Experimental Studies on The Using of Plastic Waste for Dense Bituminous Macadam

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Abstract — In India, most roads are constructed with flexible sidewalks, but the performance of the sidewalk depends largely on the quality and type of material used. The disposal of waste materials, including plastic water bottles, has become a serious problem and is not completely burned. That proves it is also harmful to the environment. In this study, plastic beg was used as a waste plastic material. In plastic waste chemical compositions like polyethylene, polystyrene, poly-propolyen, etc., melt at temperatures of 120 °C to 160 °C. The water bottles are made from HDPE plastic waste. In the given research, the use of plastic waste as a partial replacement of stone dust for different percentages. The plastic waste is cut and cleaned into a size that is passed through a 2.3 mm sieve. In the study, some tests were performed to check the physical properties of unmodified bitumen VG30 and natural aggregate to acknowledge their strength and which can be used in the design of the DBM mix. After performing the physical test, they prepared some mold at different percentages of 4%, 4.5%, 5%, and %.5.5% for the Marshall Stability test by Digital Marshall Apparatus. After obtaining the results of Marshall Properties, they found that the optimum content was 4.5%. After seeing the OPC, we took some percentages of plastic waste as 5%, 7%, 9%, and 12% replacement of stone dust and prepared the mold for testing. After testing the prepared mold, the results concluded that using plastic waste in pavement construction is better than preparing normal pavement. The plastic waste provided some more strength and liquefaction to the pavement surface. When the plastic was heated with aggregate and binders, it melted and created a bond with the aggregate and binders Due to the load applied on the surface, it will not crack easily and provided smooth surfaces for vehicles. This mixed design can also help green technologies provide a good surface at a low cost in rural and semi-urban areas.

Keywords: VG30, MARSHALL STABILITY, DBM

I. INTRODUCTION

The road system in India is around 58.98 lakh km in length, making it the second biggest in the world behind the road system in the United States of America. That includes the Interstate, the Expressway, the State Highway, the Major District Road, the Other District Roads, and the Village Roads. There are 1,32,500 kilometres of National/Expressway Roads, 1,56,694 kilometres of State Highways, and 56,08,477 kilometres of Other Roads that make up the Road network. These highways would be impractical because to the enormous expenditures associated with building and maintaining them. Professionals in the transportation industry have a formidable challenge when tasked with assessing, maintaining, and improving such a massive road network. Bituminous pavements account for 98% of all roadways because they are inexpensive to install and maintain.

There are two main categories of pavement: flexible and stiff. Rigid pavements are those with a stiffer material like Plain Cement Concrete (PCC) on top and transfer loads to earthen strata below via a slab mechanism, while flexible pavements are those with a bitumen covering on top and move loads from upper layers to bring down layers lastly to earthen layers underneath it by means of a grain to grain move component. Bituminous pavements' effectiveness has been evaluated with input from transportation experts all around the globe. To create flexible pavements, several nations now use secondary aggregates and plastic garbage. There are many types of soils and low grade materials available in India that can be used to great effect in road construction, and the country has fostered a few advancements to consolidate these negligible materials in asphalt development. IRC SP 98 likewise portrays in their review the utilization of waste plastic in hot bituminous blends. The current resources are enough; they may be put to good use. Lower-quality materials readily accessible in the area may be used in the pavement's base provided they are modified and stabilised properly.

II. MATERIAL USED

1) BITUMEN: The bitumen used in this study was of VG-30 grade. It was tested in the laboratory for basic conventional tests such as Penetration, Ductility, Softening Point, Specific Gravity, Viscosity and Flash Point.
2) STONE AGGREGATE: The physical properties of stone aggregates used in this studyare shown

S. No.	Aggregate tests	Tests Results	Requirement as per Table500-14 of MORTH (IV Revision) Specification
1.	Crushing Value (%)	24.8	-
2.	Impact Value (%)	20.0	Max 24 %
3.	Los Angeles Abrasion Value(%)	25.0	Max 30 %
4.	Water Absorption (%)	0.50	Max 2 %
5.	Specific Gravity of Coarse Aggregates	2.81	2.5-3.0
6.	Specific Gravity of	2.75	

	Fine Aggregates		
7.	Specific Gravity of Filler	2.65	

3) FILLERS: Fillers consist of finely divided mineral matter such as rock dust, hydrated lime or cement. Filler has an important effect on the voids content and the stiffness of the bitumen- fines matrix. The filler material used in the study is stone dust and cement. Out of the 5 percent filler, 3 percent stone dust and 2 percent cement was used. The grading requirements for mineral fillers indicated in Table

