Effect of Silica on Bitumen & Strength of Bitumen Mix

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Abstract— In this paper a new method has discussion. This is different content of silica 0wt% 2wt%, 4wt% , 6wt%, 8wt% have been added to bitumen to modify the physical, mechanical and rheological properties of hot mix bitumen . The rheological investigations showed that the complex modulus of base bitumen increases by increasing the percentage of silica from 2 to 6 wt% .Phase angle and rut factor for the silica modified bitumen have also decreased significantly An additional laboratory study was conducted to characterize the performance properties of the corresponding bitumen mixtures based on the resilient modulus, indirect tensile strength, fracture energy, moisture susceptibility, and fatigue life. Overall, the addition of NS material has a positive influence on different properties of the asphalt binder and mixture and can be used to construct durable pavements, thereby reduce the life-cycle costs of the pavement.

Key words: Silica, Bitumen Mix

I. Introduction

The researchers try to improve the quality of this type of asphalt mixture. Due to its environmental Advantages and low fuel consumption, modification usually is adopted as one of the best and most attractive strategies for meeting the desired properties of used materials. Better engineering of complex materials such as asphalt at the level will result in a range of newly introduced smart characteristics. Researchers have tried to utilize different types of additives to alter the performance of the bituminous materials in a good way In general, the application of technology has many benefits to bituminous materials such as enhance the storage stability of polymer modified asphalt, decrease the aging, decrease the moisture susceptibility, improve low-temperature properties, improve the pavement durability, and decrease maintenance costs. The silica material has been extensively used as an inorganic additive to improve the properties of bituminous materials the advantage of such material comes from the low cost of manufacturing and the performance benefits. As the silica material is highly reactant with the asphalt binder than conventional fillers, and the dispersal ability of NS particles into asphalt binder the asphalt binder was modified with the silica at contents 4%and 6%, by the weight. It has been observed that the performance of aging, rutting, and fatigue cracking of silica modified binders has been improved. When the modified binder was added to the reference (control) mixture, a considerable improvement was observed in terms of resistant to rutting (permanent deformation), flow number, and Dynamic modulus The objective of this study is to provide practitioners some characteristics of silica modified binder and mixture from which the feasibility of using silica in bituminous pavements can be attained. Different properties of prepared asphalt binders were examined based on the penetration test, softening point test, viscosity test, In addition, the mechanical performance of the compacted asphalt mixtures were investigated by evaluating the resilient modulus, tensile strength, fracture energy, moisture susceptibility, and fatigue life. Silica is used in several industries including medicine and engineering. The benefits of silica are the low production cost and high performance features. -silica has large surface area, strong adsorption, good dispersal ability, SiO2 increased the moisture resistance of mixture, significantly. But, it had negative effect on the low temperature cracking of mixtures. 59.5% modification was observed for the samples containing SiO2 compared to the base bitumen. The penetration decreased and softening point and penetration index increased, which indicates the modification in properties on base bitumen. The superior fatigue resistance The effect of silica on the properties of bitumen modified WMA has been investigated in this study. -silica with different contents (including 2, 4 and 6 wt.%) has been added to the Sasobit and various qualification test methods have been conducted on the prepared samples to determine the effect of -silica on the rheological, physical and mechanical properties of prepared samples. The results showed that, 4%-silica improves the rheological properties of base binder, significantly. The results of characterization of silica modified bitumen. WMA were in compliance with the rheological results.

II. Experimental program & methodology

A. Materials & Preparation of Asphalt Binders

An asphalt binder of 60/70 penetration grade obtained from Suez refinery, Egypt, was used in the present investigation. The properties of the supplied base binder are listed in Table.

