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Analysis of construction and industrial waste to strengthen flexible pavement

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Abstract: The most common type of pavement utilized in road construction is flexible pavement. By-products of crude oil are used to produce asphalt pavement, an organic material with binding properties. The country's development and growth rely on its ability to connect to its different rural areas. Flexible pavement provides the majority of connections; thus, improving the condition of bituminous roads is essential to avoid severe accidents on the roads. Given the situation, when waste materials like plastic and recycled asphalt pavement aggregates are growing daily, it is imperative to utilize this waste as much as possible so that the performance should either improve or remains stable as compared to conventional materials.

Keywords: Plastic waste, Bitumen, Modified plastic Bitumen, Recycled Asphalt pavement (RAP).

I. INTRODUCTION

The transportation infrastructure is an important element in today's growth and population. The transportation facility is completely dependent on roads during construction. Bituminous roads play an essential role in today's infrastructure in this approach. In order to change its qualities, bitumen is mixed with waste. Bitumen is a good binder and is used in the construction of roads. This modified bitumen contains natural elements and exhibits improved binding properties, stability, and resistance to water, improving the life of roads and reducing wear and strain.

According to research, common plastic products can take up to a thousand years to break down in landfills. As a result, waste plastic is one of several wastes that take too long to decompose. It might be difficult to dispose of plastic wastes consisting mostly of polyolefin, which are produced when products like carry bags, mugs, thermocol, and packing films are used.

When compared to virgin asphalt mixtures, RAP can yield comparable structural efficiency and is viewed as a low-cost and environmentally beneficial process. This substance can be used in new asphalt mixtures because of aggregates and bitumen binder in the mixture always have significance. Utilizing RAP in unique combinations can reduce the amount of new material that must be added, saving both money and natural resources. It's likely that the old binders will make the new ones unneeded. During construction and the lifespan of the road from which the RAP was extracted, the oxygen in the air caused the asphalt mix in the highway to age or stiffen.

Road construction projects have utilized RAP since the 1930s. RAP reduces the amount of fresh aggregate and asphalt used, which decreases building material prices, cuts down on the consumption of a product based on petroleum, and helps to preserve natural resources.

We use these waste materials to build pavement because they provide durability and corrosion resistance. Effective insulation against cold, heat, and sound has a positive impact on energy consumption and noise pollution. It costs less and lasts longer. It requires no maintenance, is easy to install and process, and is lightweight. RAP offers more benefits and is more economical.

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II. LITERATURE REVIEW

Dr. R. Vasudevan is an Indian Scientist has worked on waste management. His researches the damage roads caused by heavy rains and they decided the use of plastic in construction roads [1]. The use of recycled waste plastic of 5-10% be weight in asphalt pavement it improves performance of pavement and results shows that the waste plastic modified bitumen blend indicates effective binding property, density, and stability and more water resistive [2]. The use of waste plastic bag is heated and then coated to the aggregates. This coated aggregate in bituminous mixes are used in the road construction it strengthens the road and improves the life of pavement [3]. Plastic coated aggregate is better raw material for pavement and it improved binding property and less wetting property. These found that PCA is well performed of bituminous pavement and this process is eco-friendly and economical [4]. The use of 100% RAP in HMA mixture is for construction or maintenance purpose [5]. The use of waste plastic in flexible pavement it improves the pavement life and quality and increases the aggregate and bitumen properties. In that the conducted the laboratory tests on bitumen, aggregate-plastic-coated with bitumen [6]. The plastic waste mix with bitumen is affected to the performance of pavement such as fatigue, rutting, cracking and also it increases the strength, durability and water resistant [7].

III. RAW MATERIAL

A. 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 the base course, 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.

B. Aggregate – Aggregate is one of the important materials used in bituminous pavement construction. aggregates (or mineral aggregates) are hard, inert materials such as sand, gravel, crushed stone, slag or rock dust. Properly selected and graded aggregates are mixed with bitumen to form pavement of hot mix asphalt (HMA). They total 90 to 95 percent of the mixture by weight and 75 to 85 percent by volume. They are two types of aggregates are used like coarse and fine sizes 20 mm and 10 mm.

C. Filler – The filler for dense graded mixes shall comply with IRC: 111-2009. 6 mm and stone dust and lime are used for filler.

