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Evaluation of Hot Mix Asphalt and Binder Performance Modified with High Content of Nano Silica Fume

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Abstract

This research aims to evaluate the mechanical properties of hot asphalt mixtures prepared using modified asphalt binders with various contents of nano-silica fume (NSF). The modification to virgin bitumen is done by shear mixing with NSF at low contents (2, 4, 6, and 8%) and high contents (20, 30, 40, and 50%) with bitumen weight. The homogeneity of the modified asphalts was assessed using Scanning Electron Microscopy. The rotational viscosity, softening point, and penetration tests were used to evaluate the rheological-physical properties of the modified asphalt binders. The stiffness, moisture damage, rutting, and fatigue of the hot mixes prepared with NSF-modified binders were evaluated using Marshall, indirect tensile strength, and double punching tests. The results showed a significant improvement in the rheological-physical properties of the modified binders with high content compared to low content of NSF. Therefore, the modified binders with 30%, 40%, and 50% of NSF were selected to prepare NSF-modified mixtures. The results showed that asphalt mixtures incorporating 30, 40, and 50% NSF-modified binders were more resistant to moisture damage, rutting, and fatigue cracking compared to the control mixture. The novelty in this research is to produce a modified asphalt mixture with two-thirds a quantity of bitumen while achieving a high performance compared to the control mixture.

Keywords: Nanomaterial, Silica fume, Bitumen reduction, Asphalt mixture, Moisture susceptibility, Double punching, Rutting, Fatigue.

1 Introduction

Traffic volumes continue to increase coupled with fluctuations in environmental conditions causing a significant reduction in the service life of the pavement. To deal with such issues, an improvement in the asphalt mixture's performance is required to sustain the pavement service life while reducing the maintenance need. The asphalt binder (bitumen) represents a small content (about 5%) among the components of the hot mix asphalt (HMA). However, it plays a vital role in the performance of HMA. The rheological and physical properties of asphalt binders significantly influence the behavior of HMA towards distresses [1]. Most virgin bitumen requires the use of additives to improve its properties to suit traffic intensity and different environmental conditions [2, 3]. Selecting a suitable enhancer varies from country to another depending on meteorological conditions and availability of materials. In addition, the performance improvement rate of modified asphalt should not be the only factor in selecting the suitable modifier, but some other factors such as economic factors, availability, and production technology should be taken into consideration when selecting an additive.

Among the bitumen modifiers, polymers were the most widely used ones. The results of polymer-modified bitumen showed improvements in the properties of asphalt binder. However, polymer-modified bitumen has many shortcomings such as storage stability. Where the polymer separates from the asphalt binder during the storage stage. Besides, the high cost associated with some types of polymers increases the final cost of road construction, this makes them unfeasible for large-scale application [4-8].

Recently, several researchers have investigated the binders modified with nanomaterials to create a modified asphalt that meets the engineering requirements for the construction of better flexible pavements, which the conventional asphalt cannot meet [9-15]. Researchers have found a significant improvement in the asphalt modified with nanomaterials, due to the large surface area of these materials [16, 17]. However, most of them have employed chemically prepared nanomaterials at exorbitant prices and limited quantities, making them unfeasible for a wide range of road projects. Therefore, the challenge here is to use nanomaterials prepared inexpensively and can be produced in large quantities for improving the properties of asphalt.

Silica fume (S.F) is a nanomaterial produced at high temperatures and available in large quantities. S.F is an industrial waste powder produced during the production of elemental silicon or alloys containing silicon [18-20]. S.F has been widely utilized to enhance the properties of building concrete, but limited research studies explored the effect of adding S.F on the properties of the asphalt mixture [20]. Al-taher et al. modified virgin bitumen using different contents of S.F (2, 4, 6 and 8% by bitumen weight). They concluded that S.F improved the rutting resistance and Marshall stability of the HMA mixture. At 6% of silica fume, the Marshall stability value increased by 23.6% and the rutting depth decreased by 36% compared to the conventional HMA mixture [21]. Shafabakhsh et al. evaluated the asphalt mixture prepared with silica fume modified binders at different contents (3%, 5%, 7%, and 10% by bitumen weight). Their results showed that silica fume enhanced the creep behavior of HMA at high stress and temperatures compared to the conventional asphalt mixture [22]. Abutalib et al. mixed silica fume with virgin bitumen at contents of 2, 4, and 8% by bitumen weight. They found that the silica fume-modified binder was less sensitive to temperature and more resistant to the effect of aging compared to the virgin binder [18]. In other studies, silica fume with contents of 2, 4, 6% by weight of binder was used to modify virgin bitumen. The results showed that the addition of SF improved the rheological-physical properties of the virgin bitumen [23-25].

As an industrial waste, the price of silica fume is relatively low compared to the traditional modifiers and virgin bitumen as well. While the average price of SF is 0.1 US $ / kg [26, 27], the price of Egyptian virgin bitumen is around 0.35 US $ / kg according to the Egyptian General Petroleum Corporation (EGPC) [28]. This promotes utilizing SF in the manufacturing of asphalt mixtures. However, limited research explored using silica fume in improving asphalt mixture. None of them investigated the effect of utilizing silica fume in high concentrations on the performance of the asphalt binder and mixture. Therefore, this study investigated the possibility of modifying the virgin bitumen with various contents of silica fume (2, 4, 6, 8, 20, 30, 40, and 50% by bitumen weight). Also, the fatigue, rutting, and moisture damage tendency of the silica fume modified-HMA mixture were evaluated. Where these distresses are significant in equatorial regions due to relatively high temperatures during the summer.

2 Materials and Samples Preparation

2.1 Asphalt binder

A base bitumen was obtained from Alexandria Oil Company, Alexandria, Egypt, with the basic properties as following: the penetration depth at 25°C is 7.5 mm, the softening point temperature is 50.5 °C, and the rotational viscosity at 135 °C is 0.435 Pa.s according to ASTM D5, D36, and D4402, respectively [29-31].

