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EXPERIMENTAL INVESTIGATION ON USE OF RECLAIMED ASPHALT PAVEMENT MATERIALS (RAP) IN DENSE BITUMINOUS MACADAM-II WITH MODIFIED BINDER

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ABSTRACT

This study investigates the performance of Dense Bituminous Macadam (DBM) mixes incorporating varying percentages of Reclaimed Asphalt Pavement (RAP) and different fillers, including Stone Dust, Fly Ash, and Ground Granulated Blast Furnace Slag (GGBS). The research evaluates the mechanical properties of DBM mixes using Polymer Modified Bitumen (PMB-70) binder, focusing on parameters like Marshall Stability, Indirect Tensile Strength (ITS), and volumetric properties. Different RAP content levels (10%, 20%, and 30%) were assessed to determine the optimal mix for sustainable and economical road construction, aiming to reduce the consumption of virgin materials while maintaining performance standards. The analysis concludes with recommendations on the optimum binder content and RAP percentage, contributing to the efficient use of recycled materials in pavement design for enhanced environmental sustainability.

I. INTRODUCTION

India has the second-largest road network globally, spanning over 6.2 million kilometers, making the construction and maintenance of bituminous pavements a critical aspect of infrastructure development. In recent years, Reclaimed Asphalt Pavement (RAP), a byproduct of milling aged or severely distressed bituminous layers, has gained significant attention due to its potential to be reused in road construction. RAP not only conserves natural resources by reducing the demand for virgin aggregates and bitumen but also addresses environmental concerns associated with the disposal of aged asphalt materials. The recycling of asphalt pavement has become standard practice in many countries, offering substantial savings in material costs, energy consumption, and landfill space. Incorporating RAP into new bituminous layers helps to promote sustainable development while maintaining performance standards comparable to virgin mixtures. However, challenges remain in achieving the desired mechanical properties due to the presence of aged binder in RAP, which may contribute to issues like thermal cracking and reduced fatigue life.

Polymer Modified Bitumen (PMB), known for its enhanced durability and performance, is frequently used to mitigate these issues. By blending bitumen with polymers, either virgin or reclaimed, the material exhibits improved elasticity, resistance to deformation, and extended service life under varying climatic conditions. The combination of RAP with PMB offers a promising solution for sustainable road construction, ensuring cost-effectiveness without compromising structural integrity.

This study focuses on the performance of Dense Bituminous Macadam (DBM) mixes incorporating different percentages of RAP (10%, 20%, and 30%) along with various fillers, including stone dust, fly ash, and Ground Granulated Blast Furnace Slag (GGBS). The research evaluates key performance indicators such as Marshall Stability, Indirect Tensile Strength (ITS), and volumetric properties to determine the optimum mix for environmentally sustainable and economically viable road construction.

II. MATERIALS

First, This study designed and tested Dense Bituminous Macadam (DBM) mixes incorporating Reclaimed Asphalt Pavement (RAP) at 10%, 20%, and 30% replacement levels, along with Polymer Modified Bitumen (PMB-70) as a binder. Crushed aggregates of varying sizes (26.5mm, 19mm, 13.2mm, 4.75mm, and below) were used in compliance with Indian road standards. Three different fillers—Stone Dust, Fly Ash, and Ground Granulated Blast Furnace Slag (GGBS)—were employed to optimize mix properties. The bitumen content was varied between 4% and 5.5% to assess performance. RAP and fillers contributed to sustainable, high-performance pavement design.

III. METHODOLOGY

The methodology consisted of a systematic approach to designing, preparing, and testing DBM mixes to assess their mechanical properties and suitability for use in road construction. The following steps were carried out:

1. **Mix Design**: The DBM mix was designed using the Marshall Method of Mix Design, adhering to the Indian Roads Congress (IRC) guidelines. DBM mixes were prepared with varying percentages of RAP (0%, 10%, 20%, and 30%) and three different fillers (Stone Dust, Fly Ash, and GGBS). The bitumen content was also adjusted (4%, 4.5%, 5%, and 5.5%) to determine the optimal mix.

2. **Sample Preparation**: Cylindrical specimens were prepared by compacting the DBM mix at different RAP percentages and filler combinations. Each mix was heated to the required temperature, and the materials were mixed uniformly. The specimens were compacted using a Marshall compactor to achieve consistent density.

