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OPTIMAL UTILIZATION OF PLASTIC WASTE AS A BITUMEN SUBSTITUTE IN FLEXIBLE PAVEMENT: AN EXPERIMENTAL STUDY

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Abstract:The rapid growth of industries and the increasing population are significant sources of waste, with plastic waste being particularly hazardous due to its non-biodegradable nature. Bitumen, a key material in flexible pavement construction, benefits from the addition of plastic waste, which improves its water resistance, capacity, and stability. Research has shown that adding up to 10% plastic waste by weight to bitumen can enhance its mechanical properties. This study investigates the potential of using more than 10% plastic waste as a replacement for bitumen in pavement construction. The experimental methodology involves coating aggregates with a mix of single-use plastic waste and bitumen. The Marshall Stability test is used to evaluate the performance of various plastic waste proportions compared to conventional bituminous mixtures. Additionally, use of fly ash as fillers based on the weight of crushed stone aggregate shows promising results possibly for its pozzolanic action. This research explores the possibility of using optimal percentage of plastic waste which is more than 10% replacement that can be effectively incorporated into bitumen mixtures for sustainable road construction with economy.

***Index Terms* - Plastic Wastes, Bitumen, Flexible Pavement, Fly Ash, Marshall Stability**

I. INTRODUCTION

The disposal of waste from various sources has been a persistent environmental issue, leading to significant pollution. Plastic waste, in particular, is non-biodegradable and accumulates rapidly, posing a severe threat to the environment. Research indicates that plastics can remain intact for over 4500 years, exacerbated by rising demands for food and essential goods packaged in plastic. In this context, utilizing plastic waste in road construction, particularly in flexible pavements, offers a promising solution. Plastic roads have demonstrated superior performance and durability compared to conventional bitumen roads. Incorporating plastic into bitumen enhances the smoothness and longevity of pavements, reduces construction costs, and fosters an eco-friendly environment. By introducing plastic waste into the bituminous mix, the bitumen requirement can be reduced by up to 10%, improving the strength and performance of the roads. Additionally, plastic raises the melting point of the bitumen, contributing to the overall durability of the pavement. The process of creating plastic roads involves coating aggregates with plastic and mixing them with hot bitumen at temperatures between 150°C and 165°C. This mix is then used for road construction at temperatures ranging from 130°C to 140°C, with the final road laying temperature being between 110°C and 120°C. It is crucial to follow specified mixing times, temperatures, and modifier contents to prevent premature road failures.

Given the current lifestyle and widespread use of plastic, a complete ban on its use is impractical. However, reusing plastic waste presents a viable alternative. In India, approximately 10,000 tons per day (TPD) of plastic waste is generated, constituting 9% of the 1.20 lakh TPD of municipal solid waste (MSW). This plastic waste includes two major categories: thermoplastics and thermoset plastics. Thermoplastics, which are recyclable, make up about 80% of post-consumer plastic waste and include materials such as Polyethylene Terephthalate (PET), Low-Density Polyethylene (LDPE), Polyvinyl Chloride (PVC), High-Density Polyethylene (HDPE), Polypropylene (PP), and Polystyrene (PS). In contrast, thermoset plastics, which account for about 20% of the waste, include materials such as alkyd, epoxy, ester, melamine formaldehyde, phenolic formaldehyde, silicon, urea formaldehyde, polyurethane, and metalized and multilayer plastics. The increasing use of plastic materials, especially for packaging, highlights the need for innovative solutions to manage plastic waste. Utilizing plastic waste in road construction offers a sustainable approach to addressing the plastic disposal problem, potentially revolutionizing road construction and contributing to a cleaner environment.

This research focuses on a comparative study of using waste plastics in flexible pavements. The primary objectives are to evaluate the strength parameters of bituminous pavement samples incorporating waste plastic materials. Investigate the properties of various bituminous mixes with different percentages of plastic waste. Study the properties of waste plastic-coated aggregates and compare the Marshall values of bituminous mixes with plastic waste coating to those of conventional mixes. Research aims toexplore the possibility of use of Fly ash Mineral fillers to enhance the Bitumen mix performance.Existing research indicates that the optimal plastic content for flexible pavements from 10% to 12%. This research aims to explore the feasibility of increasing the optimum plastic content above 10% along with Mineral fillers and evaluate the resulting improvements in Bituminous Mix performance.

