



CHARACTERISTICS OF LABORATORY PRODUCED HARD GRADE BITUMEN WITH GILSONITE MODIFICATION

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Abstract- Pavements constructed with the conventional bitumen are unable to provide the service throughout the designed life period due to the major distresses like fatigue and rutting. These distresses are mainly due to the factors like exponential increase in repetition of traffic loads and abnormal changes in climatic conditions. To reduce the effect of these distresses the use of High Modulus Asphalt Concrete (HMAC) in the base layer produced with hard grade bitumen can be considered as a solution. In this study, the hard grade bitumen was developed by blending different percentages of Gilsonite (natural asphalt) with conventional VG 30 bitumen. The tests on conventional and gilsonite modified bitumen include physical properties, rotational viscosity test, rolling thin film oven test (RTFO) and SARA fractions. The experimental results show that addition of 15% of gilsonite (by weight of VG 30) was found to be optimum for the production of hard grade bitumen. The developed hard grade bitumen is satisfying the required specifications as per French method (EME) and can be used to produce HMAC.

Keywords- High Modulus Asphalt Concrete (HMAC), Hard Grade Bitumen, Gilsonite Modified Bitumen, Saturates Aromatics Resins Asphaltenes (SARA), Enrobés à module élevé (EME).

1. INTRODUCTION

Flexible pavements are the most widely used pavement type across the globe due to lower initial investments and higher riding comfort when compared with rigid pavements. As life of the pavement increases it is being subjected to different types of distress due to increase in traffic volume, vehicular loads and abnormal changes in climatic conditions leading to decrease the life of the pavement and increase the maintenance cost. The performance of bituminous layer of flexible pavement will have major effect on the structural capacity of the pavement as it carries major portion of applied load. Although the drainage parameters of granular layer and strength of sub-grade layer may have significant impact on distresses like rutting.

As the traffic intensity and vehicular loads are increasing rapidly the pavements constructed with conventional hot mix asphalt are being subjected to major distresses and decreasing the life of the pavement. To improve the performance of the pavement, Enrobés à module élevé (EME) method which was developed in the year 1980 by France has introduced the concept of using HMAC produced with hard grade binder in the base layer. Hard grade bitumen i.e., those having the penetration value in between 25-15 at 25°C. This hard grade bitumen can be produced in the laboratory by modifying base bitumen with hardening additives (natural asphalt) or it can be a refinery product.

The chemical characteristics of a bitumen modified with Gilsonite says that it can be used as a modifier to improve the properties of base bitumen [1]. The addition of Gilsonite has considerably improved the Marshal stability value and the resilient modulus of the HMA mixes [2]. However, the addition of Gilsonite has improved the high-performance temperature of HMA mixes, it shows negative impact on low performance temperature [3].

The rheological properties of the bitumen modified with Gilsonite at high temperatures shows that there is increase in its stiffness, elasticity and rutting resistance significantly [4]. By using HMAC in the bituminous base course, the thickness of the Dense Bituminous Macadam (DBM) layer can be reduced up to 20 mm which will save the materials and cost substantially [5][6]. In other study, using of HMAC prepared with poly phosphoric acid (PPA) modified bitumen, the thickness of DBM layer was reduced up to 40 mm for 300 msa [7]. The Fourier Transform Infrared Spectroscopy (FTIR) studies were conducted to analyse the evolution of different functional groups when the modified bitumen is subjected to short term and long-term ageing conditions [8].

Another study was conducted to improve the low temperature cracking resistance, compatibility and storage stability by adding polymer to gilsonite modified bitumen [9]. Studies were conducted to improve the fatigue performance of pavement designed with HMAC by adding additives like crumb rubber and FTIR and mechanical interactions between additives and bitumen were studied [10].

The main objective of this study is to produce a hard grade bitumen used for production of HMAC and to study the effects of hardening additive on the properties of the conventional bitumen. American Gilsonite (natural asphalt) was used in the present study as an hardening additive to the conventional bitumen.

