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Effect of Kerosene on Bituminous Mix

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Abstract*: *The flexible pavements often do not live up to the designed period due to various reasons, including the addition of petroleum diluents in the bituminous mix. The presence of petroleum diluents in the bituminous mix changes the properties of the bitumen binder as well as the mix. In hot mix plants, kerosene is used as a fuel for heating the aggregate and a little quantity of the kerosene sometimes gets mixed with aggregate in unburned condition. With the presence of petroleum diluents, the bitumen becomes less viscous and the mix becomes softer even after the normal hardening period of the bitumen. This study was conducted to evaluate the property changes in bitumen as well as in mix with the presence of kerosene including Rolling Thin Film Oven (RTFO) short ageing test. A performance study also conducted for the durability of the mix.

Keywords: Kerosene modified Bitumen, Diluents, Durability, RTFO, Ageing.

I. INTRODUCTION

The development of a nation is mainly based on the road network and durable roads play an important role. Generally, Flexible pavements fail before its designed period due to various reasons, including the addition of petroleum diluents in the bituminous mix. The distresses in the flexible pavement are very common in the forms of Potholes and Rutting. The cohesion and adhesion properties of the bitumen are reduced due to the presence of petroleum diluents and results in the failure of the pavement. “The ageing of bituminous binders is one of the key factors determining the lifespan of an asphalt pavement”. Kerosene content in the bituminous mix may influence the bitumen as well as mix properties during Short Term ageing. Due to the presence of kerosene in the mix, the bitumen never hardens within the designated period, especially in unfavorable weather conditions. It also makes the pavement soft after its hardening period and the properties of the mix do not reach up to the standard value. So, the failure may happen on the first day of traffic in the form of longitudinal depression and will lead to rutting.

The hardening period of the bitumen is less than 24 hours hence flexible pavements can be opened to the traffic after this period. The presence of kerosene in the mix influences the hardening of bitumen. During the rainy season, the ductility of the bitumen reduces due to the influence of kerosene and it leads to pothole formation.

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The elimination of the petroleum diluents in the bituminous mix is one of the best solutions to improve the durability of flexible pavements, provided other parameters are as per standards. In Hot Mix Plant, kerosene is used as fuel for heating the aggregate for the preparation of a bituminous mix.

There is one possibility of inadvertent mixing of kerosene to the aggregate due to the unburned kerosene which is used as a fuel. The presence of kerosene in the bituminous mix has already been identified in various studies. This study concentrated to scientifically evaluate property changes in bitumen and mix with the presence of kerosene in the bituminous mix. The challenge in front of Hot Mix Asphalt (HMA) plants is to prepare the bituminous mix without kerosene or any other petroleum diluents. Since the fuel for heating aggregate is petroleum products, this cannot be stopped, but it can be controlled.

II. OBJECTIVE

The objective of this study is to evaluate the effect of the kerosene in the bituminous mix and to compare with a controlled mix in terms of:

- Change in properties of bitumen added with the initial percentage of kerosene at various time periods.
- Properties of the bituminous mix with different percentage of kerosene at various time periods.
- Change in properties of the bitumen and kerosene modified bitumen during short-term ageing.
- The durability of the bituminous mix with different percentage of kerosene.

III. SCOPE OF STUDY

This work includes the study of the effect of kerosene in VG30 bitumen used in HMA. The various properties of the bitumen and bituminous mix are studied in the laboratory with bitumen mixed with kerosene and compared with virgin one. Various laboratory tests such as Marshall Stability and Wheel Rutting test of mix and Dynamic viscosity, Short Term ageing properties and other tests for bitumen are to be conducted. The effects of kerosene in HMA were studied with various percentages of kerosene at different periods of time. The properties of the bitumen strength regain over a period of time due to the evaporation of the kerosene were studied.

IV. METHODOLOGY

The various test procedures in conducting this study are:

- Basic tests on aggregate, VG30 bitumen and kerosene modified VG30 bitumen at different instants of time.

