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To Study the Mixing and Compaction Temperatures of Organophilic Nanoclay Modified Asphalt Binder

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Abstract: The use of modified asphalt binders in hot-mix asphalt has steadily increased over the past several decades. Mixing and compaction temperatures of an asphalt binder plays a vital role in the production and placement of asphalt mixes but there are no standards for mixing and compaction temperatures for modified asphalt binder especially with Organophilic nanoclay. In this study the effect of nanoclay modified binder on mixing and compaction temperatures of asphalt mixture was observed using conventional test for asphalt mixture-softening point test, penetration test and rotational viscometer test. Five different percentages i-e 3, 3.5, 4, 4.5 and 5% of Nanoclay (modifier) are selected for three different binders (ARL 60/70, ARL 80/100 & NRL 60/70). Six different samples for each binder are prepared and conventional testing is carried out using standard procedures. With an increase in the percentage of Nanoclay the softening point values and viscosity values increases, similarly the penetration values decrease. The mixing temperature range is 155-165°C and compaction temperature range is 135-145 °C to achieve maximum density in the field.

Keywords: Mixing Temperature, Compaction Temperature, Nanoclay, Viscosity

I. INTRODUCTION

Asphalt is a viscoelastic material. The term viscoelastic means that asphalt shows both viscous and elastic behavior, depending on such variables as temperature and time of loading [1]. At high temperatures, asphalt behaves like a viscous liquid and flows, and at low temperatures, asphalt behaves like an elastic solid. At intermediate temperatures, asphalt exhibits both viscous and elastic characteristics. After mixing, the mixture is compacted at the compaction temperature. If the compaction temperature cools down, the asphalt becomes very stiff and compaction becomes extremely difficult . The use of modified asphalt binders in hot-mix asphalt has steadily increased over the past several decades. Modified asphalt binders currently make up over 20% of paving grade asphalt sales in the United States, and the percentage continues to grow [2]. Temperature has a significant effect on viscosity, which is why the mixing and compaction temperatures are controlled by viscosity [3] Temperature is one of the most obvious factors that can have an effect on the rheological behavior of asphalt cement. Because asphalt cements are subjected to large temperature variations, consideration of the effect of temperature on viscosity is essential[4].The difference between the compaction temperature of the modified asphalt mixture and the compaction temperature under the condition of the best compaction effect is 5°C [5]. Nanoclay is used as a binder modifier . The nano modified binder had rutting, fatigue, and low-temperature performance better than the unmodified (neat) asphalt binder[6].Unmodified asphalt binders acts as Newtonian fluids at high temperatures i.e. their viscosity is independent of shear rate. While modified binders are shear thinning in nature, which means their viscosity decreases with increase in the shear rate. Actual mixing and compaction is done at plants at very high shear rate. Mixing and compaction temperatures for modified binders can also be determined through shear rate concept rather than using conventional equiviscous approach. [7]. Shear rate is an important factor to consider in evaluating the rheological behavior of modified asphalt binders. These materials usually show non-Newtonian, pseudoplastic flow behavior [8]. Candidate Method A, developed by Yildirim Soaimanian, and Kennedy in Texas, was based on proof that most modified binders exhibit shear thinning behavior. This method, referred to as High Shear Rate Viscosity, used measurements from a rotational viscometer at shear rates ranging from 0.1 1/s to 93 1/s at 135 and 165°C. The Cross-Williams model was used to extrapolate the measured shear rate versus viscosity data to the higher shear rate of 500 1/s. The extrapolated viscosity data were plotted on a conventional log viscosity versus Mixing and Compaction Temperatures of Asphalt Binder in Hot-Mix Asphalt and log temperature chart to obtain temperatures corresponding to the traditional viscosity criteria of 0.17 ± 0.02 Pa s for mixing, and 0.28 ±0.03 Pa s for compaction It was found that application of the shear rate concept, rather than the traditional approach used for unmodified binders, can reduce the mixing and compaction temperatures from between roughly 10 and 30°C, depending on the type and the amount of modifier[9].