1) The Silica

Material in white color powder (Fig. 1a), a synthetic amorphous silica, is structured

Properties of Bitumen
IS 73 : 1992

Characteristics	80/100	60/70	30/40
Specific gravity at 27°C	0.99	0.99	0.99
Softening Point °C	35 to 50	40 to 55	50 to 65
Penetration at 25°C, 100gm, 5 secs., 1/10 mm	80 to 100	60 to 70	30 to 40
Ductility at 27°C, in cm min.	75	75	50

Fig. 1:

Polymorphs of silicon dioxide, SiO2, has been used to modify the asphalt binder. A transmission electron microscope (model: TECNAI G2 spirit TWIN) has been used to scan the structured particles of the silica material as shown in Fig. 1b. The properties and characteristics of the used material are mentioned in Table 2. To prepare the modified binder, 100g of the base asphalt binder was heated to 160 _C and blended with the silica material using a shear mixer at a rate of 2000 rpm for 1 h. The silica material was blended with the base binder at different concentrations (2, 4 and 6 wt.%),and various qualification test methods have been carried out on the prepared samples to determine the effect of silica on the properties of asphalt binders. It is worth mentioning that the base binder has been mixed with no additive under the same mixing conditions to avoid any varied degree of aging between the unaged prepared binders during the mixing process

B. Experimental Method

In this study, the hot melting method has been used for mixing the base bitumen with modifiers, Bitumen and silica. In hot melting method, the bitumen modifiers have been introduced to the neat binder at the elevated temperature (160 for bitumen and 180 for the -silica). 2 wt% of bitumen has been utilized for all of the samples, while the silica was varied from 2 to 6 wt%, based on the base binder. It has been assumed that the viscosity of binder is too low to peel off the gallery spacing of silica and prevent the agglomeration at such a high temperature.

Analysis of silica				
SiO2	Ti	Ca	Na	Fe
>99%	<120 ppm	<70 ppm	<50 ppm	<20 ppm

Table 1:

S. N	SAMPLE	PENETRATION (MM) (80-100)	SOFTENING POINT(0°C) (40-)	DUCTILITY (CM) (75-)
1	Bitumen100gm	54	38	60
2	Bitumen100gm+ 2%silica	43	40	34
3	Bitumen100gm+ 4%silica	30	43	30
4	Bitumen100gm+ 6%Silica	25	47	15
5	Bitumem100gm +8%silica	12	49	10

Table 2: Conventional properties of Bitumen & Silica

As depicted in Tablle2, the standard mixing model of warm mix asphalt has been used for the preparation of the asphalt concretes. The characteristics of the utilized aggregates are presented in Table 3. The aggregate temperature of 135 is employed to produce the asphalt Concretes containing the silica modified bitumen

1	45mm	100
2	37.5 mm	90-100
3	35 mm	75-100
4	19 mm	-
5	13.5 mm	35-61
6	4.75 mm	13-22
7	2.36 mm	4-19
8	.300 mm	2-10
9	.075 mm	0-8

Table 3": Asphalt mixture mixing model (passing from sieve, %)

The aggregate temperature of 135 is employed to produce the asphalt concretes containing the silica modified bitumen The split tension test has been used herein for estimating the tensile strength, fracture energy, moisture susceptibility and fatigue life of the studied asphalt concrete Mixtures. For each mixture, three dry specimens and three wet specimens were tested for the Indirect Tensile Strength (ITS) test. Three outputs were examined through the ITS test: (a) tensile strength, (b) fracture energy, and (c) Tensile Strength Ratio (TSR). The ITS can be measured by applying a diametrical compressive loading on Marshall standard samples (101.6 mm diameter and approximately 63.5 mm height). The ITS test was carried out to determine the strength and strain of the compacted specimen in a displacement control mode by applying a relatively slow loading rate of 4 mm/min until failure of the specimens using a Universal Testing Machine (UTM). The slower loading rate is preferred to help monitoring reasonable results. The machine head applies loading on the ITS head through two opposite steel loading strips of 19 mm width at 25 _ C, meanwhile the horizontal and vertical deformations were recorded simultaneously . The horizontal deformation was monitored using two opposite dial gauges touching the outer horizontal diameter of the specimen. No extensometers were installed in the vertical direction; however, the moving head of the machine was used instead to measure the vertical deformation. The maximum recorded load, and appropriate geometrical factors of the specimen, diameter, and thickness, the maxi The ITS of asphalt specimens can be used as an indicator to assess the quality of asphalt mixtures against moisture damage when the values are determined for both dry and conditioned specimens (ITS wet, 60 _C, and 24 h). Another set of three specimens, also compacted to 4% air void content for each mixture, was conditioned in water bath at 60 _C, for a period of 24 h, then tested (wet ITS at 25 _C) [. The TSR is expressed as a percentage of the wet ITS to the dry ITS times 100 is used to evaluate the moisture susceptibility of asphalt mixtures which refers to the loss of serviceability of the pavements due to the effect of moisture. Typically, lower than 85% ratio, the mixture is considered susceptible or prone to stripping.