II. Literature Review

Areviewofcompletedandoutgoingresearchhasbeenconductedtoidentifycurrentknowledgeormethodologies that may be appropriate for that plastic can be used as a binder material in the bitumen mixfor construction of flexible pavements. The utilization of plastic waste as a bitumen substitute in flexible pavement construction has been extensively researched, aiming to address environmental concerns and enhance road durability. Studies have shown that incorporating plastic waste in bitumen mixes improves mechanical properties, durability, strength, and permeability of bituminous pavement [1] [2]. By blending plastic waste with bitumen, the resulting material exhibits increased resistance to deformation, durability, and reduced seepage, while also mitigating pollution and providing an effective waste disposal solution [3]. Furthermore, the use of plastic waste in combination with construction demolition waste aggregate in bituminous mixes has demonstrated significant enhancements in pavement strength and performance, offering a sustainable solution to reduce the reliance on natural resources in road construction [4]. Pinemet. al. studied on HDPE plastic waste which was used as pure asphalt substitute in pavement; it was found that content of 4% to 6% optimal for flexible mixture with bitumen, possibly the value of a more flexible mixture and optimal asphalt absorption [5]. Plastic waste was used to modify bitumen binder in roads where it has been found that the plasticity property of plastic increases ductility and softening point of bitumen [6]. Studies performed on waste polypropylene cement bags used as partial bitumen replacement, found that Optimum percentage for efficiency found to be 8.2% [7]. Anjali, Hasbanet. al. studied on effective utilization of waste Plastic and steel slag to enhance the performance of bitumen based pavement, where she found that Up to 8% plastic waste improves bitumen performance in pavement and cost saving can be achieved up to Rs. 36000 per kilometer in road construction[8]. V., M., Rajanandhini and G., Elangovan performed Marshall's stability tests to determine the stability value and flow value. It was found that the optimum amount of waste plastic to blend with bitumen was found to be 12%, based on its stability value, higher strength, lower flow value, and increased air gaps. They also found in the cost analysis that about twenty six hundred kilogram of bitumen of worth seventy-six thousand rupees was saved for 1 km of road construction[9].Overall, these findings highlight the potential of utilizing plastic waste as a viable alternative to bitumen in flexible pavement construction, promoting environmentally friendly and sustainable practices in the construction industry.

III. METHODOLOGY

3.1 Materials Selection and Preparation

Aggregates: Coarse aggregates were selected based on standard specifications for road construction materials.
Bitumen: Standard bitumen used for flexible pavements.
Plastic Waste: Various types of plastic waste to be tested and used as a bitumen substitute.

3.2 Testing of Aggregates

To ensure the quality and suitability of aggregates for pavement construction, the following tests were conducted.
Grain Size Distribution of Aggregates: Determines the particle size distribution of the aggregates.
Flakiness and Elongation Index (Shape Test): Assessed as per IS:2386 (Part 1) 1963 to determine the shape characteristics of the aggregates.
Specific Gravity and Water Absorption Test: Conducted as per IS:2386 to determine the density and porosity of the aggregates.
Aggregate Impact Value Test: Evaluated as per IS:2386 (Part 4) 1963 to measure the resistance of aggregates to sudden impact.
Aggregate Crushing Value Test: Conducted as per IS:2386 (Part 4) 1963 to determine the crushing strength of the aggregates.

3.3 Testing of Bitumen

The bitumen was tested for its properties to ensure it meets the required standards for use in flexible pavements:
Penetration Test: As per IS:1203-1978 to determine the hardness or softness of the bitumen.
Softening Point Test: Conducted as per IS:1205-1978 to find the temperature at which the bitumen softens.
Ductility Test: As per IS:1208-1978 to measure the bitumen's ductility or ability to stretch.
Flash and Fire Point Test: Conducted as per IS:1209-1978 to determine the temperatures at which the bitumen vapors ignite.
Specific Gravity Test: As per IS:1202-1978 to determine the density of the bitumen.

3.4 Marshall Mix Design

The Marshall Mix Design method was used to design the optimal bitumen mix for flexible pavement construction. The specifications followed were as per the Ministry of Road Transport and Highways (MORTH) and MS-2 standards. The steps involved:
Preparation of Test Specimens: Various bitumen-aggregate mixes were prepared, incorporating plastic waste as a binder material up to 10% by weight of the bitumen.
Stability and Flow Tests: These tests were conducted to determine the stability, flow values, and void characteristics of the mixes.
Optimum Bitumen Content (OBC): The OBC was determined for both the conventional and plastic-modified bitumen mixes.

