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DESIGN OF BITUMINOUS MIXES FOR HEAVILY TRAFFICKED ROADS – A BOON TO INDIAN ROADS

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Abstract-A large number of road construction projects are currently under design and construction stage in India. If these projects are constructed with high modulus bituminous mixes then there will be a huge amount of savings in materials, reduced maintenance cost and increased service life of the pavement. High modulus bituminous mixes can be produced by using hard grade bitumen. The present experimental study aims at production of hard grade bitumen with PPA as modifier for the preparation of high modulus bituminous mixes. Bituminous mixes were prepared with Dense Bituminous Macadam (D.B.M) gradation for both conventional and laboratory produced hard grade bitumen. The tests conducted on prepared mixes were Marshall stability, Indirect tensile strength (ITS) and Resilient modulus (Mr). From the test results the optimum binder content was found as 5.27 % and 5.46 % for virgin and hard grade bituminous mixes. The marshall stability and ITS of mixes prepared with hard grade bitumen was found as 1.14 and 1.32 times higher than the virgin bituminous mixes. Resilient modulus at 35 ^{o}C found as 3310 MPa for mix prepared with hard grade bitumen and 1746 MPa for the virgin mix. Further, a pavement section was designed for 300 msa as per IRC: 37-2018 guidelines by using IIT Pave. After conducting several trials in IIT Pave the thickness of the base course is decreased by 40 mm by considering the bituminous mix prepared with hard grade bitumen.

Keywords- Hard grade bitumen, High modulus mix, Marshall stability and Resilient modulus.

1. INTRODUCTION

At present in India, a massive amount of road construction projects are undergoing under various schemes. Most of the pavements constructed under them are flexible in nature and their performance is most important for the effective service life of the pavement. If these pavements are constructed with high modulus bituminous mix in the base course then there will be an increase in performance of pavement and thus saves material and maintenance cost (1). These savings in material and maintenance can be used for other road projects. Several research works (2 - 4), has reported that the construction of flexible pavement with high modulus bituminous mixes in the base course will effectively reduce the failures in pavement and also increases the service life of the pavement. These high modulus bituminous mixes can be produced by using hard grade bitumen which can resist rutting and fatigue in the pavement (5, 6). In the year 1990 France has developed Enrobe a Module Eleve (EME) technology for heavily trafficked roads. Generally, Enrobe a Module Eleve is hot mix asphalt (HMA) prepared with a bitumen of 10/20 or 15/25 penetration (7). Later, South Africa and Australia have developed their known hard grade bitumens for the development of high modulus mixes for high volume roads (8). From their study, it has found that the mixes produced with such hard bitumen increased the modulus of mixes and resistance to rutting and fatigue (9). However, such a high modulus layer will also strengthen the pavement and protect the underneath layers by heavy volumes (10).

Polyphosphoric Acid (PPA) is one of the commonly used stiffener for the production of hard grade bitumen. PPA was first added to the bitumen in the year 1973. Studies conducted from past researchers (11, 12) revealed that addition of PPA as modifier has shown a hardening effect on bitumen. Bitumen modified with PPA has shown decreased penetration and increased softening point. Also, (13) has revealed that the PPA modified bitumen has increased the high-performance grade (PG) without much decreasing the low PG grade.

The aim of the present study is to develop a high modulus bituminous mixes for heavily trafficked roads. In this study, hard grade bitumen was developed in the laboratory with PPA as a modifier. The properties of bituminous mixes studied were Marshall parameters, ITS and Mr. Finally, a pavement section was designed with high modulus bituminous mix as a base course in IIT Pave.

2. MATERIALS AND METHODS

2.1 Bitumen

Bitumen of VG 30 grade provided by TikiTar industries Mumbai was used in the present investigation as virgin bitumen. Polyphosphoric acid (PPA) of grade 115 % was procured from Sisco research laboratories Mumbai was used as a modifier to the bitumen. The hard grade bitumen was developed in the laboratory by heating virgin

bitumen to 160 °C. PPA was also heated at 135 °C and added to virgin bitumen, later the prepared mixture was blended for 40 minutes at 1200 R.P.M.

