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Original Article

Experimental Study of Industrial and Construction Waste for Improving the Strength of the Flexible Pavement

Pranoti V Pawar[1], Madhulika Sinha[2]

[1,2]*Construction Engineering and Management, Department of Civil Engineering, Mahatma Education Society's Pillai HOC College of Engineering & Technology, Rasayani.*

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Abstract *- Flexible pavement is primarily used in the construction of roads. Asphalt pavement is a binding organic material made from the byproducts of crude oil. Connecting to the various rural areas is, of time, important for the growth and development of the country. Major connectivity is made by flexible pavement. Thus, it is necessary to enhance the quality of bituminous roads to avoid major accidents on the road. As in today's scenario, the waste like plastic and washout bitumen from the old road is increasing day by day. It is necessary to utilise this waste to its maximum percentage such that the quality should enhance or there is no decline in quality compared to conventional material. In this paper, Conventional VG-40 Bitumen is studied for the Sub-base / DBM of flexible pavement. Further bitumen replacement of 1.25% interval ranging from 5% to 10% by CASE 1 – Shredded Plastic & CASE-2 Recycled Asphalt. All the samples were tested as per the standard testing parameter of bitumen and tested samples of aggregates and coated aggregate as per the CASES.*

Keywords *- Normal Aggregates, Plastic waste, Bitumen, Modified plastic Bitumen, Recycled Asphalt Pavement (RAP).*

1. Introduction

Transportation facility is an essential factor in today's development and population. During construction, the transport facility is time-dependent on roads. In that, Bituminous roads are essential in today's infrastructure. Bitumen has good binding properties used as a binder in road construction, and modifies by mixing with waste. This modified bitumen mixes Natural and RAP. It shows a better binding property, stability, and more resistance to water, increasing the durability of roads with resistance to wear and tear of the road.

Waste plastic is a non-decomposable material; it is one of many wastes that take too long to decompose, and researchers have found that normal plastic items take up to 1000 years to decompose in landfills. Plastic wastes consisting of the main polyolefin from items such as carry bags, cups, thermocol, and packaging films pose a significant problem for their disposal.

The use of RAP is considered an inexpensive & environmentally sustainable process; it preserves natural resources & compared to virgin asphalt mixtures, can yield comparable structural efficiency. This material can be reused in new asphalt mixtures because the components of the mix—the asphalt binder and aggregate—still have value. Using RAP in new mixtures can reduce the amount of new material that has to be added, saving money and natural resources. The old binder may reduce the need for the new binder to be added. During the construction and service life of the roadway from which the RAP obtains, the asphalt binder in the roadway became aged or hardened by reacting with oxygen in the air.

The use of RAP has been in practice since the 1930s and is necessary to reduce the cost of construction materials, reduce the use of petroleum-based products, and conserve natural resources by requiring less virgin aggregate and asphalt in road construction projects.

Why the use of Plastics/ RAP waste?

- Durable & corrosion resistant.
- Good insulation for cold, heat & sound, saving energy and reducing noise pollution.
- It is economical and has a longer life.
- Maintenance-free.
- Easy processing/installation.
- Lightweight.
- RAP is more beneficial and more cost-effective.

2. Literature Review

An Indian scientist who has worked on waste management is Dr. R. Vasudevan. The use of Plastic in road construction was decided after he investigated the harm that heavy rains do to roadways [1]. The performance of asphalt

pavement is enhanced by including recycled waste plastic at a weight percentage of 5–10%, according to the research, and the waste plastics modified bituminous blend exhibits better binding, density, and stability as greater water resistance [2]. The aggregates are heated before being coated with waste plastic. When bituminous mixes, including this coated aggregate, are used to build the roads, the road is stabilised, and the pavement's lifespan is improved [3]. Aggregate with a plastic coating enhances binding properties and makes for better materials for paving. Aggregate coated with Plastic is a better raw material for paving because it has greater binding properties and less wetting properties. These discovered that PCA works effectively on bituminous pavement and is a cost- and environmentally-friendly approach [4]. For construction or maintenance purposes, 100% RAP in the HMA mixture is used [5]. The life and quality of flexible pavement are improved, as well as the aggregate and bitumen properties, by using waste plastic. In that, bitumen, aggregate-plastic-coated with bitumen, was the objective of laboratory tests [6]. The bitumen and plastic waste mixture impacts the performance of the pavement in terms of wear, rutting, and cracking, as well as increased strength, durability, and water resistance [7].

3. Materials and Methods

3.1. Bitumen

When heated, the bitumen in the paving grade—VG 10, VG 20, VG30, and VG40—softens and has good binding properties. IRC: 111-2009 outlines the grade of viscosity that must be chosen. The bituminous mixtures used for a base course, the DBM course made with recyclable materials like used Plastic, and RAP meet the requirements of Indian Standard IS 73 for paving bitumen of a particular viscosity grade. The most commonly used asphalt grade is VG 30.