IS Sieve (mm)	Cumulative Percent Passing by Weight of Total Aggregate
0.6	100
0.3	95-100
0.075	85-100

III. METHODOLOGY USED

In this research, natural aggregates and one unaltered bitumen binder & plastic waste as filler were utilised to create a pavement construction material, and a technique was developed to evaluate its properties based on a survey of the relevant literature. Below is a flowchart illustrating the suggested approach of the current research, which was designed in order to carry out the experimental work on the DBM mixes. This suggested approach also makes an effort to explain how various plastic waste filler percentages may be employed in the making of DBM mixtures. Both the aims and limitations of this research were articulated and clarified using this methodological approach. As a result of using this strategy, we are certain that our current examination of bituminous blends will be fruitful.

1) Material Sourcing and Identification
2) Analysis of the material's physical characteristics
3) Aggregate Gradients
4) Creating a mix using aggregate and binders
5) A Look at the Data and the Outcomes

IV. RESULT AND DISCUSSION

– physical characteristics of pure bitumen (VG30):

S. No.	Properties	Test Method	VG-30 Results	MoRT&H specification (2013)
1	Penetration (100 gram, 5second at 25°C) (1/10th of mm	IS 1203	66	50-70
2	Softening Point °C (Ring and Ball Apparatus), Minimum	IS 1203	50	45-52
3	Ductility at 27 °C (5cm/ minute pull),cm	IS 1208	53	+40
4	Specific Gravity	IS 1203	1.01	0.97-1.02
6	Flashpoint, °C, minimum	IS 1209	240	220
7	Fire point, °C, minimum	IS 1209	260	247

Table 5.1: Index properties of soil

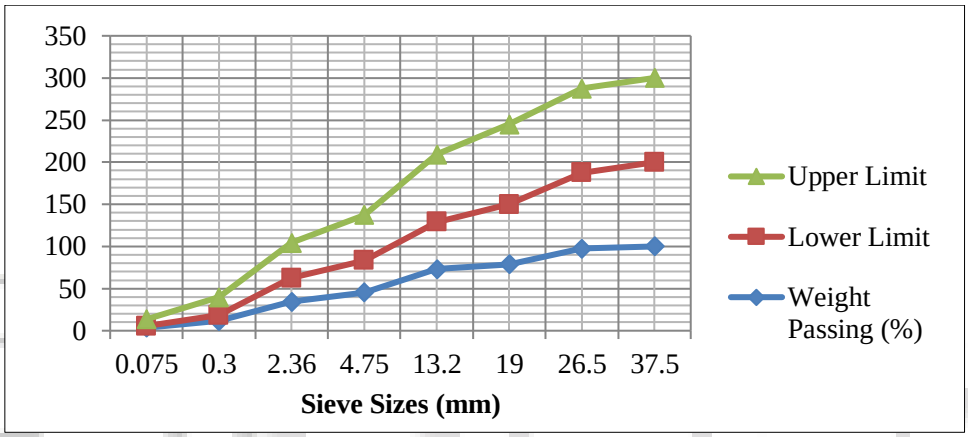
– MDD Physical Properties of Natural Aggregate used in BC

S. No.	Properties	Test Method	Natural Aggregate	MoRTH specification (2013)
01	Aggregate Impact Value	IS:2386 (IV)	15%	Max 24%
02	Los Angeles Abrasion Test	IS:2386 (IV)	21.78%	Max 30%
03	Water Absorption Value	IS:2386 (III)	1.018%	Max 2%
04	Specific Gravity	IS:2386 (III)	2.67For 10mm, 2.69 For 6mm, 2.83 For Stone Dust	2.5-3.0
05	Combined Flakiness and Elongation Index	IS:2386 (I)	26.23%	Max 35%

Table 5.2:

– Gradation of Aggregate:
The NA collected in this research has been used in the construction of DBM Then we have arranged the sieves according to the MORTH (2013) for Grading-I for bituminous concrete. We have done grading of NA by hand without using a sieve shaker. Table 5.3 lists the aggregate grade that was chosen because it best meets the parameters for the midway gradation of Grading-I of Dense Bituminous Mix as published by the Ministry of Roads and Highways (MoRTH, 2013).

