Effect of Silica on Hot Mix Asphalt Mixture

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Abstract

The hot asphalt mixture is the main layer in flexible paving as it is exposed to traffic loads and environmental factors which require high resistance, high durability and good stability to avoid structural deformities that leading to functional and structural failure. In the past few years. Several tests have been carried out on the prepared and compact specimens such as density testing, indirect tensile strength (exposed to freezing and thawing conditions and not exposed), stability and flow as well as non-destructive test using sound waves. The results of the tests showed that the specimens, containing silica fume as apart from filler aggregate (Portland cement) , have high Marshall stability-flow and extra resistance to tensile strength than conventional specimens that contain just ordinary Portland cement. All results found to be satisfied the Iraqi specifications adopted for roads and bridges.

Calculation of optimum silica fume content has achieved for all tests in order to find overall optimal content which was 4.2%.

Key words: Silica fume, Hot asphalt mix, Stability, Tensile strength, Filler.

1-Introduction

Practical experience of highway systems presented that high percentage of road pavements are suffering from rutting and cracking . For this engineer need to search for materials that have the ability to resistant these deformities to avoid the decrease in the services life and increase the cost of maintenance. This problem had often happened due to the lack in asphalt mix properties as well as absence the quality for the perfect design mix either of the binder and/or the asphalt mix. This study examines the effect of using silica fume SF , as apart from filler aggregate, on the behavior of hot mix asphalt HMA mixtures. Investigation of the properties of the asphalt mixes using different percentages of SF (2, 4 and 6% by filler weight) considered the main scope of current study.

Many researchers investigated the recent developments and current state of the application of silica fume for sustainable development of flexible pavement
Priti Chauhan et al. (2016) evaluated the effect of using lime, silica and fly ash on black cotton soil as stabilizer additives. Results found that the optimum content of lime, silica and fly ash for this stabilization soil were 5%, 3%, and 3% respectively. Black cotton soil stabilized with lime, fly ash, silica and their combination improved the soaked CBR to about 6.5 times and the un-soaked CBR to about 1.8 times of the un-stabilized soil [1].

Abd El-Aziz et al. (2004) studied the change in the properties of clayey soil after mixing with lime and SF. Laboratory experiments were carried out for several samples by lime contents of 1%, 3%, 5%, 7%, 9% and 11% and SF contents were 5%, 10% and 15%. The results of combination of L-SF soil indicated that the swelling potential was reduced from 19% to 0.016%, while the plasticity index (PI) decreased from 40.25% to 0.98% at percentages of L-SF mixture of 11-15% [2].

Naresh Kumar (2014) studied the effect of using pozzolanic material (Metakaolin and SF) on the compressive and flexure strength of the cement concrete. Metakaolin and SF were used as cement replacement materials at 5%, 10% and 15% by weight, keeping water–cement ratio at 0.42. Compressive and flexural strengths were observed after 7 and 28 days of curing. It was observed that, the optimum dose of Metakaolin is 10% by weight of cement which achieved the maximum compressive strength in the cement concrete [3].

Farag Khodary (2016) studied the effect of adding SF on the soil properties for base course in highway construction. Results indicated that adding SF improved both the strength and stability of the modified soil. Adding SF to the base course material increased CBR from 54% to 94.5% [4].

The state of art showed that SF was used in the improvement of engineering properties of subgrade soils, highway base courses and cement concrete. Using SF in the improvement of hot mix asphalt concrete (HMA) is still a research issue. This study is focused on the investigation of the effect of using SF on the characteristics of the HMA for pavement wearing surfaces. Metwally et al (2018) evaluated the properties of hot asphalt mixes employing different percentages of SF (2, 4, 6 and 8%) by bitumen weight. Results of this study indicates that Marshall Stability and flow are increased by 23.61% and 4.67%, respectively. The density increases, while the air voids percentage is kept within the accepted limits. Adding SF reduces rutting
depth by about 35.82%. The DC value increases by about 25% while the ITS value increases by about 3.83%. Finally, adding SF to the asphalt cement success in enhancing the properties of hot mix asphalt [5].

Taskiran (2010) added Silica Foam to stabilize the pavement soil and has the advantages of maximum expansion limit, but leads to a 50% increase in cost compared to cement materials [6].

Noor Moutaz (2010) investigated the influence of new different fillers (Silica fume, Portland cement, and Fly ash) removed from different local sources on the performance of asphalt mixtures. Outcomes of this study show that alteration of Portland cement by 9.8% of silica fume aggravates impedance of the mixtures to cracking and rutting [7].

2- silica

Silica is normally a highly active pozzolanic material. It typically involves of very fine vitreous particles around one thousand times smaller than the average cement particles. It has confirmed to be an admirable admixture for cement to increase durability and strength and reduction permeability [8,9]. It decreases the time of setting and rises the strength (tensile, compressive) of resulting cement in relative to other silica components that were tested [10].