Fig. 1 Bitumen

3.2. Aggregate

Aggregate is an essential element in constructing bituminous pavement. As an illustration of a hard, inert substance known as an aggregate, consider sand, gravel, crushed stone, slag, or rock dust (or mineral aggregates). In order to generate hot mix asphalt pavement, bitumen must blend with carefully chosen and graded aggregate (HMA). The sizes of the aggregates used are 20 mm coarse and 10 mm fine.

Fig. 2 Normal Aggregate

3.3. Filler

IRC: 111-2009 will be followed when using filler in dense graded mixes. Lime and stone powder filler with a 6 mm thickness is used.

3.4. RAP

Aggregate is an essential ingredient in constructing bituminous pavement. Hard, inert materials like aggregates are an example. They consist of rock dust, crushed stone, slag, and sand (or mineral aggregates). In order to generate hot mix asphalt pavement, bitumen must blend with carefully chosen and graded aggregate (HMA). Between 75 and 85% of the mixture's volume and 90 to 95 percent of its weight is made up of them. Both coarse and fine aggregates are used in 20 mm and 10 mm diameters.

Fig. 3 Recycled Asphalt Pavement (RAP)

3.5. Plastic waste

Plastic is being used more and more every day. Even though Plastic is neither environmentally friendly nor biodegradable, it is nonetheless useful. It takes close to 100 to 200 years for the thrown Plastic to decompose. In India, waste plastic amounts to more than 13.5 million tonnes annually. For the purpose of making flexible pavement, it can be added as an addition.

Compared to conventional roads, plastic roads provide many benefits, including a hollow space for the absorption of extra rainwater and benefits for sustainability.

Table 1. Physical and mechanical properties of reclaimed asphalt pavement (RAP)

Type of Property	RAP Property	Typical Range of Values
Physical Properties	Unit Weight	1940-2300 kg/m^3 (120-140 lb./ft^3)
	Moisture Content	Normal: up to 5% Maximum:7-8 %
	Asphalt Content	Normal: 4.5-6% Maximum: 3-7%
	Asphalt Penetration	Normal: 10-80 at 25^{0}C (77 ^{0}F)
	Absolute Viscosity or Recovered Asphalt cement	Normal: 4,000-25,000 poises at 60 0C (140 ^{0}F)
Mechanical Properties	Compacted Unit Weight	1600-2000 kg/m^3 (100-125 lb./ft^3)
	California Bearing Ratio (CBR)	100% RAP: 20-25% 40% RAP and 60% Natural Aggregate:150% or higher

Fig. 4 Plastic Coated Aggregate (PCA)

Table 2. Waste plastics and its origin

Waste Plastic	Origin
Low-Density Polyethylene (LDPE)	Carry bags, sacks, milk pouches, bin lining, cosmetic and detergent bottles.
High-Density Polyethylene (HDPE)	Carry bags, bottle caps, household articles etc.
Polyethylene Teryphthalate (PET)	Drinking water bottles etc.
Polypropylene (PP)	Bottle caps and closures, wrappers of detergent, biscuits, wafer packets, microwave trays for a readymade meal etc.
Polystyrene (PS)	Yoghurt pots, clear egg packs, bottle caps. Foamed Polystyrene: food trays, egg boxes, disposable cups, protective packaging etc.
Polyvinyl Chloride (PVC)	Mineral water bottles, credit cards, toys, pipes and gutters: electrical fittings, furniture, folders and pens, medical disposables: etc.

4. Design Mix

In this study, we have divided the work into Two Group I & Group II

Group I: Conventional Aggregate

Group II: Recycled Aggregate

In Group I: Conventional Aggregate coating is further divided into Three Cases where aggregate is coated with:

Case A1: Bitumen (5.87%)

Case A2: Optimum Plastic % initially, then coating with Bitumen

Case A3: Modified Bitumen + Plastic Paving Mix (5%, 6.25%, 7.5%, 8.75% & 10%)

Group II: Recycled aggregate coating is further divided into three cases where aggregate is coated with

Case B1: Bitumen (5.87%)

Case B2: Optimum Plastic % initially, then coating with bitumen.