S.No.	Sieve Size (mm)	Weight Retained (gms)	Weight Retained (%)	Cumulative Weight Retained (%)	Weight Passing (%)	Specified Limits
1.	37.5	0	0	0	100	100
2.	26.5	124	2.48	2.48	97.52	90-100
3	19	929	18.58	21.06	78.94	71-95
4.	13.2	292	5.84	26.90	73.10	56-80
5.	4.75	1387	27.74	54.64	45.36	38-54
6.	2.36	547	10.9	65.54	34.46	28-42
7.	0.3	1142.5	22.85	88.39	11.61	7-21
8.	0.075	403.5	8.07	96.46	3.54	2-8



– Gradation of Filler for DBM Mixes:
The filler material used in this study was the cement of Grade 43. The quantity of cement used was 2% weight of aggregates. The grading limits are tabulated as per the MoRTH, (2013). It has made the sieves arrangement for grading of filler material as per the requirement of DBM Layer shown in Table. The sieving of cement of 43 grade through these arrangements and find that the cumulative % passing by weight was in the limits mentioned in MoRTH, 2013

S. No.	IS Sieve (mm)	Cumulative % passing by weight of total aggregate (Obtained values)	Cumulative % passing by weight of total aggregate (MoRTH, 2013)
1	0.6	100	100
2	0.3	100	95-100
3	0.075	98	85-100

– Marshall Properties of Unmodified Bitumen:
The results of VG30 grade bitumen with natural aggregate, with some trial percentages of bitumen, i.e., 4.0, 4.5, 5.0, and 5.5. The overall weight of the aggregate is 1200 gms. Then observe the results of the VG30 grade normal DBM mix. Table represents the Marshall properties of normal Bitumen VG30

S. No.	Property Tested	Bitumen Content by weight of Aggregate			
		4.0%	4.5%	5.0%	5.5%
1	Marshall Stability (KN)	7.13	7.32	8.00	8.35
2	Marshall Flow Value (mm)	2.51	2.94	3.20	3.53
3	Bulk Density (g/cc)	2.65	3.09	3.18	3.32
4	Volume Of Voids (V_v)%	2.45	2.52	2.8	2.7
5	Void in Mineral Aggregate, (VMA)%	13.99	15.35	18.07	19.06
6	Void filled with Bitumen, VFB (%)	67	69	73	75
7	Marshall Quotient (KN/mm)	2.8	2.4	2.5	2.7

Above table displays the computed and tabulated mean values for a variety of mix parameters. The proportion of bitumen present, together with the other variables, are shown on graph paper.

- Marshall Stability Value (KN)
- Marshall Flow Value (mm)
- Unit Weight (g/cc3)
- Voids Filled with Bitumen (%)
- Void Mineral Aggregate (%)

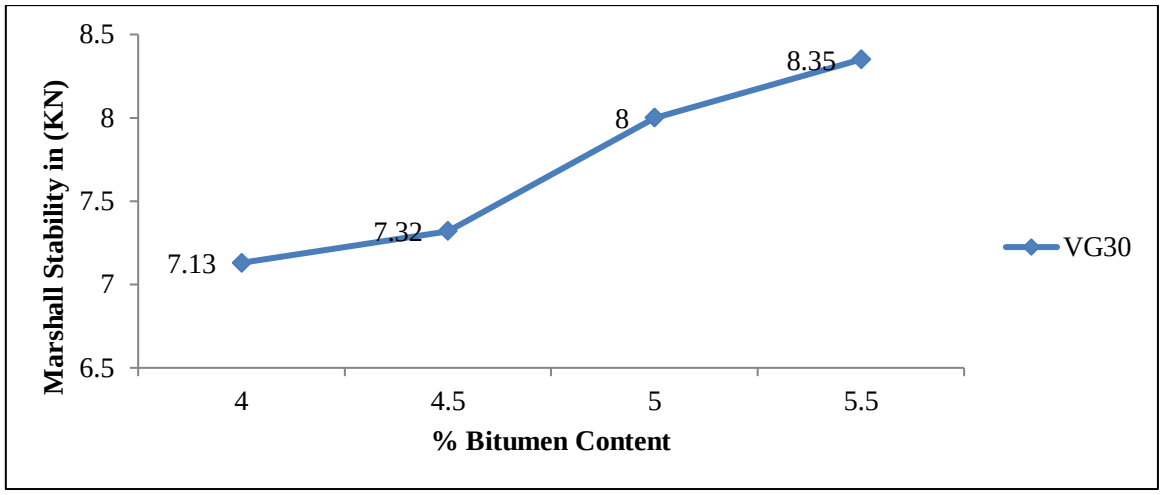


Fig. 13: Bitumen Content vs. Marshall Stability (KN)

The Marshall Stability value is shown to rise with increasing bitumen concentration up to a particular bitumen content as shown by the graphs.

