

The Effect of RAP Content and Source on the Return on Investment (ROI)

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Presentation Outline

1. Background
2. Problem Statement
3. Research Objectives
4. Research Approach
5. Experimental Plan
6. Laboratory Materials Testing
7. Using **AASHTOWare PMED** to Predict Bottom-up Fatigue Cracking
8. Using **FHWA RealCost** to Perform LCCA
9. Conclusions

Background

MassDOT proceeded with a series of demonstration projects in 2021 through 2023 using RAP contents between 25 and 30% RAP to assess the constructability and performance of **“higher RAP”** surface mixtures.

Background (Continued)

- ❖ High RAP contents may decrease a pavements resistance to various forms of cracking.
- ❖ A MassDOT study illustrated that for the same RAP content, RAP source has a significant effect on the cracking resistance of asphalt.

Problem Statement

Some questions should be addressed prior to using high RAP contents:

1. How does RAP content impact the performances of asphalt mixtures in terms of cracking?
2. For a given RAP content, what is the effect of RAP source on cracking?
3. The use of high RAP content might reduce initial construction costs, but might increase costs and frequency of maintenance.

Is it still economical to use high RAP contents over the lifespan of a pavement?

This study addressed these three questions in regard to bottom-up fatigue cracking.

Research Objectives

1. Evaluate the impact of RAP content and source on bottom-up fatigue cracking predicted using Level 1 of the AASHTOWare Pavement Mechanistic-Empirical Design (PMED), where “source” is primarily a significant difference in RAP binder PG.
2. Conduct life-cycle cost analyses (LCCA) using FHWA RealCost to analyze the return on investment (ROI) when using different RAP contents and sources.

Research Approach

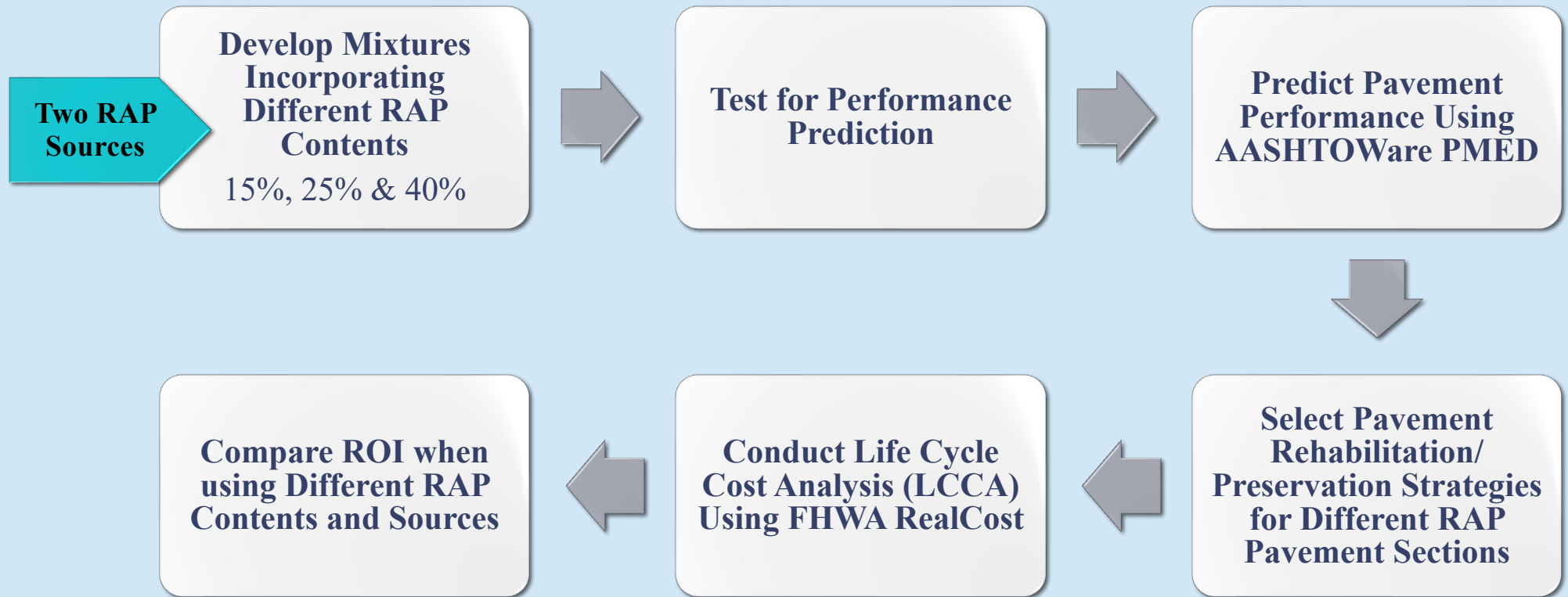
Materials Selection and RAP Mixture Designs

