

Roads of the Future: Environmentally- Friendly and Resilient Pavement

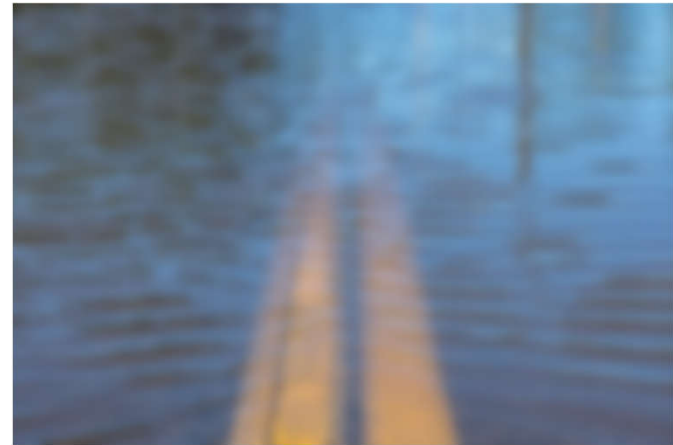
Professor Susan Tighe, Ph.D, P.Eng, FCAE, FCSCE
Deputy Provost, Associate Vice President Integrated Planning and Budgeting
Norman W. McLeod Chair in Sustainable Pavement Engineering

RILEM
High Performance Asphalt Materials Symposium
October 2, 2019



Presentation Overview

- Introduction
- Climate Change
- Sustainability
- Conclusions



CPATT Goals

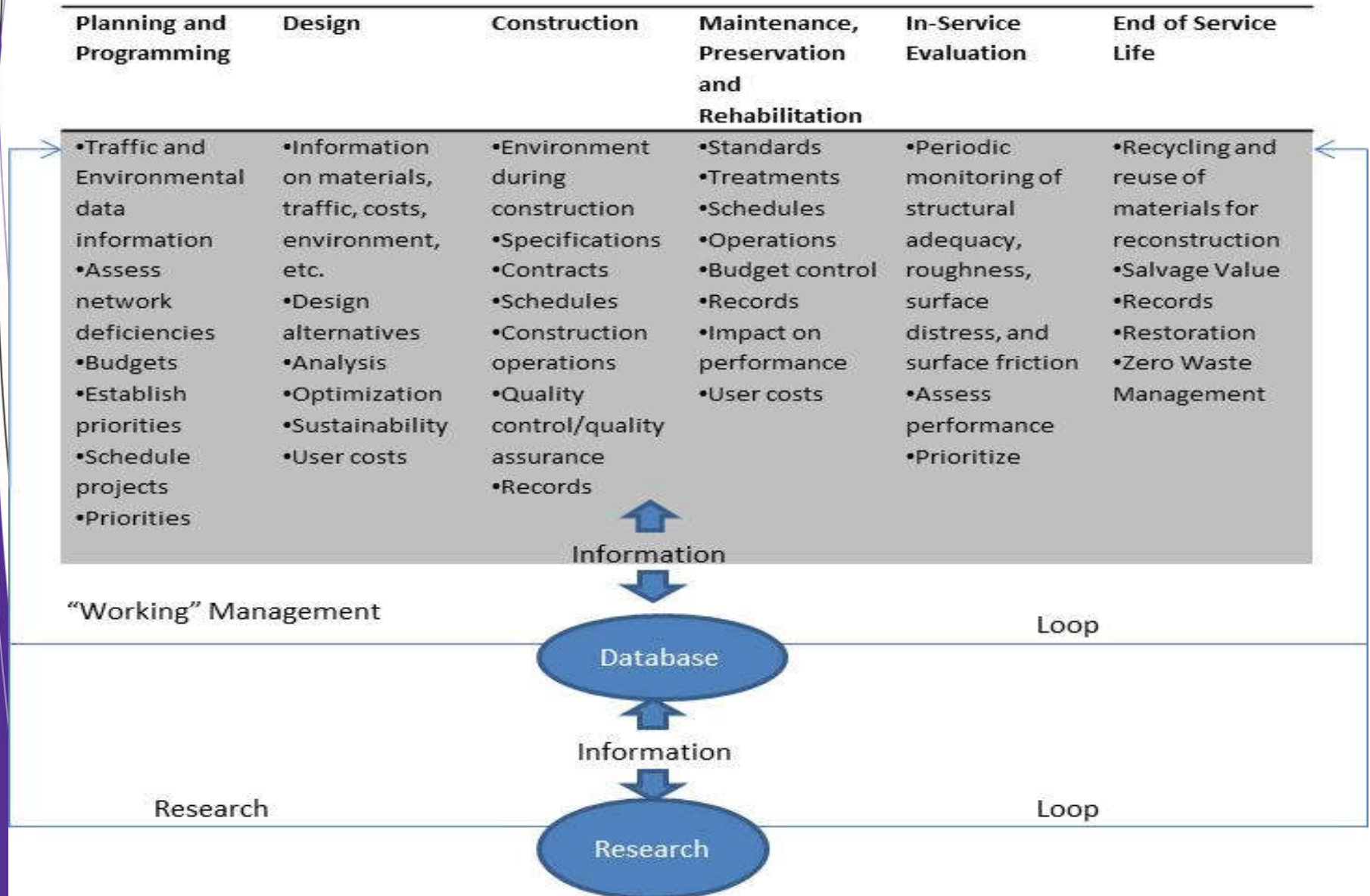
1. CPATT's initiative involves an integrated program of field and laboratory research.
2. Focus on emerging and innovative technologies.
3. State-of-the-art research infrastructure.
4. Train and educate next generation.
5. Sustained partnerships.
6. Provide national and international leadership.