D. RAP – Reclaimed Asphalt pavement is defined as removed pavement materials by milling asphalt and aggregates. When properly crushed and screened, RAP consists of high-quality, well–graded aggregate coated with asphalt cement. The majority of the RAP that is produced is recycled and used. Recycled RAP is almost always returned to the roadway structure in some form, usually incorporated into asphalt paving using hot or cold recycling, but it is also sometimes used as an aggregate in base or subbase construction.

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 Range: 3-7%
	Asphalt Penetration	Normal: 10-80 at 25°C (77°F)
	Absolute Viscosity or Recovered Asphalt Cement	Normal: 4,000 - 25,000 poises at 60°C (140°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

E. Plastic waste – Plastic consumption is increasing day by day. Plastic is non-biodegradable and not eco-friendly but it is user-friendly. This waste takes almost 100 years to 200 years to decompose the waste plastic material. In India, more than 13.5 million tons of plastics wastes are generated all over the country. It can be used as an additive in the

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construction of flexible pavement. Plastic roads have a lot of advantages compared to normal roads, including hollow space for the storage of excessive rainwater lightweight and sustainability benefits.

Table 2 Waste plastics and their 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, house hold articles etc.
Polyethylene Teryphthalate (PET)	Drinking water bottles etc.
Polypropylene (PP)	Bottle caps and closures, wrappers of detergent, biscuit, wafer packets, microwave trays for readymade meal etc.,
Polystyrene (PS)	Yoghurt pots, clear egg packs, bottle caps. Foamed Polystyrene: food trays, egg boxes, disposable cups, protective packagine etc.
Polyvinyl Chloride (PVC)	Mineral water bottles, credit cards, toys, pipes and gutters; electrical fittings, furniture, folders and pens, medical disposables; etc.

IV RAW MATERIAL

We separated the work in this study into two groups: Group I and Group II.
Group I: Standard Aggregate
Recycled Aggregate, Group II
Group I: Conventional Aggregate Coating is further separated into three scenarios in which the following three coatings are used on the aggregate:
Case A1: Bitumen (5.77%)
Case A2: Bitumen is first coated on top of Optimum Plastic%.
Case A3: Modified bitumen with plastic paver mix (5%, 6.25%, 7.5%, 8.75%, & 10%)
Group II: Coated recycled aggregate is further separated into three examples when aggregate is coated with
Case B1: bitumen (5.87%)
Case B2: Bitumen was used after the initial application of Optimum Plastic%.

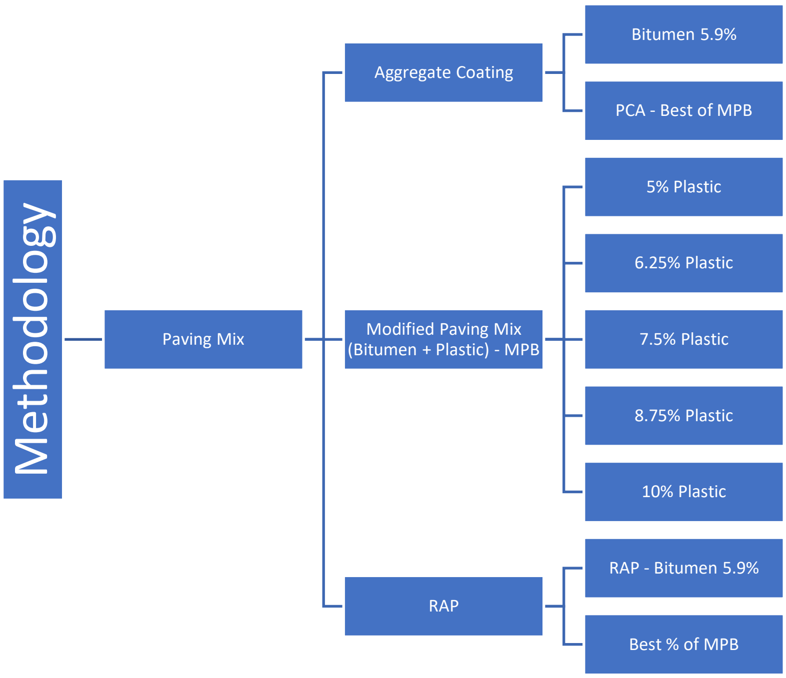

Figure 1 Flow chart of Design Mix

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

Test on Bitumen	Test results (NA)	Test results (MPB) 7.5%	Permissible limit	Test Method
Specific gravity of bitumen	1.064	1.064	0.99 (min.)	IS: 1202 -1978
Softening point of bitumen	50.4	47.3	47 °C	IS: 1205 – 1978
Bitumen penetration test	56	58	50-70 (min.)	IS: 1203 – 1978
Ductility test	42	45	40 (min.)	IS: 1208 – 1978/ ASTM D4402
Flash point of bitumen	300	308	220 °C	IS: 1209 - 1978

