WATERLOO ENGINEERING
UNIVERSITY OF WATERLOO
200 University Avenue West, Waterloo, ON, Canada N2L 3G1
519-888-4567 | uwaterloo.ca

Pavements of the Future: Environmentally- Friendly and Resilient Pavement

Professor Susan Tighe, Ph.D, P.Eng
Norman W. McLeod Chair in Sustainable Pavement Engineering
Director Centre for Pavement and Transportation Technology

November 30, 2016

CPATT
CENTRE FOR PAVEMENT AND TRANSPORTATION TECHNOLOGY

Typical Canadian Winter

WATERLOO ENGINEERING
UNIVERSITY OF WATERLOO
200 University Avenue West, Waterloo, ON, Canada N2L 3G1
519-888-4567 | uwaterloo.ca

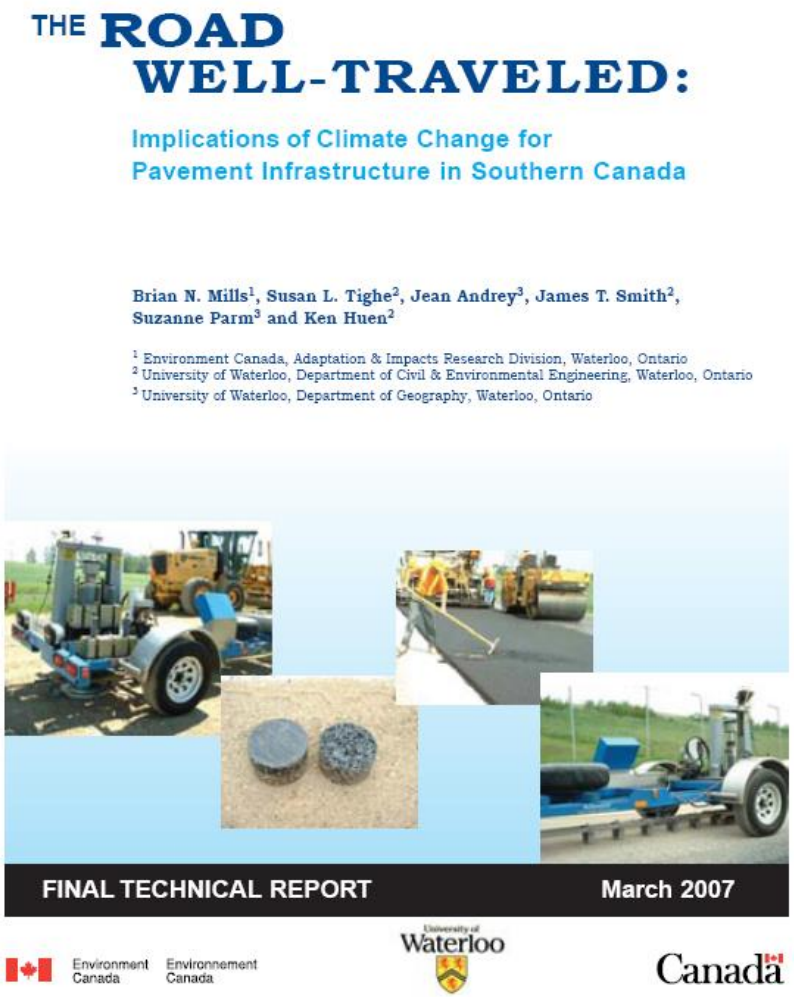
Presentation Overview

- Introduction
- Climate Change
- Natural Disasters
- Solar Pavement
- Sustainability
- Conclusions

- https://www.youtube.com/channel/UCLbomPwqCgvwr3hPm4oeyfw

WATERLOO ENGINEERING
UNIVERSITY OF WATERLOO
200 University Avenue West, Waterloo, ON, Canada N2L 3G1
519-888-4567 | uwaterloo.ca

Climate Change Impacts



GLOBAL Climate Change

WATERLOO ENGINEERING
UNIVERSITY OF WATERLOO
200 University Avenue West, Waterloo, ON, Canada N2L 3G1
519-888-4567 | uwaterloo.ca

What is a Natural Disaster?

WATERLOO ENGINEERING
UNIVERSITY OF WATERLOO
200 University Avenue West, Waterloo, ON, Canada N2L 3G1
519-888-4567 | uwaterloo.ca

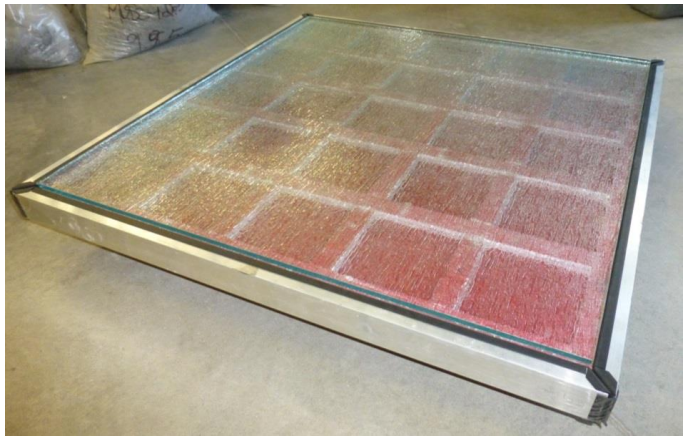
Role of Engineers and Scientists

- 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

WATERLOO ENGINEERING
UNIVERSITY OF WATERLOO
200 University Avenue West, Waterloo, ON, Canada N2L 3G1
519-888-4567 | uwaterloo.ca