3. **Marshall Stability Test**: The stability and flow values of the prepared DBM specimens were determined using the Marshall Stability Test. This test measures the maximum load the bituminous mix can withstand before failure. The test provides insights into the mix's strength and resistance to deformation under traffic loads. Stability and flow values were recorded for each combination of RAP content, filler type, and binder content.

4 **Volumetric Analysis**: Volumetric properties such as air voids (Vv), voids in mineral aggregate (VMA), and voids filled with bitumen (VFB) were calculated for each mix. These parameters are critical in ensuring the durability and longevity of the pavement structure.

5 **Indirect Tensile Strength (ITS) Test**: The Indirect Tensile Strength (ITS) test was performed to evaluate the tensile strength and moisture susceptibility of the DBM mixes. The cylindrical specimens were loaded diametrically in compression until failure, and the ITS values were calculated. This test also assesses the mix's resistance to cracking under traffic loads.

6 **Tensile Strength Ratio (TSR)**: To evaluate moisture susceptibility, the specimens were conditioned in water at low temperatures and subjected to the ITS test. The Tensile Strength Ratio (TSR) was calculated by comparing the ITS of conditioned samples to unconditioned samples, providing insights into the durability of the mix under wet conditions.

7 **Optimum Binder Content (OBC)**: Based on the results from the Marshall Stability Test, ITS test, and volumetric analysis, the optimum binder content for each DBM mix was determined. The mix with the best combination of stability, flow, air voids, and durability was

Table: Properties of bitumen PMB – 70 selected as the optimal design.

Sl. No	Name of the test / Characteristics	Test Results PMB – 70 Grade	Permissible Limits – As per IS 15462-2014 (PMB 70 Grade)	Test Method
1	Penetration test @ 25°C, 0.1mm, 100gm, 5 sec	72	50 - 90	IS 1203 - 2022
2	Softening point (R &B), °C,Min	64	55	IS 1205 - 2022
3	Flash Point °C,min	247	220	IS 1209 - 2021
4	Specific Gravity	1.016	> 0.99	IS 1202 - 2021
5	Ductility test, Min cms	87	60	IS 1208 - 2023
6	Elastic recovery @ 15°C°, (%), Min	75	70	IS 15462 – 2004 (Annex - A)
7	Separation difference in softening point test, °C,Max	2	3	IS 15462 – 2004 (Annex - B)
8	Viscosity @150°C, Poise	2.72	2-6	IS 1206 – 1978 (Part- 2)

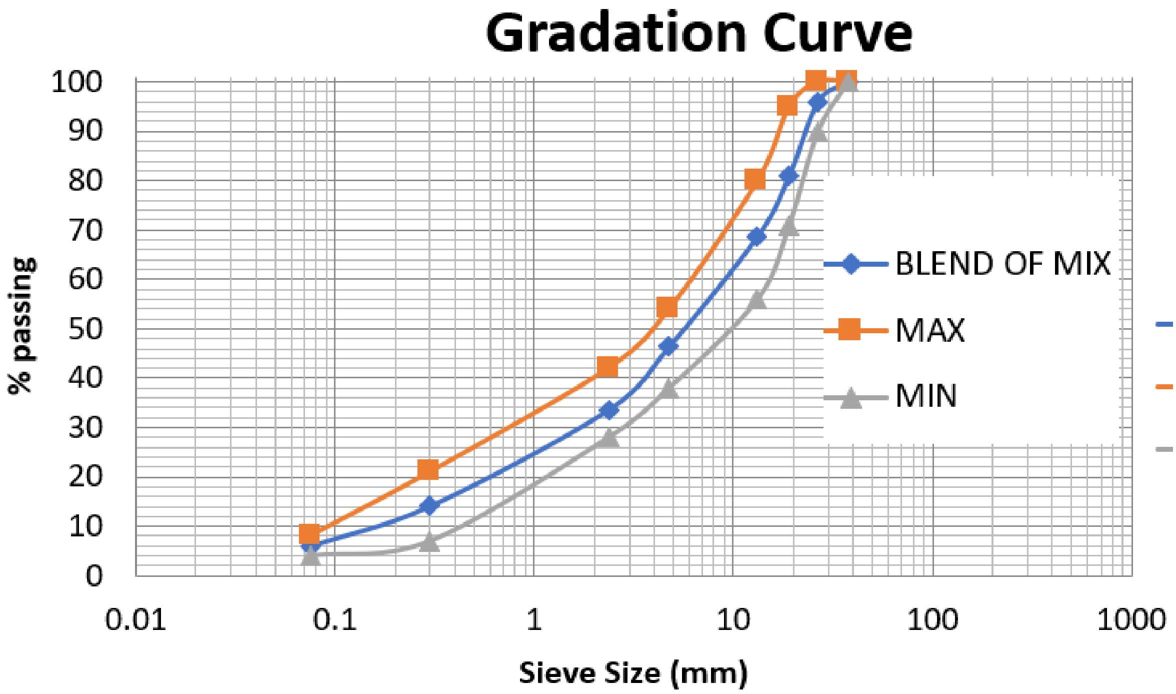
Thin film oven test and tests on residue				
9	Loss in Mass, %, Max	0.87	1.0	IS 9382 - 1979
10	Change in softening point, °C, Max	04	6.0	IS 1205 - 1978
11	Reduction in penetration of residue @ 25°C, %, Max	21	35	IS 1203 - 1978
12	Elastic recovery @ 25°C°, (%), Min	63	50	IS 15462 – 2004 (Annex - A)

