Investigating the Effect of Acrylon Acrylonitrile Acrylate on the Fatigue Life of Asphalt Mixtures

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ABSTRACT

Over time, with repeated loading, if the amount of strain or stress exceeds the strength of the asphalt mixtures, cracks will form on the surface and under the asphalt mixture layer. These cracks gradually develop as the number of loads increases and spread to the asphalt body. Fatigue is one of the most important factors that reduce the life of asphalt pavements. One of the effective parameters in the occurrence of fatigue cracking is the properties of the bitumen used. According to previous studies, the use of nanomaterials and polymer additives has been considered by researchers in recent years. Due to the much higher cost of production or production of polymeric materials, the use of these materials in this research has been considered. One way to control this type of failure is to use bitumen, aggregate or asphalt mixers. Accordingly, in this study, the effect of using a polymer additive called acrylon acrylonitrile acrylate (ASA) as a bitumen modifier on the potential for fatigue cracking in asphalt mixtures has been investigated. Two types of aggregates, with different mineralogical properties, PG 64-16 as bitumen and ASA additive, in two different percentages of bitumen mass were the materials used in this study, which were tested at two temperatures and five different stress levels. To determine the percentage of optimal bitumen, the Marshall mixing design method has been used and to determine the fatigue life of asphalt mixtures, indirect tensile fatigue test method has been used. The results of this study show that the use of polymer additives has increased the fatigue life of asphalt mixtures. The fatigue life of granite aggregate specimens was longer than that of limestone aggregates, but the increase in life resulting from the use of ASA increased the fatigue life of granite aggregate specimens. The increase in temperature and stress level, as expected, has reduced the fatigue life of asphalt mix samples, which is much lower in samples made of bitumen modified with polymeric materials than the samples.

KEYWORDS:

Asphalt mixtures, Fatigue cracking, Bitumen modification, Acrylon acrylonitrile acrylate, Indirect tensile loading

Introduction

In recent years, researchers have used various methods to improve the rheological properties of bitumen. One way to improve the performance of bitumen is to use the right additives. So far, common additives such as polymer additives and waxes have been used to correct bitumen behavior at high and low temperatures. Although the weight of bitumen in asphalt mixes is negligible, much of the research on asphalt mixtures is about bitumen. Bitumen has an important effect on the optimal performance, durability and stability of asphalt mixtures, and any change in bitumen performance will affect the performance of asphalt mix [1].

One of the materials that can be reused as a suitable additive for bitumen modification in the pavement industry is polymers. Polymers, like other modifiers, have their own advantages and disadvantages, but try to bring bitumen properties closer to ideal properties, given the conditions used. Preliminary studies have shown that limited research on the use of ASA in the bitumen and asphalt industry has been conducted mainly on the rheological properties of bitumen, especially at high temperatures. Therefore, in this study, an attempt has been made to investigate the effect of using ASA polymer on the properties of asphalt mixture against fatigue cracking, which generally occurs in intermediate temperatures. Early reasons for choosing this material include increased resistance to high temperatures under the bitumen correction process, resistance to aging, increased modulus of hardness, and low cost.

Methodology

Two types of aggregates with different properties against fatigue cracking have been investigated in this study: limestone and granite. ASA is a type of polymer that is obtained by low pressure and the use of Zieglernata catalyst and has a linear structure and this material is in the form of very fine solid particles about 150-120 micrometers.

In this research, the bitumen used is bitumen with a PG 64-16, which has been prepared by Azardavam Yol Tabriz Company. Bitumen 16-64 PG is temperate according to climatic conditions, and fatigue occurs mainly at temperatures between 5 and 25 °C.

In order to improve the bitumen, first the base bitumen is heated to 160 °C and the additive is gradually added to it. ASA additive is a solid granular powder that is gradually added to bitumen. The mixing operation is performed in a mixer with temperature control for 25 minutes at a rotation speed of 2000 rpm.

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 [3]. In this method, the optimal bitumen percentage is determined based on the average of 3% bitumen equivalent to the maximum strength, maximum specific gravity and the percentage of empty space equal to 4% and is controlled by the values of the regulations.

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 [4].

Results and Discussion

The optimum bitumen percentage for samples made with granite aggregate and limestone is 5.5 and 5.7, respectively.

Figures 1-2 show the number of load cycles leading to the failure of asphalt specimens for ASA-controlled and modified mixtures in specimens made of granite aggregate. Figures 1-2 show that ASA-modified asphalt mixture specimens show significantly better fatigue life than simple asphalt specimens. Because bitumen mixes with ASA, the released carbon fills the voids, creating strong bonds with the bitumen chains, which increases the adhesion of the bitumen to the aggregate. This better adhesion between bitumen and aggregate also minimizes the displacement of the material particles relative to each other, thus improving the fatigue life due to the delay in the process of creating and expanding cracks. In addition, residual ASA particles that do not react chemically can complete the granulation of filler materials and cover a very fine part of the granulation curve. As a result, reducing the void space in asphalt mixtures can lead to an increase in their service life. On the other hand, adding ASA to bitumen increases the hardness of bitumen. If the stress level is constant in the fatigue test, the tensile strain decreases with increasing hardness of the samples.