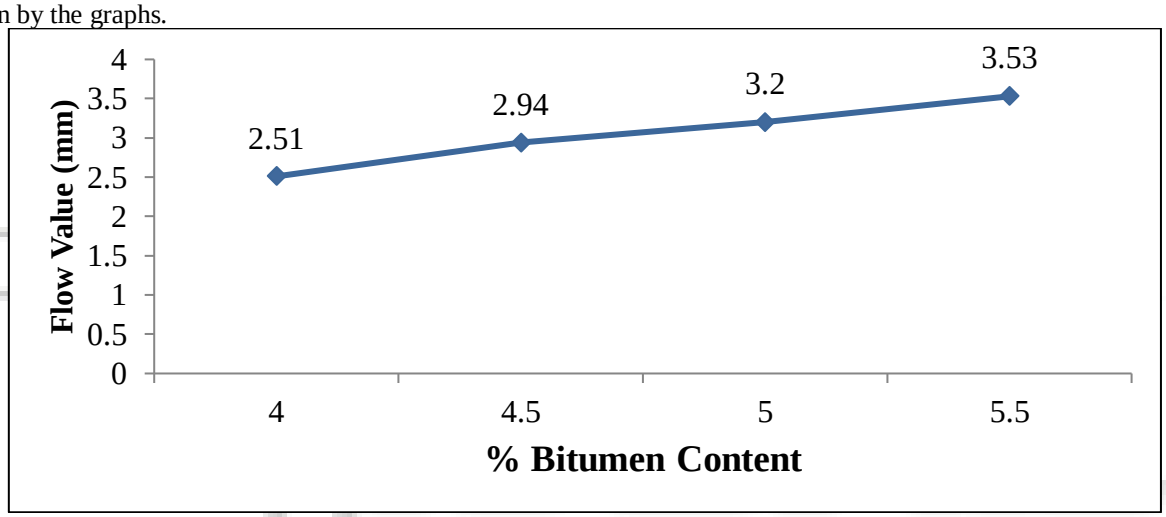


Fig. 14: Marshall Flow Value vs. Bitumen Content

The correlation between the Marshall Flow Value and Bitumen Content is seen in Fig. 14. It has been discovered that the flow value of natural BC mixes rises as the bitumen component rises.

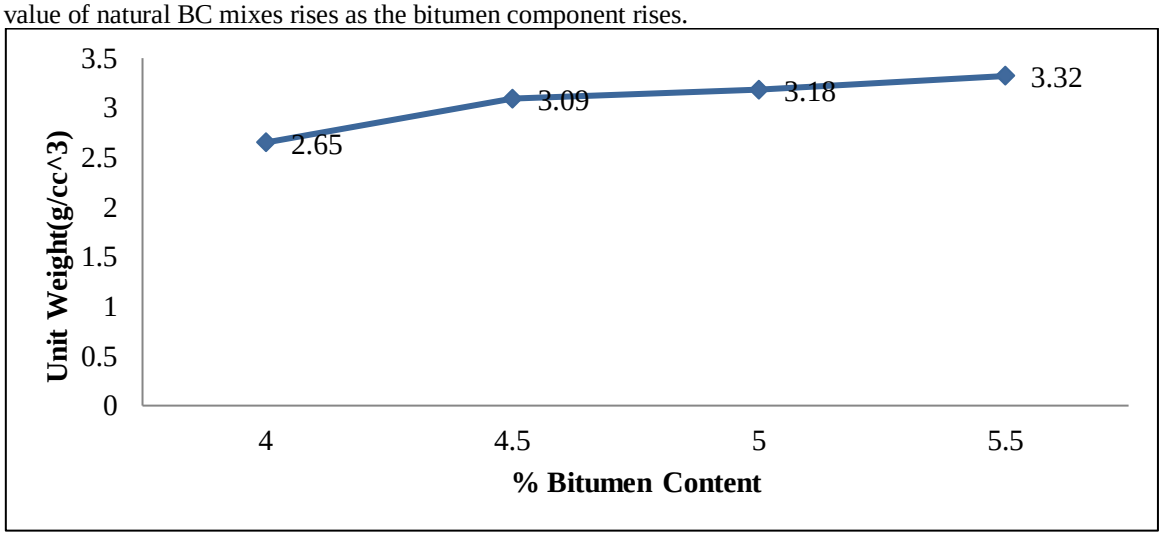


Fig. 15: Unit Weight vs. Bitumen Content

The correlation between BC mix unit weight and bitumen content is seen in Fig. 15. Increases in bitumen content are correlated with increases in unit weight, as is seen.