2.2 Aggregates

For the present experimental work aggregates were procured from nearby quarry and the physical properties were shown in below Table 2.1. Bituminous mixes were prepared with D.B.M - 2 gradation and midpoint method was adopted as per MORTH 5th specifications. The gradation of D.B.M - 2 was shown in below Fig. 2.1 with an upper limit, lower limit and the considered mid limit.

Table-2.1 Properties of Aggregates

Property	Result	MORTH Specifications (Maximum)	Test method
Aggregate Impact value	16 %	27 %	IS 2386 Part 4
Abrasion value (Los Angeles)	21 %	35 %	IS 2386 Part 4
Combined index (F & E)	19%	30 %	IS 2386 Part 1
Specific gravity	2.63	-	IS 2386 Part 3

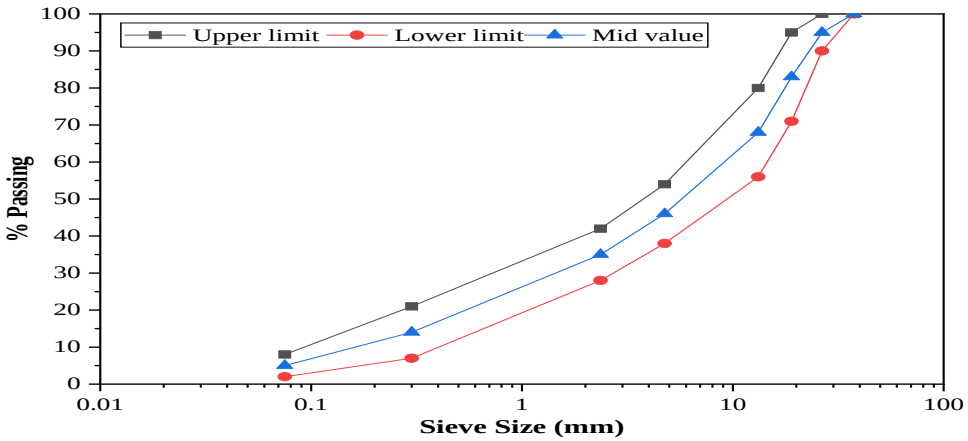

Fig. 2.1 D.B.M-2 Gradation as Per MORTH 5th Specifications

2.3 Mixing and Compaction Temperature of Bitumen

Brookfield rotational viscometer (DV-E model) was used in the present study for determining the temperature versus viscosity relationship of virgin and laboratory developed hard grade bitumen. The viscosity of two bitumens was determined from 125 °C to 195 °C with an increment of 10 °C as shown in below Fig. 2.2. The mixing and compaction temperatures corresponding to 0.17 and 0.28 Pa.s for two bitumens were tabulated in below Table 2.2.

Table-2.2 Mixing and Compaction Temperatures of Two Bitumens

Description	Virgin	Hard grade bitumen
Mixing temperature °C (0.17 Pa.s)	163	186
Compaction temperature °C (0.28 Pa.s)	145	175