- Preparation of Marshall Specimen with bitumen and with kerosene modified bitumen on various days of interval and determination of stability, flow values and percentage voids for the controlled mix as well as for kerosene modified mix.
- Determination of stability variation of kerosene modified mix over a period of time due to evaporation.
- Determination of variation of properties such as Viscosity and Softening Point after the short-term ageing process by RTFO method for virgin and kerosene modified bitumen.
- An experimental investigation by Wheel rutting test machine for the durability study on both the samples.

V. EXPERIMENT AND ANALYSIS

- Basic tests of aggregate and VG30 bitumen were carried out.
- Basic tests on aggregate, VG30 bitumen and kerosene modified VG30 bitumen at different instants of time.
- Grade II aggregate used for the study and mid values were selected as per MoRTH specifications [10] (Table I & Figure 1).
- VG30 bitumen with 1% & 2% of kerosene added and allowed for atmospheric evaporation.
- The basic tests of the kerosene modified bitumen and Marshall stability of the mix were determined on 0th, 1st, 2nd, 3rd, 5th, 10th, 20th, the 30th and 45th day after kerosene added.
- Properties such as Viscosity and Softening Point of the virgin and kerosene modified bitumen after RTFO short-term ageing method were carried out and compared the values.
- Wheel rutting test for durability study has been conducted for a controlled mix and various percentages kerosene added HMA.
- Analysis of data and comparison of results.

Table- I: Gradation Chart for HMA Mix for BC (As per MoRTH, [10])

IS Sieve (mm)	Cumulative % by weight of total aggregate passing	Mid – range of aggregate value selected (%)
19	100	100
13.2	79 - 100	89.5
9.5	70 - 88	79
4.75	53 - 71	62
2.36	42 - 58	50
1.18	34 - 48	41
0.60	26 - 38	32
0.30	18 – 28	23
0.15	12 – 20	16
0.075	4 - 10	7
Nominal Aggregate sixe – 13.20mm		

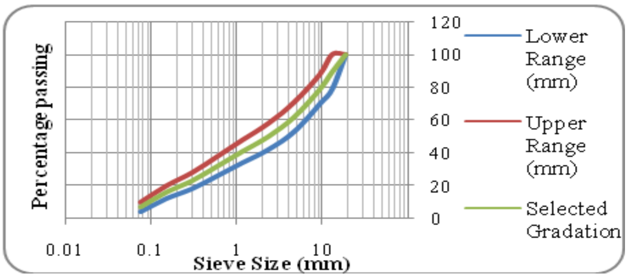

Fig. 1.Gradation for HMA Mix for BC.

A. Properties of Bitumen

The basic properties such as viscosity, softening point, Ductility, Penetration test of virgin VG30 bitumen and kerosene modified bitumen with 1%, 1.5% and 2% bitumen content were determined and shown in Table II and Figure 2 & 3. Different percentage of kerosene added and blended to the VG30 bitumen and allowed evaporation and the above properties are tested on 0th, 1st, 2nd, 3rd, 5th, 10th, 20th, 30th and 45th day after kerosene added and the results are shown in Table III & IV.

Table- II: Properties of virgin and kerosene modified bitumen

Sl No.	Test Description	Bitumen + 0% Kerosene	Bitumen + 1% Kerosene	Bitumen + 1.5% Kerosene	Bitumen + 2% Kerosene
1	Kinematic Viscosity @ 135°C	425	330	300	295
2	Softening Point (°C)	48	42	40	36
3	Ductility in' cm'	60.5	55.0	50.0	51.0
4	Penetration Value 'mm'	52.1	86.3	95.0	99.6