Determination of the Level 1 Inputs for AASHTOWare PMED

AASHTOWare PMED Simulations and Distress Predictions

Perform LCCA to Determine the Effect of RAP Source and Content on ROI

Experimental Plan



Laboratory Materials Testing

1. Mixture Designs and Sample Preparation for Performance Testing
2. Dynamic Modulus ($|E^*|$)
3. Mixture Volumetric Properties for AASHTOWare PMED
4. Flexural Bending Beam Fatigue Test

Materials

Asphalt Binder: One virgin binder PG 64S-28.

Reclaimed Asphalt Pavement (RAP): Obtained from two sources in Massachusetts.

Property	RAP Source A	RAP Source B
Binder Content (%)	5.6%	5.5%
True PG (°C)	76.8-24.7	99.3-11
PG (°C)	PG 64V-22	PG 64E-10

Aggregates: Aggregates were collected from a local source in Massachusetts.

Laboratory Materials Testing

1. Mixture Designs:

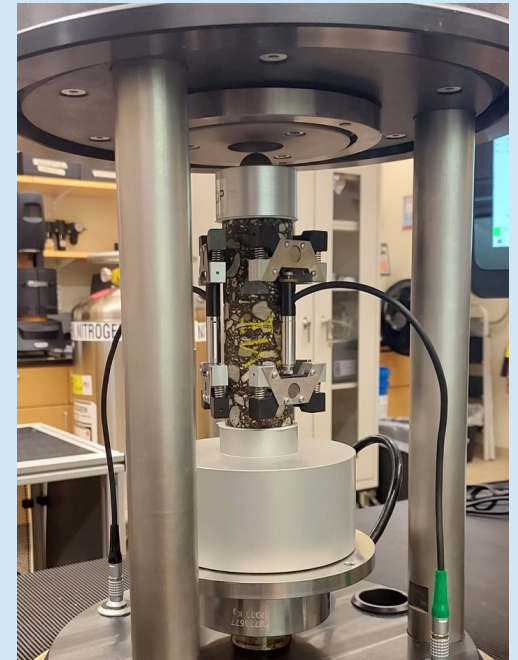
- ***Control Mixture:*** 12.5-mm (Virgin aggregates and virgin binder)
- ***RAP Mixtures:*** Six RAP mixtures using the three RAP percentages of 15%, 25%, and 40% and the two RAP sources were prepared using the selected aggregate gradation.

Sample Preparation for Performance Testing:

