

DEVELOPMENT
OF SIMPLIFIED MECHANISTIC-EMPIRICAL
DESIGN TOOL
FOR PENNSYLVANIA RIGID PAVEMENTS
(PITTRIGID-ME)

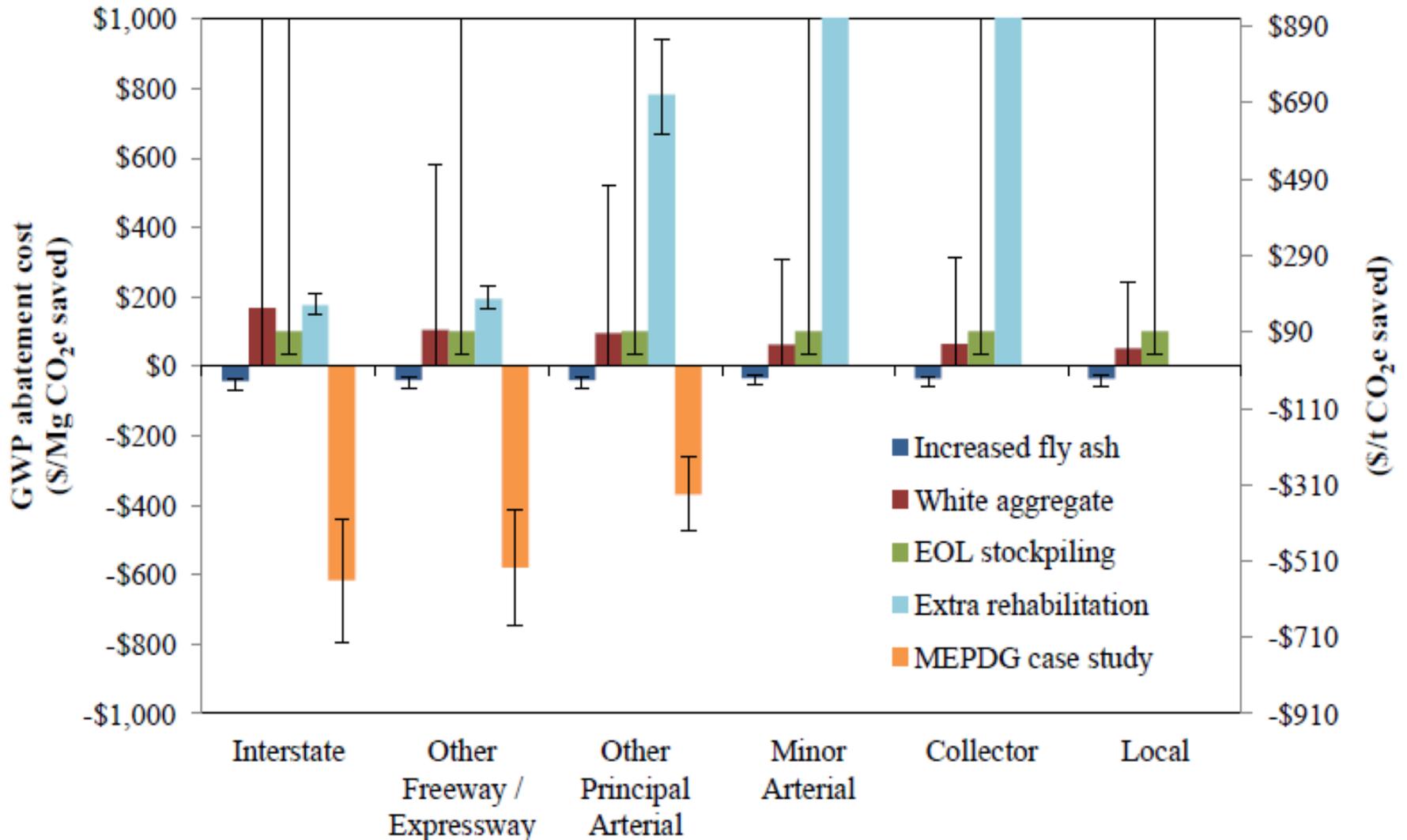
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THE PROBLEM

- The current Pennsylvania design method for rigid pavements is outdated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 transitioning 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 an expensive license

WHY AASHTO ME DESIGN?



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

AASHTOWARE PAVEMENT ME

Dashboard

The screenshot shows the AASHTOWARE PAVEMENT ME software interface. The main window displays project information for 'ATPB+2A Subbase:Project'. The interface is divided into several key areas:

- Project control panel:** Located on the left, it features a tree view of the project structure, including Traffic, Climate, JPCP Design Properties, Maintenance Strategy, and various calibration factors and tools.
- Design criteria:** A table at the top right lists performance metrics such as Initial IRI, Terminal IRI, and JPCP transverse cracking, with columns for Limit, Reliability, and Report Visibility.
- Project information:** A central panel provides details about the project, including design type (New Pavement), pavement type (Jointed Plain Concrete Pavement), design life (20 years), and construction details like June paving and September traffic opening.
- Pavement layers layout:** A vertical stack of three images shows the cross-section of the pavement layers: Layer 1 (PCC), Layer 2 (Flexible asphalt concrete), and Layer 4 (Subgrade). Each image has a 'Click here to edit' link.
- Dialog area:** On the right side, there is a metadata section for 'Identifiers' with fields for Approver, Date approved, Author, Date created, County, Description, Direction of travel, Display name/identifier, District, From station, Item Locked?, Highway, Revision Number, State, To station, and User defined fields.
- Error List:** At the bottom, an error list table shows a warning for 'ATPB+2A Subbase' regarding an asphalt binder calculation error.

