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Influence of Long – Term Aging on Mechanical Properties of Nano clay Modified Asphalt Mixtures

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Abstract
The present work is aimed at understanding the influence of long-term aging on the Nano clay modified asphalt binder. In these paper two types of Nano clay materials namely bentonite and kaolin were blended with 60/70 asphalt binder. To simulate long-term aging, the specimens of asphalt mixtures were put in an oven for 5 days at 85^{o}C. The revolution made by Nano clay on the asphalt binders was assessed by using physical tests penetration, softening point test. Indirect tensile strength, Marshall, and moisture damage tests were employed to evaluate the properties of asphalt mixes. Penetration test showed incredible low results that lead to pavements will no longer surfer from permanent deformation at high. Softening point test has remarkable increase in the temperature at which the asphalt melted. This evidence that Nano modified asphalt will resist against temperature susceptibility. Indirect tensile strength test records showed that pavement will hold heavy load traffic powerfully. Talking about moisture susceptibility it became from the past because kaolin modified asphalt indicated adorable ratio than unmodified asphalt. Marshall testing indicates that kaolin increase stability more than adding bentonite which decreases the flow of the mixes.
Index terms: *Asphalt concrete, Aging, Nano clay, Tensile strength.*

I. INTRODUCTION

Most of roads which the link between villages and cities make it easy to reach any destination produced from HMA. Hot mix asphalt contain coarse, fine aggregate and powder collect them together bituminous binder which defined as (according to ASTM) is a mixture of hydrocarbons of natural or pyrogenous origin, or combinations of both, frequently accompanied by their non-metallic derivatives, which may be gaseous, liquid, semi-solid, or solid and which are completely soluble in carbon disulfide[1]. The major component of pavement construction is petroleum asphalt which used as adhesive material for aggregate and as water proofing coat. Asphalt can define as Asphalt. Asphalt (according to ASTM) is a black to dark brown solid or semi-solid cementitious material which gradually liquefies when heated [1].

The hot-mixed asphalt (HMA) used in constructing the surface layer of asphalt concrete pavements consists of asphalt binder, aggregates, and, in some cases, chemical additives. Asphalt binder is a blend of hydrocarbons of different molecular weights. It is the product of the distillation of crude oil. The chemical additives are usually used to enhance the mixture resistance to some pavement distresses, such as moisture susceptibility, rutting, or fatigue cracking [2].

Distress is an important consideration in pavement design. In the mechanistic—empirical methods, each failure criterion should be developed separately to take care of each specific distress. Unfortunately, many of the distresses are caused by deficiencies in Construction, materials, and maintenance and are not related directly to design [3].

A durable bituminous pavement must resist the effects caused by changes in temperature, action of water and air, and abrasive action of traffic bituminous paving mixture, to be durable, must resist stripping of the bitumen from the aggregate caused by the action of water. Talking aboutResistance to Action by Air.—Bitumen surfaces in a pavement in contact with air may be affected by oxidation, volatilization, or both to cause deterioration and hardening of the bitumen. [4].

Moisture damage isn’tlike any problem fighting asphalt pavement because it don’t came alone but causes another serious problem like reduction the strength between bitumen and aggregate andaccelerate others like rutting .

Enormous kind of additives had been invited and used to achieve that like polymer, SBS, fiber but it wasn’t enough.

In recent years nanotechnology has become one of the most important and exciting forefront fields in Physics, Chemistry, Engineering and Biology. It shows great promise for providing us in the near future with many breakthroughs that will change the direction of technological advances in a wide range of application [5].

Seeking for founding areal solution for pervious problems, we found Nano science which uses physical or chemical methods to convert an ordinary material to another one of its dimension 1nm. At Nano level the properties of materials changes like electrical conductivity, color, strength. Nano materials can be used in every field of life including that civil engineering department more specific pavement construction.

Clays can be organized into several classes, including montmorillonite, bentonite, kaolinite, and a few others. It should be noted that not all clays being looked at as asphalt modifiers are Nano-sized. Some may have only one dimension that is Nano-sized, e.g., the thickness of bentonite or montmorillonite platelets Nano clays are known to enhance the properties of many polymers. Nano clays are used to improve modulus and tensile strength, flame resistance and thermal and structural properties of many materials [6].

