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Use of Waste Plastic Materials in Flexible Pavements

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ABSTRACT- Plastic waste generation and disposal contribute significantly to pollution and global warming. The properties and strength of bituminous mixtures are both enhanced by the inclusion of plastic detritus. Also, it will be a fix for other pavement issues including potholes, corrugation, ruts, and so forth. It was discovered that bitumen mixtures used in flexible pavements work well with plastic as a binder. By preventing cracks and rainwater infiltration, which would otherwise contribute to the development of potholes, this efficient method helps pavements tolerate greater temperatures. For India's hot and extremely humid climate, where temperatures regularly exceed 50°C and torrential rains cause havoc and leave the majority of the roads with large potholes, plastic roads would be a godsend. Bitumen is used as a binder in the traditional road construction process. Such bitumen can be altered with leftover plastic bits to create a bitumen mix that can be applied as the top coat of flexible pavement. This modified bitumen made from discarded plastic exhibits enhanced adhesion, stability, density, and water resistance.

KEYWORDS- Plastic waste, Bitumen, Plastic roads, Flexible pavement, Bitumen mix.

I. INTRODUCTION

Ighway development requires a substantial financial investment. A precise engineering design can ensure that the in-service roadway functions well while also potentially saving a significant amount of money. Two important aspects to take into account in flexible pavement engineering are the pavement design and mix design. Mix design elements are the main topic of the current study.

A well-designed bituminous mix ought to be sufficiently durable, resilient, fatigue-resistant, resistant to permanent deformation, cost-efficient, and so forth. Before choosing the best ratio, the mix designer tries a variety of proportions to suit these requirements. The goal of this study is to describe some of the difficulties that can be encountered when designing bituminous mixes as well as the present course of research.

The idea of using plastic to build roads is not new. In order to make plastic mats, PVC (polyvinyl chloride) or HDPE (high-density polyethylene) pipes are connected to produce pipe mat crossings, which are already in use. To make it simpler for tires to approach and leave the crossing, transition mats are added to the plastic highways. These methods prevent rutting on wetland freight routes by spreading the weight throughout the surface. Nonetheless, the use of plastic waste has long worried scientists and engineers. Recent studies in this field have shown some potential for using plastic waste to construct plastic highways

A. *Plastic waste*

One particular type of polymer that has been looked into for its potential to improve the characteristics of asphalt mixtures is polyethylene. High-Density Polyethylene (HDPE) and Low-Density Polyethylene (LDPE) were added as coatings to the aggregate (LDPE). According to the findings, powdered HDPE polyethylene modifier offers superior technical characteristics. The modifier should be used at a ratio of 12% by weight of the bitumen content. It was discovered to improve stability, decrease density, and marginally increase air spaces and mineral aggregate voids.

According to researchers, 192 coastal nations discharged eight million tons of plastic into the ocean in 2010. Although it might seem absurdly high, the quantity would actually be much higher. In addition to determining the overall amount, a report just published in the journal Science has listed the top 20 nations that have disposed of the most plastic garbage into the oceans. India does poorly, coming up at number twelve. Up to 0.24 million tons of plastic have been poured into the ocean annually, and 0.6 million tons of plastic garbage is mishandled.