Project control panel

Project information

Design criteria

Pavement layers layout

Dialog area

RESEARCH OBJECTIVES

- Provide effective, localized design tool to Pennsylvania pavement engineers compatible with the AASHTOWare Pavement ME program similar to MnPAVE Rigid, the tool used by MnDOT
- Accelerate implementation of the AASHTO Mechanistic-Empirical Pavement Design Guide (MEPDG)
- Reduce potential of design errors from the improper use of the AASHTOWare Pavement ME software
- Reduce or eliminate license fees required to perform MEPDG design using the AASHTOWare Pavement ME software

MNPAVE RIGID

Main | Load Spectra Selector | Design Values | About | Defaults 

Project: test Designer: ---

Filepath: E:\MPRI

Notes: ---

Design life, years: 35 Climate by district: D1

Two-way HCADT: 1000 Linear yearly growth, %: 1

Number of lanes (two-way): 2

Axle load spectra: MnDOT WIM Average Complete Load Spectra Selector tab to modify axle load spectra

Base type: Class 5 Aggregate Base thickness, inches: 4

Widened outer lane?: Yes Joint spacing, feet: 12

Shoulder type: HMA, Untied PCC, or Aggregate

Application started

Main | Load Spectra Selector | Design Values | About | Defaults 

MEPDG Design Features							
Climate	Curl/Warp Eff Temp Diff	Sealant Type	Joint Design		Base Properties		
			Dowel Diameter	Dowel Spacing	Erodibility Index	PCC-Base Interface	Loss of Friction
MN Districts	-10	Liquid	1, 1.25, or 1.5 (MnDOT spec)	12	Erosion Resistant (3)	Full friction contact	360

MEPDG Structure - Layer 1 - JPCP							
PCC General			PCC Thermal		PCC Mix		
Unit Weight	Poisson's Ratio	COTE	Thermal Conductivity	Heat Capacity	Cement content	W/C Ratio	Aggregate
150	0.2	5	1.25	0.28	500	0.40	Limestone

MEPDG Structure - Layer 2 - Base					
Material	Thickness	Strength Properties - Level 3			Notes
		Poisson's	CoLP, Ko	Modulus	
Class 5	4 or 12	0.35	0.5	35640	MnDOT gradation; modulus from MnDOT lab
Class 5 Quality	4 or 12	0.35	0.5	45000	MnDOT gradation; MnDOT est. modulus
Open-Graded Agg	4 or 12	0.35	0.5	45000	MnDOT gradation; MnDOT est. modulus

MEPDG Structure - Layer 3 - Subbase					
Material	Thickness	Strength Properties - Level 3			Notes
		Poisson's	CoLP, Ko	Modulus	
A-3	12 or 4	0.35	0.5	18350	Values est Select Granular; modulus from MnDOT lab; composite base thickness 16 in. avoids EICM issues

MEPDG Structure - Layer 4 - Subgrade				
Material	Thickness	Strength Properties - Level 3		
		Poisson's	CoLP, Ko	Modulus
A-6	Semi-infinite	0.35	0.5	14000

APPROACH - TASKS

Task 1. Literature and Software Review and Sensitivity Analysis

Task 2: Perform Pavement ME Factorial and Develop Simplified Design Tool, PittRigid-ME

Task 3: Conduct PittRigid-ME Verification

Task 4: Final Report

PROGRESS TO DATE

- Evaluated relevant literature dealing with Pavement ME inputs and sensitivity studies
- Performed preliminary sensitivity study and evaluated relative significance of the inputs for Pennsylvania conditions
- Recommended design features for PittRigid-ME

PAVEMENT ME INPUTS

- Traffic
 - Annual Average Daily Truck Traffic (AADTT)
 - Vehicle class distribution
 -
- Climate (weather stations)
- JPCP Design Features
 - PCC thickness
 - Joint spacing
 - Shoulder type
 - Dowel diameter
 - Base type and thickness

PAVEMENT ME TRAFFIC INPUTS

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

AA DTT

Two-way AADTT 2000

Number of lanes 4

Percent trucks in design dir: 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 axl: 17

Average spacing of short axl: 12

Identifiers

Approver

Date approved 1/1/2011

Author AASHTOWare

Date created 1/1/2011

County

Description of object Default Traffic File

To station (miles)

Traffic Capacity Cap

Vehicle Class Distribution and Growth

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

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)

Axes 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

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 Factor (HAF)

