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Effect of Liquid Polymer on Performance of Polymer Modified Bitumen and its Mixes

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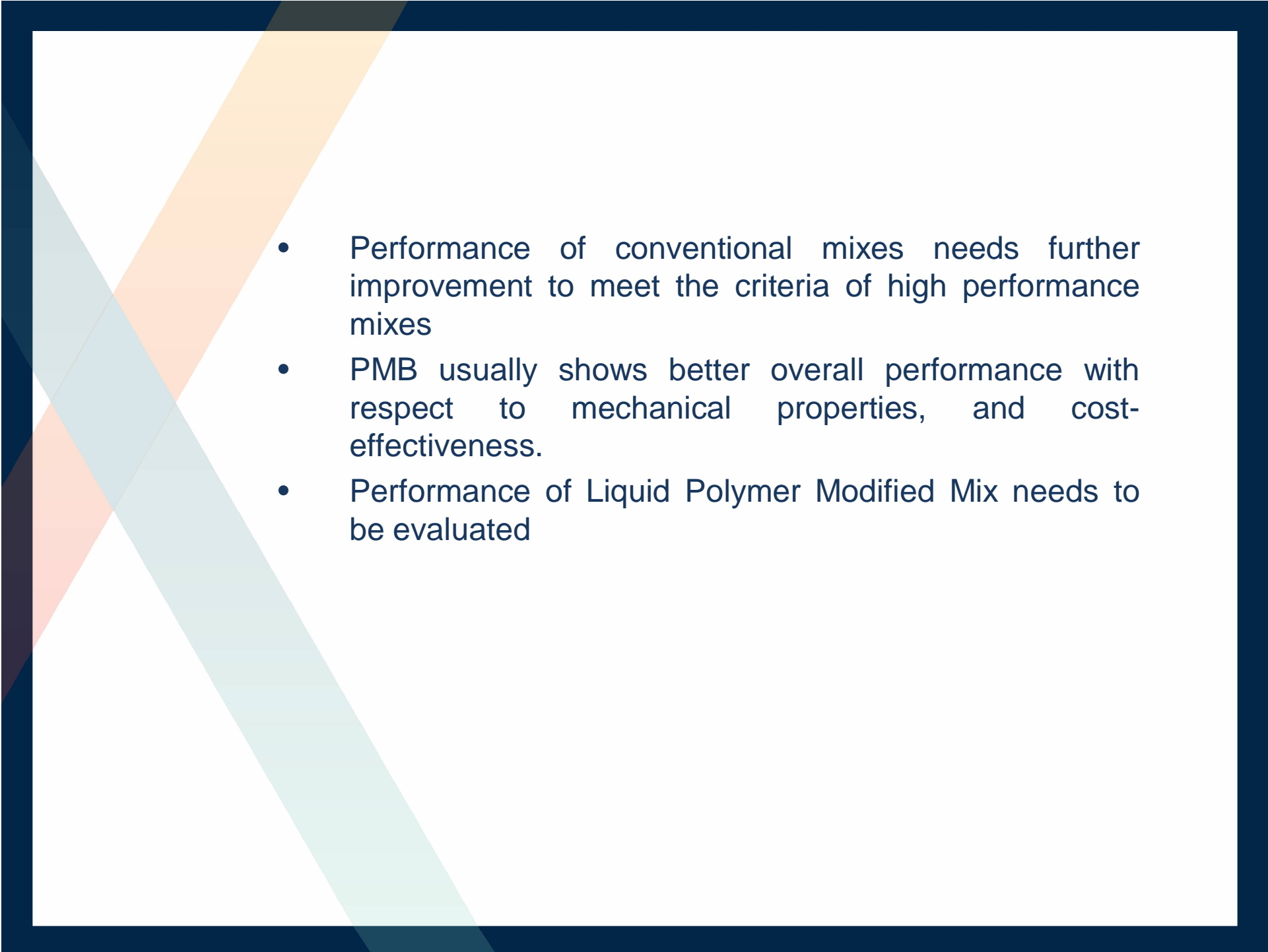
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- Introduction & Literature review
- Objective & Scope
- Materials & Methodology
- Test Results
- Conclusions

Introduction

- Bituminous Mixes are used for paving applications in India and worldwide.
- Bituminous binders including Polymer modified binders (PMBs) are used in flexible pavement surface of roads, airport, parking lots, etc.
- Polymer modification of bitumen is the incorporation of polymers in bitumen by mechanical mixing or chemical reaction.
- Different types of modifiers are responsible for different pavement performance.
- The various polymers (solid state) included plastomers (e.g. PE, PP, EVA, EBA) and elastomers (e.g. SBS, SIS, and SEBS), although none of these were initially designed for bitumen modification

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- Most of the modifiers (polymers, rubbers) used are solid in nature. Blending temperature range is 150 to 180°C and depends on their melting temperatures
 - Mixing of Modifiers (PE, PP, SBS, Crumb Rubber) with Bitumen require
 - High shear mixer
 - High blending temperature and long mixing hours to produce quality PMB
 - Additives (compatibilisers) to eliminate Phase separation problem
 - ✓ Liquid Polymers are easy to mix with bitumen at 110 to 120 °C
 - ✓ Doesn't show any phase separation at ambient temperature

