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

Lev Khazanovich, Anthony Gill Professor Haoran Li, graduate student

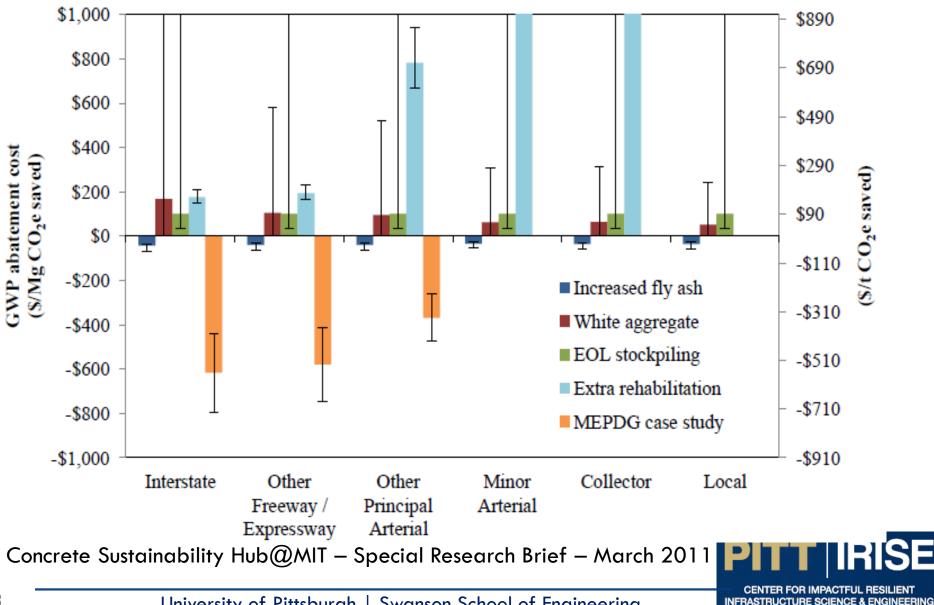


THE PROBLEM

The current Pennsylvania design method for rigid pavements is outdated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?



AASHTOWARE PAVEMENT ME

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Recent Files *	Batch Import Export Undo Redo Help	-11			• X	Stop All An	alysis
Projects	ATPB+2A Subbase:Project General Information	Ferformance Criteria		Limit Reliability F	Report Visibility		
	Design type: New Pavement ~	t ial IRI (in/mile)					
Single Axle Distribution	Pavement type: Jointed Plain Concrete Pavement (JPCP) V	eminal IRI (in/mile)		175 90			
Tandem Axle Distribution	Design life (years): 20 ~	CP transverse cracking (percent slabs)		10 90			
Tridem Axle Distribution Quad Axle Distribution	zu v			0.12 00			
Climate	Pavement construction June V 2021 V			0.12 00	C		
JPCP Design Properties			cian aritoria				
ia-ia Pavement Structure → Layer 1 PCC : JPCP Default	Traffic opening: September ~ 2021 ~		esign criteria				
Layer 2 Flexible : Default asphalt concrete	Special traffic loading for flexible pavements		_				
Layer 3 Non-stabilized Base : Permeable aggregate	🕂 🚰 Add Leyer 😂 Nemere Leyer						
Layer 4 Subgrade : A-6	Project						
Project Specific Calibration Factors							
- New Flexible	inform						
	informe	dtion base			~		
		/ Identifiers					
	Click here to edit Layer 1 PCC : JPCP Default	Approver					
Optimization		Date approved Author	2/12/2019 2:09 PM				
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E Tools		Description of object Direction of travel					
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		District From station (miles)					
- Automatic Updater Configuration Settings	Click here to edit Layer 3 Non-stabilized Base : Permeable aggree	Item Locked?	False				
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4