II. BACKGROUND

This research work focused on the investigation of the properties of asphalt binder modified with different percentages of two different nanomaterial . These materials are Nano clay, and Nano silica .The Nano clay on the other hand was found to increase the penetration and decrease the softening point temperature. At temperature of 135°C and up to 150°C, increasing Nano silica percentage was found to increase Brookfield Rotational Viscosity (RV), while Nano clay, at small percentages, increased the RV and then decreased it at higher percentages. At higher temperature, up to 165°C, the RV values did not change significantly using both Nano modifiers. Nano silica from rice husk showed improvement in the RV results. Finally, the Dynamic Shear Rheometer (DSR) results showed obvious improvement in the performance grade leading to higher resistance to permanent deformation. [7]

The objective of this study was to evaluate the conventional and rheological properties of binders containing various percentages of organic montmorillonite Nano clay particles before and after a short-term aging process. Two types of organic montmorillonite Nano clay (N3 and N4) were chosen to blend with 80/100 base asphalt in various concentrations (3%, 7% and 9%) by weight of the asphalt and subjected to aging using the Rolling Thin Film Oven in order to simulate short term aging .

The test results showed that the introducing of organic montmorillonite Nano clay to the asphalt binder improves the aging effect on the conventional and fundamental properties as compared to unaged modified asphalt. This improvement can recognized through the higher retained penetration and lower increment in softening point as well as viscosity aging index. Also, the result showed remarkable improvement in rutting resistance of the aged modified binder which results in better resistance to permanent deformation at intermediate and high temperature. [8]

This paper presents a laboratory-scale evaluation of the conventional and the fundamental rheological characteristics of modified binders including Nano clay contains 35-45 wt. % dimethyl dialkyl (C14-C18) amine (DANC) and montmorillonite. Modifiedbitumen samples were produced by mixing base bitumen with DANC and montmorillonite at three different additive contents. It was determined by the results obtained from the conventional tests that the softening point and the viscosity increased and the penetration and the thermal sensitivity decreased with increased DANC. Dynamic shear rheometer test results indicated that the temperature and the frequency had a significant effect on the complex modulus of DANC and montmorillonite modified binders. [9]

III. EXPERMENTAL WORK

MATERIALS

In this experimental work, to prepare asphalt concrete samples we used fine and coarse aggregate, powder and asphalt binder with 60/70 penetration grade was used to be modified by two kind of Nano clay (Bentonite powder -kaolin) with different concentrations (1%- 3%-5%-7%) by weight of the binder and three sample for every concentration. We used different concentration to figure out the perfect percent to be used for any performance needed.

In this project two kind of Nano clay with different chemical composition to have wide view of to how far could nanomaterial change asphalt binder or asphalt binder performance.Bentointeand kaolin Table [1] Figure. [1] Were bought in powder shape then converted to Nano material by using physicalway (top- down)in laboratory at Qena UniversityFigure. [2]. To be sure that Kaolin and Bentonite became nanomaterial we took TEM image Figure. [3] (Tem images are formed by the electron interaction with materials when an electron beam is transmitted through a material specimen. TEM is one of the techniques widely used to study structural quality and the layer number of grapheme)[10].

Bentonite is a rock formed of highly colloidal and plastic clays Composed mainly of montmorillonite, a clay mineral of the smectite group, and is produced by *in situ* devitrification of volcanic ash. The special