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- Performance of conventional mixes needs further improvement to meet the criteria of high performance mixes
 - PMB usually shows better overall performance with respect to mechanical properties, and cost-effectiveness.
 - Performance of Liquid Polymer Modified Mix needs to be evaluated

Literature Review (Liquid Polymers)

- Liquid polymers (JSR Roadex, Renolith, Furfural liquid, RBI-81 and Acrylic Vinyl Acetate,) have been used for road works mainly for **soil stabilization**
- Few of them (in emulsion form) for modification of bitumen binder and mixes.
- Furfural liquid resins have been studied for development of hot and cold bituminous mixes →
 - Cold Mixes : proved successful No emissions
 - Hot Mixes : emission of bad smell when mixed with hot melt bitumen and inferior quality of hot mixes.
 - Limited Studies

Objective

To develop improved performance bituminous mixes using admixture of liquid polymer ,lime or fly ash as a filler in VG-30 binder.

Scope

- Development of Liquid Polymer modified binder(LPMB) by blending the liquid polymer with VG-30
- Evaluation of LPMB as per IRC: SP:53-2010.
- To study comparative performance of conventional and modified mixes .
 - Marshall Stability
 - Indirect Tensile Strength(ITS)
 - MoistureSensitivity
(RetainedStability and TSR)
 - Resilient Modulus
- To study the feasibility of replacing lime with fly ash in modified mix of LPMB-fly ash-aggregates

Materials and Methodology

- Aggregates: Met the requirements of MoRTH ,2013
- Binder: VG 30 Met the requirements of IS:73 - 2013
- Liquid polymer was procured from Innovative Marketing Solutions (IMS).
- **Preparation of Liquid Polymer Modified Binder (LPMB)** 0.5% percent (w/w of bitumen) liquid polymer was added to hot VG-30 bitumen & the mixture was stirred at $115 \pm 5^{\circ}\text{C}$ for 30 to 40 minutes
- Product LPMB was characterized as per IRC: SP:53 -2010

Materials and Methodology(contd...)

- Preparation of Job mix for conventional BC mixes grade-1
- Comparative Performance evaluation of conventional and Modified BC mixes containing 2% lime
 - Marshall Stability
 - Indirect Tensile Strength(ITS)
 - Moisture Sensitivity
(Retained Stability and TSR)
 - Resilient Modulus
- Effect of fly ash on BC mix properties
 - Comparative Performance evaluation of conventional and Modified BC mixes containing 2% fly ash