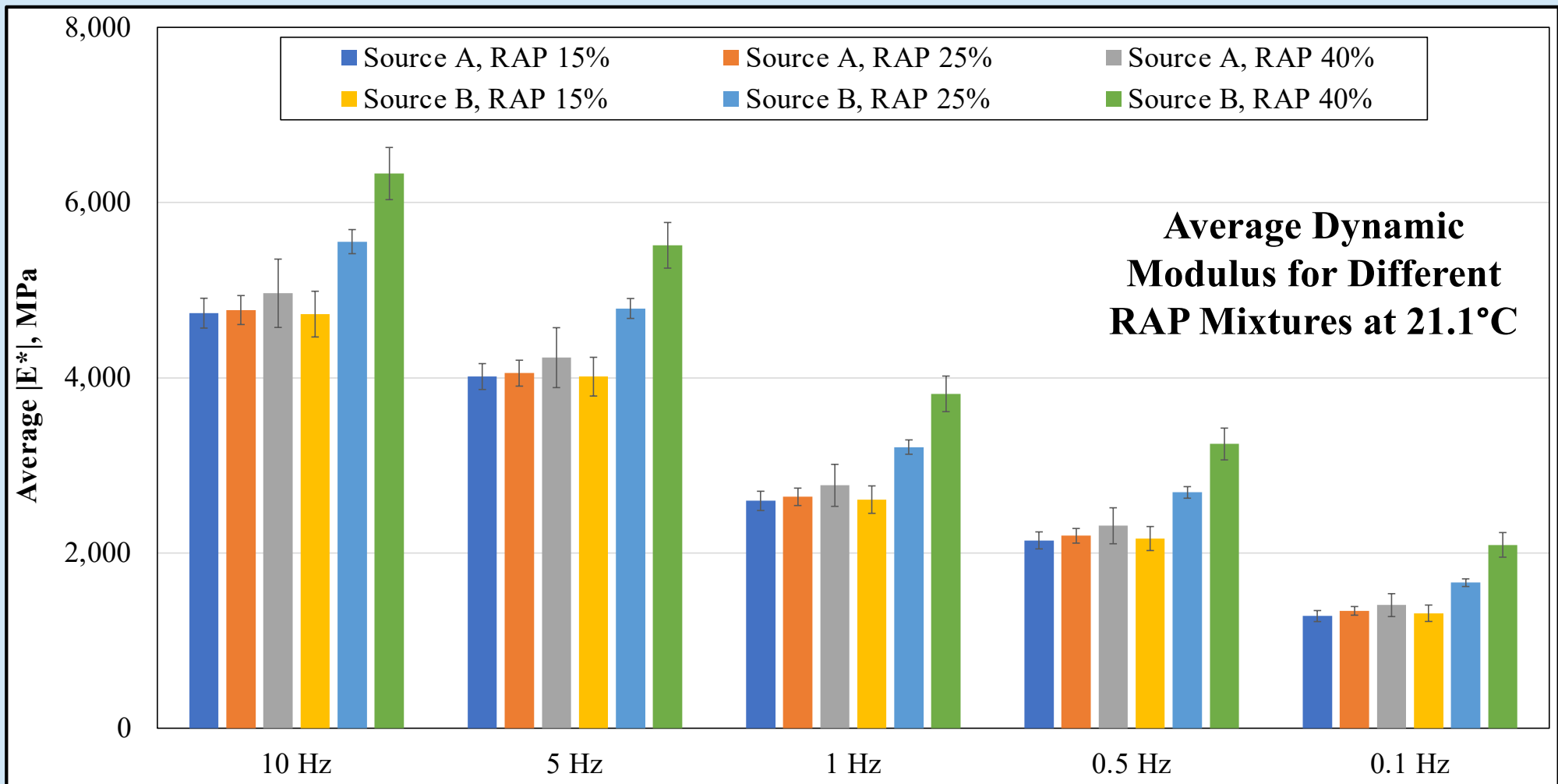
- The loose mixtures were subjected to short-term oven aging according to AASHTO R 30.

2. Dynamic Modulus ($|E^*|$):

- $|E^*|$ tests samples were performed in accordance with AASHTO TP 132
- Three samples were prepared per mixture at $7 \pm 0.5\%$ air voids
- Each specimen was tested at temperatures 4.4°C , 21.1°C , and 37.8°C and loading frequencies of 10 Hz, 5 Hz, 1 Hz, 0.5 Hz, and 0.1 Hz