V TEST RESULTS AND DISCUSSION

Table 4 Properties of Aggregate test results

Designation	Test results (NA)	Test results (RAP)	Test results (PCA)	Permissible limit (MORT&H-specification)	Test results
Aggregate Impact test	13.67	16.76	13.34	Max 27%	IS: 2386 (Part-4)
Specific gravity of aggregate					
16-6 mm	2.704	2.790	2.686	Not Specified	IS: 2386 (Part-3)
6-3 mm	2.696	2.720	2.672	Not Specified	IS: 2386 (Part-3)
3mm below	2.665	2.606	2.600	Not Specified	IS: 2386 (Part-3)
Rock filler	2.533	2.952	2.445	Not Specified	IS: 2386 (Part-3)
Bulk Specific gravity of Total aggregate (Gsb)	2.678	2.669	2.632	-	IS: 2386 (Part-3)
FI & EI Test	18.55	18.52	18.45	Max 35%	IS: 2386 (Part-1)
Abrasion test (10 mm)	15.79	16.18	15.63	Max 35%	ASTM C131
Abrasion test (20 mm)	14.28	15.14	14.21	Max 35%	ASTM C131
Water absorption test					
16- 6 mm	1.884	2.169	1.790	Max 2%	IS: 2386 (Part-3)
6-3 mm	1.824	2.060	1.868	Max 2%	IS: 2386 (Part-3)
3 mm below	2.384	2.636	2.215	Max 2%	IS: 2386 (Part-3)

- Softening Point Test –

Because it has been noticed that the softening point with all combinations continues to decline when more bituminous material is replaced by plastic. It was discovered that the values of the softening points for CB, A3/1, A3/2, A3/3, A3/4, and A3/5 were 50.4, 49.4, 48.1, 47.3, 46.5, and 45.4, respectively. When bitumen is substituted with plastic, it has been noted by A3/3 that the results are optimal according to the IS code limit. It was discovered that the softening point satisfies the requirements of the standard with bituminous is replaced by plastic and the range is between 6.25 and 8.75. The best optimal% replacement for replacing bituminous with plastic was discovered to be 7.5. The best performance was found at 47.3º C when bituminous material was replaced with plastic by 7.5%. We observed the comparable plain bitumen with modified polymer bitumen (MPB) values reduced.

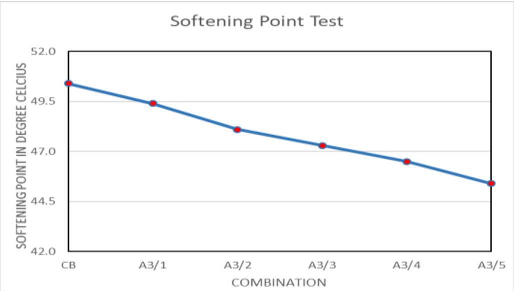

Figure 2 Softening point test with % of MPB

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F. Penetration Test-

Because it has been noted that the penetration test with all combinations continues to decline as more plastic is used to replace bituminous material. It was found that the penetration tests by CB, A3/1, A3/2, A3/3, A3/4, and A3/5 had values of 56,55,52.5,58,56.8 and 53 minutes, respectively. When bitumen is substituted with plastic, it has been noted by A3/3 that the results are optimal according to the IS code limit. It was noted that when the bituminous layer is replaced with plastic and the range is between 6.25 and 8.75, the penetration test satisfies the requirements of the standard. The best optimal% replacement for replacing bituminous with plastic was discovered to be 7.5. The best result was seen when 7.5% of bituminous material was replaced with plastic, with a value of 58 (min). We observed decreased values compared to ordinary bitumen using modified polymer bitumen (MPB).