The fracture energies of the studied mixtures were estimated from the ITS test. The fracture energy as a fundamental property has been extensively used in the study of concrete materials. Several studies (e.g., have used the ITS test to determine the fracture properties of asphalt concrete mixtures. The fracture energy is calculated as the area under applied stress versus resulting strain curve up tothe failure load, is the potential energy required to cause cracking. In general, this property is suitable for asphalt concrete materials since it is less dependent on the hypotheses of the linear elasticity and homogeneity compared to other fracture characteristics, such as stress intensity factor and critical strain energy release This property is able to consider both stress and strain behavior in one term until the crack initiation for the purpose of fatigue performance comparison of asphaltic mixtures. The history of loading against the vertical deformation was recorded and used to calculate the fracture energies of the studied mixtures. Fracture energy experiments were carried out at 25 _C to conduct a comparative study of the asphalt mixtures. A schematic representation of stress versus strain curve is shown in Fig. 2b. The crosshatched area under the experimental curve (fracture energy) can be mathematically calculated by a best fit equation and integration rate

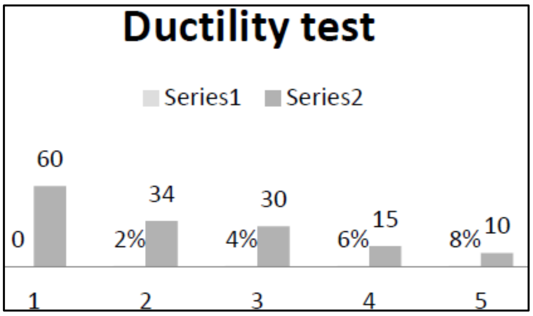


Fig. 1:

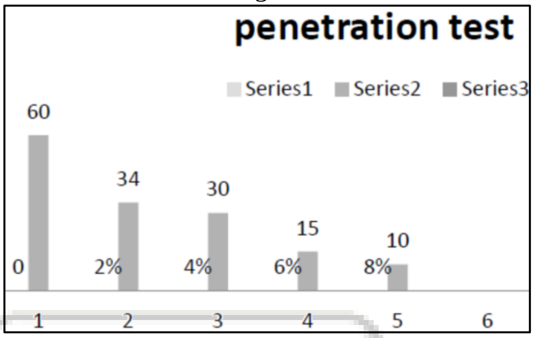


Fig. 2:

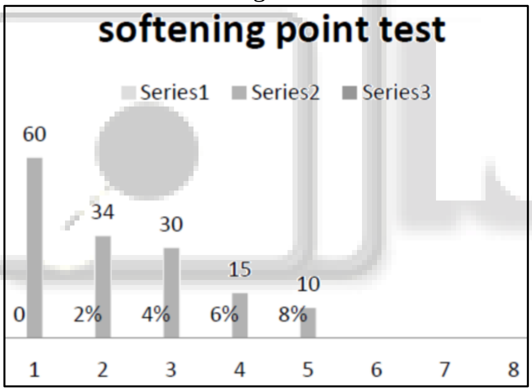


Fig. 3:

