Sensitivity to Pavement ME Input Values (Version 2.5.4)

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Major Pavement Design Input Factors – A lot of moving parts in pavement performance prediction

- Traffic
- Subgrade
- Climate Effects
- Material Properties

Understanding the Impact of Input Variability on Pavement Design

- Many design input factors are estimated
  - Traffic
  - Climatic factors
- Others are measured, but may not be comprehensively representative of site conditions
  - Subgrade support, per CBR, Mr, or other location specific sampling technique
  - Material properties
- The accuracy of estimates are often not verified

Background for Information Presented

- Study Objective: Assessment of feasibility of using a single 50 gyration asphalt base course for all PennDOT projects
- Utilized asphalt mix E* values from Table 9.5 of PennDOT Pavement ME Design User Input Guide
- Considered the range of E* values for mixes available for other layers in asphalt pavement designs
- Considered the range of traffic levels, in-state climate conditions, and subgrade conditions

Primary Factors in ‘86 and ‘93 Guides

- Traffic
- Subgrade support
- Selection of reliability

Additional ME Factors

- More detailed input information, including
  - Improved climate modeling
  - Improved subgrade and aggregate characterization
- Viscoelastic asphalt material characterization
  - Temperature effects
  - Load Speed (test frequency)
  - Mixture properties

Study Traffic Levels Considered

Traffic	Category	Two-Directional AADTT	Vehicle Class Distribution	Axle Load Distribution Factors
1	Low	700	Minor Arterials, Collectors, and Recreational (PA TPG5 to 10)	PA Statewide Typical)
2	Medium	2,308	Other Principal Arterial (PA TPG 3 & 4)	
3	Heavy	14,920	Urban Principal Arterial-Interstate (PA TPG 1)	

Study Subgrade Stiffness Levels

Subgrade	Type	Mr (psi)
1	RMS014-A6	6,200
2	RMS025-A24	20,400
3	Stabilized	50,000

ME Analysis Parameters @ 90% Reliability, for example

- Roughness, IRI - 172 in,/mile
- Total Rut Depth - 0.5”
- Fatigue Cracking - 25% of lane area
- Low Temperature Cracking - 1,000’ per lane mile
- Top Down and Longitudinal Cracking - is not used at this time

Pavement Section Variation Used, High Traffic Level

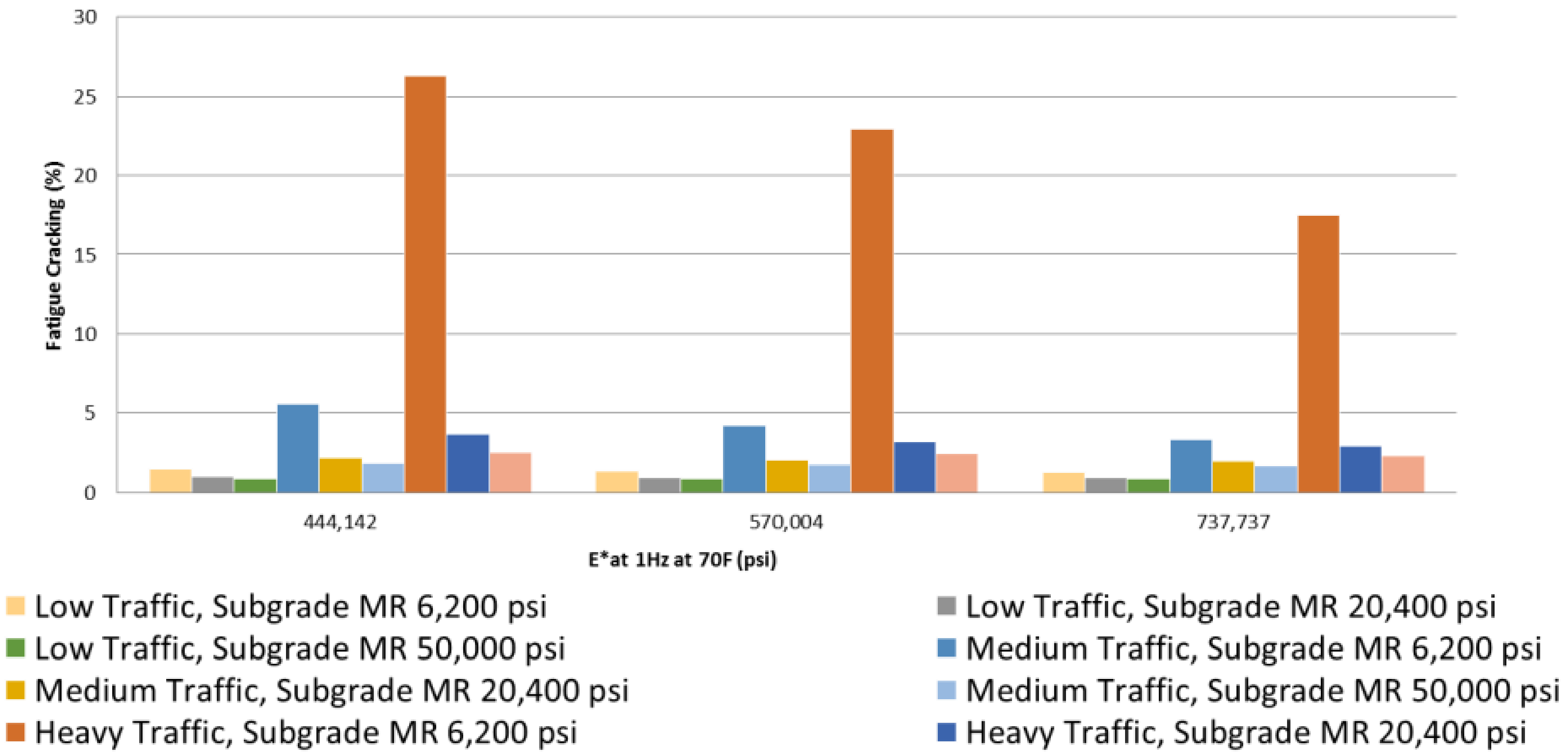
Range of Pavement Thickness

Traffic Level	Wearing	Binder	25mm AC Base	Agg. Subbase	Total AC
• Low	2”	2.5 – 3.5”	3 – 4”	6”	7.5 – 9.5”
• Medium	2”	3 – 4”	3.5 – 4.5”	6”	8.5 – 10.5”
• High	4 – 5”		5 – 6”	6”	11 – 13”

So, what is evident?

- How is a pavement design recommendation sensitive to input selection?
- Typical Relationships
  - Traffic volume
  - Subgrade support
- Additional material property different from AASHTO “93
  - Specific material properties, ie. Visoelastic behavior
    - Climate as it affects AC stiffness
    - Load Speed

