Journal of Ferdowsi Civil Engineering, Vol.33, No.1, 2020.

Creep Behavior of SMA Mixtures with Slag and Polyethylene Terephthalate

Dariush Moazami[1] Seyed Ali Sahaf[2]

Abolfazl Mohamadzadeh Moghaddam[3]

1. Introduction

Disposal of steel slag as industrial waste and plastic containers as municipal/domestic waste occupy a significant portion of landfills that causes serious environmental problems. Recently polymers have been widely used as asphalt modifiers. However, the high cost of polymer additive is the main disadvantage, which limits its wide use for most road pavement construction. With regard to the ever-increasing price of materials, energy, and the scarcity of natural resources, it is inevitable to recycle waste materials and to reuse them as additives in asphalt mixtures.

2. Experimental program

This research focused on the laboratory performance evaluation of Stone Mastic Asphalt (SMA) mixtures using waste Polyethylene Terephthalate (PET) as an additive and waste slag as the aggregate proportion. PET was added in two forms (PET particles and PET fiber) and the production process is illustrated in Figure 1. Electric Arc Furnace (EAF) steel slag was used (75% of the coarse proportion) that belongs to Isfahan and Mobarake Steel manufacturing companies

In order to thoroughly investigate the impact of PET modification, specimens with three percentages of PET (3, 5 and 7) in two forms (PET particles and PET fibers) were prepared and dynamic creep tests were done at two stress levels (100 kPa, 200 kPa), and two testing temperatures (40°C, 50°C).

Experimental chart includes preparing lime control samples (L), samples with 75% slag in the coarse proportion (S), samples prepared by PET particles (P) and PET fiber (P-F). In this respect, 5-P-F indicates samples with 5 percent PET fiber.

3. Results

Strain profiles were modeled for all samples up to 10000 load cycles by the Zhou model in the MATLAB and consequently they were compared in terms of induced permanent strain, strain rates as well as the resulted damage

3.1. Permanent strain. In all stress and temperature combinations, lime samples produced the highest strain, while slag sample with 5 percent PET fiber exhibited the best performance with minimum accumulative permanent strain after 10000 load cycles. Cumulative strain for specimens modified with 5 percent PET fiber was the lowest followed by 7 and 3 percent, respectively.
Based on the statistical analysis, the application of waste materials has large impact on the induced strain. Modified samples with 5 percent PET fiber (S-5P-F) caused 70 percent less permanent strain compared to the slag samples.

3.2. Strain rate. Based on the obtained results, strain rate is the highest for lime sample followed by slag sample. In modified specimens, samples with 5 percent PET exhibited significantly improved performance. In average strain rate (strain per cycle ($\frac{\mu\varepsilon}{N}$)) was 1.02 $\frac{\mu\varepsilon}{N}$ for the slag sample and 0.3 $\frac{\mu\varepsilon}{N}$ for the S-5P-F (110% difference).

3.3. Relative damage analysis. As shown in Table 1, based on relative damage analysis natural lime samples were 1.2, 2.1, 2.0, and 2.5 times more damaging at different stress and temperature combinations. Adding PET in the form of fiber is more effective and exhibits the lowest damage ratio. Moreover, in average S-5P-F sample caused 70 percent less damage compared to the slag samples. Considering artificial slag specimens as the control sample, it was found that, in average, natural lime samples were 2.0 times more damaging.

4. Conclusion

The effect of two waste materials including steel slag and plastic containers (three percentages and two forms) were investigated through creep performance test at four stress-temperature combinations. Generally creep curves of lime and slag control specimens developed faster than the modified specimens, which implied that modified samples had a better capability to resist creep. It was found that cumulative permanent strain was the lowest for specimens modified with 5 percent PET followed by 7 and 3 percent, respectively. Furthermore, adding PET in the form of fiber is more effective. With the increase in stress and temperature, differences between creep performance of modified and unmodified samples were more prone. Based on average damage ratios, slag samples with 5 percent PET fiber (S-5P-F) were 70 percent less damaging.

[1]. PhD Student, Department of Civil Engineering, Engineering Faculty, Ferdowsi University of Mashhad, Mashhad, Iran

[2]. Corresponding Author: Assistant Professor, Department of Civil Engineering, Engineering Faculty, Ferdowsi University of Mashhad, Mashhad, Iran.
Email: asahaf@um.ac.ir

[3]. Assistant Professor, Department of Civil Engineering, Engineering Faculty, Ferdowsi University of Mashhad, Mashhad, Iran

1. Crusher 2. Label separator 3. Hot washer 4. Floating 5. Centrifugal dryer, storage silo 6. Final product and raw material for PET fiberproduction

(a)

1. Drier 2. Extruder and melt pipe 3. Spinning beam 4. Tensioning and cooling 5. Feed screw 6. Final PET fiber product

(b)

Figure 1: PET particles (a) and PET fiber (b) production process

Table 1. Linear relative damage for various samples

Creep Testing Conditions (Stress, Temperature)	Characteristics of Samples	Strain@10000 Cycles	Linear Relative Strain
100 kPa, 40°C	L	12073	**1.19**
	S	10183	**1.00**
	S-3P	7574	**0.74**
	S-5P	5367	**0.53**
	S-7P	6317	**0.62**
	S-3P-F	6130	**0.60**
	S-5P-F	3424	**0.34**
	S-7P-F	4684	**0.46**
100 kPa, 50°C	L	33625	**2.14**
	S	15693	**1.00**
	S-3P	12006	**0.77**
	S-5P	7676	**0.49**
	S-7P	9608	**0.61**
	S-3P-F	8408	**0.54**
	S-5P-F	4634	**0.30**
	S-7P-F	6187	**0.39**
200 kPa, 40°C	L	29928	**1.96**
	S	15246	**1.00**
	S-3P	11591	**0.76**
	S-5P	7537	**0.49**
	S-7P	9780	**0.64**
	S-3P-F	8113	**0.53**
	S-5P-F	4962	**0.33**
	S-7P-F	6016	**0.39**
200 kPa, 50°C	L	60977	**2.51**
	S	24273	**1.00**
	S-3P	18039	**0.74**
	S-5P	11253	**0.46**
	S-7P	14017	**0.58**
	S-3P-F	10709	**0.44**
	S-5P-F	5768	**0.24**
	S-7P-F	7643	**0.31**