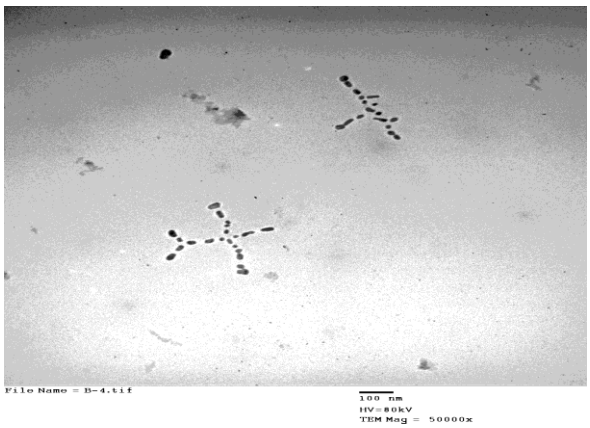
properties of bentonite are anability to form thixotrophic gels with water, an ability to absorb large quantities of water, and a high cation exchange capacity. Kaolin or china clay is a mixture of different minerals. Its maincomponent is kaolinite; in addition, it frequently contains quartz, mica,feldspar, illite, and montmorillonite. Kaolinite is made up of tiny sheetsof triclinic crystals with pseudo hexagonal morphology. It is formed byrock weathering. It has some cation exchange capacity[11].

MARSHALL METHOD PROCEDURE

To evaluate the optimum asphalt content Marshall method was used, Test specimens of 4 in. diameter and 21/2 in. height are used in this method ,sample prepared with 5,5.5,6,6.5,7 the percent of asphalt content , three specimen for each content , heat aggregate(1200 gm.) at 110C(230F) , the specimens were compacted by 75 blows from 450mm height ,The specimen then is cooled and tested for stability and flow after determining its bulk density , by using charts the optimum asphalt content is determine (5.5%).

ACING PROCEDURE

There are two kind of aging happened while pavement construction shot term aging occurs during mixing and laydown process after that long term aging happen during service life facing all weather factors. Long term aging isn'tbeing so important if it doesn't affect majority the durability of asphalt pavement. As it known that what cause aging to asphalt binder two phenomena oxidation (Oxidation is the chemical reaction that takes place when the asphalt material is attacked by oxygen in the air. This chemical reaction causes gradual hardening and considerable loss of the plastic characteristics of the material.) And Volatilization (Volatilization is the evaporation of the lighter hydrocarbons from the asphalt material. The loss of these lighter hydrocarbons also causes the loss of the plastic characteristics of the asphalt material) [12]. The samples were put in the oven for five days at specific temperature (85 °C) Figure4,to simulate aging for calculating the progress in bitumen and asphalt concrete properties after adding nanomaterial.



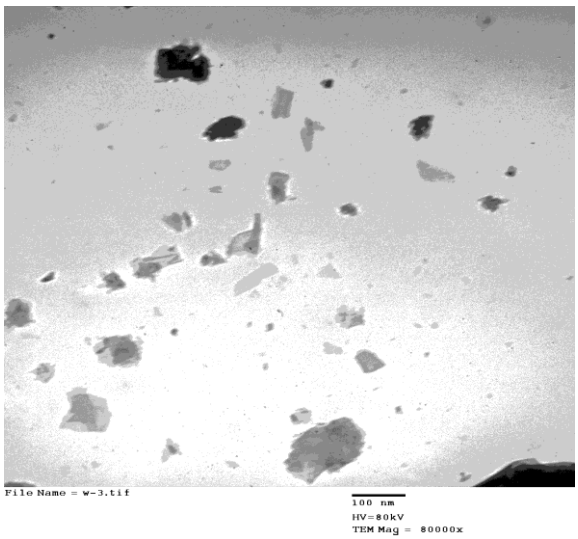


Table 1:

Maximum limits of impurities (As)Arsenic (as pb) Heavy metals Chloride(Cl)	Kaolin %0.0002 %٠.٠٠٢ %033٠.
Soluble matter Loss on drying @ 105°C	Passes test %1.5
Loss in ignition@600°C	15%

Fig.1: picture of materials products physical features of kaolin and Bentonite

Fig.2: Image of equipment used to turn material to Nanoparticles

Fig.3: Tem image of Kaolin and Bentonitepowder

Fig. 4: The specimens at oven for five days at 85°C

TESTS

PHSICAL PROPERTIES TESTS

Physical properties were conducted to measure the effect of using Bentonite,Kaolin on asphalt binder compare to unmodified aged asphalt binder.

PENETRATION TEST

Penetration test is used to evaluatethe strength of asphalt binder. By evaluate the vertical distance the standard needle will bear after loading by 100 gm. for 5 second at 25 c.

