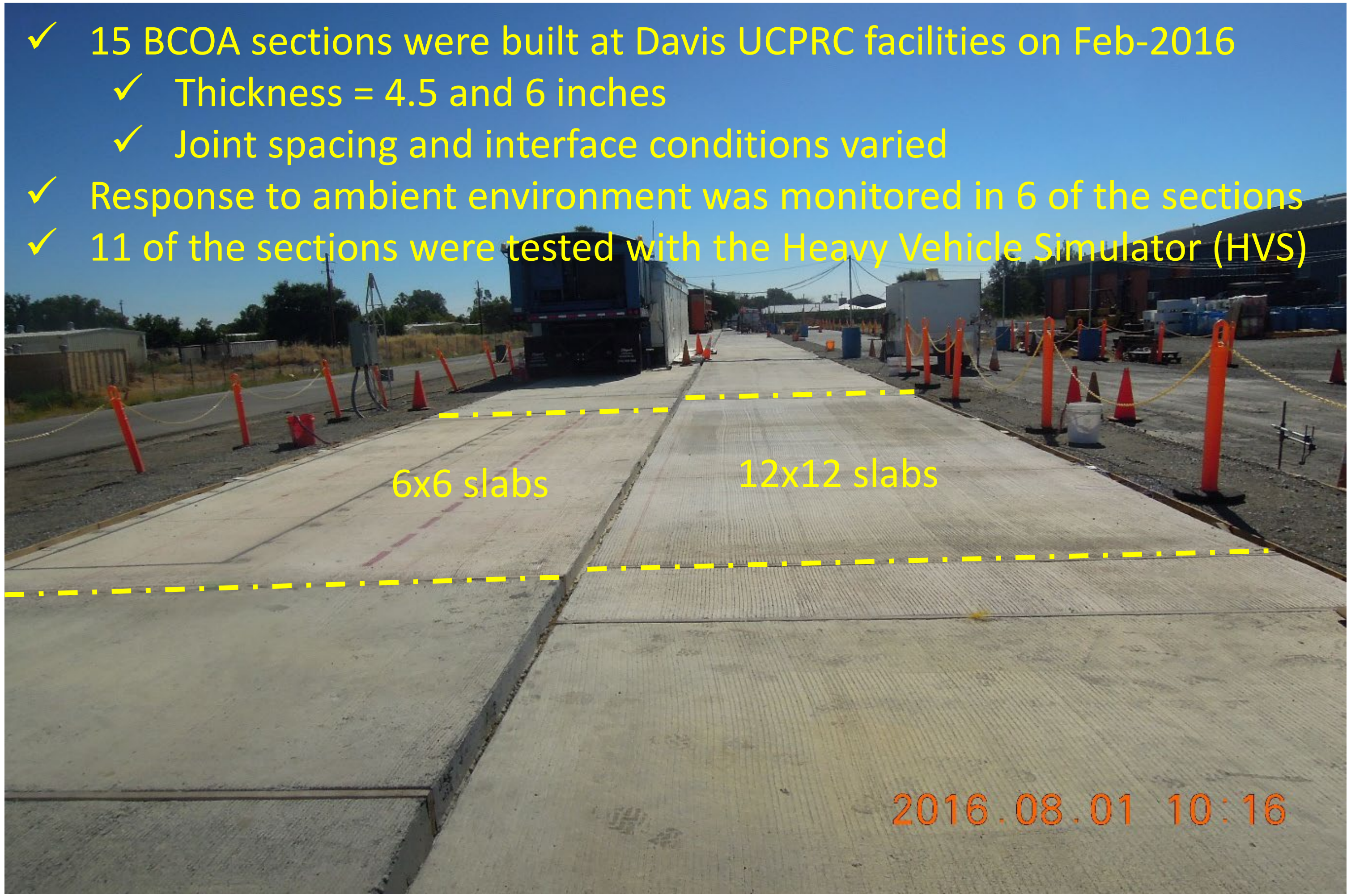
4.58B Project experimental data sources:

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

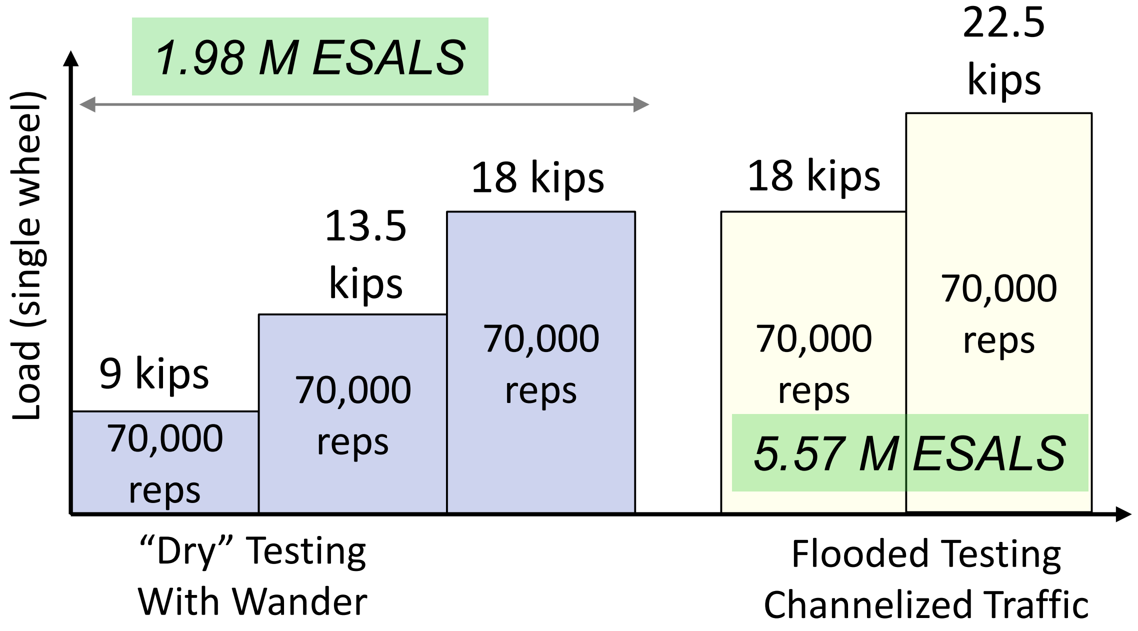


Summary of HVS Testing at UCPRC

11 full-scale BCOA sections tested with the HVS

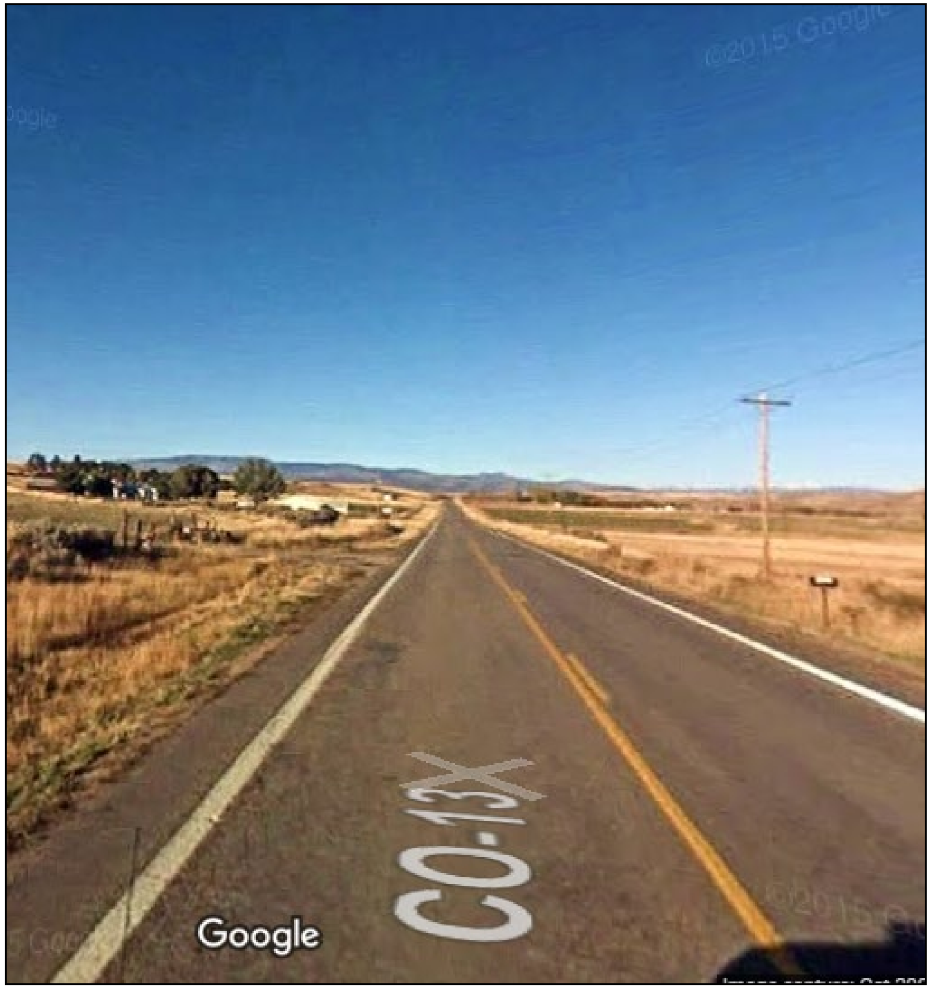
After testing 10 out of the 11 sections*...

