Application of Nanotechnology to improve the performance of asphalt materials

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Abstract---
Nanotechnology has been gradually penetrated into the field of asphalt modification. Seemingly magic effects of nanomaterial have been brought to improve the performance of asphalt. To demonstrate many of the prospective applications, researchers have conducted a series of positive and effective efforts dealing with the preparation of modified asphalt to demonstrate the mechanism of modification and the resultant improvement in performance. In this review, various nanomaterial used in asphalt modification are initially presented, followed by the methods employed to modify the asphalt with these materials and finally the effects of nanomaterial on the performance of base asphalt are presented and the modification mechanisms are discussed. Based on the current research results, the influence of preparation process parameters on the compatibility of every phase in the modified bitumen and the stability of the modified asphalt system are described.
In this study the experimental testing of:

1- Nano silica with three percentages 2%, 4%, and 6% by the weight of asphalt were blended in asphalt binder at high temperature to exfoliate the Nano silica within the asphalt.

2- Three types of Nano clay with different ratio aluminiumoxide (A, B, C) at 2% and 4% by the weight of asphalt were blended in asphalt binder

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at high temperature to exfoliate the Nano clay within the asphalt.
It shows the difference of modified bitumen Viscosity, Penetration, Softening, flash point and Marshall Stabilization showed in charts. These differences depend on the type of bitumen, the type of Nano material and the percent of additives. Using the results of these experiments to make a comparison between using Nano-silica and using Nano-clay with different percent we reached to the effects of each type and each percent of Nano material on the original bitumen properties so that the asphalt mix properties.

I.   Introduction

Bitumen which extracted from petroleum sources didn't represents the case with standard specification to use it directly in pavement, so that there are many properties should be modified to be according to standard specifications.

A. *Asphalt materials:*

The chemical composition of asphalt is quite complex, therefore, researchers mainly use percentages of SARA (Saturates, Asphaltene, Resin and Aromatic) to compare various asphalt binder produced from different origins. Composition of each asphalt binder is typically grouped into two categories: asphaltenes and maltenes. The latter can be further subdivided into saturates, aromatics and resins [1].

B. *Nanotechnology and the current development in pavement materials:*

Nanotechnology is the creation of new materials, devices and systems at the molecular level as phenomena associated with atomic and molecular interactions

strongly influence macroscopic material properties[3].Even though engineers are interested in material properties at the macro and miso scales, the Nano and micro scales provide fundamental insight for the development of science and technology. Although improvements in asphalt performance have been achieved through polymer modification, it will be interesting to explore what nanotechnology offers in improving asphalt pavement performance.

II.   Materials and Test Methods:

This section will describe various materials used in this study as well as the sources of each material and its preparation method. The base asphalt used in this study was AC 60/70 Pen grade. Asphalt binder was then blended with 2%, 4% and 6% Nano- silica, Then using the same asphalt binder to blend it with three types with different ratio of aluminium oxide of Nano-clay at 2% and 4%. The quantity of each additive was selected by weight of based asphalt binder. To conduct the mixing, an aluminum can was filled with 250 – 260 g of asphalt and placed in a thermoelectric heater. When the asphalt temperature reached to 150o C, specified amount of Nano- silica or Nano-clay was added to the can and mixing for two hours. Using this procedure one neat sample, Nano-silica modified asphalt (NSMA) samples and Nano-clay modified asphalt (NCMA) were produced. Ensure Nano-material particles are dispersed uniformly within the asphalt matrix.

III.   Laboratory testing and results:

A. *Laboratory program design:*

The research team used the information gathered from the literature review and evaluations conducted to shape the direction of the laboratory program.
(1) The asphalt binder modified with 2% and 4% of first Nano clay (Nano clay A) by weight of asphalt binder.

(2) The asphalt binder modified with 2% and 4% of second Nano clay (Nano clay B) by weight of asphalt binder.

(3) The asphalt binder modified with 2% and 4% of Third

Nano clay (Nano clay C) by weight of asphalt binder.

(4) The asphalt binder modified with 2% and 4% and 6% of Nano-silica by weight of asphalt binder.

-ASTM C131 Standard Test Method for Resistance to Degradation of Small Size Coarse Aggregate by Abrasion, Impact in Los Angeles Machine and sieve analysis.

-Viscosity Grade bitumen's are specified by the methods described in ASTM Standard Viscosity test applied according to (AASHTO_T201-10). Viscosity Graded specifications covers bitumen (asphalt) graded by Viscosity at 60 C (140 °F).
-Penetration test (Rheological properties) of asphalt binder using penetration test according to (AASHTO_T49-07).
-Softening point test according to (AASHTO_T53-09)
-Flash point test according to (AASHTO T 73 and ASTM D 93).

-Marshall TEST according to (AASHTO_T48-06).

B.   *Experimental results and analysis:*

B.1. *Aggregate tests:*

To make sure that this aggregate can be used in the asphalt mix or not; it should apply aggregate tests.
-ASTM C131 Standard Test Method for Resistance to Degradation of Small Size Coarse Aggregate by Abrasion, Impact in the Los Angeles Machine and sieve analysis test.

