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Evaluation of the Effect of Zycotherm on Moisture Susceptibility of Warm Mix Asphalt Containing Crumb Rubber

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ABSTRACT: Reducing the temperature of asphalt mixture production is one of the essential benefits of using warm mix asphalt, but this advantage also causes some pavement problems. One of the most critical issues is creating a higher moisture potential in road pavement due to asphalt mixtures' lower production temperatures. Subsequently, some of the aggregate moisture does not evaporate. This study aims to evaluate the effect of zycotherm on the moisture reduction of warm mix asphalt. Besides, Waste crumbs replaced some of the fine-grained aggregates.

Materials include different percentages of Zycotherm (0.1, 0.15, and 0.2% by total weight of bitumen) and crumb rubber (0, 10, and 20% by total weight of the fine aggregate) bitumen 60/70 and granite sum make nine mix designs. Experiments include Boiling Water Test, Indirect Tensile Test; And Resilient Modulus (MR) Test evaluated the asphalt mixture's moisture sensitivity. The boiling water test results showed that the increase in Zycotherm improves moisture susceptibility. However, the crude rubber does not significantly affect boiling water tests because of the Crumb rubber's lower density of aggregates, despite the apparent improvement in the bitumen adhesion to the sum. Resilient modulus, a model for predicting tensile strength ratio (TSR), was made based on the experimental results using one-way ANOVA. The minimum required percentage of Zycotherm for replacing 10% of the crumb rubber was 0.128%. For 20% of the crumb rubber, it is equal to 0.149%. According to the resilient modulus results, the addition of a Zycotherm increases MR, while the crumb rubber's substitution causes a slight increase in MR.

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1. INTRODUCTION

One of the most important problems of warm mix asphalt is moisture sensitivity, because of mixing temperature reduction. [1, 2]. To mitigate the effects of this problem, it should prevent water from entering the pavement using proper drainage or limestone aggregates and anti-stripping additive. Due to the high cost of transferring the materials, it is not always possible to use limestone aggregate. Therefore, to reduce the moisture susceptibility, in some cases, an anti-stripping material should be used [3, 4]. So far, many studies have been done to improve the adhesion of bitumen in order to reduce moisture damage in asphalt mixtures using additives such as Nanomaterials [5-8]. On the other hand, given the growth of waste rubble, annual production of more than 1.5 billion rubber rings in the world, it can be used as a substitution of aggregate to achieve both environmental and economic benefits [9-14]. Therefore, the purpose of this study is to investigate the effect of using Nano-anti-striping (Zycotherm) and crumb rubber as a substitute for asphalt aggregates on the moisture susceptibility of warm mix asphalt using a qualitative test (boiling water) and quantitative tests (modified Lattman and a resilient modulus).

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2. EXPERIMENTAL PROGRAM

In this research, granite aggregate and the crumb rubber with a specific gravity of 1.2 with percentages of 0%, 10% and 20% as substitute values of aggregate were prepared. The bitumen with penetration grade of 60-70 (PG58-16) was modified by Zycotherm with a total weight of 0.1, 0.15 and 0.2% (based on the previous studies) using high shear at a temperature of 120°C for 1 hour [15-18]. The asphalt mixture samples were generated by Marshall Method (ASTM D1559) and the optimum bitumen percentage was obtained, 5.6, 5.6, 6 and 6.3%, for mixtures containing 0%, 10% and 20% of crumb rubber, respectively. It should be noted that Zycotherm had no effect on this percentage. The labeling system was used as described in Table 1, where *R* represents the replacement percentage of crumb rubber and *Z* percent the percentage of Zycotherm. In this study, 15 samples were made for each mix design (a total of 135 samples), of which 95 samples were applied to construct the base model, and 40 samples were used to validate the base model. This model was used to determine the optimal percentage of additives. Finally, the

Table 1. Labeling samples of asphalt mixture

Sample Name	Percentage of Crumb Rubber	Percentage of Zycotherm	Percentage of Bitumen
R0Z1	0	0.10	5.6
R0Z1.5	0	0.15	5.6
R0Z2	0	0.20	5.6
R10Z1	10	0.10	6.0
R10Z1.5	10	0.15	6.0
R10Z2	10	0.20	6.0
R20Z1	20	0.10	6.3
R20Z1.5	20	0.15	6.3
R20Z2	20	0.20	6.3