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II. MATERIALS AND METHODOLOGY

The methodology designed to achieve the required research objectives consisted of 3 phases. In 1st phase material from National Refinery Limited , which is 60/70 Grade Asphalt Binder is selected. National Refinery Limited (NRL) . National Refinery Limited is the second largest capacity refinery of Pakistan in terms of crude oil processing facilities and is the only lube oil refinery of Pakistan. The other Two Asphalt Binders i-e are ARL 60/70 and ARL 80/100 were selected from Attock Oil Refinery. The modifier which is selected Organophilic Nanoclay. Wet method was used to mix modifier with the three different binders

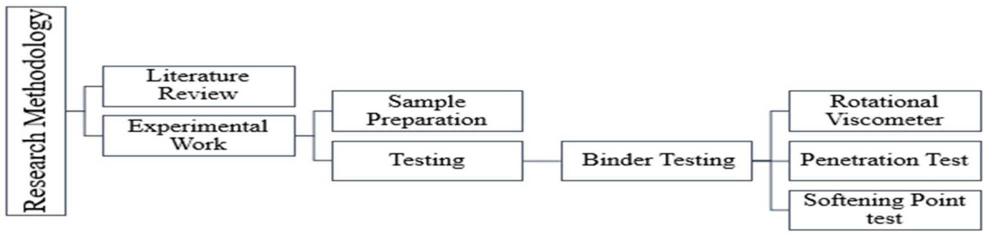

Figure 1 Methodology of Research Work

A. Asphalt Binder Testing

This phase consists of preparing the samples and them performing the tests on them. Five different percentages i-e 3, 3.5, 4 ,4.5 and 5% of Nanoclay (modifier) are selected for three different binders (ARL 60/70, ARL 80/100 & NRL 60/70) . Six different samples for each binder are prepared and conventional testing is carried out using standard procedures

Sr No.	Test Name/Condition	Standard	Pictorial Illustration
1	Softening Point (25 °C)	ASTM D36	
2	Penetration test (0.1mm)	ASTM D5	
3	Viscosity in cp (135°C)	ASTM D4402-06	

Table 2.1 Showing Standard Test Conditions for Conventional Testing

III. RESULTS AND DISCUSSION

As the percentage of Organophilic Nanoclay is increased, there is a increase in the values of softening point and viscosity . The viscosity values increase to 41% at optimum modification of ARL 60/70 Binder. Similarly the penetration values decreases by 30 % at 5 percent modification.

Sr. No.	Binder Code	Penetration Values @ 25, C	Softening Point, C	η @ Shear Rate 6.8 1/s (cP)
1.0	Neat ARL 60/70	62.0	49.0	326.3
2.0	3% NC	48.1	50.5	401.2
3.0	3.5% NC	50.0	50.0	423.4
4.0	4% NC	50.3	51.0	476.6
5.0	4.5% NC	47.0	51.0	485.3
6.0	5% NC	43.0	51.5	462.8

Table 3.1 showing Softening Point, Penetration and Viscosity values for ARL 60/70 binder

For the NRL 60/70 Binder, as the percentage of Organophilic Nanoclay is increased, there is a increase in the values of softening point and viscosity . The viscosity values increase to 44% at optimum modification of ARL 60/70 Binder. Similarly the penetration values decreases by 26 % at 5 percent modification.

Sr. No.	Binder Code	Penetration Values @ 25, C	Softening Point, C	η @ Shear Rate 6.8 1/s (cP)
1.0	Neat NRL 60/70	67.0	51.0	271.6
2.0	3% NC	54.0	52.5	336.7
3.0	3.5% NC	50.0	53.0	330.1
4.0	4% NC	48.0	52.0	364.2
5.0	4.5% NC	51.0	53.0	375.4
6.0	5% NC	49.0	54.0	391.6

Table 3.2 showing Softening Point, Penetration &Viscosity values for NRL 60/70 binder

For the ARL 80/100 Binder, as the percentage of Organophilic Nanoclay is increased, there is a increase in the values of softening point and viscosity . The viscosity values increases to 38% at 4% modification of ARL 60/70 Binder . The softening point values increases by 4 % at optimum modification