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 Des	ign Values About	Defaults DOT	Main	Load Sp	ectra Sele	ector Design Va	alues	About D	efaults	DOT
Project test	Desig	ner								
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Filepath			C !! .	Curl/Warp	Sealant	Joint Des	<u> </u>	Ba	ise Properties	
Notes			Climate	Eff Temp Diff	Туре	Dowel Diameter	Dowel Spacing	Erodibility Inde	x PCC-Base Interface	Loss of Friction
			MN Districts	-10	Liquid	1, 1.25, or 1.5 (MnDOT spec)	12	Erosion Resistar (3)	t Full friction contact	360
Design life, years 35	Climate by	/ district D1 🔹								
						MEPDG Struc		r 1 - JPCP		
		1 0/ 1		C General		PCC Ther		eat Cement	PCC Mix	
Two-way HCADT 1000	Linear yearly gr	owth, %	Unit Weight	Poisson's Ratio	' co	DTE Conducti		eat Cement acity content	W/C Ratio	Aggregate
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	Gundati	Land Caracter Calanter to b				MEPDG Struc	ure - Laye	r 2 - Base		
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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

	Vehicle Class Distrib	ution and Growth					Load Default Distribu	tion	Hourly Adjustment	1
AADTT		Deather	(9:)	C	0.45				Time of Day	Percentage
Two-way AADTT 2000	Vehicle Class	Distributio	n (%)	Growth Rate (%)	Growth Fund				12:00 am	2.3
Number of lanes 🖌 4	Class 4	3.3		2	Linear	~	-00-0	_	1:00 am	2.3
Percent trucks in design dire 50	Class 5	34		2	Linear	\sim	L , E,			
Percent trucks in design lan 🗹 95	Class 6	11.7		-		~	La B		2:00 am	2.3
Operational speed (mph)	Class 7	1.6	nnual	growth	rato	~			3:00 am	2.3
Traffic Capacity Traffic Capacity Cap		9.9	linioai	growin	Tule	~	Þ	_	4:00 am	2.3
Axle Configuration				-			0 0 0	_	5:00 am	2.3
Average axle width (ft)	Class 9	36.2		2	Linear	~		_	6:00 am	5
Tandem axle spacing (in) 🗹 51.6	Class 10	1		2	Linear	\sim				-
Dual tire spacing (in) 12	Class 11	1.8		2	Linear	~			7:00 am	5
Quad axle spacing (in) 49.2	Class 12	0.2		2	Linear	~			8:00 am	5
Tire pressure (psi) 120		0.2		2	Lincar	-	പ പംപം പ	~	9:00 am	5
Tridem axle spacing (in)	Monthly Adjustment						Import Monthly Adjust	stmen	10:00 am	5.9
Design lane width (ft) 12	Month Class 4	Class 5	Class 6 Cla	ss 7 Class 8	Class 9 Class 1	Class 11	Class 12 Class 13		11:00 am	5.9
Mean wheel location (in) 18		Class o		ss 7 Class 8	Class 9 Class 1		Class 12 Class 13	_		
Traffic wander standard devi 🖌 10	January 1	1	1 1	1	1 1	1	1 1		12:00 pm	5.9
Wheelbase	February 1	1	1 1	1	1 1	1	1 1		1:00 pm	5.9
Average spacing of long axl 18	March 1	1	1 1	1	1 1	1	1 1		2:00 pm	5.9
Average spacing of medium 🖌 15	April 1	1	1				1		3:00 pm	5.9
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Percent trucks with short ax 17	indy i	1		-	-	•			4:00 pm	
Average spacing of short ax 🖌 12	June 1	1		actor (N	AAF)		1		5:00 pm	4.6
Identifiers	July 1	1	1				1		6:00 pm	4.6
Approver	August 1	1	1 1	1	1 1	1	1 1		7:00 pm	4.6
Date approved 1/1/2011	September 1	1	1 1	1	1 1	1	1 1		8:00 pm	3.1
Author AASHTOWare		1.			· ·			· ·		
County	Axies Per Truck								9:00 pm	3.1
Description of object Default Traffic File	Vehicle Class	Single		Tandem	Tridem	G	ad	^	10:00 pm	3.1
	Class 4	1.62		0.39	0	0			11:00 pm	3.1
Basic design lane	Class 5	2		0	0	0			Total	100.0
-	Class 6	1.02		0.99	0	0				
and traffic				-	-			_		v Adjustmer
	Class 7	1		0.26	0.83	0		_	поону	Aujusimer
configuration	Class 8	2.38		0.67	0	0			Factor	
	Class 9	1.13		1.93	0	0			Factor	
To station (miles)	✓ Class 10	1.19		1.09	0.89	0				
raffic Capacity Cap	Class 11	4.29		0.26	0.06	0				
	Class 12	3.52		1.14	0.06	0		_		
				0.10						