- ✓ 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



SH 13 Existing Condition before overlay

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

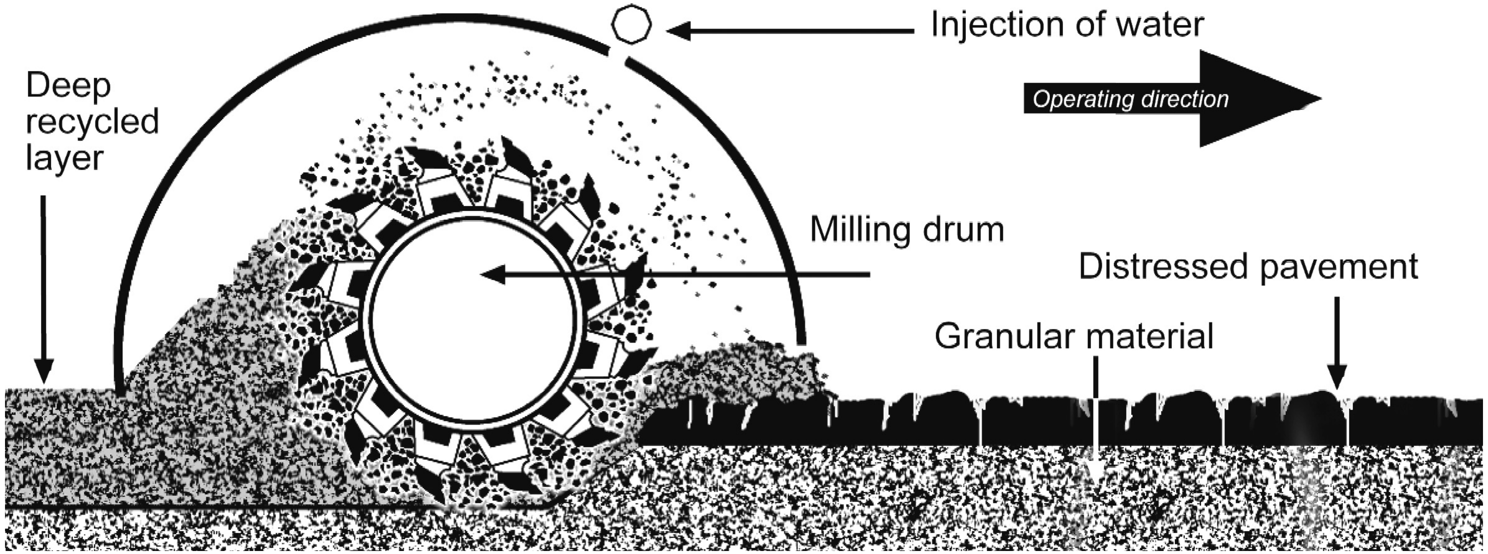
Concrete overlay was $47k lower in Initial cost & $708k Lower in Life Cycle Costs