2. MATERIALS AND METHODS

2.1 Materials

2.1.1 Bitumen

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In this study, VG 30 bitumen was used as conventional bitumen which was obtained from Tiki Tar industries (Baroda) Limited, Mumbai. The physical properties of conventional bitumen were tested according to the Indian standard specifications (IS 73: 2013). Table 2.1 illustrates the tested results of the conventional bitumen.

Table-2.1 Properties of Conventional Bitumen (VG 30)

S. No	Properties	Test Method	Result	Required value (IS 73:2013)
1	Penetration value, 0.1 mm at 25°C	IS 1203	51	45 (min.)
2	Softening point, °C	IS 1205	53	47 (min.)
3	Absolute viscosity at 60°C, Poise	IS 1206	3100	2400-3600
4	Kinematic viscosity at 135°C, cSt	IS 1206	370	350 (min.)

2.1.2 Hardening Additive

American Gilsonite which was obtained from Indian Commercial Company, Mumbai is used as hardening additive in the present study to produce hard grade bitumen. Gilsonite is a natural mineral bitumen, black in colour and brittle in nature, which is easily crushed in to powder. Below Table 2.2 summarizes the properties of Gilsonite powder.

Table-2.2 Properties of American Gilsonite Powder

S. No	Properties	Result
1	Penetration value, 0.1 mm at 25°C	0
2	Softening point, °C	160
3	Specific Gravity	1.04
4	Ash content	<1%
5	Flash point, °C	316
6	Colour in mass	Black

2.2 Production of hard grade bitumen

The conventional bitumen was heated to a temperature of 150°C in a container and the required percentage of additive (by mass of VG 30) was heated to 170°C in another container and then mixed with the conventional bitumen. The mixture of additive and the conventional bitumen was blended with higher rate stirrer for 90 mins at a temperature of 160°C until homogenous blend was obtained. The process is repeated for 10%, 12.5%, 15% and 17.5% (by mass of VG 30) of Gilsonite. The different percentages of Gilsonite are tried to produce the hard grade bitumen that satisfy the requirement of EME (class 2) method shown in Table 2.3.

Table-2.3 Specifications for Hard Grade Bitumen as per EME Method

S. No	Properties	Requirement (according to EME 2)
1	Penetration value, 0.1 mm at 25°C	15-25
2	Softening point, °C	55-71
3	Kinematic viscosity at 135°C, cSt	≥ 600
4	Dynamic (Rotational) viscosity at 135°C (Pa. Sec)	0.6

2.3 Experimental Tests

2.3.1 Physical Tests

The tests for physical properties like penetration, softening point, ductility and kinematic viscosity were conducted on the conventional bitumen and Gilsonite modified bitumen as per the procedures given in Indian standards. Rotational viscosity test is conducted to determine the mixing and compaction temperature of the conventional bitumen and gilsonite modified bitumen. The mixing and compaction temperatures will be corresponding to dynamic (rotational) viscosities of 170 cSt and 280 cSt will be respectively. Temperatures ranging from 135 to 185°C was selected to study the behaviour of samples.

2.3.2 Rolling Thin Film Oven Test

The rolling thin oven test (RTFO) is conducted to simulate the short-term ageing during mixing and compaction process. In this test 35 gm of heated bitumen is poured in to the glass bottles and immediately rotated them so that the bitumen will spread throughout the bottle surface. After 90 min of cooling in air, bottles are subjected to a temperature of 163°C for 85 min in the RTFO carousel.

2.3.3 SARA Fractions Analysis

Bitumen is an organic binder which consists of two chemical fractions as asphaltenes and maltenes, which combinedly called as SARA fractions. As maltenes are soluble in n-heptane, asphaltenes and maltenes can be separated from the bitumen. The maltenes can be further separated in to saturates, aromatics and resins by using Liquid Adsorption Chromatography. SARA fractions analysis is conducted as per ASTM D4124 method to determine the asphaltenes content as it effects the rheological properties of bitumen.

