DESIGN OF DENCE BITUMINOUS MACADAM (DBM Gr .2) USING RECLAIMED ASPHALT PAVEMENT (RAP) AND PLASTIC WASTE (Dry Process) USING HOT MIX ASPHALT (H.M.A.) TECHNIQUE

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Abstract

Reclaimed Asphalt Pavement (RAP) is simply an old, flexible pavement material with a top surface that is still in good condition; a significant amount of RAP materials are created during the building and up keep of highway projects. containing two valuable non-renewable resources: bituminous binder and aggregate. to generate a coarse aggregate fraction with a high environmental benefit by decreasing the usage of natural resources. In earlier decades, the RAP materials were either disposed of in trash dumps, which was frequently expensive, or held closer to the building site for a longer period of time. In order to advance towards improved environmental quality and sustainable growth, the construction industries now place a strong emphasis on material conservation, reuse, and recycling.Reclaimed asphalt pavement material (RAP) and plastic waste are two waste resources used in this study to create flexible pavement. Recycling the components of old pavement to create new pavement layers results in considerable material, financial, and energy savings.

***Key Words*:** Plastic waste, Marshall, stability, flow, Bitumen Reclaimed, Density, Pavement, RAP.

1.INTRODUCTION

The bituminous roads that are not frequently utilized for new construction are recovered and deposited nearby to create the reclaimed asphalt pavement material (RAP). RAP Material may use as aggregate. RAP also includes bitumen binder, which is useful for building pavement. Plastic debris has been utilised in road building for ten years. Humans have a significant issue in safely disposing of plastic garbage in order to maintain our ecosystem and eco-system. The combined usage of RAP and plastic waste are not discussed in any literature or study. Creating Dense Bituminous Macadam (DBM) Grading-II, a flexible pavement material that is currently widely utilised on National Highway (NH) and State Highway (SH). Utilizing the Job Mix Formula, samples were created using Reclaimed Asphalt Pavement Material (RAP) and virgin aggregate, fulfilling the grading and requirements of the aggregate as recommended by MoRTH (JMF). Binder is made of bitumen grade VG-30. Adding plastic trash to hot aggregate (dry process) starting at 6% and increasing by 2% up to 12% by weight of Optimum Bitumen Content in accordance with IRC SP:98 2022[2] (OBC). assuming that the binder content will be replaced by plastic up to some extent. Comparing the samples' characteristics, including their density, Marshall stability, flow value, air voids, voids in mineral aggregate, [VMA], and voids filled with bitumen, [VFB]. According to observation, plastic waste up to a particular proportion and RAP up to 25% both met all design requirements and demonstrated greater stability. Reclaimed asphalt pavement material (RAP) can prevent the need for new mining and disposal issues. The utilisation of plastic trash in highway construction also provides several environmental benefits. The cost of building the roadway project can be decreased by using both waste products.

The main Objectives of the project are:

- The basic goal is to use of Reclaimed Asphalt Pavement (RAP) with plastic waste effectively in a positive way that benefits society & environment.
- To encourage the use of Recycled material in the construction of highways to the maximum economical and practical extent possible with equal or improved performance.
- To reduce the bitumen content by replacing plastic waste and improving the properties of the bitumen pavement.

2. Martials & Process:

2.1 Methodology of Mix Design for DBM (Dance Bitumen Macadam) with Rap material & Plastic waste:

The best form of pavement for Indian circumstances is flexible pavement, which makes extensive use of bituminous materials like thick bitumen macadam. The Indian Road Congress (IRC) established defined criteria for the building of the pavements, and mixed designs were implemented as instructed by the Ministry of Road Transport and Highways (MoRTH). To enhance pavement quality and extend the design life of pavements as much as feasible, MoRTH regularly implements necessary adjustments.

The goals of the mix design are to provide enough bitumen to ensure a long-lasting pavement, enough workability to allow for simple placement without segregation, enough flexibility to prevent premature cracking due to repeated bending by traffic, enough air voids in the compacted bitumen to allow for additional compaction by traffic, and enough strength to resist shear deformation under traffic at higher temperatures.

