University of Pittsburgh

IRISE Projects:

Customizing Rigid Pavement ME and Early Opening to Traffic Study

Lev Khazanovich, Anthony Gill Professor

Department of Civil and Environmental Engineering
University of Pittsburgh

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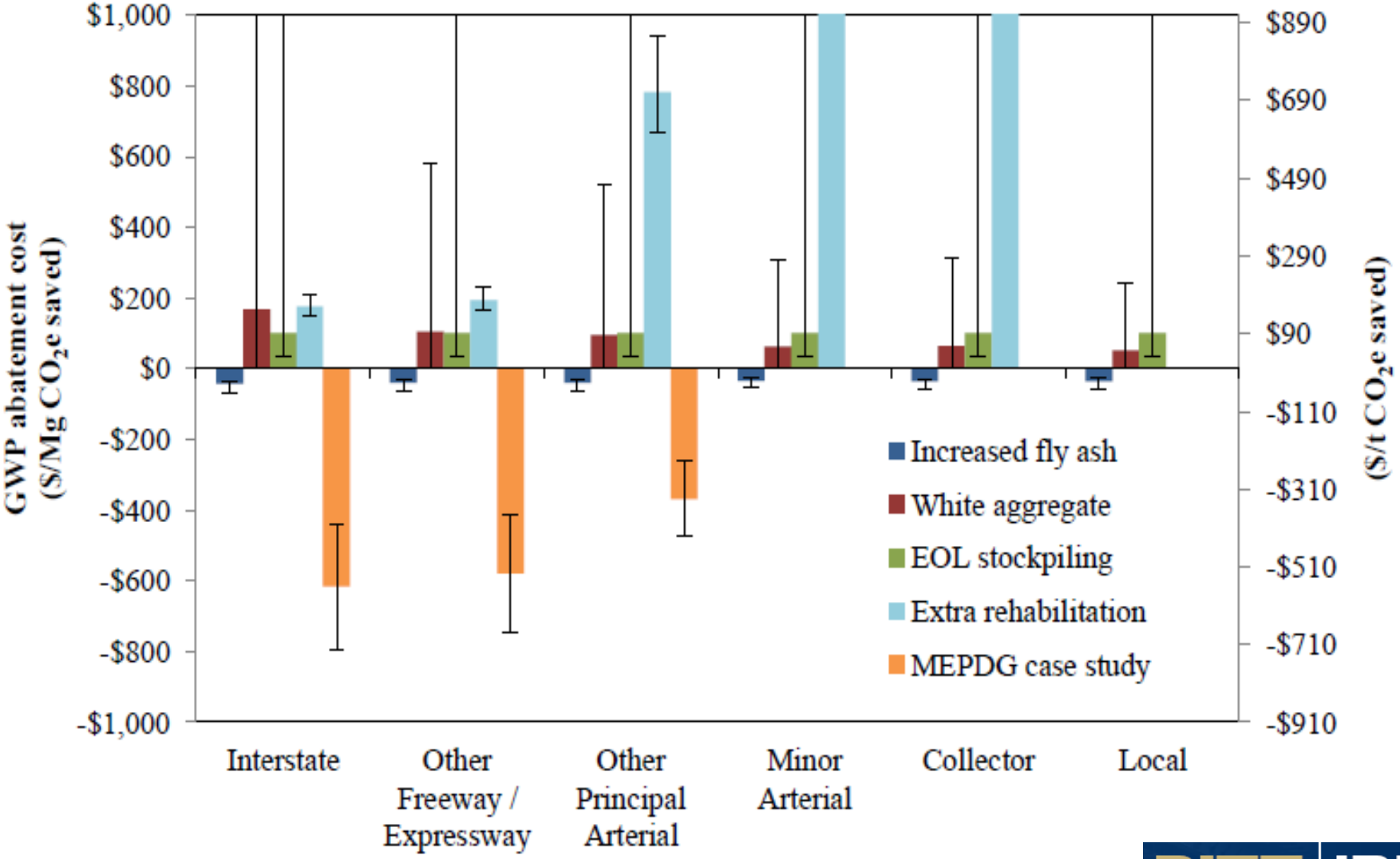
Rigid Pavement Design

- The current Pennsylvania design method for rigid pavements is outdated
  - AASHTO 93-based procedure (1960-s technology)
  - Not cost-effective: many empirical evidences of overdesign built into AASHTO 93
- Pennsylvania is considering a transition to AASHTO ME design, which requires the user:
  - to provide many inputs thus increasing possibilities of the design errors
  - to use AASHTOWare Pavement ME software with annual license fees

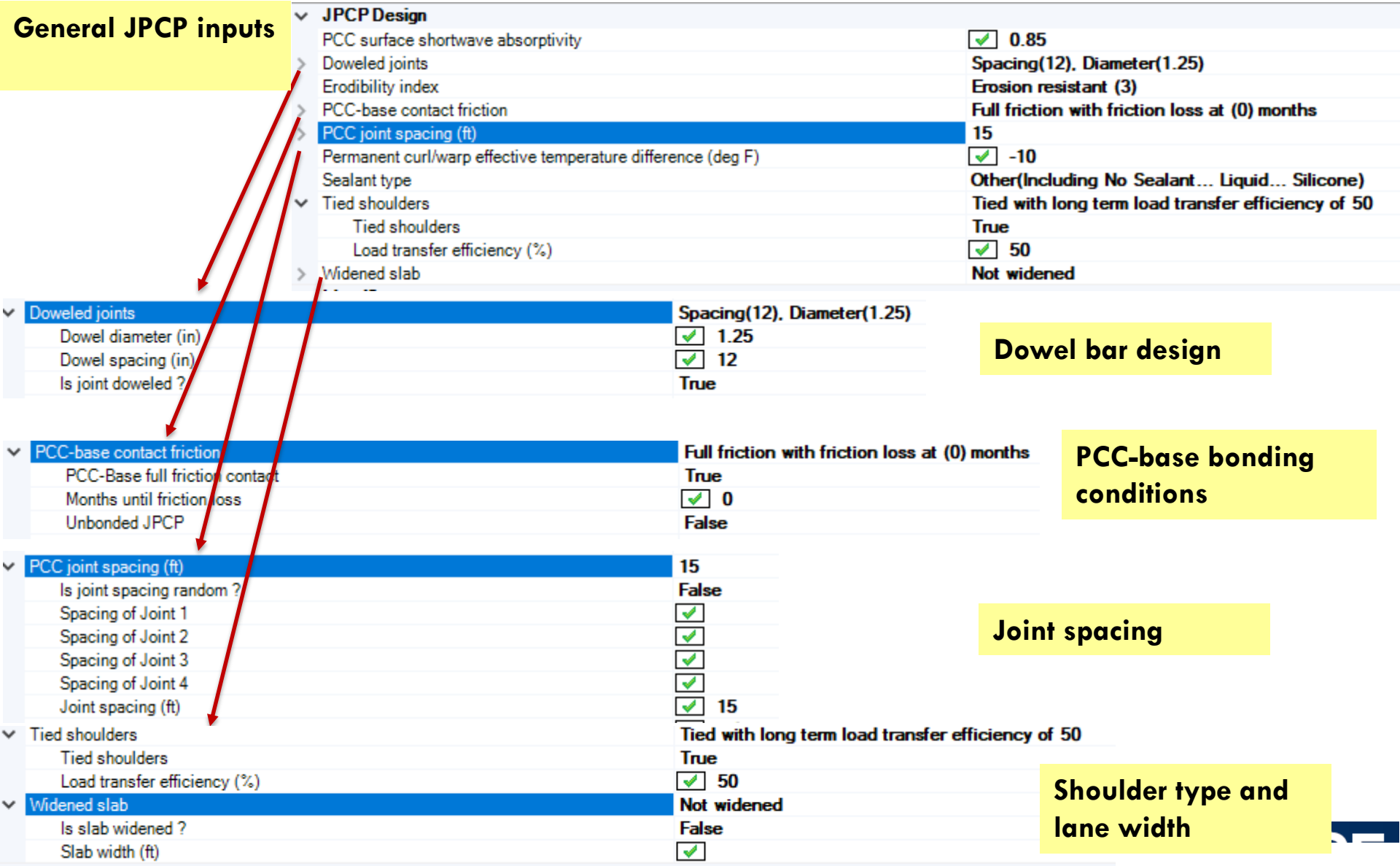
Why AASHTO ME Design?



