Al-Azhar University Civil Engineering Research Magazine (CERM)
Vol. (39) No. (2) April, 2017

The Use of Nano-Slag as an Additive to Improve the Physico-Mechanical Properties of Asphalt Cement

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ملخص البحث

أصبحت تكنولوجيا النانو من اهم المجالات التي اقتحمت كثير من المجالات منها الفيزياء والكمياء والهندسة والطب وغيرها. أيضا قام الباحثين في مجال الاسفلت باستخدام هذه التكنولوجيا في تحسين خواص الاسفلت والخلطات الاسفلتية. في هذا البحث تم استخدام الخبث الناتج عن صناعة الحديد والصلب كإضافة الي الاسفلت لتحسين خواصه بعد تحويله الي حجم النانو باستخدام الطريقة الميكانيكية حيث استخدم جهاز الطحن ذو الكرات (ball milling) في تحويل الخبث الي حجم النانو يتراوح بين ٣٠ نانو متر الي ١٠٠ نانو متر. تم خلط الاسفلت بنسب محددة من النانو خبث (Nano Slag) هذه النسب هي ٢% و٤% و٦% و٨% من وزن الاسفلت ودراسة تأثير إضافة النانو خبث بهذه النسب على خصائص الاسفلت المستخدم في الخلطات الاسفلتية. أظهرت النتائج تحسن ملحوظ في خواص الاسفلت حيث قلت قيمة الاختراق من ٦٣ في حالة الاسفلت الغير معالج الي ٥٤ في حالة الاسفلت المعالج بنسبة ٦ % من النانو خبث. أيضا زادت درجة التطرية من ٤٨ درجة مئوية في حالة الاسفلت الغير معالج الي ٥٢ درجة مئوية عند ٦ % من النانو خبث. أيضا زادت قيمة اللزوجة الكينماتيكية عند درجة حرارة ١٣٥ درجة مئوية من ٤٤٣ الي ٥٢٨ عند ٦% من النانو خبث كما أظهرت النتائج التحليلية ان القيمة المثلي لإضافة النانو خبث هي ٦% من وزن الاسفلت

ABSTRACT:

The Nanotechnology has become one of the most important and exciting forefront fields in Physics, Chemistry, Engineering, and Biology. Also, many researchers have tried to use Nanotechnology to improve the properties of bitumen and the properties of asphalt mixture. In this investigation, a new application of slag to be used as additives to improve the properties of bitumen. The methodology of this work is based on convert the Slag to Nano size using mechanical method. The ball milling machine was used to convert Slag to Nano size. The product Nano slag particle size was in the range of 30 nm to 100 nm. The Nano slag was added to bitumen with percentages 2%, 4%, 6% and 8% by the weight of bitumen and study the effect of Nano Slag with this percentages on the physco-mechanical properties of asphalt cement that used in the asphalt mixtures. The results indicated that the penetration of modified bitumen decreased with increasing the percentage of Nano slag. The softening point and kinematic viscosity increased with increasing the percentage of Nano slag. Also the results indicated that the optimum Nano slag was 6% by the weight of bitumen.

1. Introduction

Bitumen plays a very important role in determining the properties of asphalt mixtures. Therefore, many researchers around the world tried to improve the properties of bitumen using different materials such as polymer in its different types. With the widespread of using Nanotechnology around the world in different areas, the researchers in the field of highways also used this new technology to improve the properties of bitumen and asphalt mixture. From the Nano material that used as additives to improve the properties of bitumen and asphalt mixtures Nano Silica, Nano Hydrated lime, Nano Clay and Nano Calcium Oxide. ***Hui Yao and et al, 2013,*** studied the effect of Nano Silica on the rheological properties and chemical bonding of asphalt. The results indicated that the viscosity values of modified asphalt with Nano Silica decreased slightly, the dynamic modulus of modified asphalt mixture had a significant increase and the rut depth of modified asphalt mixture decreased significantly. Also ***Saad Issa Sasam ,2015,*** studied the impact of Nano Silica fumes and Nano Hydrated Lime on the rheological and physical properties of asphalt cement the results indicated that when Nano Silica fumes or Nano Hydrated Lime were added to asphalt cement, the penetration values decreased and the softening point increased. After aging, the ductility was reduced by a range of 10% to 60% based on the Nano additive types and percentages, the softening point increased after aging by a range of 6% to 8% and the penetration value showed variation by a range of 20% to 60% based on the percentages and types of Nano additives. ***Farag Khodary, 2015,*** studied the effect of Nano Clay on the properties of modified bitumen by using Styrene Butadiene Styrene (SBS). The results indicated that the penetration was decreased with increase the percentage of Nano Clay and the softening point increase with increase the percentage of Nano Clay. ***Abolfazl Zare-Shahabadi and et al, 2010,*** studied the effect of Nano Clay on the properties and rheological characterization of asphalt binders. The results indicated that the values of softening point and viscosity were increase with increase the percentage of Nano Clay. ***F.Khodary and et al, 2015,*** suggested to use Calcium Oxide (CaO) to improve the properties of bitumen and asphalt mixture the results indicated that the CaO Nanoparticles improve the penetration properties of bitumen. The value of penetration decreased by 28.9%. Also, the softening point increased with the increase of the Nano CaO percentage. The value of the softening point was increased by 24.5% when 5% Nano CaO were added to bitumen. ***M.Farmarzi et al, 2015,*** studied the effect of Carbon Nanotubes (CNT) on the asphalt binder. The results indicated that the use of CNT as an additive presented improvement in the rheological properties of asphalt binder.