The basic goal is to use of Reclaimed Asphalt Pavement (RAP) with plastic waste effectively in a positive way that benefits society & environment. However, the main goal of the research effort is to reduce the bitumen content by replacing the plastic waste and improve the properties of the bitumen mixture sample with the plastic waste.

A Marshall test was performed on Grade-II Dense Bituminous Concrete. In the test, virgin aggregate from work mix was blended with 25% Reclaimed Asphalt Pavement (RAP). Binder used is bitumen VG-30. 4.50% was established as the mix's optimum bitumen content (OBC). On Reclaimed Asphalt Pavement (RAP), residual bitumen binder is employed. The virgin binder will serve as the necessary balancing binder. It is assumed that bitumen binder will be largely replaced by plastic waste. Waste Plastic in Hot Bituminous Mixes (Dry Process) in accordance with IRC: SP:98-2020 "Guidelines for the Use of Waste Plastic". evenly distributed over hot mixing to create a priming layer over the aggregate.

The amount of plastic in the samples ranged from 6 to 12%, with each increase of 2.0% of the weight of the total amount of bitumen binder required. To determine the impact on physical parameters such as density, Marshall stability, flow value, air spaces, voids in mineral aggregate [VMA], and voids filled with bitumen [VFB], the test specimen is created using a mixture of plastic waste with varied bitumen contents of 4.0%, 4.5%, and 5.0%.

A prepared cylindrical sample measuring 101.6 mm in diameter and 63.5 mm in thickness was then put through a Marshall stability test by being crushed with 75 blows from a designated hammer on each face. A test head made up of many cylindrical segments applied the load perpendicular to the sample's axis at a continuous strain rate of 51 mm/min at the predetermined test temperature of 60 °C (a water bath set up to keep the temperature at 60 °C for 30 to 40 minutes).

The maximum load sustained at a standard test temperature of 60°C was used to define the Marshall stability of the bitumen mixed sample. The flow value, which is stated in mm and represents the total deformation of the Marshall test at maximum load when a load is applied under the prescribed test circumstances. The bitumen mixture's compacted specimen's Marshall stability value measures the resistance to deformation under the imposed incremental load, and the flow value reflects how much deformation the load or its flexibility really experiences.

2.2 Materials source: -

RAP Materials: RAP material sample collected from National Highway (NH-53) at Rajnadgaon Dist.in Chattsgarh State.

Coarse Aggregate: - Collection Sample Stone Crusher at Arajpuri Village in D.Lohara Dist.

Fine Aggregate: - Stone Dust collection Stone Crusher.

Bitumen: Bitumen VG-30 is used. The Bitumen was obtained from the storage tank.

Plastic waste: - The Sample Collection from garbage. Waste plastic shall size passing sieve 2.36 mm and retained 600 microns.

Filler: - Portland Pozzolana cement is used as filler.

Figure 2.1: Cold Removal Process (control-Depth) in NH-53 Ch 345+200 (Rajnadgaon, Chattisgarh)

Fig. 2.2: Site dumped RAP material (full-depth demolition) at sarangarh - Baramkela S.H.

Fig. 2.3 Site dumped RAP material (full-depth demolition) at Chandrapur-Dabhra State Highway

2.3Materials Tested for physical Properties:

i)Aggregate (Coarse& Fine) & Rap materials: -

a). Water Absorption & Specific gravity: -

b) Aggregate impact value:

c). Combined Flakiness and Elongation:

***ii) RAP Material**: -* RAP material is treated as aggregate for physical properties except additionally tested for binder/bitumen Content.

iii) Bitumen: Bitumen tested for density, softening points, ductility, & Penetration.

Filler: - Cement Standard-Specific gravity.