Concrete Sustainability Hub@MIT – Special Research Brief – March 2011

Pavement ME JPCP Design Inputs

General JPCP inputs



Dowel bar design

PCC-base bonding conditions

Joint spacing

Shoulder type and lane width

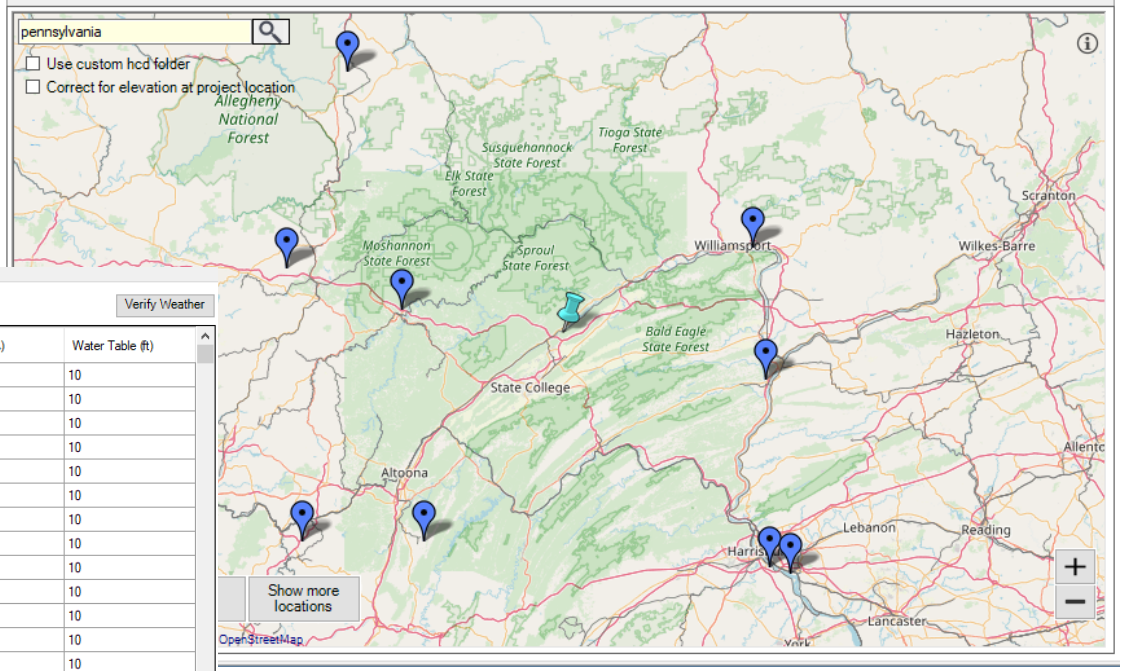
Pavement ME Climate Inputs

Climate Station	
Elevation	1240
Climate station	PITTSBURGH_NARR_GRIDPOINT,PA (
Latitude (decimals degrees)	40.35
Longitude (decimal degrees)	-79.92
Depth of water table (ft)	**Annual(10)**
Identifiers	
Date approved	**2/12/2019 2:09 PM**
Author	
Date created	**2/12/2019 2:09 PM**
County	
Description of object	
Direction of travel	
Display name/identifier	
District	
From station (miles)	
Item Locked?	**False**
Highway	
Revision Number	**0**
State	
To station (miles)	
User defined field 1	
User defined field 2	
User defined field 3	

Summary | Hourly climate data

Climate Summary	
Mean annual air temperature (deg F)	51.5
Mean annual precipitation (in)	38.2
Freezing index (deg F - days)	500.6
Average annual number of freeze/thaw cycles	64.7
Number of wet days	200.7
Monthly Temperatures	
Average temperature in January (deg F)	27.4

Mean annual air temperature (deg F)



Summary | Hourly climate data

January /1979 to June /2015 Verify Weather

Date/Hour	Temperature (deg F) (deg F)	Wind Speed (mph)	Sunshine (%)	Precipitation (in.)	Humidity (%)	Water Table (ft)
1/1/1979 12:00:00 AM	39.4	18	0	0	93	10
1/1/1979 1:00:00 AM	39.7	19	0	0.05	93	10
1/1/1979 2:00:00 AM	39.4	19	0	0	92	10
1/1/1979 3:00:00 AM	39.2	19	0	0	92	10
1/1/1979 4:00:00 AM	38.8	19	0	0.05	92	10
1/1/1979 5:00:00 AM	38.8	17	0	0	92	10
1/1/1979 6:00:00 AM	38.7	16	0	0	92	10
1/1/1979 7:00:00 AM	38.7	14	0	0.12	92	10
1/1/1979 8:00:00 AM	39.2	12	0	0	90	10
1/1/1979 9:00:00 AM	39.7	12	0	0	88	10
1/1/1979 10:00:00 AM	40.3	11	0	0.1	86	10
1/1/1979 11:00:00 AM	40.8	11	0	0	86	10
1/1/1979 12:00:00 PM	41.2	11	0	0	86	10
1/1/1979 1:00:00 PM	41.7	11	0	0.07	86	10
1/1/1979 2:00:00 PM	41.9	11	0	0	85	10
1/1/1979 3:00:00 PM	42.3	11	1	0	85	10
1/1/1979 4:00:00 PM	42.4	11	1	0.11	85	10
1/1/1979 5:00:00 PM	42.3	13	1	0	85	10
1/1/1979 6:00:00 PM	42.1	16	0	0	85	10
1/1/1979 7:00:00 PM	42.1	18	0	0.08	85	10

Pavement ME Traffic Inputs

ATPB+2A Subbase:Project | ATPB+2A Subbase:Traffic

AADTT

Two-way AADTT	2000
Number of lanes	4
Percent trucks in design dire	50
Percent trucks in design lan	95
Operational speed (mph)	60

Traffic Capacity

Traffic Capacity Cap	Not enforced

Axle Configuration

Average axle width (ft)	8.5
Tandem axle spacing (in)	51.6
Dual tire spacing (in)	12
Quad axle spacing (in)	49.2
Tire pressure (psi)	120
Tridem axle spacing (in)	49.2

Lateral Wander

Design lane width (ft)	12
Mean wheel location (in)	18
Traffic wander standard dev	10

Wheelbase

Average spacing of long axl	18
Average spacing of medium	15
Percent trucks with long axl	61
Percent trucks with medium	22
Percent trucks with short ax	17
Average spacing of short ax	12

Identifiers

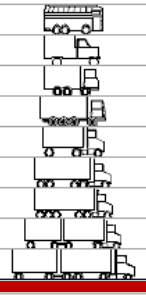
Approver	
Date approved	1/1/2011
Author	AASHTOWare
County	
Description of object	Default Traffic File
Highway	
Revision Number	0
State	
To station (miles)	

Traffic Capacity Cap

Basic traffic configuration

Vehicle Class Distribution and Growth — Load Default Distribution

Vehicle Class	Distribution (%)	Growth Rate (%)	Growth Function
Class 4	3.3	2	Linear
Class 5	34	2	Linear
Class 6	11.7		
Class 7	1.6		
Class 8	9.9		
Class 9	36.2	2	Linear
Class 10	1	2	Linear
Class 11	1.8	2	Linear
Class 12	0.2	2	Linear



Annual growth rate

Monthly Adjustment — Import Monthly Adjustmen

Month	Class 4	Class 5	Class 6	Class 7	Class 8	Class 9	Class 10	Class 11	Class 12	Class 13
January	1	1	1	1	1	1	1	1	1	1
February	1	1	1	1	1	1	1	1	1	1
March	1	1	1	1	1	1	1	1	1	1
April	1	1	1							1
May	1	1	1							1
June	1	1	1							1
July	1	1	1							1
August	1	1	1	1	1	1	1	1	1	1
September	1	1	1	1	1	1	1	1	1	1

Monthly Adjustment Factor (MAF)

Axles Per Truck

Vehicle Class	Single	Tandem	Tridem	Quad
Class 4	1.62	0.39	0	0
Class 5	2	0	0	0
Class 6	1.02	0.99	0	0
Class 7	1	0.26	0.83	0
Class 8	2.38	0.67	0	0
Class 9	1.13	1.93	0	0
Class 10	1.19	1.09	0.89	0
Class 11	4.29	0.26	0.06	0
Class 12	3.52	1.14	0.06	0