Basic design lane and traffic configuration

Axle spectrum distribution

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

Approver

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

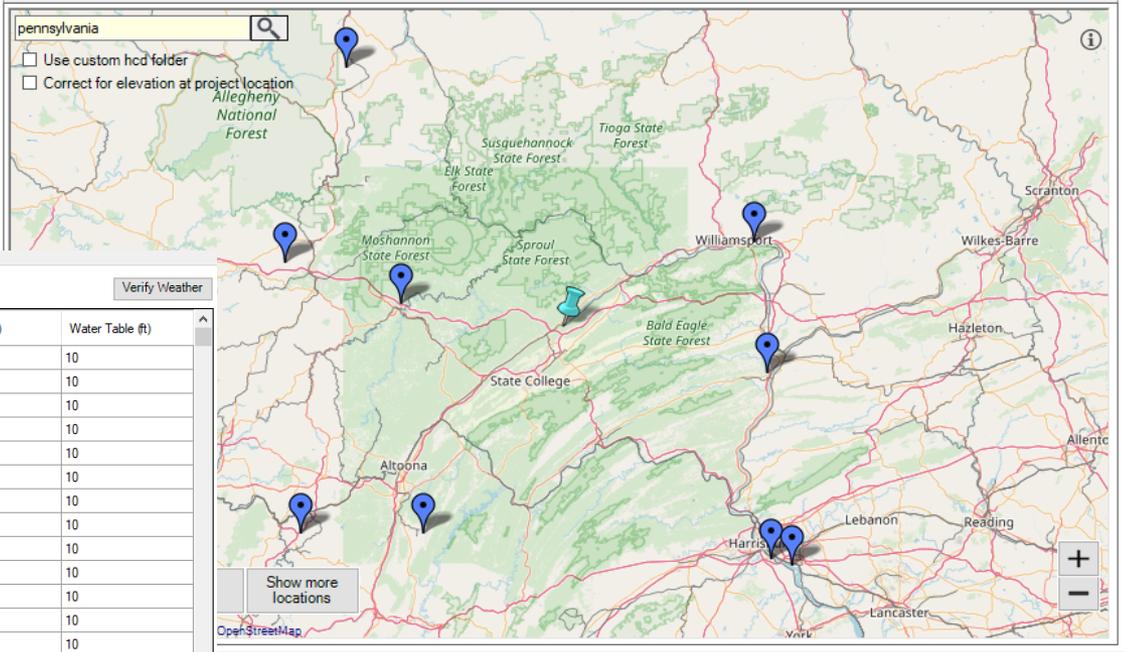
Summary Hourly climate data

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
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Summary Hourly climate data

January /1979 to June /2015

Verify Weather

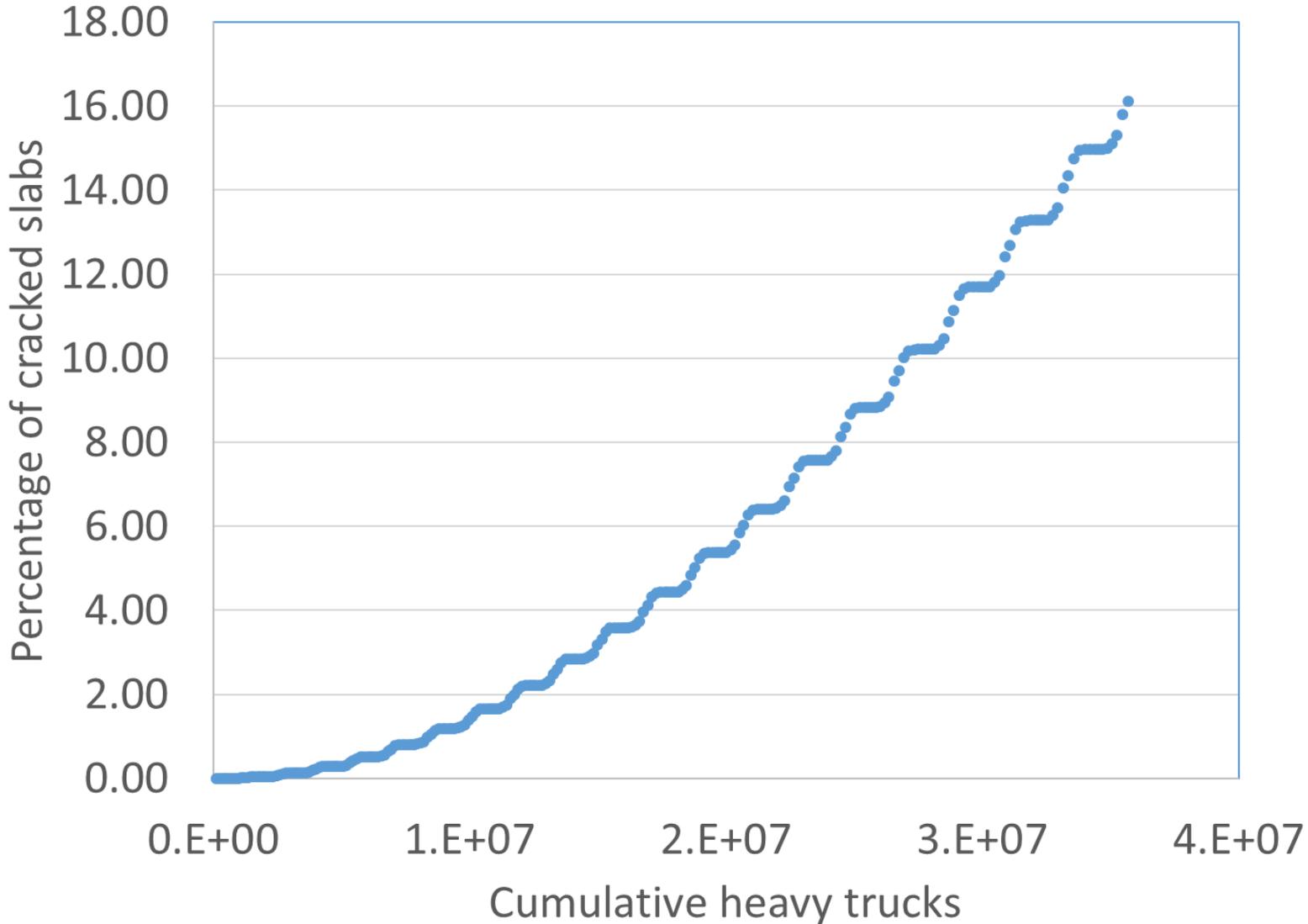
Date/Hour	Temperature (deg F) (deg F)	Wind Speed (mph)	Sunshine (%)	Precipitation (in.)	Humidity (%)	Water Table (ft)
1/1/1979 12:00:00 AM	39.4	18	0	0	93	10
1/1/1979 1:00:00 AM	39.7	19	0	0.05	93	10
1/1/1979 2:00:00 AM	39.4	19	0	0	92	10
1/1/1979 3:00:00 AM	39.2	19	0	0	92	10
1/1/1979 4:00:00 AM	38.8	19	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