Why Solar Roads? An Electrical Perspective

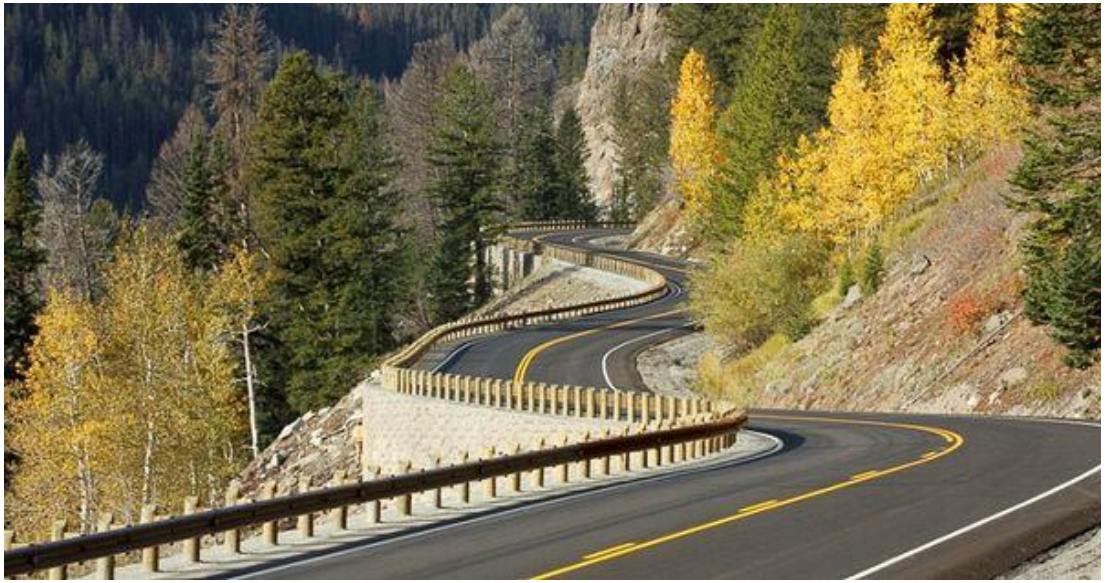
- Vast Resource
- Minimize Land Use
- Distributed Generation
- Peak-Shaving Electricity



WATERLOO ENGINEERING
UNIVERSITY OF WATERLOO
200 University Avenue West, Waterloo, ON, Canada N2L 3G1
519-888-4567 | uwaterloo.ca

Why Solar? A Pavement Perspective

- Offset Traditional Material Requirements
- Provide Additional Payback from Infrastructure
- Reduce CO2 Footprint of Pavements



WATERLOO ENGINEERING
UNIVERSITY OF WATERLOO
200 University Avenue West, Waterloo, ON, Canada N2L 3G1
519-888-4567 | uwaterloo.ca

Prototype Design and Construction

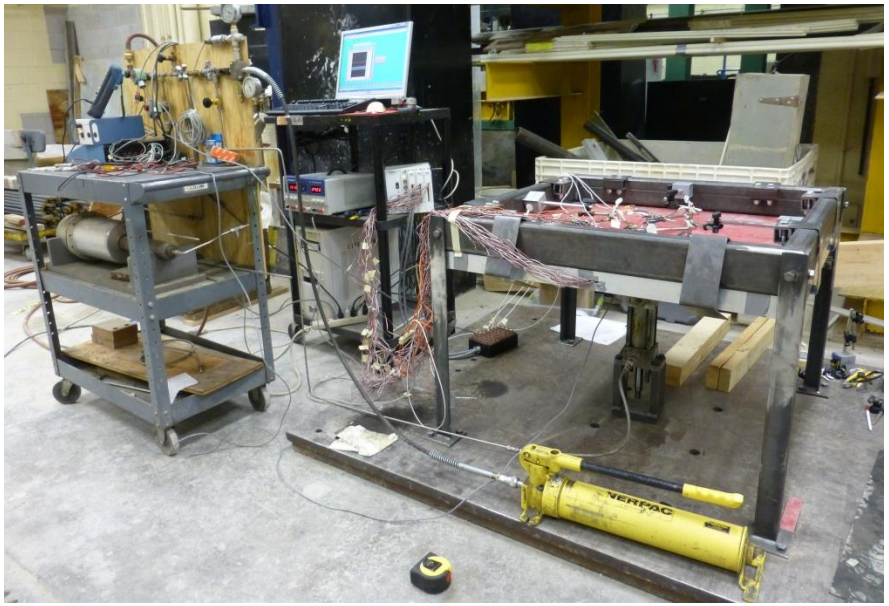
- Objective
  - Design and build a prototype solar road panel research platform
- Process
  - Review of Design Concepts
  - Design Requirement Drafting
  - Prototype Design
  - Prototype Construction

(Northmore, 2013)

WATERLOO ENGINEERING
UNIVERSITY OF WATERLOO
200 University Avenue West, Waterloo, ON, Canada N2L 3G1
519-888-4567 | uwaterloo.ca

Structural Analysis

- Objective
  - Determine and model the structural performance of the prototype solar road panel
- Process
  - Structural Testing
  - Panel Model
  - Development
  - Pavement Load
  - Case Simulation



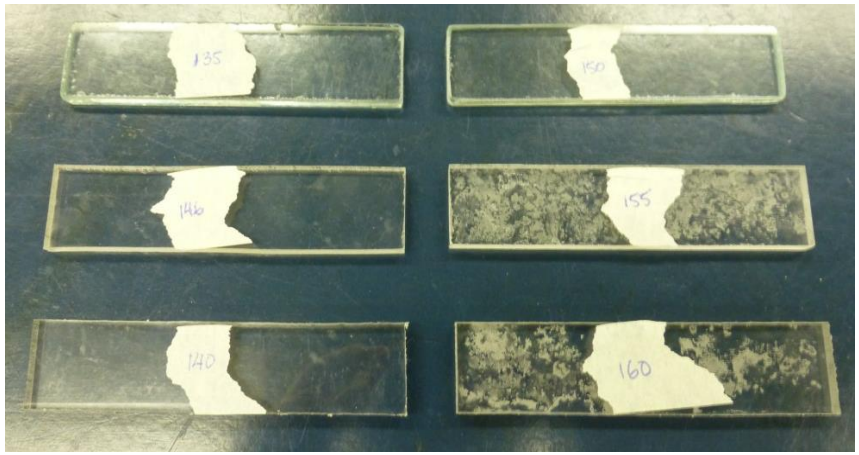
(Northmore, 2013)

WATERLOO ENGINEERING
UNIVERSITY OF WATERLOO
200 University Avenue West, Waterloo, ON, Canada N2L 3G1
519-888-4567 | uwaterloo.ca

Environmental Analysis

- Objective
  - Determine the effects of winter maintenance practices on transparent layer material options (Glass, Acrylic, Polycarbonate

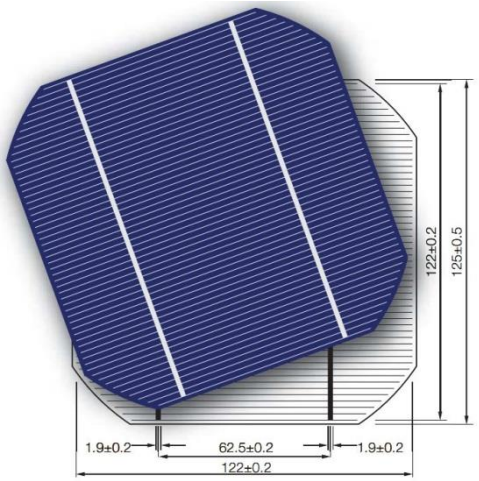
- Process
  - Scaling Resistance of Acrylic, Polycarbonate, and Glass (ASTM C672)
  - Three Point Bending
  - Testing (ASTM D790)
  - Friction Testing (ASTM E303)
  - Optical Testing (ASTM E1175)