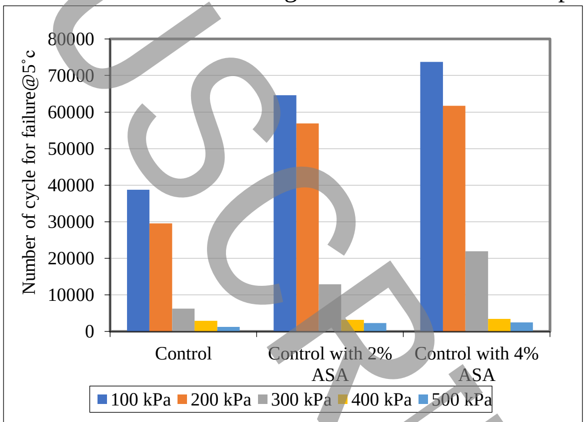

Figure 1 The number of cycles leading to failure in the fatigue test at 5 °C (granite aggregate samples)

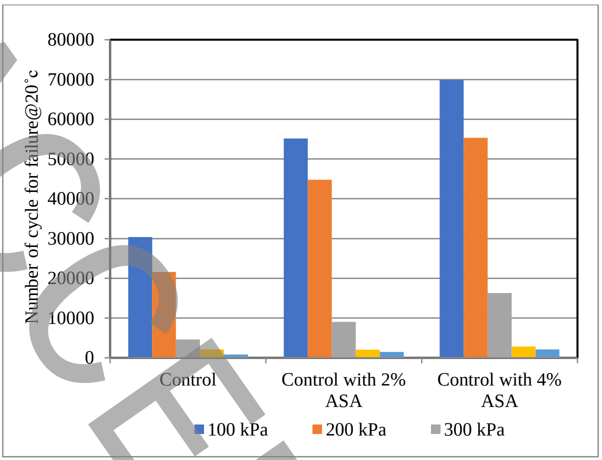

Figure 2 The number of breakdown cycles in the fatigue test at 20 °C (granite aggregate samples)

Figures 3-4 show the number of loading cycles leading to the failure of asphalt samples for ASA-controlled and modified mixtures with limestone aggregate. As can be seen, in general, samples made with limestone aggregates have a shorter shelf life than granite aggregates.

The material of the minerals and the apparent structure of the aggregates can cause resistance to fatigue cracking. Cognitively, the harder the aggregate adheres to the bitumen, the better its adhesion against fatigue cracking. In terms of appearance, the three parameters of shape, fracture and surface texture are effective in creating mechanical resistance of aggregate against fatigue cracking. Bitumen has weak acidic properties and therefore its adhesion to limestone aggregates that have game properties is stronger than its adhesion to granite aggregates.

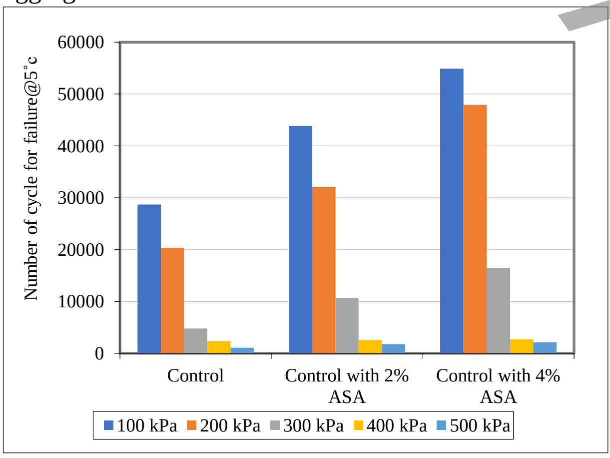

Figure 3 Number of breakdown cycles in the fatigue test at 5 °C (limestone specimens)

Similar to the samples made with granite aggregates, it is observed that with increasing temperature, the fatigue life of asphalt samples decreases. The percentage of reduction in fatigue life in samples made with limestone aggregate was lower than granite aggregate.

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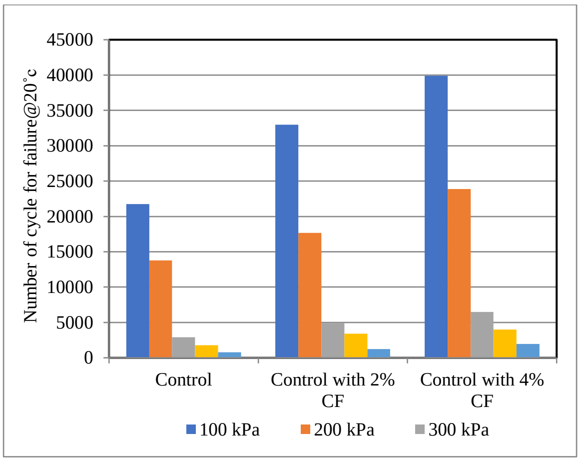

Figure 4 The number of breakdown cycles in the fatigue test at 20 °C (limestone specimens)

Conclusions

In this section, the most important results obtained from this research are given:

• Increasing the temperature reduces the hardness module of the asphalt mix. This has increased the amount of tensile strain in the asphalt mixture at high temperatures and greatly reduced the fatigue life.

• The use of ASA additives has reduced the hardness of asphalt mix samples. On the other hand, it increases the adhesion of bitumen-aggregate. This increases the resistance of asphalt mixtures to fatigue and increases the fatigue life of the samples.

• In order to determine the optimal amount of ASA additive, economic analysis must be done. On the other hand, there is a regular trend between an increase in the percentage of additives and fatigue life in samples made with limestone aggregate. These two events in the samples of the two groups indicate the need for economic analysis in samples with different aggregates.

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