Table: Engineering properties of virgin aggregate

Sl No.	Tests	Test result	IS Code	MoRT & H (2013) Specification
1	Specific Gravity 26.5mm-19mm 19mm-13.2mm 4.75mm-2.36mm 2.36mm down	2.673 2.666 2.655 2.716	IS: 2386 (Part-3)	-
2	Crushing value, %	18.20	IS: 2386 (Part-4)	-
3	Impact value, %	16.19	IS: 2386 (Part-4)	Max 27%
4	Abrasion value,%	23.00	IS: 2386 (Part-5)	Max 30%
5	Combined indices,%	22.98	IS: 2386 (Part-1)	Max 35%
6	Water absorption,% 26.5mm-19mm 19mm-13.2mm 4.75mm-2.36mm 2.36mm down	0.13 0.17 0.18 1.01	IS: 2386 (Part-3)	Max 2%

Table: Properties of rap extracted aggregates

Sl no	Property	Test results	Requirements of DBM-II as per MoRT&H (2013) Specification
1	Specific Gravity	2.593	---
2	Crushing value, %	26.02	---
3	Impact value, %	22.24	Max 27%
4	Abrasion value,%	26.15	Max 30%
5	Combined indices,%	25.04	Max 35%



IV. RESULTS

Table: Marshall Properties of DBM-II mix with 2% GGBS for different RAP percentage and PMB 70 as binder

Sl. No	Test Property	0% RAP	10% RAP	20% RAP	30% RAP
1	OBC, %	5.11	5.20	5.30	5.45
2	Stability, Kg	1900.80	1806.93	1745.07	1696.51
3	Density, g/cc	2.387	2.379	2.369	2.364
4	Air voids, %	4.04	4.05	4.27	3.90
5	Flow, mm	4.07	4.33	4.67	4.80
6	VMA,%	15.71	15.91	16.27	16.43
7	VFB,%	74.26	74.53	73.75	76.26
8	Marshall Quotient	4.7	4.17	3.74	3.53

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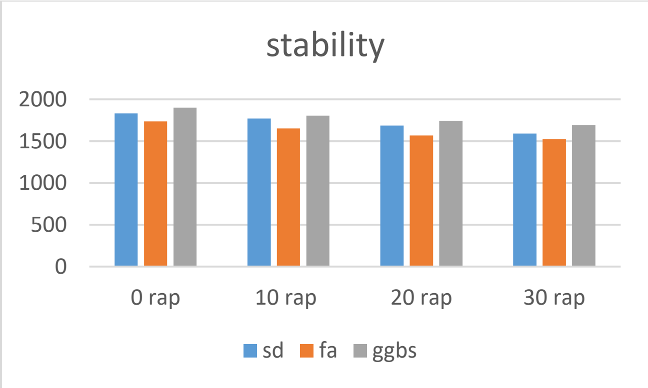