Sr. No.	Binder Code	Penetration Values @ 25, C	Softening Point, C	η @ Shear Rate 6.8 1/s (cP)
1.0	Neat ARL 80/100	92.0	46.0	275.8
2.0	3% NC	89.0	46.5	317.5
3.0	3.5% NC	92.4	46.5	338.1
4.0	4% NC	98.7	46.0	354.2
5.0	4.5% NC	97.5	47.0	381.8
6.0	5% NC	92.6	48.0	317.7

Table 3.3 showing Softening Point, Penetration and Viscosity values for ARL 80/100 binder

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As we know that for the Non-Newtonian fluids , shear thining behaviour is observed means there viscosity decrease with the increase in the shear rate[7]. Organophilic nanoclay modified binders also behaves as non-newtonain fluids and with the increase in the shear rate the viscosity values decreases.

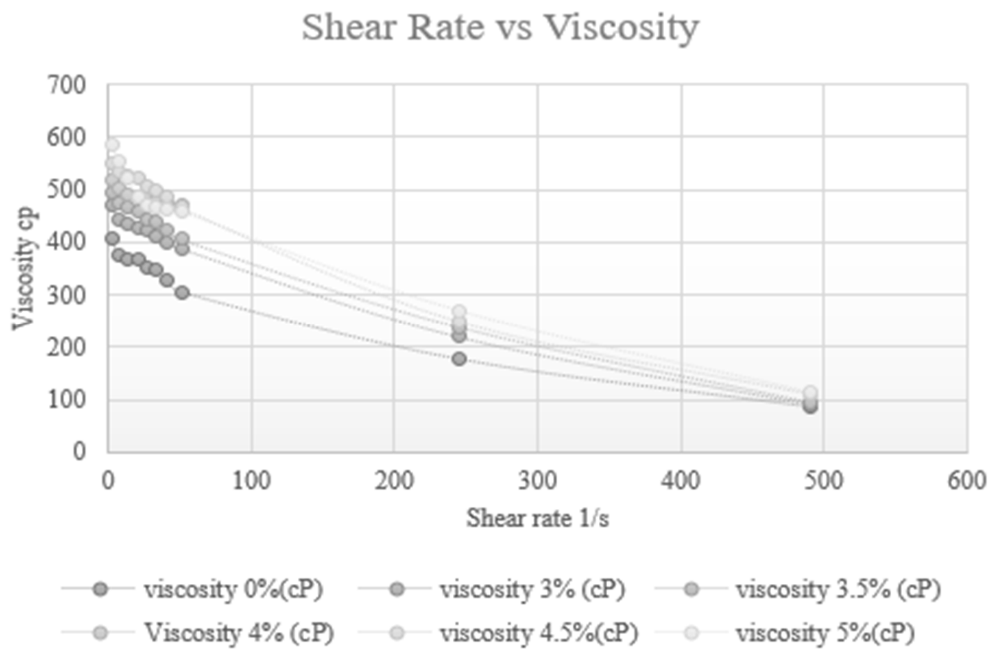

Figure 3.1 Showing Shear Rate vs Viscosity For 60/70 Grade Binder

A. Mixing and Compaction Temperatures

The mixing and compaction temperature values increase with the increase in the percentage of organophilic nanoclay. The mixing temperature range for ARL 80/100 is 159.3°**C** to 164.02°**C** and compaction temperature range is between 137.3°**C** -140.1°**C** . The mixing temperature range for ARL 60/70 is 157.9°**C** to 165°**C** and compaction temperature range is between 135.7°**C** -140.83°**C.** The mixing temperature range for ARL 60/70 is 157.4°**C** to 164.6°**C** and compaction temperature range is between 134.6°**C** -141.2°**C.**

