Influence of Modify Bituminous Mix with Fly Ash

Neha B. Kagra, Siddhi K Sheth, C.S.Modhiya

***Abstract*—**In India, the disposal of industrial waste streams like fly ash and waste tires from vehicles constitutes a significant environmental challenge. Fly ash, generated predominantly by coal-fired power stations, exceeds 0.3 billion tons annually and is a major solid waste byproduct. Concurrently, the rising popularity of automobiles, including four-wheelers and two-wheelers, has led to an increase in discarded tires. A substantial portion—approximately 60%—of these waste tires are disposed of through informal routes, both in urban and rural regions, resulting in pollution issues such as air contamination from open burning and aesthetic degradation. To address these concerns, effective utilization of these waste materials through technological innovation is essential. Developing modified bituminous mixtures that are resilient, durable, and environmentally friendly is a promising approach. Such mixtures should resist fatigue and permanent deformation while remaining cost-effective. To optimize these properties, various tests are conducted on different material combinations to identify the most suitable mix. This study employs the Marshal method for designing bituminous mixes with varying fly ash percentages, aiming to evaluate the resulting properties.

Keywords: Fly ash, Modified Bitumen, Marshall Stability

I. Introduction

Fly ash is the primary solid waste emitted from coal-powered plants. In India, the annual production surpasses 0.3 billion tons, positioning it as a significant industrial residual material. Properly managing and utilizing fly ash is a key economic and environmental challenge for the country's development. As India's infrastructure expands, especially in road construction, bituminous concrete pavements—often incorporating limestone mineral powder as a filler—are widely used. However, limestone powder production causes environmental pollution, and its high demand makes it costly. Research indicates that fly ash shares similar physical and chemical properties with limestone mineral powder. Replacing limestone filler with fly ash—partially or entirely—in bituminous concrete can offer economic advantages and environmental benefits. High-temperature stability remains a crucial pavement performance metric.

India's road network spans over 33 lakh kilometers, with about 90% of passenger and 70% of freight traffic moving via roads.

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Neha B. Kagra, Assistant Professor, Government Engineering College, Dahod

Siddhi K Sheth, Lecturer, Government Polytechnic, Dahod

C.S.Modhiya,Assistant Professor, Government Engineering College, Dahod

Studies conducted in India and abroad have shown that the properties of bitumen and bituminous mixtures can be enhanced through the use of specific additives or combinations of additives, commonly referred to as "bitumen modifiers." When bitumen is blended with these modifiers, the resulting product is known as modified bitumen. Depending on the type of modifier, degree of modification, and the process used, modified bitumen can significantly increase the lifespan of pavement surfaces—by as much as 100%.

Common types of modifiers include polymers, natural rubber, and crumb rubber. The use of modified bituminous materials offers substantial benefits for road construction and maintenance, such as improved durability and cost savings over the road's lifecycle. However, selecting the appropriate materials and understanding their performance remains a complex task, as reliable independent guidance is limited. This guide aims to assist in making informed decisions. Polymer Modified Bitumen (PMB) and Crumb Rubber Modified Bitumen (CRMB) are typically recommended for wearing courses, particularly under extreme climatic conditions. The Indian Roads Congress (IRC) has issued detailed specifications for modified bitumen in IRC: SP: 53-1999. It is important to note that the performance of PMB and CRMB is highly sensitive to temperature control during construction, and maintaining the correct temperature is crucial for achieving the desired results.

II. POLYMER MODIFIED BITUMEN

In certain cases, bitumen requires the addition of modifiers like polymers to meet performance standards under both low and high temperature conditions. While modifiers can influence a variety of bitumen characteristics, their primary role is often to reduce temperature sensitivity and limit oxidation-induced hardening in bitumen and asphalt mixtures. Polymers used in modification are long-chain hydrocarbon molecules that improve the performance of unmodified (neat) bitumen. Depending on the type of monomers used, a broad spectrum of properties can be achieved. For practical engineering applications, polymers are generally classified based on their behavior as either glassy (rigid) or rubbery (elastic), commonly referred to as plastomeric or elastomeric. Plastomers tend to deform under load and do not return to their original shape, while elastomers can recover their original form after deformation. However, the elastic behavior of elastomers is influenced by factors such as temperature, loading rate, and the amount of strain applied. As modern roadway demands increasingly surpass the performance capabilities of traditional bituminous materials, polymer modification has become an effective solution to enhance pavement durability and functionality.

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III. CRUMB RUBBER MODIFIED BITUMEN

Crumb Rubber Modified Bitumen (CRMB) is a specially enhanced form of bitumen that incorporates crumb rubber along with specific additives such as hydrocarbon compounds and resins. These additions significantly improve the physical properties of bitumen, making it more resistant to temperature fluctuations, harsh weather conditions, and heavy traffic loads. CRMB also contributes to lower maintenance costs and offers improved driving comfort.

Types of CRMB and Recommended Applications:

- **CRMB 60** – Best suited for regions with hot climates
- **CRMB 55** – Recommended for areas with moderate climates
- **CRMB 50** – Ideal for use in cold climate regions

IV. METHODOLOGY

In this study, aggregates, conventional bitumen, modified bitumen, and fly ash were used as primary materials. The physical properties of bitumen, modified bitumen, and aggregates were thoroughly tested. Various mixes were then prepared by combining bitumen, modified bitumen, and fly ash in different proportions using both the wet and dry mixing methods. Fly ash was added as a partial replacement by weight of the bitumen used in the tests. The feasibility and performance of these mixes, incorporating different ratios of bitumen, modified bitumen, fly ash, and aggregates, were evaluated.