3- Silica fume

Silica is the community name for the materials contains of silicon dioxide (SiO$_2$) and happens in amorphous and crystalline forms. The institute of American concrete clarifies silica fume as ‘Very fine non-crystalline silica created in electric arc furnaces as a byproduct of manufacture of elemental silicon or alloys containing silicon’ [11].

As the color of fly ashes or Portland cement, It has a grey colored powder. It is an ultra-fine powder collected as a by-product of the ferrosilicon and silicon alloy production and consists of sphere-shaped particles with an average particle size diameter of (150 nm). The main field of application is as pozzolanic material for high performance concrete [12].

4-Materials

Silica fume SF which one types of the materials was adopted in this study in varies percentages (2, 4, and 6) as alternative from weight of filler used as a
part of filler aggregate has been mixed with 5% of (40-50) asphalt for surface coarse Type III.

5- Methodology

a) **Design and Construct the Mix by Marshall Method:**
   This design method called Marshall Method according to (ASTM 6927)[13]

b) **Marshall Stiffness.**
   The stiffness of asphalt concrete mixtures is calculated by using the formula [14] in Equation (1):
   \[
   MS = \frac{S_i}{F_i} b
   \]  
   \[\text{(1)}\]
   Where
   - MS is the marshal stiffness
   - Si is Mixture`s stability at bitumen content (i)
   - Fi is Mixture`s flow at the same bitumen content (i)
   - b is the sample thickness

c) **Indirect Tensile Strength Test**
   By depending on the mechanistic empirical design guide part2 design inputs (NCHRP 1-37 A) and the viscosity depended from ASTM D2493[13]

d) **Stiffness Modulus.**

e) **Ultrasonic Pulse Velocity UPV Test**
   This test is performed in accordance with ASTM C597[13]

f) **Freeze-Thaw cycles test**

6-Results and Discussion

a) **Influence of Addition SF on ITS**
   ITS is one of the important tests carried out. The results obtained can be seen in Figure (1) The test was conducted at two different temperatures of 25 °C and 40 °C. Through the test conducted at a temperature of 25 °C, ITS obtained an increase rate of 22% while 35% for the test was conducted at 40 °C which approached Hanumesh (2015) results[15]. The optimum rate was 6%

b) **Influence of Addition SF on Marshall stability**
   The stability of Marshall is an important procedure to know the performance of asphalt. The results obtained showed a significant increase in the value of Marshal Stability as increase the percentage of silica additive which shown in Figure (2). The increase recorded 59% at the 4% SF which presented as optimal rate of the additive. The relation
indicated good influence of SF on the properties of the hot asphalt mixture, which has a role in improving the mixture. After this increase, there was a 31% decrease in the value of Marshal stability at 6% of SF. This is as Kadhum stated[16].

c) Influence of Addition SF on Marshall flow
The addition of SF to the hot asphalt mixture has an effect on the flow which can be seen in Figure (3). The flow decreases by 41% with the increase of SF added compared to their high value achieved in conventional mix where just OPC filler used (no addition of SF). The optimum percentage added in this test was 2%. Notice a decrease in the flow in the results obtained and this is contrary to what is reported by Kadhum [16].

d) Influence Addition of SF on Stiffness
The results of the Stiffness obtained as shown in Figure(4) show a significant increase by 136% in the Stiffness due to the increase of SF added to the mixture. The optimum percentage added in this test was 6%. Stiffness increases with low temperature as Abd Al-hussen[17].

e) Influence of Addition SF on bulk density
Through the results shown in Figure(5), increase in density slightly by 1.59% as the increase the proportion of silica additive. The minimal particles of inserts between mineral aggregate leading to increase density as found by Kadhum [16]. The optimum percentage added in this test was 6%.

f) Influence of Addition SF on air voids
Figure(6) appears a decrease by 33% in air voids versus increasing SF percent. Silica material, with a very fine and smooth texture, leads to fill the gaps in mineral aggregate at mix making it responsible for the decrease air voids by increasing SF percent [16]. The optimum percentage added in this test was 2%.

g) Influence of Addition SF on temperature susceptibility
From Figure (7), the temperature susceptibility of the mixture is reduced by adding 2% of SF then suffer from increased sensitivity by increasing the additive until achieve a higher value than the conventional mixture at 6% of SF. This increase was 3%. The optimum percentage added in this test was 6%.

h) Influence of SF Addition on ultrasonic wave speed
Ultrasonic wave speed, as demonstrated in Figure (8), where there is a significant decrease in the value of ultrasonic wave speed by 8%. The optimum percentage added in this test was 2%.

i) Influence of SF Addition on TSR Freeze and Thaw
In Figure (9), a decrease in TSR Freeze and Thaw by increasing the percentage of SF additive. The modified mixture is resistant to the effect of freezing and melting since TSR still up 80% The optimum percentage added in this test was 0%.

j) Determination of Optimum % SF content
After completing all the tests of this research and finding the optimal percentage of the additive for each one, an overall optimal ratio found to be 4.1% which achieved the standard specification of road and bridge.
7-Conclusions