*Preparation Of Plastic-Waste Coated Aggregate***:**

The aggregate is heated to around 170°C; the plastic waste is shredded to the size varying between 2.36mm and 4.75mm. This shredded plastic-waste is added over hot aggregate with constant mixing to give a uniform distribution. The plastic got softened and coated over the aggregate. The hot plastic waste coated aggregate is mixed with the hot bitumen 60/70 or 80/100 grade (160° C).

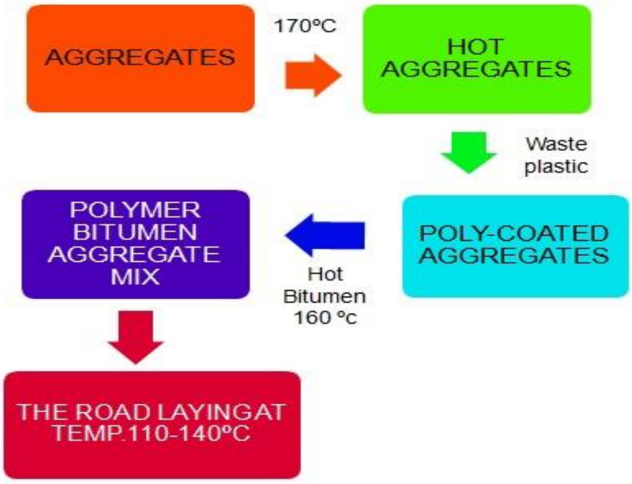


Fig.1. Methodology Flow Chart

Mixing Procedure:

Step 1: Plastic waste like bags, bottles made of PE and PP cut into a size between 2.36mm and 4.75mm using shredding machine. Care was taken to eliminate PVC waste before it proceeds into next process.

Step 2: The aggregate mix is heated to 165°C and then it is transferred to mixing chamber. Similarly, the bitumen is to be heated up to a maximum of 160°C. This is done to obtain a good binding and to prevent weak bonding. During this process monitoring the temperature is crucial.

Aggregates:

Aggregate having sufficient strength, hardness, toughness, specific gravity and shape were chosen and the prescribed tests on conventional aggregates were performed. Aggregate gradation that satisfies the requirements of IRC 111-2009 for grading-II was selected. From Figure-1, it can be observed that selected aggregate gradation is within the specified range for hot asphalt mix design. The permissible grading in between maximum and minimum limit as shown in above figure-1 was adopted to achieve maximum density and economical blend as well.

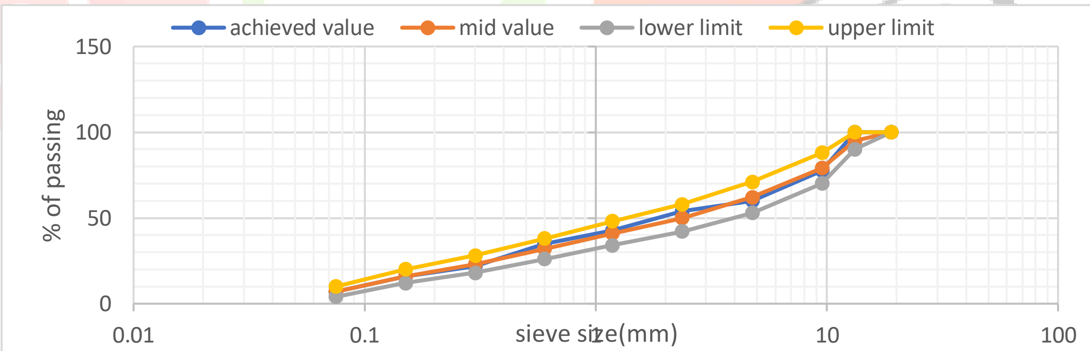


Fig.2. Gradation Curve for the Aggregates

Bitumen:

Bitumen is very well known as the binders in asphalt construction (Refer Figure 2). It is one of the most important highway construction materials. The important quality of bitumen which has made bitumen a popular binding material is its excellent binding property and gets softens when heated. For most of the test, the testing conditions are pre-fixed in the specifications. Temperature is a vital parameter which has a direct influence on the modulus and the aging of the binder. This consideration is important because binders extracted from various sources may show same physical properties at particular temperatures, but the performance may vary drastically at various temperatures.

Mineral Filler:

Filler shall consist of finally divided mineral such as rock dust or hydrated lime or cement. The use of crushed stone aggregate (CSD) is encouraged because of its economical point of view and easy availability of this filler. It is added to the hot mix asphalt, to increase the density and enhance the strength of the mixture. The gradation of filler is shown in below in table no IV

Fig.3. Mineral filler

Fig.4. Plastic waste

Plastic waste:

The processed waste plastic bags(LDPE) from the garbage of local area in the shredded form was used as additive. The shredded waste plastic was cut into pieces of uniform size of 2.36 mm to 4.75 mm.