Effect of Subgrade on Fatigue Prediction



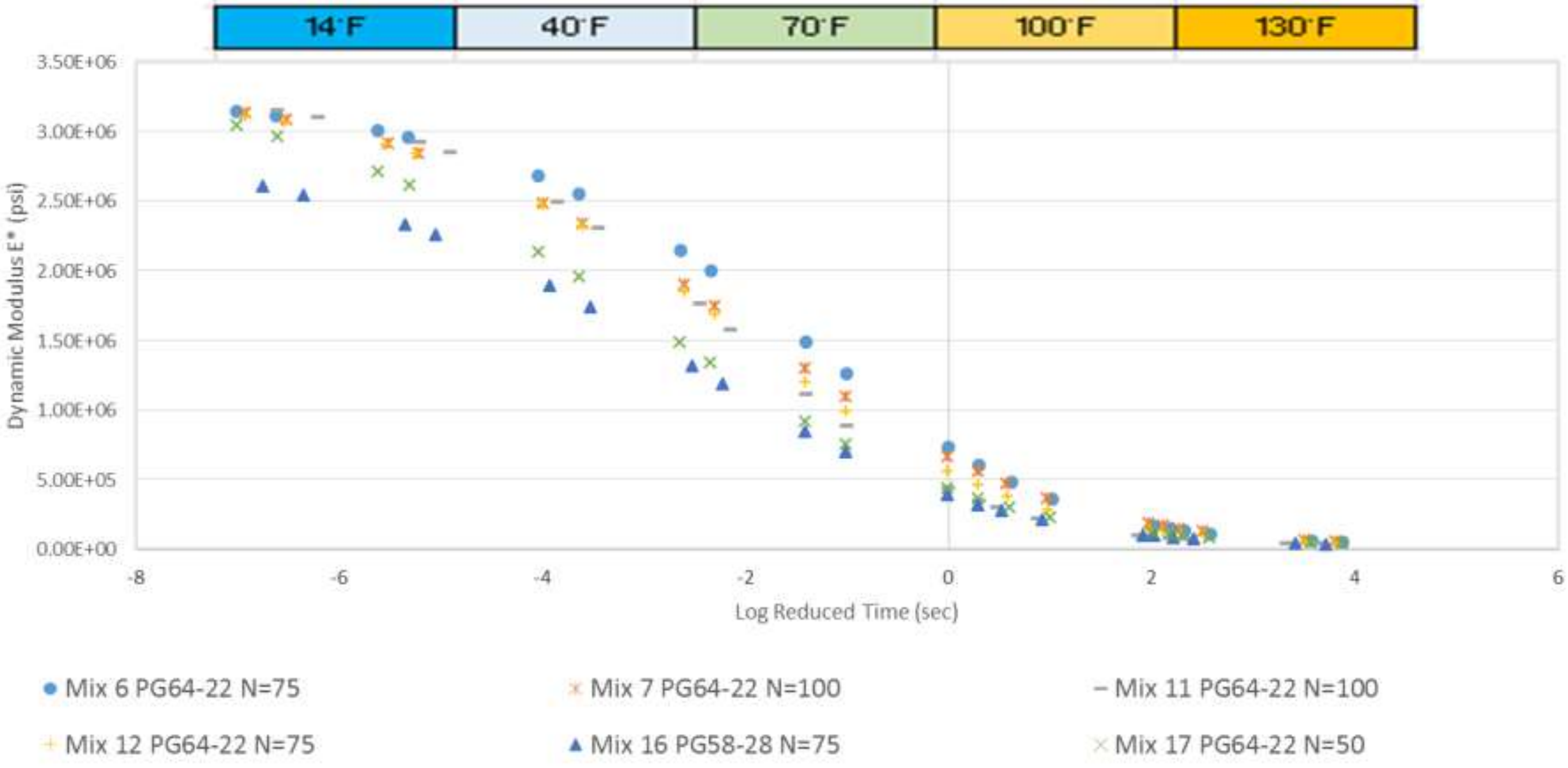
Viscoelastic Asphalt Material Properties

- PA asphalt mix stiffness

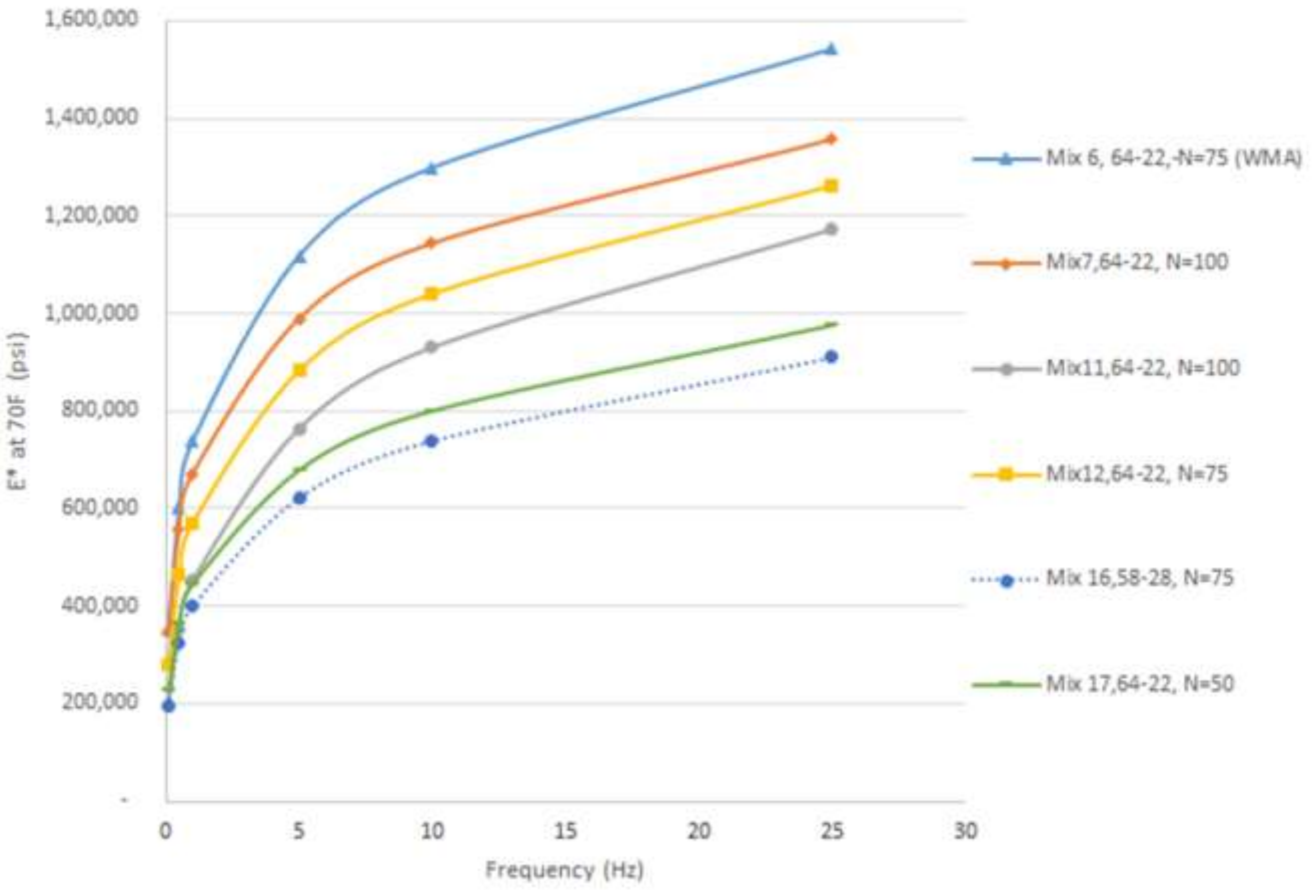
Excerpt from Table 9.5 for 25 mm Base Mixes

Mix ID	Temperature (°F)	Dynamic Modulus (E*) in psi at Different Testing Frequency					
		0.1 Hz	0.5 Hz	1 Hz	5 Hz	10 Hz	25 Hz
Mix6 25mm WMA Base PG 64-22 ESAL Range (0.3 to <3M) Ndesign = 75	14	2,483,674	2,718,217	2,798,141	2,942,814	2,990,330	3,042,116
	40	1,384,881	1,806,912	1,977,385	2,326,880	2,454,415	2,601,280
	70	352,626	599,857	737,737	1,118,219	1,299,069	1,542,680
	100	79,064	132,296	168,094	297,275	378,484	514,000
	130	32,324	43,479	50,824	78,124	96,591	130,495
Mix17 25mm HMA Base PG 64-22 ESAL Range (<0.3M) Ndesign = 50	14	1,863,151	2,157,601	2,269,551	2,492,706	2,573,368	2,666,749
	40	865,581	1,191,812	1,340,041	1,682,688	1,823,846	2,000,030
	70	225,734	364,533	444,142	678,660	799,954	975,788
	100	64,406	98,297	119,718	193,244	238,320	313,576
	130	29,739	38,730	44,285	63,418	75,493	96,579

Master Curves of Dynamic Modulus for 25 mm PennDOT Base Mixes



E* for Base Mixes in PennDOT Materials Catalog as a Function of Loading Frequency