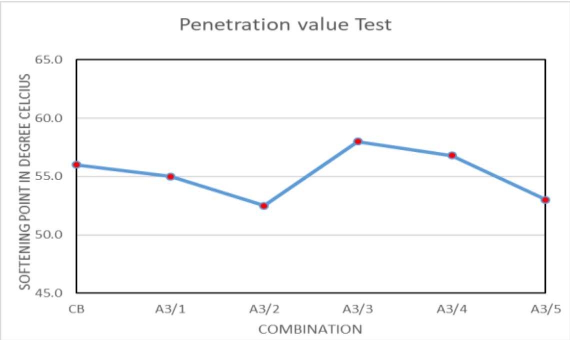

Figure 3 Penetration test with % MPB

G. DUCTILITY TEST

Because observed the Ductility test for all the combinations goes on decreasing with the increasing % of replaced bituminous by plastic Ductility tests by CB, A3/1, A3/2, A3/3, A3/4, and A3/5 were found to value 42, 43, 44.5, 45, 42.6, and 45.6 min. respectively. It was observed by A3/3 gives the best results as per IS code limit when bitumen is replaced by plastic. It was observed the Ductility test fulfils the requirement of in the standard when the replacement of bituminous by plastic, is within the limit of 6.25 to 8.75. To get the best optimum % replacement for the replacement of bituminous by plastic was found to be 7.5. We observed the 7.5 % replacement of bituminous by plastic has a 45(min) value which gives the best result. We observed the comparable plain bitumen with modified polymer bitumen (MPB) value increased.

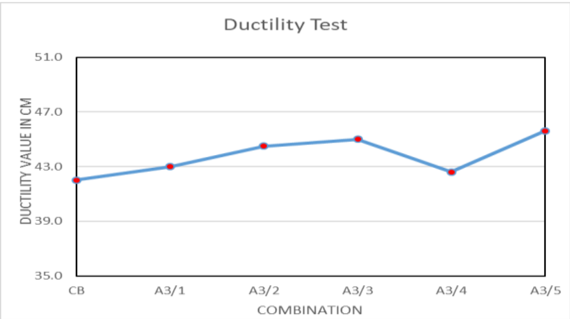

Figure 4 Ductility test with % of MPB

H. FLASH POINT TEST

Because we observed the Flash Point test for all the combinations goes on decreasing with the increasing % of replaced bituminous by plastic. Flash points tests by CB, A3/1, A3/2, A3/3, A3/4, and A3/5 were found to value 300,304,302,298,256, 245oC respectively. It was observed by A3/3 gives the best results as per IS code limit when bitumen is replaced by plastic. It was observed the Flash point test fulfils the requirement of in the standard when the replacement of bituminous by plastic, is within the limit of 6.25 to 8.75. To get the best optimum % replacement for the replacement of bituminous by plastic was found to be 7.5. We observed the 7.5 % replacement of bituminous by plastic has a 298oC value which gives the best result. We observed the comparable plain bitumen with modified polymer bitumen (MPB) values increased.

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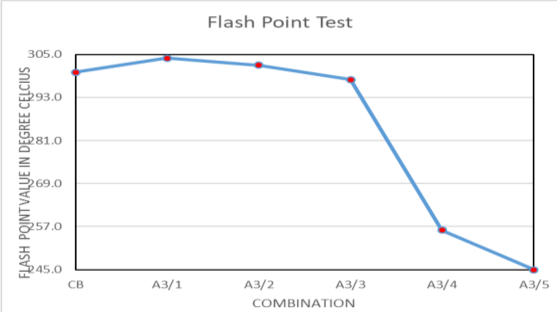

Figure 5 Flash point test with % MPB

I. SPECIFIC GRAVITY OF BITUMEN

Because we observed the Specific gravity test for all the goes on decreasing with the increasing % of replaced bituminous by plastic. Specific gravity tests by CB, A3/1, A3/2, A3/3, A3/4, and A3/5 were found to value 1.064, 1.066, 1.069,1.064,1.071, and 1.068 min. respectively. To get the best optimum % replacement for the replacement of bituminous by plastic was found to be 1.064.

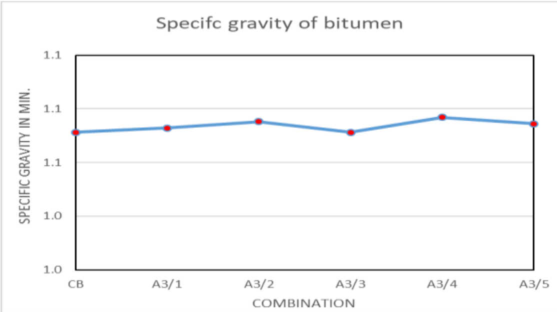

Figure 6 Specific gravity with % MPB

J. MARSHALL STABILITY TEST

Because observed the Marshall stability test for all the combinations go on decreasing with the increasing % of replaced bituminous by plastic. Marshall stability tests by CB, A3/1, A3/2, A3/3, A3/4, and A3/5 were found to value 10.47,10.76, 14.57,15.43, 15.16, 15.26 KN respectively. It was observed by A3/3 gives the best results as per IS code limit when bitumen is replaced by plastic. It was observed the Marshall stability test fulfils the requirement of in the standard when the replacement of bituminous by plastic, is within the limit of 6.25 to 8.75. To get the best optimum % replacement for the replacement of bituminous by plastic was found to be 7.5. We observed the 7.5 % replacement of bituminous by plastic has a 15.43 KN value which gives the best result. We observed the comparable plain bitumen with modified polymer bitumen (MPB) values increased.