Key Research Themes

- Advanced Pavement Materials
- Greening Roads for Sustainability
- Improving Recycling and Material Characterization
- Be Proactive on Climate Change
- Design to Mitigate Natural Disasters
- Innovative and New Designs
- Design and Build Safe Smart Long Life Pavements





Climate Change Impacts

THE **ROAD** **WELL-TRAVELED:**

Implications of Climate Change for
Pavement Infrastructure in Southern Canada



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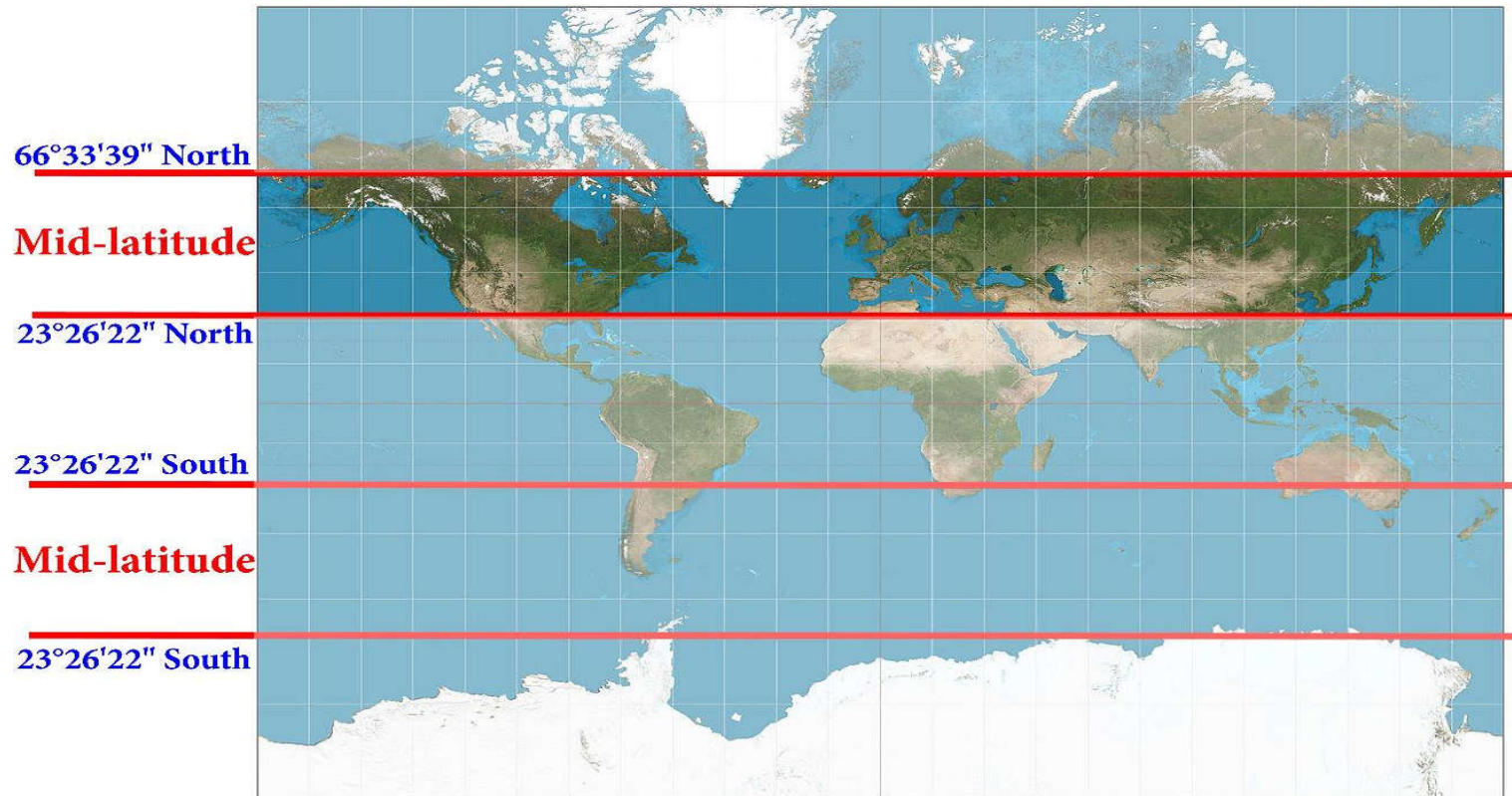