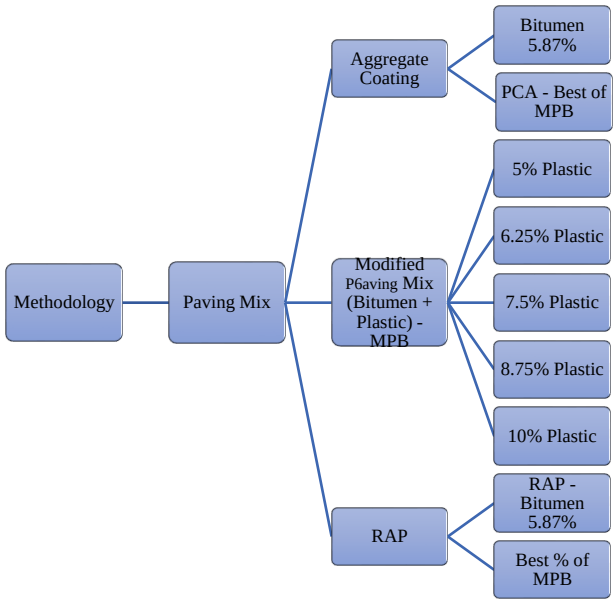

Fig. 5 Flow chart of Design Mix for Research

Table 3. As per IS:73 –1992 (VG-30) The limit of Physical properties of Bitumen

	Test on Bitumen	Permissible limit	Test Method
1	Specific Gravity of Bitumen	0.99 (min.)	IS:1202-1978
2	The softening point of Bitumen	47 ^{0}C	IS:1202-1978
3	Penetration Bitumen Test	55-70 (min.)	IS:1203-1978
4	Ductility Test	40 (min.)	IS:1208-1978/ ASTM D4402
5	Flash Point of Bitumen	220 ^{0}C	IS:1209-1978

5. Results and Discussion

Table 4. Properties of Aggregate test results

Test on Aggregate		NA	PCA
1	Impact Value Test	13.67	13.34
2	Los Angeles Abrasion Value Test		
	Aggregate – 10 mm	15.79	15.63
	Aggregate – 20 mm	14.28	14.21
3	Elongation Index and Flakiness Index Value Test	18.55	18.45
4	Water Absorption Test		
	Aggregate – 16-6 mm	1.884	1.790
	Aggregate – 6-3 mm	1.824	1.868
	Aggregate – 3-0 mm	2.384	2.215
5	Specific Gravity Test		
	Aggregate – 16-6 mm	2.704	2.686
	Aggregate – 6-3 mm	2.696	2.672
	Aggregate – 3-0 mm	2.665	2.600
	Rock Filler	2.533	2.445
6	Bulk of Specific Gravity Test	2.679	2.633

4.1 Softening Point Test

- Because it has been observed that when more bituminous material replaces with Plastic, the softening point of all combinations continues to fall.
- The softening points for CB, A3/1, A3/2, A3/3, A3/4, and A3/5 were found to be 50.4, 49.4, 48.1, 47.3, 46.5, and 45.4, respectively.
- A3/3 has observed that when the asphalt is replaced with Plastic, the results are ideal according to the IS code limit.
- It determines that the softening point meets the criteria of the standard when Plastic replaces bituminous, and the range is between 6.25 and 8.75.
- The appropriate percentage replacement for bituminous with Plastic was identified to be 7.5.
- The best performance was found at 47.3o C when bituminous material was used.
- We found that the values of comparable plain bitumen with modified polymer bitumen (MPB) were reduced.

Table 5. Bitumen test results

	0	5	6.25	7.5	8.75	10
	CB	A3/1	A3/2	A3/3	A3/4	A3/5
Softening Point Test	50.40	49.40	48.10	47.30	46.50	45.40
Penetration Value Test	56.0	55.0	52.50	58.0	56.80	53.0
Ductility Test	42.0	43.0	44.50	45.0	42.60	45.60
Flash Point Test	300	304	302	298	256	245
Marshall Stablility Test	10.470	10.760	14.570	15.430	15.160	15.260
Marshall Flow	2.00	2.05	3.60	3.90	4.10	4.03
VMA %	15.360	19.870	20.540	23.630	24.910	27.380
Air Voids (VA)	6.167	6.443	4.146	5.095	3.880	4.250
VFB %	59.860	67.580	79.812	78.437	84.440	84.490
Absorbed Binder by Wt. of Total Mix (Pbe)	4.320	3.680	4.951	6.218	7.490	8.750
Marshall Quotient	5.233	5.250	4.048	3.956	3.698	3.783
Specific Gravity of Bitumen	1.064	1.066	1.069	1.064	1.071	1.068
Fines to Binder Ratio	1.072	0.798	0.635	0.528	0.528	0.451

4.2. Penetration Test

- Because it has been observed that as more Plastic is utilised to replace bituminous material, the penetration test within all combinations continues to fall.
- The penetration tests by CB, A3/1, A3/2, A3/3, A3/4, and A3/5 were determined to have values of 56,55,52.5,58,56.8 and 53 minutes, respectively.
- A3/3 has observed that when bitumen is replaced with Plastic, the results are ideal based on the IS code limit.
- The penetration test meets the regulatory requirements when the asphalt layer is replaced with plastics, and the range is between 6.25 and 8.75.
- The optimum percentage replacement for bitumen with Plastic was observed to be 7.5.
- The optimum results obtain by replacing 7.5% of the bituminous material.

- Using modified polymer bitumen, we found lower values when compared to standard bitumen (MPB).

