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Cost-effectiveness of rubber and polymer modified asphalt mixtures as related to sustainable fatigue performance

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Abstract

Load associated fatigue cracking is one of the major distress types occurring in flexible pavements. Flexural bending beam fatigue laboratory test has been used for several decades and is considered an integral part of the Superpave advanced characterization procedure. One of the most significant solutions to sustain the fatigue life for an asphaltic mixture is to add sustainable materials such as rubber or polymers to the asphalt mixture. A laboratory testing program was performed on three gap-graded mixtures: unmodified, Asphalt Rubber (AR) and polymer-modified. Strain controlled fatigue tests were conducted according to the AASHTO T321 procedure. The results from the beam fatigue tests indicated that the AR and polymer-modified gap graded mixtures would have much longer fatigue lives compared to the reference (unmodified) mixture. In addition, a mechanistic analysis using 3D-Move software coupled with a cost-effectiveness analysis study based on the fatigue performance on the three mixtures were performed. Overall, the analysis showed that the AR and polymer-modified asphalt mixtures exhibited significantly higher cost-effectiveness compared to unmodified HMA mixture. Although AR and polymer-modification increases the cost of the material, the analysis showed that they are more cost effective than the unmodified mixture.

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Keywords: Rubber; polymer, fatigue, cost-effectivness

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1. Introduction

In 2008, a first cooperative effort between Arizona State University (ASU) and the Swedish Road Administration (SRA) took place in testing unmodified, Asphalt rubber and polymer- modified gap-graded mixtures placed on Malmo E6 External Ring Road in Sweden. In 2009, SRA and ASU undertook another joint effort to test three types of gap-graded mixtures: unmodified, Asphalt Rubber-modified mixtures, as well as polymer-modified asphalt mixtures placed on highway E18 between the interchanges Järva Krog and Bergshamra in the Stockholm area of Sweden.

Rice specific gravities for the mixtures were determined. Beam specimens were prepared according to the Strategic Highway Research Program (SHRP) and the American Association of State Highway and Transportation Officials (AASHTO): SHRP M-009 and AASHTO T321-03 (equivalent European test standards are: EN12697-24 A to D). Air voids, thickness and bulk specific gravities were measured for each test specimen and the samples were stored in plastic bags until testing.

The designated road section within the construction project had three asphalt mixtures: a reference gap-graded mixture (designation: ABS 16 70/100) used as a control, a polymer- modified mixture (designation: ABS 16 Nypol50/100-75), and a rubber-modified mixture (designation: GAP 16) that contained approximately 20 percent ground tire rubber (crumb rubber).

The Swedish Road Administration provided information stating that the field compaction produced air voids for the three mixtures around 3.0% for all mixtures. The original mix designs were done using the Marshall Mix design method. Table 1 shows the reported average aggregate gradations for each mixture. The in-situ mixture properties of the Stockholm pavement test sections are also reported in Table 1, which include percent binder content by mass of the mix, Marshall percent void content by volume of the mixture, and maximum theoretical specific gravity of the mixes (G_{mm}) estimated at the ASU laboratory. The base bitumen used was Pen 70/100 and the rubber was called GAP 16. No field fatigue performance data are currently available.

Table 1. Average aggregate gradations and mixture characteristics

	Sieve Size (mm)	Reference Unmodified Mixture	AR Mixture	Polymer-Modified Mixture
Percent Passing	22.4	100	100	100
	16	98	98	98
	11.2	65	68	65
	8	38	44	38
	4	23	24	23
	2	21	22	21
	0.063	10.5	7.5	10.5
Binder Content (%)		5.9	8.7	5.9
Air Voids (%)		2.6	2.4	2.6
G_{mm}		2.464	2.359	2.456

Previous publications showed that asphalt rubber mixtures as well as polymer-modified mixtures had superior fatigue resistance performance over the unmodified HMA mixture (1). The remaining unanswered question is: do AR and polymer-modified mixtures represent cost-effective solutions to resist fatigue cracking compared to unmodified HMA mixtures?

2. Objective

The objective of this study was to assess the cost-effectiveness of rubber and polymer modified asphalt mixtures as related to fatigue performance. The paper combines the results of the mechanical fatigue laboratory evaluations