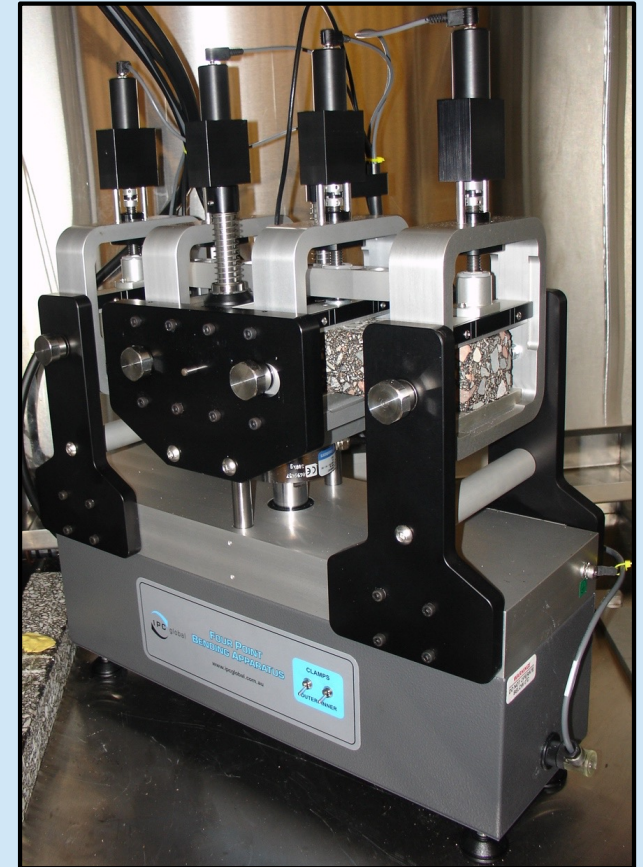


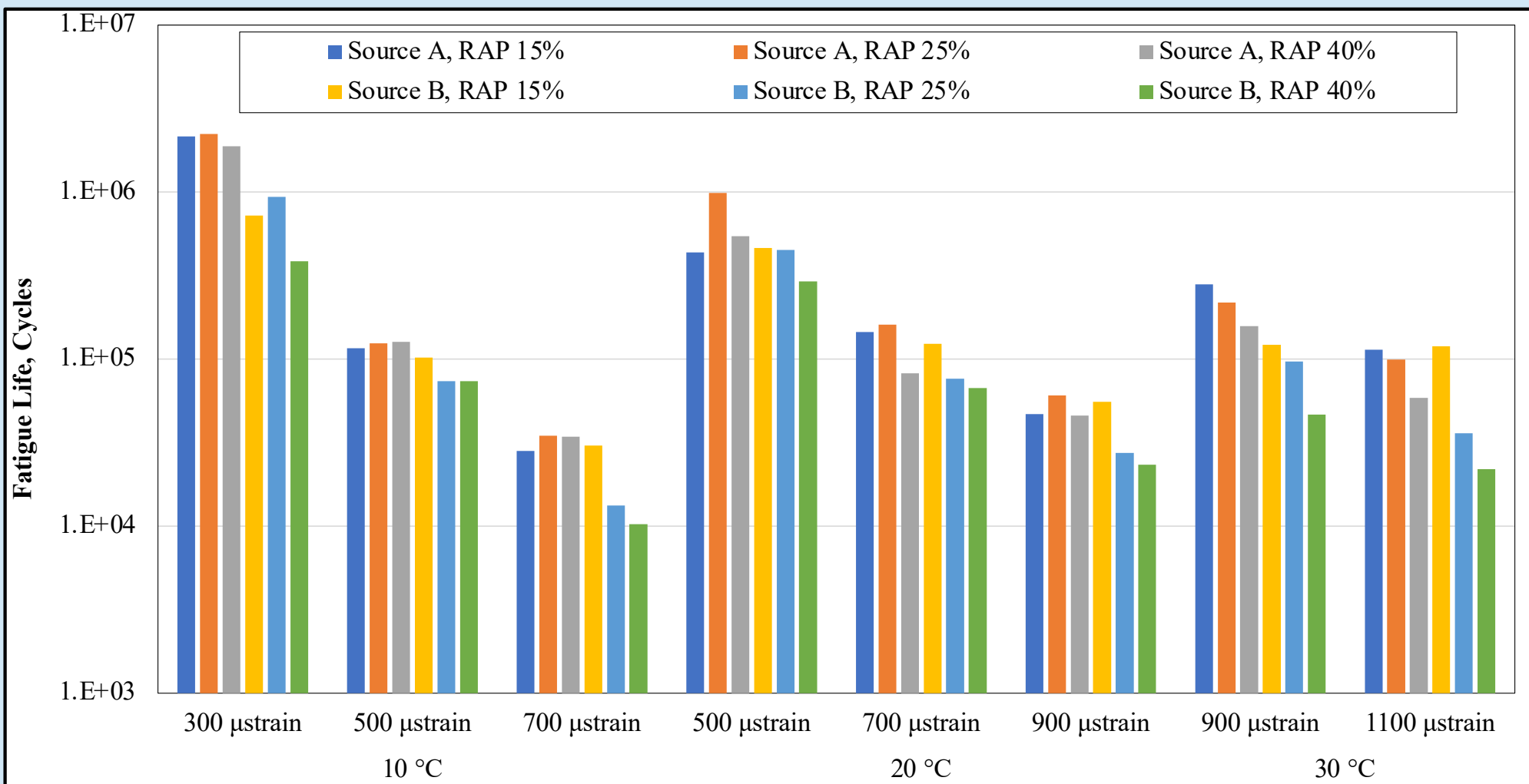
Close-up of 38-mm Diameter Specimen within AMPT Test Device