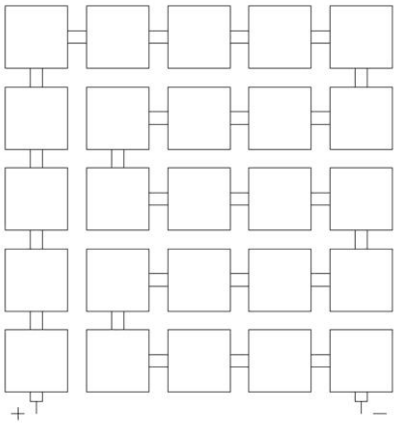


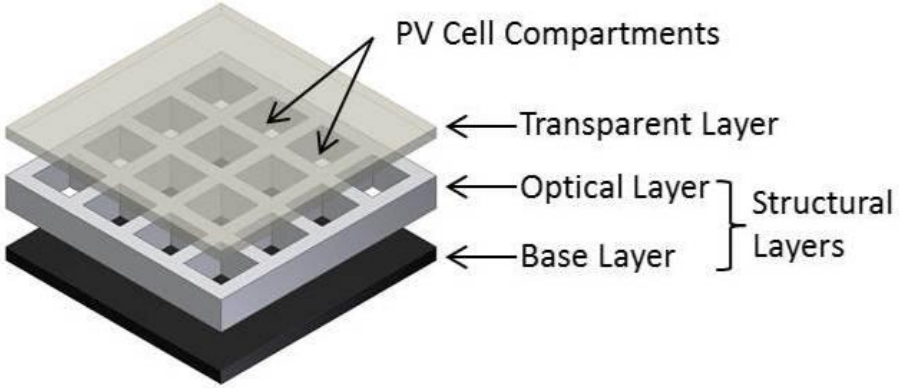
(Northmore, 2013)

WATERLOO ENGINEERING
UNIVERSITY OF WATERLOO
200 University Avenue West, Waterloo, ON, Canada N2L 3G1
519-888-4567 | uwaterloo.ca

Prototype Design



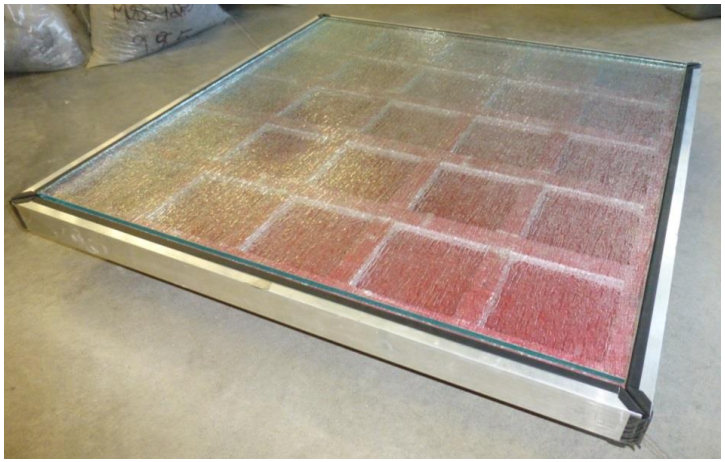


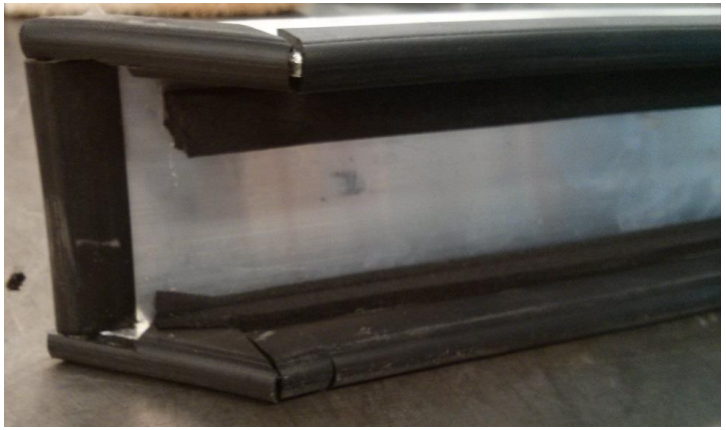


(Northmore, 2013)

WATERLOO ENGINEERING
UNIVERSITY OF WATERLOO
200 University Avenue West, Waterloo, ON, Canada N2L 3G1
519-888-4567 | uwaterloo.ca