SENSITIVITY ANALYSIS

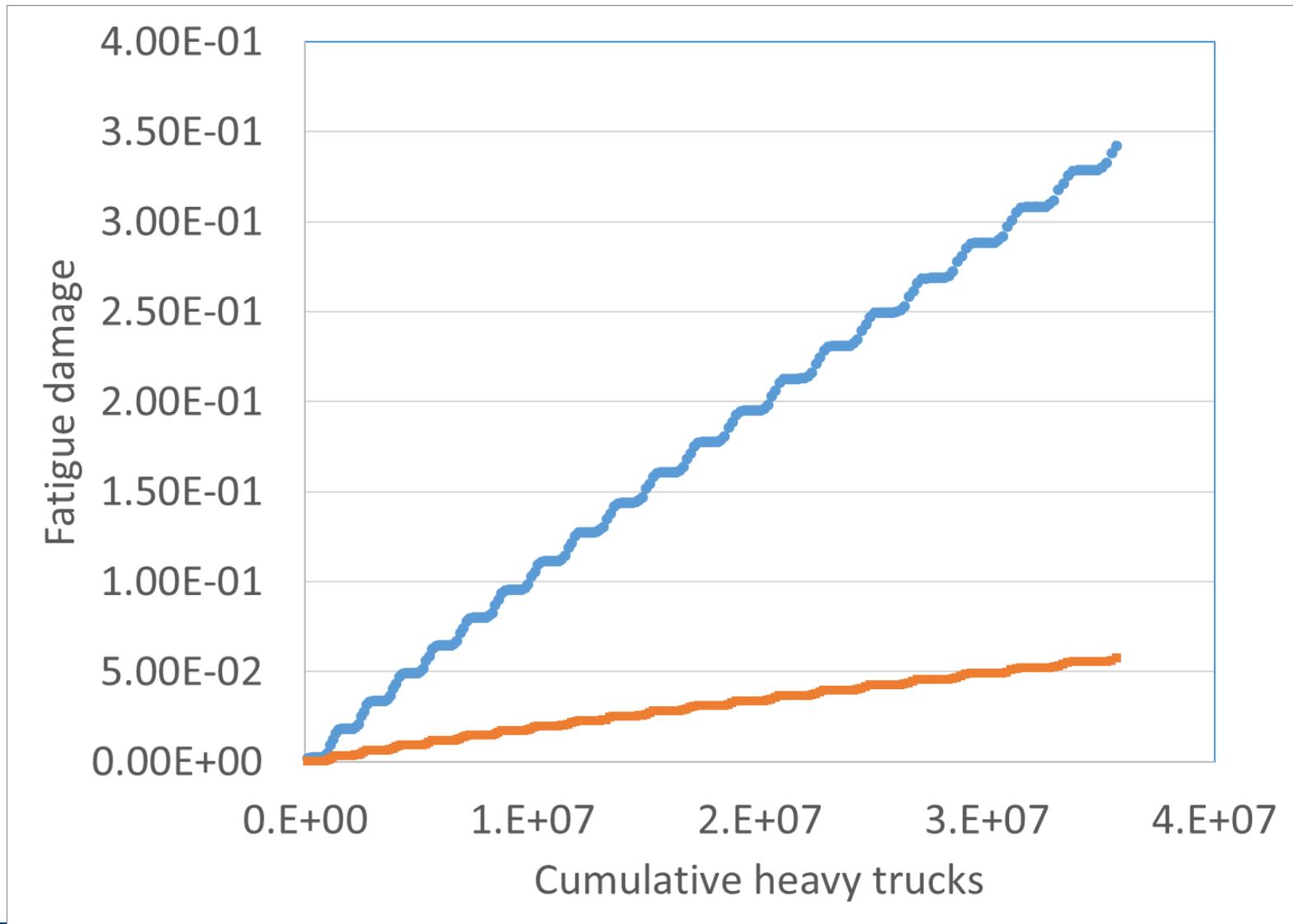
More than 100 Pavement ME runs

- 7-in thick Jointed Plain Concrete Pavement
- 9-in thick Jointed Plain Concrete Pavement