FINAL TECHNICAL REPORT

March 2007



Climate Change Impacts



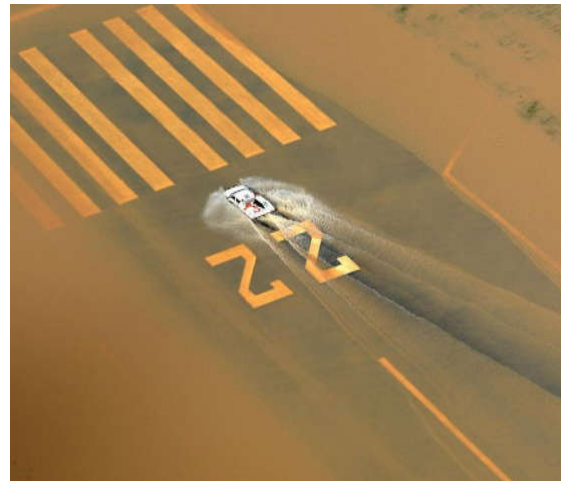
Very likely (90% certain), mid-latitude land masses will have more intense and frequent extreme precipitation events (IPCC,2014)⁷

Flooded Pavement



Credit: Hydro Ottawa

Riverside Drive area in
Ottawa, Canada, October
30, 2017



Credit: Mark Blinch

A vehicle drives down the
flooded runway at
Rockhampton Airport,
Australia, January 1, 2011



Credit: AP photo/David J. Phillip

Hurricane Harvey struck
Houston, August 27, 2017;
Heavy rains causing
widespread 1 in 500-year
flooding.

Role of Engineers and Scientists

- Many of these could possibly be avoided by better design, construction, safety systems, early warning and planning.
- Scientists and engineers try to prevent damage by warning people the natural disaster is coming.
- Try to monitor the event and try to prevent damage.
- Develop plans for emergencies



Building Climate Resistant Pavement

- Climate change induced flood hazards pose threat to critical infrastructure
- Pavement damage jeopardizes safety, mobility, comfort, functionality, and accessibility resulting in adverse social and economic implications.
- Reducing costs by understanding the risk and taking adaptation actions



Part (i) Risk Assessment (Project Level)

Vulnerability Analysis

Hazard Analysis
(Occurrence of Events,
Flood Extent under
climate change, hazard
exposure)

