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Experimental Study on Creep behavior of Stone Mastic Asphalt by Using of Nano Al_2O^3

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Abstract: In recent years, many researches were done to improve service life of asphalt pavement quality against vehicles dynamic loads. For this purpose, researchers investigated different ways such as changing the aggregate gradation and using of additive material to modify bitumen and asphalt mixture. One of this ways is using of additive materials to improve asphalt properties against dynamic loads. Due to unique characteristics of nano materials, using of them in asphalt mixtures has been interested. Therefore, in this study the effect of Nano Al2O3 in improvement of creep behavior of stone mastic asphalt (SMA) has been investigated. To achieve this goal, mixtures with different content of bitumen and nano Al2O3 are made and the effects of nano Al2O3 on the SMA mixtures are investigated. The results show that adding of nano Al2O3 had great effects on improvement of permanent deformation of SMA mixtures.

Key words: SMA, Nano Al2O3, Creep, Permanent Deformation.

1. Introduction

Damages that occur before the useful life of pavement that mainly are rutting, permanent deformation and fatigue cracking. Since the recovery and reconstruction of defects will be costly, therefore, the prevention of such cases would be more economical. To avoid failure, one of the methods is to modify the properties of bitumen. Researchers have used different methods including the use of various types of polymers and fibers [1]. To improve the performance of bitumen and asphalt concrete mixtures, the addition of modifiers such as nano materials has become popular in recent years. Nano composites are one of the most popular materials discovered recently to improve properties of bitumen and asphalt mixture [2]. Nanotechnology is a general term that refers to all technologies in the field of nanoscale. Typically, the Purpose of nanoscale is from about 1nm to 100nm. This technology has attracted the attention of many researchers. Ghaffarpour et al. carried out comparative rheological tests on binders and mechanical tests on asphalt mixtures containing unmodified and nanoclay modified bitumen. Results showed that nanoclay can improve properties such as stability, resilient modulus, and indirect tensile strength, but it do not seem to have a beneficial effect on fatigue behavior in low temperature [3].

Golestani et al. evaluated Performance of modified asphalts binder by nano composite. The physical, mechanical and rheological properties of original bitumen, and modified bitumen by nano composite have been studied and compared. The results showed that nano composite can improve the physical properties, rheological behaviors and the stability of the bitumen [4].

Martin et al. investigated nanotechnology effects on the adhesion of asphalt mixtures. Two different types of nanoclay were used to modify bitumen. In the first case, Viscosity of modified bitumen in comparison to original bitumen (70-100) did not change after the addition of 6% (by weight) of nano-clay, although improved its short-term and long-term hardening. In the second case, Nanoclay increased viscosity of bitumen. Therefore, this type of modifier is appropriate to use in asphalt mixtures to prevent water penetration [5].

Ghasemi et al. evaluated the potential benefits of nano-SiO_2 powder and SBS for the stone mastic asphalt mixtures used on pavements. Five bitumen formulations were prepared using various percentages of SBS and nano-SiO_2 powder. Then, marshall samples were prepared by the modified and unmodified bitumens. The results of this investigation indicated that the stone mastic asphalt mixture modified by 5% SBS plus 2% nano SiO_2 powder could give the best results in the tests carried out in the current study [6].

Khodadadi et al. investigated Nanoclay additive effect on long-term performance of asphalt pavement. Indirect tensile test were conducted on cylindrical specimens made of standard and modified bitumen at the stress levels of 200, 300, 400 and 500 kPa. The results showed that the addition of 2% nanoclay increases the fatigue life of the asphalt pavement [7].

Many researches are done on bitumen and asphalt mixtures modified with Nano materials. In this study, The effects of nano Al_2O_3 on creep behavior of stone mastic asphalts are investigated. It is expected that modification of SMA mixtures with Nano Al_2O_3 improve the creep behavior of SMA asphalt mixtures.

2. Experimental

2.1. Materials

The aggregates used in this study were graded using the Recommended type for stone asphalt mixtures of the AASHTO standard, which is presented in figure 1. Bitumen was a 60-70 penetration grade and its properties are shown in Table 1. Also, Properties of nano Al_2O_3 are shown in Table 2.