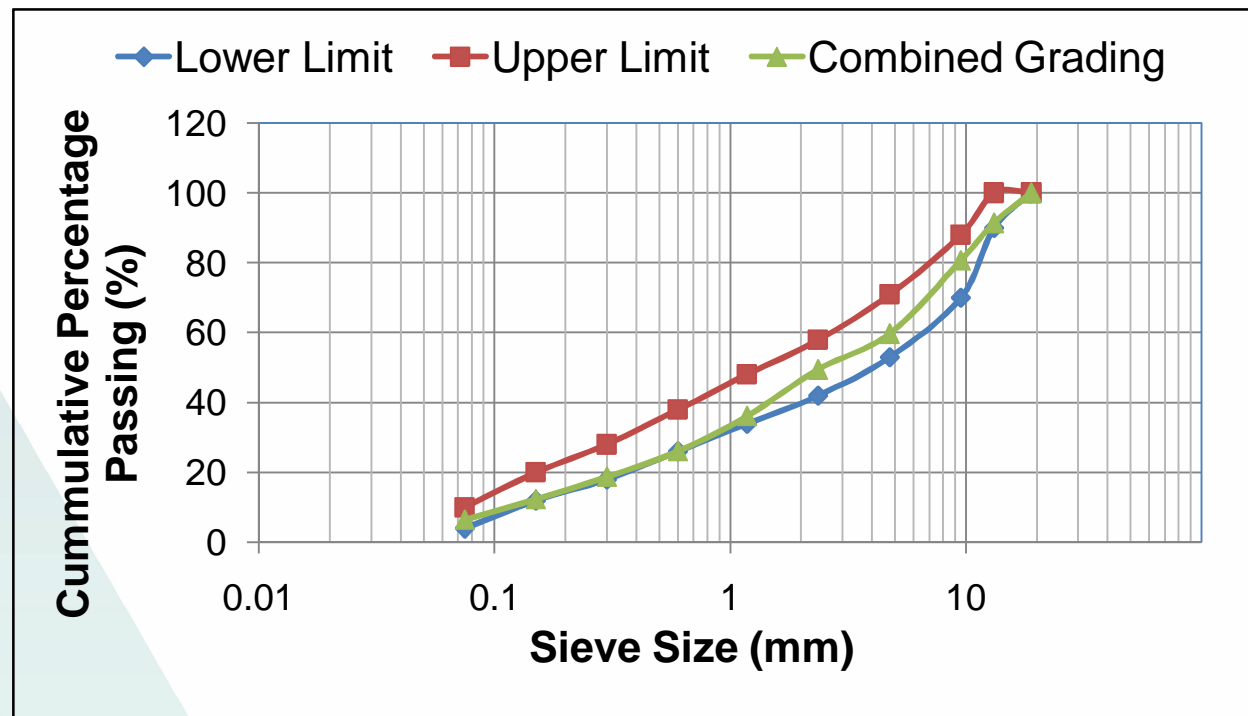
Test Results

Table 1: Comparative properties of base binder and modified binder

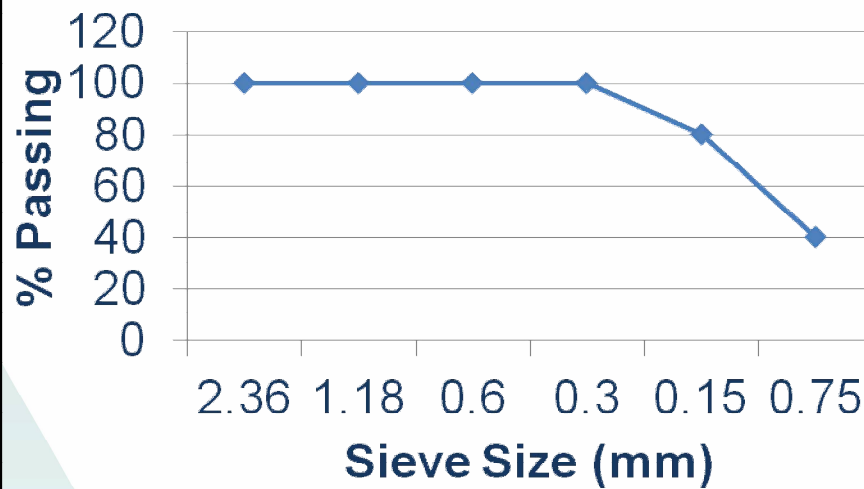
Property test	Test value obtained	
	VG-30	LPMB (Containing 0.5% Liquid Polymer)
Penetration at 25°C, 0.1 mm, 100g, 5 s.	64	59
Softening point, (R&B), °C, Min	48	53
Elastic Recovery of half thread in ductilometer at 15°C, percent, min	NA	30
Complex Modulus ($G^*/\sin\delta$) as Min 1.0 kPa at 10 rad/s.	76	78

Mix Design by Marshall Method:

Gradation curves for combined grading and specified limits.



Grading Curve of Fly Ash



Ratio of Aggregates:

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

- **Optimum Binder Content (OBC) found to be 5.2 percent by weight of mix.**
- The design requirements for conventional Bituminous Concrete (BC) mix as per the MoRT&H specifications (5th Revision, 2013) and for polymer modified mix as per IRC :SP:53, 2010 are given in Table 2 and 3.

**Table 2: Design Requirements for conventional BC Mixes
Grade -1 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

Table 3 Design Requirements 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 – 4.0
Voids in total mix, V_v %	3-5
Retained Stability.%	90 min
Tensile Strength Ratio,%	NA
Optimum Binder Content ,%,(w/w mix),BC Grade 1	5.4 min

Mechanical Properties of Conventional and Modified Mixes at OBC

- A) Mix with VG-30 & lime
- B) Mix with LPMB & lime
- C) Mix with LPMB & fly ash

TABLE 4 Marshall stability and Retained Stability for BC Mixes

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

Table 5: Test results of tensile strength ratio (TSR) for BC Mixes at OBC

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

Table 6: 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 PMB & lime	4213	3000-4500	2356	1700-2500

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.

Table 7: Properties of BC Mixes at Optimum Binder Content

Bituminous Mix	Marshall stability at 60°C (kN)	Retained Marshall stability (%)	Average Tensile strength of Samples (kg/cm ²)	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

Conclusions

- Mixing of Liquid Polymer with Bitumen at low temperature
- Phase separation - within limits as defined in the code of practice.
- LPMB(VG-30 containing 0.5% liquid polymer) satisfied the requirement of IRC:SP:53-2010 except elastic recovery.
- LPMB satisfied the requirement of rheological parameter (an alternate to Elastic recovery test) i.e. temperature to achieve minimum 1 kPa complex modulus at 10 radian /sec.
- Temperature to achieve 1 kPa complex modulus ($G^*/\sin\delta$) is found to be 2 degree centigrade higher for LPMB than VG-30.

Conclusions

- Marshall Stability and indirect tensile strength value of mixes improved with the usage of minor dose(0.5) 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%.

Conclusions

- 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.

The overall effect of using liquid polymer for bitumen modification and its mixes is positive and significant for further research

Acknowledgement

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THANKS

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Tensile Strength Ratio (TSR)

- 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-5.

Resilient Modulus Properties Of Conventional and Modified Mixes

- 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 Table 6.