Liquid Polymer and its Effect on Development of Polymer Modified Binder for Asphalt Road

Krushna Chandra Sethi
M. Tech Research Scholar, Central Road Research Institute, New Delhi, India.

E-Mail: *krushnacivil25@gmail.com*

Abstract

The limitation lies in the availability of materials as well as the blending of polymers/rubbers/latex with asphalt at high temperature for a long duration. This results in a high cost of PMBs. Another limitation is the phase separation of the polymer from Asphalt.PMB developed with indigenously available liquid copolymer – **Vinyl Acrylic Copolymer** is easy to blend with asphalt at relatively low temperature and for a short blending time. The road development programs envisaged for the country involving a 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. This poster depicts the use of a new modifier (liquid form) for the development of cost-effective and high performance modified binder and its use for construction of asphalt roads. Vinyl Acrylic Co-Polymer is a low-cost polymer and is inferior quality to achieve the goal of improving bitumen properties; however, a copolymer of Vinyl Acetate i.e. liquid polymer-1(LP1) should create a secondary network or new balance system within binders by molecular interactions or by reacting chemically with the bitumen. Polymer modified asphalt compositions were characterized as per IRC: SP: 53-2010 to assess the effect of modification on the properties of VG-30 that exhibit improved performance grade (PG) specifications for high-temperature properties. LP-1 is used for the preparation of mixes with selected aggregate grading as given in the IRC Code. Job mix was prepared using a modified binder containing 0.5% of LP-1 in VG-30. LP-1 with Viscosity Grade (VG-30) to study the behaviour modified bituminous mix. The role of LP-1 in the mix studied for various engineering properties e.g. ITS, Retained Stability, Marshall stability, flow value, unit weight, air voids are used to determine Optimum Binder Content(OBC) for VG30 and polymer-modified VG-30. The evaluation study indicated that the binder properties were improved several folds, Consequently, the mechanical properties bituminous mixes were also found improved w.r.to Retained Stability and Indirect Tensile Strength. The liquid polymer has been used for soil stabilization and Modification of VG-10 binder. Bituminous concrete (BC) mixes developed with liquid polymer modified binders satisfied the requirement of IRC SP-53, 2010. The performance of modified mixes needs to be improved further to satisfy the requirements of high-performance binders and mixes concerning rutting, thermal cracking, and fatigue. The liquid polymer has been used for soil stabilization and Modification of VG-10 binder. Bituminous concrete (BC) mixes developed with liquid polymer modified binders satisfied the requirement of IRC SP-53, 2010. The performance of modified mixes needs to be improved further to satisfy the requirements of high-performance binders and mixes concerning rutting, thermal cracking, and fatigue.

Advantages of liquid polymer with bitumen binder in mix design are ease of mixing with bitumen at relatively low temperature i.e. <100degree centigrade. Improved compatibility of polymer with bitumen as there is no phase separation low cost as compared to other solid polymers. 0.5% optimum polymer content is sufficient to modify Bitumen. Job mix formula indicated that the optimum binder content of liquid polymer modified

bitumen is 0.5% lesser than optimum binder content with VG grade bitumen. To develop cost-effective high-performance bituminous mixes using admixture of liquid polymer and fly ash for construction and maintenance of bituminous roads. To improve the storage stability of modified binders. To study Rheology, rutting, Thermal Cracking, Aging performance of modified binders vis-a-vis conventional base bitumen.

Keywords: Asphalt Road, Liquid Polymer, Blending, PMBs, Cost Economy

Introduction

Polymer modification of bitumen is the incorporation of polymers in bitumen by mechanical mixing or chemical reaction. During the last 40 years, more and more researchers began to concentrate on polymer modification of bitumen and a rapidly increasing number of research articles have been published since the 1970s. In these, the various investigated polymers 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. An effective polymer modification results in a thermodynamically unstable but kinetically stable system in which the polymer is partially swollen by the light components of bitumen. Some important factors, including the characteristics of the bitumen and the polymer themselves, the content of polymer and the manufacturing processes, determine the final properties of polymer modified bitumen (PMB). As polymer content increases, phase inversion may occur in some PMBs: from bitumen being the dominant phase to polymer becoming the dominant phase. However, an ideal microstructure for PMB contains two interlocked continuous phases, which determines the optimum polymer content for bitumen modification. With these two interlocked continuous phases; PMB usually shows better overall performance with respect to mechanical properties, storage stability and cost-effectiveness.