Fig: Stability comparison of considered RAP mixes with control mix

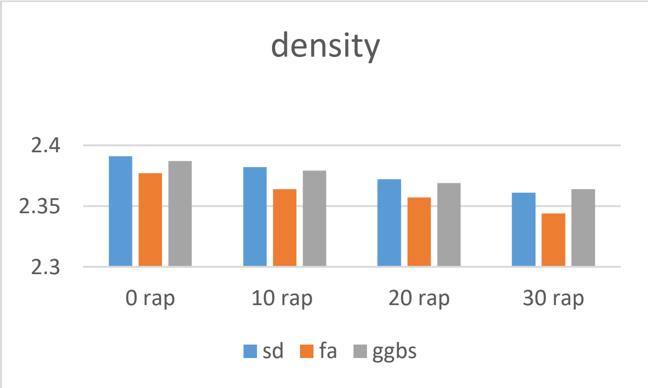

Fig: Density comparison of considered RAP mixes with control mix

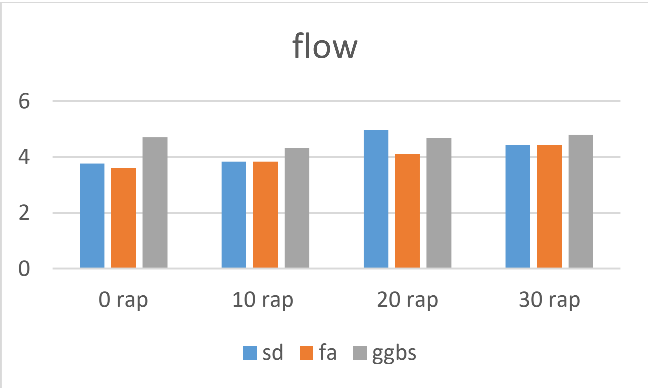

Fig: Flow comparison of considered RAP mixes with control mix

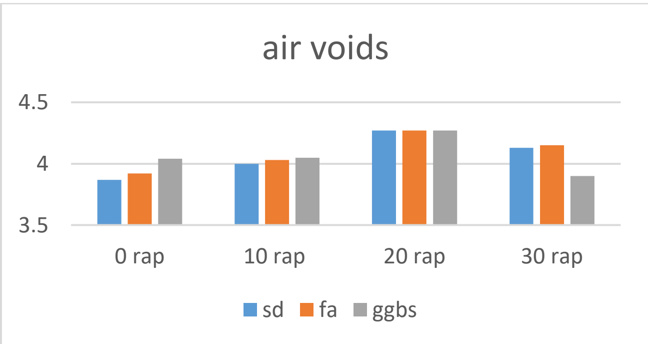

Fig: Air Voids comparison of considered RAP mixes with control mix

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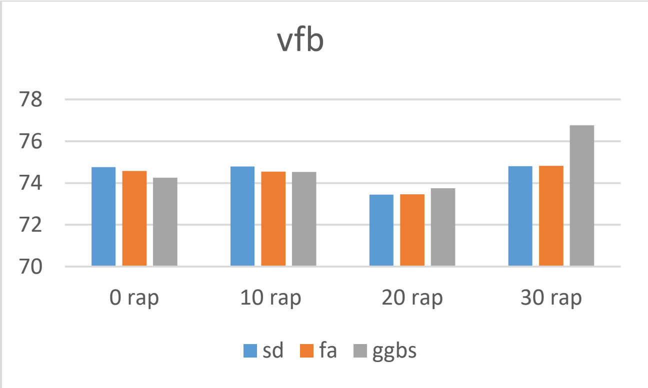

Fig: V fb comparison of considered RAP mixes with control mix

Table: Tensile Strength Ratio of Dense Bituminous Macadam mix Prepared using PMB-70 as binder with different RAP percentage and different Fillers

Binder	Filler %	RAP %	Indirect Tensile Strength N/mm²		TSR %	Requirement as per Table-500-11 MoRT&H (V Revision) Specification
			Uncondi-tioned at 25⁰ C	Conditi-oned at 60⁰ C		
PMB-70	Stone Dust 2%	0 %	1.625	1.554	95.65	Minimum 90%
		10 %	1.571	1.500	95.44	
		20 %	1.531	1.446	94.44	
		30 %	1.492	1.391	93.24	
	Fly Ash 2%	0 %	1.515	1.422	93.87	
		10 %	1.487	1.386	93.20	
		20 %	1.447	1.335	92.29	
		30 %	1.409	1.291	91.58	
	GGBS 2%	0 %	1.598	1.544	96.66	
		10 %	1.574	1.505	95.60	
		20 %	1.525	1.446	94.78	
		30 %	1.513	1.413	93.37	

