



Comparison of the effect of using mineral nanomaterials on the performance of HMA and glassphalt against the moisture damage

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ABSTRACT: Pavement response to a variety of damages is affected by the bond between bitumen and aggregate (adhesion) which is strongly affected by moisture and moisture entering from the surface or substrates of asphalt pavement causing the aggregate to be stripped. The result of moisture damage is commonly called stripping because the bitumen is separated from the aggregates and the aggregates remain uncoated. Various factors affect the moisture sensitivity of asphalt mixtures, which are generally divided into two categories: The first one is of internal origin and is directly related to the properties of the asphalt mixing constituents. In contrast, the second category is of external origin and is dependent on conditions outside the asphalt mixing system. Today, glassphalt technology is considered as an efficient way to reduce asphalt production costs, reduce fuel consumption, and reduce environmental pollution caused by the production of this type of waste. Despite the advantages of glassphalt, moisture damage is a weak point for these types of mixtures. The present study evaluated the moisture sensitivities of glassphalt and HMA and compared the performance of these two types of mixtures, along with the effects of two types of additives, nano hydrated lime and nano calcium carbonate on moisture damage. The moisture sensitivity of both types of mixtures was evaluated using a modified Lottman test and a thermodynamic test of Wilhelm plate based on surface free energy methods. The results of the indirect tensile strength test showed that the resistance of glassphalt in dry conditions was higher than that of HMA. However, glassphalt is exposed to wet conditions with a higher resistance to HMA. The results obtained from the thermodynamic test also showed that the modification of both types of asphalt binder (AC 60-70 and AC 85-100) using nano hydrated lime and nano calcium carbonate increases the total surface free energy and adhesion of the bonding of both types of base asphalt binders. This increase improves the strength of mixtures made with this type of asphalt binders against moisture damage of cohesion type, which is a positive effect in reducing the moisture damage.

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1. INTRODUCTION

The increasing growth of substance use and, consequently, the methods needed to eliminate its waste, is a major environmental concern. One solution to reducing this concern is to reuse them through recycling. Recycling is considered one of the most important foundations of sustainability of natural resources. [1, 2].

The use of waste materials in the construction of roads, in addition to reducing the volume of these waste and eliminating the space needed to bury these materials. It also has many benefits in environmental and economic terms. In addition, the use of these materials reduces the need for new natural resources, thereby reducing the use of mines [3]. Glass is one of the most critical waste materials. The benefits of scrap glass are that shattered glass is easily accessible and environmentally friendly. It also absorbs less bitumen through glass aggregates

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than conventional aggregates [4]. In contrast to these merits, there are problems such as decreased adhesion between glass and bitumen, reduced slip resistance, and increased moisture sensitivity in glass asphalt mixtures [4, 5].

The most important goals of this research are:

- Evaluation of performance of glass asphalt mixtures against moisture sensitivity using mechanical testing,
- Evaluation of the performance of hot asphalt mixtures against moisture sensitivity using mechanical testing,
- Comparison of performance of glass asphalt mixture with hot asphalt mixture against moisture sensitivity,
- Investigating the effect of using nano-mineral additives in reducing moisture damage of both types of asphalt mixtures,
- Investigate the effect of using nano-mineral additives on the surface free energy components of the base bitumen, and



•Investigation of the effect of bitumen remediation using nano-mineral additives on bitumen bond free energy parameter and resistance of asphalt mixtures to moisture sensitivity using surface free energy method.

In this study, two types of nano minerals including hydrated lime and calcium nano carbonate were used to improve the resistance of glass and hot asphalt mixtures to moisture damage. The main reason for using these two materials is that both of them in filler state have been able to reduce the moisture sensitivity of asphalt mixtures because they increase the adhesion properties of mastic and acidic aggregates.

2. METHODOLOGY

In this study, 36 different compounds were prepared to evaluate the moisture sensitivity potential of glass and hot asphalt mixtures. To prepare these compounds, as mentioned earlier, three types of aggregates include limestone, granite and quartzite, two types of bitumen with penetration rates of 70-60 and 85-85, nano-stripping additives including nano Hydrated lime and calcium nano carbonate have been used as bitumen modifiers (2% by bitumen mass) as well as scrap glass scraps. It is noteworthy, for each of the 36 compounds mentioned, three samples were prepared for dry conditions and three for wet conditions, and each sample was tested twice with repeat.