Different Grades of Bitumen

VG-10 Bitumen: VG-10 is widely used in spraying applications such as surface-dressing and paving in very cold climate in lieu of old 80/100 Penetration grade. It is also used to manufacture Bitumen Emulsion and Modified Bitumen products. The characteristics of this grade confirm to that of S 90 grade of IS-73-1992. This is the softest of all grades available in India. This is suitable for low volume roads and is still widely used in the country.

VG-20 Bitumen: VG-20 is used for paving in cold climate & high altitude regions.

VG-30 Bitumen: VG-30 is primarily used to construct extra heavy duty Bitumen pavements that need to endure substantial traffic loads. It can be used in lieu of 60/70 Penetration grade.

VG-40 Bitumen :VG-40 is used in highly stressed areas such as intersections, near toll booths and truck parking lots in lieu of old 30/40 Penetration grade. Due to its higher viscosity, stiffer Bitumen mixes can be produced to improve resistance to shoving and other problems associated with higher temperature and heavy traffic loads

Requirements of Bitumen

The desirable properties of bitumen depend on the mix type and construction. In general, Bitumen should possess following desirable properties:

- The bitumen should not be highly temperature susceptible: during the hottest weather the mix should not become too soft or unstable, and during cold weather mix should not become too brittle causing cracks.
- The viscosity of the bitumen at the time of mixing and compaction should be adequate. This can be achieved by use of cutbacks or emulsions of suitable grades or by heating the bitumen and aggregates prior to mixing. There should be adequate affinity and adhesion between the bitumen and aggregates used in the mix.
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1.3 Advantages of Viscosity Grade (VG) Bitumen

Advantages of viscosity grade bitumen are following:

Based on the fundamental Engineering Properties: VG system is based on fundamental engineering parameter i.e. actual performance on road and not on the empirical properties.

Takes care of low as well high temperature: Viscosity is measured at 60ºC and 135ºC which takes care of both low and high temperature susceptibility of the bitumen, which is not possible with penetration value at 25°C. Hence, road contractors can have better understanding of bitumen performance in the field.

Experimental Work

Aggregate constitutes the granular part in bituminous concrete mixtures which contributes up to 90-95 % of the mixture weight and contributes to most of the load bearing & strength characteristics of the mixture. Hence, the quality and physical properties of the aggregates should be controlled to ensure a good pavement. The properties that aggregates should have to be used in pavement are shown below.

1. Aggregates should have minimal plasticity. The presence of clay fines in bituminous mix can result in problems like swelling and adhesion of bitumen to the rock which may cause stripping problems. Clay lumps and friable particles should be limited to utmost 1%.
2. Durability or resistance to weathering should be measured by sulphate soundness testing.
3. The ratio of dust to asphalt cement, by mass should be a maximum of 1.2 & a minimum of 0.6.
4. It is recommended AASHTO T-209 to be used for determining the maximum specific gravity of bituminous concrete mixes.
5. Aggregates are of 2 types. i.e.

Coarse Aggregate

The aggregates retained on 4.75 mm Sieve are called as coarse aggregates. Coarse aggregate should be screened crushed rock, angular in shape, free from dust particles, clay, vegetations and organic matters. They should have following properties.

Fine Aggregate (FA)

Fine aggregate should be clean screened quarry dusts. It should be free from clay, loam, vegetation or organic matter. FA should have the following properties.

