Reducing the Impact of Climate Change Through Improved Pavement Resiliency

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Goal of this presentation

• The goal of this presentation is to discuss a few concepts for the why, what, where, when, how of thinking about pavements and climate change, based on current knowledge of the presenter
• Focus on California
• Stimulate thinking, discussion and collaboration
Climate Resiliency and Pavement

What are the issues?

• How does climate change directly affect pavement?
  • Temperatures
  • Rainfall
  • Groundwater
  • Sea level rise
  • Responding to extreme events: rainfall events, fires

• How do measures to reduce climate change affect pavement?
  • Changes in vehicles
  • Changes in materials
  • Changes in design decision-making criteria

• Stationarity
  • Assumption in design that distributions of past conditions will continue
  • Climate change takes away the assumption of stationarity

Goals of Climate Resilience

• Balance risk of not functioning, investment, and cost to customers

• Long-term: maintain functionality over entire design life
  • What is the life of roads? Seldom abandoned or torn out
  • What is the life of reconstruction and rehabilitation treatments?’
  • Designing in flexibility and adaptability

• Short-term crises: remain functional in extreme climate events
  • During the event
  • As the event subsides

• How well can we predict either of these?
Climate change is about risks:
Basic steps in risk management

- Identification
- Quantification
  - Outcome
  - Probability of outcome
- Response development
  - What is the plan
  - Performance measures
- Response control
  - Are we doing what we said we were going to do?
  - Should the plan change?
- Stakeholder engagement throughout
- Is this process underway for California local government pavement?

Risks for pavement: functionality over the long-term with climate change

- Temperatures
  - Asphalt high temperatures (PG maps)
  - Concrete temperature gradients
  - Concrete drying shrinkage gradients
- Rainfall
  - Culvert designs
  - Embankment heights
  - Pavement heights and drainage
- Groundwater
  - Generally falling in California, except where sea level rise
- Repeated flooding from sea level rise
  - Hardening approaches?
  - Plans for abandonment?

[Image: Caltrans/FHWA North Coast Plan](https://dot.ca.gov/media/dot-media/programs/transportation-planning/documents/ccpsa11y.pdf)
Risks for pavement: functionality over the long-term responding to climate change reduction measures

• Changes in vehicles
  • Heavier axles for electric vehicles
  • Increasing tire pressures
  • Not related to climate change: increasing numbers of heavier vehicles on city streets

• Changes in materials
  • Changes in oil refining industry
  • Changes in cement
  • Other materials?

• Changes in design decision-making criteria
  • Consideration of environmental impact + cost

Truck traffic axle weights increasing?

• State-wide average axle loads (115 WIM stations) virtually unchanged in 10 years
• Gross vehicle weights slightly reduced
• Battery electric trucks will increase some axle loads over next decades
Freight growth: more trucks

- 62% increase in truck counts vs 14% growth in population
- Short-haul: 69% increase
- Long-haul: 59% increase

UCPRC/Caltrans WIM data

Risks for pavement: functionality during and after extreme events

- Functionality during extreme events:
  - Mostly light vehicles going out of affected areas
- Most damage occurs during the recovery:
  - Heavy vehicles hauling out debris, demolition
  - Heavy vehicles hauling in relief materials
  - Pavements in vulnerable condition:
    - High water contents in pavement materials
    - Eroded support
    - Fire damaged materials
Risk quantification

- Climate change information
  - Do pavement and roadway designers have access to updated climate projections
  - Climate projections are at the regional level, major disconnect to local design inputs:
    - Design storm rainfall probabilities
    - Local temperature distribution changes
    - Humidity changes?
  - Sea level and groundwater changes
- Vulnerability for extreme events
  - Identification of probabilities for different locations
  - Planning for access after events

Observed Change in Intensity of Very Heavy Precipitation Events in US 1958 to 2012
National Climate Assessment 2014

Response development

- There is often a mixing of messages about reducing climate change and responding to climate change
- Designers need specific information for the design context and location, and recommended alternatives for different risks
- Maintenance forces need specific response plans for a given location
- Planners and policy-makers need to be assessing potential for major changes
- Researchers need to be working in a cross-disciplinary manner to develop design information, new approaches, and realistic assessment of risks
- Climate change response has not occurred until new information and processes are a part of the standard way of doing business
Adaptation options

- Examples from Caltrans District 1 and local communities
- Based on criticality and cost

Table 1: Adaptation Option Categories Developed from Adaptation Tool

<table>
<thead>
<tr>
<th>Approach</th>
<th>Adaptation Option</th>
</tr>
</thead>
<tbody>
<tr>
<td>Defend</td>
<td>Provide major structural protection</td>
</tr>
<tr>
<td></td>
<td>Provide protection at existing elevations/locations</td>
</tr>
<tr>
<td>Accommodate</td>
<td>Elevate the infrastructure above the impact zone</td>
</tr>
<tr>
<td></td>
<td>Enhance drainage to minimize closure time and/or deterioration levels</td>
</tr>
<tr>
<td>Retreat</td>
<td>Abandon infrastructure</td>
</tr>
<tr>
<td></td>
<td>Relocate infrastructure (horizontally)</td>
</tr>
<tr>
<td></td>
<td>Temporarily restrict use of infrastructure</td>
</tr>
<tr>
<td>Changes in policies or practices</td>
<td>Increase the infrastructure’s maintenance and inspection interval and continue to monitor/evaluate</td>
</tr>
<tr>
<td></td>
<td>Modify land use and development policies to account for future impacts</td>
</tr>
</tbody>
</table>

Where are we at?

- FHWA
  - Guidance
  - Framework and pilots
  - Research projects
  - Resilience Guidebook being put together
  - Rob Kafalenos

- Caltrans
  - Developing guidance
  - Pilot project in District 1 with FHWA
Resources Agency: Transportation Sector Plan

- Lays out framework for identification, quantification, response development and response control
- [https://resources.ca.gov/CNRAL](https://resources.ca.gov/CNRAL)egacyFiles/docs/climate/safeguarding/Transportation%20Sector%20Plan.pdf

Institute for Local Government

- Regional collaborations
- [https://www.ca-ilg.org/post/regional-collaborations-adaptation](https://www.ca-ilg.org/post/regional-collaborations-adaptation)
Specifics for pavements

• Few well reviewed specifics exist for pavement and there is no research program focused on pavement climate resilience
• An example road map exists for permeable pavements
  • Similar issues with cross-silo responsibilities
  • Transportation, flood management, stormwater
• Includes road map for developing:
  • Management structures
  • Planning guidance
  • Cost and environmental impact information
  • Asset management guidance
  • Structural design guidance
  • Construction guidance
  • Maintenance guidance
  • Training and communication guidance

Conclusions and a Question

• Climate resilience for transportation infrastructure will likely grow in importance
• Efforts to date for pavement and transportation are primarily high level
• Initial specific guidance is becoming available, primarily through FHWA piloting with Caltrans
• Question:
  • Is it worthwhile to explore a state-wide local government collaboration?