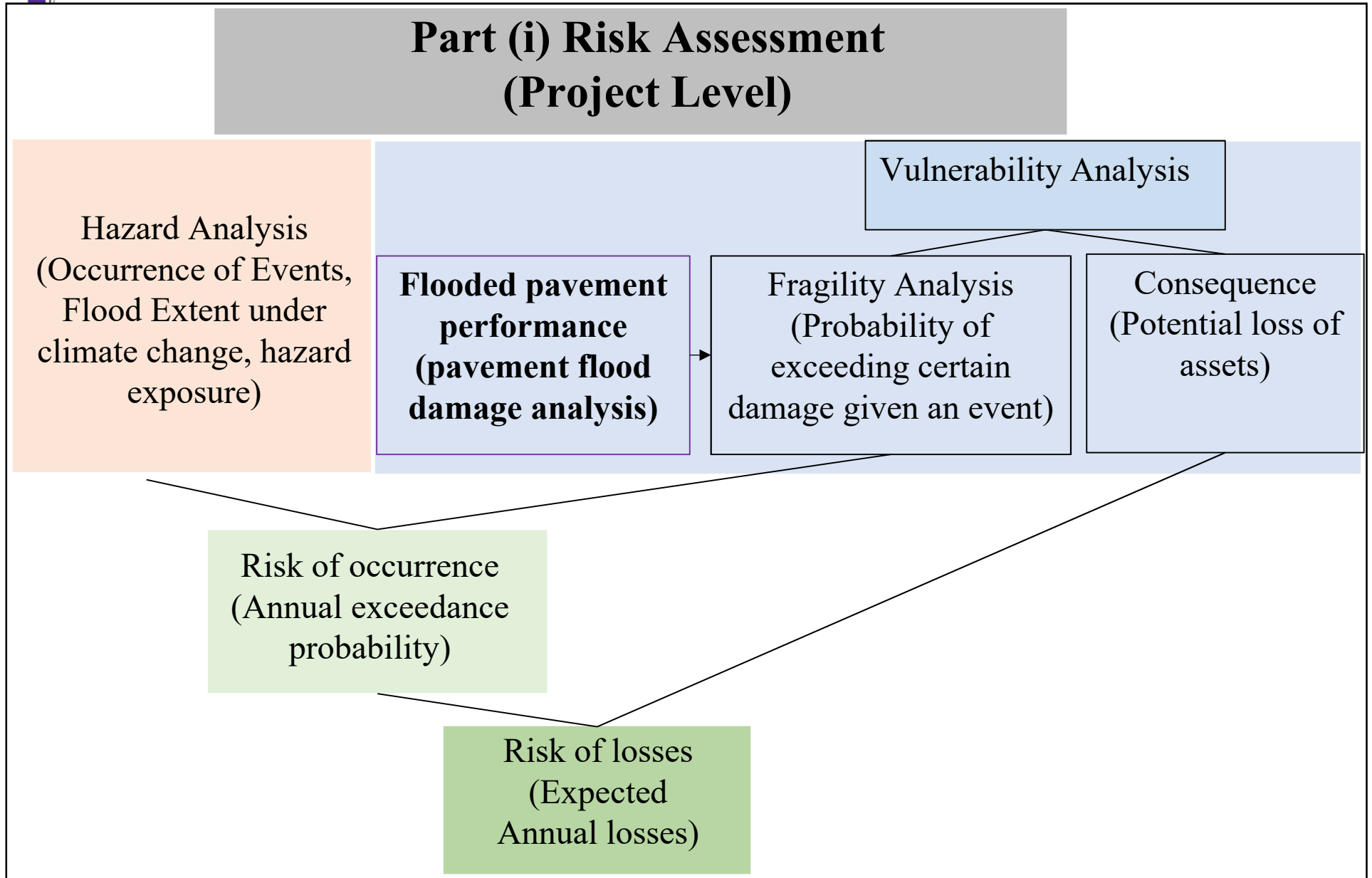
**Flooded pavement
performance
(pavement flood
damage analysis)**

Fragility Analysis
(Probability of
exceeding certain
damage given an event)