2.2 Aggregates

In this study, a blend of the three common types of aggregates was used to prepare all the asphalt mixtures. Crushed dolomite as coarse aggregates, siliceous sand resulting from crushed dolomite as a fine aggregate, and dolomite dust as a mineral filler. The bulk specific gravities of mineral filler, fine aggregate, and coarse aggregate were 2.5, 2.501, and 2.586 respectively (ASTM C127) [32]. The Loss Angeles abrasion and absorption percentages of coarse aggregate were 25% and 1.4 % respectively (ASTM C131) [33]. The aggregate blend gradation was selected according to gradation limits of wearing coarse (Dense gradation 4C) set by the Egyptian Code for Urban and Rural Roads (ECP) [34]. The aggregates were separated on standard sieves then a specific weight was taken from each sieve to achieve the gradation of the standard blend. The aggregates blend gradation and the standard limits are listed in Table 1.

2.3 Nano-silica fume

Nano-silica fume (NSF) is a very fine powder that was produced by the Egyptian Ferro-Alloys Company (EFACO) as industrial waste material. According to the American Concrete Institute (ACI), “the silica fume is produced in electric arc furnaces of the production of elemental silicon or alloys containing silicon”.

Table **2** lists the chemical and physical properties of the NSF. Figure 1(a) shows the general shape of the NSF. A Transmission Electron Microscope (TEM) was utilized to scan the NSF particles at the nanoscale. As shown in Figure 1(b), most NSF particles are in the range of 20 to 100 nm.

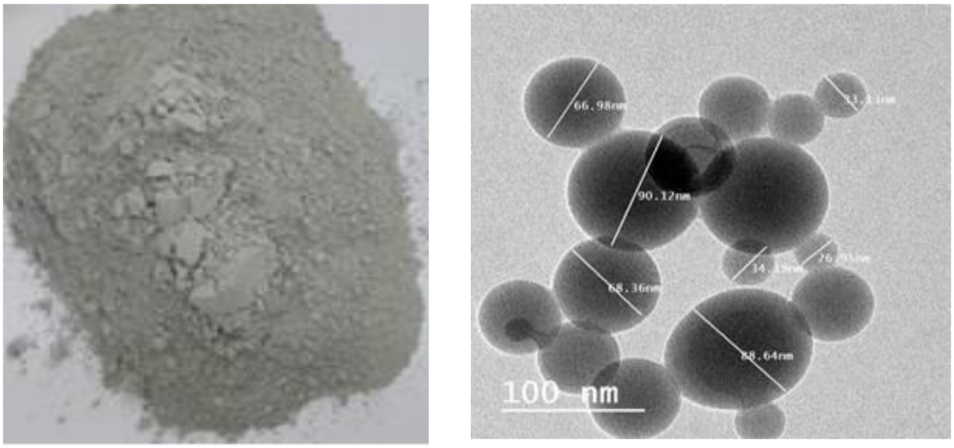
Table 1. Aggregates blend gradation and standard limits

Sieve Size	Blending Passing (%)	Standard limits (%) [34]
25.4 mm	100	100
19.51 mm	90	80-100
9.51 mm	70	60-80
4.76 mm	57	48-65
2.38 mm	43	35-50
0.595 mm	25	19-30
0.297 mm	18	13-23
0.149 mm	10	7-15
0.074 mm	5	3-8

Table 2. The physical and chemical properties of the Nano-silica fume*

Property	Measured values	Limitations
Physical properties		
Particles size (nm)	20 -100	Max 100
Color	Light gray	---
Specific gravity	2	---
Bulk density (kg/m^3)	340	250 - 350
Chemical properties		
SIO_2	97%	Min 92%
C	0.5%	Max 1%
Fe_2O_3	0.5%	Max 1.5%
Al_2O_3	0.2%	Max 1%
CaO	0.2%	Max 0.75 %
MgO	0.5%	Max 1.0 %
K_2O	0.5%	Max 1.25 %
Na_2O	0.2%	Max 0.8 %
SO_3	0.15	Max 0.5 %
Cl	< 0.01 %	Max 0.1 %
H_2O	0.5%	Max 0.5 %
PH-value (fresh)	6	5.5 – 7.5

*According to the datasheet from the supplier.



(a) (b)

Figure 1. (a) The general shape of NSF, and (b) nanostructured particles of NSF

2.4 Preparation of the NSF- modified binder

The NSF- modified asphalt was prepared using low contents (2%, 4%, 6%, and 8%) and high contents (20%, 30%, 40%, and 50%) by bitumen weight. The base bitumen was mixed with NSF using a Silverson L5M-A high-speed shear mixer at a temperature of 160^{o}C and a shearing speed of 2000 rpm for 1 hr [23, 25]. The homogeneity of modified asphalts was assessed using Scanning Electron Microscopy.

2.5 Preparation of compacted asphalt mixtures

The binders modified with 30%, 40%, and 50% of NSF were selected to prepare NSF-modified mixtures. The specific gravity of the base, 30, 40, and 50% NSF modified binder are 1.02, 1.17, 1.25, and 1.38, respectively (ASTM D70) [35]. The compacted Hot Mix Asphalt (HMA) samples were prepared according to Marshall's procedure (ASTM D6926) [36]. The mixing and compaction temperatures of HMA were computed according to the rotational viscosity standard for binders (0.17 $\pm$ 0.02 Pa.s for mixing and 0.28$\pm$ 0.03 Pa.s for compaction). All the mixtures were mixed at 170^{o}C and compacted at 155^{o}C to maintain the results comparable. The hot aggregates were mixed with four different percentages of the base and modified binders (4.5, 5, 5.5, and 6%) until homogeneity is reached. The mixed specimens were compacted with 75 blows /side using a Marshall hammer to simulate heavy traffic volume. After at least 24 h, the mixed samples were kept at room temperature for curing before any testing. The Marshall stability and flow were measured for all samples according to ASTM D6927. The bulk specific gravities of mixtures and maximum theoretical specific gravity were estimated according to ASTM

D2726 to obtain the volumetric properties of Marshall samples (%air voids, % voids in the mineral aggregate, and %voids filled with asphalt) [37]. The optimum asphalt content (OAC) for control and modified mixtures was estimated according to the Egyptian Code for Urban and Rural Roads (ECP) [34]. According to the requirements of the ECP, it has been concluded that OAC is 5.2% for the control and all modified mixtures. Therefore, the asphalt mixtures were fabricated with a 5.2% binder to evaluate the mechanistic properties of the HMA for control and modified mixtures.