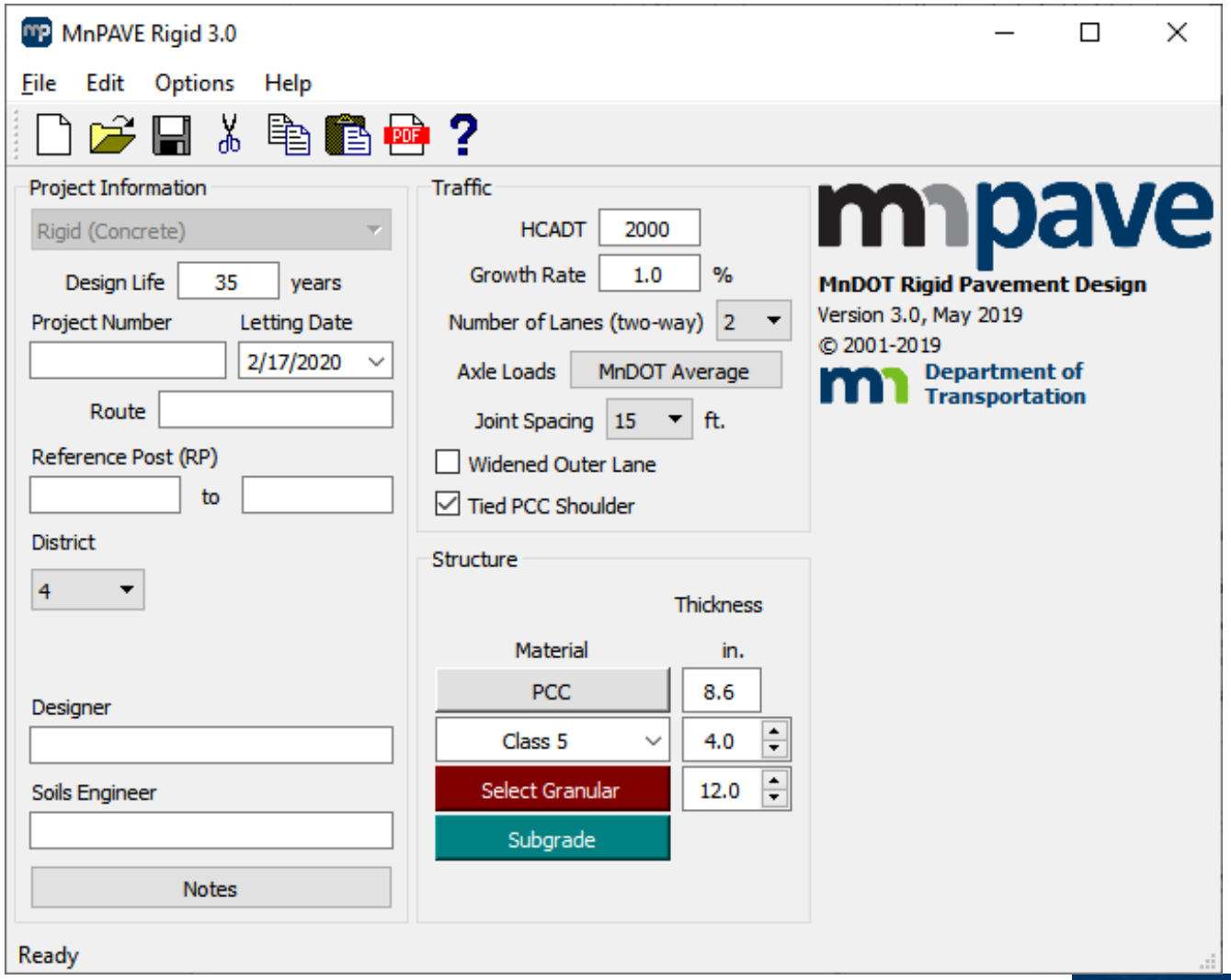
Axle spectrum distribution

Hourly Adjustment

Time of Day	Percentage
12:00 am	2.3
1:00 am	2.3
2:00 am	2.3
3:00 am	2.3
4:00 am	2.3
5:00 am	2.3
6:00 am	5
7:00 am	5
8:00 am	5
9:00 am	5
10:00 am	5.9
11:00 am	5.9
12:00 pm	5.9
1:00 pm	5.9
2:00 pm	5.9
3:00 pm	5.9
4:00 pm	4.6
5:00 pm	4.6
6:00 pm	4.6
7:00 pm	4.6
8:00 pm	3.1
9:00 pm	3.1
10:00 pm	3.1
11:00 pm	3.1
Total	100.0

Hourly Adjustment Factors (HAF)

MnPAVE RIGID

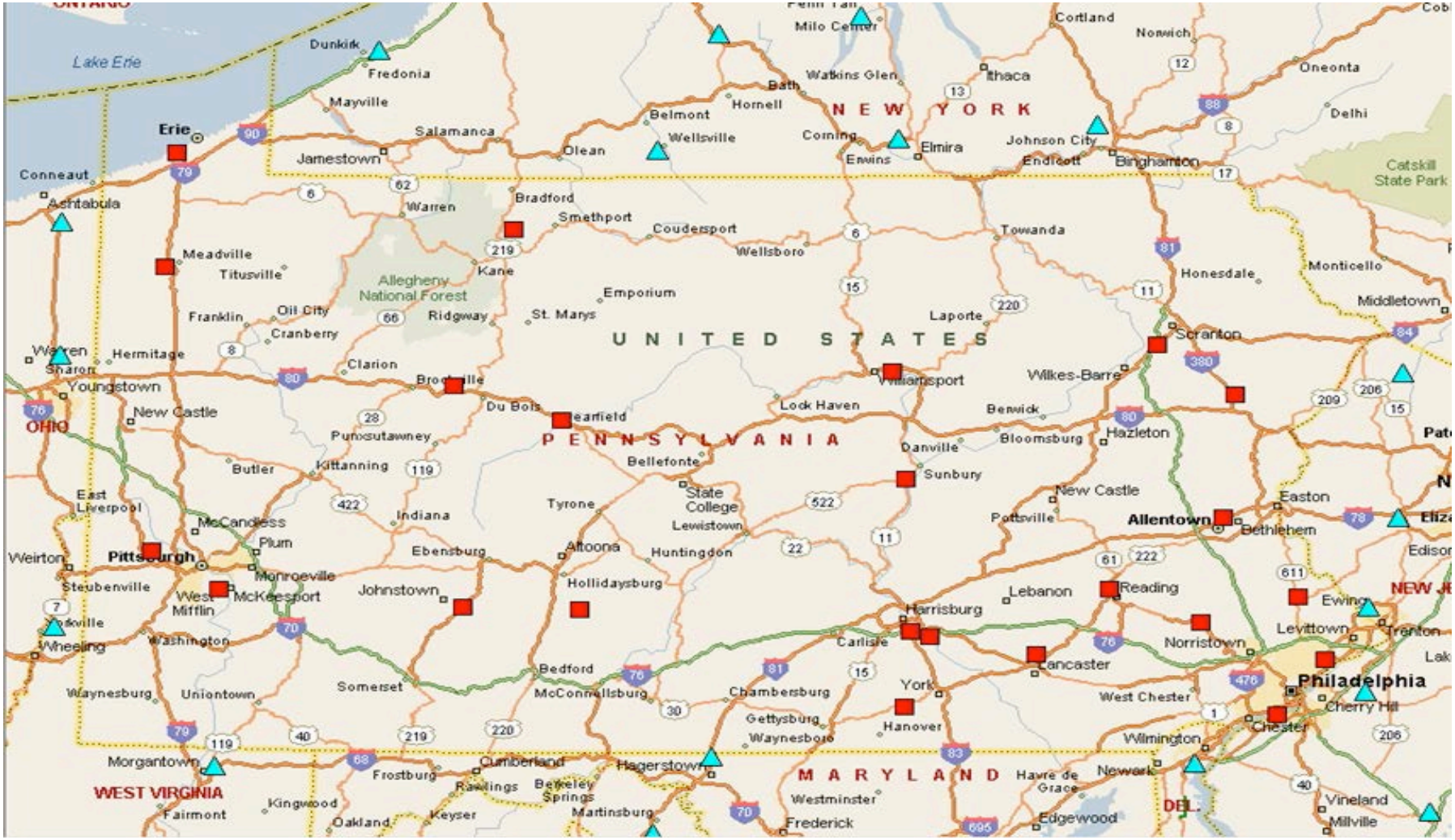


Sensitivity Analysis

More than 100 Pavement ME runs for Pennsylvania conditions:

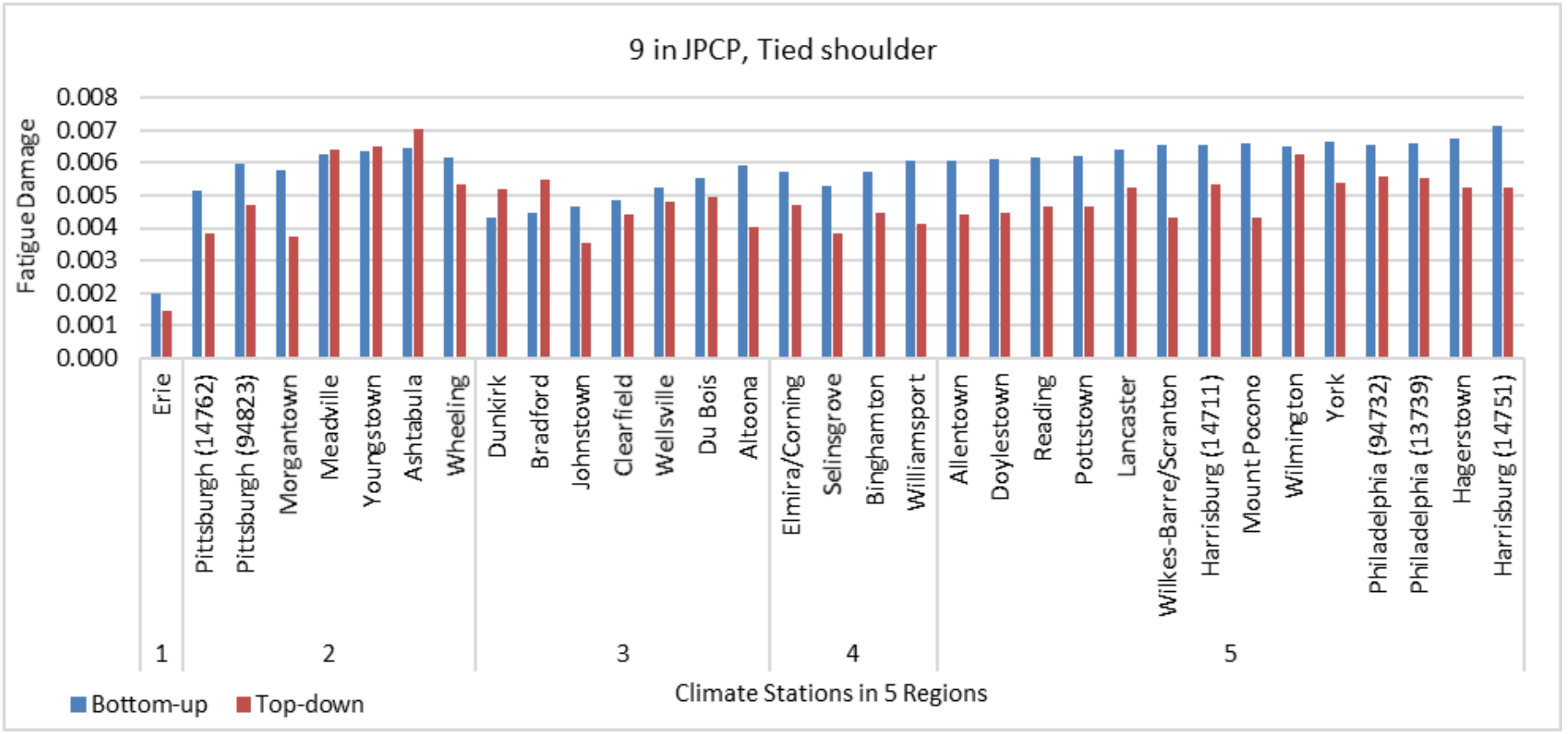
- Climate
- Traffic
- Design features
- Material properties