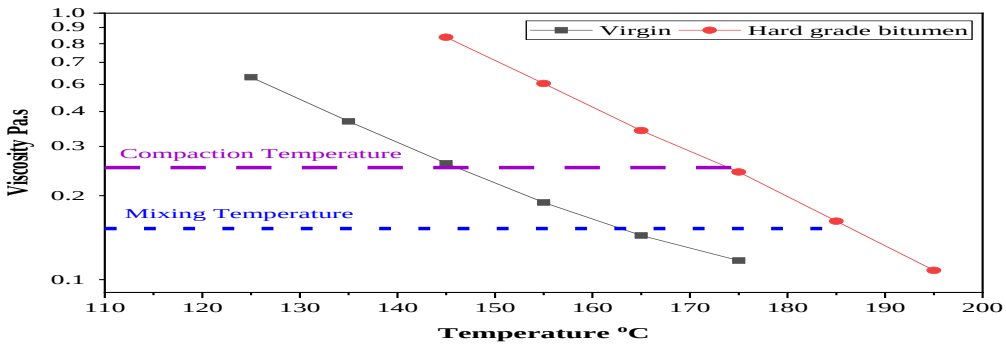

Fig. 2.2 Temperature versus Viscosity

2.4 Mix Design

Samples were cast with Marshall Mix design method with D.B.M – 2 gradation. Initially, aggregates were heated at 175 ^{o}C for 2 hours and bitumen was added and mixed at the pre-determined mixing temperature. Later the sample was kept in oven up to which it attains the desired compaction temperature. On each face of the sample, 75 blows were applied in accordance with ASTM D6927. Bitumen content corresponding to 4 % air voids as per MS – 2 guidelines was considered as optimum binder content in this study. Further the stability, flow and volumetric parameters were checked to satisfy with the established requirements.

2.5 Indirect Tensile Strength Test (ITS)

Indirect tensile strength is used to determine the resistance of mixes against cracking. The test is conducted in this study as per AASHTO T 283. ITS of bituminous mix calculated by using below formula.

$$ITS = \frac{2P}{\pi dt}$$

Where, P = Failure load in Newton
d = Diameter of sample in mm
t = Thickness of sample in mm

2.6 Resilient Modulus of Mixes (Mr)

Resilient modulus evaluates the mechanistic property of bituminous mixes. The test was conducted at 35 ^{o}C as per ASTM D7369. 10 % of the failure load corresponding to ITS was applied by the computer controlled program. The vertical and horizontal deformations for the specimens were captured through the computerized data acquisition unit.

3. RESULTS AND DISCUSSION

3.1 Physical properties of conventional and developed hard grade bitumen

Virgin (VG 30) bitumen was blended with PPA for several trials for the production of hard grade bitumen. Finally, the addition of 4.5 % PPA has found to be optimum dosage for obtaining hard grade bitumen. The physical properties of virgin and laboratory produced hard grade bitumen with the corresponding requirement of hard grade bitumen (10) are given in below Table 3.1.

Table-3.1 Properties of Conventional and Developed Hard Grade Bitumen

Property	Virgin	Hard grade bitumen	Required value for hard grade bitumen
Penetration (1/10th) mm	51	24	15 – 25
Softening ^{o}C	52	70	55 - 71
Viscosity at 135 ^{o}C cSt	380	1160	≥ 550

3.2 Marshall Properties

The marshall stability, flow value, bulk specific gravity and volumetric properties of two bitumens at 4% air voids were shown in below Table 3.2. From the results, it has revealed that the marshall parameters were satisfied with the established requirements as specified in MORTH. The stability of mix produced with hard grade bitumen has found higher than virgin mix. However, flow value is found lower for hard grade bituminous mix. This may be due to higher stiffness offered by the mix.

Table-3.2 Marshall Parameters of Mixes

Property	Virgin mix	Hard grade mix	MORTH Specifications
Bitumen content (%)	5.27	5.46	Min 4.5 %
Stability (kN)	14.09	16.14	Min 9 kN
Flow (0.25 mm)	3.75	3.5	2 – 4 mm
VMA (%)	15.60	15.48	Min 12 %
VFB (%)	73.10	72.36	65 – 75%
Bulk density (g/cc)	2.325	2.328	-

3.3 Indirect Tensile Strength

With the obtained optimum bitumen content three samples were cast for each individual mix and tested for indirect tensile strength. The average ITS value of three samples for virgin and hard grade bituminous mixes was found as 1.1 and 1.45 MPa. It has found that the ITS of mix prepared with hard grade bitumen is 1.32 times higher than virgin mix.

3.4 Resilient Modulus of mixes

The resilient modulus of mixes was determined by applying repeated load in haversine form at 35 ^{o}C. The test was conducted up to 500 cycles and the 5 cycles after 100 cycles were considered for calculating the resilient modulus of bituminous mix. The resilient modulus results were shown in below Table 3.3. The resilient modulus of hard grade bituminous mix has shown 1.98 times higher than virgin mix. This can subsequently increases resistance to rutting and fatigue in base course and reduces the thickness of layer.