3. Flexural Bending Beam Fatigue Test:

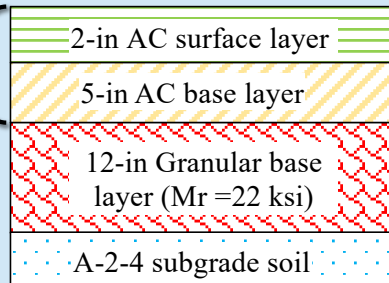
- The four-point bending beam fatigue procedure was performed according to AASHTO T 321
- Beam dimension: 63 mm in width, 50 mm in height, and 380 mm in length
- Beam fatigue tests were conducted at temperatures of 10, 20, and 30°C. The strain levels were (1) 300, 500, and 700 $\mu\epsilon$ at 10°C; (2) 500, 700, and 900 $\mu\epsilon$ at 20°C and (3) 900 and 1100 $\mu\epsilon$ at 30°C.





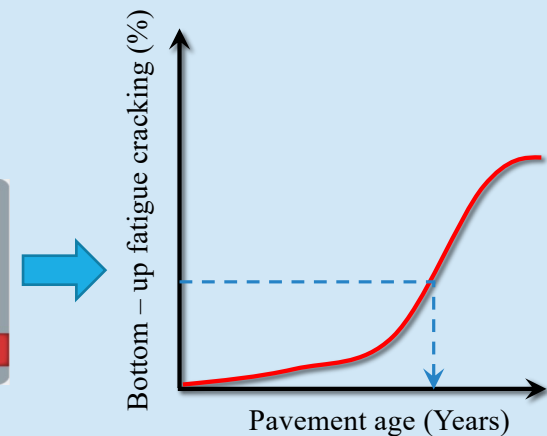
Prediction of Bottom-up Fatigue Cracking Using AASHTOWare PMED Version 2.6.1