2. Material Characterization

2.1 Bitumen

The used bitumen in this study was 60/70 penetration grade which obtained from Suez Nasr Petroleum Company (NPC). The General Authority of Roads and Bridges and Land Transport (GARBILT) laboratory was used to determine the properties of bitumen. Table 1 shows the conventional physical properties of the base asphalt.

2.2 Nano-Slag

The process of prepare Nano-Slag was done in the powder metrology and Nano technology laboratory at faculty of engineering, Al-Azhar University using the high-energy ball mill apparatus. The Slag was grained in ball milling apparatus for 5 hours. Figure 1 shows the Ball Mill apparatus. The morphology of Nano-Slag was analyzed using transmission electronic microscope (TEM) in National Research Center. Figure 2

shows the (TEM) image. The TEM images shows that the Nano-Slag diameter was in range of 30 Nm to 100Nm. Also the X-Ray fluorescence (XRF) was done using the laboratory of Housing and Building National Research Center (HBRC). It gives an information about fully chemical composition. Table 2 shows the chemical composition for Nano-Slag.

Table 1 Conventional Physical Properties of the Base Asphalt.

Binder grade	Penetration @25°C (mm)	Softening Point, (C°)	Viscosity @135°C	Flash point, (C°)
60/70	63	48	443	270

Table 2 Chemical Analysis of Nano-Slag.

Oxides	percentage	Oxides	percentage
SiO2	32.10	Al2O3	9.10
Fe2O3	3.20	CaO	37.10
MgO	2.62	SO3	3.90
Cl	0.12	Na2O3	1.20
K2O	0.12	TiO2	0.40
BaO	7.20	P2O2	0.16
MnO	1.70		

Figure 1 Ball Mill Apparatus.

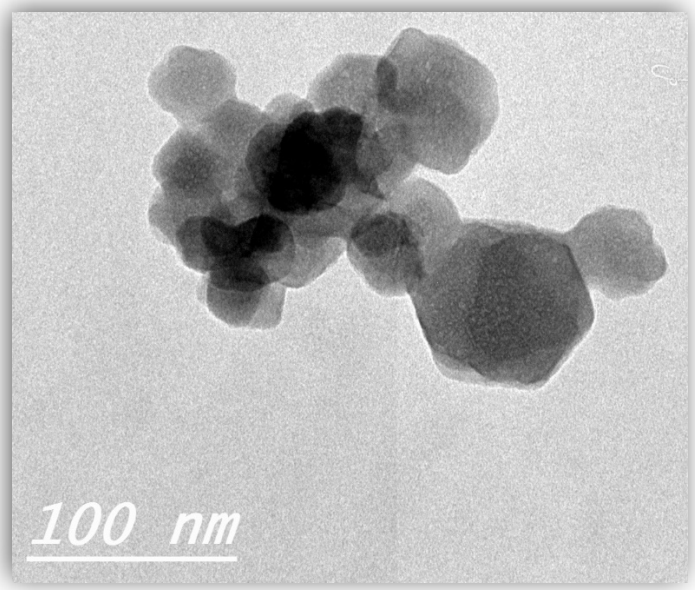

Figure 2 TEM Image of Nano-Slag.

