

## **EFFECT OF LIQUID POLYMER ON PERFORMANCE OF POLYMER MODIFIED BITUMEN AND ITS MIXES**

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### **ABSTRACT**

An efficient road transport system provides a good level of service for its users. Roadways are considered to be the most common and important way for inland transport. Asphalt road infrastructure development is one of the major sectors contributing to the National economy. The road development programmes envisaged for the country involving large amount of money, manpower, and materials will concern not only in the construction of new roads, but also the improvements of existing roads and their durability for design life. Modification of asphalt generally involves use of modifiers those appears in solid forms. The limitation of using such materials lies in the high softening and melting temperatures, blending of polymers/rubbers/latex with asphalt at high temperature for long duration, phase separation of polymer from Asphalt apart from availability of materials indigenously. This result in high cost of PMBs. Liquid polymers are easy to blend with asphalt at relatively low temperature and for a short blending time. Liquid polymers have also been used for soil stabilization. This paper depicts the use of a new modifier-in liquid state for development of cost effective and high performance modified binder and its mixes. The goal of improving bitumen properties is achieved using 0.5 percent of a co- polymer of Vinyl and Acrylic Acetate functional groups in liquid polymer-1(LP1). Advantages of liquid polymer with bitumen binder are ease of mixing with bitumen at relatively low temperature. Improved compatibility of polymer with bitumen was obtained as there is no phase separation. Polymer modified asphalt composition was characterized as per IRC: SP: 53-2010 to assess the effect of modification on the properties of VG-30. LP-1 modified binder is used for preparation of asphalt mixes for BC grade-1 as per MoRTH 5th revision 2013. Job mix was prepared using VG-30 as per Marshall method and optimum binder content was obtained as 5.2(w/w mix). For comparative study Marshall Samples were also prepared with modified binder at the same optimum binder content (i.e. 5.2%). To study the behavior of conventional and modified bituminous mixes various engineering and properties e.g. Retained Stability, Tensile Strength, Tensile Strength Ratio (TSR), Marshall Stability and air voids are determined.

The study indicated that the binder properties were improved marginally & accordingly Marshall Stability, Retained Stability, Indirect Tensile Strength and Tensile Strength Ratio of bituminous mixes were also found improved. Bituminous concrete (BC) mixes developed with liquid polymer modified binders satisfied the requirement of IRC SP-53, 2010 at a lower binder content than the specified one. The performance of modified mixes improved further with admixture of liquid polymer and fly ash to satisfy the requirements of high performance parameters such as rutting, thermal cracking and fatigue.

### **KEY WORDS**

Asphalt Road, Liquid Polymer, Blending, PMBs.

## 1. INTRODUCTION

Polymer modification of bitumen is the incorporation of polymers in bitumen by mechanical mixing or chemical reaction. The various polymers investigated included plastomers (e.g. polyethylene (PE), polypropylene (PP), ethylene-vinyl acetate (EVA), ethylene-butyl acrylate (EBA)) and thermoplastic elastomers (e.g. styrene-butadiene-styrene (SBS), styrene-isoprene-styrene (SIS), and styrene/ethylene/butylene-styrene (SEBS)), although none of these were initially designed for bitumen modification. These polymers were reported to lead to some improved properties of bitumen, such as higher stiffness at high temperatures, higher cracking resistance at low temperatures, better moisture resistance or longer fatigue life (1-7). PMB usually shows better overall performance with respect to mechanical properties, and cost-effectiveness. However some of the polymers when added in their solid state into hot bitumen melts and mix in hot stage but phase separate at ambient temperature during storage and application of modified binders. Additives are needed to achieve adequate storage stability. Liquid polymers are easily mixed with bitumen at its molten stage and show negligent phase separation thereafter.

## 2. MATERIALS AND METHODOLOGY

### 2.1. Materials

#### 2.1.1. Aggregates

Met the requirements of MoRTH-2013.

#### 2.1.2. Binders

Bitumen VG-30 satisfied the requirement of IS-73, 2013. Liquid polymer was procured from Innovative Marketing Solutions (IMS) and already tried used for soil stabilization in CRRI.

#### 2.1.3. Preparation of Liquid Polymer Modified Binder (LPMB)

0.5% and 1.0 percent (w/w of bitumen) liquid polymer was added to hot VG-30 bitumen & the mixture was stirred at 115+/-5°C for 30 to 40 minutes. Liquid polymer modified binder (LPMB) satisfied the requirement of PMB as per IRC-SP- 53, 2010 except elastic recovery property. However, LPMB satisfied the requirement of rheological parameter (an alternate to Elastic recovery test) i.e. minimum temperature to achieve 1 kPa complex modulus at 10 radian /sec.  $G^*/\sin\delta$  for LPMB is found to be 2 °C higher than VG-30. Phase separation is also found to be within limits as defined in the code of practice. A comparative data for VG-30 & LPMB is shown in Table-1.

