PARTIAL REPLACEMENT OF BITUMEN WITH WASTE PLASTIC IN FLEXIBLE PAVEMENTS

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Abstract: *The main objective of this project is use of waste plastic material in the flexible pavement construction and analyse the Marshall Stability value for the bituminous mix in the laboratory. Since the traffic intensity is increasing every year, because of which there will be more repetition of loaded vehicles. There is a need for better quality of pavement in terms of strength, durability and resistance to the deformation for avoiding deterioration of pavement and obtain better raiding quality. This study will take care of aspects like better pavement characteristics and eco-friendly nature in terms of reusing the waste materials. In the present study twenty mm down aggregates is replaced for about five percent with plastic waste and BC grade-II mix is prepared. This can be used for surface course of flexible pavement in road construction. The Marshall Stability values are checked for the above samples and is compared with the conventional BC grade-II mix. By using above plastic waste materials there will be increase the strength, durability, resistance to the deformation and water resistance as well as providing a mean to dispose of wastes. At the end, it concludes that the modified bituminous mix is cheaper than conventional bituminous mix. The test result of modified bituminous mix is found to be better than conventional bituminous mix.*

Keywords: Marshall Stability, bituminous mix, waste plastic material, BC Grade-II, flexible pavement

1.INTRODUCTION

A material that contains one or more organic polymers of large molecular weight, solid in its finished state and at some state while manufacturing or processing into finished articles, can be shaped by its flow, is called as 'Plastic'. Plastics can be divided in to two major categories: thermoses and thermoplastics. A thermoset solidifies or sets irreversibly when heated. They are useful for their durability and strength, and are therefore used primarily in automobiles and construction applications. A thermoplastic softens when exposed to heat and returns to original condition at room temperature. Thermoplastics can easily be shaped and moulded into products such as milk jugs, floor coverings, credit cards, and carpet fibres. With increase in the global population and the rising demand for food and other essentials, there has been a rise in the amount of waste being generated daily by each household. Plastic in different forms is found to be almost 5% in municipal solid waste, which is toxic in nature. Due to its biodegradability it creates stagnation of water and associated hygiene problems. In order to mitigate this problem experiments have been carried out whether this waste plastic can be reused productively. The experimentation at several institutes indicated that the waste plastic, when added to hot aggregate will form a fine coat of plastic over the aggregate and such aggregate, when mixed with the binder is found to give higher strength, higher resistance to water and better performance over a period of time. Waste plastic such as carry bags, disposable cups and laminated pouches like chips, pan masala, aluminium foil and packaging material used for biscuits, chocolate, milk and grocery items can be used for surfacing roads. Use of plastic in road construction not only increases its durability but also makes it economically sound and environment friendly. In the present study plastic waste is used by replacing the twenty mm down size aggregates and Marshall Stability value for the bituminous mix is checked. The roads that are constructed using plastic waste are known as Plastic Roads and are found to perform better compared to those constructed with conventional bitumen. The steady increase in high traffic intensity in terms of commercial vehicles, the increase in over loading of trucks and the significant variation in daily and seasonal temperature demand improved road characteristics. Under these situations, it is essential to modify the asphalt cement using modifiers to improve its engineering properties. On the other hand, the environmental problem such as disposal of waste plastic is major concern. To overcome the problems the modifiers (waste plastic) are used. Among various types of modifiers, polymers are probably the most promising.

1.1 Objectives

Main motto is to efficiently utilize the waste plastic in constructive way so that it can be beneficial to society however main objectives of current project work are:

1) To utilize the plastic waste and to reduce its impact on environment.
2) To analyse the performance tests like Marshall Stability value for conventional BC Grade-II mix and compared with BC grade-II mix that is prepared by replacing 5% of waste plastic material.