Construction: Prototype

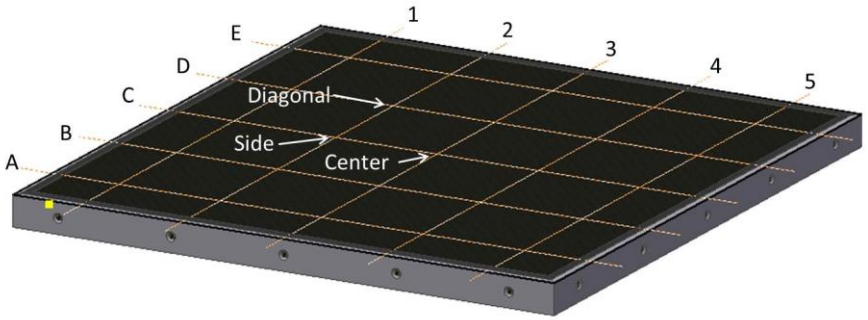


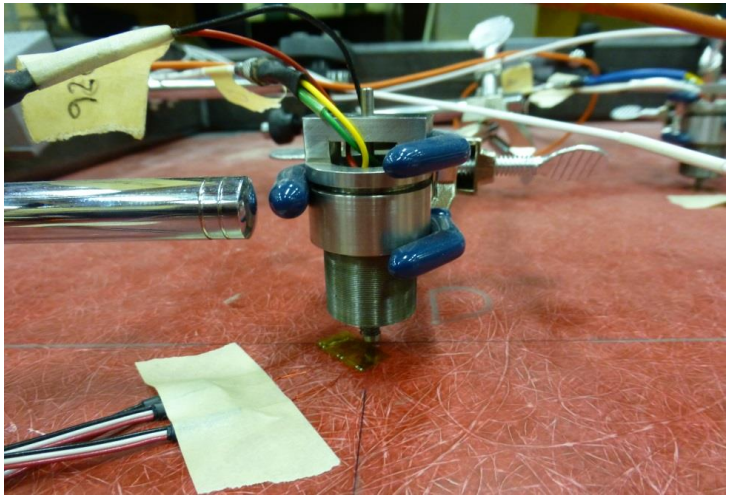


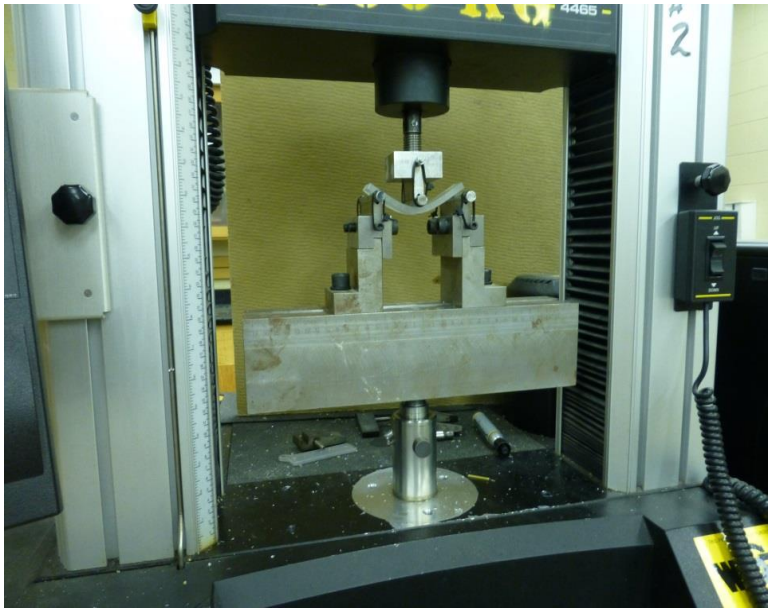
(Northmore, 2013)

WATERLOO ENGINEERING
UNIVERSITY OF WATERLOO
200 University Avenue West, Waterloo, ON, Canada N2L 3G1
519-888-4567 | uwaterloo.ca

Structural Analysis

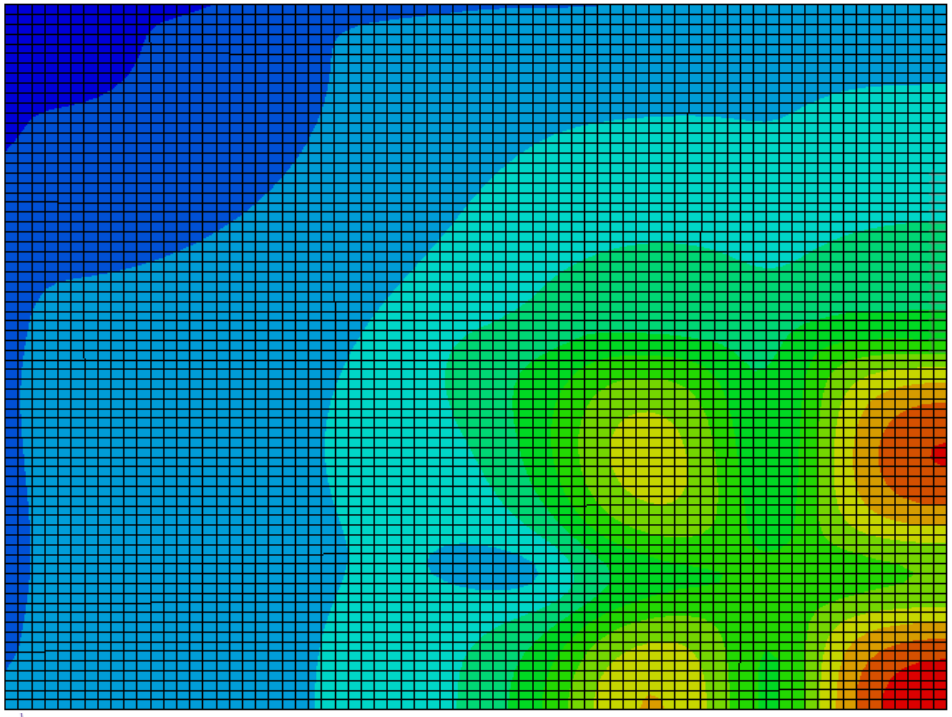


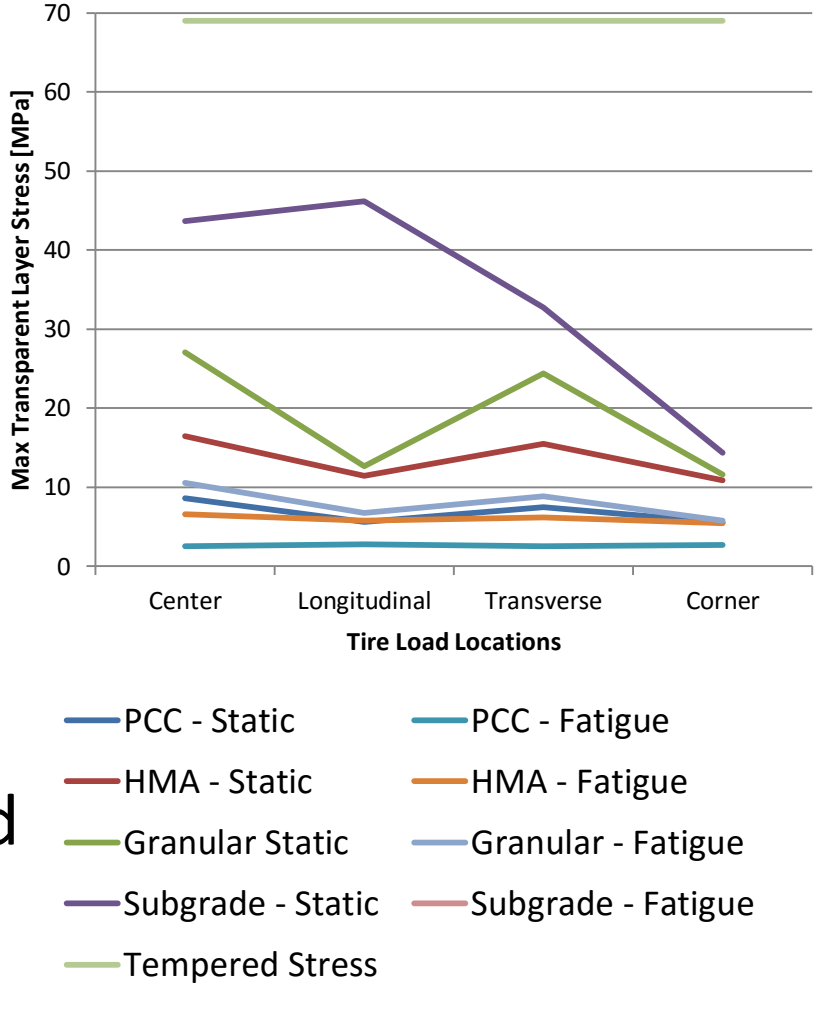




WATERLOO ENGINEERING
UNIVERSITY OF WATERLOO
200 University Avenue West, Waterloo, ON, Canada N2L 3G1
519-888-4567 | uwaterloo.ca