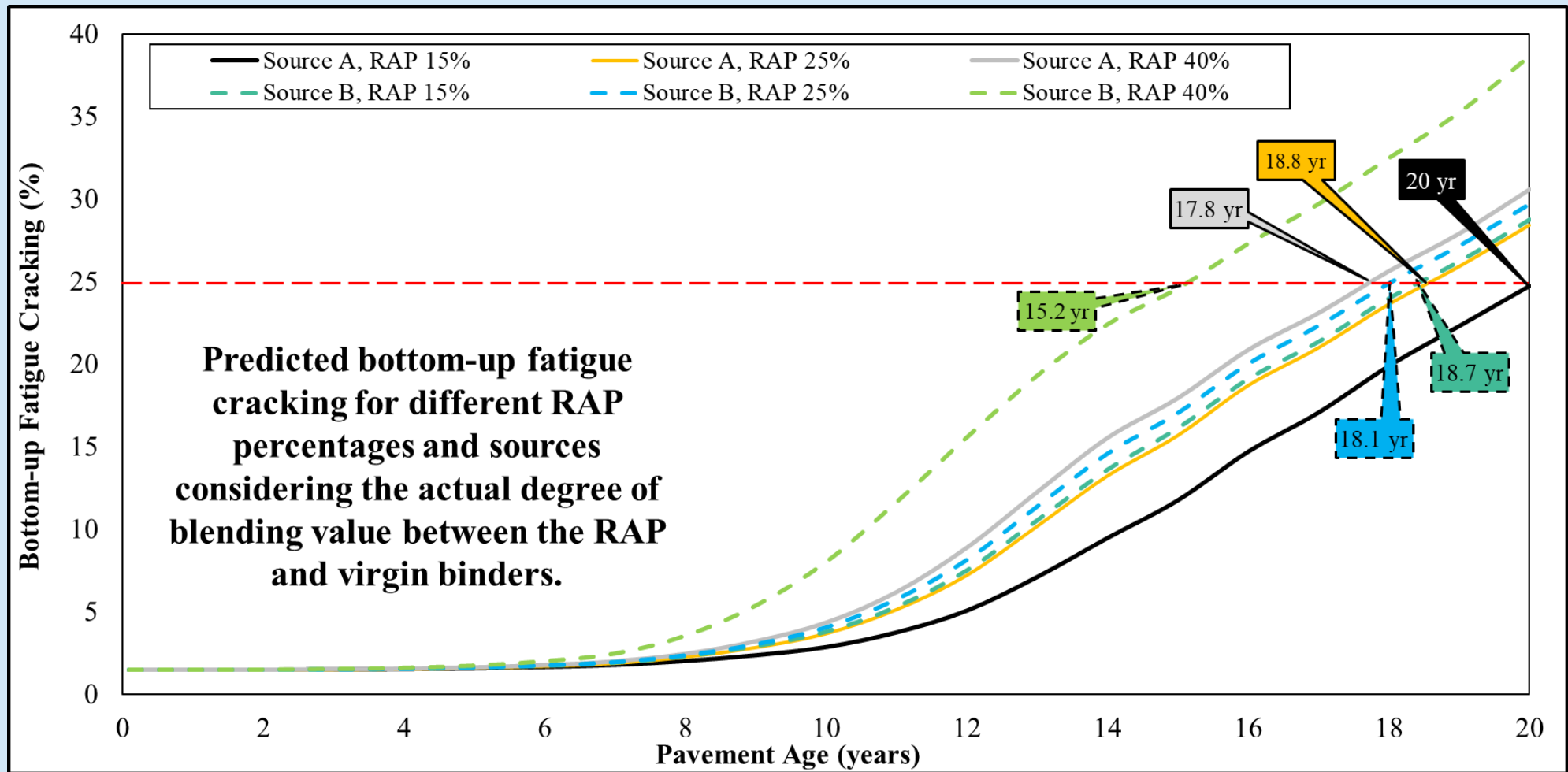
$ E^* $ dynamic modulus master curves
G^* and δ at multiple temperatures
Volumetric properties
Fatigue coefficients: k_{f1} , k_{f2} , k_{f3}



Traffic Data	
Design Life (years)	20
Initial two-way Annual Average Daily Truck Traffic (AADTT)	4,000
Number of lanes	4
Percent of trucks in design direction (%)	50
Percent of trucks in design lane (%)	85
Percent of trucks in design lane (%)	3.0