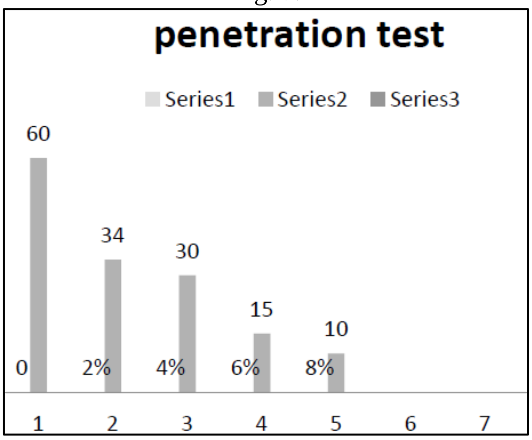


Fig. 4:

Another set of three specimens for each prepared mixture was utilized to perform the split tension fatigue test to evaluate the fatigue life of the aforementioned mixtures. In the selected fatigue test, the cylindrical Marshall specimen is subjected to a compressive loading distributed along two opposite 19 mm curved loading strips, a condition which generates a relatively uniform tensile stresses perpendicular to and along the load-line plane. A number of researchers have carried out this test for materials and pavement evaluations. In this study, the ITS fatigue test was performed using the UTM under the controlled-stress/load mode at 25 _C. A sinusoidal loading was applied on each tested specimen at frequency of 10 Hz, no rest period was considered, and constant mean stress level (20% of the calculated ITS). Multiple criteria are used for determination of the fatigue life of bituminous mixtures, however, herein, when the applied load/stress drops sharply (the stress goes up), i.e. the specimen is no longer withstand loading, the fatigue life was recorded. The stress ratio, i.e. ratio of minimum and maximum applied compressive stress was maintained 25% for all fatigue tests.

BITUMIN CONTENT	STABILITY KG	FLOW Unites	Vv %	VFB	Gm
3.4 +0%silica	738	6mm	2.22	92.1%	2.42
3.4 +2% slica	943	4mm	2.02	87.78 %	2.48
3.4 +4%silica	1066	3.5mm	1.4	58.07 %	2.65
3.4+6% silica	1025	2.5mm	1.30	84.09 %	2.32

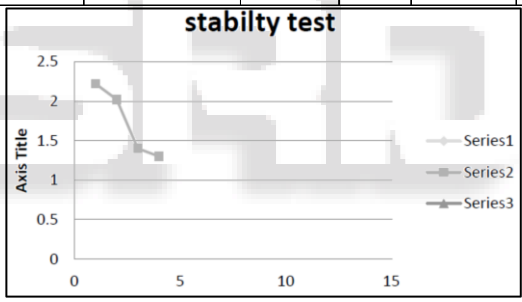
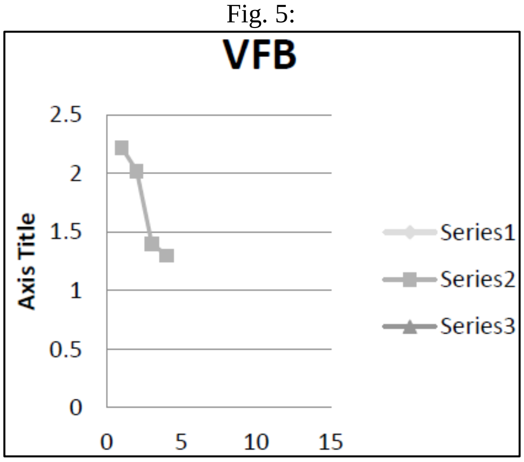


Fig. 5:



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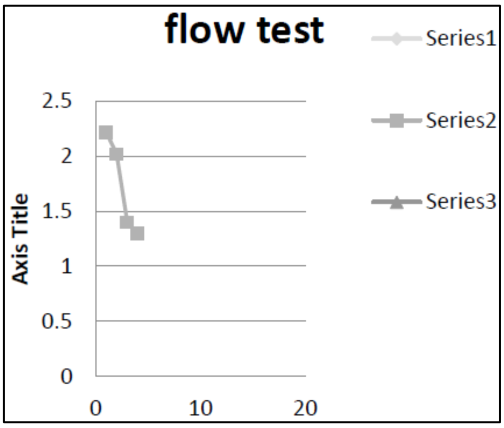