2.LITERATURE REVIEW

1. The design of Flexible Pavement using Waste Plastic **[Devesh ojha et al, 2014] 2.** Use of Biomedical Plastic Waste in Bituminous Road Construction. International Journal of Engineering and Advanced Technology (IJEAT) ISSN: 2249 – 8958, Volume-3 Issue-6, August 2014 [**Bhageerathy K. P] 3.** "Utilization of Polymer Waste for Modification of Bitumen in Road Construction", Scientific Reviews and Chemical Communications, Volume 2, Issue 3, 2013, PP. 198-213 **[Shirish N. Nemade** and **Prashant V. Thorat].4.**Explains that by coating the aggregate with the polymer has many advantages and which ultimately helps in improving the flexible pavement quality not only it improve the pavement quality but also improve the aggregate quality **[S.Rajasekaranetal, 2013]5.**Application of Waste Plastic as an effective Construction Material in Flexible Pavement. International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056 Volume: 02 Issue: 03 | June-2015,ISSN: 2395-0072. **[Sasane Neha .B., Gaikwad.Harish, Dr.J R Patil and Dr. S D Khandekar] 6.**Some encouraging results were reported in this study that there is possibility to improve the performance of bituminous mixes of road pavements**[V.S. Punith, 2001] 7.** Pavement performance on roads surfaced using bituminous mixtures with coated aggregates. International journal of Engineering research & technology.[**Sreedevi, B.G. & Salini, P.N. (2013)]. 8.**The "Stability and Flow by Means of the Marshall Apparatus", to Matthew Church, Highway Materials laboratory. The purpose of the Marshall Stability and flow test was to determine the stability and flow values of asphaltic specimens. The Marshall method of mix design used the values obtained as well as the unit weight and the voids in the total mix to determine an optimum mix design**[Christopher M. Smemoe, 1994].**

3. MATERIAL AND METHODOLOGY ADOPTED

Selection of mix constituents:
Binder and aggregates are the two main constituents of bituminous mix.
Binder: VG-30 grade bitumen is used in the present study.
Aggregate: Aggregate of 20mm down, 12.5mm down, Stone Dust and cement is used as Filler Plastic

Plastic: Waste bottles are in shredded form and they can be used as a binder and/or they can be mixed with a binder like bitumen to enhance their binding property. this may be an honest modifier for the bitumen, used for road construction.

3.1 Marshall Stability Test

To determine the Marshall stability of bituminous mixture as per ASTM D 1559.Marshall stability is the resistance to plastic flow of cylindrical specimens of a bituminous mixture loaded on the lateral surface. It is the load carrying capacity of the mix at 60oC and is measured in kg.

Test Procedure

- Heat the weighed aggregates and the bitumen separately upto 170°C and 163°C respectively.
- Mix them thoroughly, transfer the mixed material to the compaction mould arranged on the compaction pedestal.
- Give 75 blows on the top side of the specimen mix with a standard hammer (45cm, 4.86kg).

- Reverse the specimen and give 75 blows again. Take the mould with the specimen and cool it for a few minutes.
- Remove the specimen from the mould by gentle pushing. Mark the specimen and cure it at room temperature, overnight.
- A series of specimens are prepared by a similar method with varying quantities of bitumen content, with an increment of 0.5% (3 specimens) or 1 bitumen content.
- Before testing of the mould, keep the mould in the water bath having a temperature of 60°C for half an hour.
- Check the stability of the mould on the Marshall stability apparatus.

Table-3.1: Corrections factors for Marshall sample

Volume of specimen in Cm³	Thickness of specimen in mm	Correction factors
427-470	57.1	1.19
471-482	58.7	1.14
483-495	60.3	1.09
496-508	61.9	1.04
509-522	63.5	1.00
523-535	65.1	0.96
536-546	66.7	0.93
547-559	68.3	0.89
560-573	69.9	0.86

The above procedure is repeated on specimen prepared with other values of bitumen content; in suitable increments say 5%, 5.5%, 6%, 6.5% bitumen by weight of total mix. The bulk density, percent air voids, voids in mineral aggregates, and voids filled with bitumen are calculated using following relationships.

Properties of the mix

The properties that are of interest include the theoretical specific gravity G_t, the bulk specific gravity of the mix G_m, percent air voids V_v, percent volume of bitumen V_b, percent void in mixed aggregate **VMA** and percent voids filled with bitumen **VFB**. These calculations are discussed next. To understand these calculation a phase diagram is given in Figure.