**TABLE 1 Comparative properties of Base binder and Modified binder**

Property test	Test value obtained	
	VG-30	PMB Containing 0.5% Liquid Polymer
Penetration at 25°C, 0.1 mm, 100g, 5 s.	64	59
Softening point, (R&B), °C, Min	48	53
Elastic Recovery of half thread in ductilometer at 15°C, percent, min	NA	30
Complex Modulus ( $G/\sin\delta$ ) as Min 1.0 kPa at 10 rad/s, at a temperature, °C	76	78
Separation difference between in softening point(R&B), °C, Max	NA	1
Viscosity at 150°C, Poise	3.20	3.75

#### 2.1.4. Mix Design by Marshall Method

The design requirement for Bituminous Concrete (BC) mix as per the MoRT&H specifications (5th Revision, 2013) and for polymer modified mix as per IRC -SP- 53, 2010 is given in Table 2.

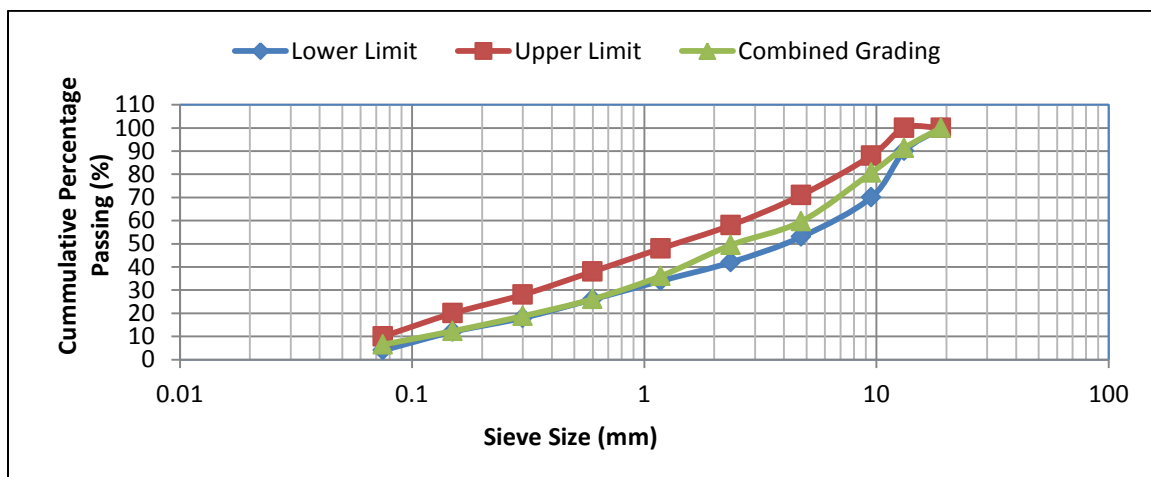
**TABLE 2 Design Requirements for BC Mixes Grade -1**  
For conventional mixes as per MoRT&H, 2013, Specification

Property	Specified Value
Marshall Stability values,(kN) at 60°C	9.0 min
Marshall flow values, mm	2-4
Voids in total mix, $V_V$ %	3-5
Voids in mineral aggregates filled with bitumen,VFB,%	65-75
Tensile Strength Ratio,%	80 min
Optimum Binder Content ,(w/w mix)	5.2 min

For Polymer modified mixes as per IRC -SP- 53, 2010

Property	Specified Value
Marshall Stability values,(kN) at 60°C	12.0 min
Marshall flow values, mm	2.5 - 4
Voids in total mix, $V_V$ %	3-5
Retained Stability.%	90 min
Tensile Strength Ratio,%	NA
Optimum Binder Content ,(w/w mix)	5.4 min

The aggregate gradation and proportion of aggregates in a dry aggregate blend are given figure -1



**FIGURE 1 Gradation curves for combined grading and specified limits**

Proportions of aggregates are as follows:

A (20 mm)	B (10 mm)	C (6 mm)	D (Stone Dust)	E (lime)
12	22	24	40	2

#### 2.1.5. Determination of Optimum Binder Content (OBC) for VG-30

To determine the optimum binder content (OBC), Marshall Samples were prepared at varying percentage of VG-30 bitumen. Bulk density, Marshall Stability, Flow, and other volumetric properties were then determined. Optimum Binder Content (OBC) was found to be 5.2 percent by weight of mix.

#### 2.1.6. Properties of Conventional and Modified Mixes at Optimum binder content

Marshall Stability & Retained Marshall Stability of two different mixes were evaluated and test results are given in Table 3.