2.2. Experimental Setup and Procedure

The tests generally used to assess the resistance of asphalt concrete mixtures to permanent deformation are the Marshall test, the static creep test, the dynamic creep test, repeated axial load test (RLA), and the wheel-tracking test [8]. In this study, the resistance to permanent deformation of stone mastic asphalt mixtures by different percent of nano materials is evaluated by using dynamic creep test.

For this study, cylindrical samples were made with a diameter of 101 mm and the height is 70 mm. Specimen preparation and compaction were conducted in accordance with ASTM D1559 [9].

The dynamic creep test is used to evaluate the effects of nano Al_2O_3 on the creep behavior of SMA asphalt mixtures. The nano Al_2O_3 contents selected are 0.3%, 0.6%, 0.9%, and 1.2% by weight of bitumen.

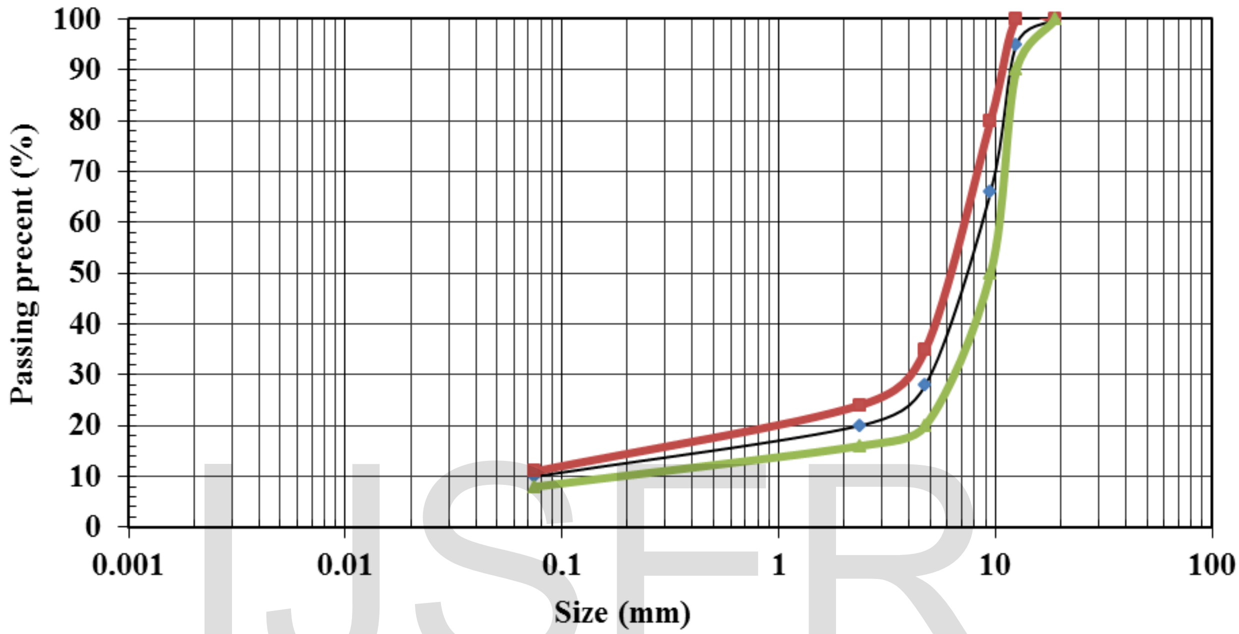

Figure 1. Gradation of aggregates used in this study

Table 1. Properties of bitumen used in this study

Test	Standard	Result
Penetration (100 g, 5 s, 25 ºC), 0.1 mm	ASTM D5-73	68
Ductility (25 ºC, 5 cm/min), cm	ASTM D113-79	102
Solubility in trichloroethylene, %	ASTM D2042-76	99.6
Softening point, ºC	ASTM D36-76	50
Flash point, ºC	ASTM D92-78	308

Table 2. Properties of nano Al_2O_3 used in this study

Specification	Result
Molecular formula	Al_2O_3
Color	white
Particle size (nm)	80

Specific Gravity(gr/cm^3)	0.90
Solubility (%)	99.0

2.3. Laboratory Tests.

2.3.2. Dynamic creep test

To determine the optimum content of Nano Al_2O_3 according to creep behavior of SMA asphalt mixtures, dynamic creep test has been used for a long time to determine creep behavior of asphalt mixtures, which is because of its simplicity and logic relation with permanent deformation of asphalt mixture.