Table-3.3 Resilient Modulus Test Results

Type of bitumen used in bituminous mix	Test temperature (^{o}C)	Load (N)	Horizontal deformation (um)	Resilient modulus in (MPa)
Virgin	35	1100	6.15	1746
Hard grade	35	1450	4.27	3310

4. DESIGN OF PAVEMENT SECTION FOR HEAVILY TRAFFICKED ROAD AS PER IRC: 37-2018

As per IRC: 37-2018 guidelines a pavement section is designed for traffic of 300 msa. The allowable vertical compressive strain at top of sub – grade and the allowable horizontal tensile strain in bottom of bituminous layer was computed by below equations 1 and 2 as per IRC: 37-2018 guidelines. In this study, for attaining strains less than the allowable limits a trial section was considered with CBR value of sub-grade as 8 % and thickness of granular layer as 450 mm. For bituminous layers the surface course (BC) thickness is kept constant as 50 mm and the base course (D.B.M) thickness is computed by conducting several trials using IIT Pave. Below Fig. 4.1a and 4.1b shows the computed pavement composition when virgin and hard grade bitumen used in D.B.M mixes respectivley. From the Fig. 4.1b the use of hard grade bitumen in base course has reduced the D.B.M thickness by 40 mm. The reduction in 40 mm in bituminous layer will saves materials like aggregates and especially the reduced usage of large amount of bitumen.

$$N_R = 1.4100 * 10^{-08} * [1/\varepsilon_v]^{4.5337} \quad \text{(for 90 \% reliability)} \quad - 1$$

$$N_f = 0.5161 * C * 10^{-04} * [1/\varepsilon_t]^{3.89} * [1/M_{Rm}]^{0.854} \quad \text{(for 90 \% reliability)} \quad - 2$$

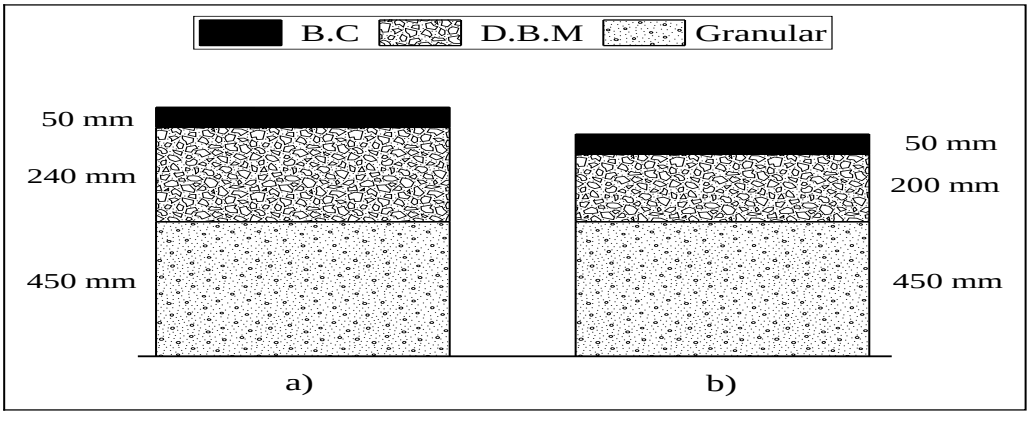

Fig. 4.1 Pavement Composition with Virgin and Hard Grade Bitumen in D.B.M Mix

CONCLUSION

- Physical properties of laboratory produced hard grade bitumen have found to resist more towards high temperature than virgin bitumen.
- Stiffer bitumen produced with PPA can resist more against plastic deformation than the virgin bitumen.

- Marshall stability and Indirect tensile strength of bituminous mix prepared with hard grade bitumen has found higher than conventional mix.
- Resilient modulus of hard grade bituminous mix is approximately twice the virgin mix.
- Use of hard grade bituminous mix in base course has reduced pavement thickness by 40 mm.

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