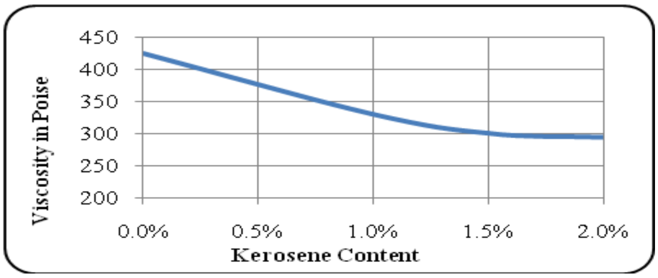

Fig. 2.Viscosity of different % of kerosene modified bitumen

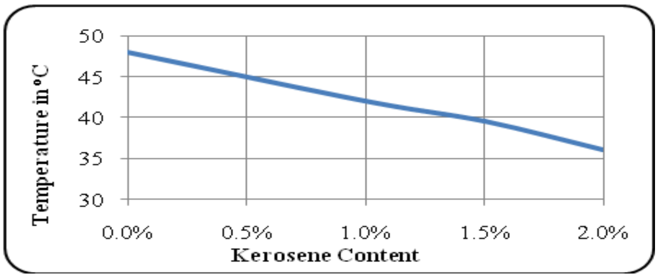

Fig. 3. Softening of different % of kerosene modified bitumen

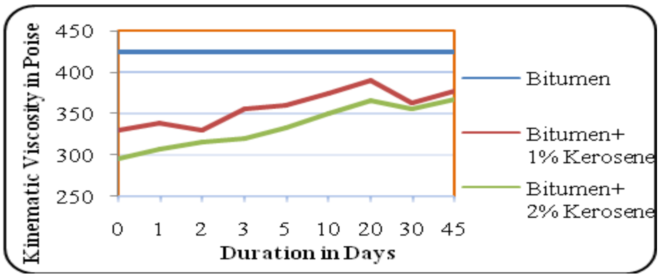

Fig. 4.Kinematic Viscosity at the different instant of time due to evaporation of kerosene

Table- III: Properties of Bitumen & 1% kerosene modified bitumen on various days

Sl No.	Test	Bitumen	Bitumen + 1% Kerosene								
		On 0th Day	0th	1st	2nd	3rd	5th	10th	20th	30th	45th
1	Kinematic Viscosity @ 135°C	425	330	339	330	355	360	375	390	363	378
2	Softening Point (°C)	48.0	42.0	43.5	44.0	45.0	47.0	43.0	45.0	44.5	44.0
3	Ductility in 'cm'	60.5	55.0	66.0	67.0	67.0	68.0	54.0	49.5	58.0	52.0
4	Penetration in 'mm'	52.1	86.3	82.4	79.3	78.2	78.6	79.2	78.9	77.9	77.9

Table- IV: Properties of Bitumen & 2% kerosene modified bitumen on various days

Sl No.	Test	Bitumen	Bitumen + 2% Kerosene								
		On 0th Day	0th	1st	2nd	3rd	5th	10th	20th	30th	45th
1	Kinematic Viscosity @ 135°C	425	295	308	315	320	333	350	365	355	368
2	Softening Point (°C)	48	36	37	41	42	43	43	45	44	45
3	Ductility in 'cm'	60.5	51	57	59	59	53	55	51	57	55
4	Penetration in 'mm'	52.1	100	95	92	91	91	89	88	86	83

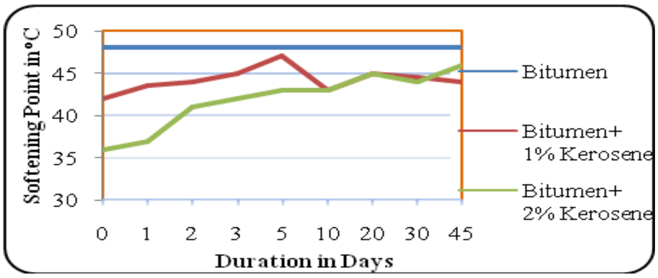

Fig. 5.Softening Point at the different instant of time due to evaporation of kerosene

The Kinematic Viscosity, Softening point and ductility are inversely proportional (Figure 2 & 3) to the percentage of kerosene content. The Viscosity of the modified bitumen was tested with an increment of 0.50% kerosene.