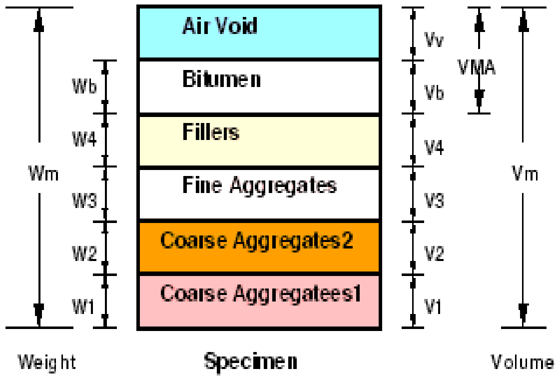

Figure 2: Phase diagram of a bituminous mix

Theoretical specific gravity of the mix G_t :

Theoretical specific gravity G_t is the specific gravity without considering air voids, and is given by:

$$G_t = \frac{W_1 + W_2 + W_3 + W_b}{\frac{W_1}{G_1} + \frac{W_2}{G_2} + \frac{W_3}{G_3} + \frac{W_b}{G_b}} \quad (1)$$

where, W_1 is the weight of coarse aggregate in the total mix, W_2 is the weight of fine aggregate in the total mix, W_3 is the weight of filler in the total mix, W_b is the weight of bitumen in the total mix, G_1 is the apparent specific gravity of coarse aggregate, G_2 is the apparent specific gravity of fine aggregate, G_3 is the apparent specific gravity of filler and G_b is the apparent specific gravity of bitumen,

Bulk specific gravity of mix G_m:

The bulk specific gravity or the actual specific gravity of the mix G_m is the specific gravity considering air voids and is found out by:

$$G_m = \frac{W_m}{W_m - W_w} \quad (2)$$

where, W_m is the weight of mix in air, W_w is the weight of mix in water, Note that $(W_m - W_w)$ gives the volume of the mix. Sometimes to get accurate bulk specific gravity, the specimen is coated with thin film of paraffin wax, when weight is taken in the water. This, however requires to consider the weight and volume of wax in the calculations.

Air voids percent V_v:

Air voids V_v is the percent of air voids by volume in the specimen and is given by:

$$V_v = \frac{(G_t - G_m)100}{G_t} \quad (3)$$

where G_t is the theoretical specific gravity of the mix, given by equation 1. and G_m is the bulk or actual specific gravity of the mix given by equation 2.

Percent volume of bitumen V_b:

The volume of bitumen V_b is the percent of volume of bitumen to the total volume and given by:

$$V_b = \frac{\frac{W_b}{G_b}}{\frac{W_1+W_2+W_3+W_b}{G_m}} \quad (4)$$

where, W_1 is the weight of coarse aggregate in the total mix, W_2 is the weight of fine aggregate in the total mix, W_3 is the weight of filler in the total mix, W_b is the weight of bitumen in the total mix, G_b is the apparent specific gravity of bitumen, and G_m is the bulk specific gravity of mix given by equation 2.

Voids in mineral aggregate VMA:

Voids in mineral aggregate **VMA** is the volume of voids in the aggregates, and is the sum of air voids and volume of bitumen, and is calculated from

$$VMA = V_v + V_b \quad (5)$$

where, V_v is the percent air voids in the mix, given by equation 3. and V_b is percent bitumen content in the mix, given by equation 4.

Voids filled with bitumen VFB:

Voids filled with bitumen **VFB** is the voids in the mineral aggregate frame work filled with the bitumen, and is calculated as:

$$VFB = \frac{V_b \times 100}{VMA} \quad (6)$$

where, V_b is percent bitumen content in the mix, given by equation 4. and **VMA** is the percent voids in the mineral aggregate.

$$V_v = \frac{(G_t - G_m)100}{G_t}$$

4. RESULTS AND DISCUSSIONS

Marshall properties for nominal bitumen mix samples of bitumen content of 5% by weight of total mass.

Total mass of marshall sample =1200+5gm

weight of coarse aggregate, W_1 = 572.00 gm

weight of fine aggregate, W_2 = 531.00 gm

weight of filler, W_3 = 97.00 gm

weight of bitumen, W_b = 60 gm (5%)

specific gravity of coarse aggregate, G_1 = 3.16

specific gravity of fine aggregate, G_2 = 2.8

specific gravity of filler, G_3 = 2.65

specific gravity of bitumen, G_b = 1.021

weight of mix in air, W_m= 1250 gm

weight of mix in water, W_w= 735 gm

Specific Gravity

Bulk specific gravity of mix, Gm

$$G_m = \frac{W_m}{W_m - W_w} = \frac{1250}{1250 - 735} = 2.43$$

Theoretical specific gravity of the mix, Gt

$$G_t = \frac{W_1 + W_2 + W_3 + W_b}{\frac{W_1}{G_1} + \frac{W_2}{G_2} + \frac{W_3}{G_3} + \frac{W_b}{G_b}}$$

$$= \frac{572 + 531 + 97 + 60}{\frac{572}{3.16} + \frac{531}{2.8} + \frac{97}{2.65} + \frac{60}{1.02}} = 2.57$$