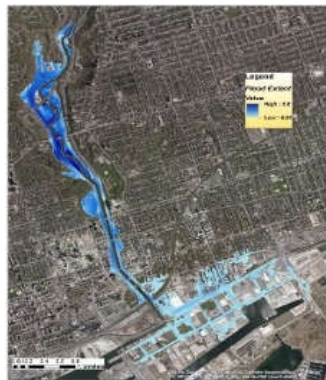
Consequence
(Potential loss of
assets)

Risk of occurrence
(Annual exceedance
probability)

Risk of losses
(Expected
Annual losses)



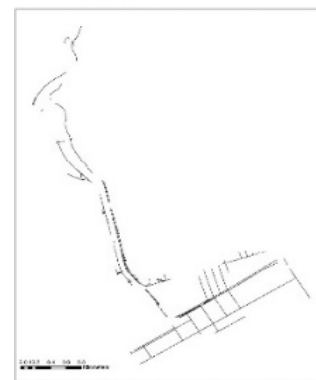
Part (ii) Risk Assessment (Network Level)



Step 1 Identify flood extent for a flood event



Step 2 Identify flood exposure network



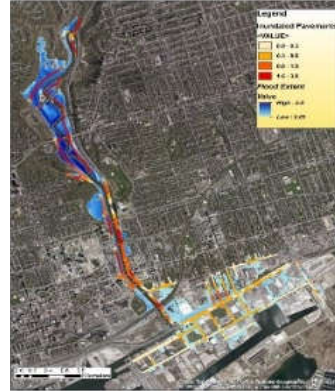
Step 3 Determine submerged road network



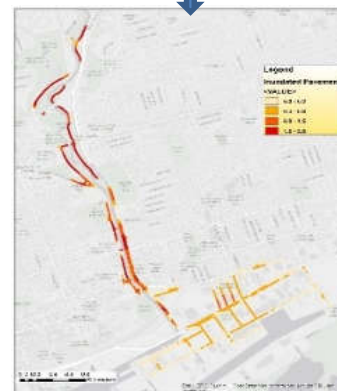
Step 4 Identify road functional classes



Step 8 Total up risk of all flood hazard events across the network