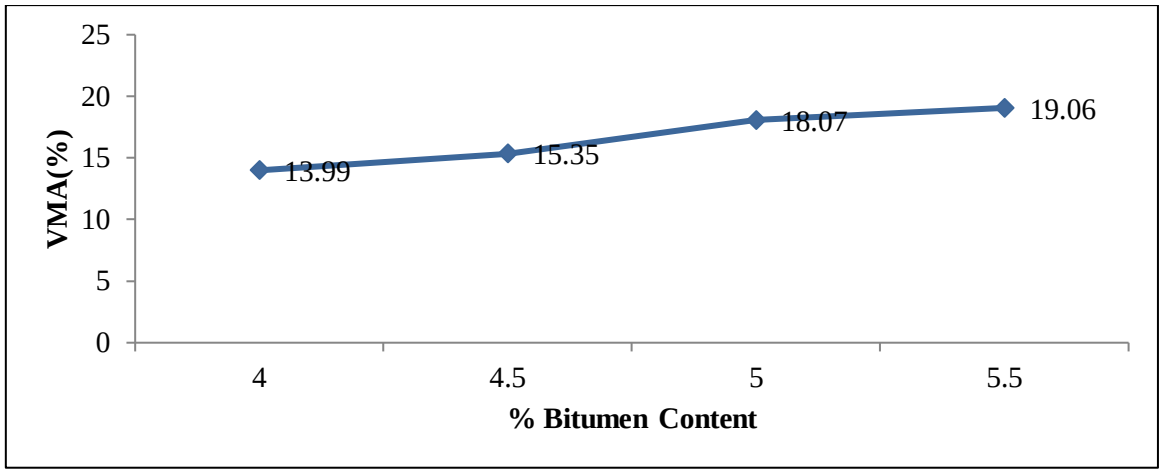


Fig. 16: VMA (%) vs. Bitumen Content

Fig.16 shows the relationship between the percentage of void mineral aggregates and bitumen content. It is clear from the graph that there is an increase in bitumen content and the increase in %VMA

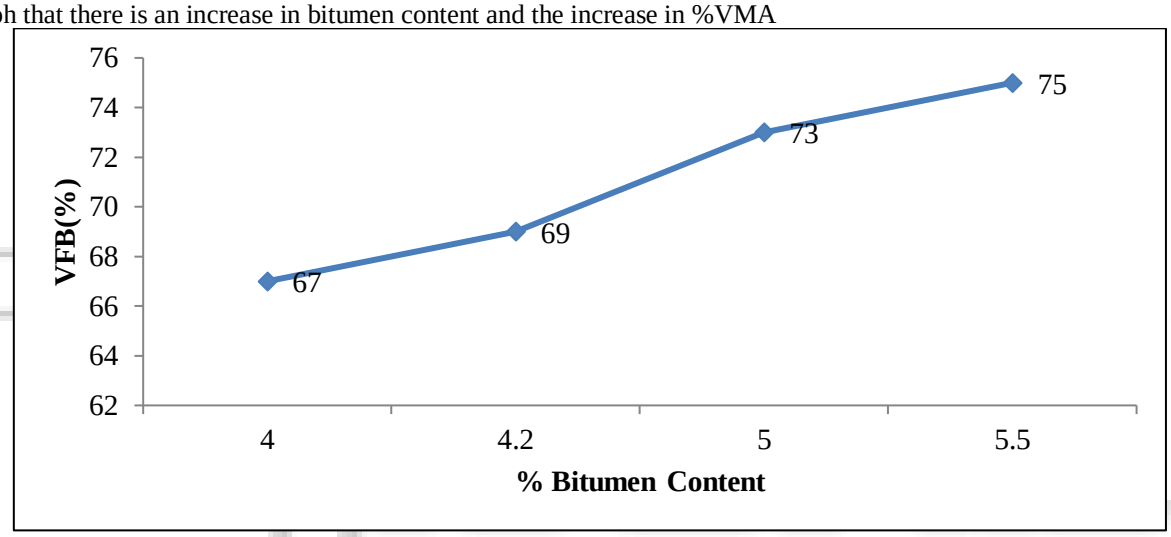


Fig. 17: VFB (%) vs. Bitumen Content

Fig, 17 shows the relationship between bitumen content and the percentage of the void filled with bitumen. The graph shows the parabolic relation between these two parameters. After tabulating and graphing the relationships between various BC mix parameters and bitumen content, it becomes clear that as bitumen content rises, %VFB rises as well. The suggested research suggests that the optimum bitumen content may be determined by finding the value of bitumen content at which the sample exhibits both the lowest Marshall Stability Value and the lowest Marshall Flow Value. By comparing Figure 5.1 and Figure 5.2, we may deduce that 4.5 percent bitumen is the sweet spot for plastic blends.