In this method 10 gm of bitumen is dissolved in 100 ml per gm of n-heptane and stirred it thoroughly so that the bitumen will not stick to the bottom of glass vessel and is allowed to soak in n-heptane for 24 hrs. The asphaltenes which are not soluble in n-heptane are separated by using filter paper and suction pump as shown in Fig. 2.1. After drying the filter paper, the difference between the initial and final weights of filter paper is reported as percentage of asphaltenes content in bitumen.



Fig.2.1 Separation of Asphaltenes from Bitumen

3.RESULTS AND DISCUSSIONS

3.1 Effect of Gilsonite on the Physical Properties

The test results of physical properties of the conventional bitumen and the gilsonite modified bitumen including penetration value and softening point are shown in **Fig. 3.1 and 3.2**. The test results show that as the percentage of Gilsonite increases the penetration value decreased, while the softening point is increased. This shows that the performance of the gilsonite modified bitumen has improved at high temperatures. The penetration values of conventional bitumen and gilsonite modified bitumen (10%, 12.5%, 15% and 17.5% by weight of VG 30) are 51, 37, 28, 22 and 18 respectively. The softening point of 15% of gilsonite modified bitumen was increased by 11°C when compared with conventional bitumen. Literature says that the acceptable ductility value of hard grade bitumen is 10 cm at 25°C [11]. Table 3.1 shows the test results of conventional bitumen and gilsonite modified bitumen.

The optimum percentage is selected as 15% of gilsonite by weight of conventional bitumen to produce hard grade bitumen as the penetration value is between 25-15. Table 3.2 shows the test results of hard grade bitumen produced in this study with EME2 specifications.

Table-3.1 Test Results of Conventional Bitumen and Gilsonite Modified Bitumen.

	Penetration value	Softening point (°C)	Kinematic Viscosity (cSt)
VG 30	51	53	380
VG 30+10% Gilsonite	37	57	780
VG 30+12.5% Gilsonite	28	61	1100
VG 30+15% Gilsonite	22	64	1530
VG 30+17.5% Gilsonite	18	67	2240

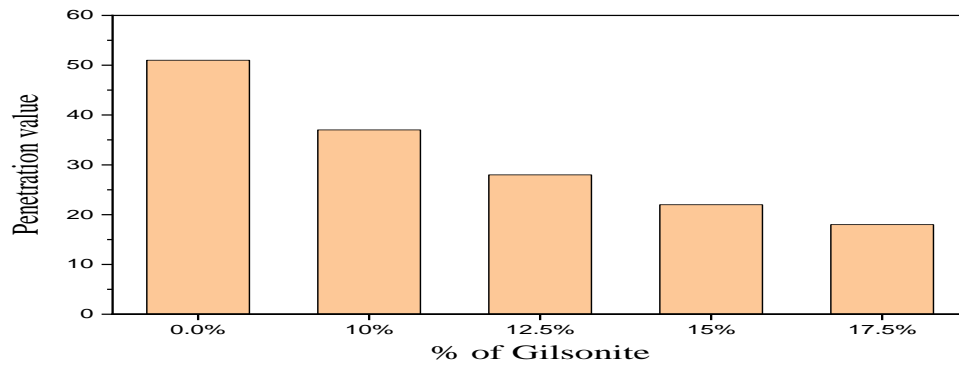


Fig.3.1 Penetration Values of Conventional Bitumen and Gilsonite Modified Bitumen