B.2. *Bitumen and asphalt mix test:*

Coverage of test procedures related to the characteristics of bitumen and asphalt mixes and finished asphalt pavements. Tests include measurement and evaluation of bitumen and asphalt mix performance. The viscosity, penetration, softening, flash point of bitumen improved and Marshall Test of asphalt mix improved by adding Nano silica and Nano clay with different ratios.

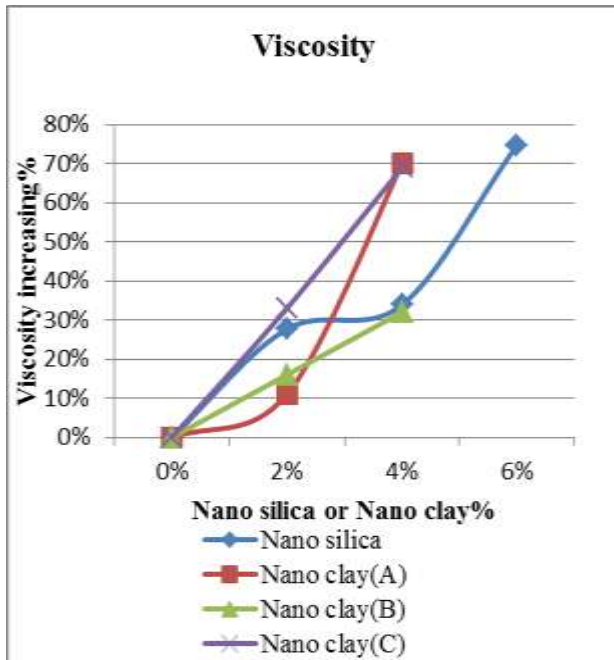## c. *Experimental results and analysis:*

Chart (1)
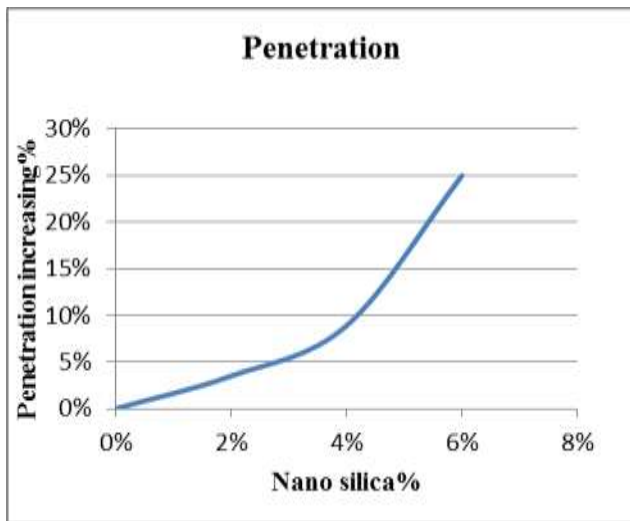Chart (1): Effect of adding Nano silica or Nano clay on Viscosity.

Chart (2)
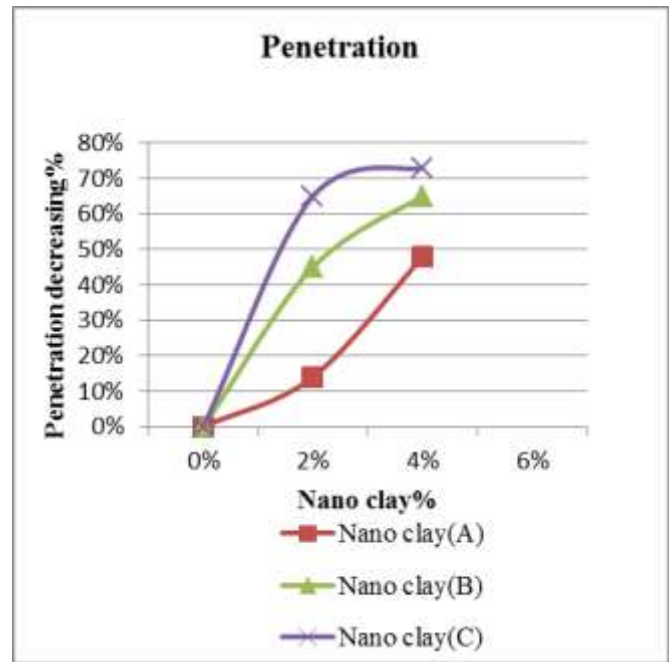Charts (2): Effect of using Nano silica on Penetration.

