An Experimental Study to Analyze the Effect of Warm Mix Additives on the Performance of Bituminous Mix

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Abstract — The increasing demand for sustainable pavement construction has led to the development of warm mix asphalt (WMA) technology, which enables reduced production temperatures and improved environmental performance. Current experimental study investigates the effect of warm mix additives on the performance characteristics of bituminous mixes. Two additives, Zycotherm and Rediset LQ, were used with VG-30 bitumen for Bituminous Concrete (BC) Grade II and Dense Bituminous Macadam (DBM) Grade II mixes. Laboratory tests including Marshall Stability, Tensile Strength Ratio (TSR), and aggregate coating tests were conducted to evaluate mechanical properties and moisture susceptibility. The results indicated that the optimum binder content was 5% for BC and 4.5% for DBM. The optimum additive dosages were found to be 0.1% for Zycotherm and 0.5% for Rediset LQ. The inclusion of warm mix additives significantly improved stability, durability, and moisture resistance of the mixes. The study demonstrates that WMA technology not only enhances pavement performance but also contributes to energy efficiency and environmental sustainability.

Keywords: Warm Mix Asphalt, Zycotherm, Rediset LQ, Marshall Stability, Bituminous Mix

I. INTRODUCTION

The rapid growth of transportation infrastructure has significantly increased the demand for durable and sustainable pavement materials. Conventional Hot Mix Asphalt (HMA) requires high production temperatures, typically ranging between 150°C and 180°C, resulting in high energy consumption and increased emission of greenhouse gases. In recent years, Warm Mix Asphalt (WMA) technology has emerged as a promising alternative that allows asphalt production at lower temperatures without compromising performance.

WMA technology involves the use of additives or processes that reduce the viscosity of bitumen, thereby enabling mixing and compaction at temperatures 20–40°C lower than conventional methods. This not only reduces fuel consumption but also minimizes environmental impacts such as CO_2 emissions and worker exposure to fumes.

Among the various additives available, chemical additives such as Zycotherm and Rediset LQ have gained attention due to their ability to improve coating, adhesion, and moisture resistance of bituminous mixes. These additives enhance the bond between bitumen and aggregates, thereby improving durability and resistance to stripping.

Several studies have investigated the performance of warm mix asphalt (WMA) additives in improving the engineering properties of bituminous mixes. Previous research indicates that additives such as Rediset LQ and Zycotherm significantly enhance Marshall stability, moisture resistance, and overall durability of asphalt mixtures. A few studies have reported optimum binder contents in the range of 4.5%–4.62% for VG-30 bitumen, with Rediset LQ showing effective performance at dosages between 0.4% and 0.6%, while Zycotherm demonstrated optimum results around 0.1% dosage.

The inclusion of these additives not only improves adhesion between bitumen and aggregates but also reduces mixing and compaction temperatures by 30–40°C, resulting in lower energy consumption and emissions. Furthermore, WMA mixes exhibit better resistance to moisture damage and permanent deformation compared to conventional hot mix asphalt. Overall, the warm mix additives provide both performance and environmental benefits, making them a sustainable alternative in modern pavement construction.

This study aims to evaluate the performance of bituminous mixes prepared with warm mix additives and to compare their properties with conventional mixes. The research focuses on key performance indicators such as stability, moisture resistance, and aggregate coating to assess the effectiveness of WMA technology.

II. METHODOLOGY

The below figure-1 shows the methodology flow chart for current study.

A. Materials Used

The materials used in this study include Bitumen, Aggregates and Additives. Bitumen as VG-30 grade bitumen was selected due to its suitability for heavy traffic conditions. Aggregates as Crushed aggregates conforming to standard specifications for BC Grade II and DBM Grade II were used. Additives as Zycotherm (0.05%–0.15% by weight of bitumen) and Rediset LQ (0.4%–0.6% by weight of bitumen) were utilized.

B. Mix Design

Marshall Mix Design method was adopted to determine the optimum binder content (OBC). Different bitumen contents were tested to evaluate stability, flow value, air voids, and voids filled with bitumen. The optimum binder content was determined based on Maximum stability, Desired air voids and Proper flow values.

C. Preparation of Specimens

Bituminous specimens were prepared for Conventional mix (control), Mix with Zycotherm and Mix with Rediset LQ. Mixing and compaction were carried out following standard procedures.

