Towards Sustainable and Resilient Pavement Systems

Thomas Van Dam, Ph.D., P.E.
NCE

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Sustainable Pavements

• Not an oxymoron
  – Must consider life cycle economic, environmental, and societal factors in our decision making process
  – Must adopt a systems approach

• FHWA has been facilitating the adoption of sustainable pavement technologies
  – Reference Document, Tech Briefs, and web site
  – Conducting outreach
Tech Brief: Climate Change Adaptation for Pavements

- Authored by Steve Muench
  - Co-author Thomas Van Dam

- Most previous work focuses on pavement technologies that are designed to mitigate climate change (i.e., reduce GHGs)

- Tech Brief (TB) focuses on the adaptation of pavement systems to climate change
  - Application of existing literature on climate change and general adaptation strategies to pavement systems
  - Initial ideas on how pavement adaptation might progress
Tech Brief Does Not Address

- Relocation of vulnerable routes due to storm surge or sea level rise
  - Important strategy but not pavement specific
- Identification and treatment of vulnerable structures (e.g., bridges)
- Fortification of pavement systems against extreme weather events where relocation or complete reconstruction is more cost effective
TB Climate Change Background

• Preaching to the choir at this conference
  – Not generally the case amongst pavement technologist

• TB provides the argument that climate change is real
  – The science is clear

• Three broad categories of change are identified
  – Temperature, precipitation, and sea level rise
Temperature Impacts
2010 to 2050

Temperature Impacts 2010 to 2050

• General increase in temperature
  – Around 4 °F
• Higher extreme temperatures
  – Increase in frequency and duration
• Fewer freezing days
  – Impact on freeze-thaw cycles unclear
Precipitation Impacts 2010 to 2050

- Changes in average annual precipitation
  - Varies with region
- Wetter winters and drier summers
  - Results vary by model
- Increased precipitation intensity
- Hurricanes
  - Fewer but more powerful
Rise in Sea-Level Impacts

- Estimates vary, but range from 0.8 to 6.5 ft by 2100
  - Will vary by region
- Will result in more frequent and severe coastal flooding
Adaptation Strategies – Higher Average Temperatures

- Asphalt pavements will have increased risk of rutting and shoving
  - Make asphalt mixtures more resistant to rutting
  - Must consider increased age embrittlement
- Concrete pavements may have increased tendency for curling and warping
  - Must better consider temperature and moisture effects
  - Alternative design features
Adaptation Strategies – Higher Extreme Maximum Temperatures

• In general, may impact construction during peak temperatures

• Asphalt pavements will have increased risk of rutting and shoving
  – Historical temperature data may be invalid

• Concrete pavements may see increased risk of suffering “blow ups”
Adaptation Strategies – Extreme Rainfall Events

• Must establish and maintain excellent skid resistance
  – Acceptable texture and surface drainage

• Enhance visibility and pavement marking demarcation

• Reduced capacity of unbound layers and soil when pavements are submerged
  – Develop better understanding of impact and recovery time
Adaptation Strategies – Higher Average Precipitation

- Reduced capacity of unbound layers and soil
  - Reduce moisture susceptibility of unbound layers
  - Reduce moisture susceptibility of unbound layers
- Impacts construction
Adaptation Strategies – Wetter Winters and Drier Summers

- Increased potential for soil volume change
- Asphalt pavements must be less susceptible to changing soil properties
- Increased chance of concrete reaching critical saturation during freezing
  - Must have better freeze-thaw resistance
Adaptation Strategies – Low Summer Humidity

• Increased potential for aging of asphalt mixtures
  – More frequent use of preservation techniques

• For concrete pavements,
  – Increased risk of slab warping must be addressed through mixture design
  – More difficult construction conditions required prevention of plastic shrinkage cracking
Monitoring Key Performance Indicators

- When should current practice be modified?
- Strategy is to closely monitor performance indicators
  - The canary in the coal mine
  - Different pavement distresses are related to different distress mechanisms
  - Carefully monitor distress development
  - Link changes in distress development to causation
Use Mechanistic-Empirical Pavement Design

• M-E design allows for incorporation of climate-change in design
  – Impact on materials and structural performance
• Must consider changes to the historical climatic database reflecting the new reality
• Must consider changing the distress prediction coefficients
  – Requires significant modeling effort
More Robust Paving Materials

• For asphalt mixtures, must decrease temperature and moisture susceptibility

• For concrete, must make it more volumetrically stable
  – Increased resistance to damage from freeze-thaw cycling may also be required

• This will require changing specifications
  – Not always easy to do
Resilience to Extreme Weather Events

• Pavements are essential to support relief efforts
  – Support aid shipments in and getting vulnerable populations out

• Pavements that have been submerged lose structural capacity
  – Recovery rate is not clearly understood and research is underway to better quantify this
  – Use of less moisture susceptible materials may be justified in areas prone to flooding
Concluding Remarks

- Climate change is slow on the scale of current pavement life cycles (20-40 years)
  - Immediate adaptation response is thus not warranted, but will be
- Predictive pavement performance models should be adapted to incorporate current predictive climate models
  - Critical for long-life pavement projects
Concluding Remarks

• Pavement performance indicators should be closely monitored
• Investigations should be conducted to investigate more robust paving materials
• Pavements that will be submerged must be made less sensitive to saturation
• Roadways expected to be affected by extreme weather events should be relocated, if possible