Structural Analysis





HMA base, center fatigue load glass stress

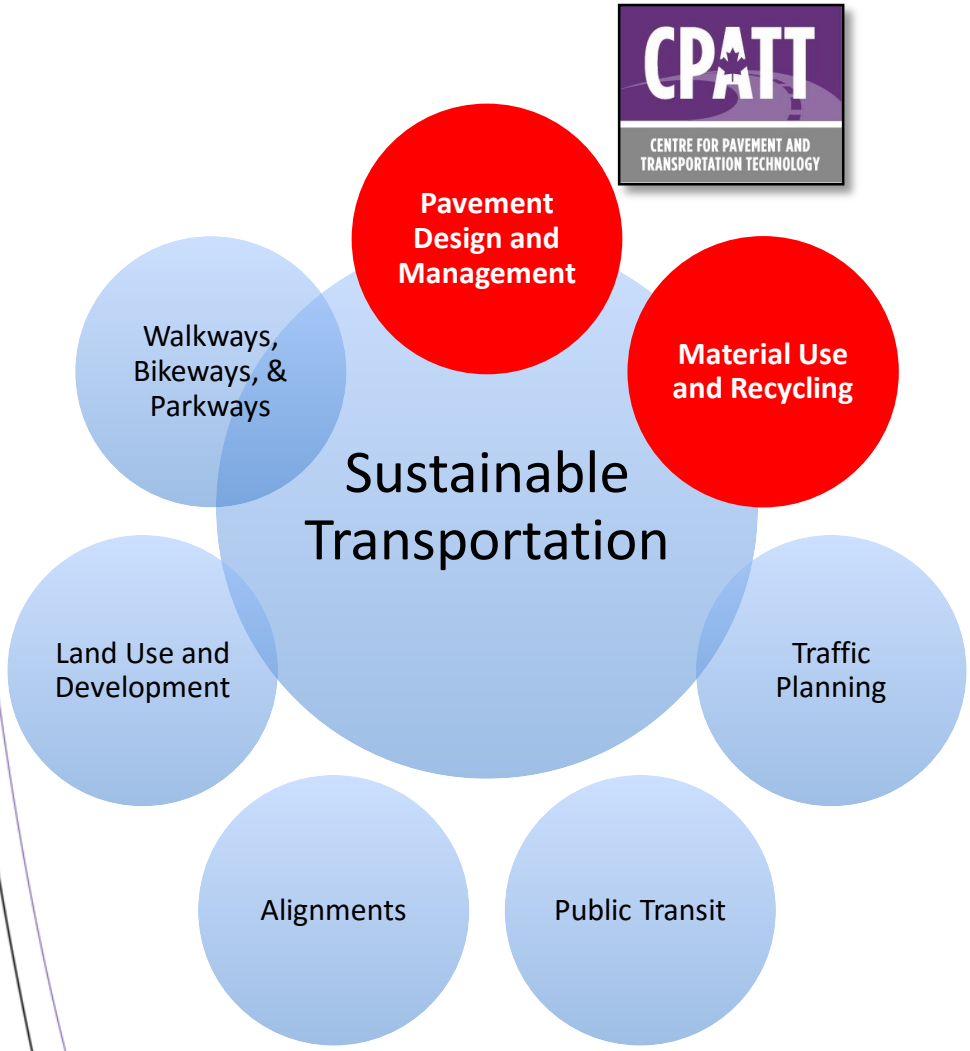
(Northmore, 2013)

WATERLOO ENGINEERING
UNIVERSITY OF WATERLOO
200 University Avenue West, Waterloo, ON, Canada N2L 3G1
519-888-4567 | uwaterloo.ca

Solar Pavement Future?

- It is possible to design a solar panel to withstand Canadian structural and environmental loads
- Ideal materials: (Tempered glass transparent layer, GPO-3 (or like) optical layer,)
- Design optimization of:
  - Panel material thicknesses
  - Panel area dimensions
  - Structural bases
  - Friction development on glass surfaces through modification
  - In-situ load testing of a prototype

WATERLOO ENGINEERING
UNIVERSITY OF WATERLOO
200 University Avenue West, Waterloo, ON, Canada N2L 3G1
519-888-4567 | uwaterloo.ca



Sustainable pavement is a subset of sustainable transportation

Main focus on Pavement Design and Management; and Material Use and Recycling

WATERLOO ENGINEERING
UNIVERSITY OF WATERLOO
200 University Avenue West, Waterloo, ON, Canada N2L 3G1
519-888-4567 | uwaterloo.ca

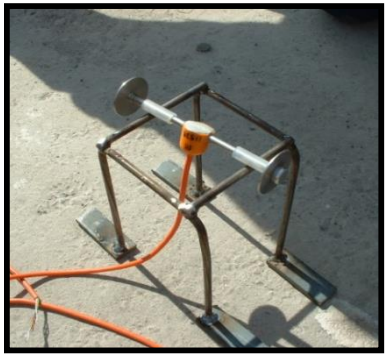
Key Sustainability Issues

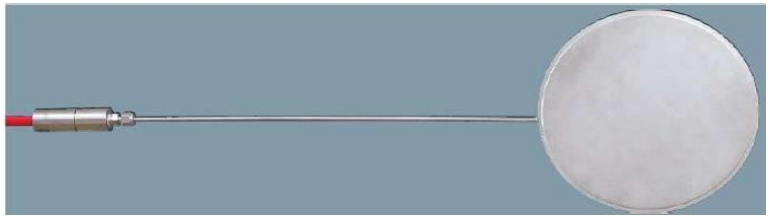
- Virgin Material Usage
- Alternative Material Usage
- Program for In-Service Monitoring and Management
- Air Quality/Emissions
- Water Quality
- Noise
- Energy Usage