The variation of the viscosity curve is uniform over a period of 45 days and a total reduction of 30.59% is recorded at 2% of kerosene content (Figure 4).

The softening point is uniform for both 1% and 2% kerosene content after 10 days evaporation period (Figure 5).

Even the kerosene modified bitumen is more ductile, the tensile strength is less and it touches the bottom of the test basin and results in the unstable values and are not considered for the comparison.

B. Properties of HMA Mix

Different percentages of kerosene added and blended to the VG30 bitumen and allowed evaporation and HMA mixes were prepared using this bitumen at different instants of days (Figure 6).

The stability, flow value, unit weight, air voids of kerosene modified bitumen mix were tested and compared with values of control mix properties.

Marshall Stability tests were conducted with VG30 bitumen for controlled mix and kerosene modified bitumen by varying content from 1.0% to 2.0% and the results are shown in Table V.

The percentage of bitumen added is 5.30 % for virgin and modified bitumen and the variation of the Marshall Stability and percentages of voids in the mix are shown in Figures 7 & 8. HMA Mix without any additives/diluents is taken as a control sample. Different percentage of kerosene added (1% and 2%) and blended to the VG30 bitumen and allowed evaporation and the Marshall properties were tested on 0th, 1st, 2nd, 3rd, 5th, 10th, 20th, 30th and 45th day after kerosene added and the results are shown in Table VI & VII.

Fig. 6.HMA Marshall Samples

Table- V: Properties of specimen using Bitumen & Kerosene modified bitumen

Sl No.	Test Description	Bitumen + 0% Kerosene	Bitumen + 1% Kerosene	Bitumen+ 1.5% Kerosene	Bitumen + 2% Kerosene
1	Marshall Stability (kN)	50.59	28.62	28.31	27.59
2	Marshall Deflection (mm)	1.66	3.03	2.91	3.00
3	Percentage of Voids	4.57%	2.68%	2.51%	2.51%

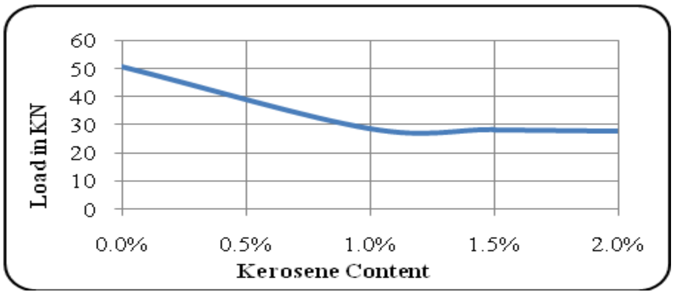

Fig. 7.Marshall Stability of different % of kerosene modified bitumen

Table- VI: Properties of Bitumen & 1% kerosene modified bitumen on various days

Sl No.	Test	Bitumen	Bitumen + 1% Kerosene								
		On 0th Day	0th	1st	2nd	3rd	5th	10th	20th	30th	45th
1	Marshall Stability (kN)	50.59	28.6	30.3	34.9	35.3	35.8	36.5	37.2	38.3	40.6
2	Marshall Deflection (mm)	1.66	3.03	2.91	1.84	1.84	1.27	1.42	1.88	0.83	1.25
3	% Voids in mix	4.6	2.7	2.5	3.1	3	3	3.3	3.2	3.2	3.3

Table- VII: Properties of Control mix and 2% kerosene modified HMA on various days