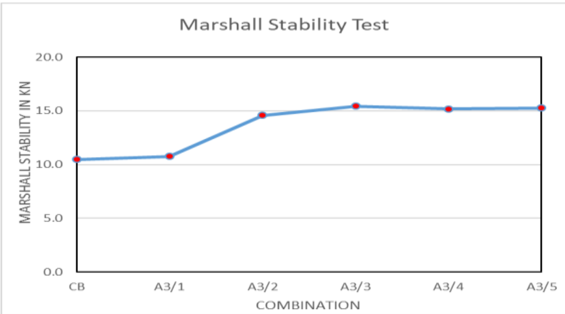

Figure 7 Marshall stability with % MPB

K. MARSHALL FLOW TEST

Because observed the Marshall flow test for all the combinations goes on decreasing with the increasing % of replaced bituminous by plastic Marshall flow values by CB, A3/1, A3/2, A3/3, A3/4, and A3/5 were found to value 2.00, 2.05, 3.60, 3.90, 4.10, and 4.03 mm respectively. It was observed by A3/3 gives the best results as per IS code limit when bitumen is replaced by plastic. It was observed the Marshall flow value fulfils the requirement of in the standard when the replacement of bituminous by plastic, is within the limit of 6.25 to 8.75. To get the best optimum % replacement

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for the replacement of bituminous by plastic was found to be 7.5. We observed the 7.5 % replacement of bituminous by plastic has a 3.90 mm value which gives the best result. We had seen an increase in the values of the equivalent plain bitumen by modified polymer bitumen (MPB).

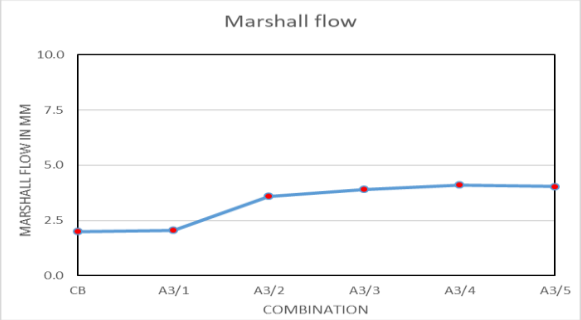

Figure 8 Marshall Flow with % MPB

L. BITUMEN EXTRACTION TEST

This test determined the bitumen content in RAP aggregate, we collected the sample of RAP by milling machine and then tested. In the Bitumen extraction test value was found to be 5-6 % of bitumen content. We observed the values increases of Reclaimed Asphalt Pavement (RAP) aggregate by Normal aggregate.

M. IMPACT VALUE TEST ON AGGREGATE

The strength of coarse aggregate can be determined using aggregate crushing tests. A high level of pavement quality can be achieved by using aggregates with high crushing resistant or a low aggregate crushing value. When compared to conventional aggregate and RAP aggregate, we found that impact values comparable with plastic-coated aggregate (PCA) were tougher.

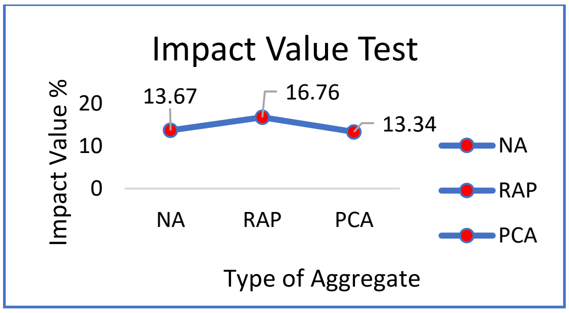

Figure 9 Results of Impact value of NA with PCA & RAP

N. LOS ANGELES ABRASION TEST ON AGGREGATE

To determine the percentage wear caused by relative rubbing, the Los Angeles Abrasion test is utilized. We found that PCA (Plastic coated aggregates) provides greater strength compared to regular and recycled asphalt pavement aggregate because the abrasion values have higher strengths.