3 Experimental Program

3.1 Asphalt binder evaluation tests

3.1.1 Tests of rheological and physical properties

The penetration test (ASTM D5), softening point test (ASTM D36), and rotational viscosity test (ASTM D4402), were used to evaluate the properties of the base and modified binders [29-31]. The Penetration Index (PI) was computed to assess the temperature sensitivity of binders. It can be calculated using the softening point and penetration at 25^{o}C as presented in Equation (1) [38].

$$\mathrm{PI} = \frac{(1952 - 500 \times \log(P25) - 20 \times \mathrm{SP})}{(50 \times \log(P25) - SP - 120)} \quad (1)$$

Where SP is the softening point and P25 is the penetration value at 25^{o}C.

3.2 Asphalt mixtures evaluation tests

3.2.1 Marshall test

The control and NSF-modified mixtures were prepared at the same asphalt binder content (5.2%). The Marshall parameters of control and NSF-modified mixtures were investigated to evaluate the effect of the NSF-modified binder on the properties of mixtures. The stability, flow, bulk density, and air voids of the asphalt mixtures were evaluated for all mixtures. Rigidity or Marshall Quotient (MQ) was estimated for all mixtures, where the MQ is the ratio of stability to flow value.

3.2.2 Indirect tensile strength test

Indirect tensile strength (ITS) test was performed according to ASTM D6931 to investigate the effect of moisture on the tensile strength of the control and NSF-modified mixtures [39]. The ITS can be calculated by applying a diagonal compressive load to standard Marshall samples. Six samples with air voids of 7 ± 0.5 % were prepared at OAC for each mixture. The samples were divided into two groups. For the first group, three samples were tested in a dry state at a temperature of 25^{o} C with a loading rate of 50.8 mm/minute until failure of the samples. For the second group, the other three samples were conditioned in a water bath for 24 hrs at 60 ^{0}C then 2 hrs at 25 ^{o}C. The conditioned samples were tested with the same loading rate until failure of the samples. The ITS of conditioned and unconditioned compacted mixtures were calculated to estimate the tensile strength ratio (TSR). The ITS and TSR can be computed by using Equations (2) and (3), respectively. The TSR is used to investigate the moisture susceptibility of asphalt mixtures.

$$\text{ITS} = \frac{2000\text{P}}{\pi\text{HD}} \tag{2}$$

$$\text{TSR\%} = 100\left(\frac{\text{ITS}_{\text{wet}}}{\text{ITS}_{\text{dry}}}\right) \tag{3}$$

Where ITS is indirect tensile strength in kPa; P is collapse load in N; D is the diameter of the sample in mm; H is the thickness of the sample in mm; TSR is tensile strength ratio (%); ITS_{dry} is average indirect tensile strength for the dry group of samples in kPa; ITS_{wet} is average indirect tensile strength for the conditioned group of samples in kPa.

3.2.3 Double punching test

A double punching test (DPT) was performed to assess the fatigue and rutting behavior of the asphalt mixture [40]. Marshall cylindrical specimens (101.6 mm diameter and 63.5 mm height) were used to run this test. The cylindrical specimens were immersed in a water bath at 60^{o}C for 30 mins immediately before testing to assess the rutting, while other specimens were tested at 20^{o}C to assess the fatigue behavior of the asphalt mixture [40]. As shown in Figure 2, the cylindrical specimen was placed in the center of two steel punches (25 mm diameter each) and then loaded vertically at a rate of 1.27 mm/min until collapse. The average failure loads of three specimens for each mixture were used in estimating the tensile strength (σ_t) as showed in Equation (4) [40-42].

$$\sigma_t = \frac{P}{\pi(1.2bH - a^2)} \tag{4}$$

Where σ_t is tensile strength (kg/cm^2), P is collapse load (kg), b is sample radius (cm), H is sample height (cm), and a is steel punch radius (cm).