Bitumen Content on RAP: 3.88 %

Table 2.1: Physical Characteristics of Coarse Aggregate

S. No.	Type of Test		As per Lab Test results	Specifications (MoRTH V Rev. Table 500-8)
1	Material Finer than 75mic. Sieve (%)		Nil	< 3
2	Combined Flakiness & Elongation indices (Average %)		27.67	< 35
3	Aggregate Impact Value (Average %)		16.61	< 27
4	Soundness (%)	Sodium Sulphate	2.53	< 12
		Magnesium Sulphate	3.24	< 18
5	Water Absorption		0.26 %	Max. 2%
6	Coating and Stripping Value of Bitumen with Aggregate Mixture (%)		100 %	Minimum Retained Coating 95%

Table 2.2: Properties of Virgin Bitumen (Bitumen Complying with VG-30 grade of IS 73)

S. No.	Type of Test	As per Lab Test results	Requirement As Per IS73: 2013
1	Penetration in (1/10mm)	50.10	Minimum 45
2	Specific gravity at 27°C	1.015	-
3	Softening point in °C	61.90°C	Minimum 47°C
4	Ductility Test (cm)	145 cm	Minimum 40 cm
5	Flash Point °C	240°C	Minimum 220°C

Table 2.3: Properties of Reclaimed Asphalt Pavement (RAP)

S. No.	Type of Test	Test Result	Sp. Limit
1	Aggregate Impact Value	12.20	Max.24%
2	Flakiness & Elongation Index	28.27	Max. 30%
3	Stripping Value	100	Min.95% Retained Coating

Table 2.4: Properties of Recovered Binder from RAP

S. No.	Type Of Test	Test Result	Sp. Limit
1	Penetration (1/10 mm)	38	Minimum -15
2	Softening Point (°C)	56	-
3	Ductility Test (cm)	100	-

Table 2.5: Summary of Individual Grading of all Material / aggregate

Sieve size (mm)	Cumulative % by weight of Total Aggregate Passing				
	RAP	20mm	13 mm	10-6 mm	Dust
45	100	100	100	100	100
37.5	100	100	100	100	100

26.5	98.06	95	100	100	100
19.0	87.08	10.65	100	100	100
13.2	70.26	0.39	19.51	100	100
4.75	29.32	0.00	0.49	17.73	100
2.36	16.74	0.00	0.28	4.70	87.53
0.300	2.50	0.00	0.00	2.25	35.24
0.075	0.55	0.00	0.00	1.65	11.24

2.4 Binder Selection:

Table 2.6: AASHTO M 323 Binder Selection Guideline for RAP Mixtures. (Source: MS-2)

Recommended Virgin Asphalt Binder Grade	RAP Percentage
No change in binder selection	< 15
Select virgin binder one grade softer than normal (e.g., select a PG 58-28 if a PG 64-22 would normally be used)	15 to 25
Follow recommendations from blending charts	> 25

From the above table, it is recommended to use up to 25% RAP. Our Source RAP contenting VG-40 Grade bitumen therefore we are using VG-30 Grade bitumen as additional Virgin bitumen.

2.5 RAP material Percentage Selection

In hot mix plant there are generally set up for four bins. It will be convenient to use Avg. 25% in each bin. From combined gradation and trails Job Mix Formula (JMF) RAP material can be used up to 40% for the particular gradation. However, here we are using 25 % RAP material. Use of RAP more than 25 % is a critical process in design and selection of bitumen grade or quality. From the above table 3.12 it will be convenient to use up to 25% to keep process simple for basic users.

2.6 Blending of Aggregate for DBM Grade (II) as per MS-2 Appendix (Step -1):

Table 2.7: The blending of Materials as per Grading (Theoretical)

IS. sieve (mm)	**RAP**	**20 mm**	**10-6 mm**	**stone dust**	**Blending results**	**MoRTH Limit (Table 500-10)**
Proportion	**25.0%**	**25.0%**	**15.0%**	**35.0%**	**100%**	
37.50	25.0	25.0	15.0	35.0	**100.0**	100
26.50	24.5	23.7	15.0	35.0	**98.30**	90 – 100
19.00	21.7	2.66	15.0	35.0	**81.50**	71 – 95
13.20	17.5	0.10	15.0	35.0	**61.50**	56 - 80
4.75	7.33	0.00	2.66	35.0	**44.99**	38 - 54

2.36	4.19	0.00	0.70	30.6	**35.52**	28 - 42
0.300	0.63	0.00	0.34	12.3	**13.30**	7 - 21
0.075	0.14	0.00	0.25	3.93	**4.32**	2 - 8