* 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

CEMEX

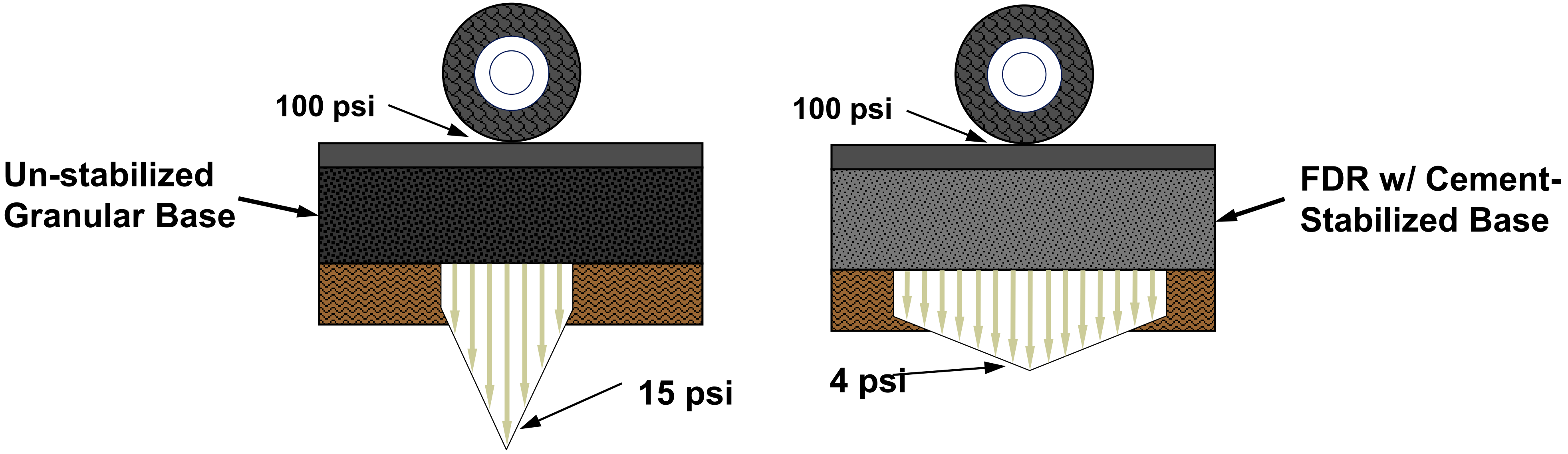
FULL-DEPTH RECLAMATION (FDR) WITH CEMENT RECYCLES AN EXISTING DETERIORATED ASPHALT PAVEMENT INTO A NEW STABILIZED BASE