The samples were heated and added to them Bentonite and Kaolin according to different concentration depend on the weight of asphalt binder for each sample. At 25 degree Celsius we put the dish at the base of device then allow the standard needle freely penetrate the specimen for 5 seconds only while it loaded by 100gm.At the end we measure the depth of penetration in 1/10 mm which can be considered as classification asphalt cement consistency.

SOFETENING POINT TEST

The ring-and –ball softening point test con be used as classification of susceptibility of asphalt binder to temperature changes by evaluating the temperature at which the binder will be soften and allow a standard ball to pass through it. It’s known that softening doesn’t take place at specific temperature or time so that the method of the test must be confined so we can trust the results and use numbers to compare between different materials. We put tested bitumen in a small a brass ring with 16 mm diameter and 6.3 height, above bitumen a steel ball 9.5 mm diameter , all of this put in water bath at room temperature , the water is heated we record the temperature at which the sink to the bottom of the bath

ASPHALT MIXTURE TESTS

INDIRECT TENSILE TEST

The indirect tensile strength test involving measure material resistance to compressive loading Crosses through the center of sample by recording the load at which the specimen will break. The machine loading Generatesvertical tensile strains perpendicular to the loading direction which yielding the specimen. . By calculating the tensile failure load and the dimension of the specimen we can have the tensile strength of the material.

MOISTURE DAMAGE TEST

HMA consist of material which deeply affected by the presence of water at surface level. Water causes the loss of adhesion between asphalt cement and aggregates (stripping), while the asphalt cement is the glue which collect asphalt pavement material together. The specimens are selected to be conditioned by saturating with water for 24 hours at desired temperature. The specimens are then tested for indirect tensile strength by loading the specimens at a constant rate and measuring the force required to break the specimen. The tensile strength of the conditioned specimens is used to determine the loss of strength due to the moisture susceptibility of the aged samples.

MARSHALL TEST

The Marshall tests were performed on compacted aging Nano modified specimens. We put in a tank of water for 30min at 60c the kinds of modified specimen the one which mixed with Kaolin and other with bentonite. After that the specimens put in Marshall Test equipment and compression load is applied. The force needed to break the samples is recorded as Marshall Stability and deformation happened while loading refers to flow rate. At the end dividing Marshall Stability to the flow gives us a record of the strength of the material against permanent deformations

IV. RESULTS AND DUSCUSSION

PHSICAL PROPERTIES TESTS

PENETRATION TEST

After experience aging mixed specimen with nanoparticles anew evidence showed up that as much as raise the amount of Nano clay the resistance penetration get high. The pavement will be able to hold heavy duty service in perfect way. This high progress is the heart of this seek to find an opportunity for roadways to resist rutting after long term aging get happened .

Bentonite (3%) and Kaolin (3%) penetration decreased by (10%) compare to Bentonite (1%) and Kaolin (1% -5%) the stiffness was more than pervious by (10%), likely the improvement in material jump to magnificent percent reach to (30%-35%) for Bentonite (5%, 7%) with Kaolin (7%) as shown at Figure 5.

The summary of this test that as we increase the amount of Nano clay as the value of penetration decease that information has been written in a paper (the addition effects of macro and Nano clay on the performance of asphalt binder). [13]