Voids percentage: Percent volume of bitumen, Vv

$$V_b = \frac{\frac{W_b}{G_b}}{\frac{W_1+W_2+W_3+W_b}{G_m}} = \frac{\frac{60}{1.021}}{\frac{572+531+97+60}{2.43}} \times 100$$

$$= 11.32\ \%$$

Air voids percent, Vv

$$= \frac{2.57 - 2.43}{2.57} \times 100 = 5.74\ \%$$

Void in mineral aggregate VMA

$$VMA = V_v + V_b$$
$$= 11.32 + 5.74 = 17.06\ \%$$

Voids filled with bitumen VFB

$$VFB = \frac{V_b \times 100}{VMA}$$
$$= \frac{11.32 \times 100}{17.06} = 66.36\ \%$$

Unit weight (kg/m3)= 9.81 × bulk density(Gm)

= 9.81 × 2.43 = 23.81

The same procedure is apply for plastic content from an results are shown in Table-4.2

4.1 Plotting Curves

Curves are plotted for the results obtained from Marshall tests conducts on nominal bitumen mix and plastic modified bituminous mix to get the optimum contents of bitumen and plastic. the both contents are obtained from Marshall stability curves, that which gives higher stability value

Marshall test results of bitumen for nominal mix: The results of the Marshall test of Marshall properties of specimens for nominal mix with varying percentage of bitumen contents have been presented in **Table- 4.1**

BC (%)	Weight of specimen (gm)		Specific gravity		Voids (%)			VFB (%)	stability	Flow (mm)
	Air	Water	Bulk	Theoretical	V_b	Vv	VMA			
5 %	1250	735	2.43	2.57	11.32	5.74	17.06	66.36	1792	1.8
5.5 %	1255	740	2.44	2.54	12.44	4.17	16.61	74.90	2912	2.1
6 %	1265	745	2.43	2.51	13.49	3.14	16.63	81.10	2387	2.6
6.5 %	1285	755	2.42	2.48	14.49	2.28	16.77	86.40	1505	2.85

Table-4.1 Marshall Properties of nominal bituminous

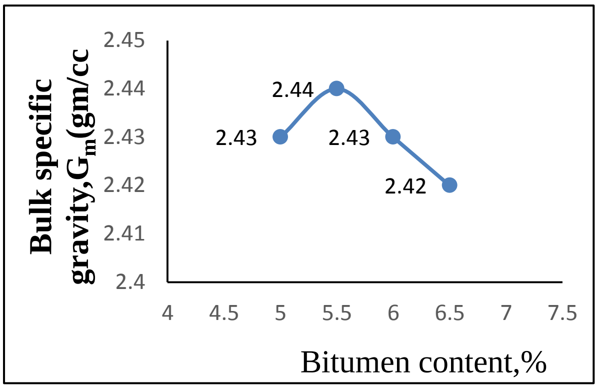

Fig.4.1 Variation of bulk specific gravity with bitumen content

Fig-4.1 Shows the variation of Marshall bulk specific gravity value with percentage of bitumen content where it is seen that usually an increasing trend is followed with increase in bitumen content after reach maximum point it is decreasing.

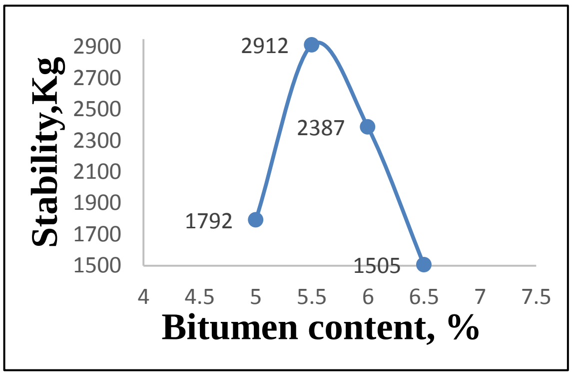

Fig-4.2: Variation of Marshall stability with bitumen content

Fig-4.2 Shows the variation of Marshall stability with bitumen content where it is seen that usual the stability value increases with bitumen content initially and then decreases. Maximum stability value of 14.21kn (1420.65) is observed at 6% bitumen content.