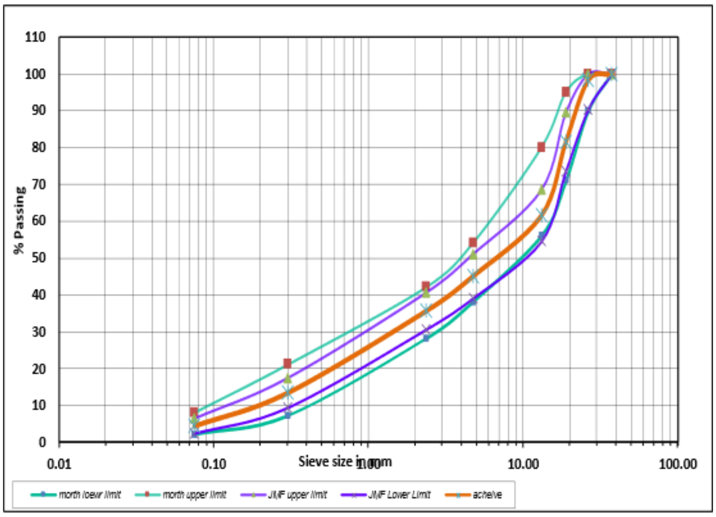

Fig.2.4 : Graph between Sieve size & cumulative % passing for selected blending, comparing MoRTH Limits & JMF limits. (Thermotical)

Table 2.8 : Combined Grading with RAP after finding out blending percentage (Actual)

Size of Aggregate	RAP	20 mm	13 – 6 mm	Dust	Total Wt. (gm)	
Percentage	25%	25%	15%	35%	30000	
I.S Sieve size (mm)	Wt. Retained	Cumm. Wt. Ret.	Cumm. Ret. (%)	Passing (%)	Mid Value	MoRTH limit (Table 500-10
37.5	0	0	0	100	100	100
26.0	480	525	1.75	98.25	95	90 – 100
19	6915	5250	17.50	82.50	83	71 – 95
13.2	3359	9855	32.85	67.15	68	56 – 80
4.75	5679	16164	53.88	46.12	46	38 – 54
2.36	2102	20133	67.11	32.89	35	28 – 42
0.300	5818	26022	86.74	13.26	14	7 – 21
0.075	1910	28545	95.15	4.85	5	2 – 8

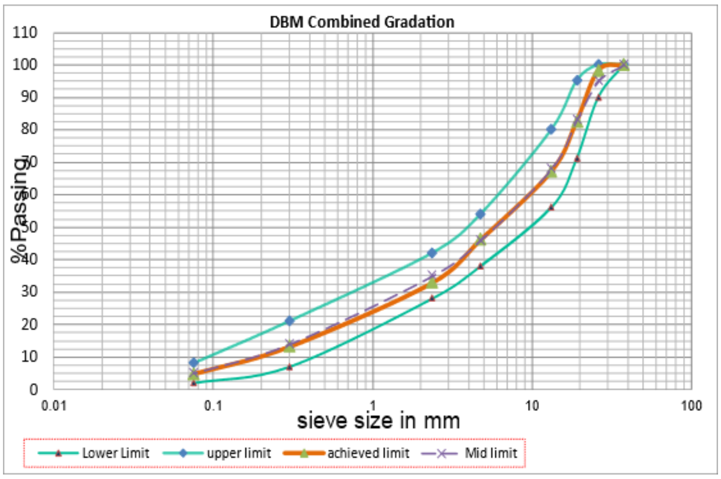

Fig.2.5: Graph between Sieve size & % passing (in log chart) for selected blending (Actual)

2.7 Marshall Method of Mix Design For determining the designed Optimum Bitumen content: Specimens of the compacted paving mixture were prepared as per ASTM D6926-10. The bulk-specific gravity of the compacted paving mixture was measured as per ASTM D2726. The following graphs are plotted.

1. Percentage air voids Vs Bitumen content
2. Voids filled with Bitumen content Vs Bitumen Content
3. Stability Vs Bitumen content
4. Voids in mineral aggregate Vs Bitumen content
5. Density Vs Bitumen content
6. Flow Vs Bitumen content.