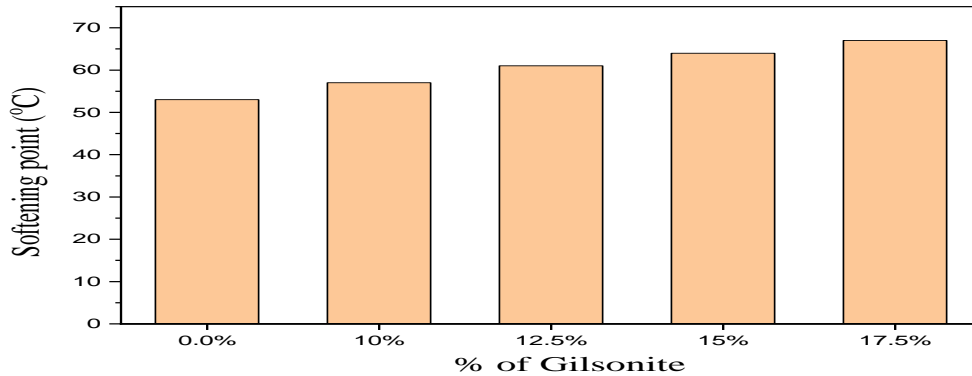


Fig.3.2 Softening Point of Conventional Bitumen and Gilsonite Modified Bitumen

Table-3.2 Test Results of Hard Grade Bitumen Produced with EME2 Specifications.

S. No	Properties	Test Method	Result	Requirement (according to EME2)
1	Penetration value, 0.1 mm at 25°C	IS 1203	22	15-25
2	Softening point, °C	IS 1205	64	55-71
3	Kinematic viscosity at 135°C, cSt	IS 1206	1550	≥600
4	Ductility at 25°C, cm	IS 1208	21	
5	Dynamic (Rotational) viscosity at 135°C (Pa. Sec)		1.53	0.6 (Min.)

3.2 Rotational Viscosity Test Results

The viscosity of the modified bitumen is dependent on temperature. As the temperature increases, viscosity decreases. The results of dynamic (rotational) viscosity of conventional bitumen and gilsonite modified bitumen at 135°C are shown in **Fig 3.3**. The handling of bitumen will be easy at the lower viscosity values for mixing and compaction. The mixing temperature corresponding to 170 cSt and compaction temperature corresponding to 280 cSt was increased by 20°C for 15% of gilsonite. As the addition of additive is increasing the viscosity of bitumen, it increases the cohesion between the bitumen and aggregate in bituminous mix. The mixing and compaction temperatures of conventional and gilsonite modified bitumen are shown in **Fig 3.4**.