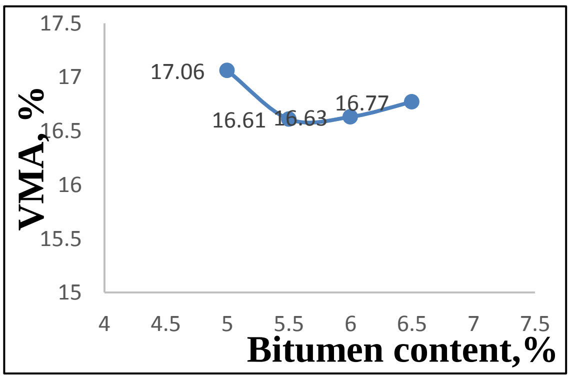

Fig-4.3: Variation of VMA with bitumen content

Fig-4.3 Shows the variation of Marshall flow value with percentage of bitumen content where it is seen that usually an increasing trend is followed with increase in bitumen content.

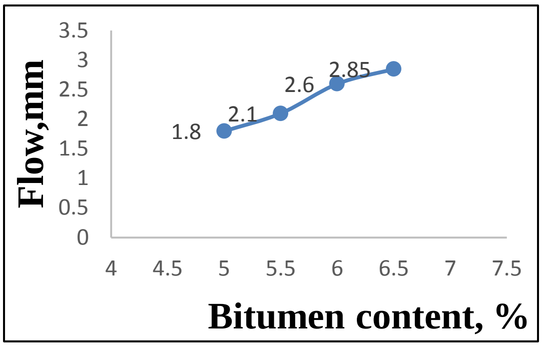

Fig-4.4: Variation of Flow with bitumen content

Fig-4.4 Shows the variation of VMA with variation in percentage of bitumen content with the minimum percentage of 15.28 %VMA being observed at 5.5 % bitumen content.

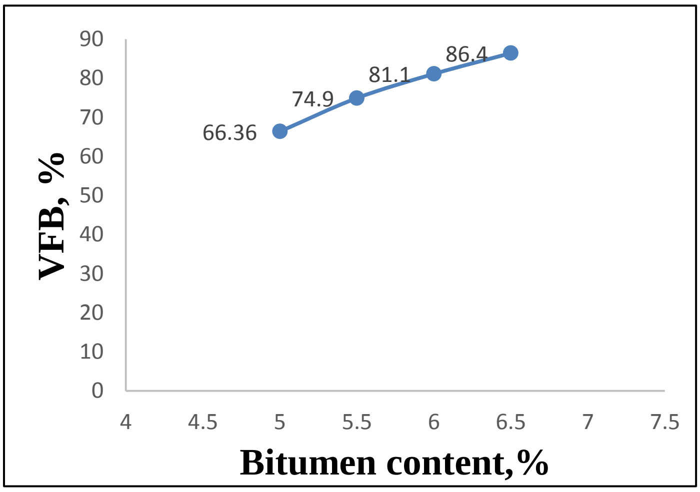

Fig-4.5: Variation of VFB with bitumen content

Fig-4.5 Shows the variation of Marshall VFB value with percentage of bitumen content where it is seen that usually an increasing trend with increase in bitumen content.

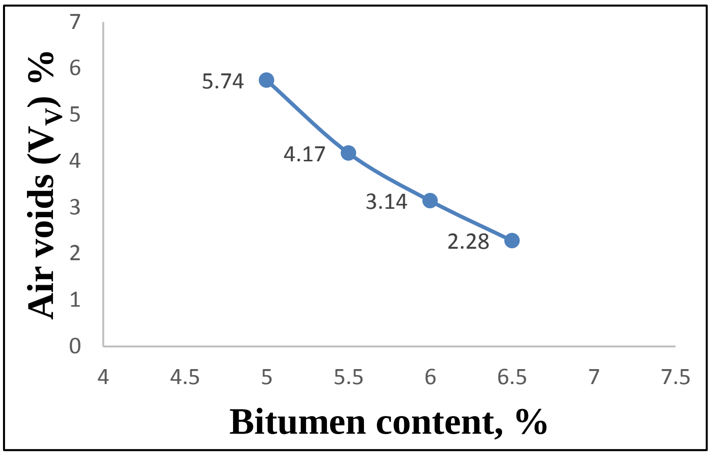

Fig-4.6: Variation of Air Voids with bitumen content

Fig-4.6 Shows the variation of air voids with percentage of bitumen content where it is seen that usually an decreasing trend with increase in bitumen content.

