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Evaluation of properties of hot mix asphalt modified with nano-graphene

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ABSTRACT: One of the methods to improve the properties of asphalt mixtures is using additives. One of the additives that have received much attention in recent years is nanomaterials, which have been very popular due to their unique characteristics. In this study, the effects of nanographene on the performance characteristics of hot asphalt mixtures have been investigated. For this purpose, bitumen was modified in 0.1%, 0.3%, and 0.5% (by weight of bitumen), and by performing bitumen tests, the amount of nanographene selected was 0.5%. Then, to evaluate the performance characteristics of the mixtures, repeated axial load tests (RLA), indirect tensile strength modulus (ITSM), and indirect tensile fatigue test (ITF) were performed. Besides, to evaluate the moisture sensitivity of the mixtures, indirect and compressive tensile tests were performed on the samples in both dry and wet conditions. The results showed a decrease in the final deformation an increase in stiffness at 5, 25, and 40 by 15, 36, and 54%, respectively. Also, in some samples, the fatigue life of modified asphalt mixtures was improved by up to 55% compared to conventional mixtures. Increasing the TSR index in the indirect tensile test indicates an improvement in the performance of the modified sample compared to conventional samples and a decrease in their sensitivity against moisture, to the extent that the indirect tensile strength of the modified sample in dry and wet conditions compared to conventional samples Increased by 23% and 38% respectively.

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1- Introduction

Asphalt concrete is one of the most widely used materials in the construction of pavements, roads and airports. Researchers have always tried to improve the properties of asphalt mixtures to increase the resistance of these mixtures to damage in order to reduce the maintenance costs of pavements [1]. Damages that appear before the end of the pavement useful life include groove damage, permanent deformation and fatigue, and heat cracks. Because repairing and repairing these failures can be costly, researchers use a variety of methods to prevent or delay the onset of these failures [2, 3]. Due to the fact that bitumen makes up about 5 to 7% by the weight and 13 to 15% by the volume of asphalt mixtures, it plays a very important role in the performance of asphalt mixtures [4]. One of these methods is bitumen modification by different materials. It seems that nanomaterials due to their special properties such as high specific surface area and structural properties can improve the performance of asphalt mixtures against cracking, fatigue and heat cracks. Additives are commonly used to increase the durability and performance of asphalt mixtures against cracking, fatigue and thermal cracking. Grooving due to deformation of asphalt mixtures is one of the main mechanisms of failure in asphalt pavements that can occur in any weather conditions, especially at high temperatures, which ultimately leads to a reduction in pavement life [5].In this study, in addition to investigating the effect of the properties of this material on the moisture sensitivity of asphalt mixtures, the grooving potential and fatigue life of modified asphalt mixtures with nanographene have been investigated. The bitumen used in this research is 70-60 bitumen from Isfahan Oil Company. The stone materials used are also of the siliceous material type and the grading of all samples is based on the grading of Ashto Regulation No. 4.

2- Methodology

GNPs were added to bitumen at 0.1, 0.3, and 0.5% (by the bitumen weight) to prepare the samples. To achieve a homogeneous and uniform mixture, the bitumen was heated to 150°C, and the mixing operation was performed by a high-shear mixer at 4500 rpm for 45 minutes. Mixing time and speed were selected specifically to create a homogeneous mixture according to previous studies and the properties of nanomaterials. To check the uniformity of the modified bitumen after sampling, samples were taken from different parts of the modified bitumen container, and the penetration grade test was performed.

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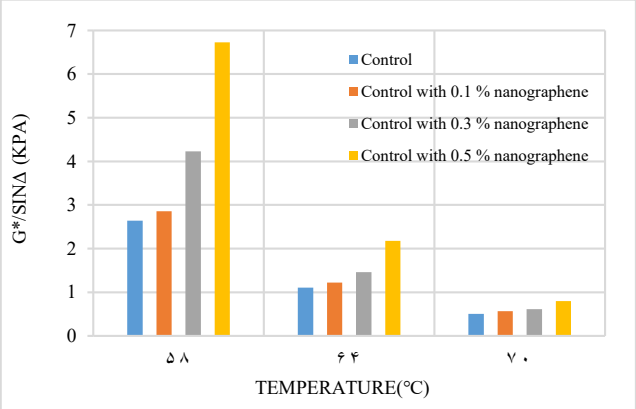

Fig. 1. DSR test and G*/Sinδ rutting index results for unaged bitumen

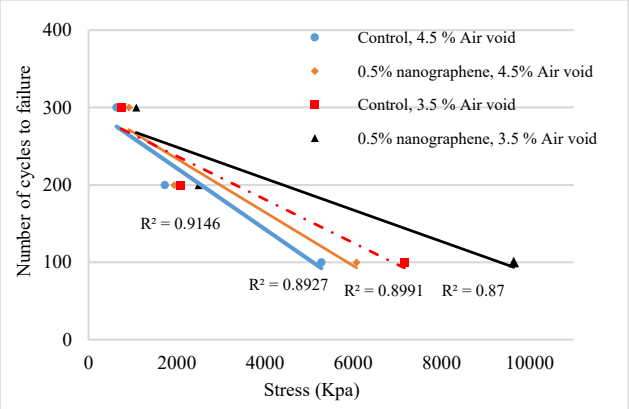

Fig. 2. ITF test results

The mixing plan of asphalt mixtures used in this study was performed according to the Marshall method according to the instructions of MS-2 of the asphalt institute. The fatigue life of asphalt mixtures is obtained by indirect traction testing. Indirect tensile test is a type of fatigue test in which the load is repeatedly applied to a cylindrical specimen so that the compressive load is applied to the cylindrical faces in a parallel and vertical manner. This form of loading causes uniform tensile stress in the specimen. Which will be perpendicular to the direction of loading and along the cylindrical sample