SENSITIVITY ANALYSIS



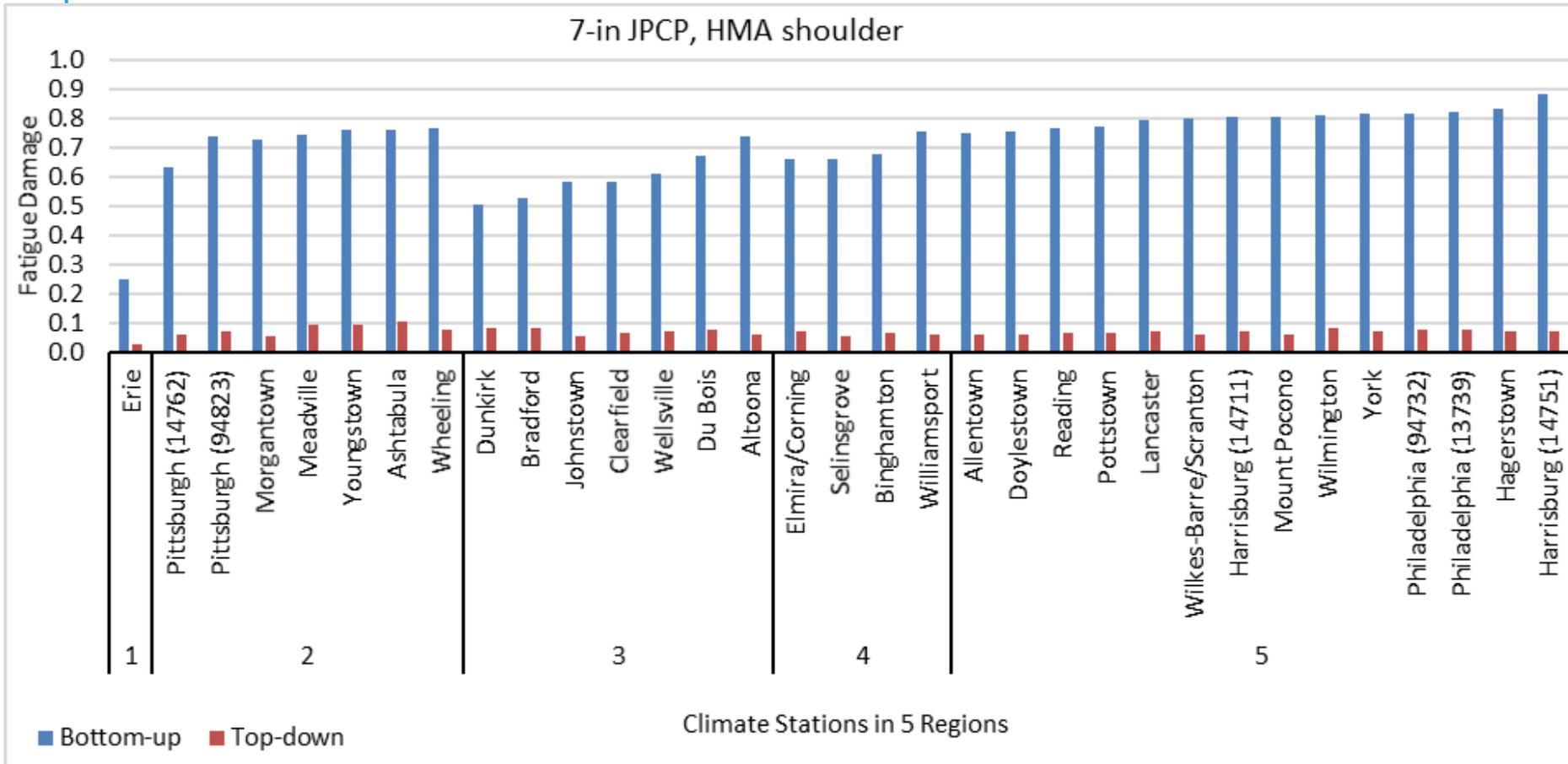
SENSITIVITY ANALYSIS



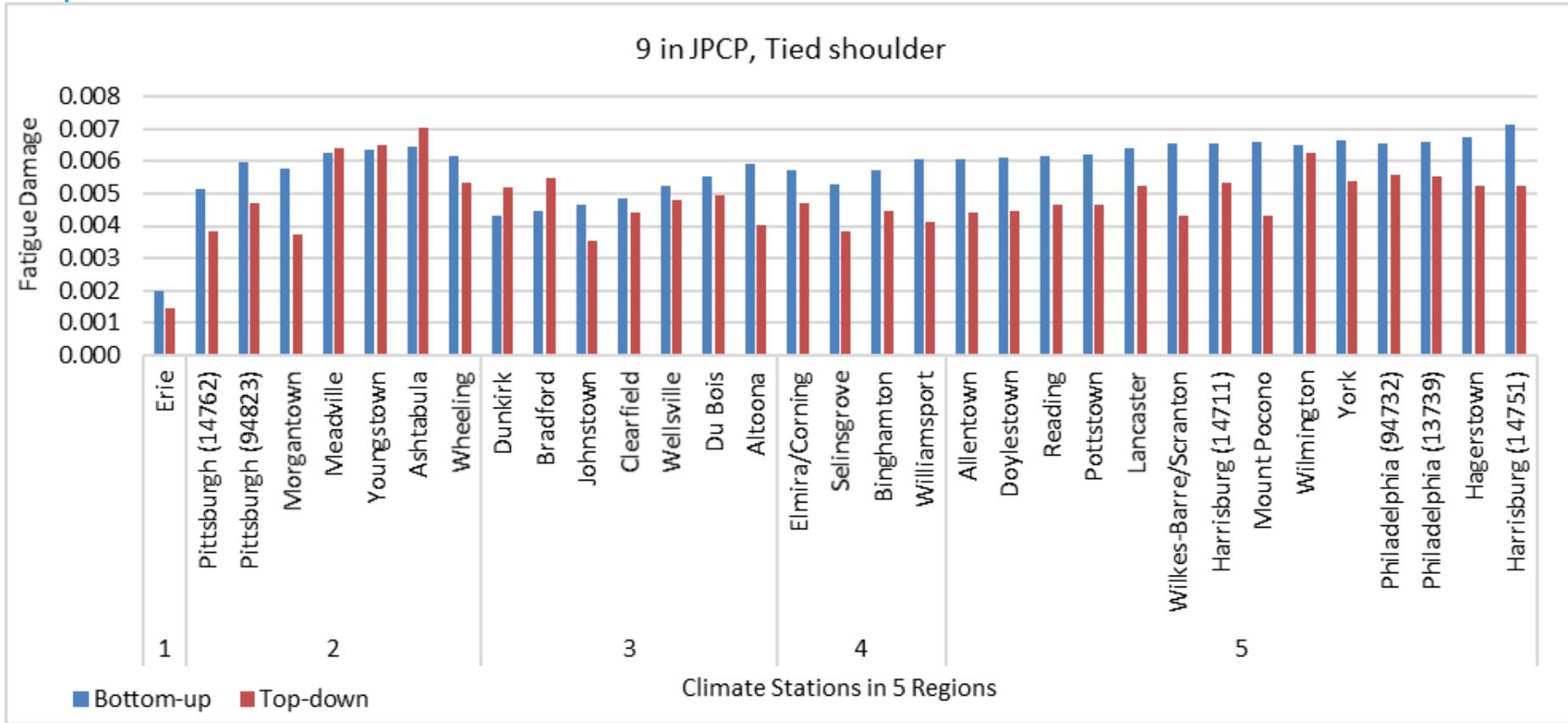
CLIMATE INPUTS



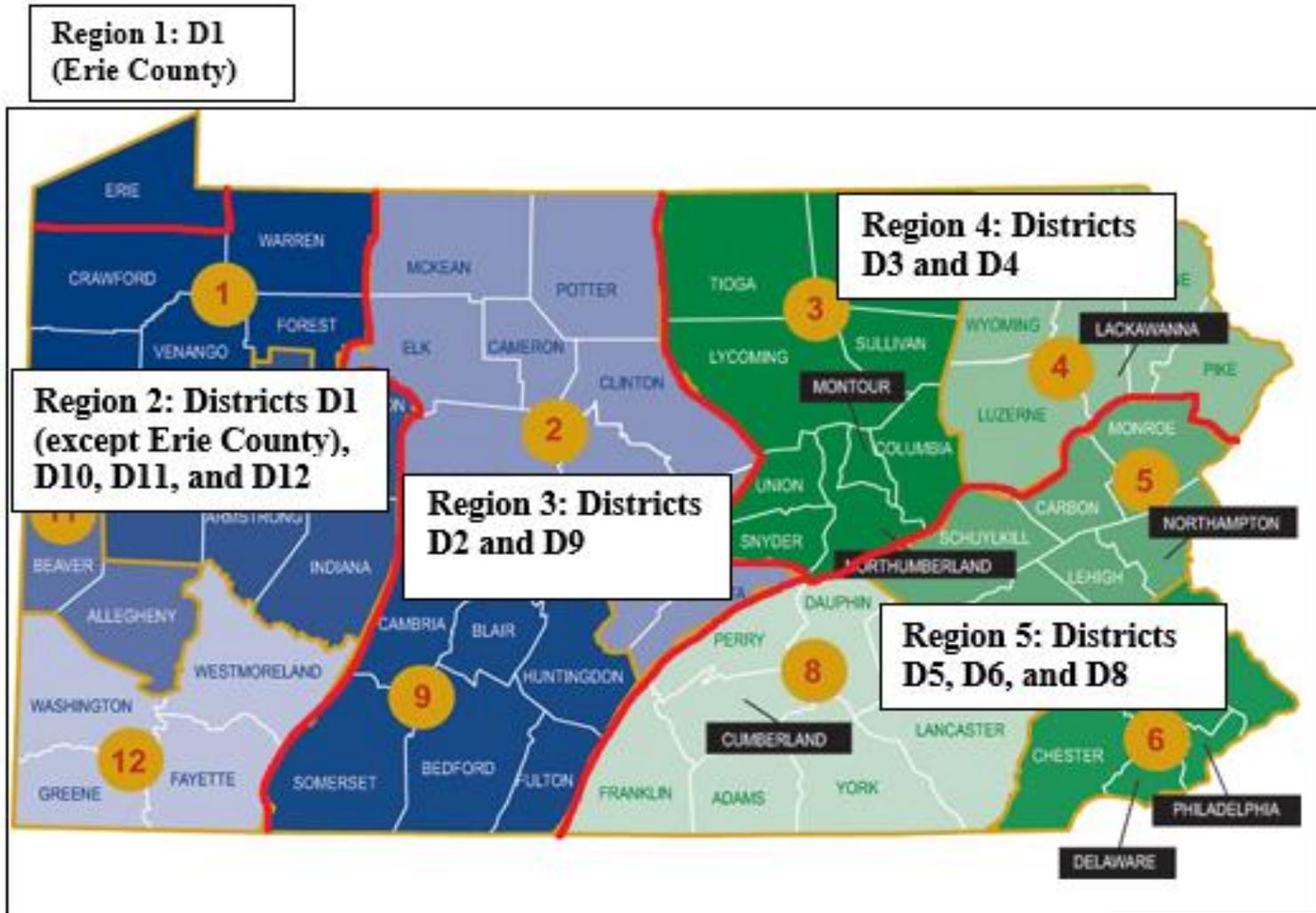
CLIMATE INPUTS



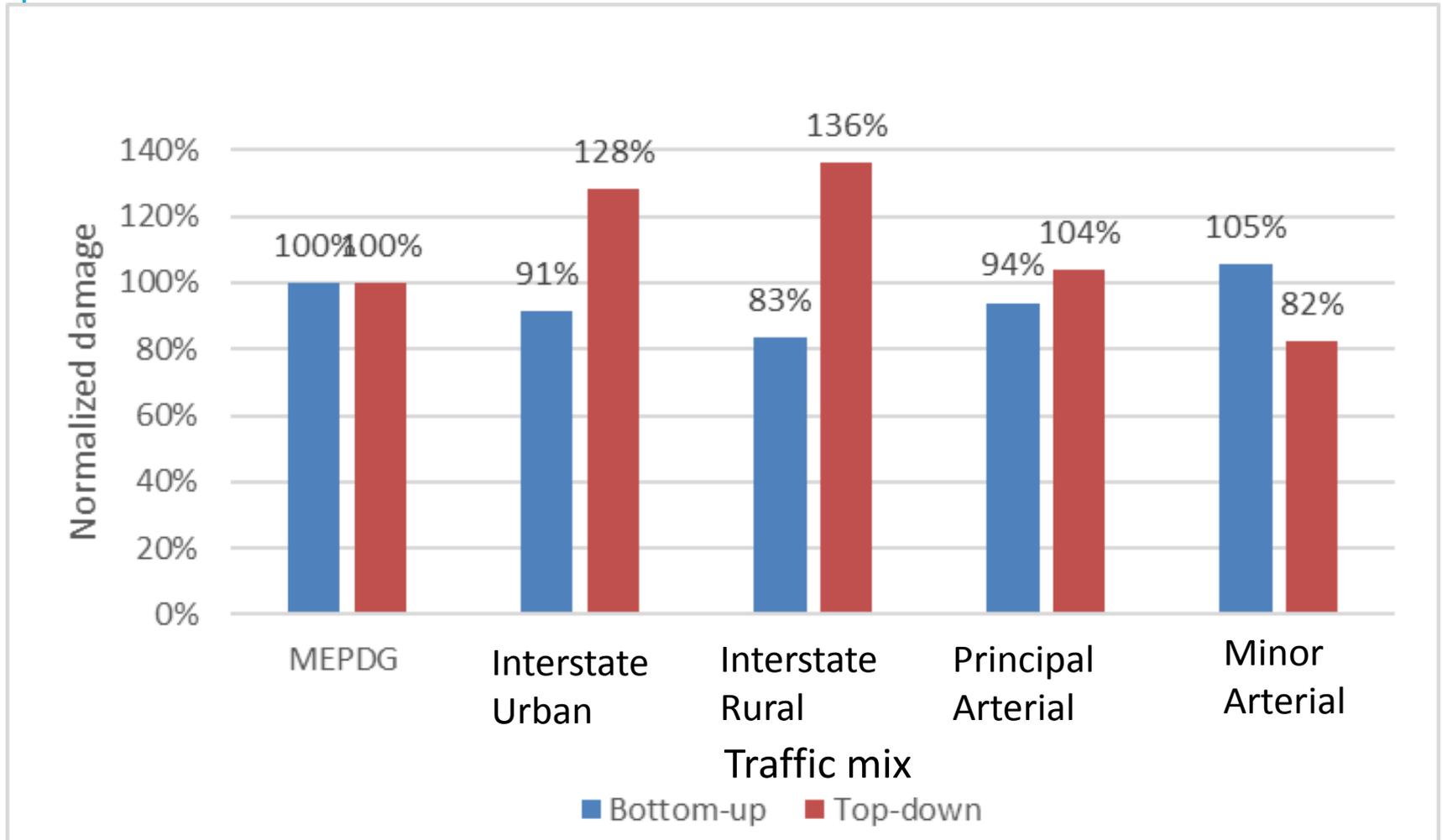
CLIMATE INPUTS



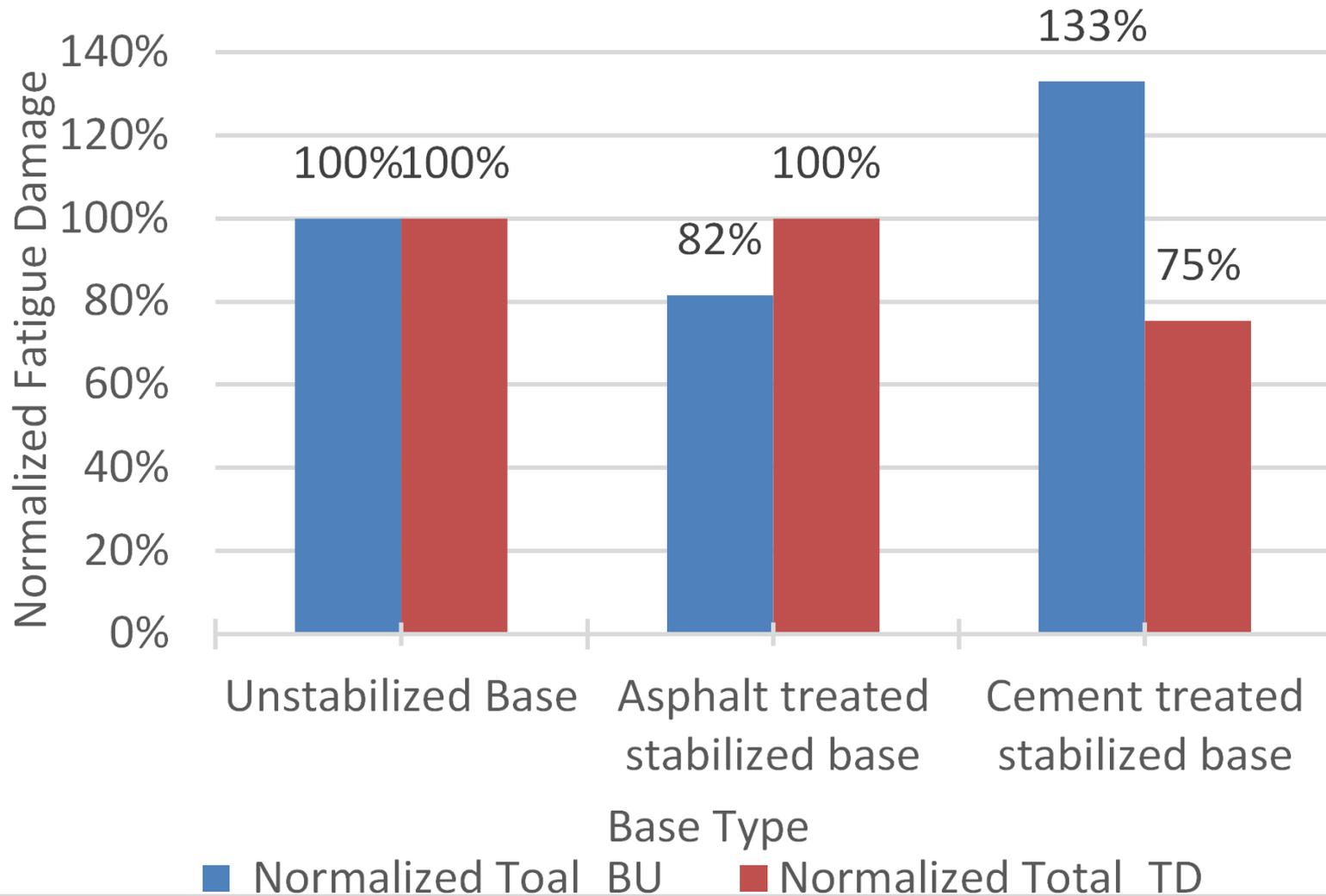
CLIMATE INPUTS RECOMMENDATIONS



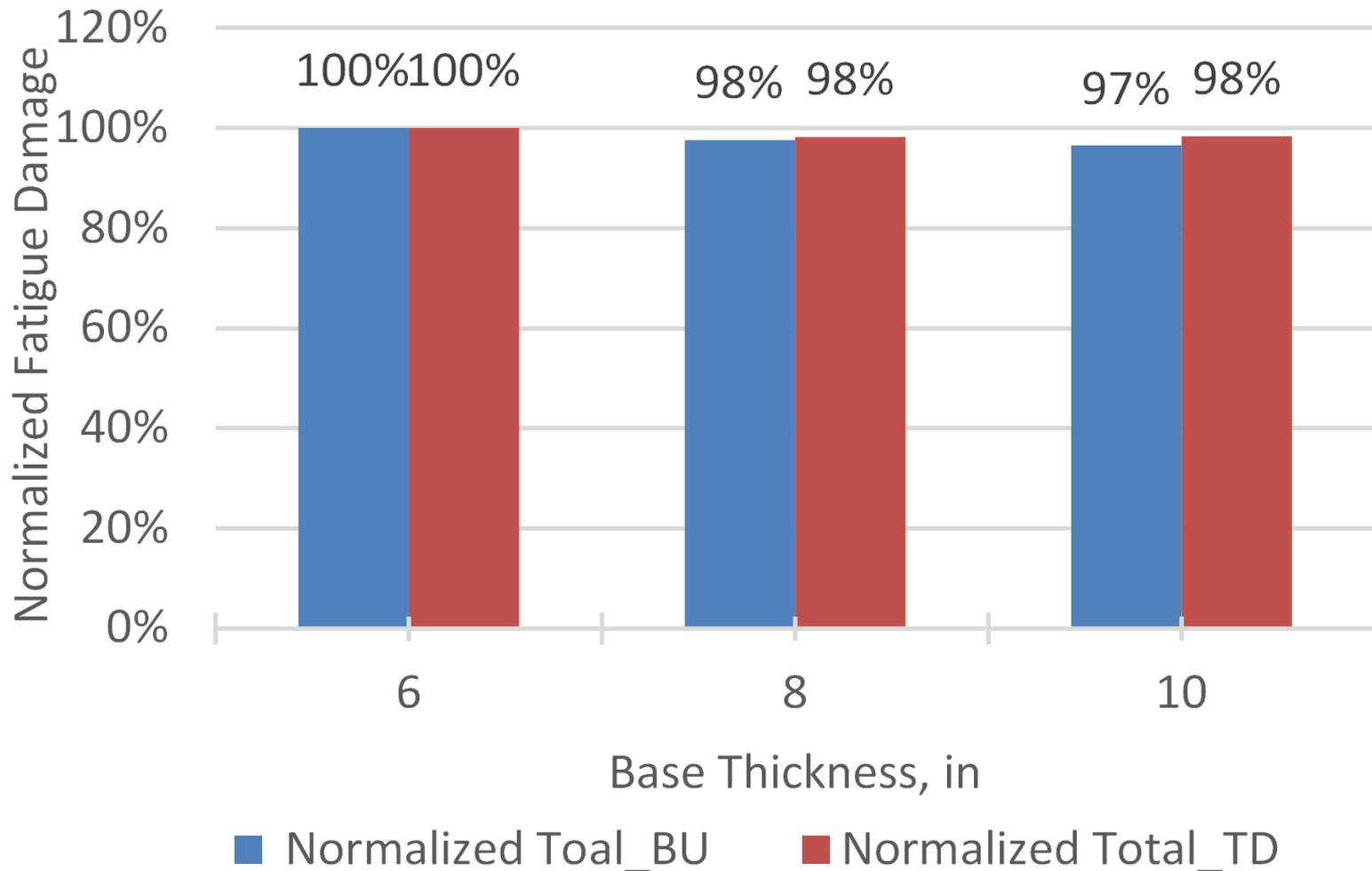
TRAFFIC INPUTS



EFFECT OF BASE TYPE



EFFECT OF BASE THICKNESS



RECOMMENDED PITTRIGID-ME DESIGN INPUTS

- Design life: 1-100 years
- Climate Regions
 - Region 1: Erie County
