MSW MANAGEMENT -Multidisciplinary, Scientific Work and Management Journal
ISSN: 1053-7899
Vol. 36 Issue 2, 2026, Pages 1571-1573

Performance Assessment of Bituminous Concrete Mix Incorporating Reclaimed Asphalt Pavement and Plastic Waste

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Abstract:
This study explores the use of sustainable materials in bituminous concrete mixes for eco-friendly pavement construction. The investigation focuses on incorporating Reclaimed Asphalt Pavement (RAP) aggregates, plastic waste, and molasses as partial replacements for conventional materials in mixes prepared with VG-30 grade bitumen. Initially, a conventional bituminous concrete mix using virgin aggregates is prepared as a control mix. Subsequently, RAP aggregates are introduced to evaluate the feasibility of recycling pavement materials. In further trials, plastic waste is used as a partial replacement for bitumen to address environmental pollution and improve mix characteristics. Molasses is also incorporated as a partial bitumen replacement to study its influence on stability and durability. The performance of all mixes is assessed through Stability, Indirect Tensile Strength (ITS) and Tensile Strength Ratio (TSR) tests. The study aims to achieve improved mechanical performance while reducing environmental impact. Results indicate that the combined use of RAP aggregates, plastic waste, and molasses can produce durable and sustainable bituminous concrete mixes suitable for future green pavement applications.

KEYWORDS: Reclaimed Asphalt Pavement (RAP): Molasses: Waste Shredded plastic: Indirect Tensile Strength (ITS): Tensile Strength Ratio(TSR): Bituminous Concrete (BC)

Chapter 1- Introduction

In view of the huge paving infrastructure demand both in new construction and rehabilitation, the main concerns for the paving industry are conservation of natural resources and utilization of waste materials for achieving economy and protecting the environment. Reclaimed asphalt pavement (RAP) which is referred to as the old and damaged bituminous paving materials is being used for the construction or maintenance of bituminous pavements. Waste materials like RAP which contains aggregates and aged bitumen are being reutilized for benefits such as reduced cost, conservation of natural resources, and control of environmental issues. Molasses is a thick by-product of sugar industry. It is used as an additive in bitumen to improve road performance. When molasses is mixed with bitumen, it becomes softer and easier to work with. It also improves the bonding between bitumen and aggregates. The objectives of the this study is to obtain an optimum bituminous mix by adding shredded plastic waste, rap aggregates and molasses. Also to understand the feasibility in rap with different proportions in bituminous mixes and to get the maximum usage of rap by replacing the natural aggregate in BC mix. And to determine indirect tensile strength (ITS) and tensile strength ratio(TSR) about the mixture for different specimens.

Chapter-2 Material Characteristics

Aggregates were collected from nearby quarry source. RAP aggregates were collected from NH-48 near Davangere. The aggregates were separated from BC mix by bitumen extraction test. Virgin bitumen of VG 30 grade is considered. Waste plastic in shredded form of LDPE (Low Density Polyethylene) type is considered and purchased from a shredding industry near Hubli, Karnataka. As per IRC: SP-98, the plastic sizes were taken and used in this study.

Fig. 3.1: Waste Shredded Plastic

Fig. 3.2: Waste Shredded Plastic

The Basic Test results are as follows:

Table No. 3.1: Aggregate Test Results

Sl. No.	Description	Result	Ranges as per IS CODE	Code Reference
1	Specific gravity test on natural aggregates	2.8	3	IS: 2386 (Part 3)
3	Impact test on natural aggregates	22.65%	20-30%	IS: 2386 (Part 4)
5	Crushing value test on natural aggregates	11.35%	<16%	IS: 2386 (Part 4)

Table No. 3.2: Bitumen Test Results

Sl. No.	Description	Result	Ranges as per IS CODE	Code Reference
1	Specific gravity test	0.98	0.97-1.02	IS:1202-1978
2	Penetration test	69 cm	60-70	IS:1203-1978
3	Ductility test	52 cm	50-100	IS:208-1978
4	Viscosity test	314 sec	10-600	IS:1206- 1978
5	Bitumen softening point test	59°	35°-70°	IS:1205-1978