Fly Ash:

One of the by-products of generation of energy through thermal processes is fly ash, whose safe disposal incurs monetary and environmental costs. Review of various literatures has found the following results, application of fly ash, in both flexible and rigid pavement, is common in the form of a filler material.

Preparation of Plastic Waste Coated Aggregate Sample:

The aggregate is heated to around 170°C; the plastic waste is shredded to the size varying between 2.36mm and 4.75mm. This shredded plastic-waste is added over hot aggregate with constant mixing to give a uniform distribution. The plastic got softened and coated over the aggregate. The hot plastic waste coated aggregate is mixed with the hot bitumen of VG 40 grade (160° C).

Fig.5. Aggregate sample & filler

Fig.6. Aggregate & Bitumen Mix

IV. RESULTS AND DISCUSSION

The various tests conducted on aggregates in the laboratory are crushing test, impact test, flakiness and elongation index, specific gravity and water absorption test and stripping value test and the results obtained are tabulated below in Table 1.

TABLE 1 RESULTS OF THE TESTS CONDUCTED ON AGGREGATES

Sl. No	Test	Property Determined	Results
01	Impact test	Toughness	9.34%
02	Crushing test	Crushing strength	23.49%
03	Specific gravity test	Specific gravity value	2.61
04	Water absorption test	Water absorption value	1.51%
05	Shape test	Flakiness index	13.55%
06	Shape test	Elongation index	11.72%

The bitumen used in the experiment was VG-40 grade and was tested in the laboratory for basic tests, penetration, ductility, softening point, specific gravity and flash and fire point test.

Fig. 7. Marshall Stability Test

Fig.8. Bitumen Sample used for Experiment

The results of the tests conducted on our sample are tabulated below in Table 2.

TABLE 2 RESULTS OF THE TESTS CONDUCTED ON BITUMEN

Sl. No	Test	Results
01	Penetration test	42 mm
02	Softening point test	46.15°C
03	Specific gravity test	1.05
04	Ductility test	76 cm
05	Flash point test	290°C
06	Fire point test	3540°C

TABLE 3 GRADATION REQUIREMENT OF MINERAL FILLER

IS Sieve Size in mm	Cumulative % by Weight f Total Aggregate Passing
0.6	100
0.3	95-100
0.075	85-10

The results of the tests conducted on the plastic-coated aggregates are tabulated below in Table 5.

TABLE 5 RESULTS OF THE TESTS CONDUCTED ON AGGREGATES COATED WITH DIFFERENT PERCENTAGES OF PLASTIC.

Sl. No	Percentage of Plastic	Aggregate Impact Test	Water Absorption Test	Stripping Test
01	10%	8.74%	1.21%	1.5%
02	11%	7.93%	1.09%	1%
03	12%	7.43%	1.01%	Nil

TABLE 6 THE OPTIMUM BITUMEN CONTENT FOUND TO BE 5% AND THE VARIOUS MARSHALL PARAMETERS AT 5% BITUMEN CONTENT LIST

Maximum Specific Gravity Test(GMM) of Bituminous paving mixture						
Type of Mix- BC Mix (Grading-II)						
Sl. No.	**Description**	**Unit**	**Trial -1**	**Trial -2**	**Trial -3**	**Trial -4**
A	Plastic content	%	0	10.00	11.00	12.00
B	% Binder Content	%	5.00	5.00	5.00	5.00
C	Weight of Bowl with lid (A)	(gm)	1251	1251	1251	1251
D	Weight of Sampled in Air (B)	(gm)	1281	1304	1276	1314
E	Weight of Bowl + Sample + distilled Water (C)	(gm)	4212	4219	4202	4200
F	Weight of Bowl + distilled Water (D)	(gm)	3460	3460	3460	3460
G	Maximum Specific Gravity of the Mixture. GMM=B/(B-(C-D))		2.40	2.38	2.385	2.29

Table 6 presents the results of the Maximum Specific Gravity Test (GMM) conducted on a bituminous paving mixture, specifically BC Mix (Grading-II). Four trials were performed, each with varying plastic content while maintaining a constant binder content. These observations suggest that incorporating plastic waste into the bituminous mix affects the specific gravity of the paving mixture, with higher plastic content leading to a lower specific gravity. This information is crucial for understanding the impact of plastic waste on the properties of bituminous paving mixtures.