Experimental Program

Bituminous mixes were designed using the Marshall Method. The mix design involved both conventional and modified bitumen with varying percentages of fly ash. The experimental procedure and methodology are described in detail below.

Recommended Value as per MORTH section 500 clause 509

Table-1 Detail of Aggregate Tests

Table-2 Detail of Bitumen Tests

Sr. No	Test	Recommendation as per IS 73- 2006
1	Penetrationat25°C,0.1 mm, 5sec	50-70
2	Softening Point,°C,min	47
3	Specific Gravity	0.99
4	Ductility,27°C,cm	75
5	Viscosity,60°C,Poise	2400
	Viscosity,135°C,cst	350

Table-3 Detail of PMB70 Tests

Sr. No	Test	RecommendationasperI RC SP 53- 2002
1	Penetrationat25°C,0.1 mm, 5sec	50-90
2	Softening Point,°C,min	55
3	Specific Gravity	0.90
4	Ductility,27°C,cm	40
5	Viscosity,150 °C, Poise	2-6

Table-4 Detail of CRMB55 Tests

Sr .No	Test	Recommended Value as per MORTH section 500 clause 509
1	Grain size analysis	Max 5% passing 0.75 mm sieve
2	Loss Anglos abrasion test	30% Max
3	Aggregate Impact value	24% Max
4	Flakiness and elongation Index(combined)	30% Max
5	Water absorption	2% Max
6	Specific Gravity	2.5-3.0
7	Stripping value	95%min

Sr. No	Test	Recommendation as per IRC SP 53- 2002
1	Penetrationat25°C,0.1 mm, 5sec	<60
2	Softening Point,°C,min	55
3	Specific Gravity	0.90
4	Ductility, 27°C,cm	-
5	Viscosity, 150 °C, Poise	-

V. RESULT AND DISCUSSION

The bituminous mix was prepared using the Marshall Method with bitumen, and various mix design parameters were determined. These included Marshall Stability, Flow Value, Bulk Density, Air Voids (Vv), Voids in Mineral Aggregate (VMA), and Voids Filled with Bitumen (VFB). The corresponding results are presented in the table.

Table5. Results BituminousMix Design using Bitumen

Sr no	Bitumen(%)	Marshal stability (Kg)	Flow value (mm)	BulkDensity(g m/cc)	Airvoids %Vv	VMA	VFB %
1	5.00	994.67	4.07	2.35	3.97	15.07	73.65
2	5.50	1176.33	3.40	2.38	2.36	14.63	83.89
3	6.00	933.00	3.20	2.36	2.34	15.58	84.96

Table6.Results Bituminous Mix Design using CRMB

Sr no	Bitumen(%)	Marshal stability (Kg)	Flow value (mm)	BulkDensity(g m/cc)	Airvoids %Vv	VMA	VFB %
1	5.00	1180.67	3.90	2.48	4.90	19.80	85.60
2	5.50	1220.02	3.75	2.46	3.45	20.30	89.76
3	6.00	1118.30	3.50	2.45	2.25	20.86	90.24

Table7.Results Bituminous Mix Design using CRMB

Sr no	Bitumen(%)	Marshal stability (Kg)	Flow value (mm)	BulkDensity(g m/cc)	Airvoids %Vv	VMA	VFB %
1	5.00	1180.67	3.90	2.48	4.90	19.80	85.60
2	5.50	1220.02	3.75	2.46	3.45	20.30	89.76
3	6.00	1118.30	3.50	2.45	2.25	20.86	90.24

Table8.Results Bituminous Mix Design using PMB

Sr no	Bitumen(%)	Marshal stability (Kg)	Flow value (mm)	BulkDensity(g m/cc)	Airvoids %Vv	VMA	VFB %
1	5.00	1356.69	3.98	2.59	5.10	20.20	88.26
2	5.50	1434.15	3.85	2.54	4.25	20.35	90.24
3	6.00	1210.19	3.64	2.53	2.30	20.70	91.15

The results indicate that a 5% bitumen content yielded a higher Marshall Stability value and greater density. All other parameters also remained within the specifications set by MORT&H. Therefore, with 5% bitumen content, varying percentages of fly ash were added to prepare the bituminous mix.

VI. CONCLUSIONS

The study on the use of fly ash shows that the Marshall Stability value—a key strength indicator for bituminous mixes—exhibited an increasing trend, with maximum values rising by approximately 25% due to the addition of fly ash. Additionally, the mix density also improved when fly ash was used, compared to the mix with 60/70 grade bitumen. This will result in a more stable and durable mix for flexible pavements. Compared to traditional construction methods, it also offers improved serviceability and better resistance to moisture. The values of other parameters—Vv, VMA, and VFB—were also found to be within the required specifications when fly ash was used. This study not only promotes the beneficial use of waste materials like fly ash and scrap tyres in road construction, but also enhances key performance indicators, leading to stronger and longer-lasting roads. Additionally, it contributes positively to the environment by reducing the amount of waste sent for incineration or land filling. The approach adds value to waste materials while promoting an eco-friendly construction technology.

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