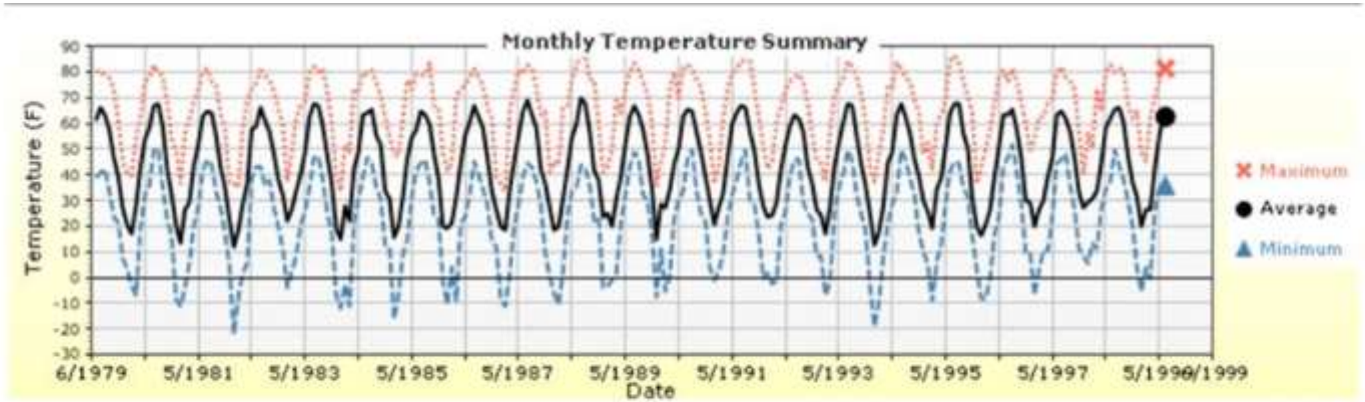


PA Climate Effect on Asphalt Properties

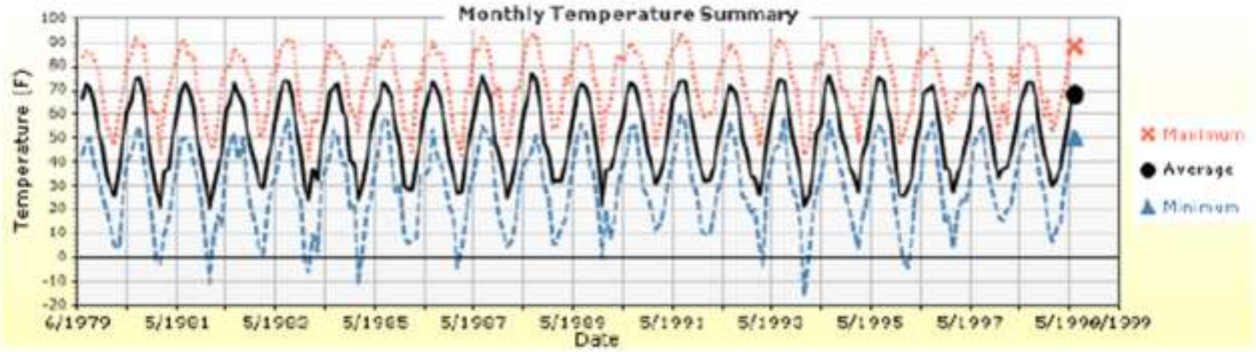
- Coldest in state vs. Warmest in state
  - Bradford
    - Low temperature - Typically 10 to -10
    - high temperature - Typically 90-95 degrees F
  - Reading
    - Low temperature - 0 to-20 degrees F
    - high temperature - Typically 80-85 degrees F
- Reflected as Impact on material properties
  - Low temperature increases AC stiffness
  - High temperature decreases AC stiffness