Step 7 Calculate risk for the entire road network for various damage states



Step 6 Determine inundation depth of flooded pavements



Step 5 Modeling fragility curves for different functional classes

Risk Map Products

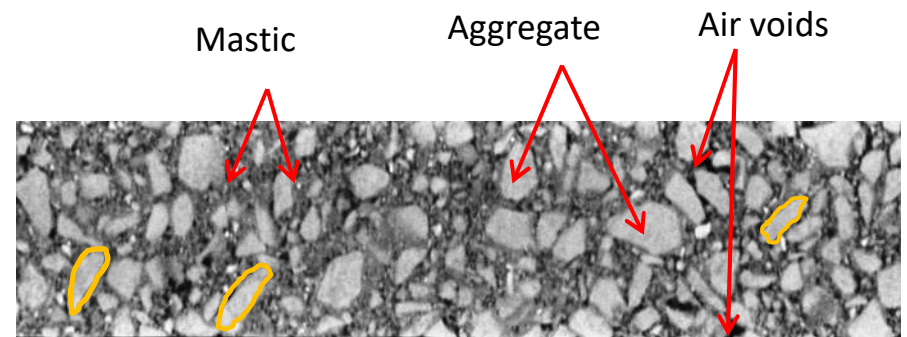
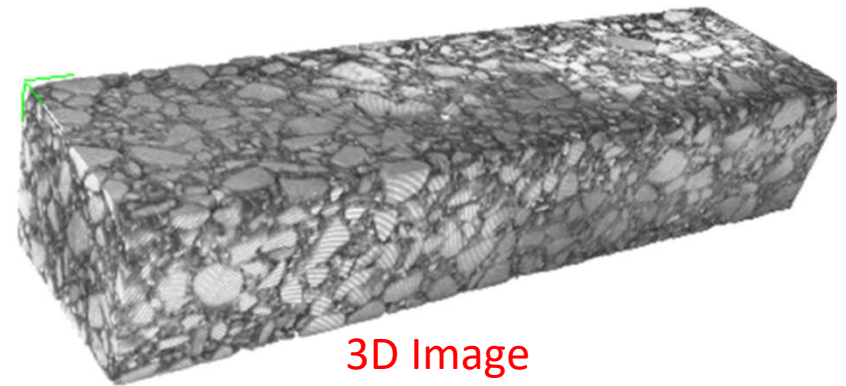
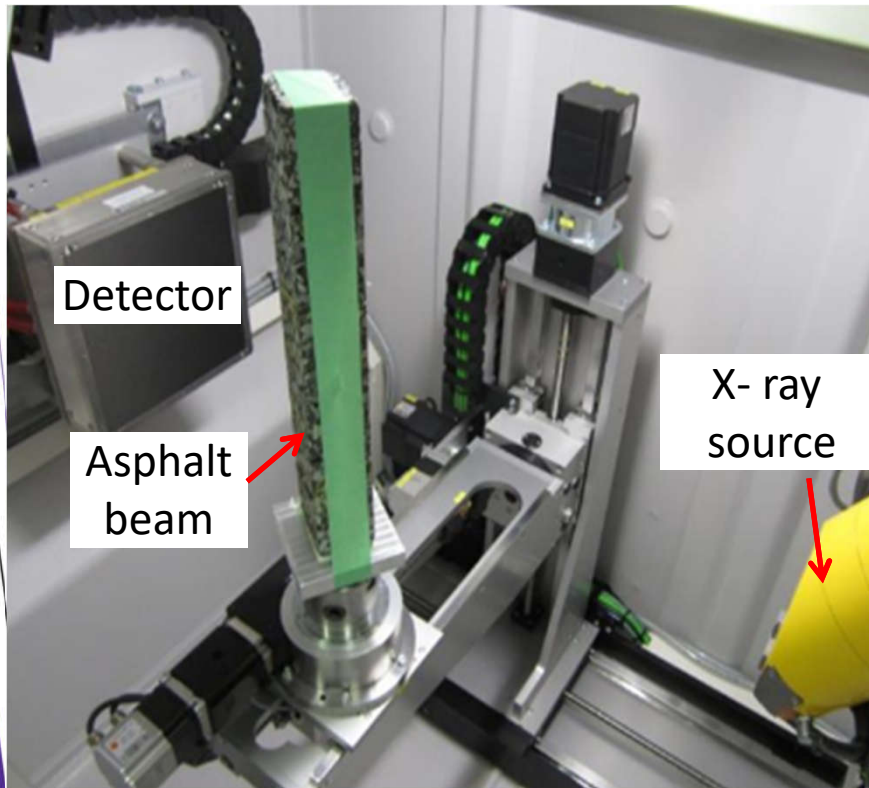


Integrating Laboratory and Field

- Demonstrate differences between materials
- Using innovative tools to measure field performance
- Calibrating design models using finite element, finite differences, mechanistic empirical methods
- Technical/economic/sustainable designs
- Moving laboratory to field