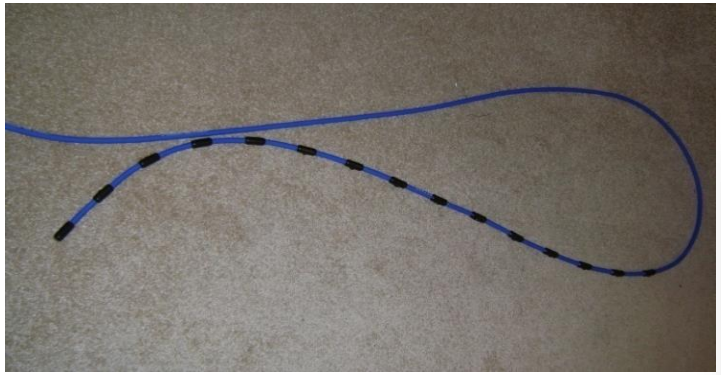
WATERLOO ENGINEERING
UNIVERSITY OF WATERLOO
200 University Avenue West, Waterloo, ON, Canada N2L 3G1
519-888-4567 | uwaterloo.ca

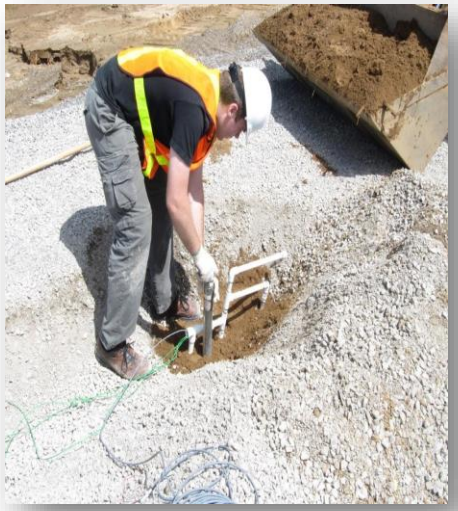
Research Methodology

- Technical
- Economic
- Sustainable
- Costs/Benefits



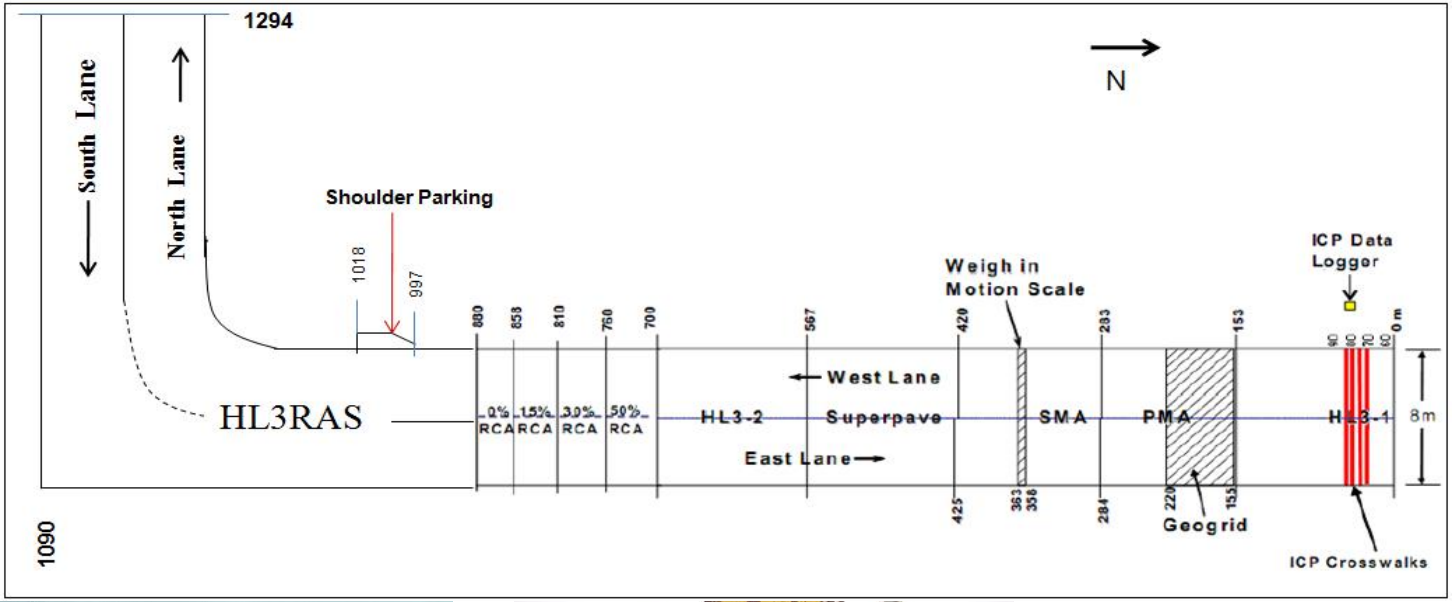


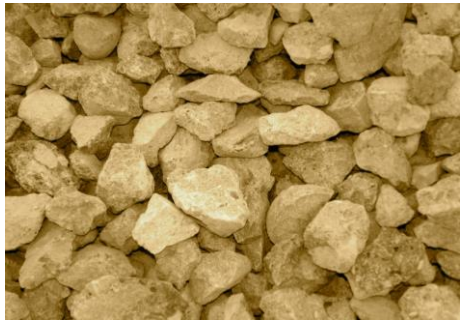




WATERLOO ENGINEERING
UNIVERSITY OF WATERLOO
200 University Avenue West, Waterloo, ON, Canada N2L 3G1
519-888-4567 | uwaterloo.ca

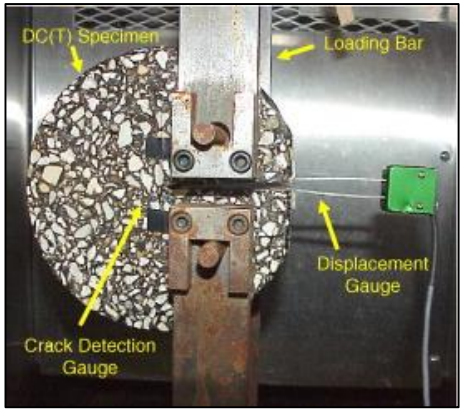
Recycled Materials

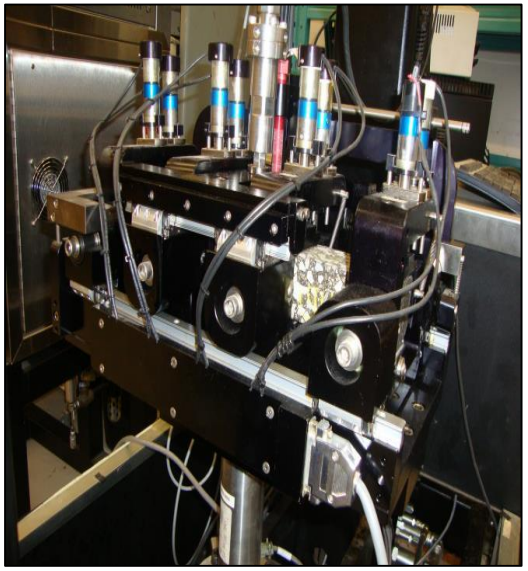




WATERLOO ENGINEERING
UNIVERSITY OF WATERLOO
200 University Avenue West, Waterloo, ON, Canada N2L 3G1
519-888-4567 | uwaterloo.ca