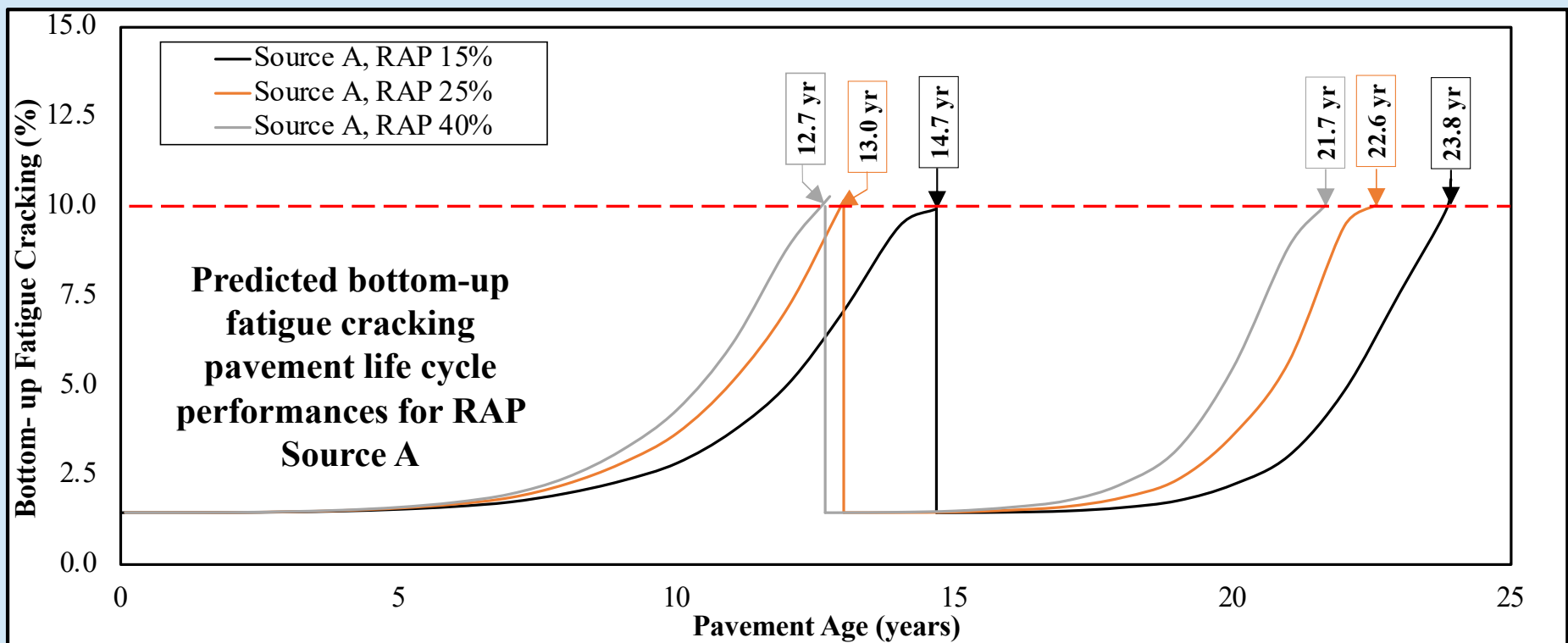
Climate Data	
Weather Station	Boston, MA
Latitude (degrees.minutes)	• 42.50 • 42.00
Longitude (degrees.minutes)	• -71.25 • -71.25
Elevation, ft	• 134 • 148