3- Results and Discussion

The results of the G*/Sinδ rutting parameter in the non-aged state for dynamic rheometer testing are presented in Figure 1. Based on this figure, the incorporation of nanographene in modified bitumens was associated with a concomitant decline in phase angle (δ) and an increase in G*. This caused an increase in G*/Sinδ which is evident in samples containing 0.5% of nanographene compared to those containing 0.3 and 0.1% and control samples. At high temperatures, the control samples and the ones containing 0.1 and 0.3% nanographene did not meet this criterion, whereas the samples containing 0.5% nanographene can perform reasonably well at higher temperatures.

As depicted in Figure 2, samples containing GNPs displayed better fatigue performance than conventional samples. This increase in fatigue life varied at different stress levels. In some specimens, the fatigue life of the modified asphalt mixtures was improved by up to 55% compared to conventional mixtures. These factors, along with promoted asphalt mixture elasticity due to the presence of nanographene, delay the formation and expansion of cracks and thus improve the sample's fatigue life. By being placed

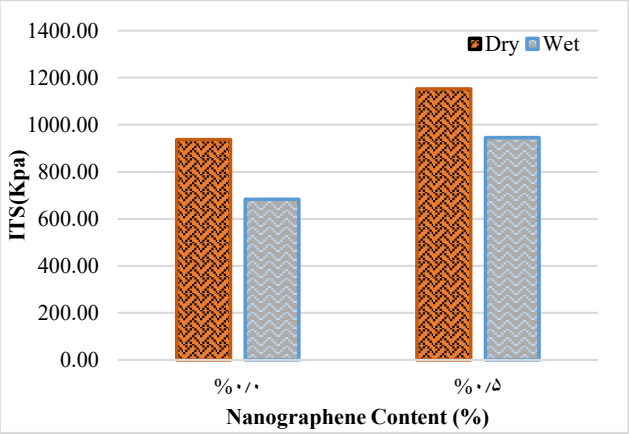

Fig. 3. ITS test results

between the bitumen's polymer molecules, GNPs sheets strengthen the bitumen network and enhance the mixtures' resistance to the expansion of fatigue cracks.

According to Figure 3, the ITS of the modified dry and wet samples increased by about 23% and 27%, respectively, compared to the conventional samples. The mixtures modified with 0.5% GNPs displayed a significant rise in tensile strength compared to the base sample, both dry and processed. GNP incorporation reduced the decline in wet samples' tensile strength compared to that of dry samples

The TSR index, which shows the conditioned to unconditioned specimens' ITS ratio, must be at least 75% according to AASHTO T283. Based on Fig. 4, this index was 73% and 82% in conventional and modified samples, respectively.

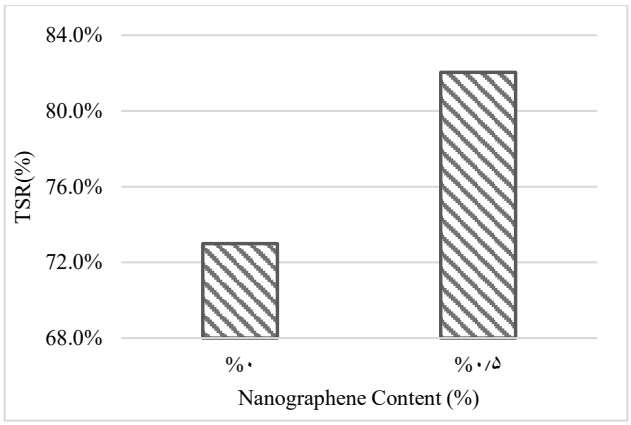

Fig. 4. Results of wet to dry samples' tensile strength ratio

4- Conclusions

• Modified bitumen samples had a lower degree of penetration, higher softening point, and more ductility than base bitumen samples, indicating that nanographene modification improved bitumen properties.

• The fatigue performance of the modified specimens was significantly promoted compared to the conventional specimens. This elevation occurred at both air void contents. An increase in stress significantly reduced the number of cycles leading to rupture, such that by increasing the stress from 100 to 300 kPa, the number of cycles leading to rupture decreased by about 80-90%.

• In both dry and wet conditions, in the indirect tensile test, the modified specimens showed more resistance than the conventional specimens, demonstrating the asphalt mixtures' diminished sensitivity to moisture.

• The GNP-modified mixtures had improved fatigue life, reduced final deformation, and diminished moisture sensitivity compared to conventional samples.

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