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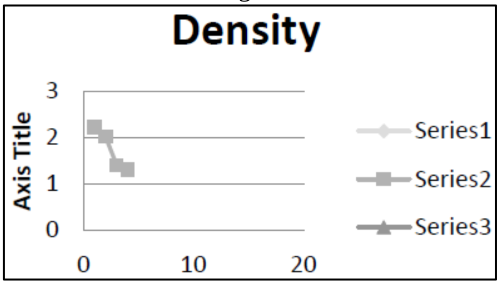

Fig. 8:

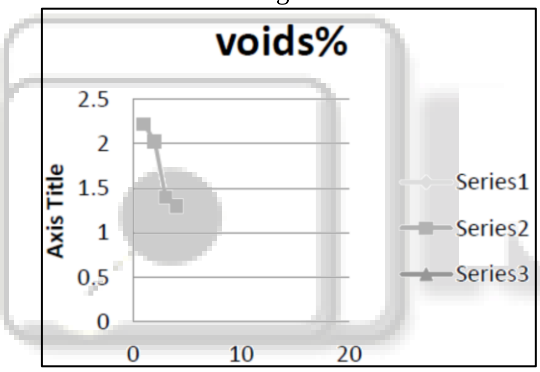

Fig. 9:

The value of the resilient modulus has increased by increasing the content of the silica. In consistence with others findings (e.g. due to the increased resilient modulus of the silica modified mixtures, it is therefore expected that these mixtures will exhibit increased elasticity and therefore better resistance to rutting than the conventional mixture The curves shown in represent the average values of three ITS tests for each mixture in the dry and wet conditions versus the resulted vertical and horizontal strains, respectively. For each ITS test, two displacements were recorded and strains were calculated as the ratio of displacement to specimen diameter. . It is evident from these figures that NS-modified mixture exhibited the highest tensile strengths compared to the unmodified mixture. The ITS of the 4% silica-modified mixture is the highest. Excessive amounts of NS seem adversely affecting the ITS of the mixture. This is quite clear from the 6% silica results. The silica-modified mixtures showed higher strains to failure in contrast to the unmodified mixture. Mixtures that can tolerate high strains prior to failure are more likely resist cracking than the mixture that cannot endure high strains. The higher strains of the NS-modified mixtures until failure also infer expected extended creep resistance and less rutting potential than the unmodified mixture the fracture energies of the dry and wet compacted mixtures. The general trend shows that the higher the NS content up to 4%, the higher the fracture energies. With much higher silica contents (6%), a slight decrease in the fracture energies was registered, while still maintaining higher value than the unmodified mixture. There is no proof this trend would continue at higher concentrations of the silica. The fracture energy decreased after conditioning the samples due to the loss of mixture strength in terms of the loss of cohesion and/or the loss of adhesion in the asphalt-aggregate system. The 4% silica modified mixture showed almost same fracture energy after conditioning.

III. SUMMARY & CONCLUDING REMARKS

The present study focused on understanding the feasibility of adding the silica to bituminous pavements based on the characteristics of bitumen binder and mixture. Physical tests, including penetration, softening point, and rotational viscosity have been carried out to address the effectiveness of silica modification on the binder properties. Further, an experimental investigation has been carried out to characterize the mechanical performance of the asphalt mixture modified with silica based on the resilient modulus, tensile strength, fracture energy, moisture damage evaluation, and fatigue life. Based on the study findings, the following conclusions have been drawn

Based on the binder physical properties tests, the silica modified binder increased the softening point and viscosity, while the penetration grade decreased leading to stiff and high modulus behavior of the modified binder. Furthermore, the addition of silica did not have obvious detrimental effects on the temperature susceptibility of the binder.

It has been observed that the addition of NS increased the resilient modulus, split tensile strength, the fracture energy and fatigue life, and decreased the moisture susceptibility of the mixtures, thus would help construct more durable pavement.

As the silica can be produced at low cost, therefore, it is expected to reduce life-cycle costs of bituminous pavements in light of the distinct characteristics proved in this study.

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