The Properties of coarse and fine aggregates for preparation of BC (Grade I) mix shall conform to Table -1 of MORTH Fifth Revision, 2013 .The test results of aggregates used in this study are given in Table-3.1

Table-2.0 Physical Requirements for Course Aggregate for Bituminous Concrete

Property	Test	Specification as Per MORTH ,2013	Value Obtained
Particle Shape	Combined Flakiness and Elongation Indices	Max 35%	25%
Durability	Soundness in Sodium Sulphate	Max 12%	9%
Water Absorption	Water absorption	Max 2%	0.35
Stripping	Coating and Stripping of Bitumen Aggregate Mix	Minimum retained coating 95%	97%
Water Sensitivity	Retained Tensile Strength	Minimum 80%	82%

Characterization of bitumen

Bitumen VG-30 is tested as per IS-73, 2013 and test properties are given in Table-3.2

Table 2.1 Properties of Bitumen (VG-30)

Property Tested	Test Result	Requirement as per IS 73:2013 for VG-30
Penetration at 25°Ç100g,5s 0.1mm	64	45(Min)
Softening point(R&B),°C	48	47(Min)
Absolute Viscosity at 60°C	2570	2400(Min)
Kinematic Viscosity,135°ÇcSt	725	350(Min)
Solubility in trichloroethylene, % by mass	99.34	99.0(Min)
Viscosity ratio at 60°ÇTest on residue from thin –film oven test/RTFOT	3.5	4.0(Max)
Ductility at 25°Çafter thin-film oven test/RTFOT	52	40(Min)
Complex Modulus (G/sin£) as Min 1.0 kPa at 10 rad/s, at a temperature, °C	76	Not Specified

Mix Design by Marshall Method

Suitably designed bituminous mix will withstand heavy traffic load under adverse climatic conditions and also fulfill the requirement of structural and pavement surface characteristics. The objective of the design of bituminous mix is to determine an economical blend through several trial mixes. The gradation of aggregate and the corresponding binder content should be such that the resultant mix should satisfy the following conditions.

- Sufficient binder to ensure a durable pavement by providing a water proofing coating on the aggregate particles and binding them together under suitable compaction.
- Sufficient stability for providing resistance to deformation under sustained or repeated loads. This resistance in the mixture is obtained from aggregate interlocking and cohesion which generally develops due to binder in the mix.
- Sufficient flexibility to withstand deflection and blending without cracking .To obtain desired flexibility, it is necessary to have proper amount and grade of bitumen.
- Sufficient voids in the total compacted mix to provide space for additional compaction under traffic loading.
- Sufficient workability for an efficient construction operation in laying the pavement mixture.
  In the present study, the design of bituminous mix was carried out using VG-30 bitumen by Marshall Method of mix design for determining the optimum binder content (OBC).

Design Requirements

The design requirement for Bituminous Concrete (BC) mix. Should be fulfilled as per the MoRT&H specifications (5th Revision, 2013) as given in Table -3.5

Table -3.1 Design Requirements for BC Mixes Grade as per MORT&H, 2013, Specification

Property	Specified Value
Marshall Stability values,(KN) at 60°C	9.0
Marshall flow values, mm	2-4
Voids in total Mix V_V%	3-5
Voids in mineral aggregates filled with bitumen VFB,%	65-75
Loss of stability on immersion in water at 60°C	60

In the present study, the mix design has been carried out with and without fly ash for the conventional BC mixes and polymer modified mixes.