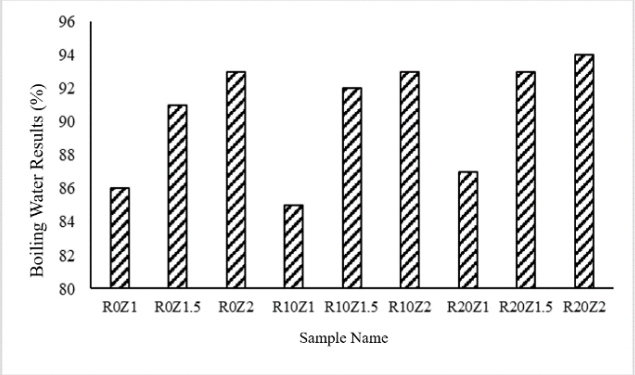

Fig. 1. Boiling water test results

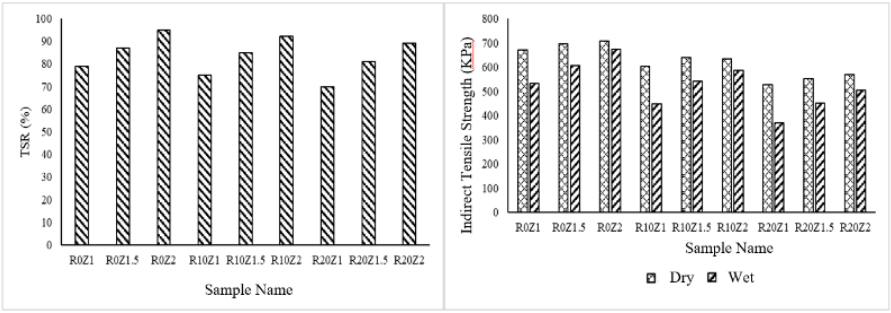

Fig. 2. Results of ITS and TSR

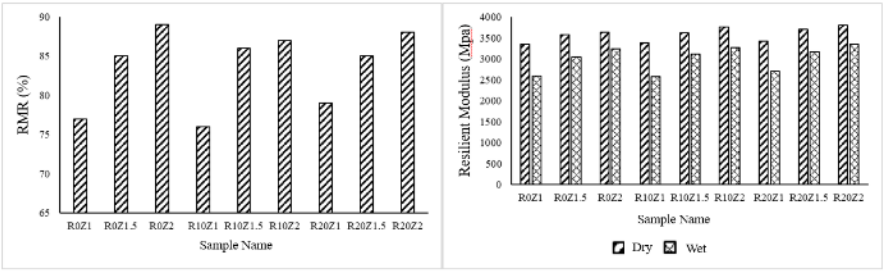

Fig. 3. Results of Mr and RMR

tests of boiling water, moisture susceptibility, and resilience modulus were performed on the samples according to ASTM D3625, ASTM D3625, and ASTM D4123-82, respectively.

3. RESULTS AND ANALYSIS

According to the results of the boiling water test (Figure 1), the addition of Zycotherm from 0.1 to 0.15% resulted in an improvement of 7% in boiling water and an increase in Zycotherm from 0.1 to 0.2%, resulting in an improvement of 8.5% of the test results. The addition of crumb rubber had no significant effect on the moisture properties of the samples.

According to the results of the indirect tensile strength (ITS) in Figure 2, with an increase in Zycotherm dosage from 0.1 to 0.2%, an increase of 6% and 31% can be seen in dry ITS and wet ITS, respectively. While increasing the crumb rubber percentages from 0 to 20%, the weakening ITS value was equal to 20% and 27% in dry and wet conditions, respectively. Also, with an increase in the percentage of Zycotherm from 0.1 to 0.2, an increase of 23% was observed in the values of TSR, while about 8% of the TSR values would be decreased when the dosage of crumb rubber rises from 0 to 20%. According to these results, the asphalt mixtures of crumb rubber with Zycotherm dosage less than 0.15% were not suitable for pavement because of their TSRs being lower than 80%.

According to the resilient modulus test (Mr) and its ratio (RMR) in Figure 3, increasing the percentage of Zycotherm from 0.1 to 0.2 caused an increase in dry and wet Mr (10% and 25%, respectively). However, by increasing the percentage of crumb rubber from 0 to 20%, this increase was equal to 3% and 4% for dry and wet conditions, respectively. According

to these results, all mix designs had satisfied the minimum requirement of the RMR parameter (70%).

Finally, a linear regression was used to determine the relationship between TSR and RMR (as independent parameters) with the percent of Zycotherm additive and crumb rubber substitution (as dependent parameters) applying SPSS software and one-way ANOVA analysis for 70% of the samples. The remaining samples (30%) validation model was done and the results are the relations given in Eq. 1 (98.8=R^2) and Eq. 2 (88.8=R^2), respectively.

$$TSR = 61.17 + (173.33 \times Z) - (0.35 \times R) \quad (1)$$

$$RMR = 67.56 + (106.67 \times Z) \quad (2)$$

4. CONCLUSIONS

The results of this study are summarized as the following:

• Using Zycotherm as an anti-striping modifier had significant effects on the boiling test results, while the addition of crumb rubber had a little effect on improving the moisture resistance of the warm mix asphalt.

• Improvement of bitumen with gyro increased the indirect tensile strength, but with the increase in the percentage of the tire, decreasing of indirect tensile strength was observed in all samples.

• Modifying of bitumen with Zycotherm increased the indirect tensile strength (ITS), but with the increase in the percentage of crumb rubber, decreasing of ITS was observed in all samples.

• According to the obtained linear equations for TSR and RMR, in order to control the moisture susceptibility of mixtures containing 10% and 20% of crumb rubber, the minimum required value of the Zycotherm was equal to 0.128% and 0.149%, respectively.

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