By observing the above graphs, it is clear that the maximum stability value obtained at the bitumen content of 6 %. Hence it is proved that the optimum bitumen content (OBC) is 6 %.

Now, plastic modified mix is prepared in such a way that, taken the bitumen content from 2.5%, 2.8%, 3%, 3.3% and changing in the plastic percentages as 2.5%, 2.8%, 3%, 3.3%. conducts the Marshall test on the sample prepared as mentioned above and draw the graphs for Marshall properties and find out the optimum plastic content(opc).

Bitumen/ plastic content (%)	Weight of specimen (gm)		Specific gravity		Voids (%)			VFB (%)	stability	Flow (mm)
	Air	Water	Bulk	Theoretical	Vb	Vv	VMA			
2.5/ 2.5 %	1154	565	1.96	2.05	28.3	4.4	15.7	71.97	1485	2.7
2.8/ 2.8 %	1149	569	1.983	2.052	11.35	3.2	14.55	75.9	1833	3.3
3/ 3 %	1134	560	1.969	2.055	10.85	4.02	14.87	72.4	1802	2.9
3.3/ 3.3 %	1127	549	1.944	2.058	13.23	5.56	15.79	65.56	1011	2.56

Table-4.2 Marshall stability values for bitumen plastic samples

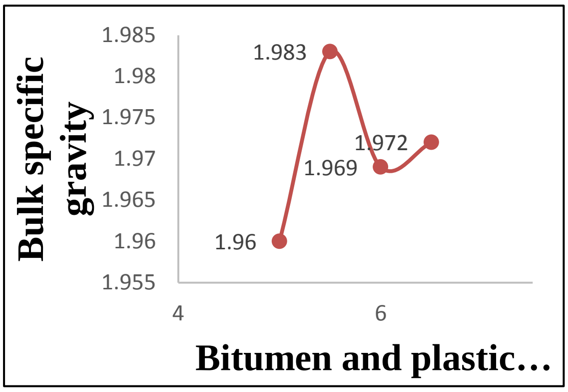

Fig-4.7: Variation of bulk specific gravity with bitumen and plastic content

Fig-4.7 Shows the variation of Marshall bulk specific gravity with percentage of bitumen & plastic content where it is seen that usually an increasing trend is followed with increase in plastic content.

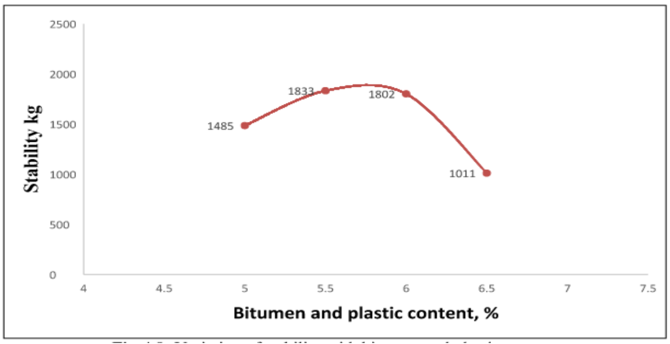

Fig-4.8: Variation of stability with bitumen and plastic content

Fig-4.8 Shows the variation of Marshall stability with bitumen content where it is seen that usual the stability value increases with bitumen and plastic content initially and then decreases. Maximum stability value of 1833 is observed at 5.5% bitumen and plastic content.

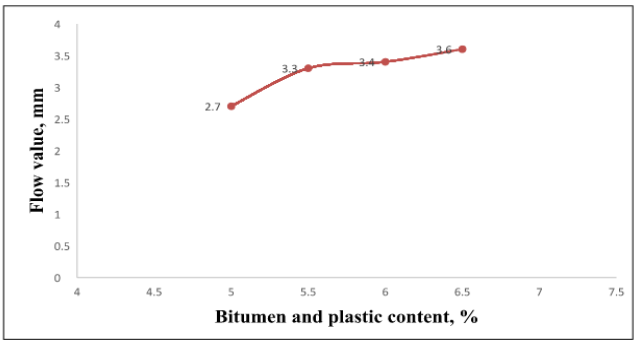

Fig-4.9: Variation of flow with bitumen and plastic content

Fig-4.9 Shows the variation of flow value with percentage of bitumen & plastic content where it is seen that usually an increasing trend is followed with increase in plastic content.