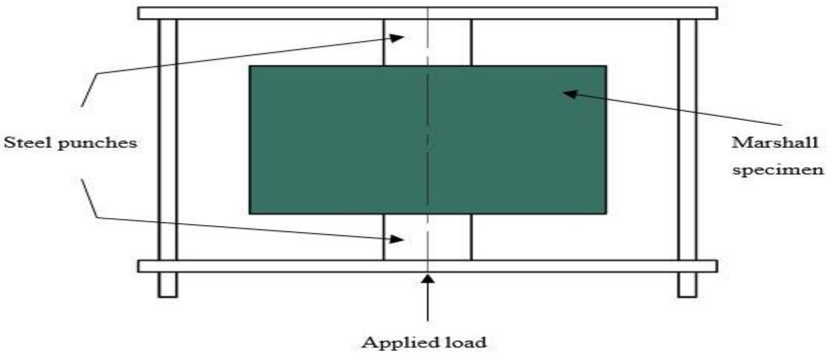


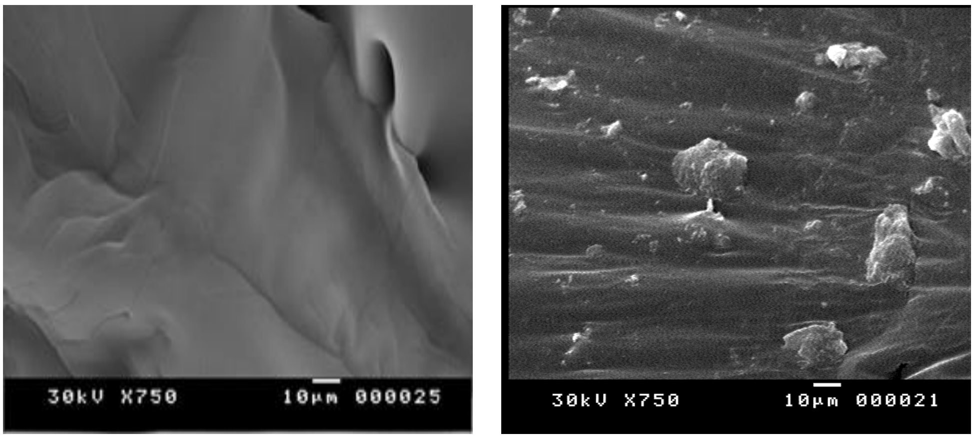
Figure 2 Double punch test Setup

4 Results and analysis

4.1 Asphalt binders

4.1.1 Microstructural evaluation of modified binders

A scanning electron microscope was used to evaluate the binder's homogeneity and quantify the dispersion of NSF within it. SEM images of the base and 40% NSF modified asphalt are presented in Figure 3. As can be seen, the nanoparticles have been well dispersed within the binder. Moreover, the surface of the 40% NSF modified binder is more rough compared to the base asphalt indicating a difference in surface properties, which led to a difference in the physical properties between them [43].



(a) Base asphalt (b) 40% NSF modified binder

Figure 3. SEM images: (a) base asphalt and (b) 40% NSF modified binder

4.1.2 Rheological and Physical properties of modified binders

Figure 4 shows the penetration values of the NSF-modified binder at different contents of NSF. As can be seen, the addition of NSF decreased the penetration values, which indicates increasing the hardness of the modified binder [12]. On the other hand, the softening point values increased with increasing the NSF contents as presented in Figure 5. The change of the physical properties was more significant at the high concentrations compared to low concentrations of NSF. This trend implies a lower temperature sensitivity and higher stiffness of the NSF-modified asphalts that are important properties, especially in the regions that have high temperature and heavy traffic [44].

The penetration index (PI) was used to evaluate the temperature sensitivity of the modified binders. The higher penetration index indicates a lower temperature sensitivity. The PI of asphalt binder used for road construction has been standard to be between + 2.0 and – 2.0 [45].

Figure **6** shows the change in the PI values as a function of the NSF contents. As can be seen, the PI values of the binder modified with low concentrations of NSF are decreasing inconsistently with increasing the content of the NSF from 2% to 8%. While the PI values increased when using high concentrations of NSF from 20% to 50%. Where the PI values of modified asphalt with low NSF concentrations were negative values and the opposite occurred when using high NSF concentrations. This reveals a significant improvement in the temperature sensitivity of the binder modified with high NSF concentrations. As can be seen, all the PI values are within the acceptable range of -2.0 to +2.0 for asphalt binders used in pavement construction [12, 45].