From the Above found that:

Theoretical Bitumen Content @4 % Air Voids= 4.52 %

% Optimum Binder (Bitumen content) = 4.52%

Table 2.8: Specific gravity of mix material:

Properties	Values
Bulk specific gravity of aggregate mix (Gsb):	2.667
Apparent specific gravity of aggregate mix (Gsa): -	2.717
Maximum specific gravity of Mix at 4.50% bitumen content (Gmm): -	2.485
Effective specific gravity of mix (Gse): -	2.663

2.8 Material Requirement for making Marshall Sample mold for check Stability Flow

Table 2.9: Weight of material for 1200-gram sample / one mold

S. No.	Material	Blend Percentage	Stockpile % for combined Gradation	Weight of aggregate/ material (in gram)
1	RAP	25 %	23.87 %	286.44
2	20	25 %	25.37 %	304.44
3	13 - 6 mm	15 %	15.23 %	182.76
4	Dust	35 %	35.53 %	426.36

2.9 Preparation Marshall mold Casting with plastic waste:

As shown in the above table, 1200 gm of blended aggregate is taken, and the material is heated while maintaining a temperature range of 1500C to 1700C. (per MoRTH - Vth Revision Table-500-02). Plastic garbage has been added to the hot aggregate, and its weight is calculated based on the entire amount of bitumen that is needed to mix it. Spread over heated aggregate, the preparation of the sample waste plastic standard according to IRC SP 98: 2020 forms a base/prime coat on the aggregate surface for the Mix. Our presumption in this approach is that the amount of plastic will replace the bitumen content based on literature reviews, reviews, and past investigations. There is no addition of a renewing substance or agent.The available bitumen in RAP was utilised to compute the mix's optimal bitumen content (OBC), which was calculated at 4.52%. Virgin bitumen will provide the necessary additional binder in accordance with the MS-2 Asphalt Mix Design procedure (11.5.4). The ideal bitumen temperature is from 150 to 165 C. (table-500-02)The amount of plastic in the samples ranged from 6 to 12%, with each increase of 2.0% of the weight of the total amount of bitumen binder required. To assess the impact on physical qualities such as density, marshal stability, flow value, air spaces, voids in mineral aggregate [VMA], and voids filled with bitumen [VFB], the test specimen is made up of a mixture of plastic waste with various bitumen contents of 4.0%, 4.52%, and 5.0%. A manufactured cylindrical sample measuring 101.6 mm in diameter and 63.5 mm in thickness was then put through a Marshall stability test by being crushed with 75 blows from a designated hammer on each face. A test head made up of many cylindrical segments applied the load perpendicular to the sample's axis at a continuous strain rate of 51 mm/min at the predetermined test temperature of 60 °C (a water bath set up to keep the temperature at 60 °C for 30 to 40 minutes). The maximum load sustained at a standard test temperature of 60°C was used to define the Marshall stability of the bitumen mixed sample. The flow value, which is stated in mm and represents the total deformation of the Marshall test at maximum load when a load is applied under the prescribed test circumstances. The bitumen mixture's compacted specimen's Marshall stability value measures the resistance to deformation under the imposed incremental load, and the flow value reflects how much deformation the load or its flexibility really experiences. By increasing the stability value by the correlation ratios provided in the Asphalt Institute handbook, the stability value produced by specimens with a thickness different than 63.5 mm is adjusted (Asphalt Institute MS-2).

Figure.2.6 : Blending of aggregate with RAP

Figure 2.7: Samples for Marshal stability and Flow test.

Figure 2.8 Marshall l Equipment

Figure 2.9 Arrangement of Water Bath at 60°C

Table 2.10 : Summary of data obtained

S.No	Particulars	Ratio
A.	Optimum Bitumen Content (OBC) for the Mix	4.52 %
B.	Bitumen available on Reclaimed Asphalt Pavement (RAP) Material	3.88%
C.	Total Binder Weight Required for the Mix	54.24 gram
D.	% of virgin bitumen $\left(\frac{43.25}{54.24}\right) \times 100 =$	79.74%
E.	Virgin binder weight Required for Mix =	43.25 gram
F.	Available old Bitumen weight for the mix (C-D) =	10.99 gram
G.	Ratio of reclaimed Bitumen Vs Virgin Bitumen on Mix =	1:3.94