D. Laboratory Testing

The experimental tests were conducted such as Marshall Stability Test which is used to evaluate the load-bearing

capacity and deformation characteristics of the mix. The Tensile Strength Ratio (TSR) test determines moisture susceptibility by comparing tensile strength of conditioned and unconditioned samples. The Aggregate Coating Test assesses the coating efficiency of bitumen over aggregates.

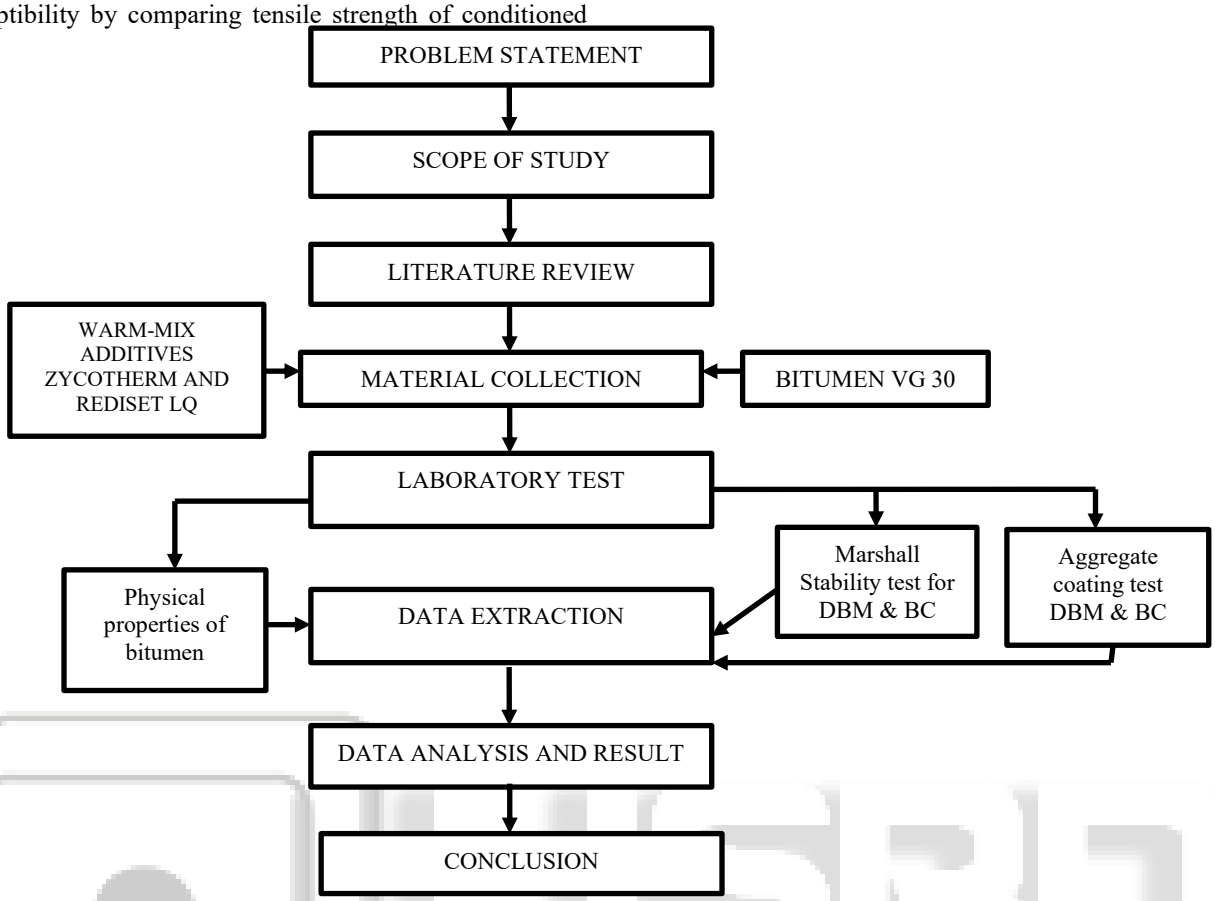

Fig. 1: Methodology Flow-Chart

III. Results and Discussion

The Basic properties of bituminous mix (Table-1) like penetration, ductility, softening point, viscosity etc test are conducted with warm mix additives are Zycotherm with 0.05%,0.1%,0.15% dosage and Rediset LQ with 0.4%,0.5%,0.6% dosage with 130 ºC.

