



## Evaluation of the dual additive effect of rubber powder and PET numerically and laboratory in Hot asphalt mixture

A. Ameri<sup>1</sup>, M. Ameri<sup>1</sup>, H. Shaker<sup>1</sup>, F. Jafari<sup>2</sup>, B. Badarloo<sup>3</sup>

<sup>1</sup> Department of Civil Engineering, Iran University of Science and Technology, Tehran, Iran

<sup>2</sup> Department of Civil Engineering, Malayer University, Malayer, Iran

<sup>3</sup> Department of Civil Engineering, Qom University of Technology, Qom, Iran

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**ABSTRACT:** Utilizing Polyethylene Terephthalate (PET) and Crumb Rubber (CR) together in asphalt mixtures may result in the omission of these two materials from the environment and the formation of more resilient asphalt, enjoying the simultaneous softening quality of crumb rubber (CR) and hardening quality of polyethylene terephthalate (PET). Therefore, the two additives were combined in (0 and 100) %, (25 and 75) %, (50 and 50) %, (75 and 25) %, and (100 and 0) %, and the mixture was formed. Two additives were added to the mixture in 10% and 15% by weight of bitumen. Resilient Modulus Testing, Dynamic Creep Test, Moisture Sensitivity, and ITS Method were used to assess the modified mixture. Results revealed that the recommended material had the desired characteristics so that the use of every 15% Dual-use Additives of Crumb Rubber (CR) and Polyethylene Terephthalate (PET) to bitumen used leads to a 1.5% increase in Resilient Modulus and Dynamic Creep. Moreover, Indirect Tension in the dry state will be 1.14 times of the control sample (Crumb Rubber (CR): 25% and Polyethylene Terephthalate (PET): 75%). For the Moisture sensitivity test, the sample including 10 % of Crumb Rubber (CR) alone can cause an increase in the moisture sensitivity by 11%. Finally, the neural network method is used to estimate the lab results and evaluate the model's accuracy.

### 1- Introduction

Polymer-based materials, Recycled materials, and Nanomaterials may be used for bitumen modification, depending on the primary purpose. In addition to improving some properties of the mixture, recycled materials have many environmental benefits because they reduce waste accumulation and environmental degradation [1]. Crumb Rubber (CR) and Polyethylene Terephthalate (PET) – two recycled materials – have been used in various studies and different methods. Crumb Rubber is usually based on rubber and tubes and is used either wet or dry to improve the asphalt mixture quality. There are different types of PET and the final composition and grading type used may affect the final result [2]. For example, some studies have mentioned that components inside the bitumen made it possible to use polyethylene plastic waste to improve some of the bitumen properties [3].

Moreover, research findings indicate that using waste plastic bottles in SMA mixtures may improve the rutting resistance and mixture hardness [4]. Furthermore, adding waste plastic bottles into the hot asphalt mixtures can increase the hardness of bitumen and viscosity of the modified mixtures. An increase in viscosity of the modified mixtures can reduce the density of sample asphalt [5]. In general, studies have shown that using plastomers like polyethylene to increase the rutting resistance at operating temperature

may improve the bitumen used. Some researchers have used other recycled materials made of crumb rubber to have a hot asphalt concrete mixture. Findings demonstrate that these recycled materials can improve bitumen qualities such as bitumen adhesion resistance, adhesive property of bitumen and increase the viscosity (to some extent) due to the loss of some of the oils in mixing crumb rubber and bitumen. In this regard, some elastomers, such as styrene-butadiene-styrene (SBS), have increased the bitumen adhesion resistance and fatigue resistance and reduced the thermal rutting sensitivity. According to statistics, millions of tires are annually collected and stored as waste after being discarded, creating many environmental problems and a lack of space required for storage. Additionally, Polyethylene Terephthalate (PET), used to make plastic bottles and rigid food packaging, is one of the most commonly recycled plastics. But more than half of the plastics used to make these bottles are not collected for recycling. Using these two wastes and their usage in the construction industry has been investigated separately in research; however, utilizing dual-use additives of CR and PET together in previous research is one issue that needs to be thoroughly investigated. In this study, the usage of a mixture of Crumb Rubber (CR) and Polyethylene Terephthalate (PET) of bottle grade (one of the recycled plastic wastes) as elastomers and plastomers are investigated. The main aims of this study are to assess the newly-introduced material, to

\*Corresponding author's email: ameri@iust.ac.ir



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estimate the additive effect using the Moisture sensitivity test, Resilient Modulus Testing, Dynamic Creep Test, and finally, the determination of the optimal mixing ratio of these two materials and mixture of two materials with bitumen. Furthermore, it is expected that the combination of the two additives will result in the production of dual-use additives that benefit from both the softening quality of the crumb rubber and the hardening quality of PET.