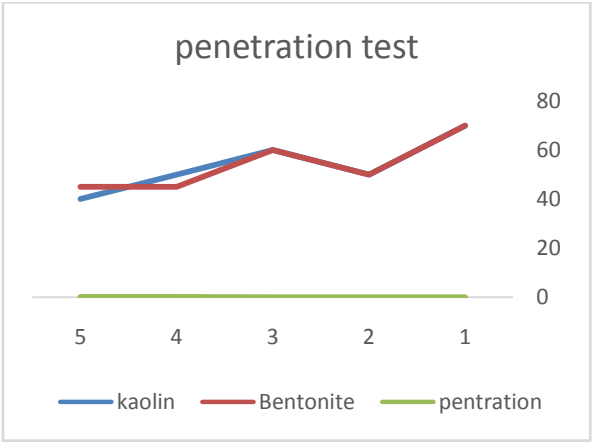
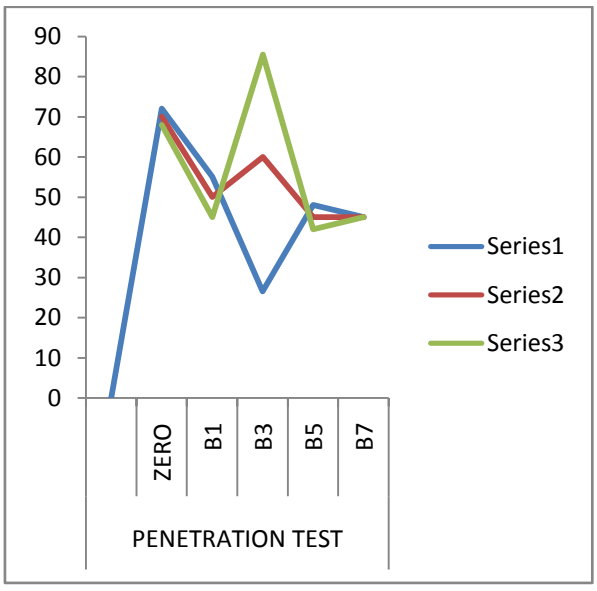
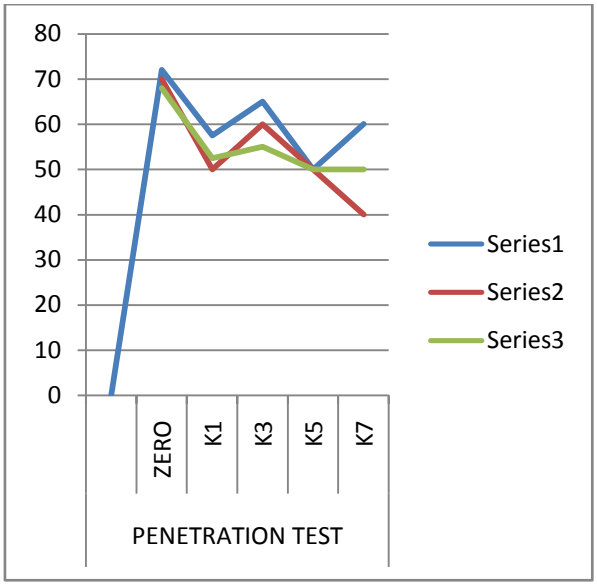


Fig. 5: The results of penetration test





SOFETENING POINT TEST

The magic records present an increasing in asphalt mixtures consistency by using kaolin more than Bentonite(Figure6). That reduces asphalt susceptibility for temperature that was outcome from increase the temperature at which the ball sink

The increment in consistency of asphalt cement was between (5%-10%) by adding Bentonite (3%- 5%-7%), but using Bentonite (1%) and Kaolin (1%-3%-5%-7%) the percent of progress range of (15%-20%).