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10

PAVEMENT ME CLIMATE INPUTS

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	✓ Climate S	tation	✓ 1240				
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		(decimal degrees)	-79.92			Mean annual precipitation	
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	Date create	ed	2/12/2019 2	-09 PM			
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	Direction o	f travel					
		me/identifier				pennsylvania	
	District					The second second	
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1/1/1979 7:00:00 AM			0	0.12	92	10	Lebanon Reading
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1/1/1979 9:00:00 AM			0	0	88	10	Show more
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1/1/1979 11:00:00 AM	-		0	0	86	10	OpenStreetMag
1/1/1979 12:00:00 PM			0	0	86	10	
1/1/1979 1:00:00 PM	41.7		0	0.07	86	10	
1/1/1979 2:00:00 PM	41.9		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	PITT IRISE
		-			-		

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PAVEMENT ME JPCP DESIGN INPUTS

	JPCP Design				
General JPCP inputs	PCC surface shortwave absorptivity	ſ	✓ 0.85		
	Doweled joints	-		2), Diameter(1.25)	
	Erodibility index		Erosion res		
	PCC-base contact friction			sistant (3) with friction loss at (0) months	
				with metion loss at (U) months	5
/ /?.	PCC joint spacing (ft)		15 ✓ -10		
• ///	Permanent curl/warp effective temperature diffe			dia No Contrat Limited Cit	·>
	Sealant type			uding No Sealant Liquid Sil	-
///~				ong term load transfer efficienc	cy of 50
///	Tied shoulders				
///	Load transfer efficiency (%)		✓ 50 Not widene		
▶ / / ≧	Widened slab		NOT WIDENE	;u	
✓ Doweled joints		Spacing(12), Diameter(1.25)			
Dowel diameter (in)		✓ 1.25			
Dowel spacing (in)		✓ 12	Dowe	<mark>el bar design</mark>	
Is joint doweled ?		True			
✓ / /					
✓ PCC-base contact friction		Full friction with friction loss at (0)	months	PCC-base bonding	1
PCC-Base full friction contact		True		Ŭ	
Months until friction loss		✓ 0		conditions	
Unbonded JPCP		False			
* /					
 PCC joint spacing (ft) 		15			
Is joint spacing random ?		False			
Spacing of Joint 1			laint	spacing	
Spacing of Joint 2			Joint	spacing	
Spacing of Joint 3					
Spacing of Joint 4					1
Joint spacing (ft)		✓ 15	_		
 Tied shoulders 		Tied with long term load transfer eff	ficiency of	50	
Tied shoulders		True			
Load transfer efficiency (%)		50		Shoulder type and	
✓ Widened slab		Not widened			
Is slab widened ?		False		ane width	
Slab width (ft)		✓			
May 12, 2019	University of Pittsburg	h Department of Civil a	and En	vironmental Engine	Perina
					comy
12 Univ	'e				