Bitumen test	VG-30+ Zycotherem (0.05%)	VG-30+ Zycotherem (0.1%)	VG-30+ Zycotherem (0.15%)	Requirements as per IS 73-2013
Penetration at 25^{0}C, mm	64	65	66	Min 45
Softening point	49	49	49	Min 47
Ductility @27^{0}C, cm	87	98	90	NA
Specific gravity	1.00	1.03	1.02	NA

Table 1: Basic properties of bituminous mix

Sieve Designation mm	Actual % passing			% Passing proposed mix design			Total Passing, %	Limit as per MoRTH-V rev. Table - 500/10
	13.2 to 4.75 mm	6mm	Stone Dust	13.2 to 4.75 mm	6mm	Stone Dust		
				0.25	0.35	0.40		Grading 2
19	100.00	100	100	25	35	40	100	100
13.2	79.83	100	100	19.95	35	40	94.95	90-100
9.5	15.55	100	100	3.89	35	40	78.89	70-88
4.75	3.32	60.69	100	0.82	21.31	40	62.13	53-71
2.36	0.00	28.71	100	0.00	10.04	40	50.04	42-58
1.18	0.00	12.78	91.69	0.00	4.47	36.67	41.14	34-48
0.6	0.00	8.71	73.98	0.00	3.04	29.59	32.63	26-38
0.3	0.00	7.93	48.98	0.00	2.78	19.59	22.37	18-28
0.15	0.00	3.47	37.27	0.00	1.21	14.90	16.11	12-20
0.075	0.00	2.14	15.53	0.00	0.75	6.21	6.96	4-10

Table 2: Gradation for Bitumnious Concrete Grade 2

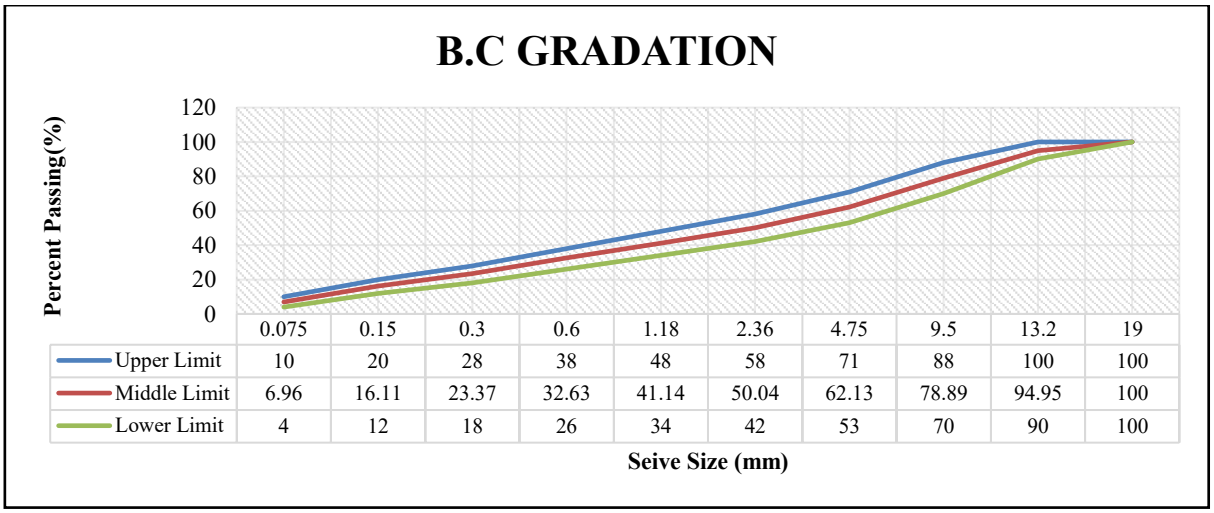

Fig. 2: Gradation for Bitumnious Concrete Grade 2

A. Optimum Binder Content

The optimum binder content was found to be (i) 5% for BC Grade II and (ii) 4.5% for DBM Grade II. These values were selected based on maximum stability and acceptable volumetric properties.