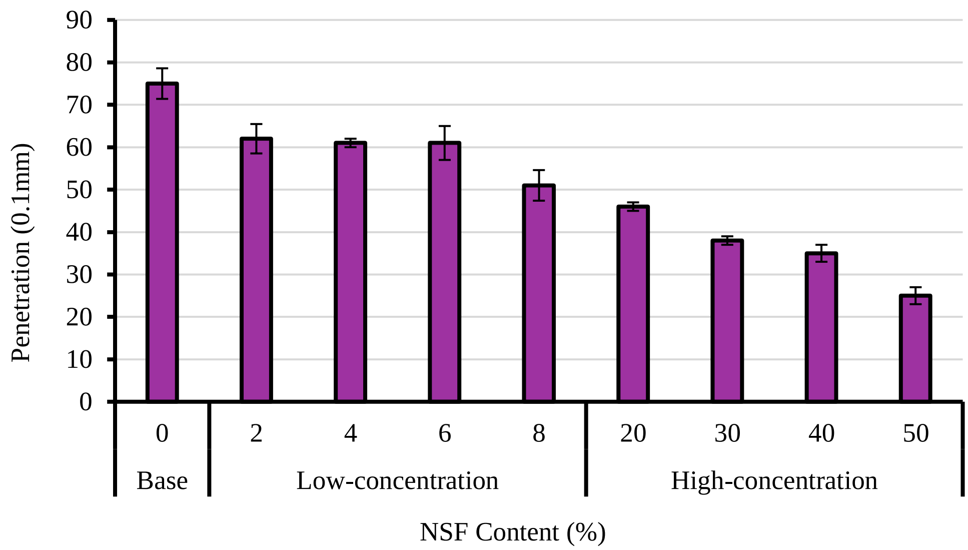


Figure 4. Penetration values of the base and NSF-modified binders

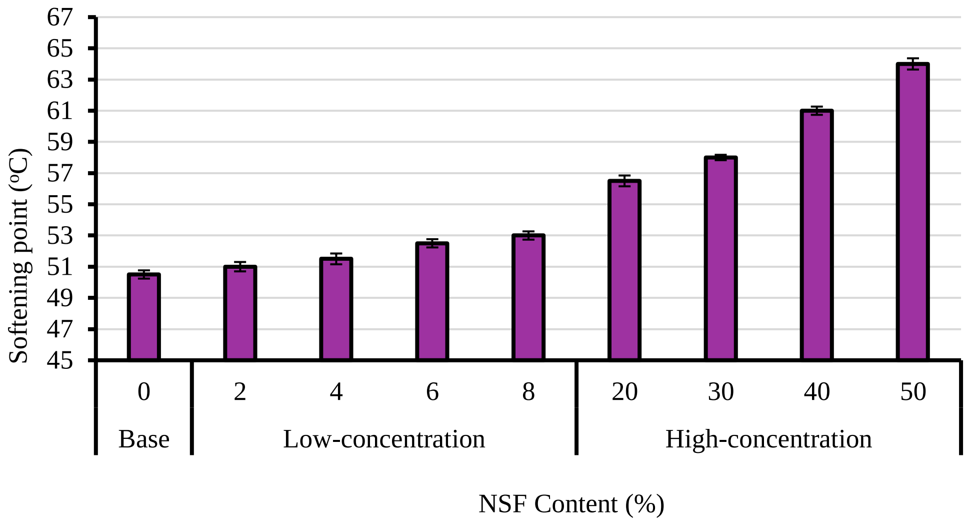


Figure 5. Softening point values of the base and NSF-modified binders

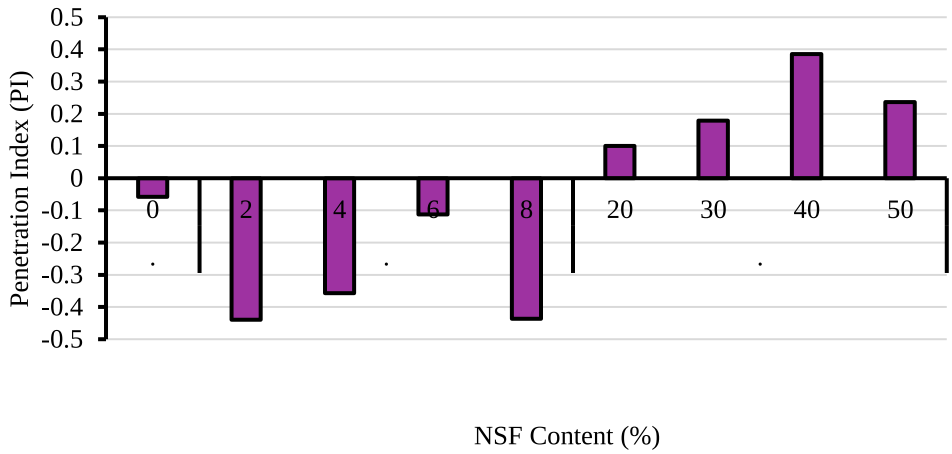


Figure 6. Penetration index values of the base and NSF-modified binders

The purpose of the rotational viscosity test at high temperatures (above 135 °C) is to investigate the ability to pump the binder into the HMA manufacturing plant during the mixing and compaction [31]. The increase in viscosity always indicates a significant improvement in the rutting resistance of the binder [1, 44, 46]. The rotational viscosities values at a temperature of 135 and 165 °C for the base bitumen and NSF-modified asphalts at different contents of the NSF are presented in Figure 7. As can be seen, the addition of NSF increased the binder's viscosity at 135 and 165 °C. The results show that modified binders with high concentrations of NSF have the highest viscosity values, while there was no significant difference between the viscosity values of the low concentrations-modified binders and the base asphalt at 135 and 165°C. Where the viscosity values at 135°C of the binders incorporating 30, 40, 50% NSF were higher than the base asphalt by 229, 358, and 570%, respectively. As can be seen, the rotational viscosity values at 135 °C for all NSF-modified binders satisfied the Superpave limit of 3000 cP or less according to AASHTO M 320 [47].

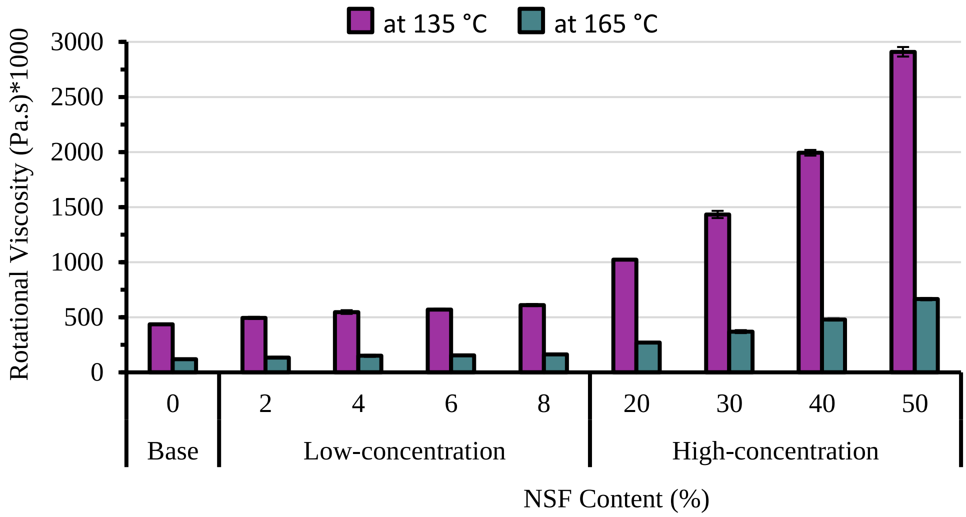


Figure 7. Rotational viscosity values of the base and NSF-modified binders

4.2 Compacted asphalt mixtures

The results of binder evaluation tests showed a significant improvement in the physical-rheological properties of the binder modified with high contents compared to low contents of NSF. Therefore, the binders modified with 30%, 40%, and 50% of NSF were selected to prepare NSF-modified mixtures.

4.2.1 Stiffness of asphalt mixtures

Figure 8 shows Marshall stability and flow of the control and modified HMA mixtures. As can be seen, the stability and flow values of all HMA mixtures comply with the Egyptian standards of more than 900 kg and (2–4) mm, respectively [34]. As can be seen, the addition of NSF significantly increased the stability of HMA mixtures. Where the stability value of the mixtures incorporating 30, 40, 50% NSF-modified binder was higher than the control mixture by 54, 83, and 88%, respectively. This indicates that the HMA mixtures incorporating NSF-modified asphalt are more resistant to rutting [48].