## 2- Research Method

In the present study, experimental methods were used. Using a control sample is one of the main characteristics of this research method. To make these samples, we will consider stone materials selection, types of bitumen, dual-use additives bitumen, and the ways they can be mixed. After that, the findings and results of the conducted experiments to investigate the effect of dual-use additives on the bitumen are discussed. Finally, the data will be numerically and experimentally analyzed and the results of both sections will be presented.

### 2- 1- Materials

Bitumen tests include Used materials and their grading, which influence the qualities of asphalt mixture, some of which are hardness, durability, permeability, performance, and moisture sensitivity. Hence, in this study, pure bitumen penetration grade 60/70 has been used, given that it is widely used in asphalt samples. Tests run on bitumen are as follows: permeability test, Softening point, ductility of bitumen, Flashpoint, and specific gravity of bitumen.

#### 2- 1- 1- Used Additive

As mentioned above, the crumb rubber dual-use additive based on the tube and polyethylene terephthalate (PET) is made in Malaysia under the trade name BG 1021. To be sieved, the size of the primary particles of the two substances shall be 50. The two substances were mixed, and the dual-use additive was formed using the Plastics Extrusion method. Plastics extrusion is a high-volume manufacturing process in which raw plastic is melted, and the materials are mixed in the liquid state, and the plastic profile is extracted. The input parameters of this device are three turning drums for mixing the substances. In this study, the recommended temperatures of the drums are 270, 280, and 270°, respectively. Finally, the output was the profiles of the dual-use additives. Afterward, these profiles were crushed into powder and mixed with the bitumen with the high-speed stirrer. To that aim, the asphalt mixtures were formed with the modified bitumen. Following previous studies, the amount of polyethylene terephthalate and crumb rubber used in this study ranged widely (0, 25, 50, 75, 100). We tried to reach a better perception of the simultaneous performance of these substances by mixing these two in different proportions (10% and 15%) with bitumen. Amounts lower than 10% and higher than 15% were tested and the optimum percentage was determined after the formation and mixing the bitumen. One of the

reasons for selecting the additive of 10% and 15% is that the bitumen AC 60-70 is used. The behaviors of this bitumen will lead to dissolving the additives immediately in a way that if the amount of additive exceeds 15%, it would settle in the bitumen.

## 3- Results and Discussion

At the very best, the tensile strength in the dry sample containing 15% PET additive is improved up to 20% compared to the control mixture. However, the indirect tensile strength for the samples which underwent the melting and freezing process is slightly different, in a way that by increasing the percentage of PET in the additive, the strength will reduce and if the additive contains more than 50% PET, the indirect tensile strength will be less than that of the control sample. In this case, the sample containing 15% additive of crumb rubber only has the most indirect tensile strength, which is improved up to 14% compared to the control sample.

The results of the comparison of the strength of wet and dry samples indicate that the mixtures containing the crumb rubber only and the mixtures containing 75% crumb rubber and 25% PET have desirable moisture sensitivity.

The boiling water test results indicated that the scour is less for the mixtures with the crumb rubber only. Yet, by increasing the PET in the additive, the scour increases, and the stripping aggregates in these samples are more. The scour in the additive of crumb rubber only in the samples containing 15% additive are less than the samples with 10% additive. However, this item follows a different procedure for the samples with more than 50% PET, in a way that there is no notable difference between the samples with 10% and 15% additive.

The results of the dynamic creep test indicate that the mixture with additives containing 75% crumb rubber and 25% PET has the most creep strength. In this type of modifier, the mixture containing 15% additive also has more resistance. All in all, using more PET instead of crumb rubber will reduce the creep strength so that in mixtures containing 100% PET, the creep strength is less than that of the control sample.

It can be concluded from the module test that all the additives (10% and 15%) will increase the static module and the static modules which use PET instead of crumb rubber will improve in a way that the proportion of the static modules of samples containing 15% PET additive to control sample is 50%.

## 4- Conclusions

The former research results indicate that in order to optimize the neural networks in concrete and asphalt, using this network can be beneficial in predicting the numerical results. Using the ANFIS networks in order to predict the result of tests pertinent to hot asphalt concrete indicated that we could predict the experimental data using the neural networks with low error rates.

The optimum mixture for the formation of dual-use additive is 75% of crumb rubber and 25% of PET; 15% of this mixture will be mixed with the bitumen.

Given that they are recyclable, the dual-use additive is less expensive than the bitumen and this factor, in addition to the optimized particulars of the asphalt, makes the product economical.

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