PA Climate Effect on Asphalt Properties

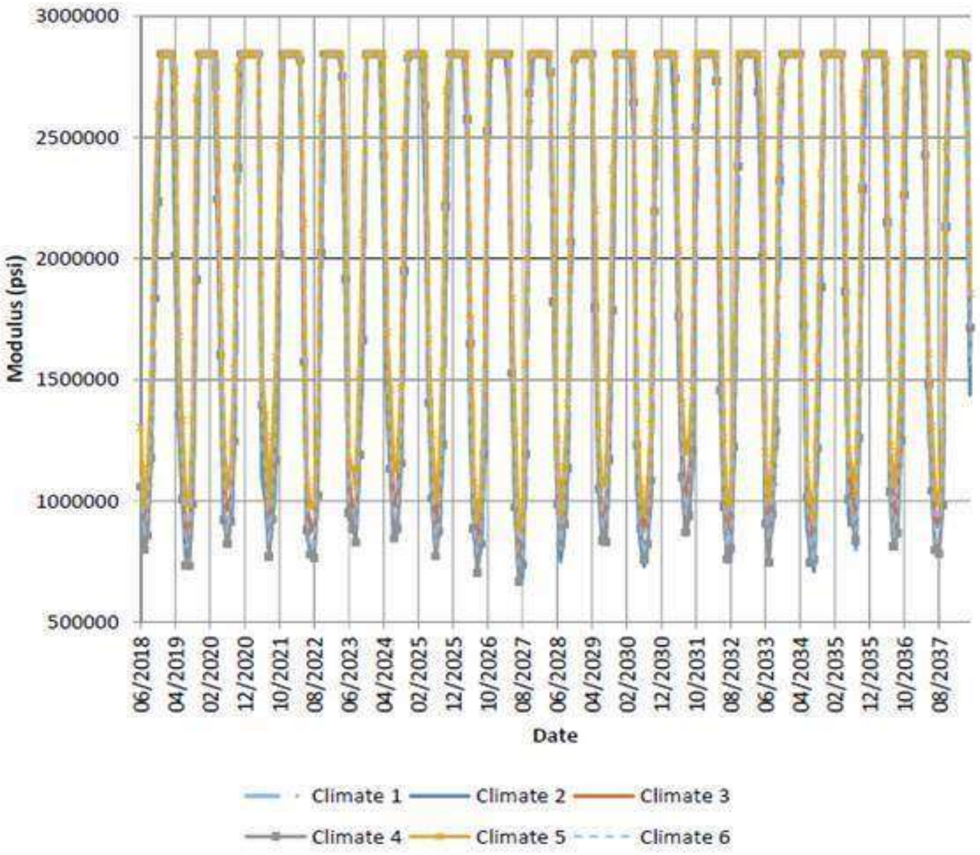
- Bradford



- Reading

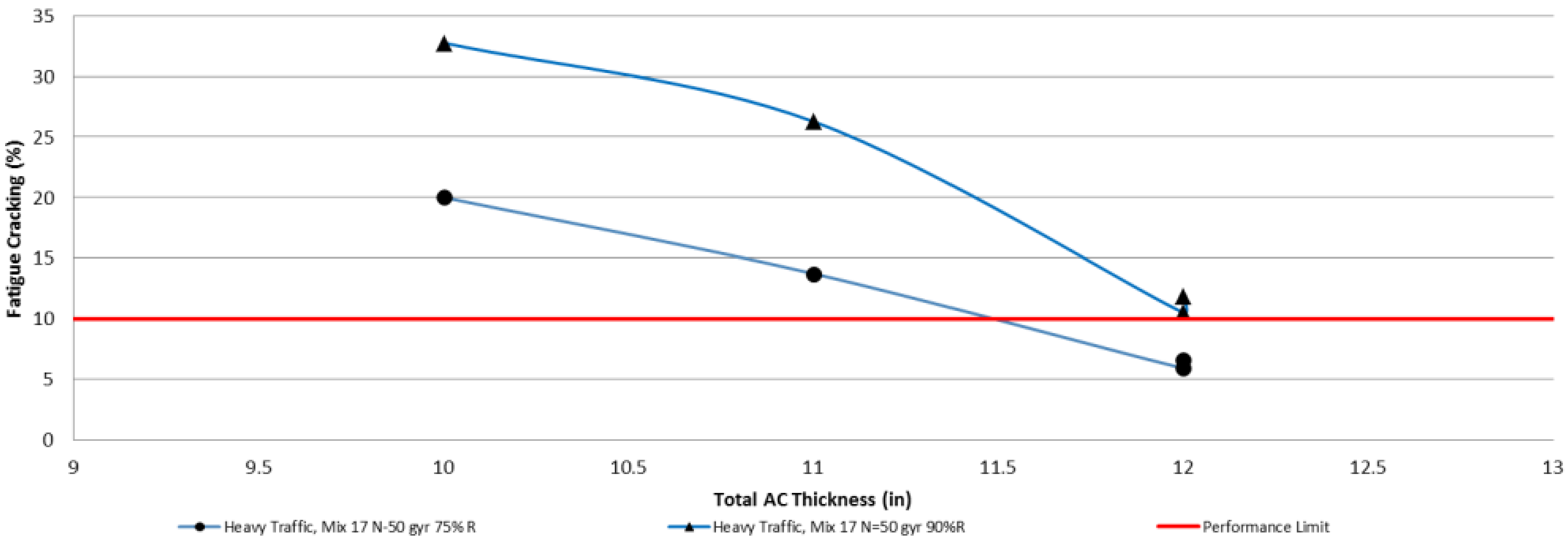


E* values: Reading #4, Bradford # 5

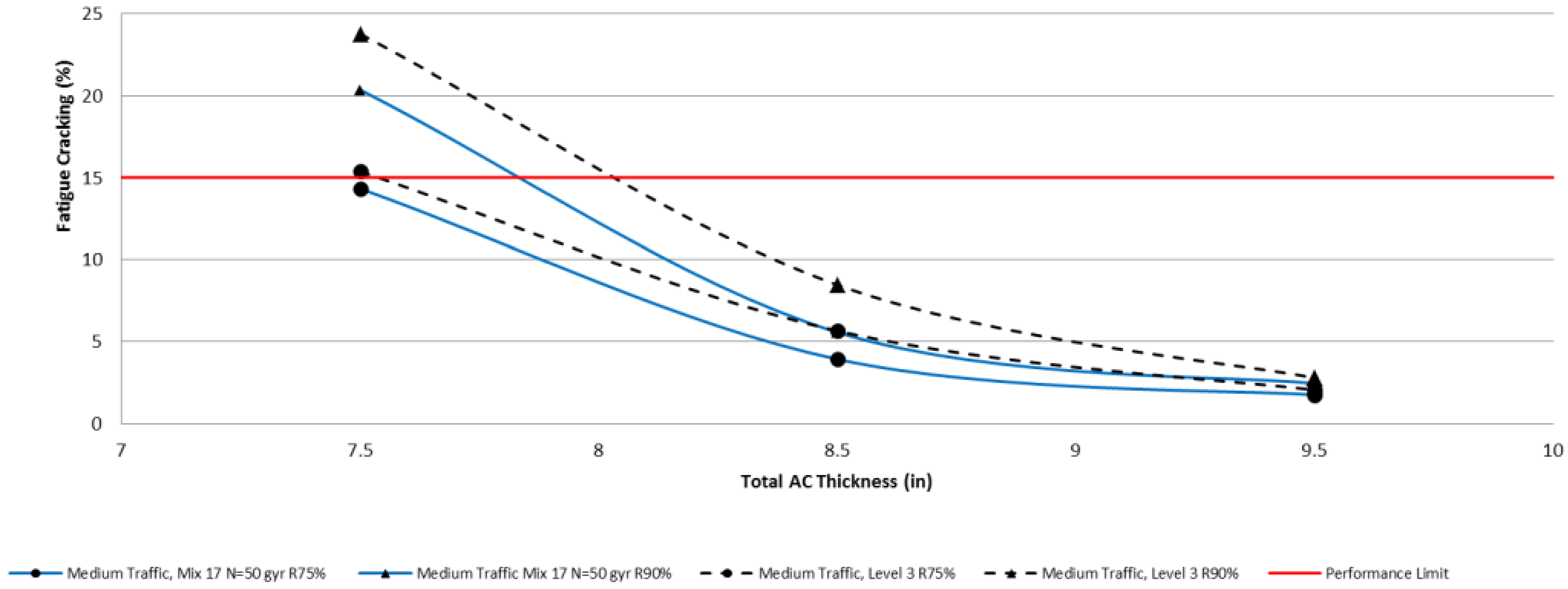


- Traffic Level has a significant affect on pavement thickness!

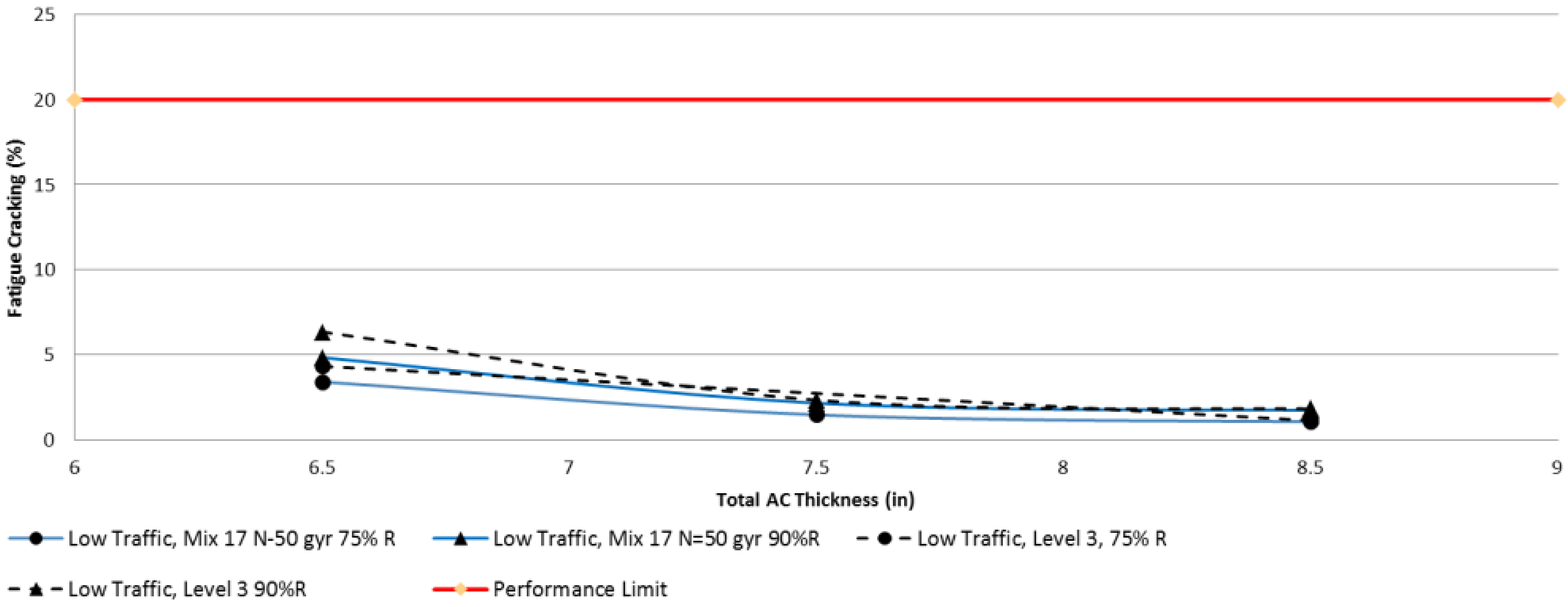
Example Sensitivity of Fatigue Crack Prediction for a Single Mix at High Traffic Level