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



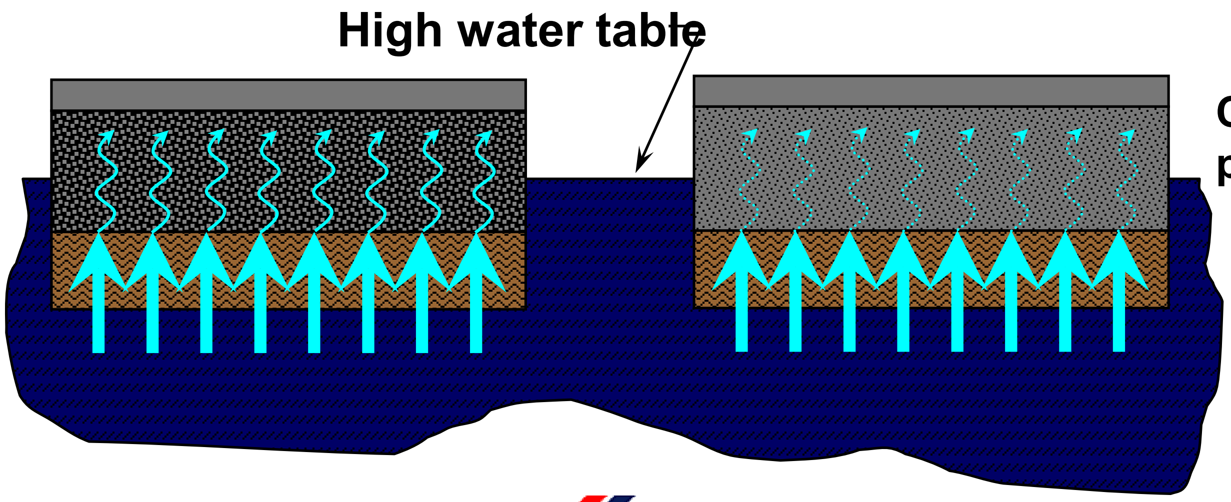
- **Utilizes In-Place Materials (reduces cost)**
- **Saves Energy by Reducing Trucking Requirements**
- **Increased Rigidity Spreads Loads**
- **Minimizes Rutting**
- **Reduced Moisture Susceptibility**

FDR W/ CEMENT INCREASES RIGIDITY TO SPREADS LOADS AND REDUCES PERMEABILITY TO REDUCE MOISTURE SUSCEPTIBILITY



Moisture infiltrates base

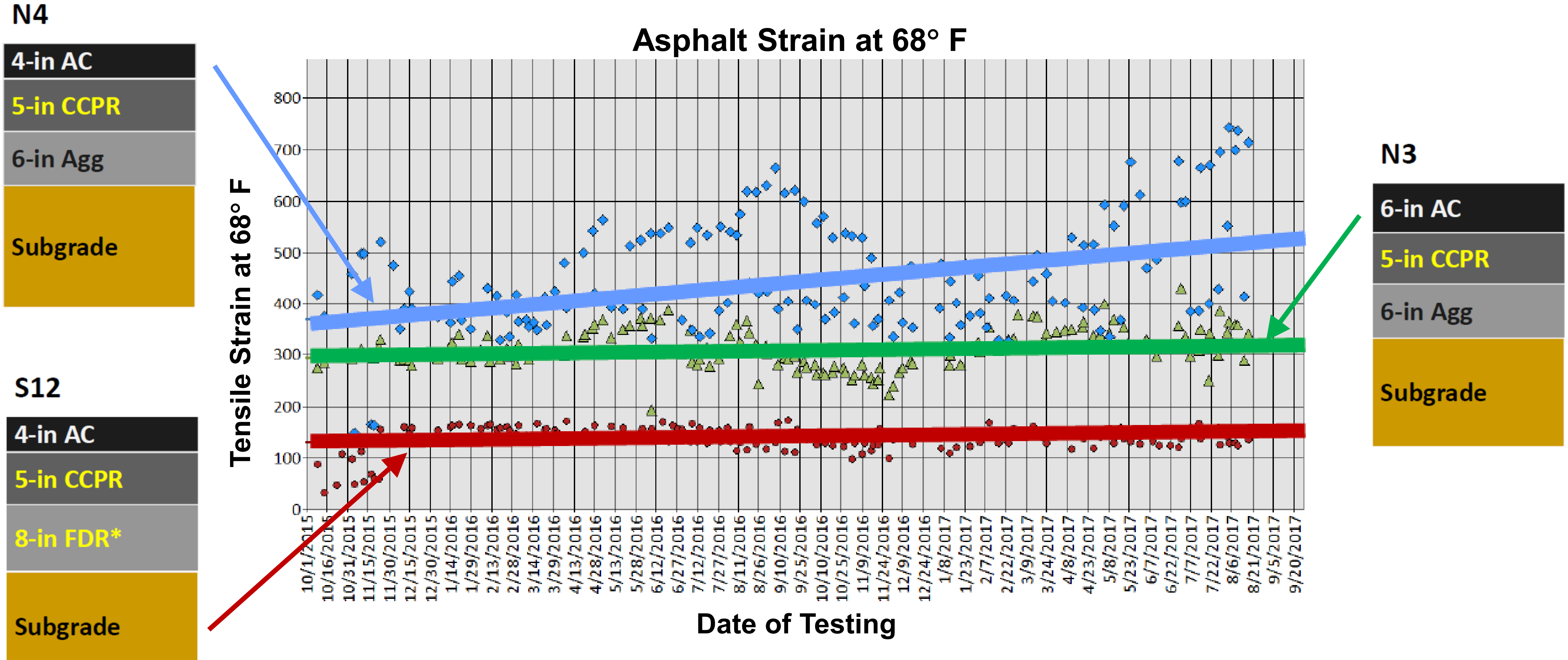
- Through high water table
- Capillary action
- Causing softening, lower strength, and reduced modulus