As per the research studies designed the Four new modified DBM mixes by replacing the Stone Dust with Waste plastics. As the proportions of these modified DBM mixes are mentioned in Table 4.8. The proportions of waste plastic mixes are 5%, 7%, 9% and 12%. Table 8 provides a comparison of the Marshall characteristics and volumetric properties of the several modified DBM blends.

S. No.	Property Tested	Plastic Content by weight of Aggregate			
		5%	7%	9%	12%
1	Marshall Stability (KN)	8.38	8.55	8.9	9.20
2	Marshall Flow Value (mm)	2.31	2.16	2.10	1.95
3	Bulk Density (g/cc)	2.53	2.76	2.98	3.15
4	Volume Of Voids (V_v)%	4.20	4.53	4.92	5.10
5	Void in Mineral Aggregate, (VMA)%	13.99	14.35	16.07	18.06
6	Void filled with Bitumen, VFB (%)	70	72	74	76
7	Marshall Quotient (KN/mm)	3.06	3.95	4.23	4.71
8	Optimum Bitumen Content(OBC)	4.5%			

Table 5.3: shows Marshall Properties after Mixing Plastic Waste

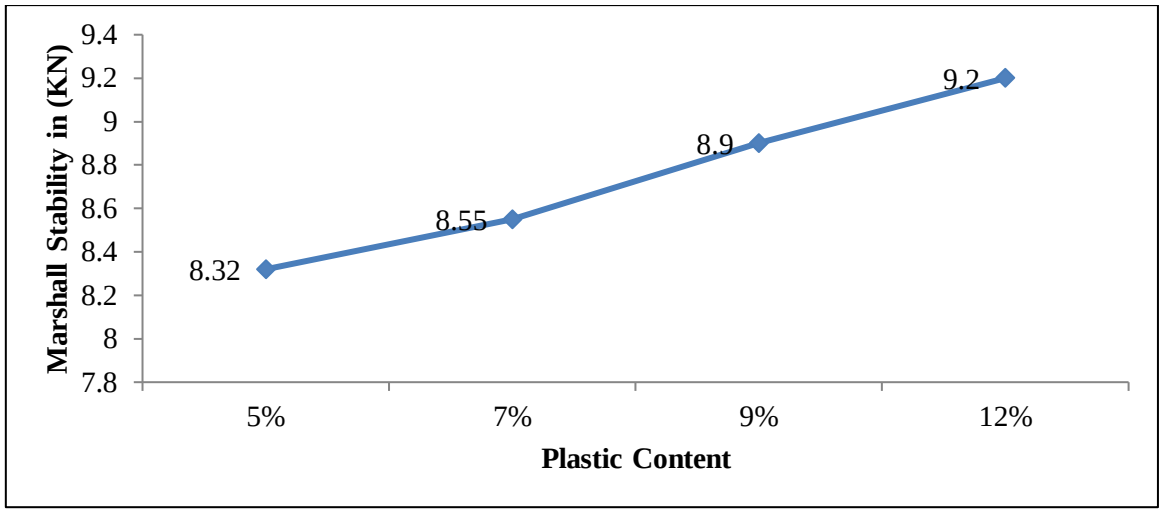


Fig. 18: Plastic Content vs. Marshall Stability (KN)

After replacing the stone dust with various percentages of plastic waste, discovered that the Marshall Stability increases as the percentage of plastic content increases