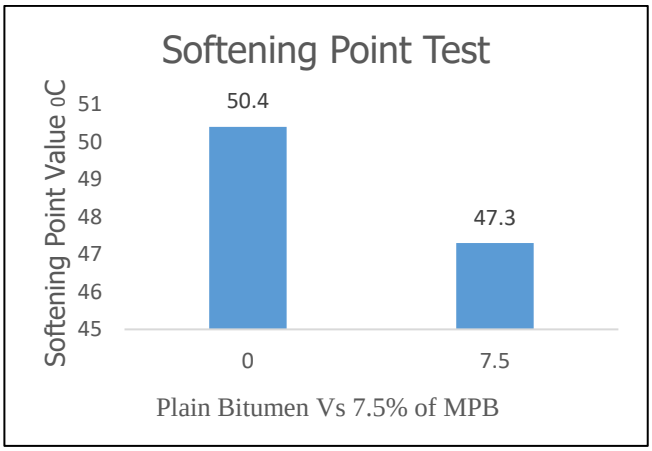

Fig. 6 Softening point test with % of MPB

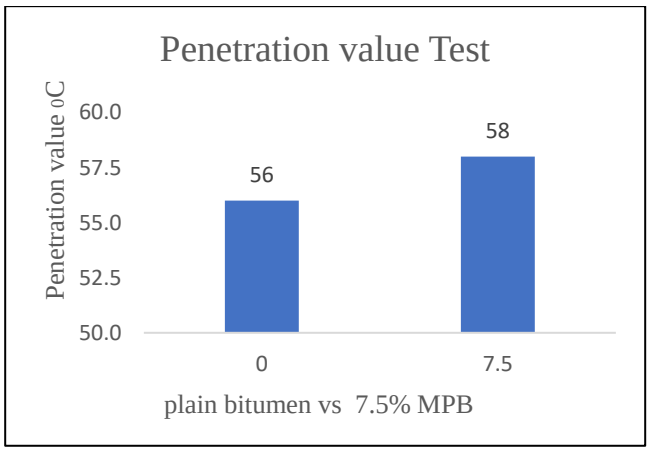

Fig. 7 Penetration test with % MPB

5.3 Ductility Test

- As noted, the ductility test for all combinations decreases as the percentage of bituminous replaced by plastic increases.
- CB, A3/1, A3/2, A3/3, A3/4, and A3/5 ductility tests were determined to be 42, 43, 44.5, 45, 42.6, and 45.6 minutes, respectively.
- When asphalt is replaced with Plastic, A3/3 produces the best results according to IS code limits.
- It was found that the Ductility test exceeds the standard requirement, so when replacing bituminous with Plastic is within the range of 6.25 to 8.75.
- The best optimal% replacement for bituminous by plastics was found to be 7.5.
- We observed that the 7.5% bituminous replacement by plastics has a 45(min) value, which gives the best results.
- We noticed a rise in the value of comparable plain asphalt with modified polymer bitumen (MPB).

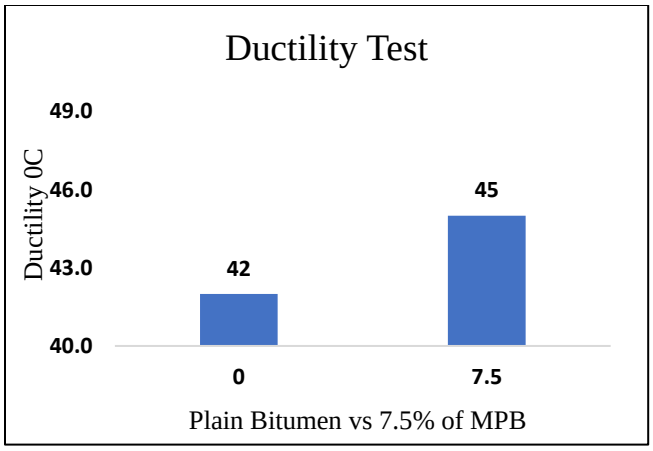

Fig. 8 Ductility test with % MPB

5.4 Flash Point Test

- we observed that the Flash Point test, for all combinations, reduces as the percentage of asphalt replaced by plastic increases.
- CB, A3/1, A3/2, A3/3, A3/4, and A3/5 flash point tests produced values of 300,304,302,298,256, and 245oC, respectively.
- When asphalt is replaced with Plastic, A3/3 produces the best results according to IS code limits.
- It was discovered that the Flash point test exceeds the standard requirement when the bitumen replacement by Plastic is within the range of 6.25 to 8.75.
- The best optimal% replacement for bitumen by Plastic was discovered to be 7.5.
- We observed that the 7.5% bituminous replacement with plastics has a 298oC value, which produces the best results.
- We found that the values of similar plain asphalt with modified polymer bitumen (MPB) increased.