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



* 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,
Brian K. Diefenderfer, Ph.D., P.E., Benjamin F. Bowers, Ph.D. (VTRC), Miguel Díaz Sánchez, David H. Timm, Ph.D., P.E., Auburn University
http://www.virginiadot.org/vtrc/main/online_reports/pdf/17-r9.pdf

AGENCIES SHOULD MODIFY “DESIGN STANDARDS” TO BE BASED ON WEAKENED SUBGRADE CONDITION

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

NSW GOVERNMENT

Roads and Maritime Supplement to Austroads Guide to Pavement Technology

Part 2: Pavement Structural Design

Document No: RMS 11.050 Version 3.0 | August 2018

Supersedes: RMS 11.050 Version 2.2

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

Median annual rainfall (mm)	Specimen compaction moisture content	Testing condition	
		Excellent to good drainage	Fair to poor drainage
< 600	OMC	Unsoaked	4-day soak
600 – 800	OMC	4-day soak	10-day soak
> 800	OMC	10-day soak	10-day soak

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

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

apps.trb.org/nchrpballoting/DocThread.asp?CandidateId=2321&clsbtn=on

Problem Statement
FHWA
NCHRP
Submitter Response

Home

Close this page

American Association of State Highway and Transportation Officials
Special Committee on Research and Innovation

1. **Problem Number:** 2021-C-16

2. **Problem Title**

Impact of Flooding and Inundation on the Performance of Pavements

3. **Background**

The performance of pavements after inundation by flooding will gain greater significance in the foreseeable future. For many years, transportation agencies have dealt with the aftermath of flooding from major storm events, but the threat of sea level rise from global climate change now looms more ominously. During the 20th century, the sea level rose 15-20 centimeters (roughly 1.5 to 2.0 mm/year), with the rate actually accelerating towards the end of the century.

Climatological projections predict an even faster sea level rise in the 21st century. For example, the Southeast Florida Regional Climate Change Compact is estimating the SE Florida region will experience an increase between 9 and 24 inches in the next 50 years. To help mitigate some of the impacts, the region has already implemented $400 million worth of mitigation/adaption projects of to construct 2 pump stations to in part to keep the roads from flooding.

FHWA Technical Brief on Climate Change and Pavement Sustainability (FHWA-HIF-15-015) provides an introduction to how pavements may be fortified against climate change impacts, due to extreme conditions such as longer heat waves and severe flooding, and explains how these changes will accelerate the deterioration of highway pavements. However, it recognizes that the state of the practice is largely limited to general observations and is lacking with regards to specific adaptation strategies.