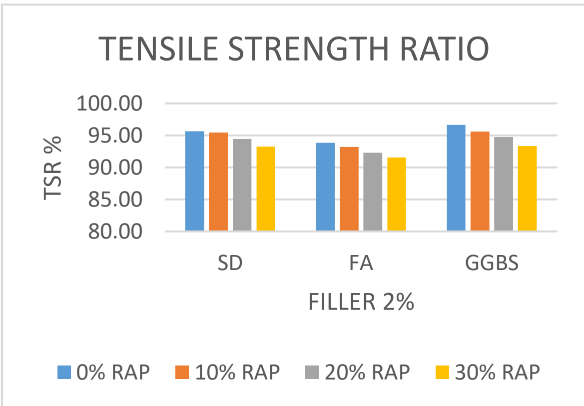

Fig D: Variation of TSR with respect to Different Filler and RAP percentage

V. CONCLUSION

The research demonstrates the viability of incorporating Reclaimed Asphalt Pavement (RAP) in Dense Bituminous Macadam (DBM) mixes with varying RAP content (10%, 20%, and 30%) and fillers (Stone Dust, Fly Ash, and GGBS). RAP effectively replaces virgin aggregates, contributing to resource conservation and cost savings without sacrificing mechanical properties. Polymer Modified Bitumen (PMB-70) further enhances performance, improving resistance to deformation, cracking, and moisture damage. Marshall Stability and Indirect Tensile Strength (ITS) tests identified optimal results with 20% RAP and 5.1%-5.4% bitumen content. Fillers, particularly Fly Ash and GGBS, improved volumetric properties and moisture resistance, providing a sustainable and high-performance solution for road construction while reducing the environmental footprint.

VI. REFERENCES

[1] G. Eason, B. Noble, and I. N. Sneddon, "On certain integrals of Lipschitz-Hankel type involving products of Bessel functions," Phil. Trans. Roy. Soc. London, vol. A247, pp. 529–551, April 1955. (references)

[2] J. Clerk Maxwell, A Treatise on Electricity and Magnetism, 3rd ed., vol. 2. Oxford: Clarendon, 1892, pp.68–73.

[3] I. S. Jacobs and C. P. Bean, "Fine particles, thin films and exchange anisotropy," in Magnetism, vol. III, G. T. Rado and H. Suhl, Eds. New York: Academic, 1963, pp. 271–350.

[4] K. Elissa, "Title of paper if known," unpublished.

[5] R. Nicole, "Title of paper with only first word capitalized," J. Name Stand. Abbrev., in press.

[6] Y. Yorozu, M. Hirano, K. Oka, and Y. Tagawa, "Electron spectroscopy studies on magneto-optical media and plastic substrate interface," IEEE Transl. J. Magn. Japan, vol. 2, pp. 740–741, August 1987 [Digests 9th Annual Conf. Magnetics Japan, p. 301, 1982].

[7] M. Young, The Technical Writer's Handbook. Mill Valley, CA: University Science, 1989.

[8] K. Eves and J. Valasek, "Adaptive control for singularly perturbed systems examples," Code Ocean, Aug. 2023. [Online]. Available: https://codeocean.com/capsule/4989235/tree

[9] D. P. Kingma and M. Welling, "Auto-encoding variational Bayes," 2013, arXiv:1312.6114. [Online]. Available: https://arxiv.org/abs/1312.6114

[10] S. Liu, "Wi-Fi Energy Detection Testbed (12MTC)," 2023, gitHub repository. [Online]. Available: https://github.com/liustone99/Wi-Fi-Energy-Detection-Testbed-12MTC

[11] "Treatment episode data set: discharges (TEDS-D): concatenated, 2006 to 2009." U.S. Department of Health and Human Services, Substance Abuse and Mental Health Services Administration, Office of Applied Studies, August, 2013, DOI:10.3886/ICPSR30122.v2