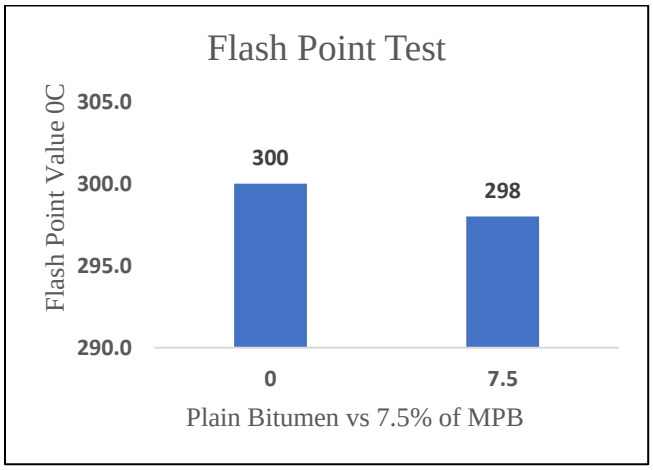

Fig. 9 Flash point test with % MPB

5.5. Specific Gravity of Bitumen

- Because we found that the Specific gravity test for all continues to decrease as the percentage of bituminous replaced by plastic increases.
- CB, A3/1, A3/2, A3/3, A3/4, and A3/5 specific gravity tests showed values of 1.064, 1.066, 1.069,1.064,1.071, and 1.068 min., respectively.
- The best optimal% replacement for bitumen by plastics was found to be 1.064.

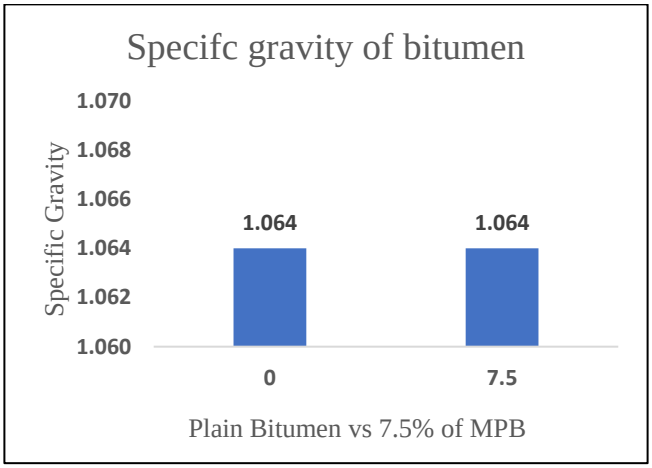

Fig. 10 Specific gravity of bitumen

5.6. Marshall Stability Test

- As more bituminous is replaced by Plastic, the Marshall stability test for all combinations has been shown to degrade.
- As more bituminous is replaced by Plastic, the Marshall stability test for all combinations has been shown to degrade.
- According to IS code standards, A3/3 produces the best outcomes when the asphalt is replaced with Plastic.
- When bituminous is replaced by Plastic and the range of the bituminous replacement is between 6.25 and 8.75, it was observed that the Marshall stability test satisfies the standard requirement.
- The best acceptable replacement rate for bituminous by plastics was observed to be 7.5.
- The best optimal proportion for replacing bituminous materials with Plastic was found to be 7.5.
- We observed an increase in the values of comparable plain bitumen with modified polymer bitumen (MPB).

5.7. Marshall Flow Test

- Due to the fact that the Marshall flow test for all combinations has been found to decline with a growing percentage of Plastic replacing asphalt
- Marshall flow values were determined to be 2.05, 2.05, 3.60, 3.90, 4.10, and 4.03 mm for CB, A3/1, A3/2, A3/3, A3/4, and A3/5, respectively.
- According to IS code guidelines, A3/3 yields the best results when Plastic is used in place of asphalt.
- When bituminous by plastics replacement ranges between 6.25 to 8.75, it was discovered that the Marshall flow value exceeds the required standard.
- The best optimal percentage for replacing bituminous with Plastic was found to be 7.5.
- The best results, measured as a 3.90 mm value, are obtained when Plastic replaces 7.5% bitumen.
- The values of the equivalent plain bitumen were raised by the modified polymer bitumen (MPB).

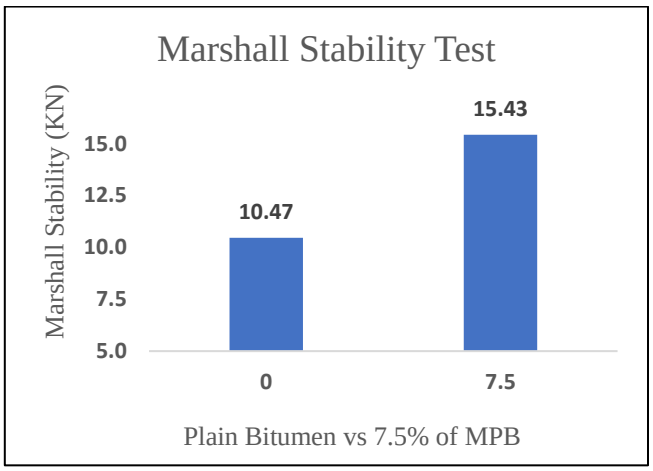

Fig. 11 Marshall Stability test with % of MPB

5.8. Bitumen Extraction Test

- Using a milling machine to extract a sample of RAP, we conducted this test to evaluate the bitumen content in the RAP aggregate.
- The bitumen percentage in the bitumen extraction test result was found to be 5-6%.
- We noticed that Reclaimed Asphalt Pavement (RAP) aggregate values increased compared to Normal aggregate.