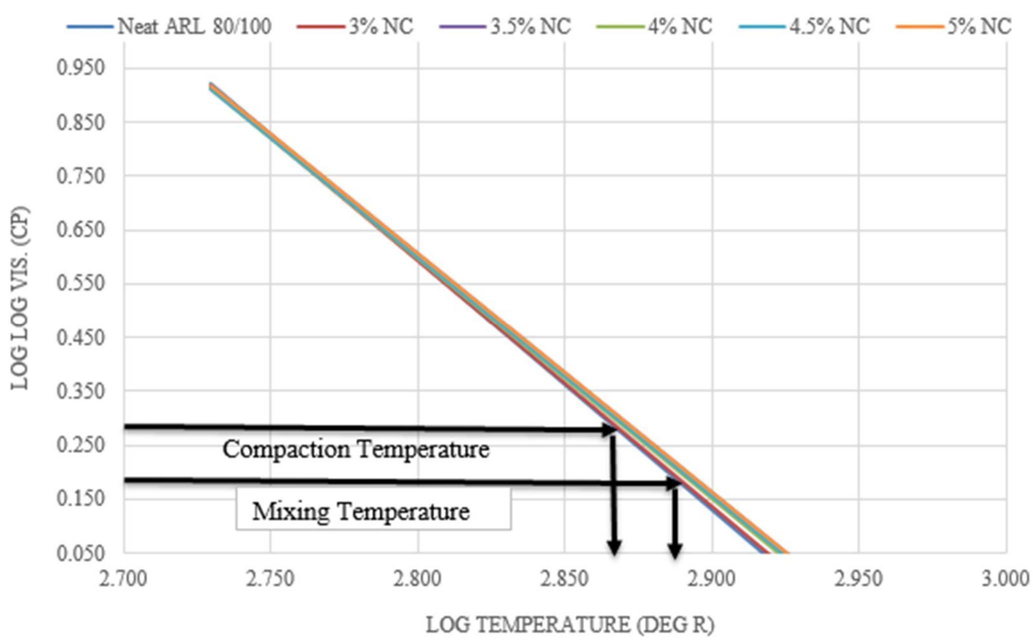

Figure 3.2 Showing Log Mixing and Compaction Temperature Values for ARL 80/100 Binder

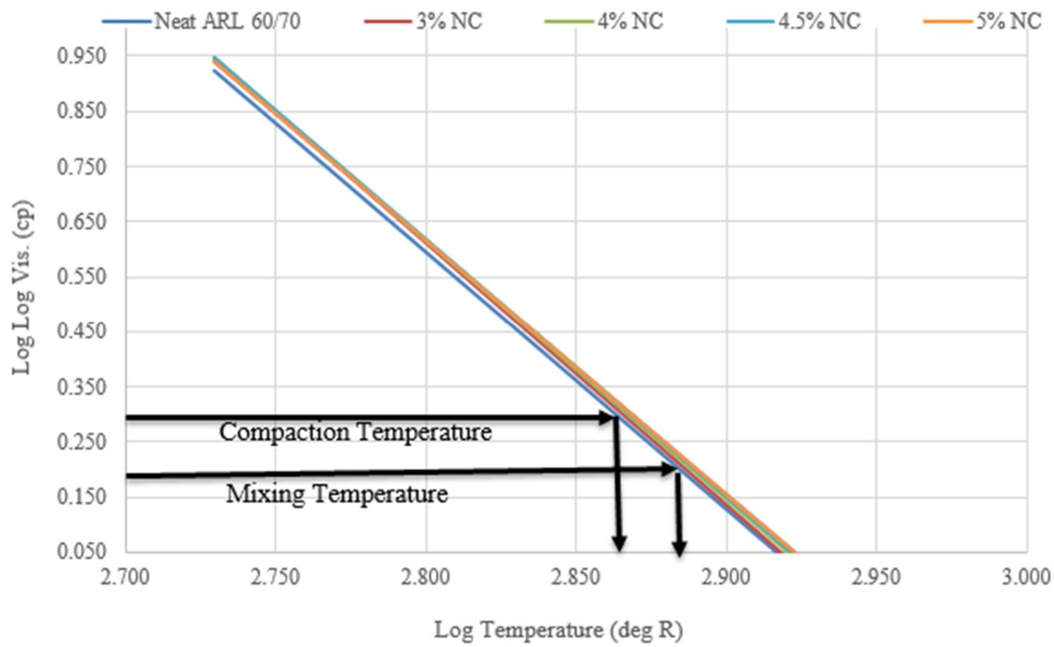

Figure 3.3 Showing Log Mixing and Compaction Temperature Values for ARL 60/70 Binder