Medium Traffic Level, Fatigue Cracking Sensitivity

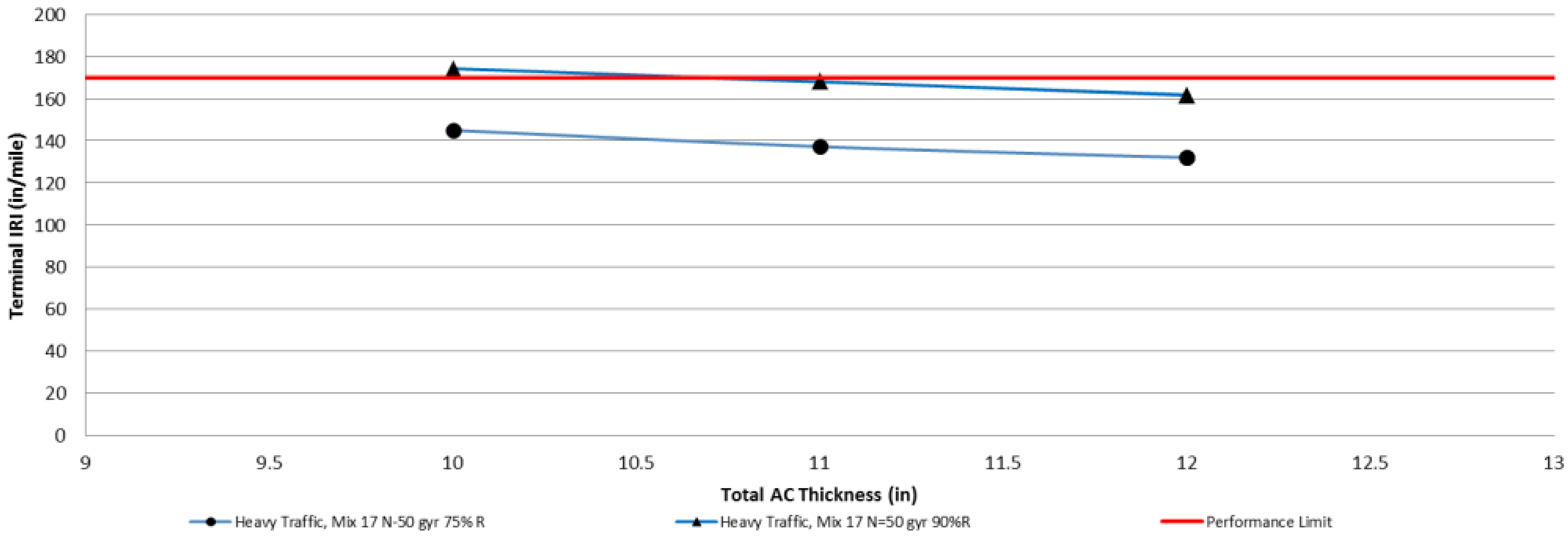


At low traffic level, fatigue cracking relatively insensitive, even though tolerance level is higher

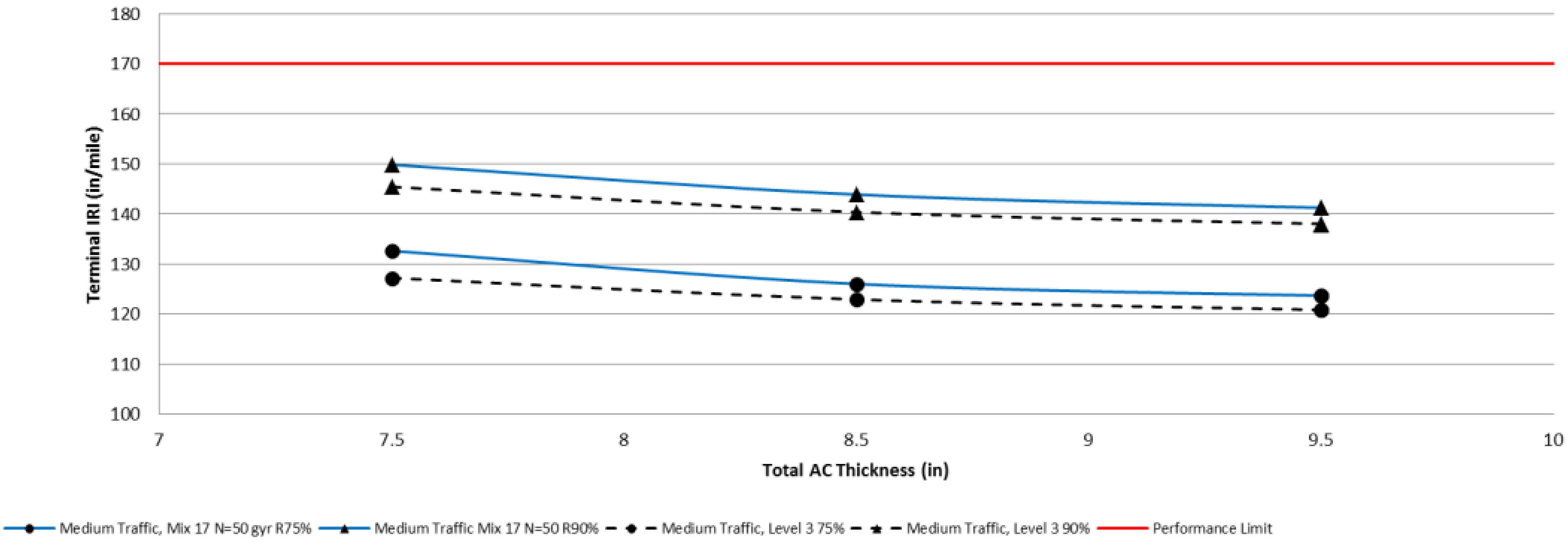


Take a look at IRI affect on thickness at three traffic levels

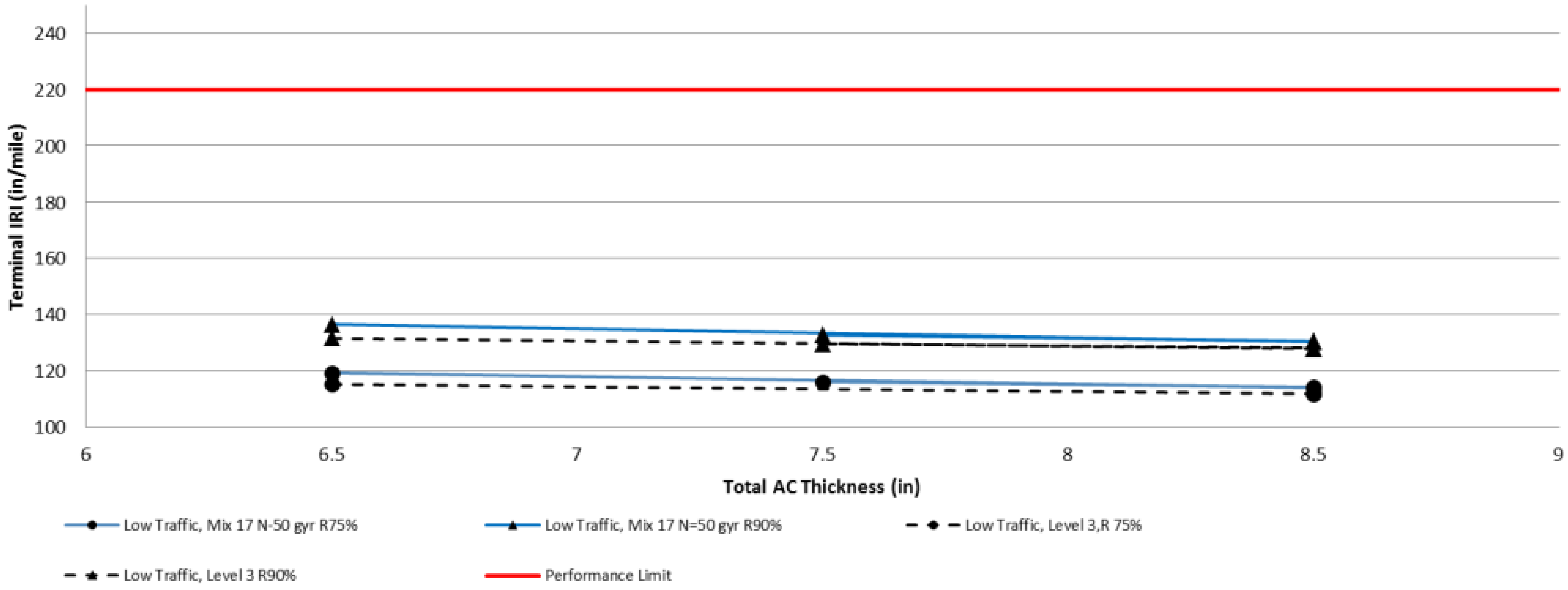
Example IRI Prediction for a single mix at High traffic level