5.9 Impact Value Test On Aggregate

- Aggregate crushing tests can determine the strength of coarse aggregate.
- To obtain a high level of pavement quality, aggregates with strong crushing resistance or a low aggregate crushing value are desired.
- We observed the values of Impact value comparable with Plastic coated aggregate (PCA) as higher Toughness compared to Normal aggregate and RAP aggregate.

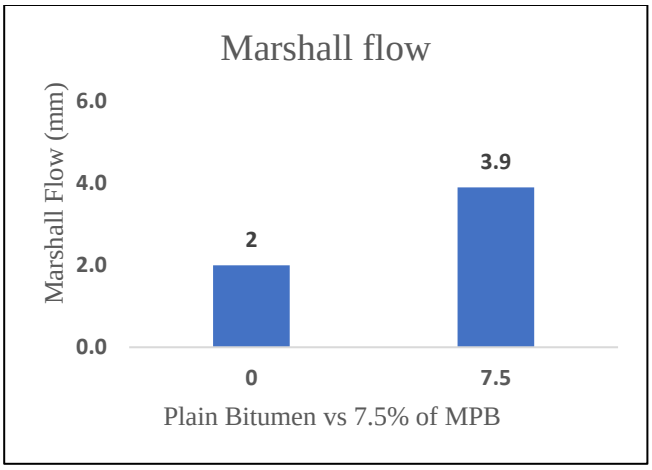

Fig. 12 Marshall flow value with % of MPB

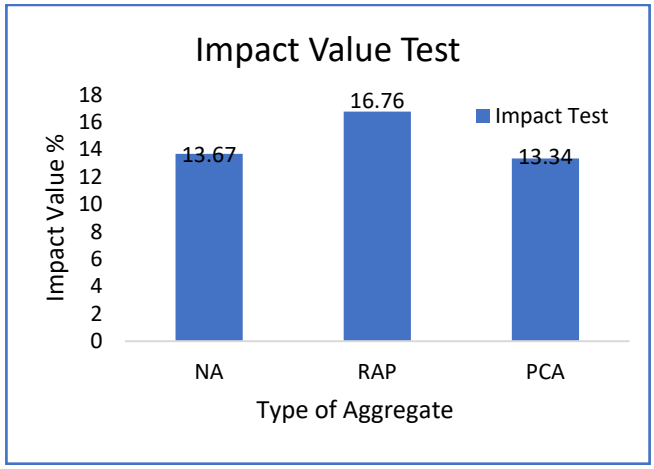

Fig. 13 Results of Impact value Comparison of NA with PCA & RAP

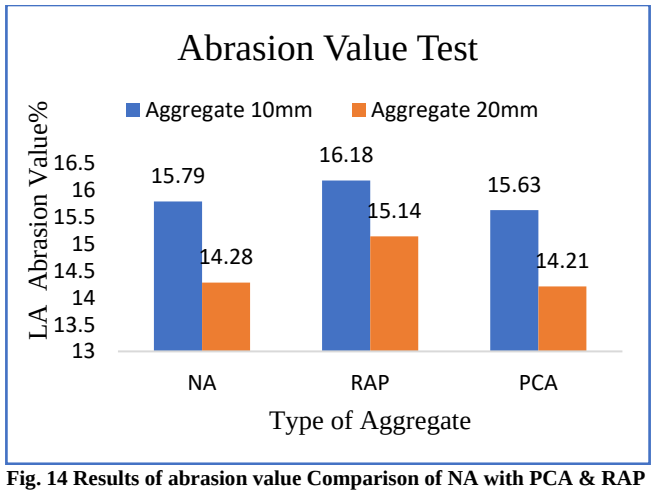

Fig. 14 Results of abrasion value Comparison of NA with PCA & RAP

5.10. Los Angeles Abrasion Test On Aggregate

- The Los Angeles Abrasion test calculates the percentage of wear brought on by relative rubbing.
- We observed that the abrasion values have great strength, so PCA (Plastic coated aggregates) gives higher strength compared to Normal and Recycled asphalt pavement aggregate.