The creep compliance was determined by applying a dynamic compressive load of fixed magnitude of 200 and 400 KPa for 1 h at different temperature 40, 50 and 60°C along the diametric axis of a cylindrical specimen. The resulting vertical deformation was measured by two LVDTs. In each test, the sides of the specimen were capped and the sample was placed in the loading machine under the conditioning stress of 10 KPa for 600 s. Next, the conditioning stress was removed and the main stress was applied for 3600 cycles, which included a 1-s loading period and a 1-s resting period [10].

3. Dynamic Creep test results

The values of final strain versus Nano Al_2O_3 contents in SMA asphalt specimens at different stresses and temperatures are shown in Figures 2-4.

The results of the RLA tests that presented in figures 2-4 show that the samples without nano Al_2O_3 have more permanent deformation than the samples containing nano Al_2O_3 as modifier of bitumen.

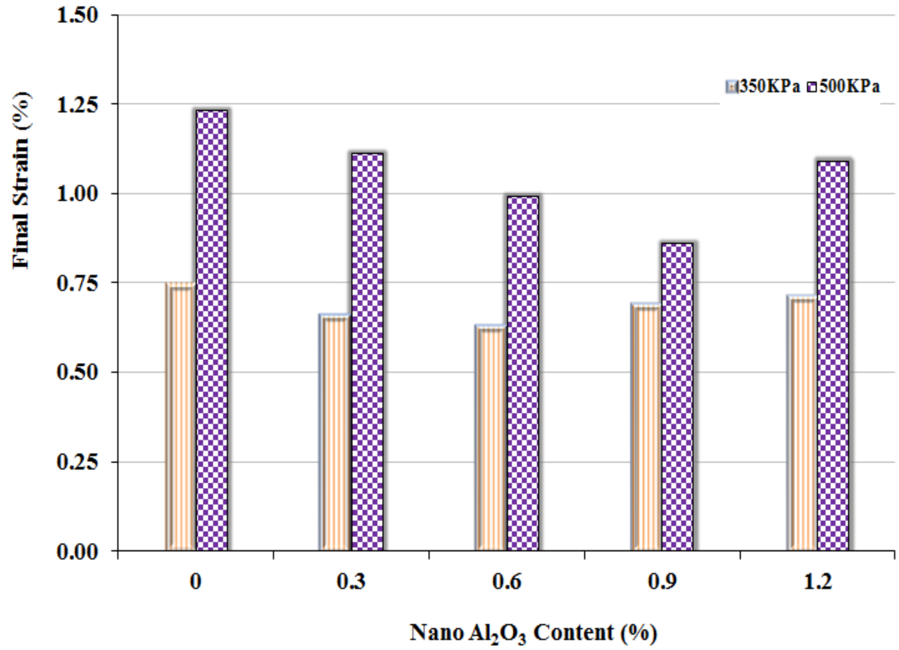

Figure 2. Final strain versus Nano Al_2O_3 content in SMA specimens at 40ºC

The amount of final strain at a special temperature for samples with different containing nano Al_2O_3 is less than conventional samples. From Figures 2-4, it can be concluded that greater adhesion between aggregate and modified bitumen in modified SMA mixture in compare with conventional SMA mixtures is the main reason of decreasing final strain.

It can be seen from figures, increment of temperature cause significant increasing in the amount of final strain of SMA asphalt samples. For a special mixture like modified sample with 0.9% nano Al_2O_3, the amount of final strain at 60 °C and 350 KPa is about 3.15 times of final strain at 40 °C. This is due to high sensitivity of bitumen and SMA asphalt mixtures to temperature. Bitumen and SMA asphalt mixtures have visco-elasto-Plastic behavior, that in high temperature, plastic behavior is more than elastic. In conclusion, more final strain is occurred at high temperatures, such as 60 °C.