Climate Stations

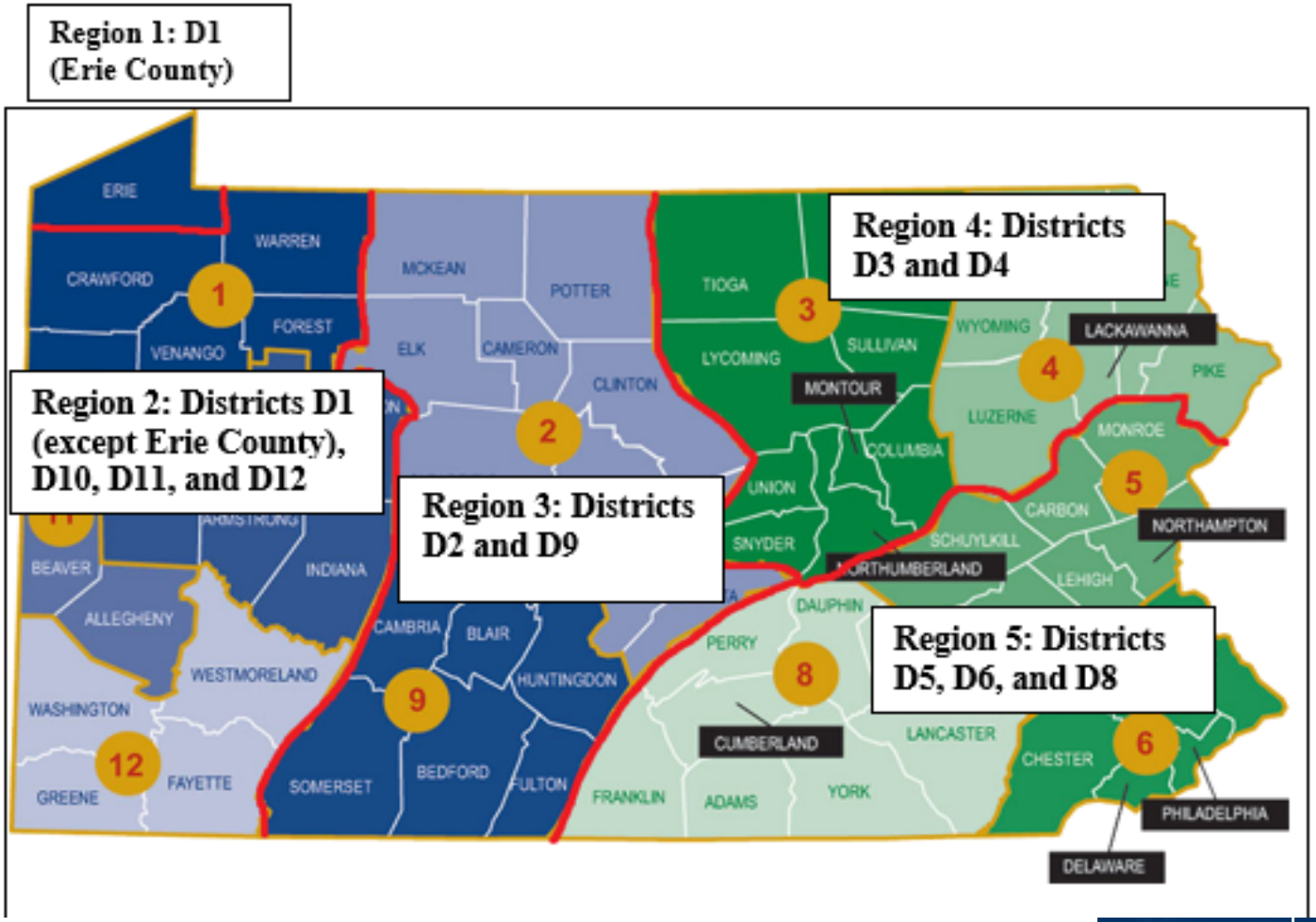


PITT | IRISE
CENTER FOR IMPACTFUL RESILIENT INFRASTRUCTURE SCIENCE & ENGINEERING

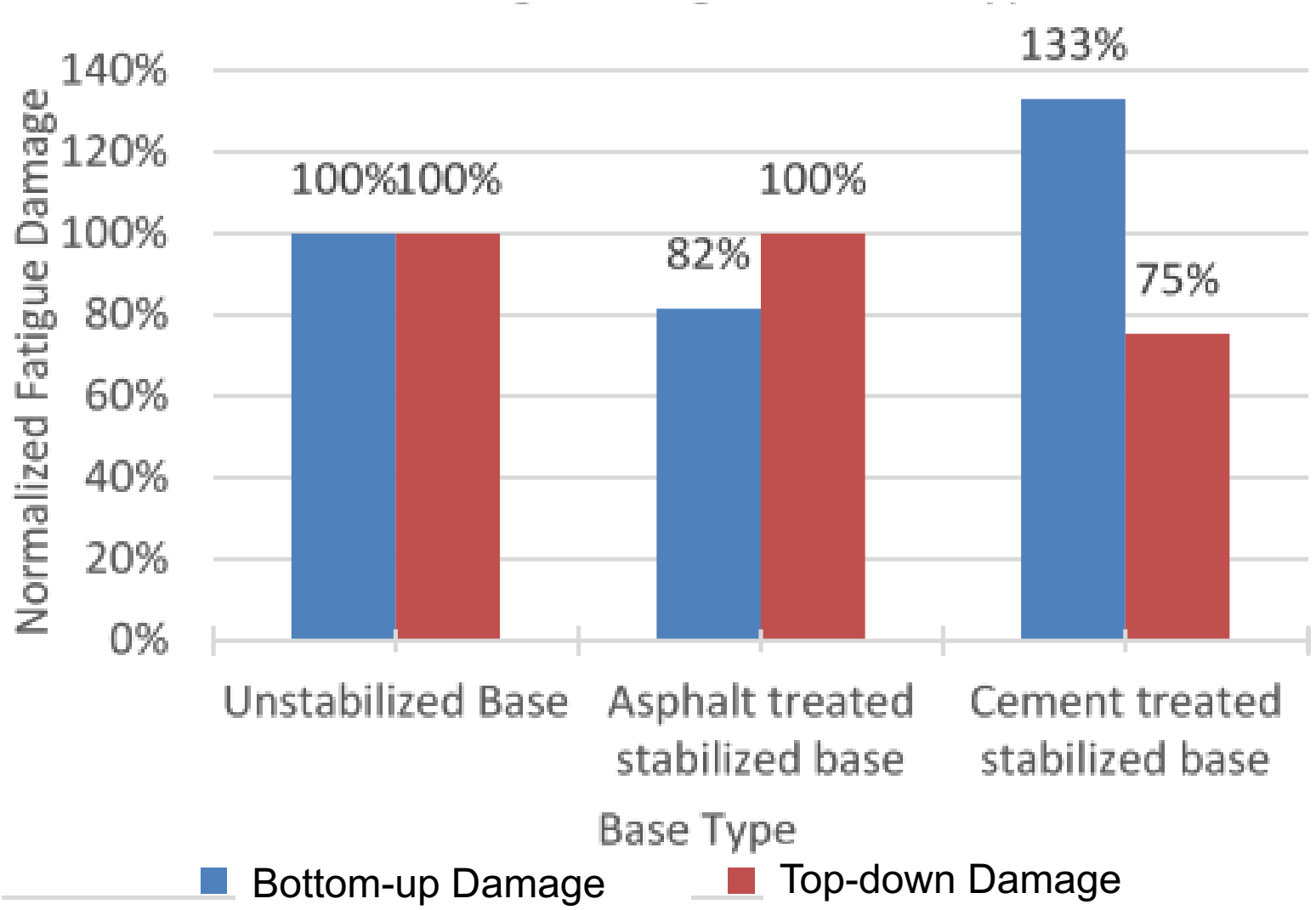
Effect of Climate Inputs



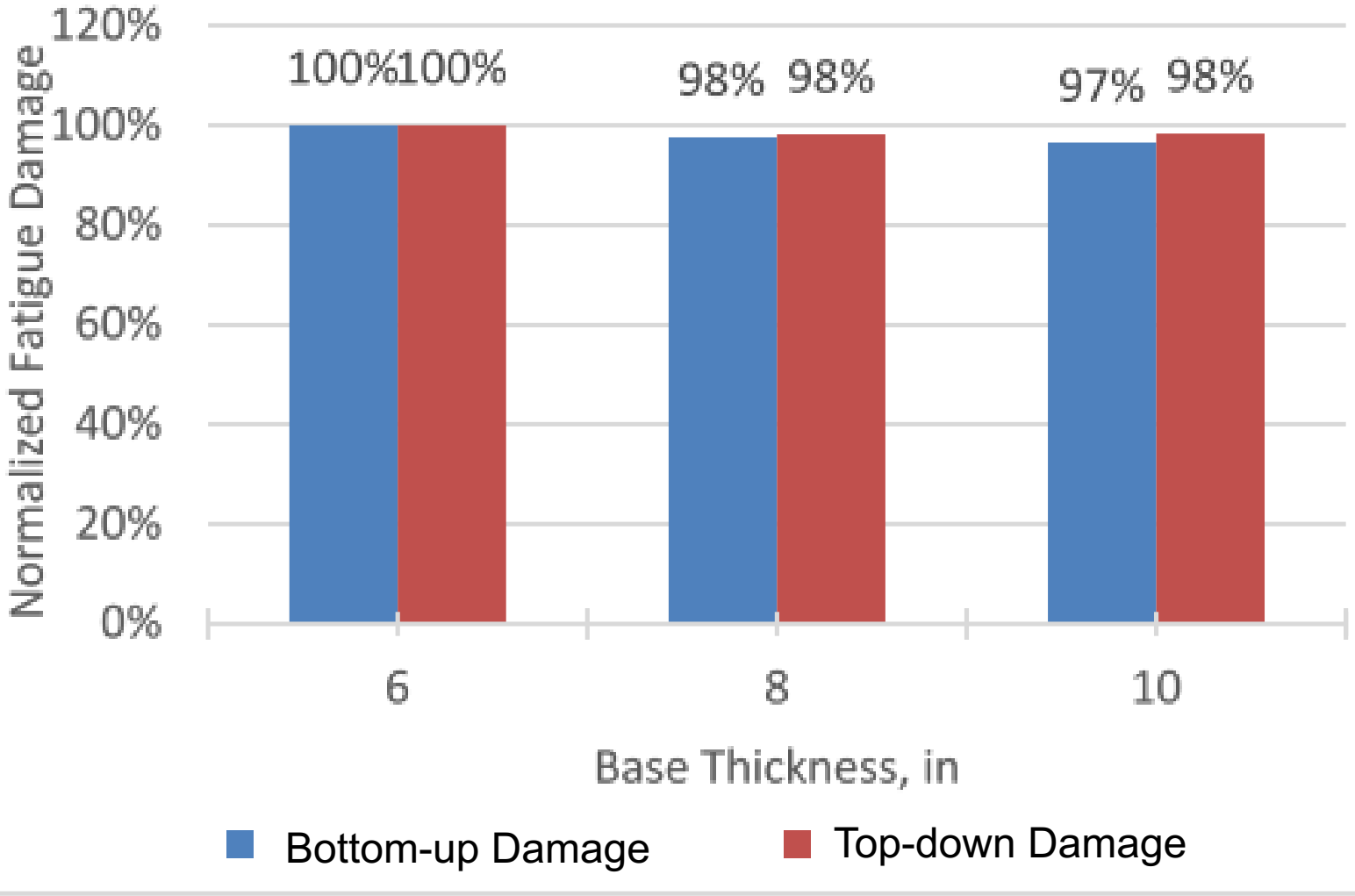
Recommended Climate Regions



Effect of Base Type



Effect of Base Thickness



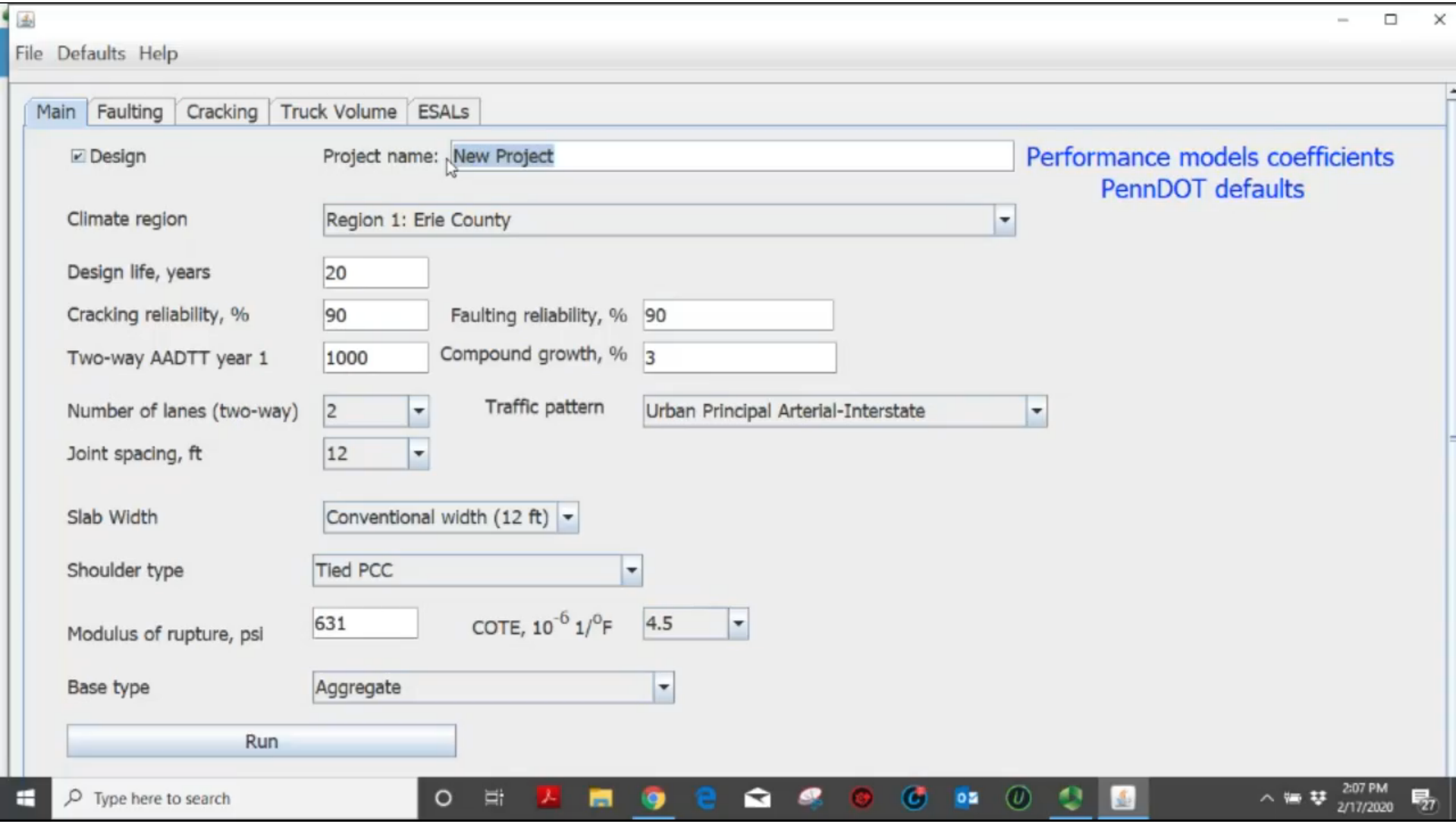
PittRIGID-ME Design Inputs

- Design reliability
- Two-way AADTT: 0-20,000
- Compound growth rate: 0-10%
- Traffic Patterns:
  - Urban Principal Arterial-Interstate
  - Rural Principal Arterial-Interstate
  - Minor Arterials, Collectors, and Recreational
- Number of lanes: 2, 4, 6, or 8

PittRIGID-ME Design Inputs (cont.)

- Concrete modulus of rupture and coefficient of thermal expansion
- Shoulder type
- Concrete slab width
- Base type

Other parameters: defaults recommended by ARA, Inc. for Pennsylvania conditions (ARA 2015)