Figure 9 presents the volumetric properties of control and modified HMA mixtures. As can be seen, the air voids percentage (AV%) of mixtures prepared using NSF-modified asphalt are slightly higher compared to the control mixtures, this may be due to the higher specific gravity of NSF-modified binder compared to the base binder. However, all AV% values of control and modified mixtures within the limits (3 to 5%) set by ECP [34]. As shown, the voids percentage in the mineral aggregate (VMA%) and voids percentage filled with asphalt (VFA%) of modified mixtures are slightly less than the control mixture. It is noted that the VMA% and VFA% values for control and modified mixtures comply with the asphalt institute standards of more than 13% and (65–75%), respectively [49].

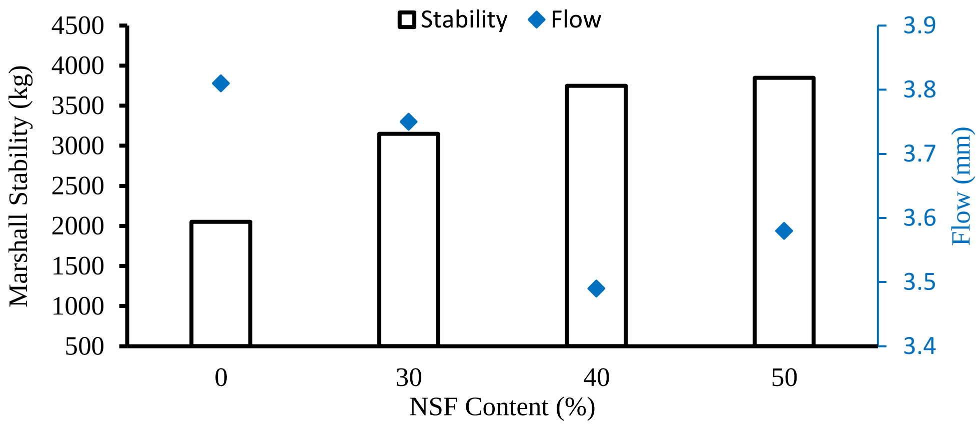


Figure 8. Marshall stability and flow values of control and modified HMA mixtures

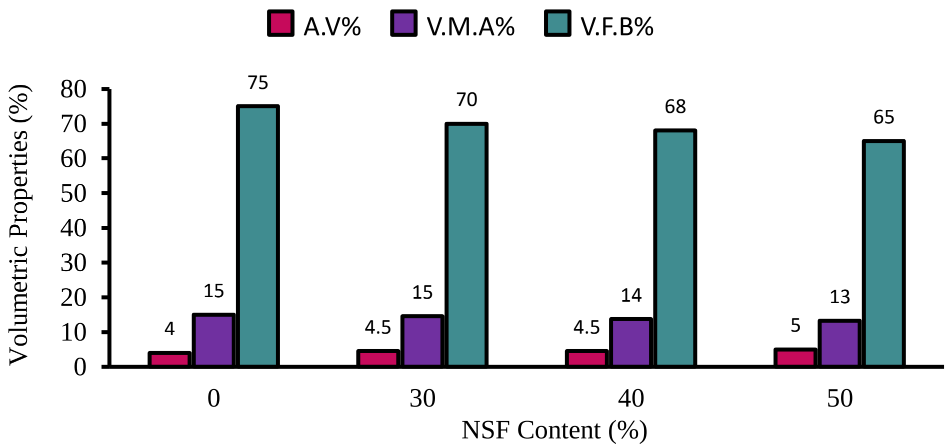


Figure 9. Volumetric properties of control and modified HMA mixtures

Marshall Quotient (MQ) or Rigidity values were computed by dividing the stability by the flow of HMA mixtures. The MQ is an indicator of the rutting of HMA mixtures, higher MQ indicates higher resistance of permanent deformation (deceased rutting tendency) [7, 50]. As shown in Figure 10, it can be noted that increasing NSF contents significantly increased the mixture rigidity, where the MQ value of the control mixture increased by 56, 99, 100% when using 30, 40, and 50% NSF-modified binder, respectively. This indicates that the mixtures incorporating NSF-modified asphalt are more resistant to permanent deformation and appropriate for heavy traffic volume requirements [51].

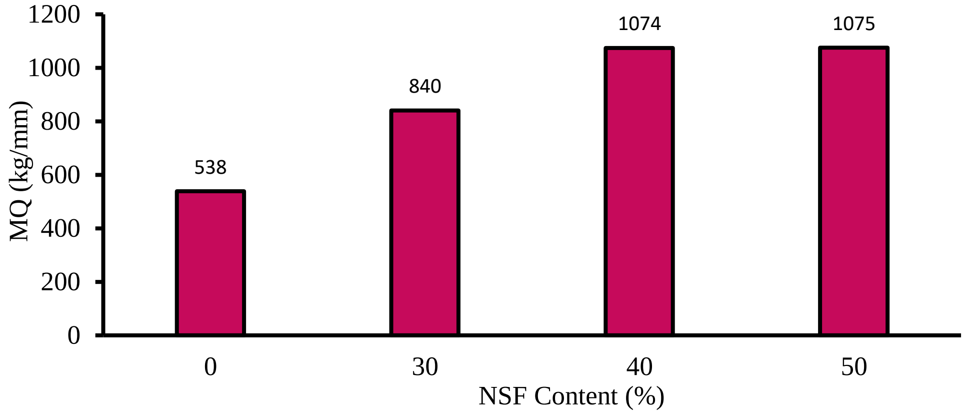


Figure 10. Marshall Quotient (MQ) values of control and modified HMA mixtures

4.2.2 Moisture damage and stripping resistance of asphalt mixtures

The indirect tensile strength (ITS) and the tensile strength ratios (TSR) values of the control and NSF-modified mixtures are showed in Figure 11. The results showed a slight increase in the ITS values of the modified mixtures for dry and wet samples compared to the control mixture. However, the TSR of the control mixture increased with increasing the NSF content. This indicates that the mixtures incorporating NSF-modified asphalt are more resistant to moisture damage compared to the control mixture [12]. Moreover, the bonding between the aggregates and NSF- modified binder was improved, and consequently higher stripping resistance was obtained. However, only the 50% NSF-modified mixture satisfied the minimum value of TSR (80%) set by the Egyptian code of practice [34].