6. Conclusion

1. The effect values experiment found that the quantity of recycled plastic content decreased as the amount of sustainable materials content increased. The highest ideal outcome of an Impact value test included a% replacement for bitumen by Plastic, with 7.5% replacement offering the finest result. It also concluded that RAP aggregate values were lower and normal aggregate values were higher when compared to PCA and normal aggregate values.
2. The value of the Los Angeles Abrasion test decreases as the recycled plastic content increases. The greater ideal result of the Abrasion test had a% replacement for bituminous by plastics, with 7.5% replacement offering the best result. It also concluded that RAP aggregate values were lower or normal aggregate values appeared to be more significant when compared to waste plastics or normal aggregate values.
3. It was observed that Flakiness and Elongation index values decreased as RAP content increased.
4. The strength increases as the specific gravity. The specific gravity of natural aggregates is higher than that of PCA but lower than that of RAP aggregate. As a result, the specific gravity of aggregate values increased, as would their strength.
5. Normal aggregate penetration values decrease as waste plastic content increases, as does RAP-coated aggregate, including waste plastic. MPB-modified bitumen is more durable and uniform than the ordinary aggregate. It determined that increasing rutting resistance was favourable.
6. The Softening point test values of regular aggregate decrease as waste plastic content and RAP coated with waste plastic increase.
7. The Ductility test results of regular aggregate decreased as the waste plastic manufacturing MPB content increased and increased as the RAP-coated aggregate with plastic wastes increased. Increased ductility value owing to polymer interlocking has excess waste plastic material, making bitumen stiffer.
8. It has been observed that the flash point value will increase as the percentage of waste plastic components increases.
9. It was observed that the Marshall Stability test results increase as an increase in the normal aggregate with MPB, and it was also seen that the RAP aggregates with MPB Marshall stability test values increase.
10. It was observed that the Marshall flow values increased as the average aggregate with MPB increased, and so the RAP aggregates to MPB Marshall stability test findings.
11. Overall, the results show that plastics coated aggregate (PCA) and recycled asphalt pavement aggregates

(RAP) are more cost-effective and environmentally friendly materials to employ in the bituminous pavement.

12. Compared to the conventional aggregate, the PCA and RAP produce the highest results, while the RAP produces the poorest.

Conflicts of Interest

Hereby, I declare that there is no conflict of interest regarding the publication of this paper.

Acknowledgments

I am beholden to Ms. Madhulika Sinha (Professor, Pillai HOC College of Engineering and Technology), Mr. Shrikant Varpe (Deputy Manager, Ambuja Cements Ltd, Mumbai), J.M Mhatre Infrastructure (Quality work team) for explaining to me the diverse facts of the experimental work involved in our present study.

Last but not least, I express my gratitude to those who directly or indirectly helped complete our studies.

Table 6. Comparison with Plain bitumen with MPB %

	CB	A3/1	A3/2	A3/3	A3/4	A3/5
Test on Bitumen	**Type of MPB**					
Softening Point Test	0.00	-1.980	-4.560	-6.150	-7.740	-9.920
Penetration value Test	0.00	-1.790	-6.250	3.570	1.430	-5.360
Ductility Test	0.00	2.380	5.950	7.140	1.430	8.570
Flash Point Test	0.00	1.330	0.670	-0.670	14.670	-18.33
Marshall Stability Test	0.00	2.830	39.25	47.43	44.85	45.81
Marshall Flow	0.00	2.500	80.00	95.00	105.00	101.67
VMA %	0.00	29.380	33.720	53.840	62.170	78.260
Air Voids (Va)	0.00	4.480	32.770	17.380	-37.08	-31.08
VFB %	0.00	12.890	33.320	31.030	41.050	41.140
Absorbed binder by Weight of Total mix (Pbe)	0.00	14.780	14.540	43.870	73.190	102.51
Marshall Quotient	0.00	0.320	22.640	24.390	29.340	27.700
Fines To Binder ratio	0.00	-25.60	40.760	50.790	50.790	57.920

References

[1] Indian Roads Congress IRC: 37-2012 - Guidelines for the Design of Flexible Pavements-August, 2012

[2] Dr. R. Vasudevan, et al., "Utilisation of Waste Polymers for Flexible Pavement and Easy Disposal of Waste Polymer," *Proceedings of the International Conference on Sustainable Solid Waste Management*,5 - 7 September 2007, Chennai, India, pp.105-111, 2007. *Crossref*, https://doi.org/10.6135/IJPRT.ORG.TW%2F2010.3%281%29.34

[3] Amit Gawand, et al., "An Overview on Waste Plastic Utilisation in Asphalting of Roads," *Journal of Engineering Research and Studies*, vol .3, no. 2, pp. 01-05, 2012.

[4] Miss Apurva J Chavan, "Use of Waste Plastic in Flexible Pavements," *International Journal of Application or Innovation in Engineering and Management*, 2013.