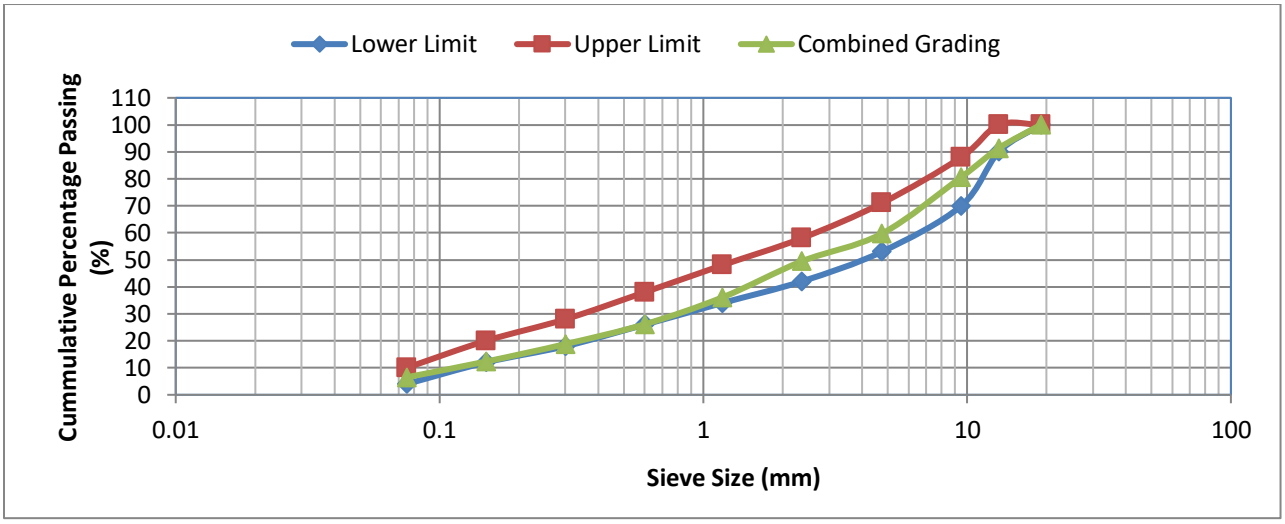
Design for Conventional BC Mix with Lime (Mix-A)

The individual gradation of selected component aggregates and their proportioning achieved by trial and error method is given in Table-3.6. The designed gradation along with the specified limits is shown in figure 3.2

Table 3.2 Aggregate Gradation and Blend Proportion for BC Layer with Lime

Sieve Size	Percentage of aggregates passing through sieve size						
	Nominal size of aggregates					Blend Proportion by wt. of aggregate A: B: C: D:E 12:22:24:40:2	Specified Limits for 50mm BC (MORTH,2013)
	A 20mm	B 10mm	C 6mm	D Stone Dust	E Lime		
19	100.00	100.00	100.00	100.00	100	100	100
13.2	30.00	99.00	100.00	100.00	100	91.38	90-100
9.5	10.23	61.00	100.00	100.00	100	80.65	70-88
4.75	0.00	4.00	70.00	100.00	100	59.68	53-71
2.36	0.00	0.00	36.00	97.00	100	49.44	42-58
1.18	0.00	0.00	10.32	79.00	100	36.08	34-48
0.6	0.00	0.00	8.92	55.00	100	26.14	26-38
0.3	0.00	0.00	0.00	42.00	99.4	18.79	18-28
0.15	0.00	0.00	0.00	26.00	96	12.32	12_20
0.75	0.00	0.00	0.00	13.00	64	6.48	4_10

Figure 3.1 Gradation Adopted and Specified Limits for BC Mix



Determination of Optimum Binder Content (OBC)

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 obtained which are given in Table 3.7. The relationship between binder content and test values obtained is shown in Figure 3.2. Optimum Binder Content (OBC) was found 5.1 percent by weight of aggregates.

Table 3.1 Volumetric and Mechanical Parameters Obtained for Conventional BC with lime

Binder content, % by weight of Aggregate	Bulk Density, gm/cc	Stability (kN)	Flow Value (mm)	Air Voids,%	Void in Mineral Aggregates VMA	Voids Filled with Bitumen, VFB, %
4.5	2.37	12.42	2.98	4.65	15.55	68.76
5.0	2.38	14.98	3.09	4.06	14.50	73.31
5.5	2.37	15.03	3.37	3.76	16.15	76.69
6.0	2.36	11.02	3.73	3.62	16.94	78.62

Results and Discussion

The results obtained through various tests, as mentioned above, are discussed and presented in this section of the report.

A. 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.
B. The VG 30 bitumen met all the required properties and satisfies limits as described in IS 73-2013 and LPMB met all the required properties and satisfies limits as described in IRC SP- 53- 2010
C. Based on the findings of the study, it is concluded that it is possible to design acceptable-quality bituminous mixes with up to 0.5% Liquid Polymer that meets the required Volumetric, mechanical properties and desired performance criteria. The bituminous mix with Polymer modified bituminous mixes equivalent to be better than the mixtures produced without Polymer modified bituminous mixes.

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