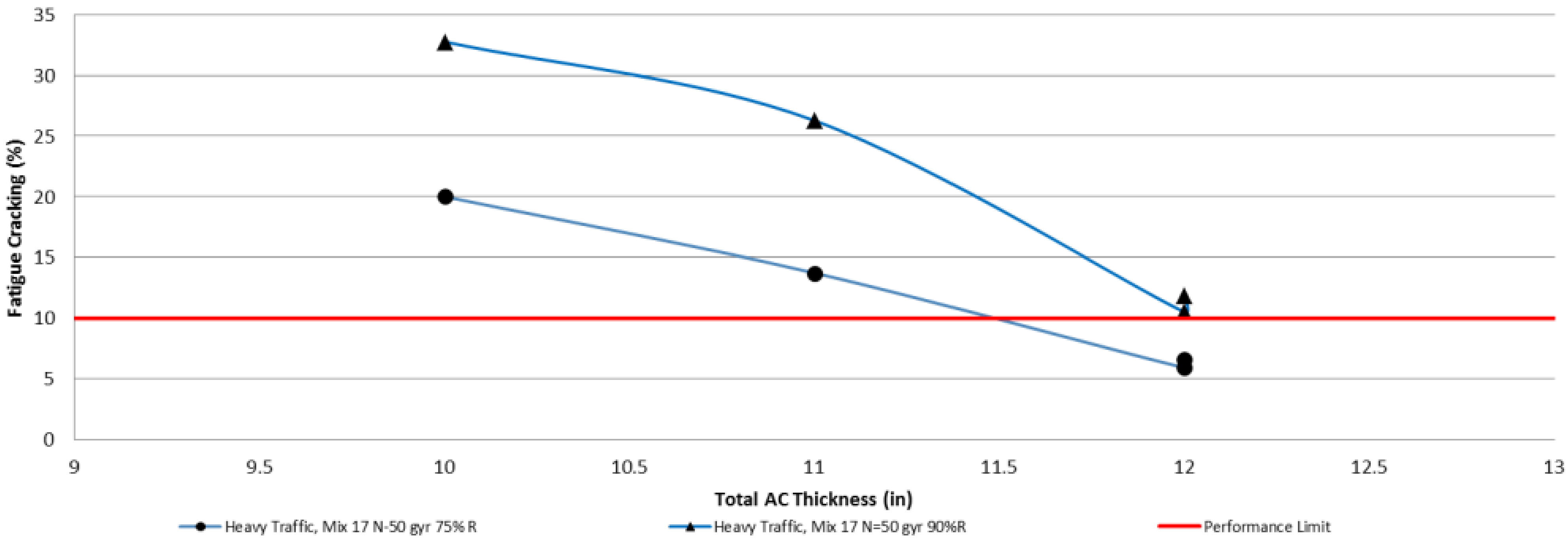
Medium traffic level IRI prediction



Contrast predictions for low traffic level



Reliability Impact on thickness at High Traffic Level



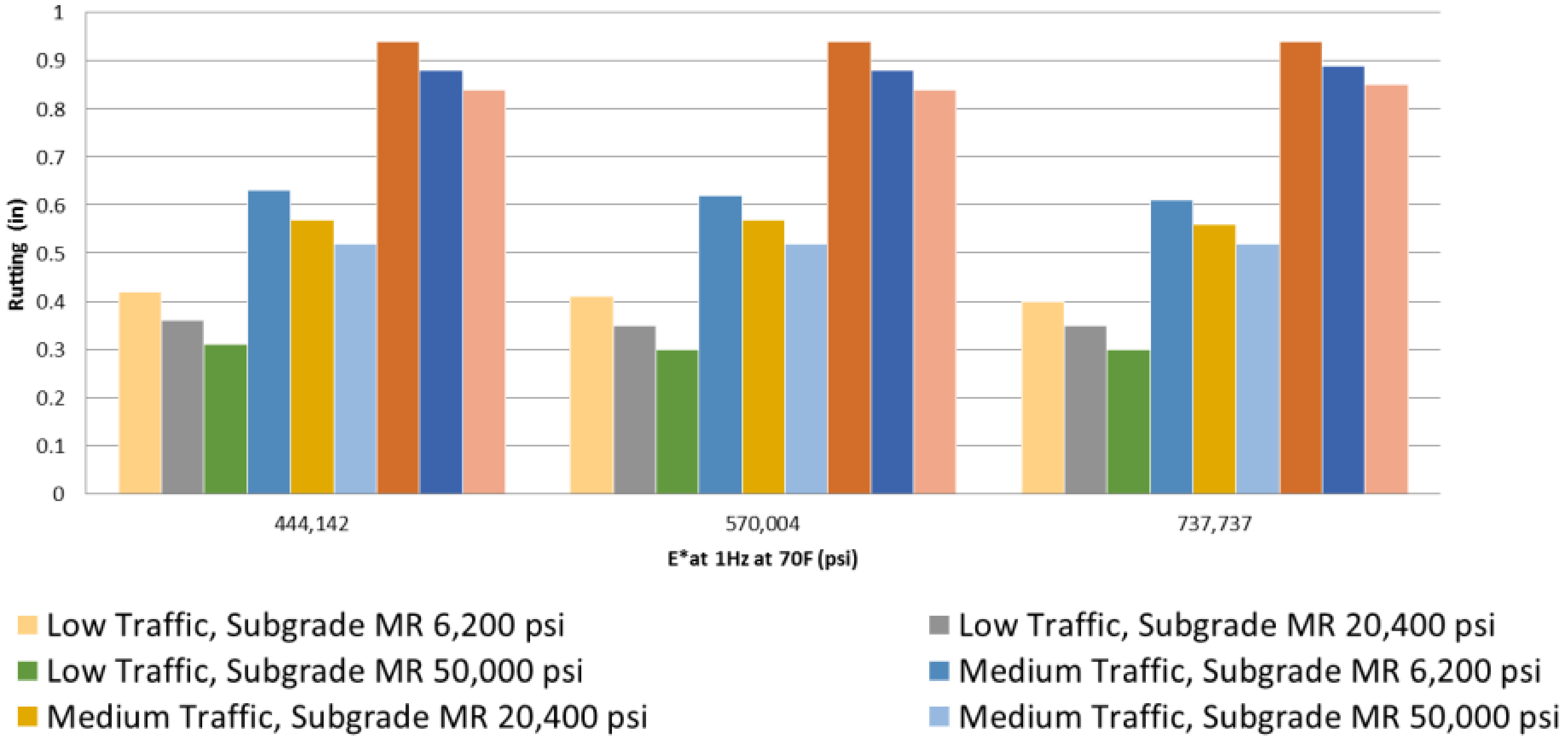
Significance to Design Thickness

- At lowest thickness level (7.5”), the fatigue cracking threshold is distinguished by reliability level (90 vs 75)
  - R=75% is below threshold,
  - R=90% does comply