TABLE 7 THE OPTIMUM BITUMEN CONTENT FOUND TO BE 5% AND THE VARIOUS MARSHALL PARAMETERS AT 5% BITUMEN CONTENT LIST

MARSHALL STABILITY AND FLOW VALUE [ASTM D 1559]

Type of Mix	BC Grading-II	Date of Testing	
Type of Bitumen	VG-40	Bulk Sp. Gr. Of total Agg.(Gsb)	2.575
Nos. of blows each face	75 blows on each face of the specimen	Sp. Gr. Of bitumen (Gb)	1.029

The optimum bitumen content found to be 5% and the various marshall parameters at 5% bitumen content are listed below

Sample no.	Specimen Thickness in (mm)	Bitumen % by wt. of mix	% of Aggregate	wt. in Air (gm)	wt. in water (gm)	wt. of SSD (gm)	Vol. of specimen = e-f (cc)	Density =d/g (g/cc)	GMM	Air Voids =(i-h)/ i*100	VMA=100-(h*c)/Gsb	VFB=(k-j)/k*100	Correlation Ratio as per Table-7.1 of MS-2	Stability (kg)		Flow in mm
														Measured	Corrected	
***	a	b	c	d	e	f	g	h	i	j	k	l	m	o	p	q
1	63.6	5	95	1199	729	1246	520	2.304					1	1090	1090	2.5
2	63.3	5	95	1180	733	1245	512	2.306					1	1025	1025	2.8
3	63.5	5	95	1191	733	1250	521	2.288					1	1061	1061	3.4
Average			95					2.299	2.418	4.9	15.17	67.65		1058.7	1058.7	2.9

TABLE 8 THE OPTIMUM BITUMEN CONTENT IS 5% AND THE VARIOUS MARSHALL PARAMETERS AT VARIOUS PLASTICS CONTENT BY THE WT. OF THE BITUMEN CONTENT LIST

MARSHALL STABILITY AND FLOW VALUE [ASTM D 1559]

Type of Mix	BC Grading II	Date of testing	
Type of Bitumen	VG 40	Sp. Gr. of total aggregate (Gsb)	2.575
Nos. of blows each face	75 Blows on each face of the specimen	Sp. Gr. Of bitumen (Gb)	1.029

The optimum bitumen content is 5% and the various marshall parameters at various plastics content by the wt. of bitumen content are listed below

Sample no.	Specimen Thickness in (mm)	Plastic % by wt. of bitumen	% of Aggregate	wt. in Air (gm)	wt. in water (gm)	wt. of SSD (gm)	Vol. of specimen = e-f (cc)	Density =d/g (g/cc)	GMM	Air Voids =(i-h)/ i*100	VMA=100-(h*c)/Gsb	VFB=(k-j)/k*100	Correlation Ratio as per Table-7.1 of MS-2	Stability (kg)		Flow in mm
														Measured	Corrected	
***	a	b	c	d	e	f	g	h	i	j	k	l	m	o	p	q
1-A	63.3	10	95	1202	1257	735	522	2.303					1	1180	1180	3.5
1-B	63	10	95	1210	1259	729	530	2.283					1	1190	1190	3.9
1-C	63.5	10	95	1198	1255	716	539	2.223					0.93	1235	1148.55	3.4
Avg.		10	95					**2.269**	2.38	**4.65**	**16.27**	**71.45**		1201.67	**1172.85**	**3.60**
2-A	63.1	11	95	1222	1257	721	536	2.280					0.96	1122	1077.12	3.8
2-B	63.4	11	95	1227	1274	736	538	2.281					0.96	1080	1036.8	3.62
2-C	63.7	11	95	1225	1246	712	534	2.294					0.93	1095	1018.35	4.56
Avg.		11	95					**2.285**	2.385	**4.20**	**15.70**	**73.26**		1099.00	**1044.09**	**3.99**
3-A	63.6	12	95	1209	1230	724	540	2.239					0.93	1132	1052.76	4.6
3-B	63	12	95	1195	1235	737	533	2.242					0.96	1063	1020.48	5.1
3-C	63.4	12	95	1180	1240	740	537	2.197					0.93	1043	969.99	5.3
Avg.		12	95					**2.226**	2.29	**2.79**	**17.87**	**84.39**		1079.33	**1014.41**	**5**

TABLE 9 THE OPTIMUM BITUMEN CONTENT IS 5% AND THE VARIOUS MARSHALL PARAMETERS AT VARIOUS % OF FLY ASH CONTENT BY THE WT. OF CSD CONTENT LIST