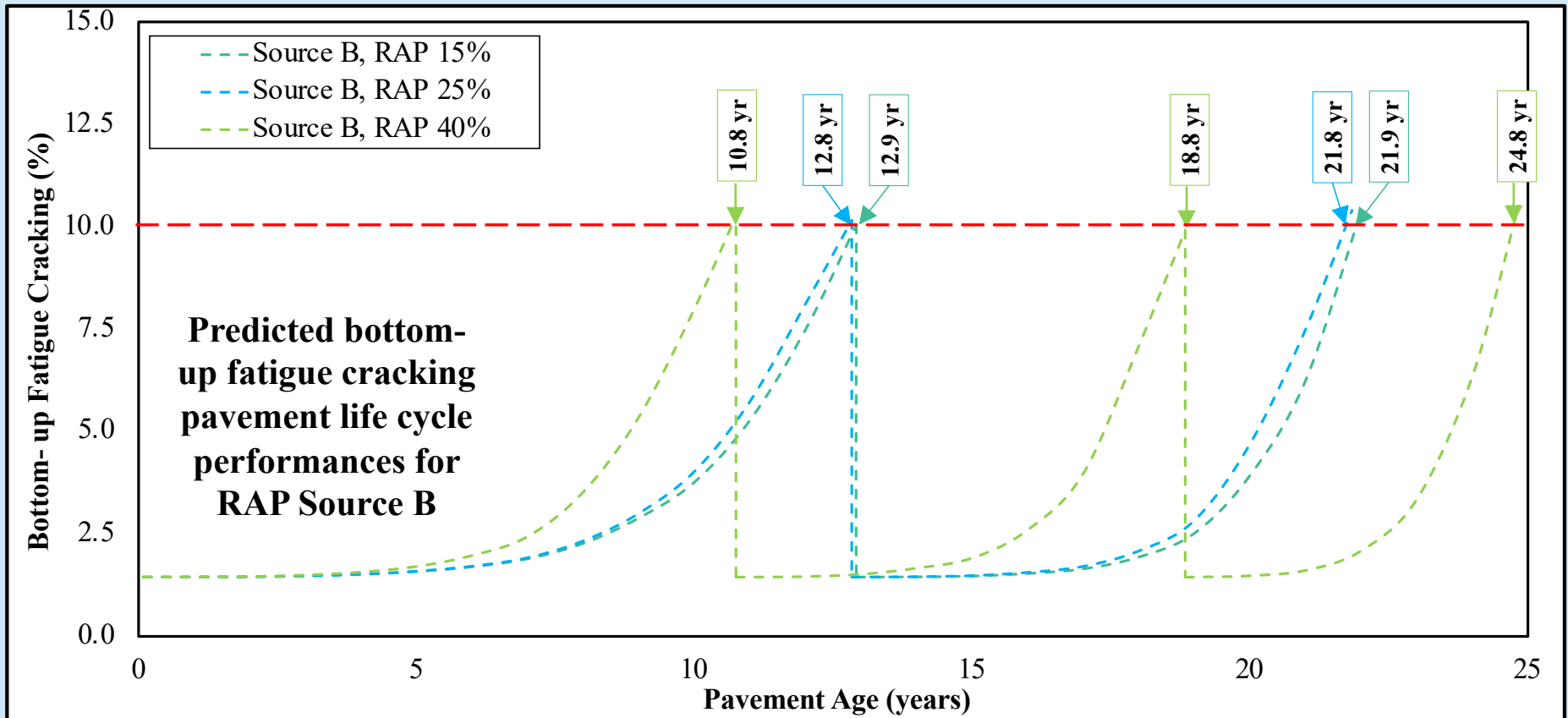




Predicted Lifecycle Performance Based on Proposed Pavement Rehabilitation/Preservation Strategies

The 2-in (51-mm) RAP surface layer mixture was replaced with the same RAP mixture when the predicted bottom-up fatigue cracking reached 10% of the lane area.







ROI for the RAP Pavement Sections Using FHWA RealCost

Based on the AASHTOWare PMED outputs, Life Cycle Cost Analyses (LCCAs) were performed using FHWA RealCost:

1. A 20-year analysis period was selected.
2. The remaining service life value (RSLV) for both agency and user costs were included in each LCCA.

A detailed software methodology and procedures for computing the NPV for both agency and user costs are presented in an FHWA Technical Bulletin .

ROI for the RAP Pavement Sections Using FHWA RealCost

Cost	Most economical  to  Least economical					
Total NPV	Source A, RAP 40%	Source A, RAP 25%	Source B, RAP 25%	Source A, RAP 15%	Source B, RAP 40%	Source B, RAP 15%

Conclusions

1. The most cost-effective pavement over the 20-year analysis period was provided by the 40% RAP Source A pavement which implies that using high RAP contents could be more economical for RAP sources having low RAP binder PGs and higher degrees of blending.
2. For RAP Source A, the ROI increased as the RAP content increased from 15% to 25% to 40% while it did not for RAP source B. Hence, using a higher RAP content will NOT always provide a higher ROI and it emphasizes the necessity of calculating the ROI when using high RAP contents.

Conclusions

3. While the 25% RAP Source B pavement yielded a higher ROI than the 15% RAP Source A pavement, increasing the RAP Source B content to 40% provided a lower ROI than the 15% RAP Source A. Hence, using a high RAP content may not always provide a higher ROI compared to a low RAP content when the RAP sources are different.
4. Because of the effect of RAP source, it could not be generalized that using either a higher or lower RAP content will always provide a higher ROI.

Thank you