Sl No.	Test	Bitumen	Bitumen + 2% Kerosene								
		On 0th Day	0th	1st	2nd	3rd	5th	10th	20th	30th	45th
1	Marshall Stability (kN)	50.59	28	29	33	34	35	36	37.8	40	40.5
2	Marshall Deflection (mm)	1.66	3	3.1	2.3	3.3	2.8	3.2	2.21	1.4	1.04
3	% Voids in mix	4.6	2.5	2.5	2.9	2.7	3.4	3	3.2	3.4	3.6

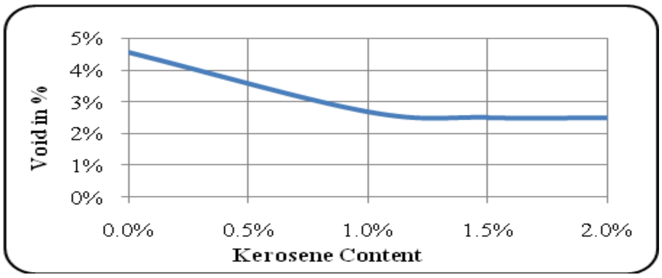

Fig. 8. % voids in the mix of different % of kerosene modified bitumen

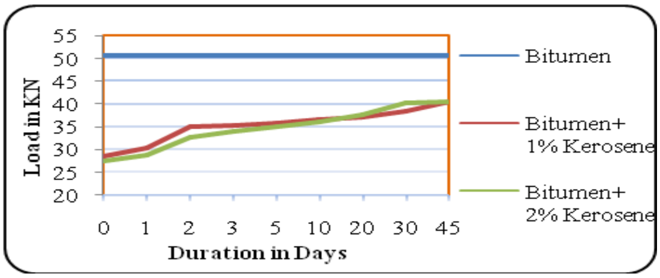

Fig. 9.Marshall Stability at the different instant of time due to evaporation of kerosene

The load carrying capacity of the bituminous mix prepared with kerosene modified bitumen is less compared to the control mix (Figure 9).

The load carrying capacity gradually decreases up to 1% kerosene content and is remain constant later (Figure 7). The failure load on the 0th day is around 28 kN which is 44.65% less than that of virgin one. Due to the evaporation of the kerosene, a total of 85% of the strength is attained during 45 days. The variation of the Marshall stability distribution over a period of 45 days is shown in Figure 9. The void in the mix is linearly increasing for both the kerosene content during 45 days of the testing period (Figure 10). The Voids in Aggregate (Va), Voids in Mineral Aggregate (VMA) and Voids in Fine Aggregate (VFA) were calculated corresponding to the various percentage of kerosene content and the results are shown in Table VIII and Figure 11.

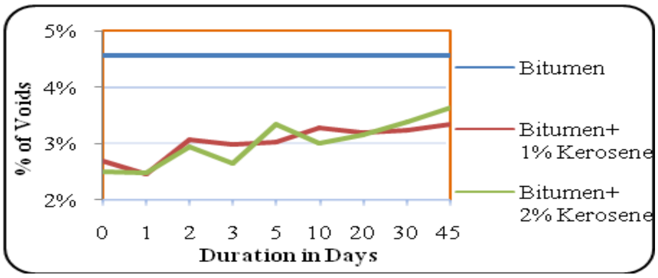

Fig. 10. Voids in the mix with various percentages of kerosene at different durations of time due to evaporation.

Table- VIII: Void parameters in HMA corresponding to kerosene content

Sl No.	Kerosene Content %	Va in %	VMA in %	VFA in %
1	0	4.57	13.22	65.43
2	1.0	2.68	13.22	79.73
3	1.5	2.46	13.37	81.60
4	2.0	2.51	13.75	81.75

The percentage of voids in compacted mixture corresponding to 1% kerosene content is 46.17% less than that of the control mix. The percentage of voids in the mix between 1.25% and 2.0% are stable (Figure 11).

