Development of Fatigue Predictive Models for Asphalt Concrete Mixes Containing Electric Arc Furnace Steel Slag Based on Fracture Energy Concept

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1-Introduction

This study was conducted in order to assess fatigue resistance properties of asphalt mixtures containing Electric Arc Furnace (EAF) steel slag. Two types of aggregates, namely a limestone and a steel EAF slag from Mobarakeh Steel Complex in Isfahan were used to be mixed at various portions. The binder was 60/70 penetration grade bitumen from Refinery of Isfahan. Once assessing properties of EAF steel slag (using XRD, XRF and Scanning Electric Microscope (SEM) methods), five sets of mixes were prepared in laboratory. Each set was consisted of a combination of a control limestone aggregate with a specific amount of EAF steel slag.

2- Material and Method

Marshall Mix design method (ASTM D-6927) was used to determine the optimum binder contents of mixes. Marshall Specimens, consisting of five sets of samples, containing different proportions of slags, were prepared. These involved one control set of the specimens which made of limestone aggregates (L) and four sets were consisted of combined mixes in which 25% (E-25), 50% (E-50), 75% (E-75), and 100% (E-100) of the natural coarse aggregate particles (≥2.36mm) were replaced with EAF slag materials. Aggregates gradation was selected based on maximum nominal size of 12.5 mm. At the first stage of the research, the optimum binder contents of mixtures containing various amounts of EAF were determined. At the second stage, the trend of changes in Marshall Parameters due to the addition of EAF materials were determined and the results were analyzed.

3- Results and Discussion

Resilient Modulus (ASTM D4123) and Indirect Tensile Strength values of the specimens at their optimum binder contents were determined at 20˚C. For performing the tests, Universal Testing Machine (UTM 14) that was equipped with a temperature control chamber was used. The results are shown in Figure1 and Table1.

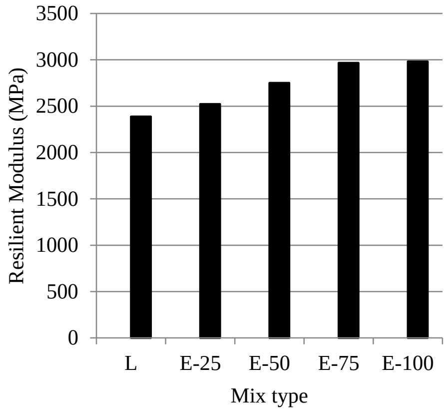

Figure 1. Resilient modulus test results

Table 1. IDT test results

Mix type	L	E-25	E-50	E-75	E-100
Tensile stress (kPa)	625	693	732	750	756
Toughness (kPa)	424	440	505	524	546
DE_{IDT} (kPa)	322	334	388	406	437

Although various fatigue testing could be performed, in this research due to its availability, four point bending test was used to perform all the fatigue tests. AASHTO T321-07 and ASTM D7460-10 testing methods were followed to prepare and test beam fatigue samples. Slab samples were prepared and were cut at beam sizes of 380×63×50mm. Fatigue tests were conducted both at strain control modes and at frequency of 10Hz. Three strain levels of 500, 700 and 800 micro strains and three replications at each stress and strain levels were used. All the tests were performed at 20˚C. Sinusoidal wave form testing mode was applied since it produces the intended stress and strain wave form that is anticipated in field conditions.

Different approaches were used to analyze fatigue testing data. These were mainly based on stiffness method to develop several fatigue models. Moreover, a fatigue prediction model, based on fracture energy (obtained from indirect tensile test) was developed.

4- Fatigue Models based on IDT and resilient modulus test results

The results of indirect tensile strength test showed that the inclusion of EAF slag resulted in increased tensile strength of asphalt mixes. Increased slag contents in asphalt mixes resulted in the increased resilient modulus of mixes. This was attributed to rougher texture of the slag

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particles which are more angular, and have greater adhesion, compared to limestone aggregates. The results also show that the inclusion of EAF in mixes improved fatigue life of mixes considerably. In addition, models based on the proposed fatigue prediction model (Table 2) can reasonably predict the fatigue lives of the mixes incorporating EAF slag materials.

Table 2. Proposed fatigue prediction model

Mix type	$e^{a\left(\frac{DE_f}{DE_{IDT}}\right)+b}$				
	Coefficients	50% stiffness reduction		R&B	
		N_{50}	R^2	$N_{R\&B}$	R^2
E-25	a	-4.471E4	0.984	-5.006E4	0.997
	b	15.590		15.450	
E-50	a	-6.241E4	0.981	-6.237E4	0.961
	b	16.024		15.531	
E-75	a	-3.584E4	0.656	-2.076E5	0.721
	b	14.376		20.937	
E-100	a	-5.160E4	0.826	-5.989E4	0.915
	b	15.130		15.263	
L	a	-3.171E4	0.831	-1.069E5	0.909
	B	13.665		16.771	