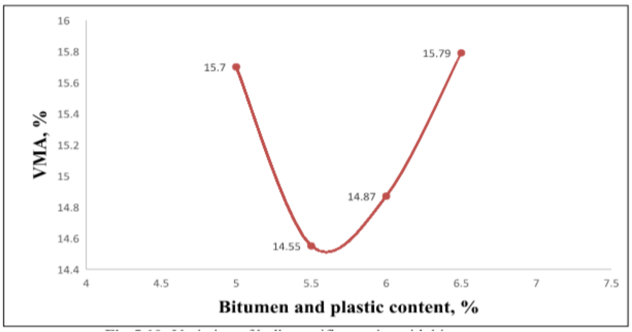

Fig-4.10: Variation of bulk specific gravity with bitumen content

Fig-5.10 Shows the variation of Marshall VMA value with percentage of bitumen & plastic content where it is seen that initially decreasing trend is followed with increase in bitumen and plastic content and after increasing in bitumen and plastic content.

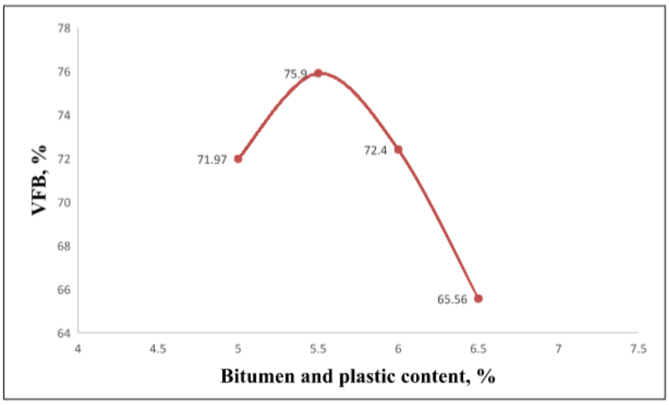

Fig-4.11: Variation of VFB with bitumen & plasticcontent

Fig-4.11 Shows the variation of Marshall VFB value with percentage of bitumen & plastic content where it is seen that usually an decreasing trend is followed with increase in bitumen and plastic content

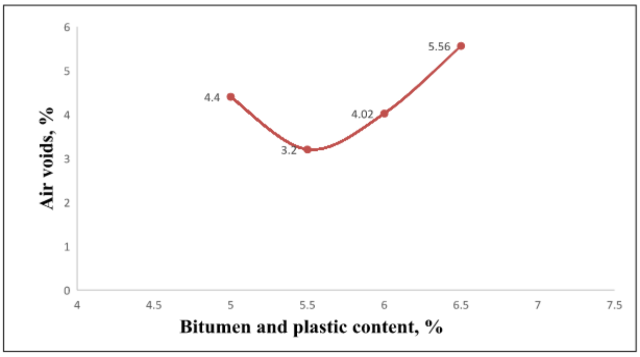

Fig-4.12: Variation of air voids with bitumen& plastic content

Fig-4.12 Shows the variation of air voids with percentage of bitumen & plastic content where it is seen that usually an increasing trend is followed with increase in bitumen and plastic content.

5. CONCLUSION

Recycled plastic along with aggregates is used for the better performance of roads. The polymer coating also reduces the voids. This prevents the moisture absorption and oxidation of bitumen by entrapped air. This has resulted in reducing rutting travelling and there is no pothole formation. The roads can withstand heavy traffic and show better durability. The ideal plastic content which needs to be added is 5% weight of 20mm down size aggregates. The Marshall Stability value of plastic coated bitumen is 1.1 times greater than the one which is coated normal bitumen mix. This indicates the strength which plastic content imparts to the aggregate thus improving load carrying capacity with minimal deflection. Thus the analysis and results presented above shows that plastic obtained from plastic waste, proved to be a better binder for pavements than normal bitumen. The properties displayed by plastic coated bitumen are beneficial without incurring much cost leading for effective, economic and efficient laying of roads. In this way plastic waste can be re-used.

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