3. RESULTS AND DISCUSSION

Figures 1-2 show the results of this index for glass and hot asphalt mixtures made with the two types of bitumen used in this study. According to these graphs, as indicated for the values of indirect tensile strength (ITS), the ratio of indirect tensile strength (TSR) of glass and ordinary specimens also decreased with increasing number of ice-thaw cycles. Also, the values of this ratio were lower for glass asphalt mixtures than for hot asphalt mixtures, indicating lower resistance of these types to wet conditions. In addition, specimens made of bitumen 60-70 showed better performance than specimens made of bitumen 100-85. On the other hand, based on the results, it can be seen that the use of anti-stripping additives of hydrated nano-lime and calcium nano-carbonate increases this ratio and consequently improves the strength of specimens made with all three types of aggregates. Glass asphalt as well as hot asphalt mixtures compared to the control samples. For both types of bitumen, this ratio is higher for basic and modified calcareous aggregates. In other words, calcareous aggregates have the highest resistance to moisture damage and quartzite aggregates have the least resistance to moisture. Finally, in completing the results obtained from the modified Lattman experiment, it can be said that the glass asphalt mixtures, despite being resistant to moisture, can be obtained by using anti-stripping additives. This study also used two types of nano-minerals to offset this resistance and achieve a roughly equivalent strength to hot asphalt mixtures. The use of nano additives has reduced the separation energy of modified asphalt mixtures. This means that the bitumen-aggregate system is in a more thermodynamically balanced state and the tendency for stripping is reduced. This reduces the moisture sensitivity of the modified asphalt mixtures.

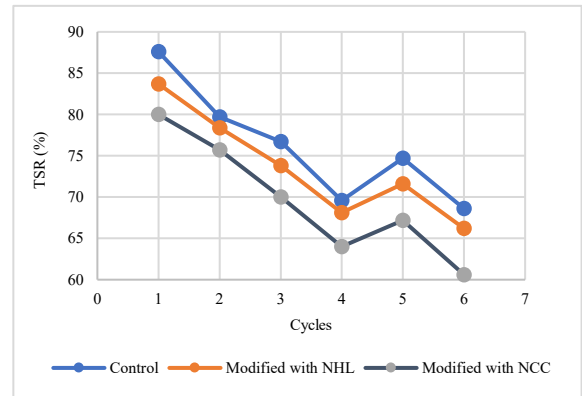


Fig. 1. Indirect Tensile Resistance Ratio (TSR) of AC 60-70

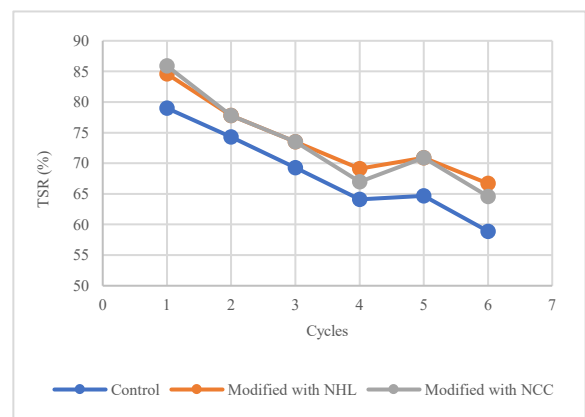


Fig. 2. Indirect Tensile Resistance Ratio (TSR) of AC 85-100

4. CONCLUSION

- The use of nanomaterials in this study has increased the resistance of glass asphalt mixture in dry and wet conditions. This increase was more pronounced in samples modified with hydrated nano-lime.
- Glass asphalt blend specimens are more resistant to moisture than normal asphalt blend specimens. This has made a greater difference in the number of higher ice-melting cycles.
- The results of mechanical tests of moisture sensitivity have shown that the use of both additives used in this study has reduced the moisture sensitivity of glass asphalt mixture.
- The performance of samples made with quartzite aggregates was significantly weaker for both asphalt mixtures in wet conditions than for samples with two other aggregates. In contrast, lime aggregates in both asphalt mixtures had better moisture resistance. On the other hand, the two bitumen used in the study showed that the bitumen 60-70 had better performance than the bitumen bitumen 85-85 in the resistance of the glass and hot asphalt mixture.
- Indirect tensile strength ratio for glass asphalt mixtures was lower than for hot asphalt mixtures and decreased with increasing number of ice and thaw cycles. In addition, the use

of both nanocomposites has significantly increased this index and consequently improved the resistance of both types of asphalt mixtures to moisture sensitivities.

•The use of nanomaterials has reduced the acid component and increased the amount of base bitumen free energy. This will increase the adhesion between bitumen and glass, which has strong acidic properties over other aggregates.

•Using both hydrated nano-lime and calcium nano-carbonate additives increased the bond free energy parameter for both bitumens, resulting in improved bond breakage resistance, which resulted in a better performance in the hydrated nano-lime. Improved resistance of mixtures made with both types of bitumen used in this study.

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