 - Region 2: PennDOT Districts D1 (except Erie County), D10, D11, and D12
 - Region 3: PennDOT Districts D2 and D9
 - Region 4: PennDOT Districts D3 and D4
 - Region 5: PennDOT Districts D5, D6, and D8

RECOMMENDED PITTRIGID-ME DESIGN INPUTS (CONT.)

- Two-way AADTT: 0-10000
- Yearly 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.)

- Shoulder type
- Concrete slab width
- Base type

PITTRIGID-ME OUTPUT

- Required concrete slab thickness
- Required dowel diameter

NEXT STEPS

- Perform more than 50,000 Pavement ME simulations
- Screen the output files for predicted:
 - Fatigue damages at the bottom and top surfaces of the concrete slab
 - Differential energy of subgrade deformation
- Develop procedures for predicting cracking and faulting for various levels of traffic and concrete strength
- Develop procedures for thickness and dowel diameter prediction

SCHEDULE

	Year 1												
	Months	1	2	3	4	5	6	7	8	9	10	11	12
Task 1: Literature and Software Review and Sensitivity Analysis		█	█	█	█								
Task 2: Develop PittRigidME						█	█	█	█	█			
<i>Deliverable: An alpha-version of PittRigidME</i>											█		
Task 3: Conduct PittRigidME verification												█	
<i>Deliverable: A Memo comparing PittRigidME and PavementME</i>												█	
Task 4: Final Report												█	█
<i>Deliverable: Final Report and the final version of the software</i>													█

APPLICATION OF RESEARCH PRODUCT

- Design of new concrete pavements
 - Implementation of the AASHTO ME design procedure for concrete pavements in Pennsylvania without software license fees
 - Simplification of design and reduction of design errors
- Pavement type selection
- Improvement/local calibration of AASHTO ME for Pennsylvania conditions