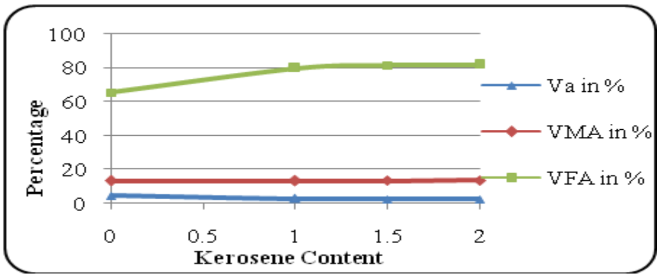

Fig. 11. Void parameters in HMA corresponding to kerosene content

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C. RTFO method of Short-Term ageing

The basic properties such as Kinematic Viscosity and a softening point of virgin VG30 bitumen and kerosene modified bitumen 1% and 2% and tested after ageing with Rolling Thin Film Oven method. The results are shown in Table- IX.

Table- IX: Properties of Kerosene modified Bitumen after Short-Term Ageing

Sl No.	Test Description	Kerosene Content		
		0%	1%	2%
1	Kinematic Viscosity @ 135°C	800	1100	1100
2	Softening Point (°C)	59.5	61.0	61.5

D. Performance Test

Wheel rut tests were conducted with VG30 bitumen for controlled mix and 1% kerosene modified bitumen. The rut depth corresponding to 45 minutes pass and 60 minutes pass were recorded and shown in Table X.

Table- X: Rut depth of control and kerosene modified HMA

Sl No.	Sample	Rut Depth (mm)	
		At 45 min. Pass	At 60 min. Pass
1	VG30	1.95	2.99
2	VG30 + 1% Kerosene	2.15	3.18

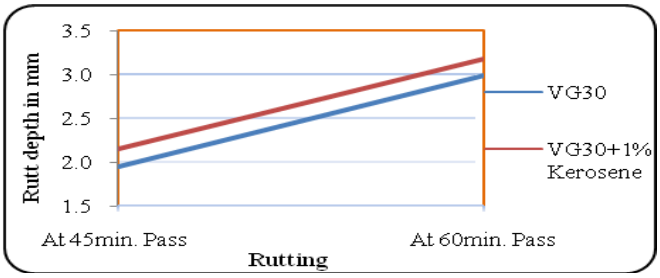

Fig. 12. Rut depth of control and kerosene modified HMA

It is observed that the rut depth of 1% kerosene modified HMA mix shows 6.35% to 10.25% more rut depth than the control HMA mix (Figure 12). The following are the findings from this work.

VI. CONCLUSION

- Initially, the kerosene modified bitumen becomes soft and as a result of evaporation, it gradually hardens. The properties of the kerosene modified bitumen significantly vary with respect to time.
- The stability is found to be reduced to about 40% with the addition of 1% and 2% kerosene respectively. On keeping the mix for evaporation, the stability value was observed to be increased tremendously for 2 days and gain up to 30.92% and 35.36% respectively for 1% and 2% kerosene content, whereas a very gradual increase in stability was observed on further ageing. At the end of 45 days of the test period, almost 80% of initial stability was attained by the sample.
- The Kinematic viscosity of the aged VG 30 bitumen is found to be 800 poise and kerosene modified bitumen is found to be 1100 poise for both 1% and 2% kerosene content. The Kinematic viscosity of the kerosene modified bitumen is increased up to 37.5% compared to the aged VG 30 bitumen and becomes more brittle.
- The performance test reveals that the kerosene modified HMA mix will be subjected to high rutting value when compared to that of the control mix. The Rutting depth of the control mix was found to be 1.95mm for a test period of 45 minutes which was increased to the 2.15mm depth at 60 minutes test period. Whereas, a high value of rutting depth, that is 2.99mm was observed for a 1% kerosene modified mix for 45 minutes test period which was increased to 3.18mm after 60 minutes.

It can be concluded that the inadvertent addition of kerosene to bitumen causes a considerable reduction in stability during initial periods of pavement operations. It is also noticed a significant increase in the rut formation of such mixes.

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