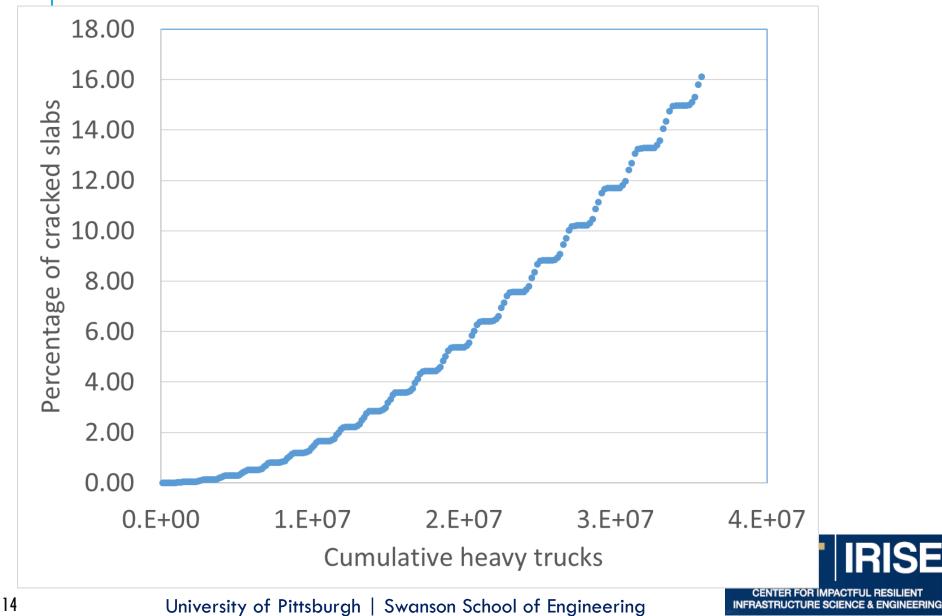
SENSITIVITY ANALYSIS

More than 100 Pavement ME runs

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

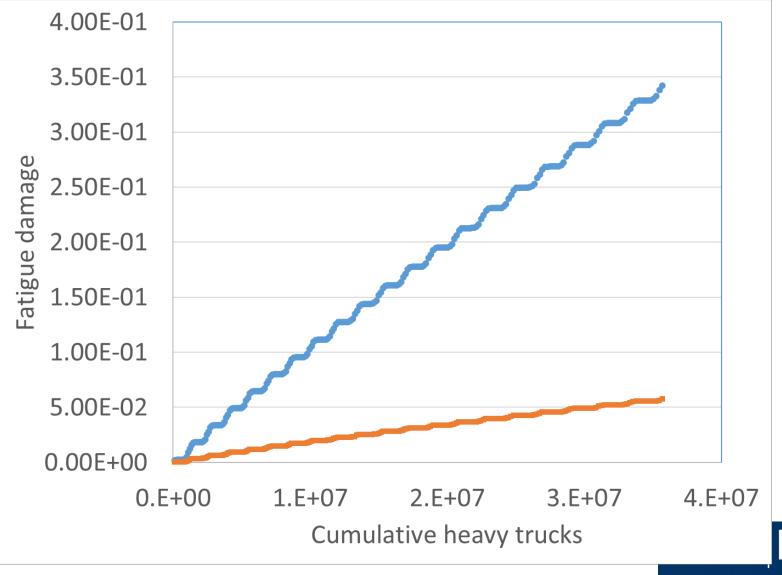


SENSITIVITY ANALYSIS



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SENSITIVITY ANALYSIS



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33

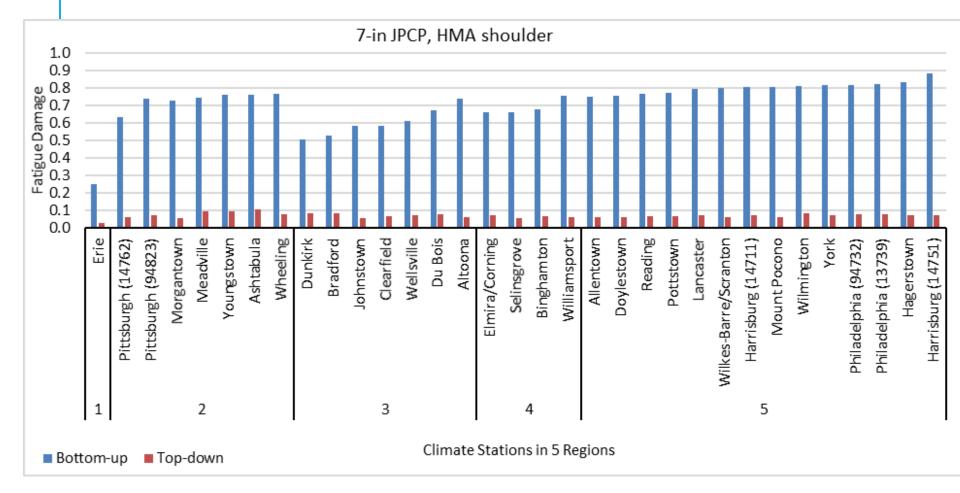