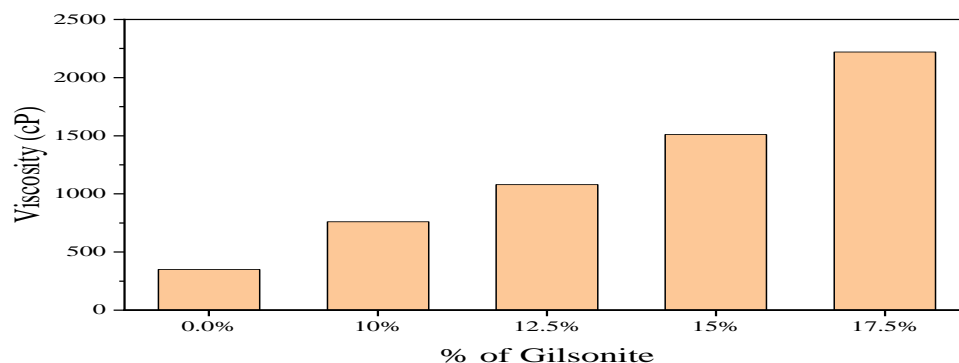


Fig.3.3 Viscosity of Conventional Bitumen and Gilsonite Modified Bitumen

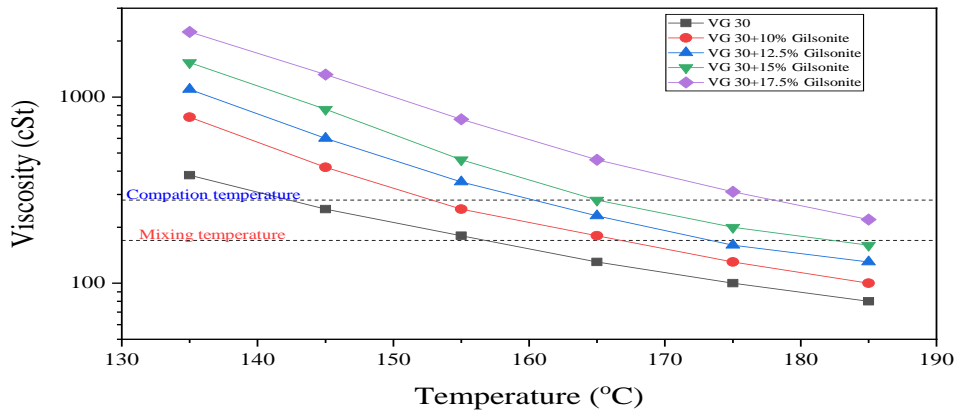


Fig.3.4 Mixing and Compaction Temperatures of Conventional Bitumen and Gilsonite Modified Bitumen

3.3 SARA Fractions Analysis Results

SARA fractions analysis was conducted on both the conventional bitumen and modified bitumen. The analysis says that the asphaltenes percentage increases as the percentage of gilsonite increases. The asphaltenes percentages for the conventional bitumen and gilsonite modified bitumen before and after short term ageing are shown in **Fig 3.5**. Asphaltenes percentage for conventional bitumen and 15% of gilsonite modified bitumen before ageing was 16% and 31% and was increased to 20% and 34% after short term ageing respectively.

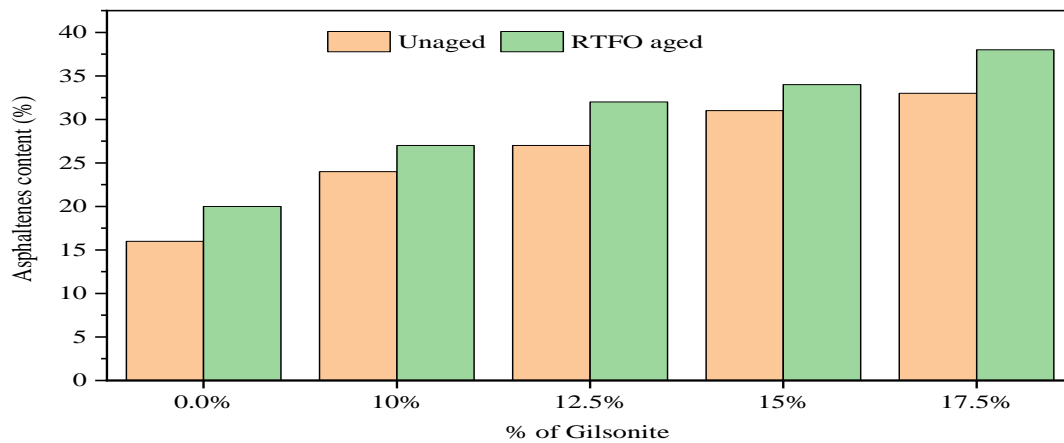


Fig. 3.5 Asphaltenes Content (%) for Aged and Unaged Bitumen

CONCLUSIONS

The current study is carried out to develop hard grade bitumen by adding gilsonite to conventional bitumen VG 30. The developed hard grade bitumen will be used in design of HMA according to French EME method. The conclusions drawn from the study are

- Optimum percentage to produce hard grade bitumen was selected as 15% of Gilsonite (by weight of conventional bitumen).
- 2.The developed hard grade bitumen is satisfying the required specifications as per French method (EME) and can be used to produce HMA.
- 3.As the penetration value of hard grade bitumen is decreased by 57% of conventional bitumen, its resistance to penetration is more than conventional bitumen.
- 4.The temperature susceptibility of hard grade GMB bitumen has been reduced due to increase in softening point by 11°C when compared with conventional bitumen.
- 5.The mixing and compaction temperatures of hard grade bitumen are increased by 25°C when compared to conventional bitumen.
- 6.Asphaltene content increased from 16% to 20% and 24% to 27% for conventional and modified respectively after subjecting to short term ageing.

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