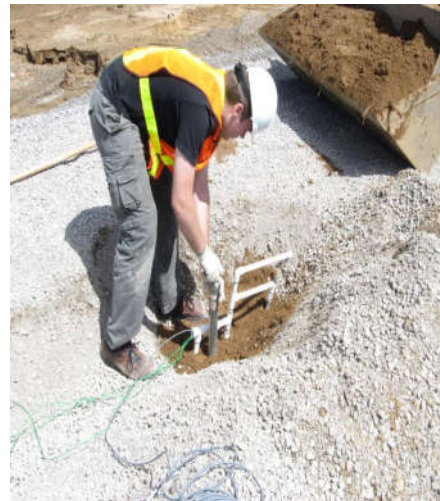
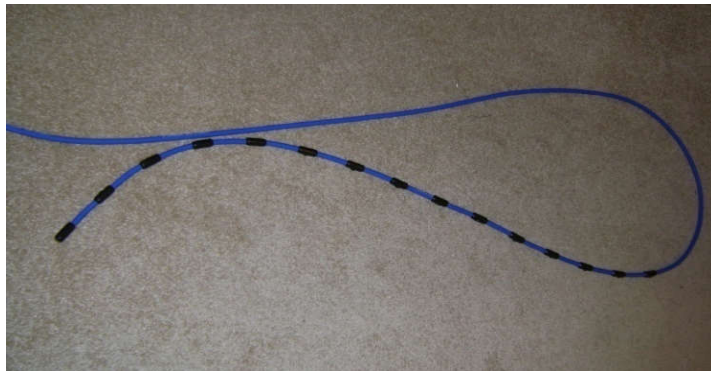
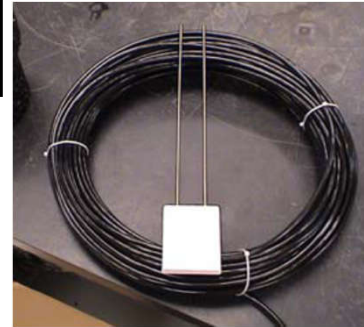
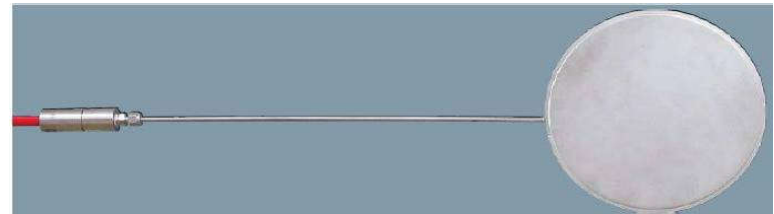
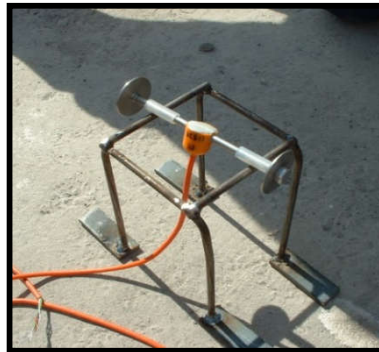


Integrating Laboratory and Field



Research Methodology

- Technical
- Economic
- Sustainable
- Costs/Benefits



Premium Aggregate

1" (25 mm) TYP

**Rubberized Open Friction
Course (rOFC)**

Premium Aggregate

Stone Mastic Asphalt (SMA)

Local Aggregate

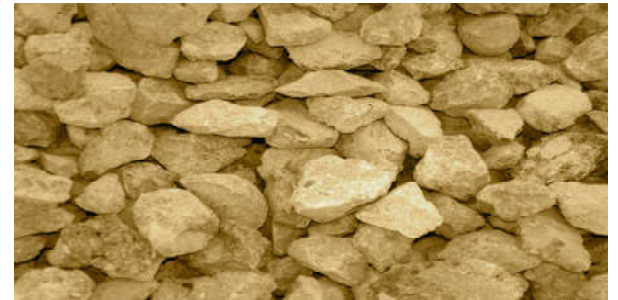
**Rubberized Open Graded
Course (rOGC)**