File Defaults Help
Main Faulting Cracking Truck Volume ESALs
Design
Project name: New Project
Performance models coefficients
PennDOT defaults
Climate region
Region 1: Erie County
Design life, years
20
Cracking reliability, %
90
Faulting reliability, %
90
Two-way AADTT year 1
1000
Compound growth, %
3
Number of lanes (two-way)
2
Traffic pattern
Urban Principal Arterial-Interstate
Joint spacing, ft
12
Slab Width
Conventional width (12 ft)
Shoulder type
Tied PCC
Modulus of rupture, psi
631
COTE, 10-6 1/°F
4.5
Base type
Aggregate
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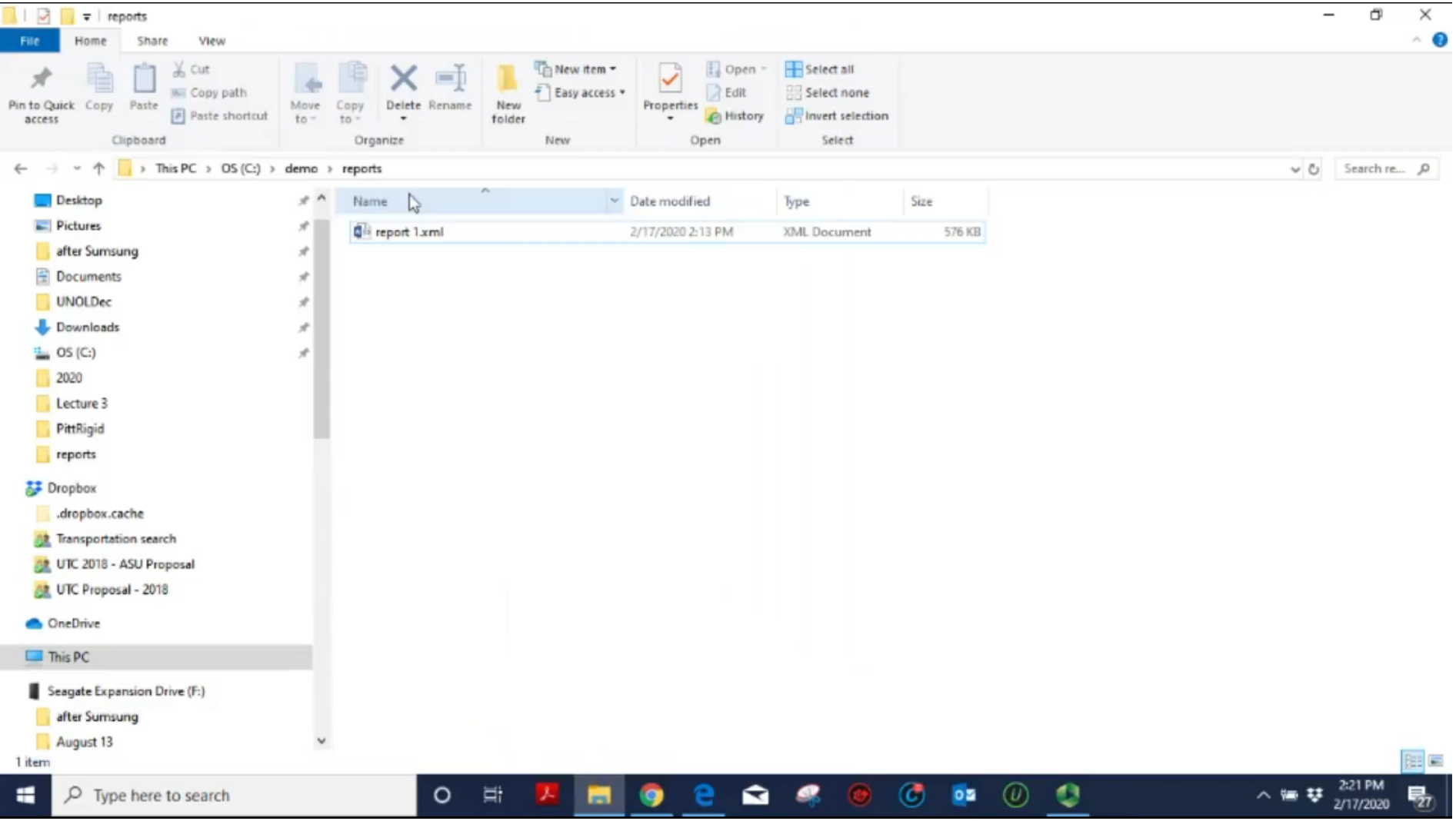
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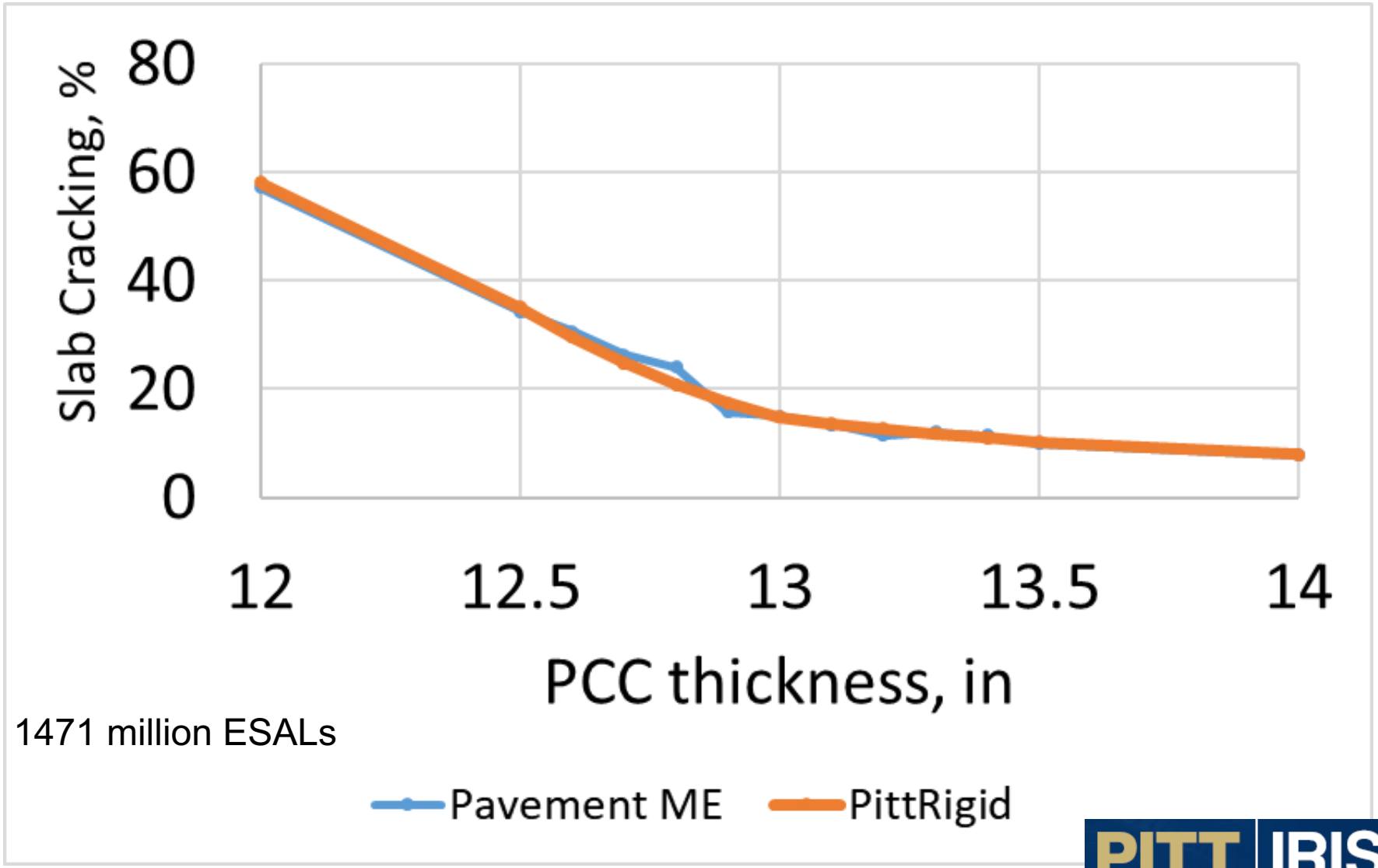
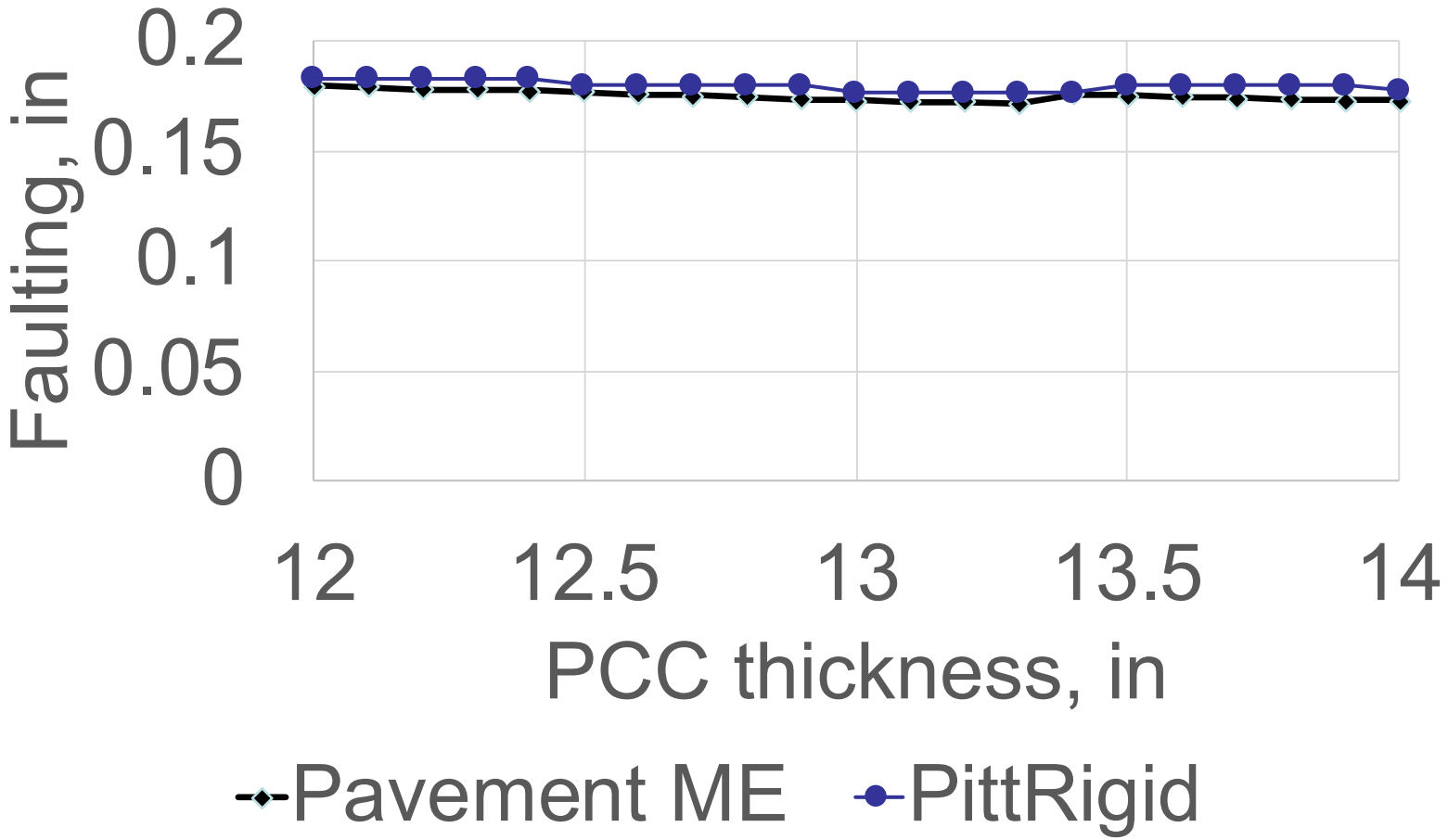
Comparison of Cracking Predictions



Comparison of Faulting Predictions



260 million ESALs

Conclusions

- PittRigid-ME is not intended to replace Pavement ME, but to supplement it
- PittRigid-ME is a simple MEPDG-based design and analysis tool for Pennsylvania concrete pavements
- PittRigid-ME:
  - Matches Pavement ME for the selected sets of inputs
  - Can be expanded for other design inputs
  - Can be updated after local calibration or for improved performance prediction models

Early Opening of Concrete Pavements to Traffic

The Problem

- Current traffic-opening criteria
  - empirical
  - overly conservative (Crovetti and Khazanovich, 2005)
  - causing unnecessary construction delays and cost
- Concrete strength measurements
  - indirect (based on strength of cast aside beams or cylinders)
  - expensive

MnDOT Specification 2301.O

"Do not open a new pavement slab to general public traffic or operate paving or other heavy equipment on it for 7 days, or until the concrete has reached a minimum flexural strength meeting the requirements of Table 2301-18, or minimum compressive strength of 3,000 psi; whichever occurs first."