MARSHALL STABILITY AND FLOW VALUE [ASTM D 1559]

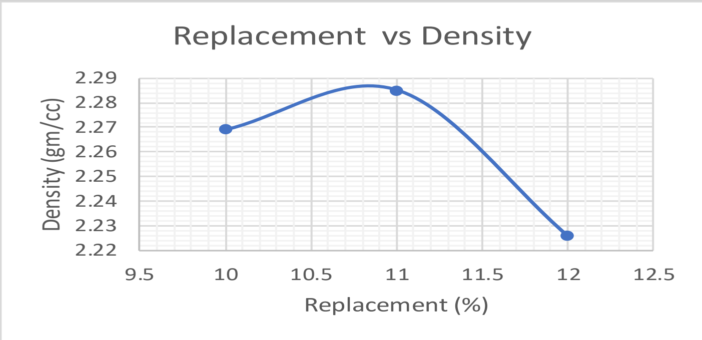
Type of Mix	BC Grading II	Date of testing	
Type of Bitumen	VG 40	Sp. Gr. of total aggregate (Gsb)	2.575
Nos. of blows each face	75 Blows on each face of the specimen	Sp. Gr. Of bitumen (Gb)	1.029

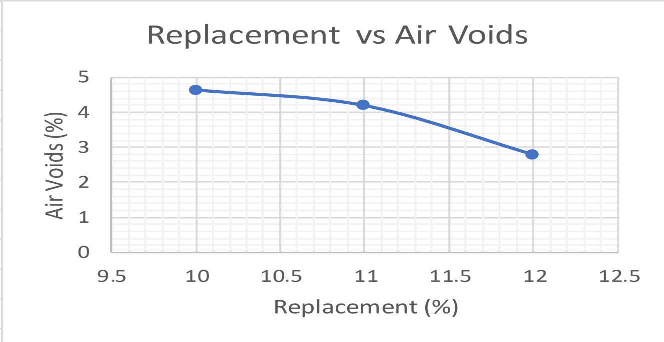
The optimum bitumen content is 5% and the various marshall parameters at various % of fly ash content by the wt. of CSD content are listed below

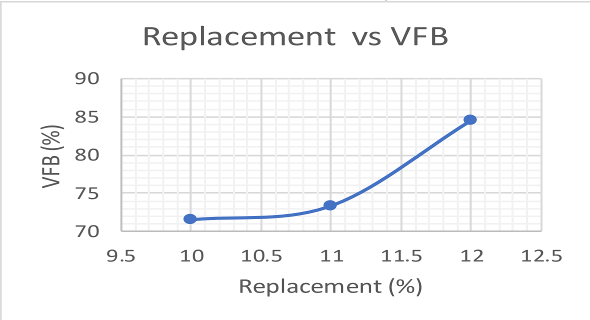
Sample no.	Specimen Thickness in (mm)	FA % by wt. of CSD	plastic% by wt. of bitumen	% of Aggregate	wt. in Air (gm)	SSD wt.(gm)	wt.in water(gm)	Vol. of specimen = e-f (cc)	Density =d/g (g/cc)	GMM	Air Voids =(i-h)/ i*100	VMA=100-(h*c)/Gsb	VFB=(k-j)/k*100	Correlation Ratio as per Table-7.1 of MS-	Stability (kg)		Flow in mm
															Measured	Corrected	
***	a	b		c	d	e	f	g	h	i	j	k	l	m	o	p	q
1-A	64.2	25	12	95	1217	1258	721	537	2.266					0.93	1217	1131.81	3.23
1-B	65	25	12	95	1215	1256	729	527	2.306					0.96	1209	1160.64	2.86
1-C	63.9	25	12	95	1205	1263	735	528	2.282					0.96	1156	1109.76	2.91
Avg.		25	12	95					**2.285**	2.357	**3.07**	**15.71**	**80.47**		1194.00	**1134.07**	**3.00**
2-A	64.4	40	12	95	1209	1251	724	527	2.294					0.96	1195	1147.2	2.58
2-B	64.7	40	12	95	1212	1263	711	552	2.196					0.89	1203	1070.67	2.12
2-C	63.2	40	12	95	1213	1247	709	538	2.255					0.93	1177	1094.61	2.67
Avg.		40	12	95					**2.248**	2.312	**2.76**	**17.06**	**83.81**		1191.67	**1104.16**	**2.46**
3-A	63.8	55	12	95	1215	1240	716	524	2.319					0.96	1126	1080.96	2.53
3-B	63.5	55	12	95	1211	1236	724	512	2.365					1	1011	1011	2.33
3-C	64.3	55	12	95	1213	1249	740	509	2.383					1	1181	1181	1.26
Avg.		55	12	95					**2.356**	2.419	**2.62**	**13.09**	**80.01**		1106.00	**1090.987**	**2.04**