3. Preparation of Modified Bitumen

To prepare the modified bitumen the bitumen firstly heated alone to 120Cº to 130Cº then the specific percentage of Nano-Slag is added to the bitumen. The specific percentages of Nano-Slag are 2%, 4%, 6% and 8% by the weight of bitumen. The mixing temperature of Nano-Slag with bitumen was between 120Cº to 130Cº. Low shear mixer with constant speed of 600 rpm was used for 30 minutes to sure the completion of the mixing process to obtain a homogeneous mixture**.**

4. Laboratory Data Investigation and Analysis

4.1 Penetration Test

The penetration test (ASTM D5-97) was used to determine the effect of added Nano-Slag on the penetration grade of bitumen. Three modified samples were prepared to determine the distance of tenths of millimeters that standard needle penetrates the bitumen sample at 25Cº. Figure 3 shows the results of penetration test. The results indicated that adding Nano-Slag to bitumen decrease the penetration value. The value of penetration decrease from 63 for the unmodified bitumen to 54 at adding 6% Nano-Slag that mean that adding 6% Nano-slag to bitumen can reduce the penetration value with about 14.3%. This reducing in penetration value is preferable for hot areas. At 8% Nano-Slag, no more significant effect on the penetration value, that is mean that the percentage of 6% can be consider as optimum Nano-Slag content to obtain lowest penetration value.

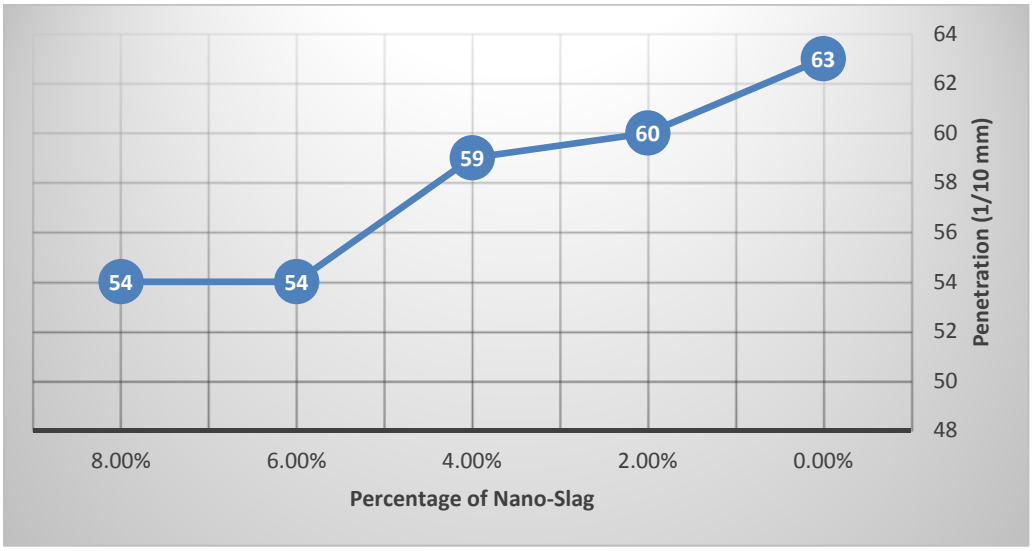

Figure 3 Results of Penetration Test.

4.2 Softening Point

The ring and ball method (ASTM D 36-95) was used to determine the softening point of modified bitumen by Nano-Slag. The results indicated that the using Nano-Slag to modify the bitumen increase the softening point. This increasing in softening point indicate that the asphalt mixtures have more resistance to high temperature. Figure 4 shows the results of softening point. The softening point was increased by 8.3% When 6% of Nano-Slag was added to bitumen. At 8% Nano-Slag, no change in the value of softening point. So 6% Nano-Slag can be considered as optimum Nano-Slag content to obtain maximum softening point.