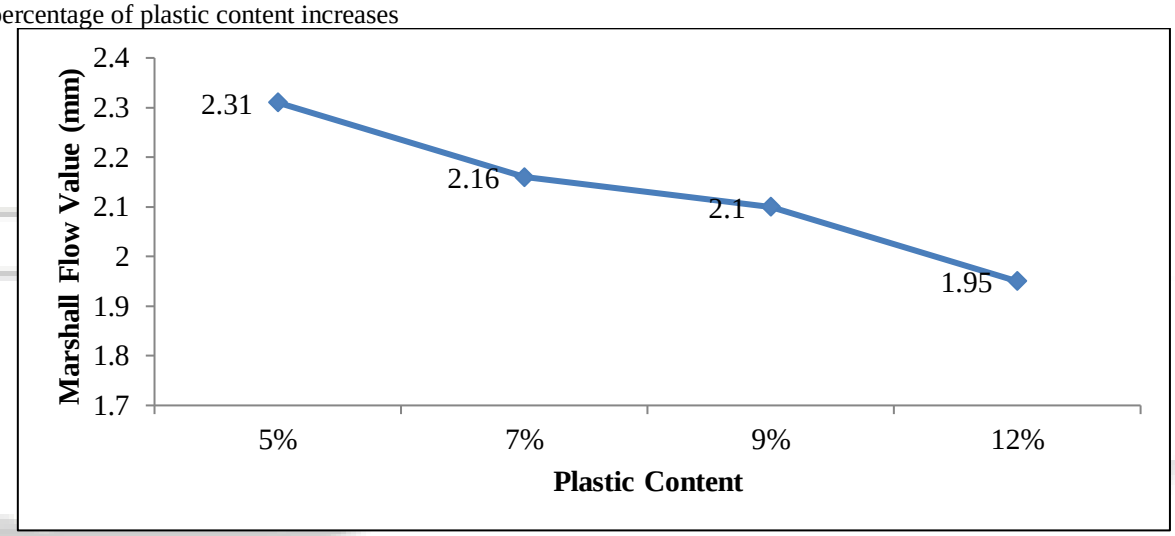


Fig. 19: Plastic Content vs. Marshall Flow Value (mm)

The Marshall Flow Value is decreasing as we increase the percentage of bitumen. The main reason for the decrease in Marshall Stability is that, after melting, the plastic makes a stronger bond with the aggregate. so that after applying the load, cracks will not develop.

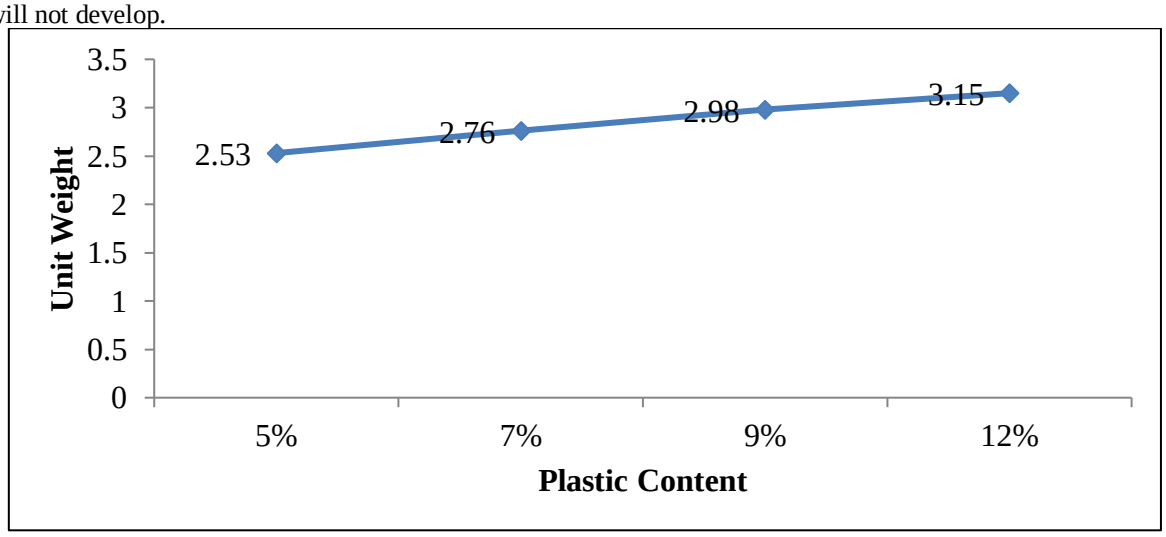


Fig. 20: Plastic Content vs. Unit Weight

Fig. 20 shows the relationship between the Plastic content and the unit weight of DBM mixes. It has been discovered that when the bitumen concentration rises, so does the unit weight.