By this simple study, it conclude some outputs for learning and indicate the behavior of asphalt with ranges of temperature degrees, below list of conclusions:
1. Marshall stiffness has a good correlation with the ITS. The rate of increase was 136%.
2. The optimum content of SF can be reported as 4.5% that corresponds high value of Marshall stability (MS) after this value there was a very slight decreased.
3. Marshall stability (MS) for hot mixtures prepared with filler silica fume (SF) increased in comparison with control mixture. The rate of increase was 59% and the rate of decrease was 31%.
4. The ultrasonic waves not depend on the viscosity or consistency exchange but depend on the voids in mix. The rate of increase of waves speed due SF content was 8% compared with conventional mixture.
5. The rate of increase ITS versus SF content was 22% and 35% at 25 °C and 40°C respectively.
6. Increase in density slightly by 1.59% as the increase the proportion of silica additive.
7. A decrease by 33% in air voids versus increasing SF percent.
8. The temperature susceptibility of the mixture is reduced by adding 2% of SF then suffer from increased sensitivity by increasing the additive until achieve a higher value than the conventional mixture at 6% of SF.
9. The overall optimum SF content in hot mix asphalt mixture consisting 5% from (40-50) asphalt grade found to be 4.2% by weight of aggregate.
10. Silica fume with Portland cement have more workability and higher tensile strength in hot asphalt mixes.

8-Reference

1. Priti Chauhan and S.W.Thakare (2016), "Stabilization of Expansive Soil with Micro Silica, Lime and Fly Ash for Pavement", Department of Civil Engineering, Government College of Engineering, Amravati, M.S, International Journal of Engineering Research.
2. Abd El-Aziz A. M., Mostafa A. Abo-Hashema A.M., and El-Shourbagy M., (2004), "The effect of lime-silica fume stabilizer on engineering properties of clayey subgrade", civil engineering dep., Cairo University – Fayoum branch.
3. Naresh Kumar (2014), "A study of Metakaolin and Silica Fume used in various Cement Concrete Designs", Dept. of Civil Engineering, Shree Baba Mast Nath Engineering College, Asthal Bohar, Rohtak, Haryana.
India, International Journal of Enhanced Research in Science Technology & Engineering.

4. Farag Khodary (2016), "Impact of Silica fume on the properties of Asphalt pavement base course", Civil Engineering Department, Qena Faculty of Engineering, South Valley University, Qena, Egypt, International Journal of Engineering Trends and Technology (IJETT).

5. Metwally, G., Hassan ,D. H., Mokhtar, F., and Ahmed, M. (2018). Investigation of the Effect of Adding Silica Fume on Asphalt Concrete Properties.

6. https://en.wikipedia.org/wiki/Silica_fume

7. Noor M. E.(2010) EFFECT OF MINERAL FILLER TYPE AND CONTENT ON PROPERTIES OF ASPHALT CONCRETE MIXES, Al-Mustansiriya university. Journal of Engineering, Volume 16 . No.3. pp.5352-5362.

8. 8Loland. K.E. (1981). Silica Fume in Concrete, University of Trondheim, Norway. Sft65-F81011.

9. 9Aitcin, P. C. Hershey, P.A. and Pinsonneault (1981). Effect of the addition of condensed silica fume on the compressive strength of mortars and concrete, American Ceramic Society. 22:286-290.

10. Roddy, Craig. W., Duncan O.K. (2008). Well Treatment Compositions and Methods Utilizing Nano-Particles. United States, patent No. 02777116 A1 U.

11. ACI Committee 226. 1987b. “Silica fume in concrete: Preliminary report”, ACI Materials Journal March–April: 158–66.

12. Prasad AS, Santanam D, Krishna Rao SV (2003). Effect of micro silica on high strength concrete, National conference-emerging trends in concrete construction, 22-24 January 2003, CBIT, Hyderabad, India.

13. ASTM Standards 2004., Roads and Paving Materials, in: Annual Book of the American Society for Testing and Materials Standards, Section 4, vols. 03–04. Washington, USA

14. Brown, S.F. and Cooper, K.E., (1984), “The Mechanical Properties of Bituminous Materials for Road Bases and Base courses”, Proceeding, AAPT, Volume 53.

15. Hanumesh B. M1 , B. K. Varun2 , Harish B. A. (2015). The Mechanical Properties of Concrete Incorporating Silica Fume as Partial Replacement of Cement, International Journal of Emerging Technology and Advanced Engineering, Volume 5, Issue 9,pp270-275.

16. Kadhum(2018) 11ACI Committee 226. 1987b. “Silica fume in concrete: Preliminary report”, ACI Materials Journal March–April: 158–66.
17. Abdul Hussain F. K., (2009), “Stability behavior of asphalt concrete mixture for a surface layer of the temperature path for Marshall examination”, 2009 - Al-Tanniyy Magazine / Volume 22 / Issue 3.