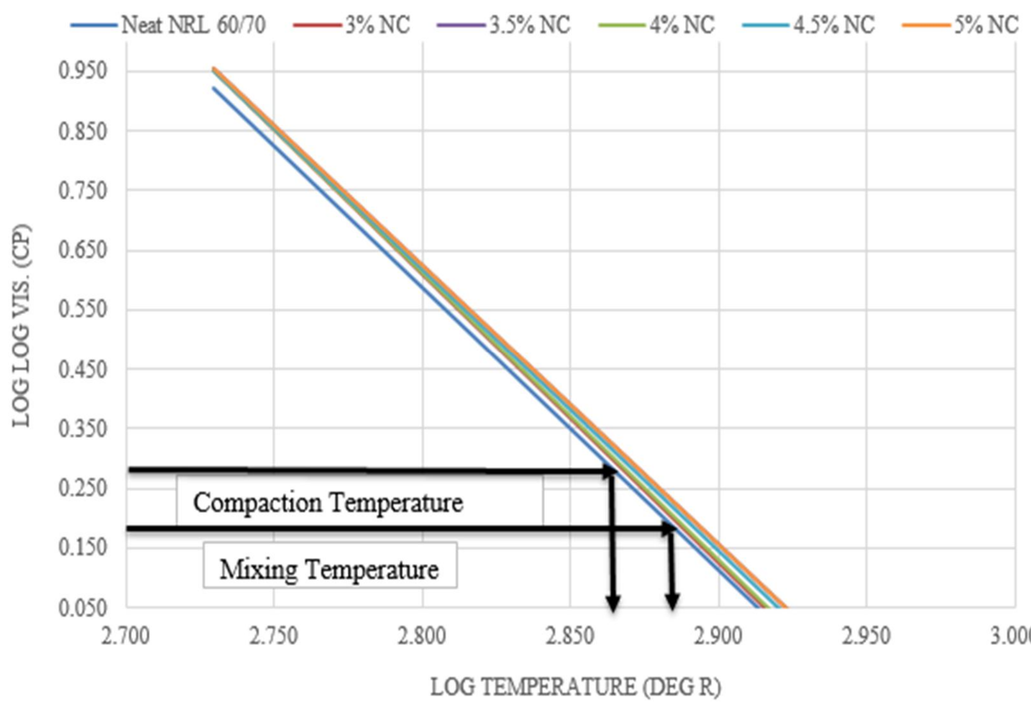

Figure 3.4 Showing Log Mixing and Compaction Temperature Values for NRL 80/100 Binder

IV. CONCLUSION

As the use of modified binder is increasing there is need for the range of mixing and compaction temperatures .For most modified binders, High values of mixing and compaction temperatures causes emission and degradation concerns. The result of this research work provides laboratory mixing and compaction temperatures and it will be used to evaluate laboratory mixing and compaction for Nanoclay modified binders at controlled temperatures

A. With an increase in the percentage of Nanoclay , the penetration values decreases. A decrease of 30% was observed for ARL 60/70 & ARL 80/100 and 28% was observed for NRL 60/70 at optimum modification. Similarly, the softening point values increases. An increase of 4% was observed for ARL 60/70 & ARL 80/100 and 6% was observed for NRL 60/70 at optimum modification.

B. With an increase in the percentage of Nanoclay , the viscosity values increases by 38-44% at 5% modification of binders

C. With the increase in the percentage of Nanoclay , the mixing and compaction temperature of Asphalt Binder increases. For ARL 60/70, ARL 80/100 & NRL 60/70, The mixing temperature range is 155-165**°C** and compaction temperature range is 135-145 **°C**

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