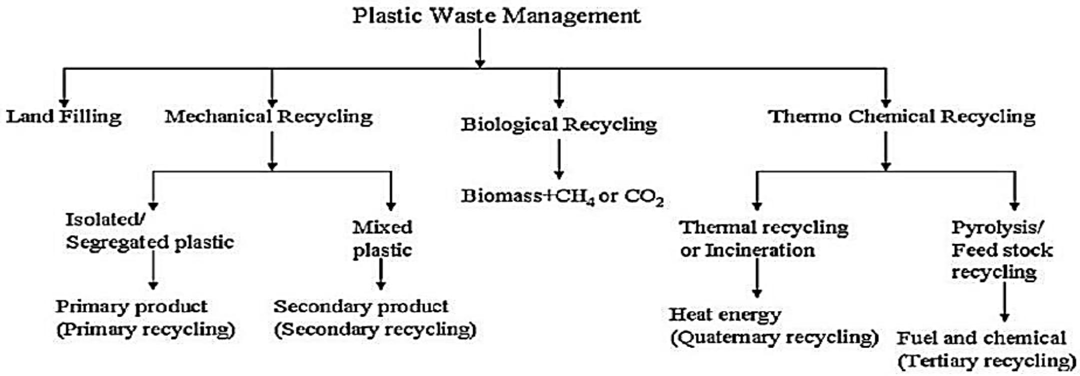

Figure 1: Plastic waste Management

II. MATERIALS

A. Bitumen (grade A-20)

In some natural deposits, bitumen is a viscous, sticky, and dark liquid or semi-solid. It is also a by-product or residue of the fractional distillation of crude oil. Bitumen is predominantly made up of highly condensed polycyclic aromatic hydrocarbons, with up to 5% Sulphur, 1% nitrogen, 1% oxygen, and 2000 ppm metals. It also contains 95% carbon and hydrogen (or 87% carbon and 8% hydrogen). Moreover, bitumen is a mixture of between 300 to 2000 different chemical elements, with 500 to 700 being the norm. It is the portion of crude oil that weighs the most and has the highest boiling point (525°C).

Figure 2: A20 Grade bitumen

B. Waste Plastic

Asphalt of the paving grade mixed with plastics like polypropylene (PP), low density polyethylene (LDPE), and high density polyethylene (HDPE) [13]. Rheological experiments were performed on both the unmodified and modified asphalt binders. Marshall stability test and loss of stability test results showed that asphalt concrete performed better than other types of construction materials. They came to the conclusion that using waste plastic as a binder material can be done successfully and successfully.

Figure 3: Preparing waste plastic

C. Coarse Aggregates

The coarse aggregates were a 70:30 blend of two sizes of crushed stone that were readily available locally: 20 mm and 10 mm. The aggregates were cleaned to get rid of dirt and dust, then dried until they were surface dry.

Bitumen and discarded plastic combined.

Collected as much as feasible, plastic was cut into very small bits. The plastic fragments were passed through a 4.75 mm sieve and collected at a 2.36 mm sieve. The bitumen was first heated to roughly 160°–170°C, which is its melting point. Bits were gradually added to the heated bitumen, which was 160–170 °C in temperature. About 20 to 30 minutes were spent manually stirring the mixture. The temperature during that time was maintained at between 160 and 170 °C. The Penetration Test and the Ductility Test were carried out using polymer-bitumen combinations of various compositions

III. LITERATURE SURVEY

Kalpana, D. Surendaran, et al., (2018): By incorporating plastic waste into the mix, it is possible to reduce the demand for bitumen by 10%, improve the strength and functionality of the road, eliminate the requirement for anti-stripping agents, prevent the cremation and landfilling of plastic waste, and eventually create an environmentally friendly technology. Roads' lifespans will and already are being shortened by increased traffic. Plastic roads are a preventative measure and, in the end, a remedy. It will decrease the quantity of resources needed for development and save millions of dollars in the long run.

R. Manju[1], Sathya S, Sheema K, et al., (2017): The environment faces a serious danger from waste plastic and its disposal, which causes pollution and global warming. The characteristics and strength of bituminous mixtures are improved by the addition of plastic waste1. Additionally, it will be a fix for various surface flaws like potholes, corrugation, ruts, etc., as well as a way to dispose of plastic. Polyethylene, Polystyrene, and Polypropylene make up the used refuse plastic. The discarded plastic is crushed, covered with aggregate, and combined with hot bitumen to create a mixture that is used to create pavement. The sidewalk will be strengthened and become more durable as a result. The smoke from the vehicles will be absorbed by the titanium dioxide, which is used as a smoke absorbent substance. The hot, humid environment of India will benefit from this cutting-edge technology.