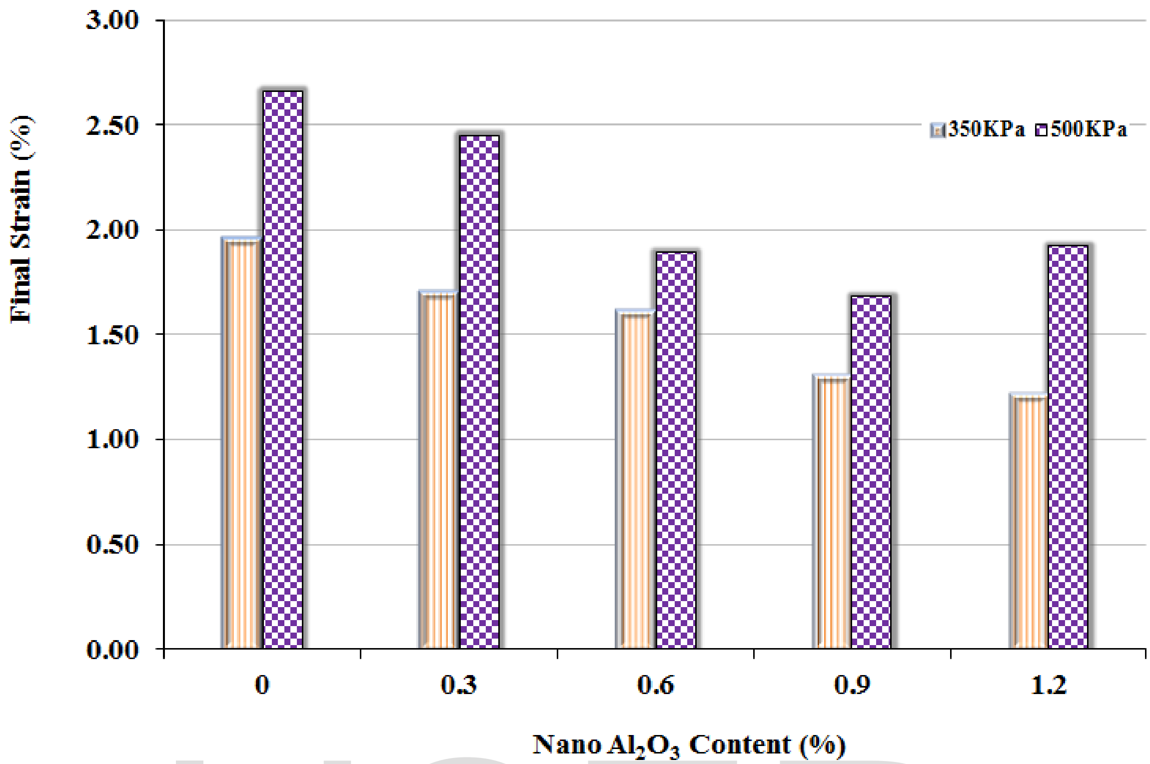

Figure 3. Final strain versus Nano Al_2O_3 content in SMA specimens at 50ºC

Also, another remarkable point was that the process of decreasing final strain due to nano content increase would be less by increasing temperature. Because of the high sensitivity of the bitumen to the variations of temperature, the final strain and permanent deformation of the conventional and modified mixtures decreased at higher temperatures. This phenomenon could be explained by the viscosity and stiffness modulus of the bitumen, which decreased at higher temperatures. Results of this study show that nano Al_2O_3 modified high sensitivity of bitumen and SMA asphalt mixtures, thus final strain of modified SMA mixtures is less than control mixtures.

The results obtained by this research show that the best replacement for reducing final strain and permanent deformation of SMA samples is the replacement of 0.9% bitumen with Al_2O_3.