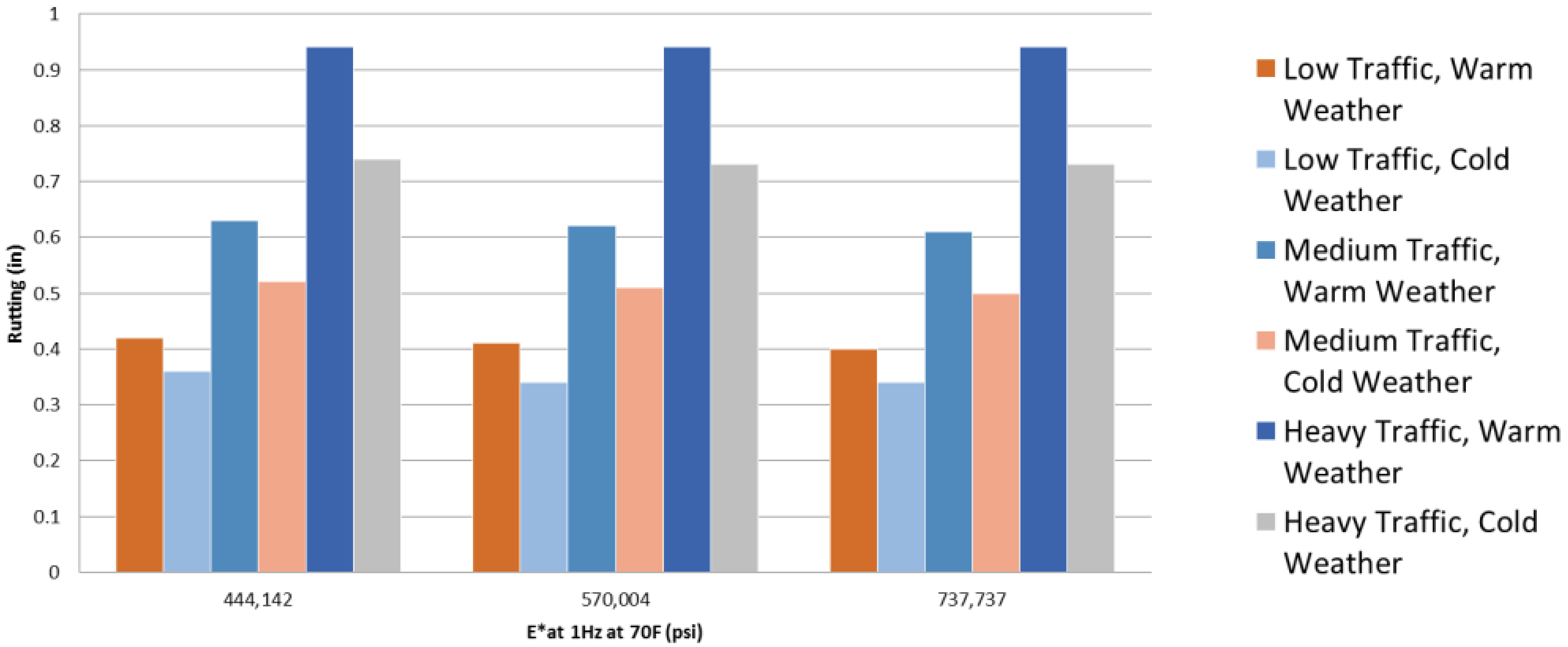
- For R=90% one additional inch is required to comply with the fatigue cracking threshold - equates to about 130% increase in traffic loading

- At 2 additional inches (9.5”) the fatigue cracking performance is clustered below the threshold value - 270% increase in traffic loading

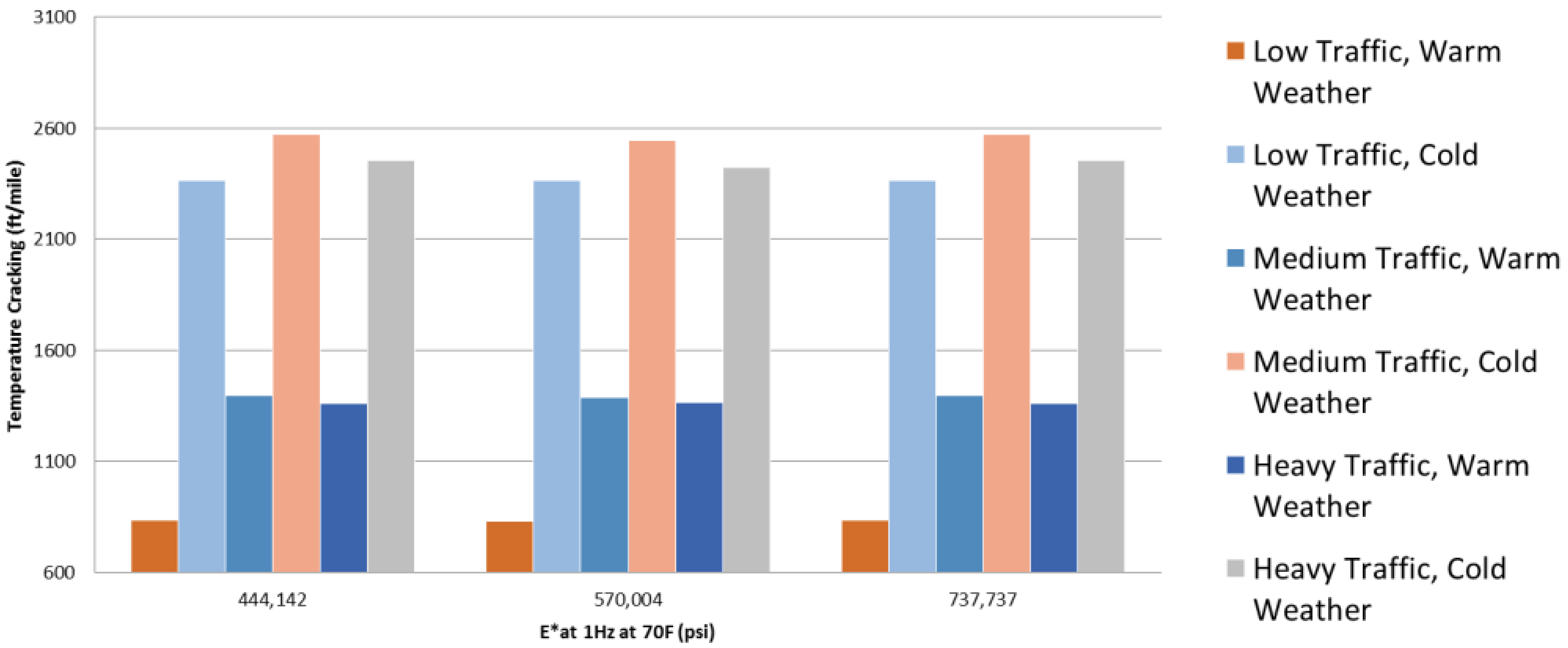
Traffic Impact on Rutting, Low - High



AC Rutting at Warm and Cold Temperature Extremes in PA

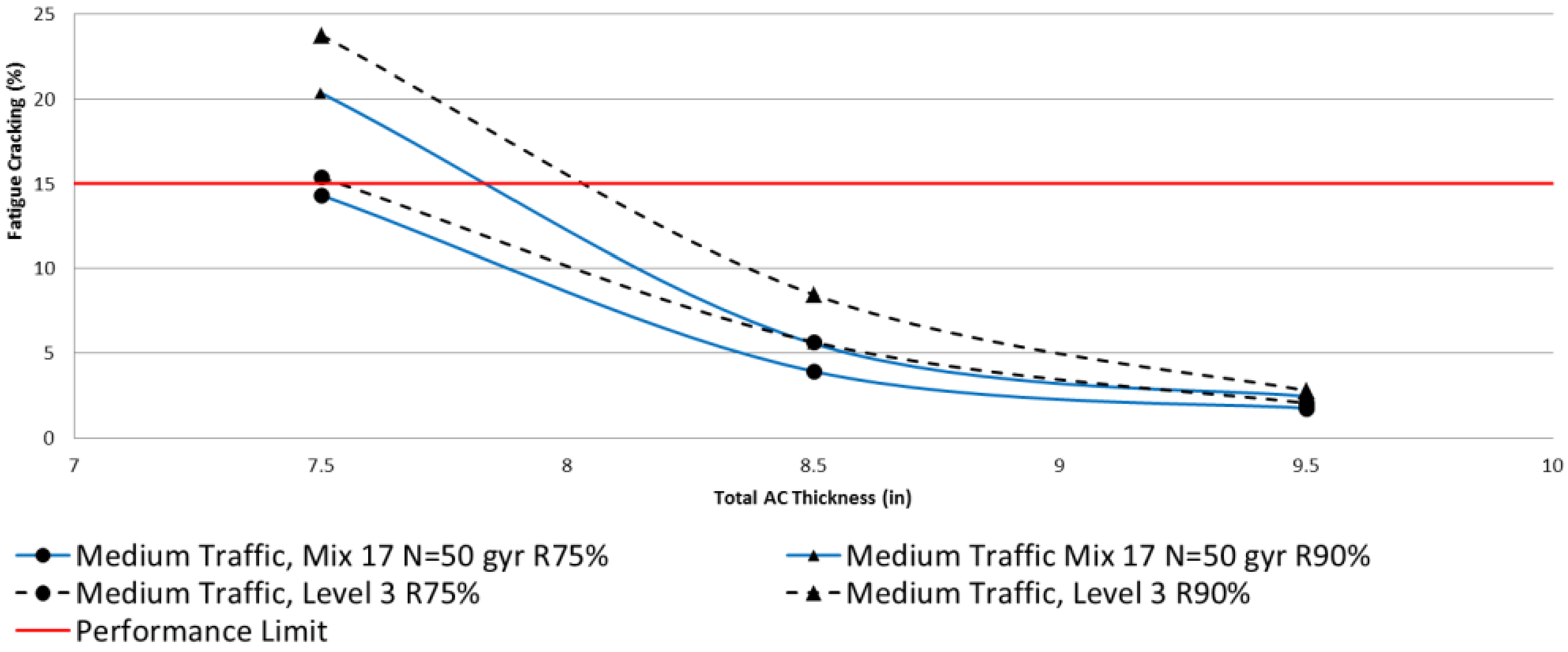


Thermal cracking predicted at Bradford (cold) vs. Reading (warm) climates, not sensitive to mix E*