Azmat Shaikh, Nabeel Khan, Faisal Shah, et al., (2017):

This study's findings suggest that the modified mix had enhanced Marshall characteristics thanks to the addition of plastic debris to the BC. Marshall Stability value is seen to rise with plastic content, while Marshall Flow value is seen to fall with the addition of polythene, meaning that the resistance to deformations under heavy wheel loads is seen to rise. We may infer from all the studies that were done that adding plastic debris improves a bituminous road's varied characteristics. By modifying the polymer in the pavement mix, we can guarantee that the mix will be more stable and lasting. This tiny study not only makes good use of the leftover non-biodegradable plastics but also gives us a better pavement with greater strength and durability.
Amit Kumar Sahu[1], R. K Singh[2], et al., (2017): This study's analysis of plastic tarp road performance demonstrates unequivocally that it is suitable for high traffic because of improved binding, enhanced strength, and better surface condition with prolonged exposure to climatic variations. Above important, the method makes it simple and easy to dispose of unwanted plastics. Develop an environmentally friendly technology. Make work for rag pickers available. Avoid burning and landfilling to dispose of plastic garbage. Increase your use of plastic garbage. 10% less bitumen is needed overall. In hot climates, issues like bleeding are less common. Use of anti-stripping chemicals should be avoided. It demonstrates that the characteristics of aggregate and bitumen increase as the amount of waste plastic in bitumen increases.

IV. METHODOLOGY

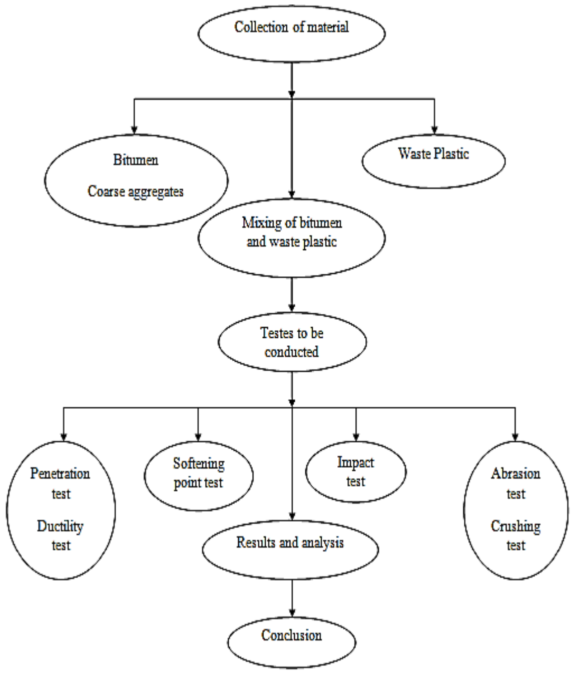

Figure 4: Methodology

V. RESULTS AND DISCUSSION

The conducted experiments indicate that incorporating waste plastic materials into flexible pavements improves fatigue resistance, reduces rutting, and enhances the overall durability of the pavement structure. The waste plastic forms a flexible and robust modified bitumen, contributing to sustainable pavement construction while addressing plastic waste management concerns.

A. Penetration Test of Bitumen

Table 1: Penetration test of bitumen

S.NO	Percentage of waste plastic	Penetration test Trial-1 In cm	Penetration test Trial-2 In cm	Penetration test Trial-3 In cm	Average penetration value
1	0	3.8	2.5	2.5	2.933
2	5	6.5	6.0	5.3	5.933
3	10	5.8	5.5	5.6	5.633
4	15	4.8	5.1	6.0	5.301
5	20	3.04.6	5.0	4.5	4.7

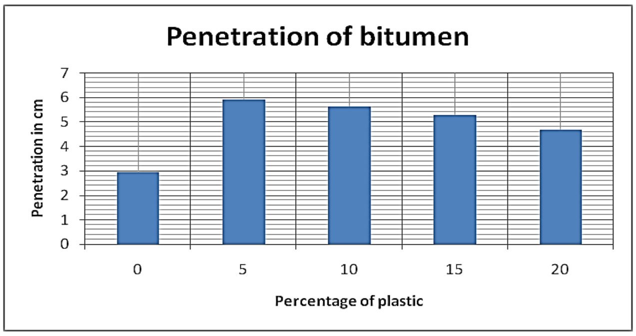

Figure 5: Penetration of bitumen

From the above table and graph it was observed that maximum value of penetration was observed at 5% plastic waste and minimum value of penetration was observed at 0% plastic waste. So the 5% plastic waste has more strength than remaining cases.