CLIMATE INPUTS



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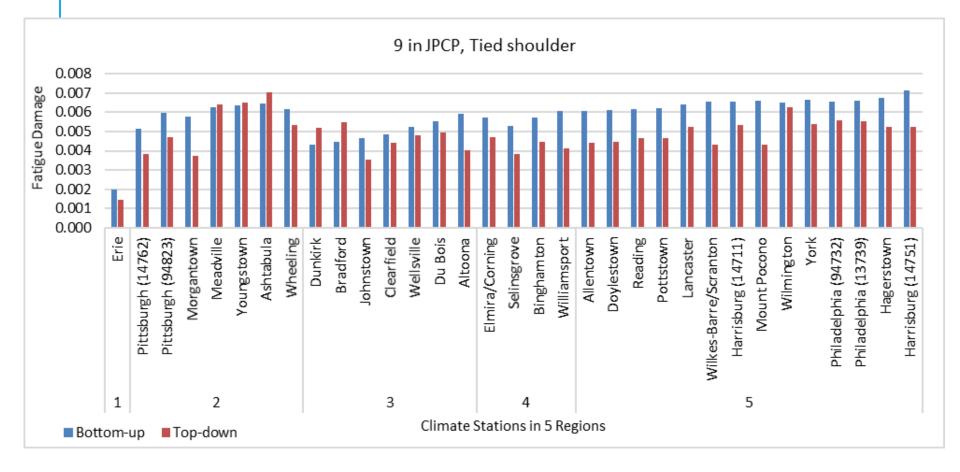
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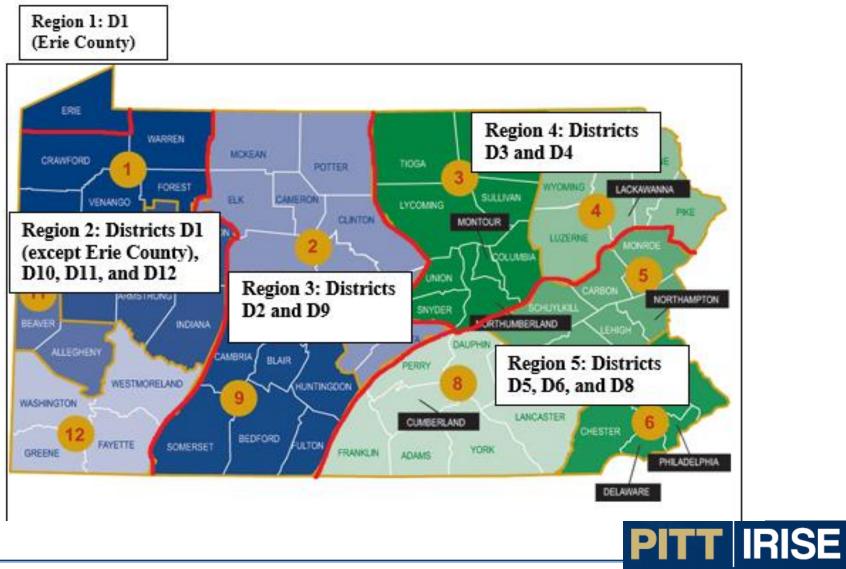


CLIMATE INPUTS



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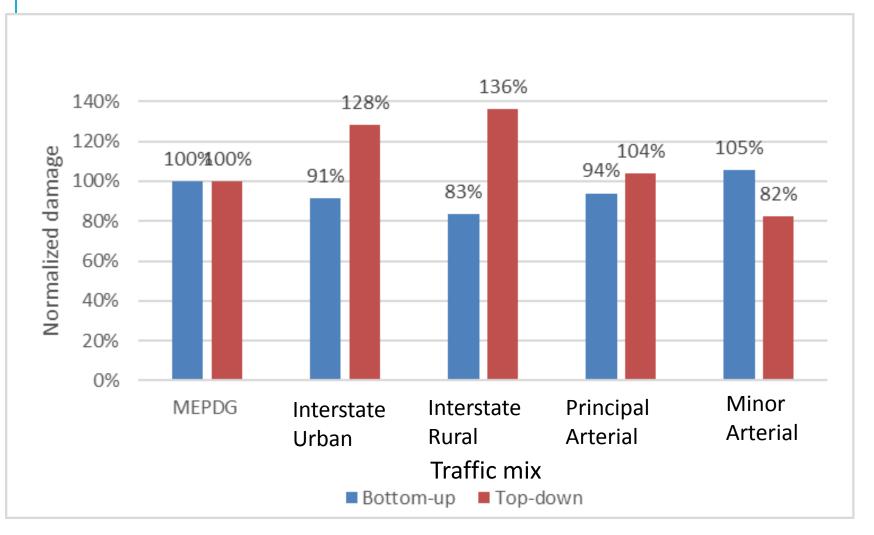
CLIMATE INPUTS RECOMMENDATIONS