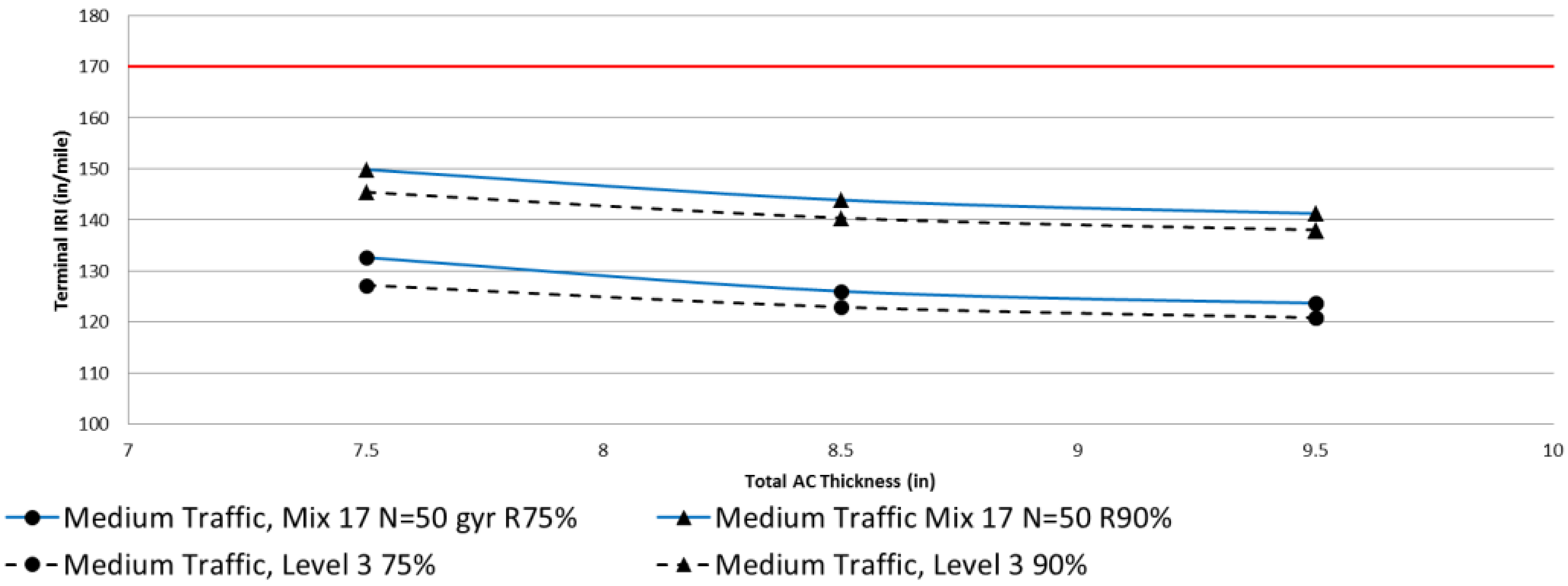


Effect of Reliability

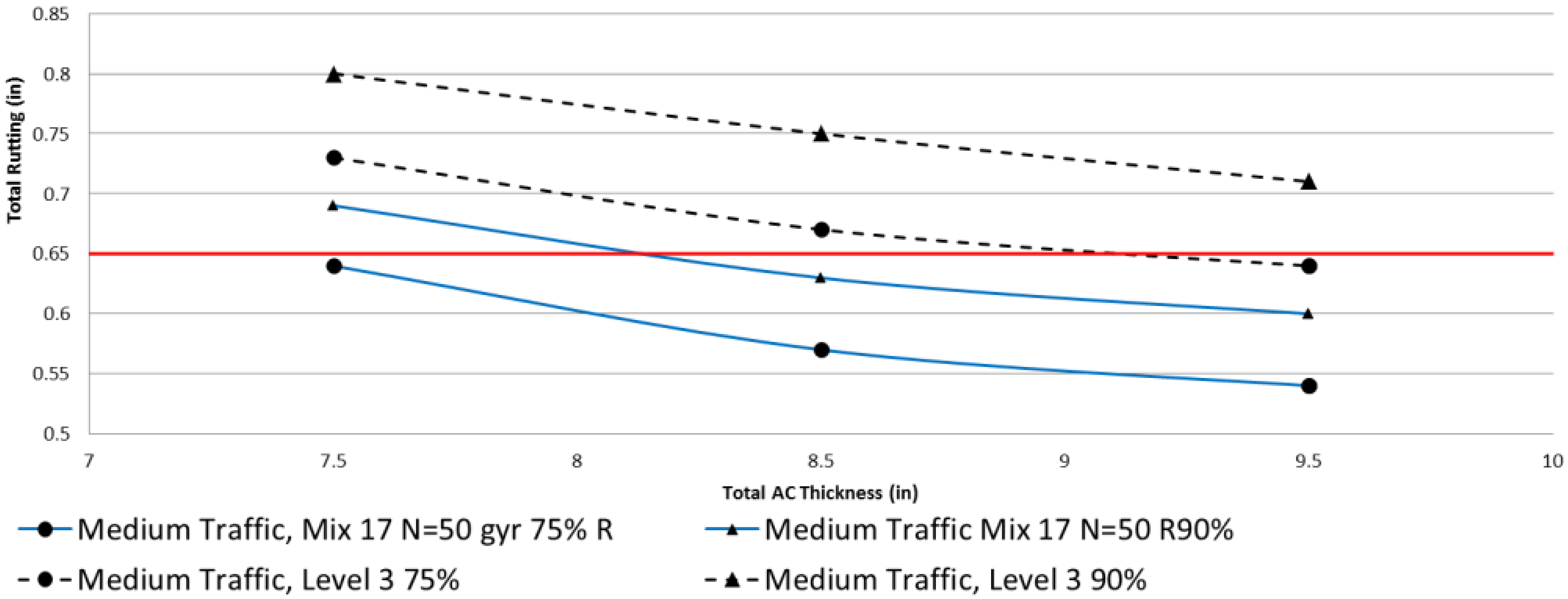
Example, 50 gyration mix effect on fatigue



Reliability effect on IRI



Reliability effect on Rutting



Observation Regarding the Impact of Reliability

- Reliability has a significant influence on the recommended pavement thickness
- There is no distinction for reliability by data input level, even though:
  - Level 1 includes greater detail, which should improve the reliability of the model
  - vs. Level 3 uses generic input with no specific refinement of the model
- Lower level reliability (50%) is recommended for lower volume roads, although investment cycles for these roads is typically longer than for higher volume roads

Observations

- Traffic and subgrade support are still significant,
- At hi traffic level, predicted differences in performance are significant
- Climate effect can have significant impact on AC material properties
- Specific AC mix properties can have significant impact
  - Loading rate
  - AC binder stiffness
  - Effect of aggregate and binder sources for the same class of material, i.e., 25 mm base
- Impact of Reliability associated with data input level, detailed vs. national average
- Reliability impact on predicted pavement performance
- Other relationships between other project specific factors

Questions?