4.2.3 Rutting behavior of asphalt mixtures

The double punching test (DPT) is a viable alternative test for evaluating the asphalt mixture's rutting [40, 52, 53]. Where the tensile strength (σ_t) computed by DPT at 60°C is an indicator for the rutting of HMA mixtures, higher σ_t indicates lower the rutting of asphalt mixtures [40]. Figure 12 presents the tensile strength values of the control and NSF-modified asphalt mixtures at 60°C. As can be seen, the addition of NSF significantly increased the tensile strength of HMA mixtures. Where the tensile strength values of the mixtures incorporating 30, 40, and 50% NSF-modified binder were higher than the control mixture by 105, 205, and 247%, respectively. The significant increase in tensile strength at 60°C of NSF-modified mixtures indicates a great improvement in pavement resistance to permanent deformations and stripping susceptibility [41]. This promotes using the NSF-modified mixers in hot regions or heavy traffic areas.

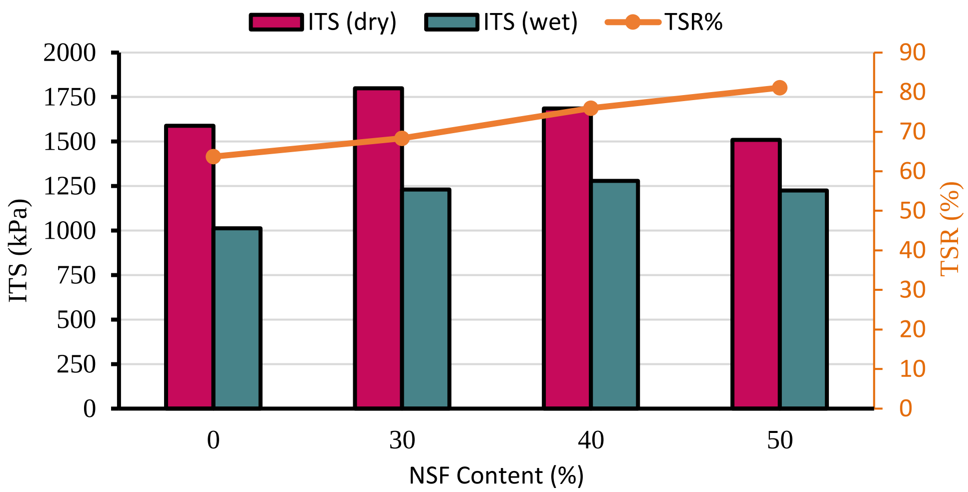


Figure 11. Moisture damage resistance of control and modified HMA mixtures

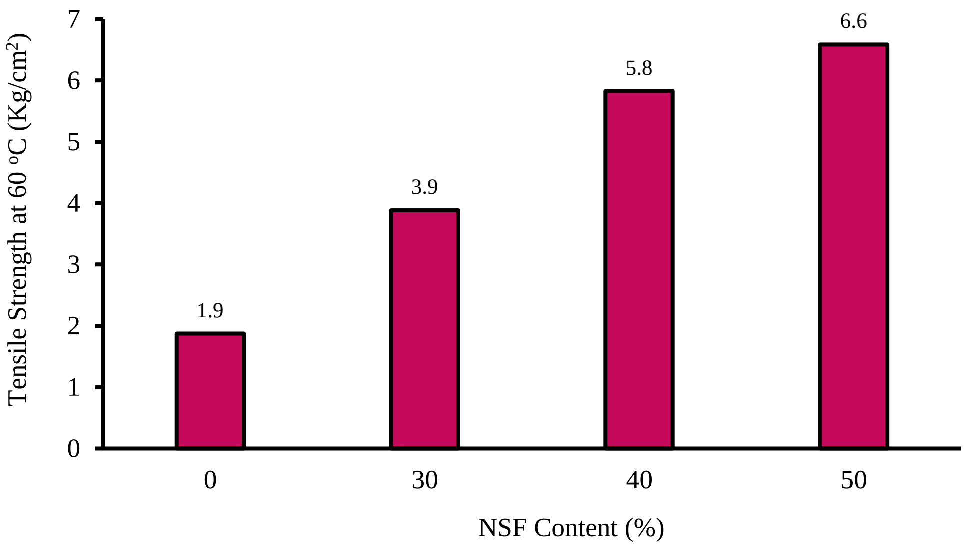


Figure 12.The tensile strength at 60°C as indicator for asphalt mixture's rutting

4.2.4 Fatigue behavior of asphalt mixtures

The double punching test (DPT) is a viable surrogate test for quantifying the asphalt mixture's fatigue. Where the tensile strength (σ_t) computed by DPT at 20°C is an indicator for the fatigue behavior of HMA mixtures, higher σ_t indicates reduced cracking in asphalt mixtures resulting from fatigue [40]. The HMA mixture that has a high σ_t is expected to demonstrate a high ability to absorb the energy without fracture [54]. Figure 13 shows the tensile strength values of the control and NSF-modified asphalt mixtures at 20 °C. The result showed a significant increase in tensile strength of HMA mixtures with increasing NSF content. Where the σ_t of control mixture increased by 26, 32, and 51% when using the asphalt binder modified with 30, 40, and 50% NSF, respectively. This indicates a significant improvement in the resistance of the NSF-modified mixtures to fatigue cracking [40].