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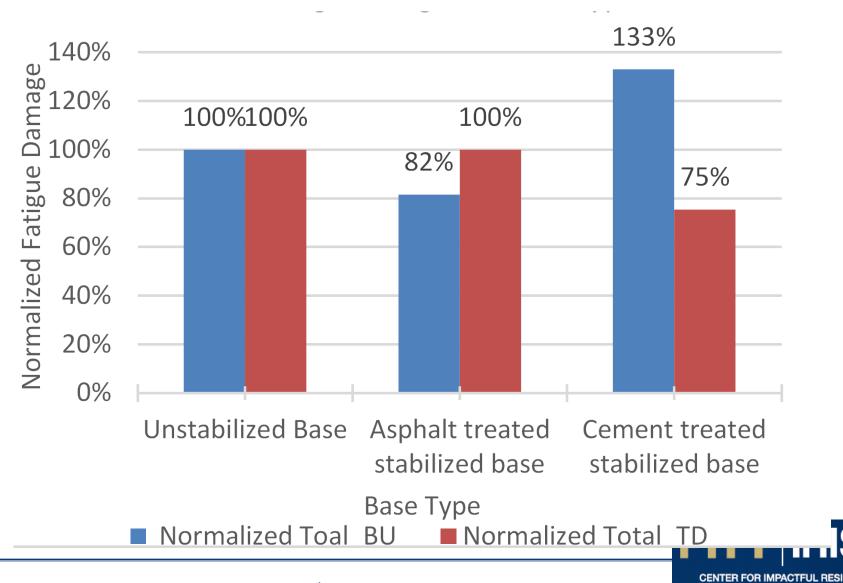
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TRAFFIC INPUTS



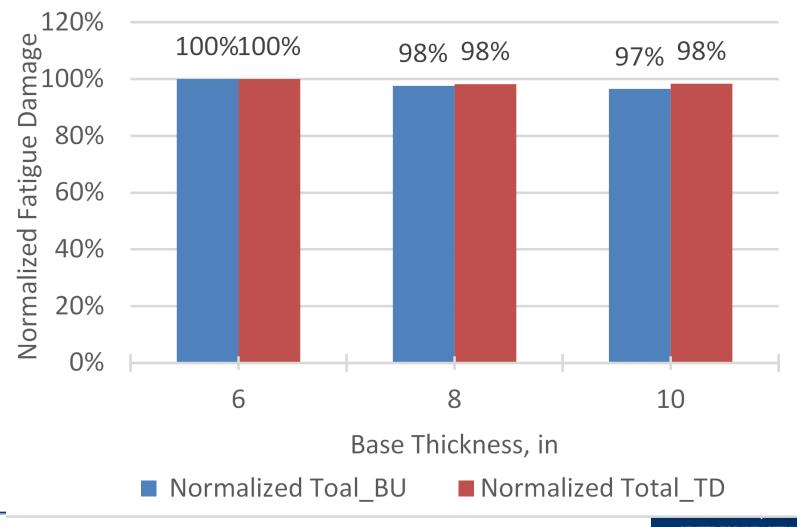


EFFECT OF BASE TYPE



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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 Eire 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 INTPUTS (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	Months 1											12
Task 1: Literature and Software Review and Sensitivity Analysis												
Task 2: Develop PittRigidME												
Delieverable: An alpha-version of PittRigidME												
Task 3: Conduct PittRigidME verification												
Delieverable: A Memo comparing PittRigidME and PavementME												
Task 4: Final Report												
Delieverable: Final Report and the final version of the software												



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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