Local Aggregate

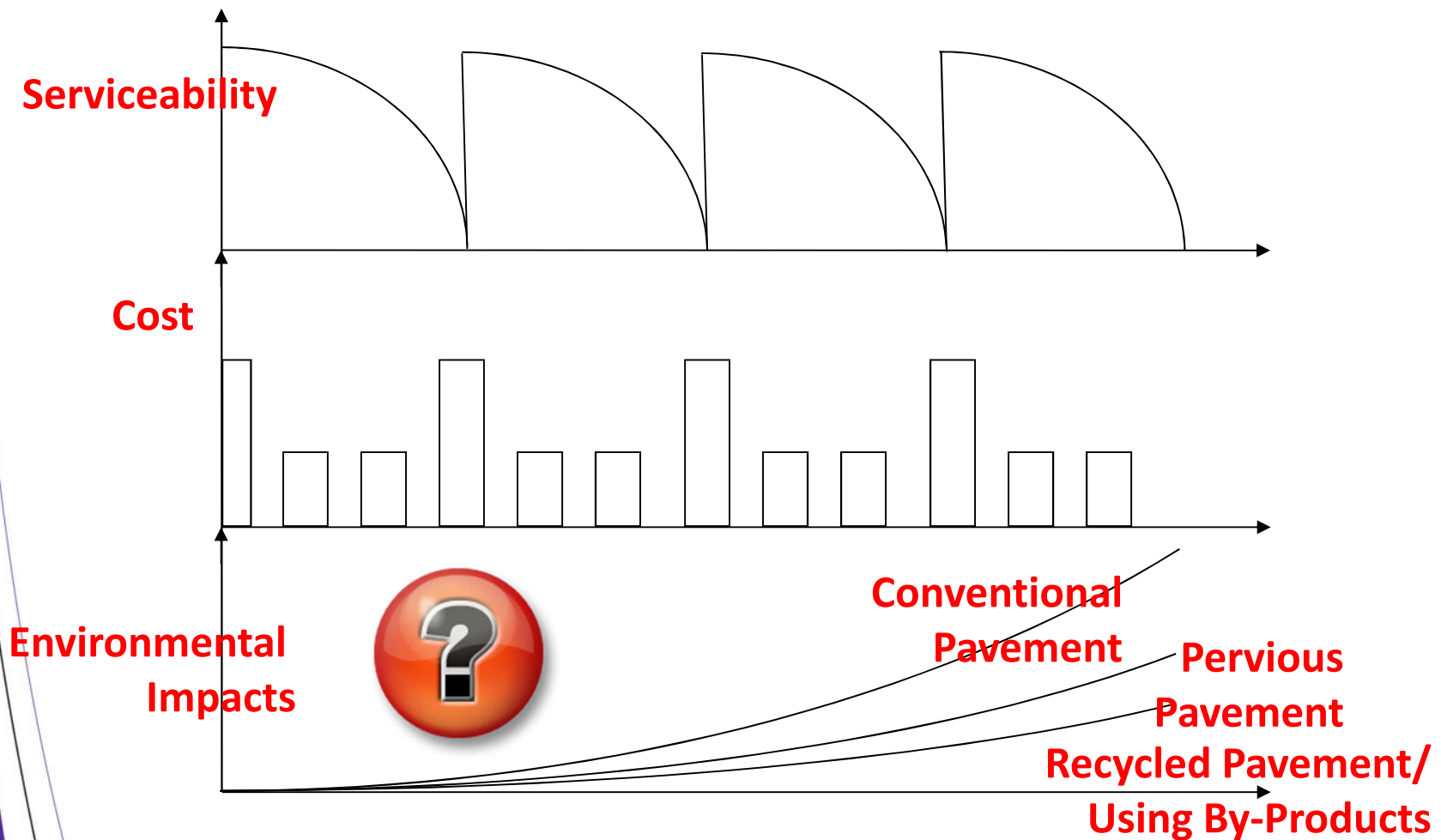
Control: Hot-Laid 3 (HL-3)

Recycling

- Consider sustainable preservation and rehabilitation options that are:
 - Safe
 - Efficient
 - Environmentally Friendly
 - Cost effective
- Optimize recycling
- Best Use of Materials



Quantify All Costs/Benefits



(Tighe, 2010)

Recycling

- Usage of Raw Materials
- Alternative Materials
- Usage of Management Systems
- Air Quality
- Water Quality
- Noise
- Energy Usage



Closing Remarks

- Good technology and People = Advances
- Climate Change must be examined for Long Life Infrastructure
- Staged process: lab testing, field testing
- Experimental Design Essential!!!
- Public-Private –Academic Partnerships Work
- Adoption of New Materials and Designs

Acknowledgements

- Undergraduate and Graduate Students
- Natural Sciences and Engineering Research Council of Canada (NSERC)
- Partners in Norman W. McLeod Chair
- CPATT Partners

THANK YOU TO OUR PARTNERS



Transport
Canada



CEMATRIX™
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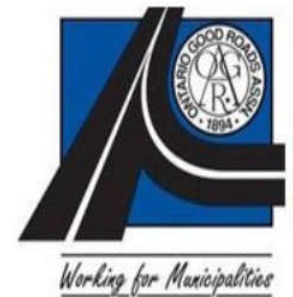
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