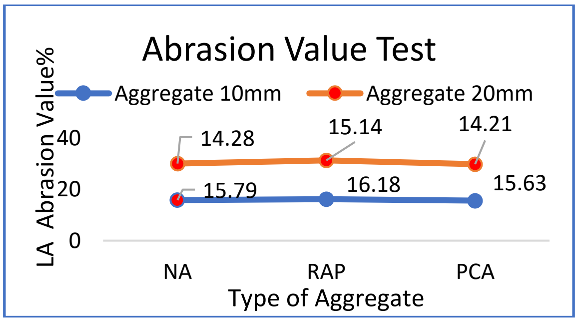

Figure 10 Results of Los Angeles Abrasion value of NA with PCA & RAP

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Table 5 Bitumen Test Results with MPB %

0	CB	A3/1	A3/2	A3/3	A3/4	A3/5
Softening Point Test	0.00	-1.98	-4.56	-6.15	-7.74	-9.92
Penetration value Test	0.00	-1.79	-6.25	3.57	1.43	-5.36
Ductility Test	0.00	2.38	5.95	7.14	1.43	8.57
Flash Point Test	0.00	1.33	0.67	-0.67	-14.67	-18.33
Marshall Stability Test	0.00	2.83	39.25	47.43	44.85	45.81
Marshall flow	0.00	2.50	80.00	95.00	105.00	101.67
VMA % (min. 12)	0.00	30.79	33.72	53.84	62.17	78.26
Air voids (Va) (3-5%)	0.00	4.48	-32.77	-17.38	-37.08	-31.08
VFB %(65-75 %)	0.00	13.48	33.32	31.03	41.05	41.14
Absorbed binder by wt. Of total	0.00	-17.13	12.22	41.57	70.92	100.27
Stability KN	0.00	2.83	39.25	47.43	44.85	45.81
Flow (2 - 4 mm)	0.00	2.50	80.00	95.00	105.00	101.67
Marshall Quotient (2-5)	0.00	0.32	-22.64	-24.39	-29.34	-27.70
Fines To Binder ratio (0.6-1.2)	0.00	-26.16	-41.47	-51.52	-51.52	-58.62

IV. CONCLUSION

1. The impact values experiment was found to decrease as the amount of recycled plastic content increased. It was determined that the greatest optimum result of an Impact value test had a% replacement for bituminous by plastic, with 7.5% replacement providing the best result. It also concluded that when compared to PCA and normal aggregate values, RAP aggregate values are lower and normal aggregate values were also higher.

2. In the Los Angeles Abrasion test, the value decreases as the waste plastic content increases. It was determined that the better optimum result of the Abrasion test had a % replacement for bituminous by plastic, with 7.5% replacement providing the best result. It also concluded that when compared to waste plastic or normal aggregate values, RAP aggregate values have been lower or normal aggregate values seem to be higher.

3. It observed that the Flakiness index and Elongation index values decreased with RAP content.

4. The greater the specific gravity, the greater the strength. Natural aggregates have higher specific gravity than PCA but a lower specific gravity than RAP aggregate. As a result, as aggregate values' specific gravity increased, so did their strength.

5. Penetration values of normal aggregate decrease as waste plastic content increases, as does RAP-coated aggregate with waste plastic. MPB-modified bitumen is tougher and more consistent than the regular aggregate. It was concluded that an increase in rutting resistance was beneficial.

6. The Softening point test values of normal aggregate decrease on an increase in the waste plastic making MPB content and RAP coated with waste plastic.

7. It was observed that the Ductility test values of normal aggregate decrease on an increase in the waste plastic making MPB content and increase on an increase in the RAP coated aggregate with waste plastic. The increases in the ductility value due to polymer interlocking has excess waste plastic content which makes bitumen stiffer.

8. It is observed that the flash point values increase with the increased % of waste plastic content.

9. It concluded that the Marshall Stability test values increase on an increase in the normal aggregate with MPB, and also observed the RAP aggregate with MPB Marshall stability test values increases.

10. It was found that as the normal aggregate with MPB increased, the Marshall flow values increased, as did the RAP aggregate to MPB Marshall stability test results.

11. The overall observed result indicates that plastic coated aggregate (PCA) and recycled asphalt pavement aggregate (RAP) are both more cost-effective and environmentally friendly materials to use in the bituminous pavement.

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12. 12 The PCA and RAP produce the best results when compared to the normal aggregate, while the RAP produces the worst results.

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