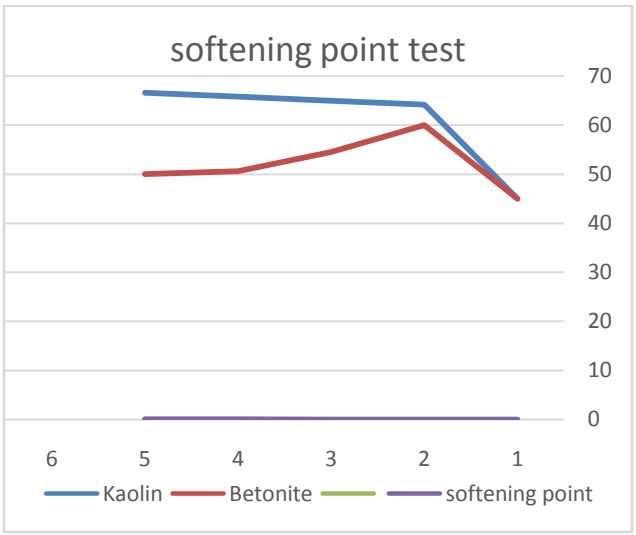
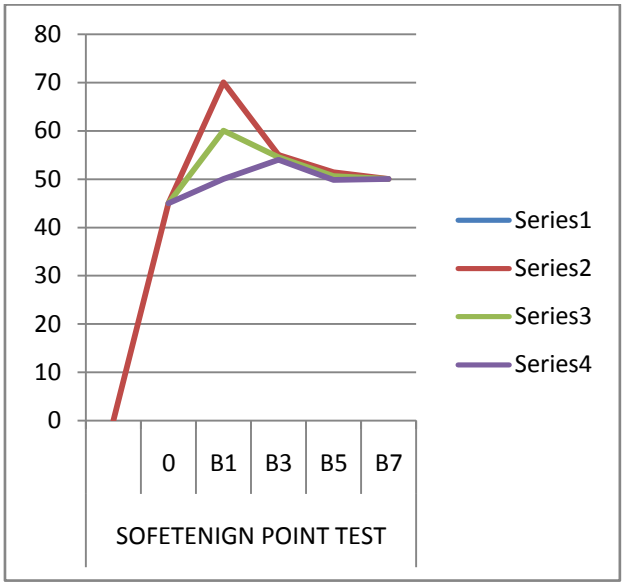
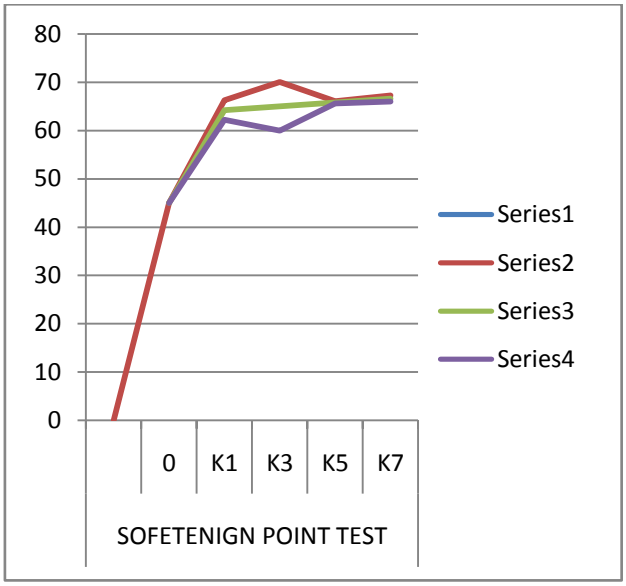