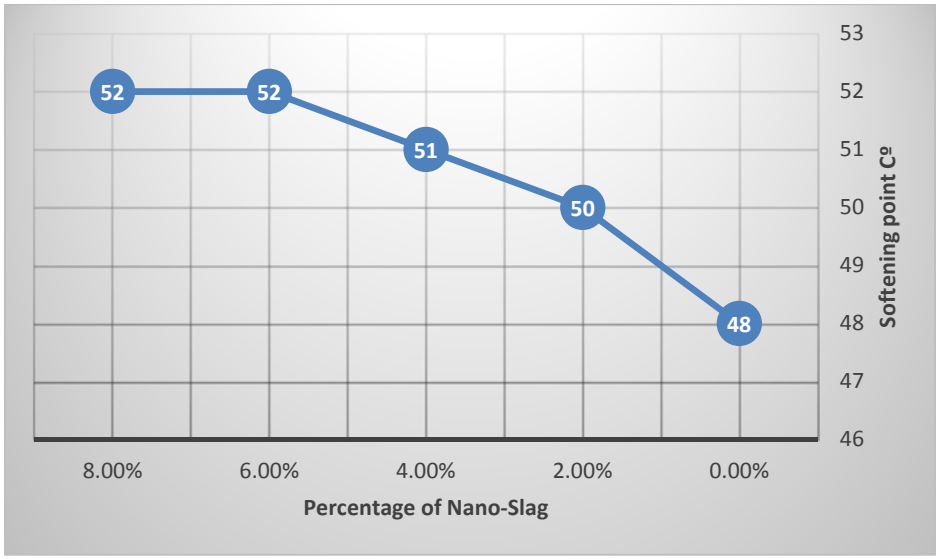

Figure 4 Softening Point Test Results

4.3 Kinematic Viscosity

The kinematic viscosity test at 135C° was used to determine the effect of Nano-Slag on the viscosity of bitumen. Figure 5 shows the results of Kinematic viscosity test. The results indicated that adding 6% Nano-Slag to bitumen will increase the Kinematic viscosity with about 19%. At 8% Nano-Slag the kinematic viscosity will decrease again, so the 6% Nano-Slag can be considered as the optimum percentage to obtain highest kinematic viscosity.

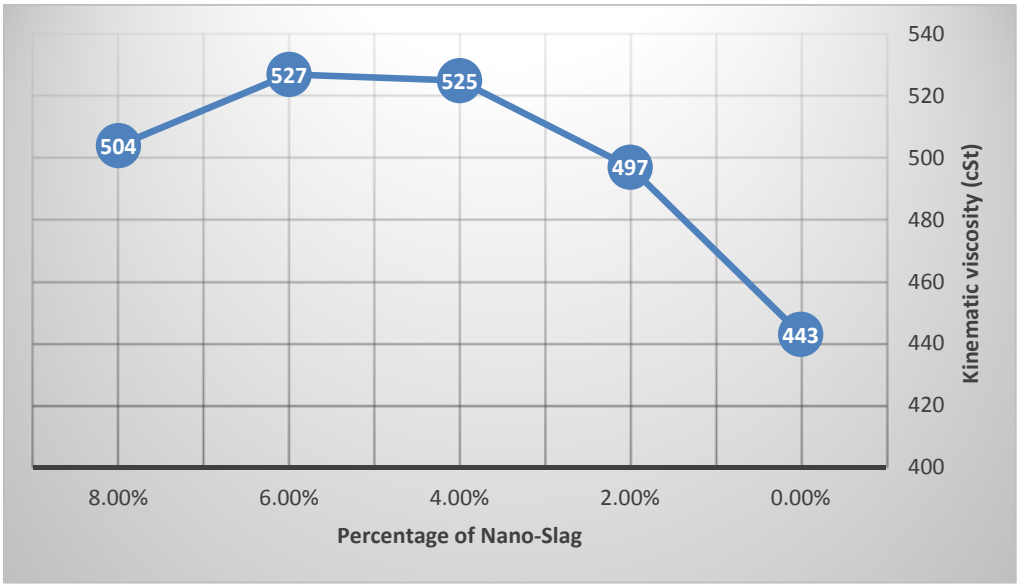

Figure 5 Kinematic Viscosity Test Results

5. Conclusion

The Nano-Slag has a significant effect on the properties of bitumen. The results indicate that the using of Nano-Slag as modifier to bitumen can significantly improve the bitumen properties to resist high temperature and high traffic loads.

The results indicated that the optimum Nano-Slag content was 6% by the weight of bitumen. At this percentage, the penetration value reduced with about 14.3%. Also at the optimum content of Nano-Slag, the softening point temperature increased with about 8.3%, the decreasing of penetration value and increasing in softening point make the bitumen is more suitable for use in hot places also the asphalt mixtures have more resistance to high temperature. The results indicated that also the kinematic viscosity decreased with about 19% at the optimum content of Nano-Slag.

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