Chart (3)
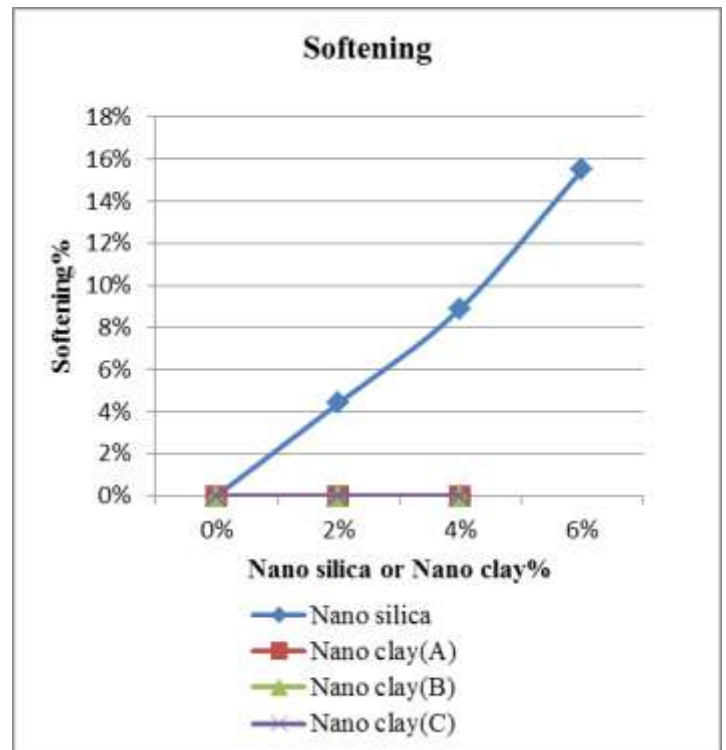Charts (3): Effect of using Nano clay on Penetration.

Chart (4)
Chart (3): Effect of adding Nano silica or Nano clay on softening, In case of adding Nano silica it increased but not affected by Nano clay.
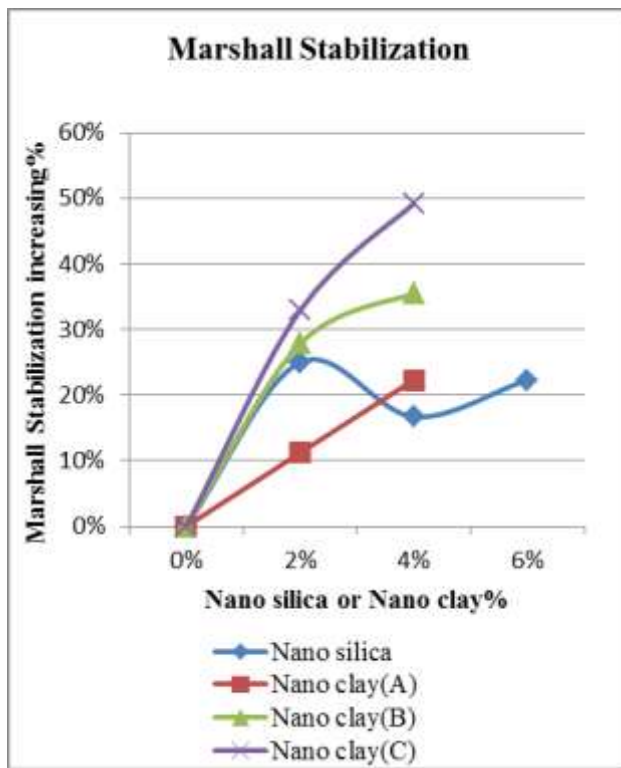
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Chart (5)

Charts (5): Effect of adding Nano silica or Nano clay on Marshall Stabilization.

Every chart shows the effect of adding each type and percent of Nano silica or Nano clay on one property of bitumen and asphalt (increasing or decreasing). These properties affected also by the chemical composition of original sample (Saturates, Asphaltene, Resin and Aromatic). The types of additives:

1- one type of Nano-silica was added at 2%, 4% and 6%.

2-Three types of Nano-clay with different ratio of aluminium oxide (A, B, C) which added at 2% and4%.

Conclusion:

Type of additives	Nano-silica			Nano-clay					
				A		B		C	
Additives%	2%	4%	6%	2%	4%	2%	4%	2%	4%
viscosity	Increase 27.7%	Increase 33.9%	Increase 74.8%	Increase 11%	Increase 70%	Increase 16%	Increase 32%	Increase 33%	Increase 69%
penetration	Increase 3.5%	Increase 8.9%	Increase 25%	Decrease 14%	Decrease 48%	Decrease 45%	Decrease 65%	Decrease 65%	Decrease 73%
softening	Increase 4.4%	Increase 8.9%	Increase 15.5%	Not affected					
Flash point	Not affected								
Marshall Stabilization	Increase 25%	Increase 16.7%	Increase 22.3%	Increase 11.2%	Increase 22.3%	Increase 27.8%	Increase 35.5%	Increase 32.9%	Increase 49.2%

-Viscosity of bitumen increased after adding Nano silica or Nano clay.

-Penetration of bitumen increased after adding Nano silica but decreased after adding three types of Nano clay.

-Softening of bitumen increased after adding Nano silica but not affected by adding Nano clay.

-Flash point of bitumen not affected in two cases.

-Marshall Stabilization of asphalt mix also increased after adding Nano silica or Nano clay.

The main objective of this research not to determine the best type of additives; because the results of tests depending not only on the type of additives but also the chemical composition of the bitumen sample. So the research explains the effect of each additives and percent of Nano silica or Nano clay on the bitumen sample and asphalt mix which we use.

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