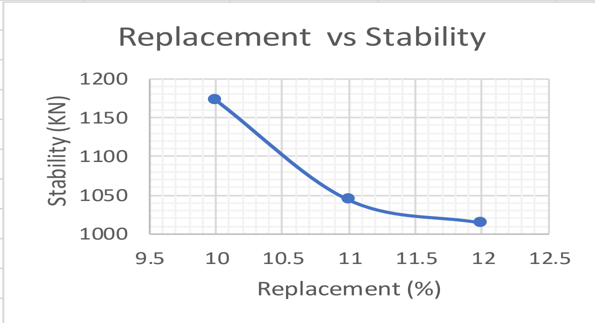
TABLE10 AVERAGE MARSHALL PROPERTIES OF BITUMINOUS MIXES WITH PLASTIC CONTENT AT 5% OBC

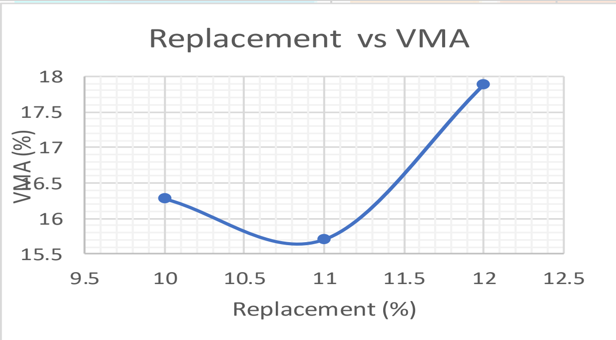
Replacement by plastic (in %)	Density (gm/cc)	Air Voids(%)	VMA (%)	VFB (%)	Stability (KG)	Flow (mm)
10	2.269	4.65	16.27	71.45	1172.85	3.6
11	2.285	4.2	15.7	73.26	1044.09	3.99
12	2.226	2.79	17.87	84.39	1014.41	5











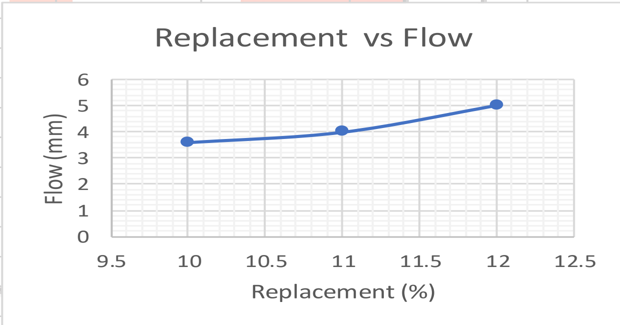


Table 11 below presents a comparison of various properties between a conventional bituminous mix and an OPC (Ordinary Portland Cement) modified bituminous mix. The OPC modified mix includes 11% OPC by weight of OBC (Optimum Binder Content) and an additional 40% fly ash by the weight of the filler. The OPC modified bituminous mix with fly ash shows improved strength and slightly better flexibility compared to the conventional mix. Density and Air Voids The modified mix is denser and has fewer air voids, which can contribute to better performance and longevity. Higher VMA and VFB values in the modified mix suggest a more efficient use of the bituminous binder, with better coating and filling of aggregates.

TABLE 11 COMPARISON OF WASTE PLASTICS AND FLY ASH MODIFIED BITUMINOUS MIX WITH THE CONVENTIONAL MIX

Sl. No.	Properties	Conventional Mix	(11%) OPC modified bituminous mix (by the wt. of OBC) for the addition of 40% fly ash by the wt. of filler
1	Marshall Stability (kN)	10.59	11.80
2	Flow Value (mm)	2.9	3.03
3	Density (kN/m^3)	22.99	22.74
4	Air voids (V_a) in %	4.9	3.26
5	VMA (%)	15.17	16.09
6	VFB (%)	67.65	79.75

V. COST BENEFIT ANALYSIS

Calculation of quantity of bitumen and aggregate from conventional bituminous mix:
Considering the length of a flexible pavement of 1 km and 3.75 m width and thickness of 40 mm (for BC grading ii), the following data are needed.