Fig.6: the results of softening point test

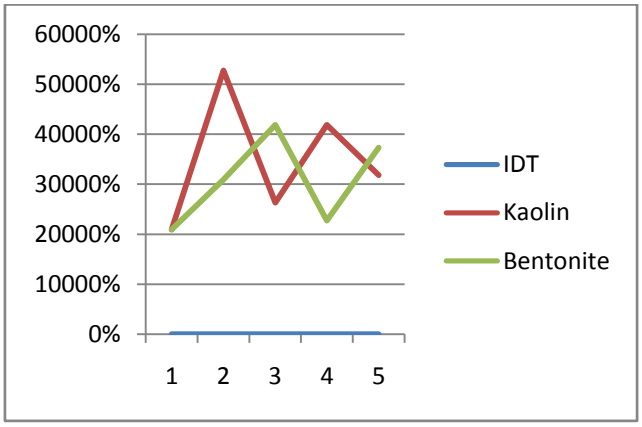


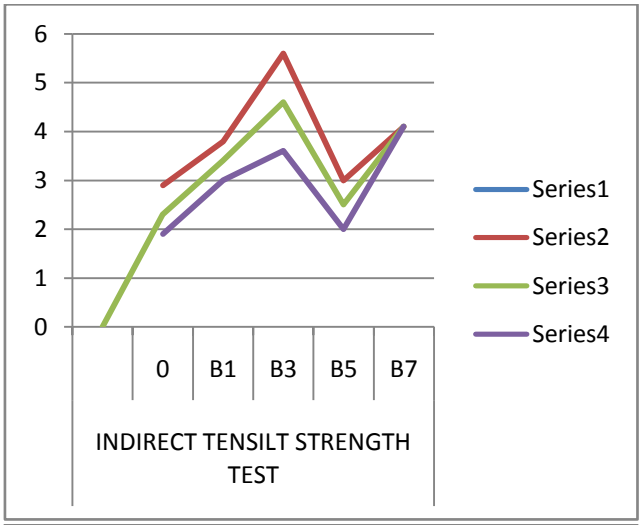


ASPHALT MIXTURE TESTS
INDIRECT TENSILE TEST

Expert Nanoparticles make a revolution in tensile strength of asphalt mixtures, will not exist not any more cracks in roadways at high temperature. Above all of this that occurs at aging level when asphalt supposed to be brittle and more stiffener, the mission has been accomplished.

The high effect of Nano clay(5%) happened when we used Bentonite (3%,7%) as much as Kaolin (1%,5%) , on anther hand Bentonite (1%) similar to Kaolin(7%) gives us improvement (1.5%) , nothing was important about Bentonite (5%)and Kaolin (3%) it was just (.5%-.8%) high than unmodified specimen as showed in Figure 7.





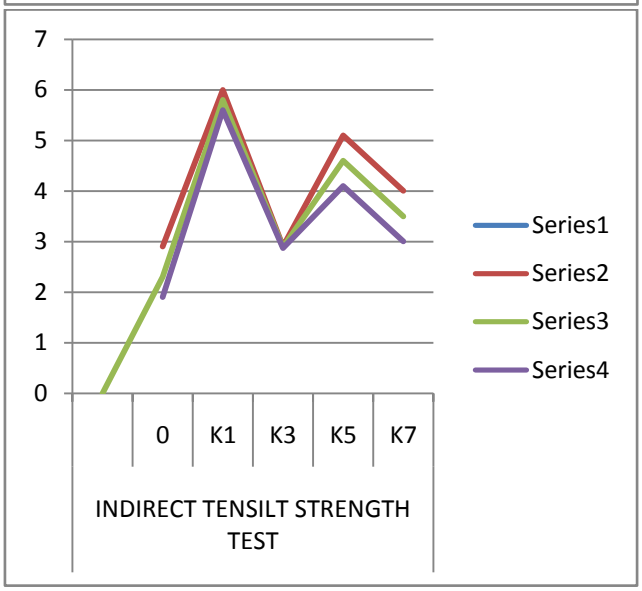


Fig. 7: The results of indirect tensile test

MOISTURE DAMAGE TEST

The moisture susceptibility of Nano modified aged samples were discovered by using moisture damage test (AASHTO T-283). The results of indirect tensile test after one day in tank of water for 24 hours at desired temperature showed at fig [8]. The charts approved that the strength of modified samples are higher than unmodified one. But the percent 7% and 1% of kaolin beside the concentration 7% and 3% of bentonite gives the best acting against water effect on strength.