Chapter-4 Results and Discussion

Marshall Stability test method is used to evaluate the strength of the BC mix in laboratory. The RAP was cleaned from dust and dirt, washed and dried. Later it was inserted in bitumen extractor machine to separate the aggregates from aged bitumen

Fig 4.1: a)Marshall stability Specimen preparation b) Marshall stability Specimen

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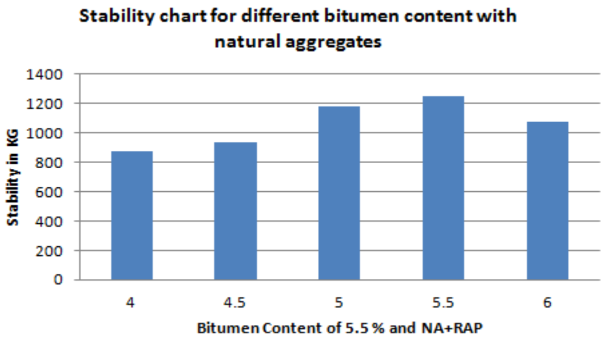
4.1 Marshall Stability Test Results:

Table 4.1: Stability Values for 5.0% bitumen content

	Marshall Parameters			for bitumen 5.0 %
Sample No.	**Stability (KG)**	**Avg. Stability (KG)**	**Flow (mm)**	**Avg. Flow (mm)**
1	1258.45	1178.45	3.0	3.1
2	1298.45		3.1	
3	978.45		3.2	

A sample table is provided here for bitumen 5 % which shows that for each bitumen content 3 samples were casted and tested. Likewise from 4.0 % to 6.0% bitumen contents with 0.5% increment marshall stability was found out. For OBC 5.5%, the RAP aggregates were added with replacement of 5% by weight of natural aggregates till 30% of RAP aggregates. The 25% replacement of RAP against NA were found and the same mix proportion is taken for replacing bitumen with waste shredded plastic. As per IRC:SP98, waste plastic is added upto 10% by increment of 2% against the bitumen as a replacement material. And 8% of plastic replacement was found to be in gaining in the stability. Again Molasses is used in the mix as a replacement for bitumen from percentages of 5, 10, 15, 20, 25 and 30 % by the weight of bitumen which obtained after replacing the waste plastic.



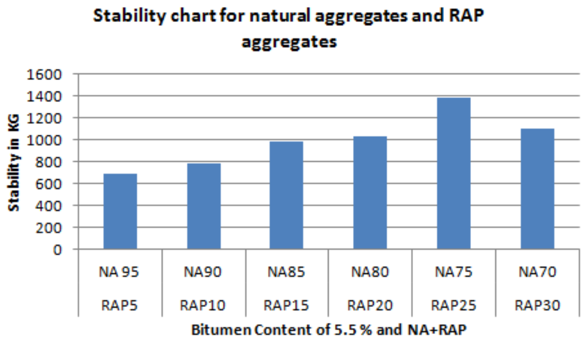
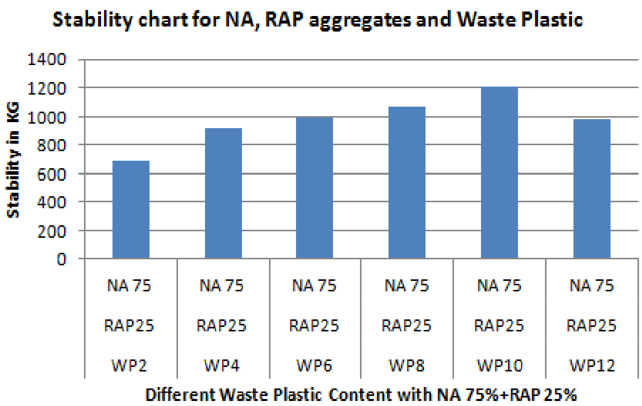


Fig4.2 : Graph showing Optimum binder content **Fig4.3 : Graph showing max. stability for 5.5% Optimum binder content and RAP, NA**