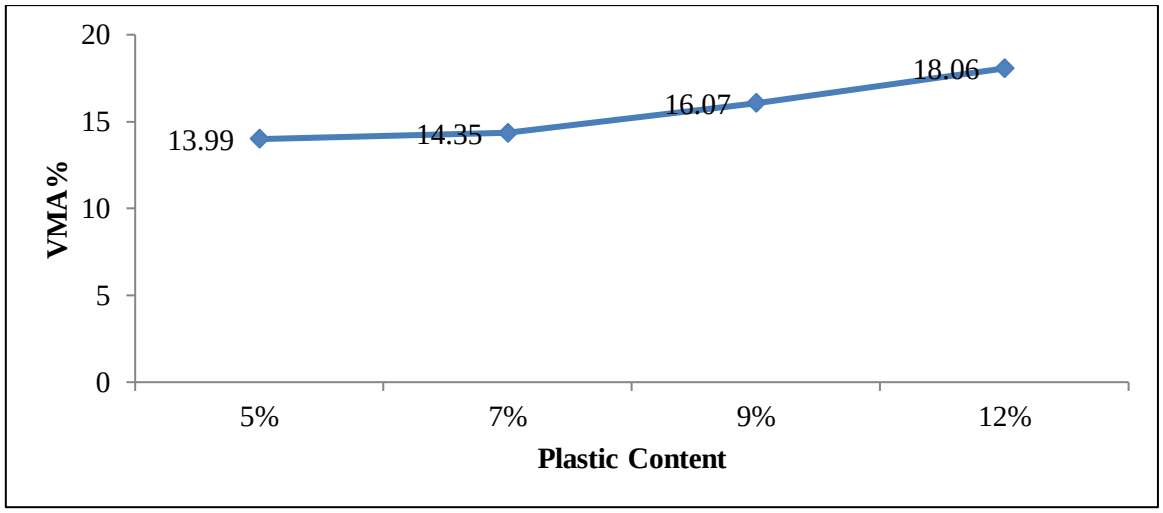


Fig. 21: Plastic Content vs. VMA%

Once the bitumen content in a mixture is raised, the velocity-momentum asymmetry (VMA) is shown to rise gradually at first, and subsequently at a quick pace. A graph depicting the change in VMA values across binder contents and plastic contents is shown. The VMA values are higher than those of normal mixes when plastic trash is added to the mixture, as shown in the graph.

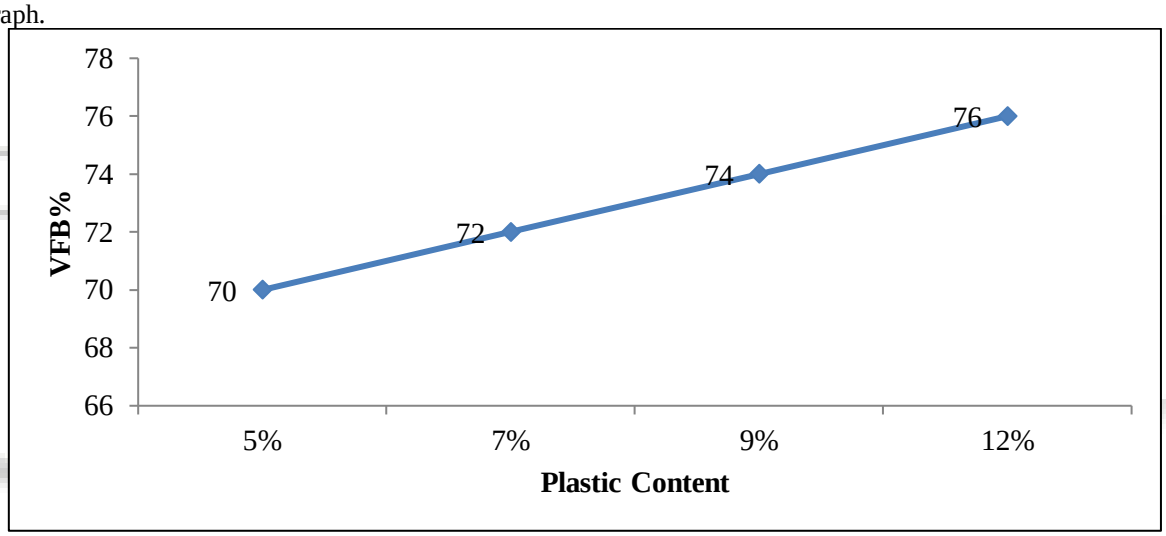


Fig. 22: Plastic Content vs. VFB%

When bitumen concentration is raised, it is shown that VFB values for various mixtures rise at a precipitous pace. The graphs below demonstrate the variation in VFB between binder contents of varying polyethylene contents. Polyethylene's inclusion in the mixture results in a higher VFB compared to more traditional types of mix, as seen by the graphs.

V. Conclusion

Based on the experimental investigations carried out and results obtained, following conclusion are drawn from the study

1) Flexible pavements made from recycled plastic give superior outcomes than those from traditional methods.
2) The aggregates' polymer covering decreases voids and water absorption.
3) In addition to being more long-lasting than flexible pavement, plastic pavement can also sustain significant amounts of vehicular traffic.
4) The use of plastic mix may reduce the amount of bitumen needed to construct the road by 10% without sacrificing performance or durability.
5) As the amount of plastic trash added to bitumen grows, the material's aggregate and bitumen characteristics improve, as shown.
6) The technology is very sustainable since it recycles the plastic that would otherwise wind up The plastic waste provided some more strength and liquefaction to the pavement surface. When the plastic was heated with aggregate and binders, it melted and created a bond with the aggregate and binders.
7) After the load applied to the surface, it will not crack easily and will provide vehicles with smooth surfaces. This mixed design can also help green technologies provide a good surface at a low cost in rural and semi-urban areas.

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