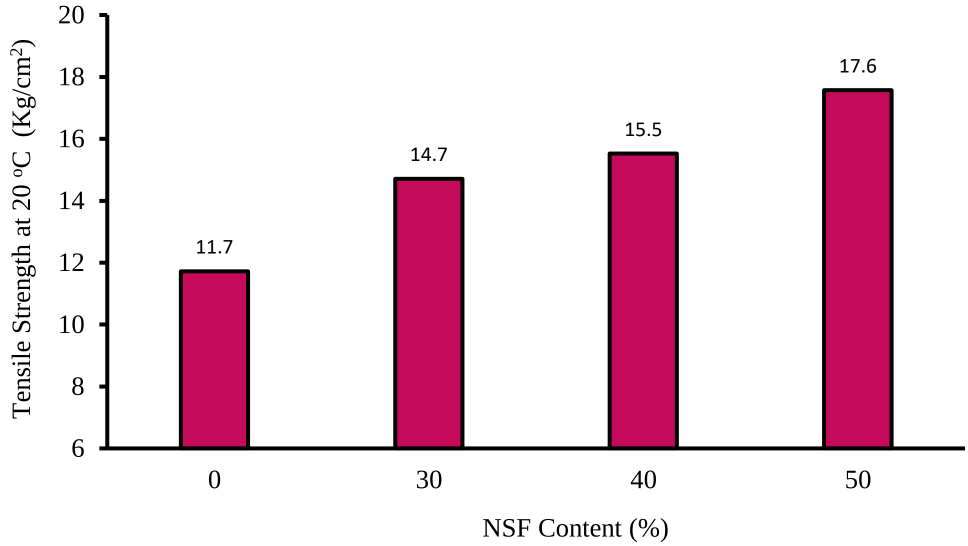


Figure 13. The tensile strength at 20 °C as indicator for asphalt mixture's fatigue

5. Conclusions

The general conclusions from this study were as follow:

- Results showed an improvement in the physical properties of the NSF-modified asphalt with increasing in its stiffness and a decrease in its susceptibility to temperature compared to the base binder.
- Asphalt mixes prepared with 30, 40, and 50% NSF-modified binders have the same optimum asphalt content as the control mixture, which leads to

the use of fewer quantities of virgin bitumen for economical pavement construction.

- The adding of NSF as a binder-modifier significantly increased the Marshall Quotient of asphalt mixtures, thus mixtures incorporating NSF-modified asphalt are more resistant to permanent deformation and suitable for heavy traffic volume requirements.
- The mixtures incorporating NSF-modified binder are more resistant to moisture damage compared to the control mixture. Moreover, the bonding between aggregate and NSF-modified binder was improved, and consequently higher stripping resistance was obtained.
- The addition of NSF increased the tensile strength of the asphalt mixtures at 60 ^{o}C indicating a significant improvement in the pavement resistance to rutting. This promotes the use of NSF-modified mixers in hot regions or heavy traffic areas.
- The result showed a significant increase in the tensile strength of asphalt mixtures at 20 ^{o}C with increasing NSF content. This indicates a significant improvement in the resistance of the NSF-modified mixtures to fatigue cracking.

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تقييم أداء المخلوط والرابط الاسفلتي المعدل بتركيزات عالية من النانو سيليكا فيوم

الملخص

مع زيادة الوعي البيئي أصبح اعاده استخدام النفايات الصناعية هو الحل الأمثل لتجنب اضرار التخلص غير السليم من تلك النفايات. السيليكا فيوم هي عباره عن بودر غاية في النعومة، وهي عباره عن ماده ثانويه وجدت داخل افران تصنيع السبائك الحديدية. تزامنا مع تلك الحقيقة، أصبح الحصول على اضافه متوفرة بكميات كبيره وغير مكلفه ضرورة ملحه لتحسين خواص البيتومين والحفاظ على كمياته غير المتجددة. ولذلك فان الهدف من هذا البحث هو تقييم الخواص الميكانيكية للخلطات الإسفلتية الساخنة المحضرة باستخدام الرابط الاسفلتي المعدل بالنانو سيليكا فيوم. تم خلط البيتومن البكر الناتج من مصفاة الإسكندرية مع السيليكا فيوم بتركيزات منخفضه (٢ و٤ و٦ و٨٪) وتركيزات عالية (٢٠ و٣٠ و٤٠ و٥٠٪) كنسبه من وزن البيتومين. تم تقييم تجانس الاسفلت المعدل باستخدام الفحص المجهري الإلكتروني (SEM). تم إجراء اختبار الاختراق واختبار التطرية (SP) واختبار اللزوجة الدورانية (RV) لتقييم الخواص الروهولجية (rheological) والفيزيائية للإسفلت المعدل. تم استخدام كلا من اختبار مارشال والشد الغير مباشر والاختراق الثنائي لتقييم الصلابة وحساسيه الرطوبة (moisture damage) والتخدد (rutting) والكلال (fatigue) للخلطات الإسفلتية الساخنة التقليدية والمعدلة بالنانو سيليكا فيوم. اظهرت النتائج تحسن ملحوظا في الخصائص الروهولجية والفيزيائية للإسفلت المعدل بتركيزات عالية من النانو سليكا فيوم مقارنه بالتركيزات المنخفضة. لذلك تم اختيار الاسفلت المعدل بنسب ٣٠ و٤٠ و٥٠٪ من النانو سليكا فيوم للاستخدام كرابط اسفلتي لأعداد الخلطات الإسفلتية المعدلة. اظهرت النتائج ان الخلطات الإسفلتية المحتوية على الرابط الاسفلتي المعدل بنسب ٣٠ و٤٠ و٥٠٪ من النانو سليكا فيوم أكثر مقاومه للتخدد والكلال والرطوبة إذا ما قورنت مع الخلطات الإسفلتية التقليدية. الجديد في هذا البحث هو انتاج خلطات اسفلتيه باستخدام رابط اسفلتي ثلثيه بيتومين والثلث الأخر نانو سيليكا فيوم مع تحقيق خصائص ميكانيكية وفيزيائية جيدة لتلك الخلطات مقارنه بالخلطة التقليدية.