- Length= 1000 m
- Width =3.75 m
- Thickness/depth= 40 mm or 0.04 m
- Marshall density= 2.299 gm/cc
- As per mix design aggregate percentage,

10 mm=50%
6mm=20%
Dust/filler=30%
Bitumen= 5%
Mass= Volume x Density
Volume= LXBXD = 1000X3.75X0.04 = 150 cum
Weight of Mix = Volume x Density = 150 x 2.299 = 344.85 or 345 tonnes
Qty. of Bitumen = 345 x 5%= 17.25 tonnes @ Rs 43000/ton
Weight of aggregates = 345-17.25 = 327.75 tonnes
10 mm (50%) = 163.875 tonnes @ Rs 1100/ton
6 mm (20%) = 65.55 tonnes @ Rs 990/ton
Dust/filler (30%) = 98.325 tonnes @ Rs 700/ton

5.13.2 Calculation of cost of bitumen and aggregate from bituminous mix

Cost of bitumen = Rs 7,41,750/-
Cost of 10 mm aggregate =Rs 1,80,263/-
Cost of 6 mm aggregate = Rs 64,895/-
Cost of dust/filler = Rs 68,827/-
Total cost/km = Rs 10,55,803/-
Weight of bitumen replaced = 17.25 x 11% = 1.9 tonnes = 1900 kg
Cost of replaced bitumen = 1.9 x 43000 = Rs 81,700/-
So, the actual cost of bitumen = 7,41,750-81,700 = Rs 6,60,050/-
The cost of waste plastic including cleaning and shredding @ Rs 22/kg
The cost of waste plastic = 1900 x 22 = Rs 41800/-

For the 40% addition of fly ash by the weight of CSD (30%), the following adjustment is done by the total weight of the mix,
Wt. of, 10 mm aggregate (38%) = 124.545 tonnes @Rs 1100/ton
6 mm aggregate (20%) = 65.55 tonnes @Rs 990/ton
Dust/filler (30%) = 98.325 tonnes @ Rs 700/ton
Fly ash (12% by the weight of total mix, if taken or 40% by the wt. of CSD) = 41.4 tonnes @ Rs 450/ton
Cost of, 10 mm aggregate = Rs 1,37,000/-
6 mm aggregate = Rs 64,895/-
Dust/filer = Rs 68,828/-
Fly ash = Rs 18,630/-
Bitumen = Rs 6,60,050/-
So, the total cost/km = Rs 9,91,203/-

5.13.3 Cost Comparison:

Total cost/km = Rs 10,55,803/- for the conventional mix.
So, the total cost/km = Rs 9,91,203/- for the 11% waste plastic as replacement (by the weight of OBC, 5%) of bituminous mix with the addition of 40% fly ash by the weight of CSD
So, Total cost saved/km =10,55,803-9,91,203 = Rs 64,600/km.
Hence, the construction of flexible pavement using waste plastic along with the fly ash is proved to be economical.

VI. CONCLUSION

Based on the study and experimental data for waste plastic modified bituminous concrete mix compared with conventional bituminous concrete mix, the following conclusions can be drawn

I. The results showed that waste plastic can be conveniently used as a modifier for bituminous concrete mix as it gets coated over the aggregates of the mixture and reduces porosity, absorption of moisture and improves binding property of the mix.
II. The Optimum Bitumen Content (OBC) was found to be 5.00% by weight of aggregates. The Optimum Plastic Content (OPC) to be added as a modifier of bituminous concrete mix was found to be 11% weight of Optimum Bitumen Content (OBC) when there is a 40% addition of fly ash by the wt. of CSD filler of bituminous concrete mix.
III. Bituminous concrete mix modified with waste plastic coated aggregates along with the addition of fly ash showed higher Marshall stability value by 1.21 KN and increases the flow value slightly by 0.13 mm as compared to conventional bituminous concrete mix.
IV. The density value of the waste plastic aggregate bituminous mix along with the fly ash (replacement of 11% bitumen by the waste plastic and addition of 40% fly ash by the weight of CSD), decreases by 0.25 gm/cc as compared to the conventional mix.
V. The air voids value has also shown positive results, i.e., it also decreases by 1.64% when we modified the conventional mix with the 11% replacement of bitumen by the waste plastic along with the addition of 40% fly ash.
VI. The waste plastic aggregate bituminous mix (11% OPC) along with the addition of 40% fly ash has also showed that the VMA and VFA values also increases respectively by 6% and 17% as compared to the conventional mix.
VII. From cost analysis of project it is observed that, the cost reduction for one kilometer road is approximately Rs 64,600/-.

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