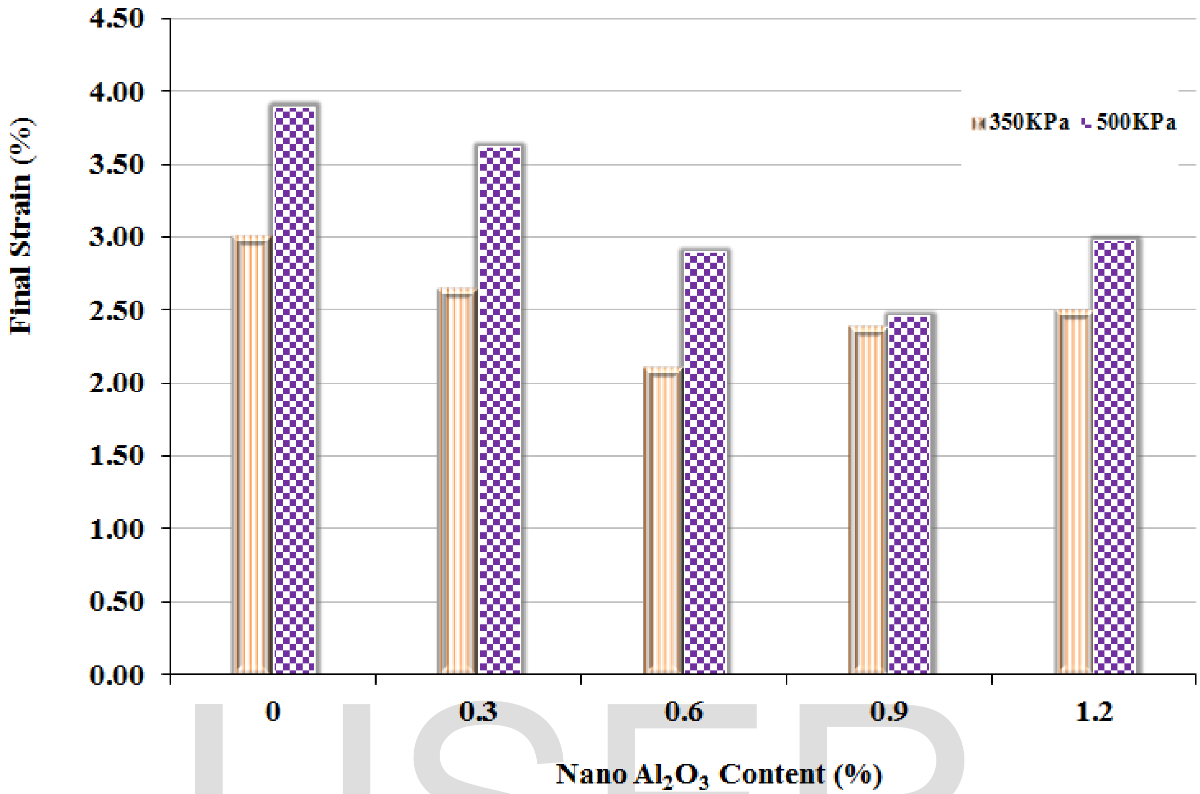

Figure 4. Final strain versus Nano Al_2O_3 content in SMA specimens at 60ºC

4. Conclusions

The objective of this study is to evaluate the effects of nano Al_2O_3 as modifier of bitumen in creep compliance of SMA mixtures. Dynamic creep test was used to evaluate the creep characteristics of SMA mixtures by varying contents of nano Al_2O_3. Based on the laboratory test results, the following conclusions were obtained:

- The results obtained by the dynamic creep tests for samples show that 0.9% nano Al_2O_3 as modifier of bitumen is an optimal content in SMA mixtures.

- Using nano Al_2O_3 as modifier of bitumen in SMA mixtures increases the efficiency of asphalt mixes. It is found that replacing 0.9% of the bitumen by nano Al_2O_3 improves the creep compliance behavior of the SMA mixtures.
- The results obtained by this research show that the best replacement for reducing final strain and permanent deformation of SMA samples is the replacement of 0.9% bitumen with Al_2O_3.

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