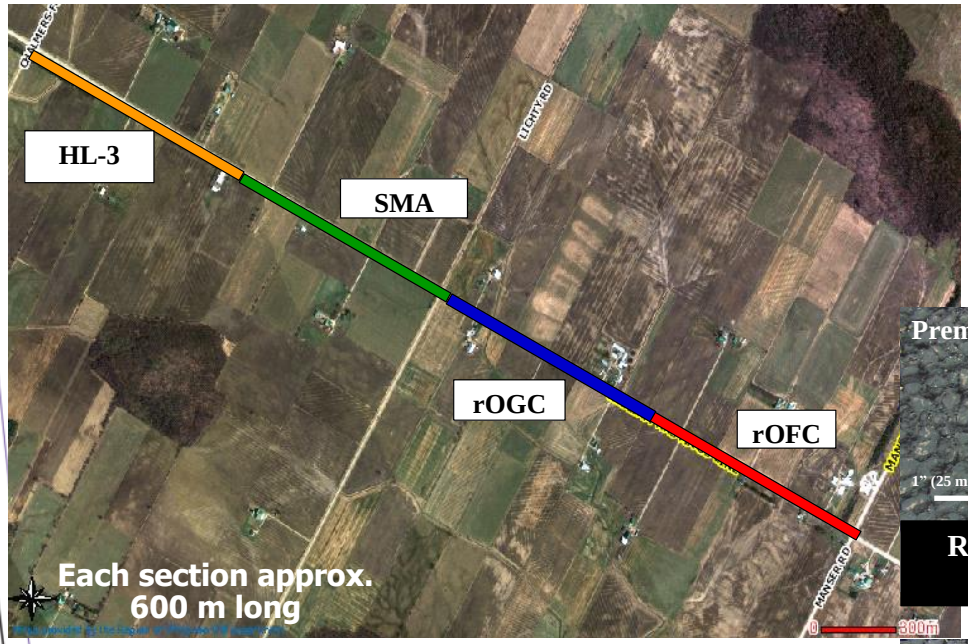
Examples of Projects





WATERLOO ENGINEERING
UNIVERSITY OF WATERLOO
200 University Avenue West, Waterloo, ON, Canada N2L 3G1
519-888-4567 | uwaterloo.ca

Examples of Projects



Rubberized Open Friction Course (rOFC)

Stone Mastic Asphalt (SMA)

Rubberized Open Graded Course (rOGC)

Control: Hot-Laid 3 (HL-3)

First truly controlled study
Integrated CPX and PBM

WATERLOO ENGINEERING
UNIVERSITY OF WATERLOO
200 University Avenue West, Waterloo, ON, Canada N2L 3G1
519-888-4567 | uwaterloo.ca

Recycling Concrete









WATERLOO ENGINEERING
UNIVERSITY OF WATERLOO
200 University Avenue West, Waterloo, ON, Canada N2L 3G1
519-888-4567 | uwaterloo.ca

Examples of Projects








WATERLOO ENGINEERING
UNIVERSITY OF WATERLOO
200 University Avenue West, Waterloo, ON, Canada N2L 3G1
519-888-4567 | uwaterloo.ca





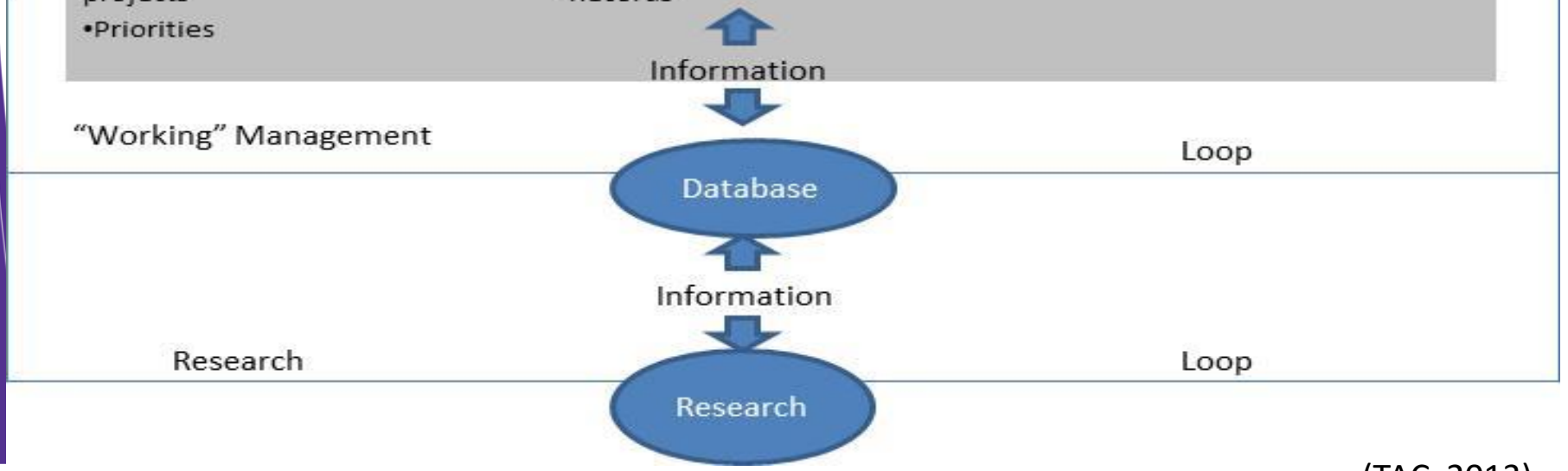





Category	Point ID	Description	Max Credit
Pavement Technology	PT-1	Long-Life Pavement Designs	3
	PT-2	Permeable Pavements	1
	PT-3	Quiet Pavements	3
	PT-4	Cool Pavements	2
Materials and Resources	MR-1	Recycled Content	6
	MR-2	Reuse of Pavement	3
	MR-3	Local Materials	3
	MR-4	Construction Quality	2
Energy and Atmosphere	EA-1	Reduce Energy Consumption	3
	EA-2	GHG Emission Reduction	2
	EA-3	Improve Rolling Resistance	1
	EA-4	Pollution Reduction	3
Innovation and Design Process	I-1	Innovation in Design	2
	I-2	Exemplary Process	2
Max Credit			36