A. Softening point of bitumen

Table 2: Penetration test of bitumen

S.NO	Percentage of waste plastic	Trial-1	Trial-2	Trial-3	Average temperature in °
1	0	66	68	68	67.33
2	5	85	82	83	83.33
3	10	70	74	75	73
5	15	72	75	71	73
6	20	120	110	115	115

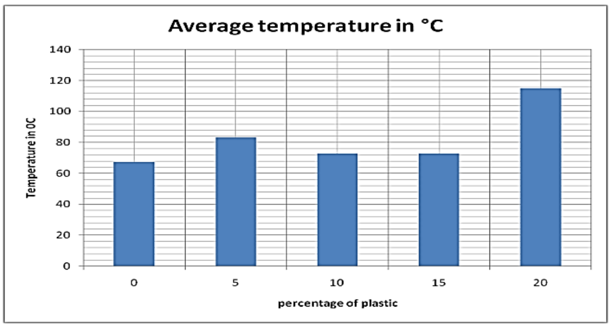

Figure 6: Average temperature in c

From the above table and graph it was observed that the maximum value of softening point was observed at 20% and 0% plastic waste and minimum value of softening point was observed at 0% plastic waste. So from this point it was concluded that by using plastic waste temperature effect on the bitumen reduces for the Flexible pavements.

B. *Ductility of bitumen*

Table 3: Ductility of bitumen

S.NO	Percentage of waste plastic	Ductility in cm
1	0	25
2	5	30
3	10	40
4	15	30
5	20	50

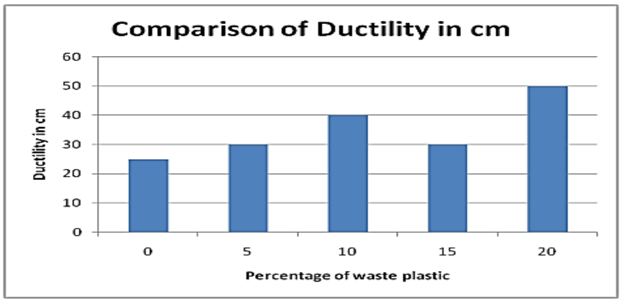

Figure 7: Comparison of ductility in cm

From the above table and graph it was observed that the at 0% plastic waste and minimum value of ductility was observed at 20% plastic waste maximum value of ductility was obtained.

C. *Aggregates Impact Test*

Table 4: Aggregates impact test

S. No	**Percentage of waste plastic**	**Weight of sample Retained on 2.36 sieve in grams(A)**	**Total weight of sample In Grams(B)**	**Aggregate impact value in percentage C=(A/B)X100**
1	0	115	686	16.76
2	5	70	675	10.37
3	10	70	653	10.72
4	15	60	690	8.70
5	20	36	622	5.78

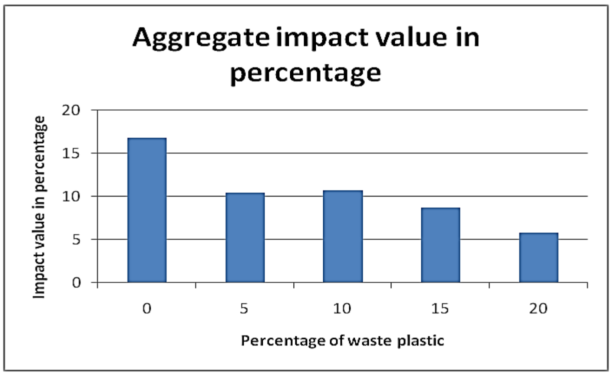

Figure 9: Value of aggregates impact test in percentage

The value of aggregates impact test in percentage decreases with increasing the percentage of waste plastic from 0% to 20%.