Table 2301-18 Minimum Strength Requirements for Opening Pavements to Construction and to General Public Traffic	
Slab Thickness, in	**Flexural Strength, psi**
≤7.0	500
7.5	480
8.0	460
8.5	440
9.0	390
≥ 9.5	350

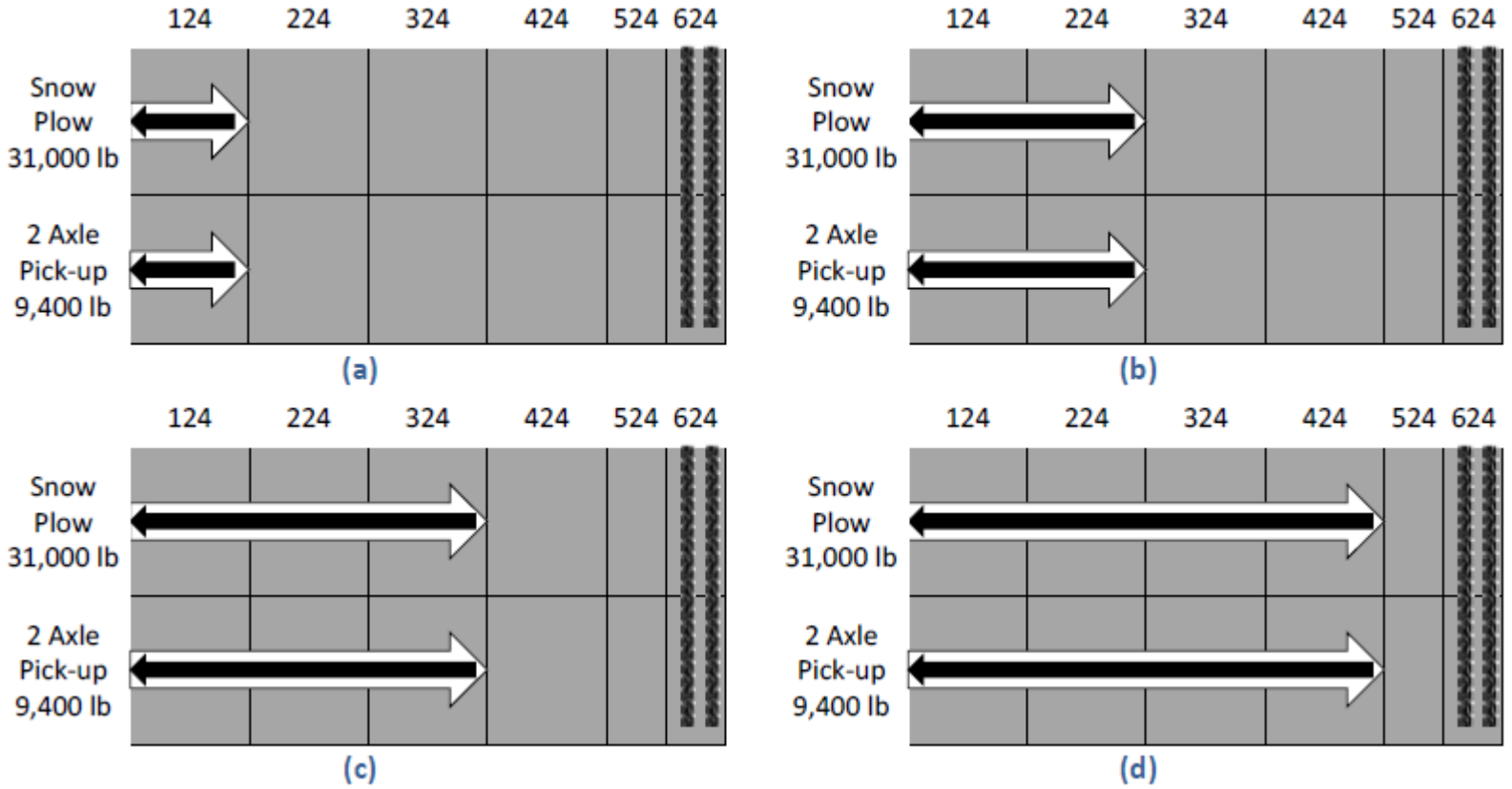
MnROAD Study

Loading 2 hours after paving

Van Deusen et al, 2018

MnROAD Study

Loading 3-11 hours after paving



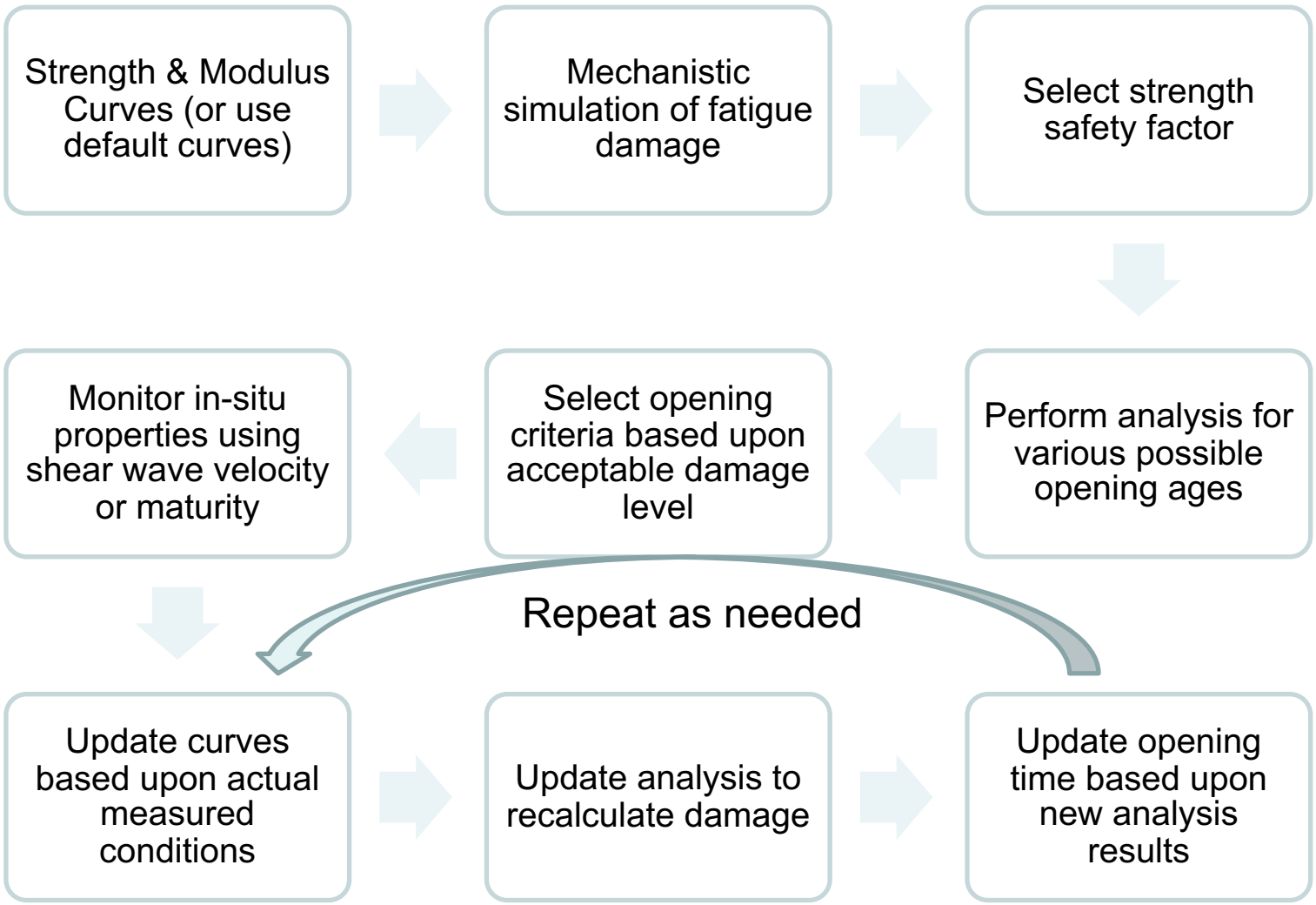
No visible damage!

Van Deusen et al, 2018

Project Tasks

- Task A: Literature review
- Task B: Laboratory and field testing
- Task C: Develop mechanistic-empirical model
- Task D: Conduct traffic simulation
- Task E: Final Report

Mechanistic-Empirical Model



Potential Project Benefits

- Reduction of construction time and cost
- Reduction of traffic congestion and user cost