[5] S. Varun, and M. Vasudeva Naidu, "Experimental Study on Use of Plastic Waste in Flexible Pavements," *International Journal of Engineering Science and Computing*, vol. 6, no. 10, pp. 2987-2995, 2016.

[6] Dr. Umesh Sharma, Giri, Harish Kumar, and Khatri, Ankita, "Use of Recycled Asphalt Material for Sustainable Road Construction," *Indian Highways* , vol. 46, no. 9, pp. 29-36, 2018.

[7] Prashant Singh, et al., "Use of Plastic Waste in Flexible Pavement – Green Highway," *International Journal of Engineering Research & Technology (IJERT)*,vol. 9, no. 9, pp. 751-757, 2020. *Crosref*, https://doi.org/10.17577/IJERTV9IS090423

[8] S.Rajasekaran, Dr. R. Vasudevan, and Dr. Samuvel Paulraj , "Reuse of Waste Plastics Coated Aggregates-Bitumen Mix Composite for Road Application – Green Method," *American Journal of Engineering Research (AJER)*, vol. 2, no. 11, pp. 01-13,2013.

[9] Sasane Neha.B, et al., "Application of Waste Plastic as an Effective Construction Material in Flexible Pavement," *International Research Journal of Engineering and Technology (IRJET)*, vol. 2, no. 3, pp. 1943-1948, 2015.

[10] Amit Tyagi, and Apoorv Agarwal, "Use of Plastic Waste in Construction of Flexible Pavement: A Creative Waste Management Idea," *International Journal of Engineering Research & Technology (IJERT)*, vol. 4, no. 23, 2016. *Crossref*, https://doi.org/10.17577/IJERTCONV4IS23072

[11] Dr. Soosan George T, et al., "Pavements Using Reclaimed Aggregates," *Civil Engineering and Urban Planning: An International Journal*, vol. 3, no. 2, 2016. *Crossref*, https://doi.org/10.5121/civej.2016.3213

[12] R. Manju, Sathya S, and Sheema K, "Use of Plastic Waste in Bituminous Pavement," *International Journal of Chemtech Research*,vol. 10, no. 8, pp. 804-811, 2017.

[13] Rasha H Ali, "New Innovation in Concrete Using Industrial and Agricultural Wastes," *SSRG International Journal of Civil Engineering*, vol. 9, no. 5, pp. 16-19, 2022. *Crossref*, https://doi.org/10.14445/23488352/IJCE-V9I5P103

[14] Dr. Umesh Sharma, Giri, Harish Kumar, and Khatri, Ankita, "Use of Recycled Asphalt Material for Sustainable Road Construction," *Indian Highways*, vol. 46, no. 9, 2018.

[15] Dr. S.L. Hake, R M Damgir, and Prashant Ramesh Patil Awsarmal , "Utilization of Plastic Waste in Bitumen Mixes for Flexible Pavement," *Elsevier*, vol. 48, pp. 3779-3785, 2020. *Crossref*, https://doi.org/10.1016/j.trpro.2020.08.041

[16] Salim G. Shaikh, et al., "Scientific Study of Asphalt Road Surface Distress and Their Role in the Design of Flexible Pavements," *International Journal of Engineering Trends and Technology*, vol. 70, no. 3, pp. 241-248, 2022. *Crossref*, https://doi.org/10.14445/22315381/IJETT-V70I1P227

[17] S Naveen Bheempal, and B Vinayaka , "Use of Waste Plastic in Flexible Pavement Construction", *SAMRIDDHI-A Journal of Physical Sciences, Engineering and Technology*, vol.10, 2019. *Crossref*, https://doi.org/10.18090/samriddhi.v11iSUP-1.17387

[18] Anuj Bhardwaj, et al., "Plastic Used in Flexible Pavements: Retrospects and Prospects," *2020 International Conference on Intelligent Engineering and Management*, 2020. *Crossref*, https://doi.org/10.1109/ICIEM48762.2020.9160181

[19] Rajneesh Kumar, and Maaz Allah Khan, "Use of Plastic Waste Along With Bitumen in Construction of Flexible Pavements," *International Journal of Engineering Research & Technology (IJERT)*, vol. 9, no. 3, 2020. *Crossref*, https://doi.org/10.17577/IJERTV9IS030069

[20] Arcita Biswasa, Amit Goela, and Sandeep Potnisb, "Performance Comparison of Waste Plastic Modified Versus Conventional Bituminous Roads in Pune City: A Case Study," *Case Studies in Construction Materials*, vol. 13, pp. e00411, 2020. *Crossref*, https://doi.org/10.1016/j.cscm.2020.e00411

[21] S. M. Mhlongo, et al., "Use of Recycled Asphalt Materials for Sustainable Construction and Rehabilitation of Roads," *International Conference on Biological, Civil and Environmental Engineering (BCEE-2014)* March 17-18, 2014 Dubai (UAE), 2014. *Crossref*, https://doi.org/10.15242/iicbe.c0314157