D. *Aggregates crushing test*

Table 5: Aggregates crushing test

S. No	**Percentage of waste plastic**	**Weight of sample Retained on 2.36 sieve in grams (A)**	**Total weight of sample In grams (B)**	**Aggregate crushing value in percentage C=(A/B)X100**
1	0	750	3000	25
2	5	680	3000	22.66
3	10	670	3000	22.33
4	15	610	3000	20.33
5	20	550	3000	18.33

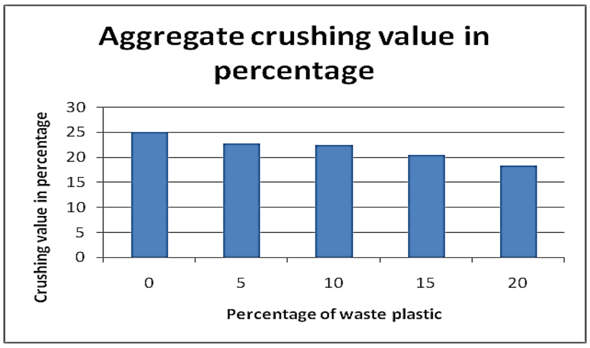

Figure 8: Aggregates crushing test in percentage

The value of aggregates crushing test in percentage decreases with increasing the percentage of waste plastic from 0% to 20%.

E. Abrasion test

Table 6: Abrasion test

S. No	Percentage of waste plastic	Weight of sample Retained on 2.36 sieve in grams (A)	Total weight of sample In grams (B)	Abrasion value in percentage C=(A/B)X100
1	0	340	2500	13.6
2	5	290	2500	11.6
3	10	280	2500	11.2
4	15	240	2500	9.6
5	20	210	2500	8.4

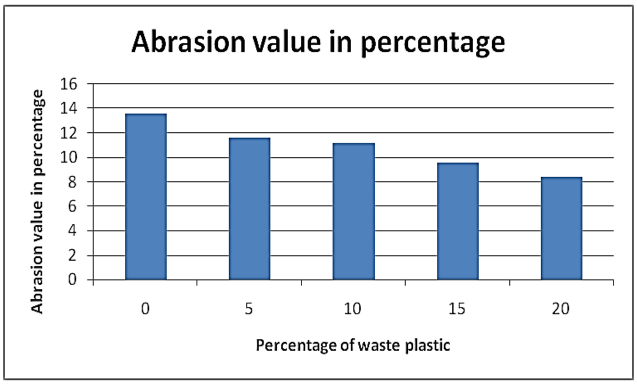

Figure 9: value of abrasion test in percentage

The value of abrasion test in percentage decreases with increasing the percentage of waste plastic from 0% to 20%.

VI. CONCLUSION

- Building a motorway requires a significant financial expenditure. A precise engineering design could result in significant financial savings and reliable performance of the motorway.
- A well designed bituminous mix should be sufficiently strong, resilient, resistant to fatigue, impervious to permanent deformation, economical, and so forth.
- A penetration value of 5% plastic waste produced the highest value and 0% plastic trash produced the lowest value. Hence, the 5% plastic trash is stronger than the remainder instances.
- The lowest value of softening point was observed at 0% plastic waste, and the maximum and minimum values were 20% and 0%, respectively. From this, it was deduced that incorporating plastic waste would lessen the bitumen's effect on temperature for flexible pavements.
- Minimum ductility was found at 0% plastic waste, while maximum ductility was attained at 20% plastic waste.
- As the percentage of waste plastic increases from 0% to 20%, the value of the aggregates impact test declines.
- From 0% to 20%, the value of the aggregates crushing test in percentage drops as the amount of waste plastic increases.
- When the percentage of waste plastic is increased from 0% to 20%, the value of the abrasion test in percentage drops.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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