**TABLE 3 Test Results of Marshall stability and Retained Marshall Stability for BC Mixes**

Bituminous mix	Marshall stability of controlled sample at 60 °C (kN)	Retained Marshall stability (%)
A) Mix with VG-30 & Lime	10	87
B) Mix with LPMB & lime	14	91

#### 2.1.7. Tensile Strength Ratio (TSR)

The degree of susceptibility to moisture damage is determined by preparing a set of laboratory-compacted specimens conforming to the job mix formula. The specimens are compacted to a void content corresponding to void levels expected in the field, usually in the 6 to 8% range. The samples were compacted using gyratory compactor at target air voids of 7%. . TSR was then determined as per AASHTO T-283. Test results are shown in Table-4.

**TABLE 4 Test results of tensile strength ratio (TSR) for BC Mixes at OBC**

Bituminous Mix	Average Tensile strength of unconditioned Samples (kg/cm <sup>2</sup> )	Tensile Strength Ratio (TSR)%
A) Mix with VG-30 & Lime	5.61	86.0
B) Mix with LPMB & lime	7.52	91.2

#### 2.1.8. Resilient modulus properties of conventional & modified mixes

A material's resilient modulus is actually an estimate of its modulus of elasticity.. The value of resilient modulus is used to evaluate the relative quality of material, designing the pavement as well as to generate input for pavement evaluation and analysis. The resilient modulus of bituminous mixes with VG-30 & lime and bituminous mixes with liquid polymer & lime was studied at different temperatures .The test was done on Universal Testing Machine (UTM-16) according to ASTM D 4123, "Standard Test Method for Indirect Tension Test for Resilient Modulus of Bituminous Mixture". The Test was conducted by applying the compressive load with a haversine waveform at 25°C, 35°C. The test results are shown in Table5.

**TABLE 5 Resilient Modulus at Optimum Binder Content for BC Mix**

Bituminous Mix	Resilient Modulus(MR.) at 25°C	Specified indicative values as per IRC 37-2012	Resilient Modulus(MR.) at 35°C	Specified indicative values as per IRC 37-2012
A ) Mix with VG-30 &Lime	3689	3000-4500	1963	1700-2500
B) Mix with LPMB & lime	4213	3000-4500	2356	1700-2500

### 2.1.9. Effect of fly ash on BC mixes properties

The properties of BC mix prepared with VG-30 were further improved by replacing VG-30 with LPMB and 2 % lime with 2 % fly ash .These results are summarized in Table 6.

**TABLE 6 Properties of BC Mixes at Optimum Binder Content**

Bituminous Mix	Marshall stability at 60°C (kN)	Retained Marshall stability (%)	Average Tensile strength of unconditioned Samples (kg/cm <sup>2</sup> )	Tensile Strength Ratio (TSR)%
Mix with VG-30 &Lime	10.0	87.0	5.61	86.0
Mix with LPMB & fly ash	13.8	88.1	6.93	90.8

## 3. RESULTS AND DISCUSSIONS

The results obtained through various tests, are discussed in the following text:

The physical properties of aggregate used lies within the limit as specified in MoRT&H for Marshall Mix design ensuring its further use for preparation of bituminous mixes. VG -30 bitumen met all the required properties as described in IS 73-2013 .LPMB met most of the required properties as described in IRC SP- 53- 2010 except elastic recovery. Dynamic Shear Rheometer (DSR) test on unaged VG-30 and LPMB indicated temperature for the failure of bitumen 76 °C and 78 °C respectively under the similar test condition as specified in IRC SP-53- 2010. Marshall Stability and indirect tensile strength value of mixes improved with the usage of minor dose of liquid polymer in modified binder. The retained stability was found to be 87% for samples containing VG-30 and lime whereas the retained stability of sample prepared with Liquid polymer was found to be 91%.The tensile strength ratio for bituminous mix prepared with VG-30 and lime as a filler was found to be 86 % and the same property for mix prepared by lime with liquid polymer modified binder was found to be higher i.e. 91%.This indicated approx 5 % improvement in TSR values. Marshall Stability, retained stability, indirect tensile strength and tensile strength ratio were found to be further improved by replacing lime with fly ash.

## 4. CONCLUSIONS

Based on the test data obtained in laboratory and analysis of data the following conclusions are drawn

- The tensile strength ratio of BC mixture containing LPMB was more than the mix without polymer. This indicates that incorporation of liquid polymer modified mix improved resistance to moisture.

- Similarly the retained stability of the BC mixture containing liquid polymer modified bitumen showed higher resistance to moisture to BC mix prepared with liquid polymer as compared to BC mix prepared with VG-30 bitumen (Without Polymer).
- Elastic recovery of LPMB did not meet the requirements of IRC SP-53, 2010. However  $G^*/\sin\delta$  for LPMB is found to be 2 degree centigrade higher than VG-30.

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