WATERLOO ENGINEERING
UNIVERSITY OF WATERLOO
200 University Avenue West, Waterloo, ON, Canada N2L 3G1
519-888-4567 | uwaterloo.ca

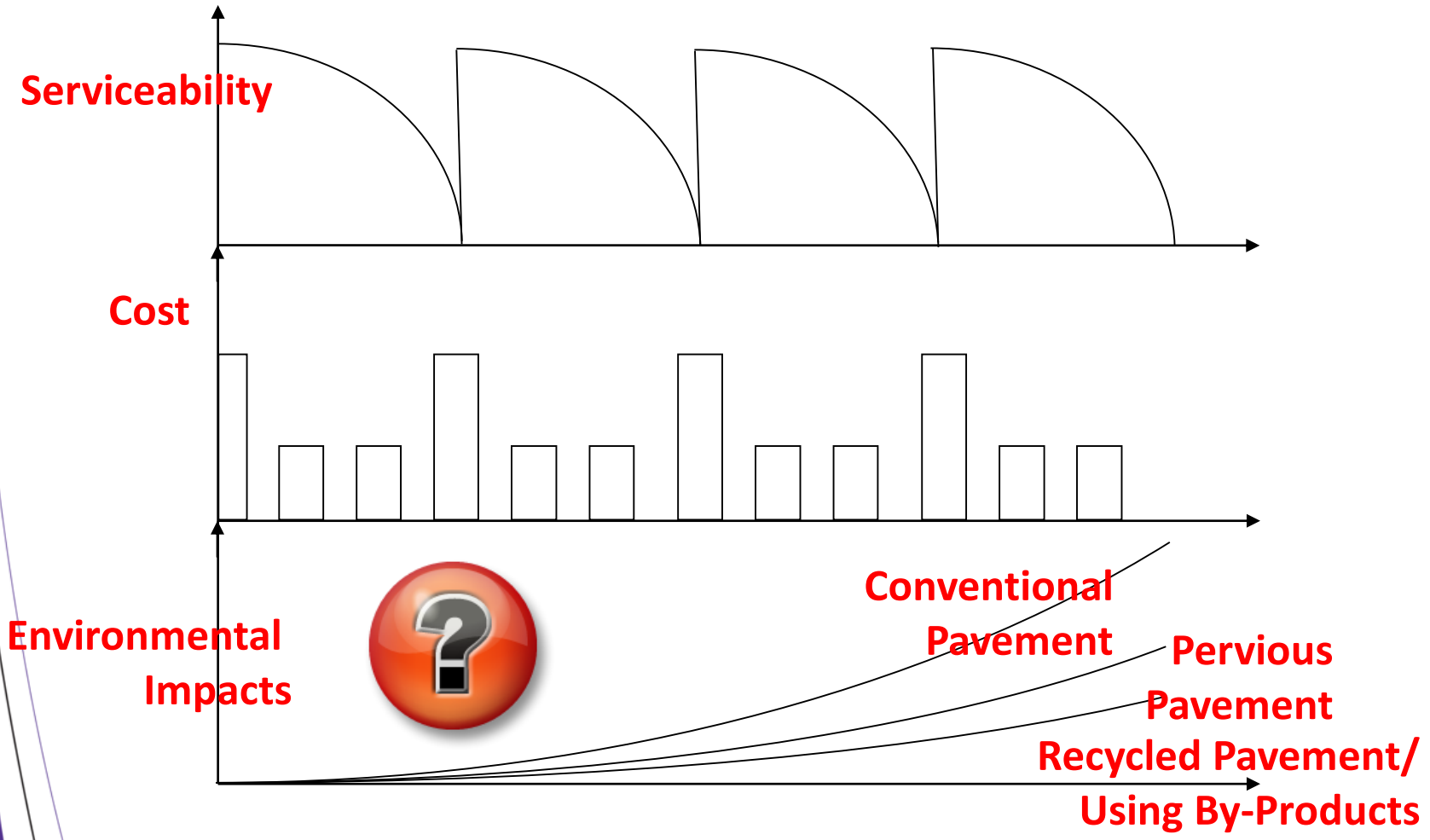
Planning and Programming	Design	Construction	Maintenance, Preservation and Rehabilitation	In-Service Evaluation	End of Service Life
•Traffic and Environmental data information •Assess network deficiencies •Budgets •Establish priorities •Schedule projects •Priorities	•Information on materials, traffic, costs, environment, etc. •Design alternatives •Analysis •Optimization •Sustainability •User costs	•Environment during construction •Specifications •Contracts •Schedules •Construction operations •Quality control/quality assurance •Records	•Standards •Treatments •Schedules •Operations •Budget control •Records •Impact on performance •User costs	•Periodic monitoring of structural adequacy, roughness, surface distress, and surface friction •Assess performance •Prioritize	•Recycling and reuse of materials for reconstruction •Salvage Value •Records •Restoration •Zero Waste Management



(TAC, 2013)

WATERLOO ENGINEERING
UNIVERSITY OF WATERLOO
200 University Avenue West, Waterloo, ON, Canada N2L 3G1
519-888-4567 | uwaterloo.ca

Quantify All Costs/Benefits



(Tighe, 2010)

WATERLOO ENGINEERING
UNIVERSITY OF WATERLOO
200 University Avenue West, Waterloo, ON, Canada N2L 3G1
519-888-4567 | uwaterloo.ca

Closing Remarks

- Sustainable Construction and Maintenance is achievable
- 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

WATERLOO ENGINEERING
UNIVERSITY OF WATERLOO
200 University Avenue West, Waterloo, ON, Canada N2L 3G1
519-888-4567 | uwaterloo.ca

Acknowledgements

- Undergraduate and Graduate Students
- Ministry of Transportation Ontario (MTO)
- Natural Sciences and Engineering Research Council of Canada (NSERC)
- Ontario Hot Mix Producers Association (OHMPA)
- Cement Association of Canada
- Partners in Norman W. McLeod Chair
- CPATT Partners

ohmpa Ontario Hot Mix Producers Association

CPATT CENTRE FOR PAVEMENT AND TRANSPORTATION TECHNOLOGY

Ontario

NSERC CRSNG

Cement Association of Canada
Association Canadienne du Ciment

WATERLOO ENGINEERING
UNIVERSITY OF WATERLOO
200 University Avenue West, Waterloo, ON, Canada N2L 3G1
519-888-4567 | uwaterloo.ca

Questions/Comments