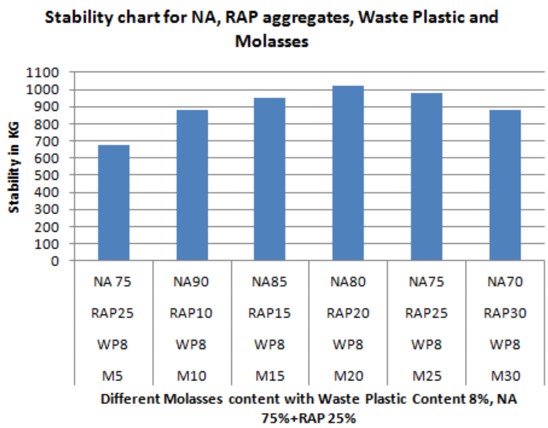


Fig. 4.4 : Graph showing max. stability for 5.5% Optimum binder content, RAP, NA and WP **Fig. 4.5: Graph showing max. stability for Optimum binder content 5.5% , RAP, NA,WP and Molasses**

4.2 INDIRECT TENSILE STRENGTHS AND TENSILE STRENGTH RATIOS OF BC MIX

If TSR Values for bituminous mix is ≥ 80%, it is Acceptable / good moisture resistance, if ≥ 85%, it will be Excellent moisture resistance, likewise 70–80%, it is Marginal and if < 70%, it is Poor / moisture susceptible.

Fig. 4.6.: Indirect tensile strength test for BC mix Specimens

Formula: $ITS=\frac{2XP}{\pi X\ tX\ d}$

TSR indicates resistance to moisture damage. ITS and TSR values improve gradually with RAP content up to 25%. Addition of waste shredded plastic enhances bonding and moisture resistance, with optimum performance around 8% plastic replacement. Excess plastic (10%) slightly reduces strength due to reduced flexibility and workability. Molasses replacement beyond 4–6% lowers ITS and TSR because of reduced stiffness and moisture susceptibility.

Table 4.2: ITS and TSR for conventional Mix

Bitumen %	ITS_{dry}	ITS_{wet}	TSR (%)
4.0	0.88	0.78	88.81
4.5	0.94	0.82	87.20
5.0	1.18	0.97	82.13
5.5	1.25	1.15	91.76
6.0	1.08	0.95	87.90

Table 4.3: ITS and TSR for NA+RAP with different proportions for 5.5% bitumen content

NA	RAP	ITS_{dry}	ITS_{wet}	TSR (%)
95	5	0.86	0.72	83.99
90	10	0.91	0.75	82.03
85	15	0.99	0.82	82.87
80	20	1.03	0.9	87.32
75	25	1.39	1.15	82.82
70	30	1.11	0.75	67.52

Table 4.4: ITS and TSR for for NA75+RAP25 , waste plastic with different proportions for 5.5% bitumen content

NA+RAP	Waste plastic	ITS_{dry}	ITS_{wet}	TSR (%)
75+25	2	0.86	0.72	83.99
75+25	4	0.91	0.75	82.03
75+25	6	0.99	0.82	82.87
75+25	8	1.03	0.9	87.32
75+25	10	1.39	1.15	82.82
75+25	30	1.11	0.75	67.52

Table 4.4: ITS and TSR for for NA75+RAP25+WP8 , Molasses with different proportions for 5.5% bitumen content

NA+RAP+WP	Molasses	ITS_{dry}	ITS_{wet}	TSR (%)
75+25+8	5	0.86	0.72	83.99
75+25+8	10	0.91	0.75	82.03
75+25+8	15	0.99	0.82	82.87
75+25+8	20	1.03	0.9	87.32
75+25+8	25	1.39	1.15	82.82
75+25+8	30	1.11	0.75	67.52

5 Conclusion

The optimum quantity of materials in reaching the maximum stability was achieved by the RAP aggregates, waste plastic and Molasses. The stability of all RAP mixes was higher than the standard limits (8.0 kN). The findings also

showed that all RAP mixes satisfied the Marshall stability, flow. Waste plastic is used as dry process method as per available guidelines IRC SP:98. By using RAP as an alternative material along with waste plastic, molasses makes the pavement sustainable, durable. Molasses can be successfully blended with the bitumen in making the bituminous mixture and hence obtained the satisfactory stability value upto 20% percent.

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