B. Effect of Additives on Marshall Stability

The addition of warm mix additives resulted in a noticeable increase in Marshall Stability values. Among the two additives, Zycotherm showed higher improvement in stability compared to Rediset LQ. The optimum dosage was found to be (i) 0.1% for Zycotherm and (ii) 0.5% for Rediset LQ. The increase in stability indicates improved load-bearing capacity and resistance to deformation.

C. Moisture Susceptibility (TSR Test)

Moisture damage is one of the major causes of pavement deterioration. The TSR values obtained in this study were above 80% for both additives, indicating good resistance to moisture damage. Zycotherm showed slightly better performance due to its anti-stripping properties, which enhance adhesion between bitumen and aggregates.

D. Aggregate Coating Performance

Aggregate coating tests revealed, Coating efficiency of more than 95% for both additives. It also improved workability and uniform coating at lower temperatures. This demonstrates the effectiveness of warm mix additives in ensuring proper bonding.

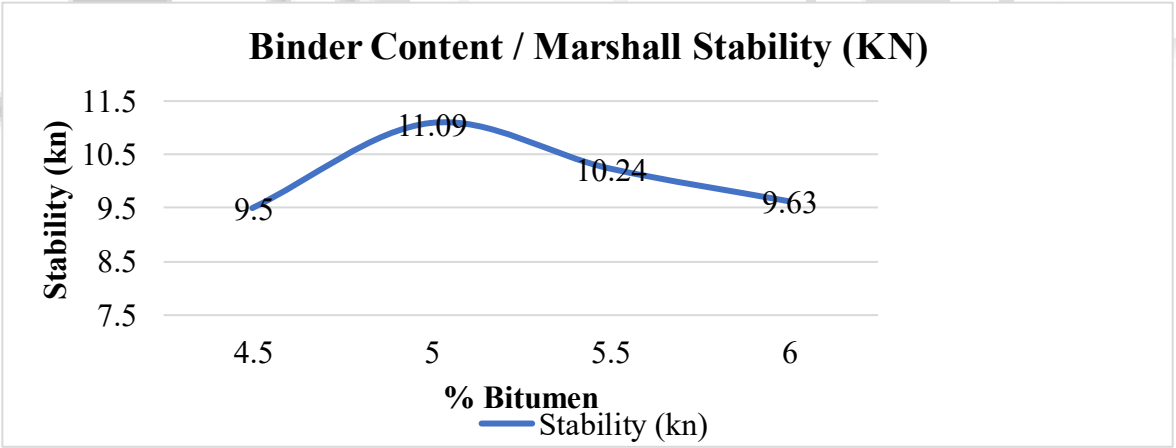

Fig. 3: Stability (kN) vs. Bitumen (%)