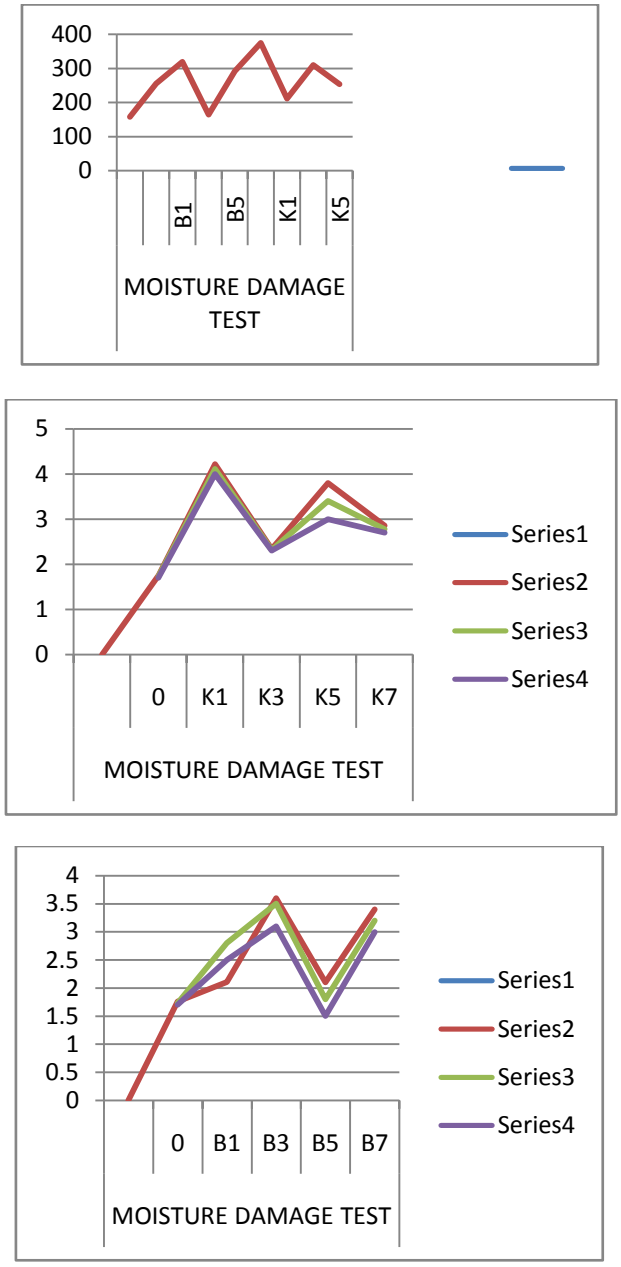


Fig. 8: The results of moisture damage test

MARSHALL TEST

The samples were loaded by compressionload after being put in water for 30min at 60.The magnificent results approvinghow adding Nano clay delay the effect of aging on the strength of samples. Figure9, shows that adding 7% of Bentonite gives the highest stability but not too much reduces the flow like 5%. On the other side the stability 3%of kaolin is too high but the perfect flow can be real by 7% of kaolin.

Chart 9 at paper (Effect of using Nano- clay to improve asphalt materials)gives evidence that using Nano clay and Nano silica increase the stability but the samples weren't aged [14].

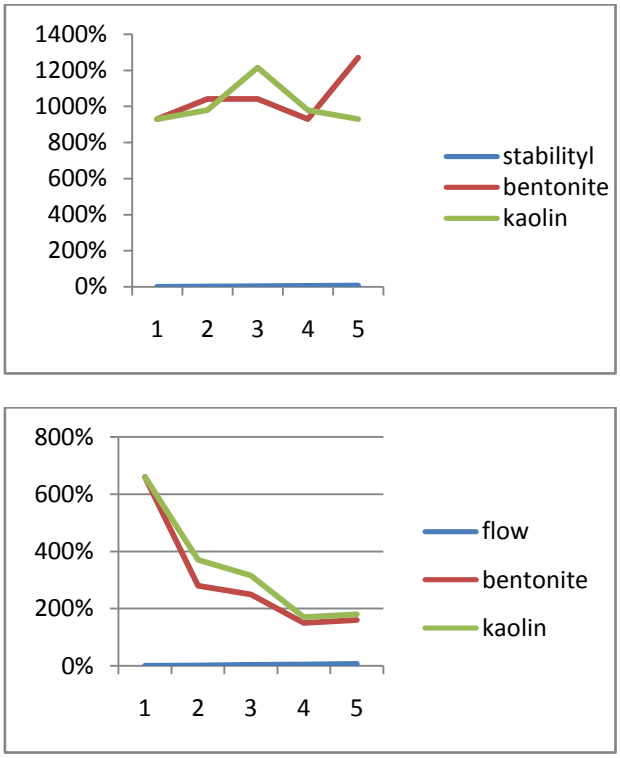


Fig. 9: The results of Marshall test

V. CONCLUSION

In this experimental work three tests were conducted to approve how wonderful the change of asphalt cement agingstrength, asphalt concrete because of put a few amount of Nanoparticles.

From conducted tests the following points are discovered:-

1- Using Nano clay is incredible as aging resistance modifiers.

2- Tensile strength with Bentonite (3%, 7%) similar to Kaolin (5%) is double stiffness more than original specimen.

3- High numbers are gained by using Nano materials for softeningpoint vice versa lower readings for penetration test.

4-The powerful aging resistance pavement can be reality as possible as usingNano materials.

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