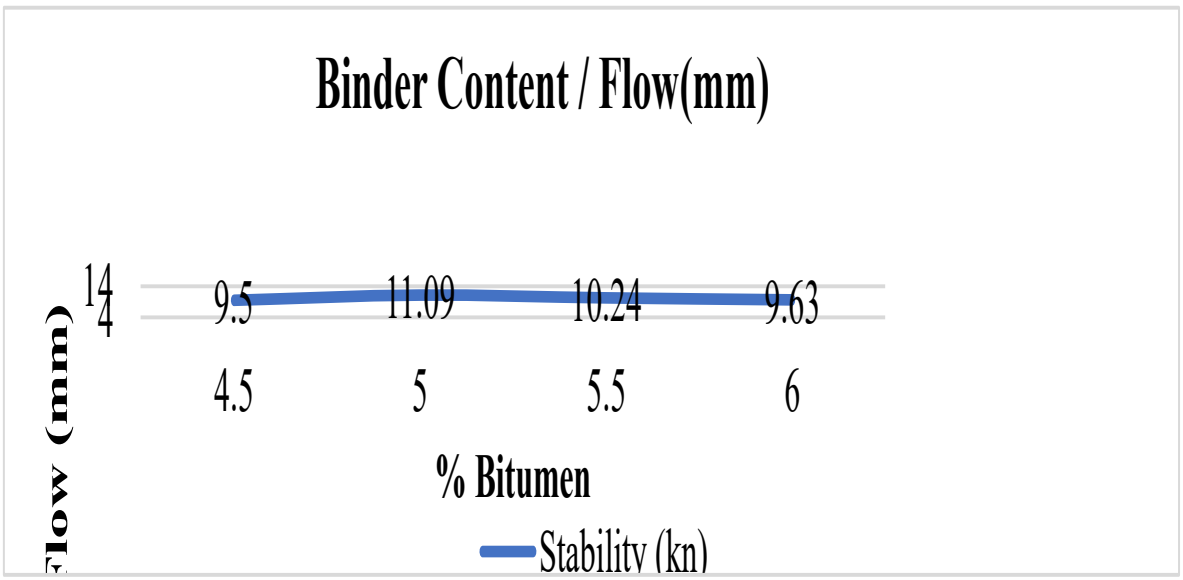

Fig. 4: Flow (mm) vs. Bitumen (%)

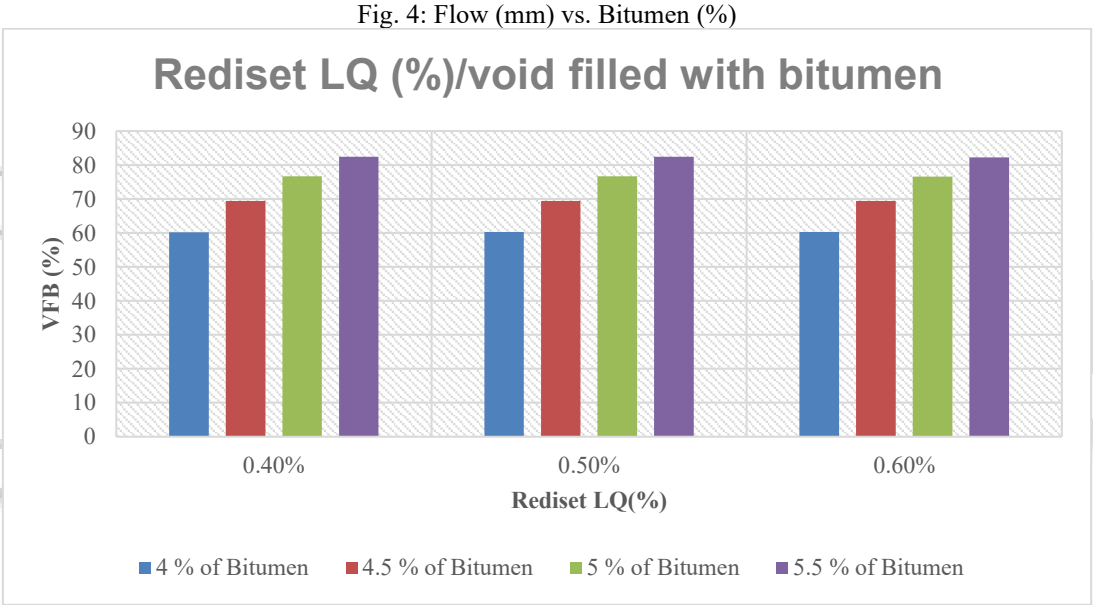

Fig. 5: Rediset LQ (%)/void filled with bitumen

From the comparison, it is evident that both additives significantly improved the performance. Zycotherm performed slightly better in terms of moisture resistance.

The use of WMA technology offers reduced mixing temperature, Lower fuel consumption, Reduced emissions and Improved working conditions. These advantages make WMA a sustainable alternative to conventional HMA.

Property	Conventional Mix	Zycotherm Mix	Rediset Mix
Stability	Moderate	High	High
TSR	~75–80%	>80%	>80%
Coating	Good	Excellent	Excellent

Table 3: Overall Performance Comparison

IV. Conclusion

This study evaluated the performance of bituminous mixes using warm mix additives Zycotherm and Rediset LQ. Based on the experimental results, the following conclusions were drawn:

The optimum binder content was found to be 5% for BC Grade II and 4.5% for DBM Grade II. The optimum dosage of additives was 0.1% for Zycotherm and 0.5% for Rediset LQ.

Both additives improved Marshall Stability, indicating enhanced strength and load-bearing capacity.

TSR values greater than 80% confirmed improved resistance to moisture damage.

Aggregate coating efficiency exceeded 95%, demonstrating better adhesion properties.

Warm mix additives allow lower production temperatures, contributing to energy savings and environmental benefits.

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