3. Results:

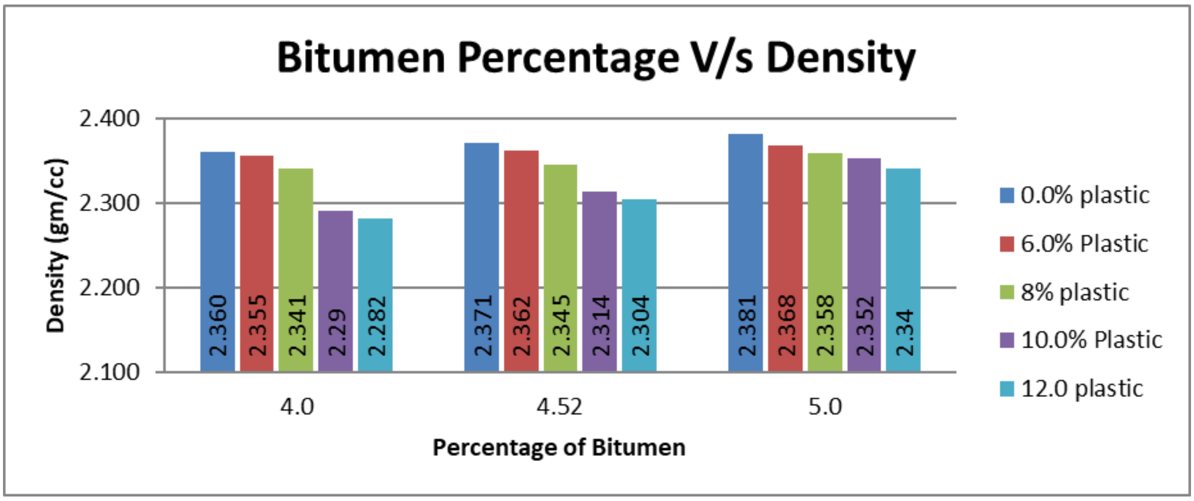

Fig: 3.1 Graph between Bitumen % Vs Density

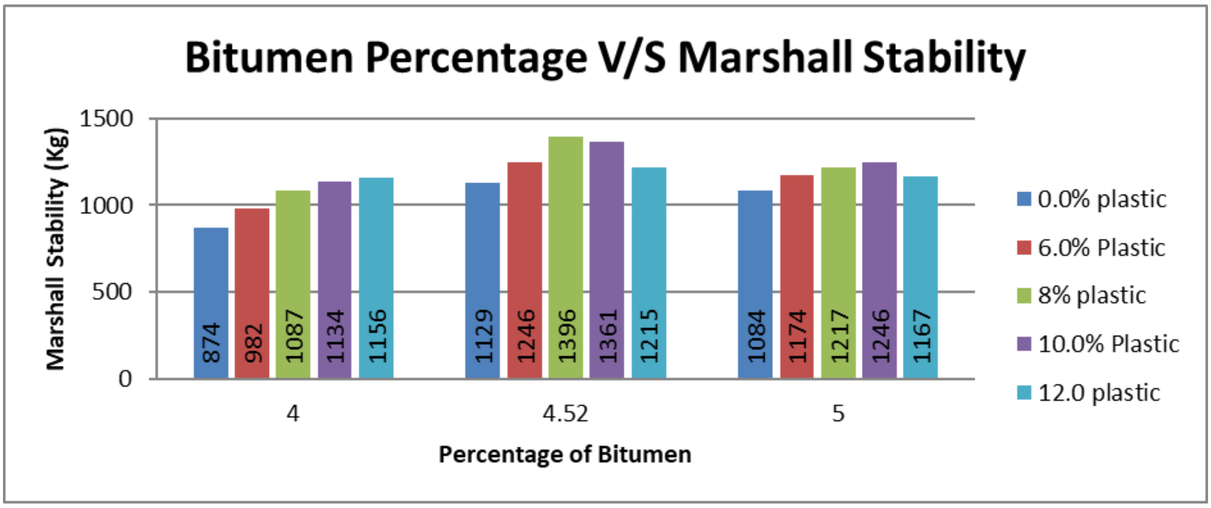

Fig: 3.2 Graph between Bitumen % Vs Stability

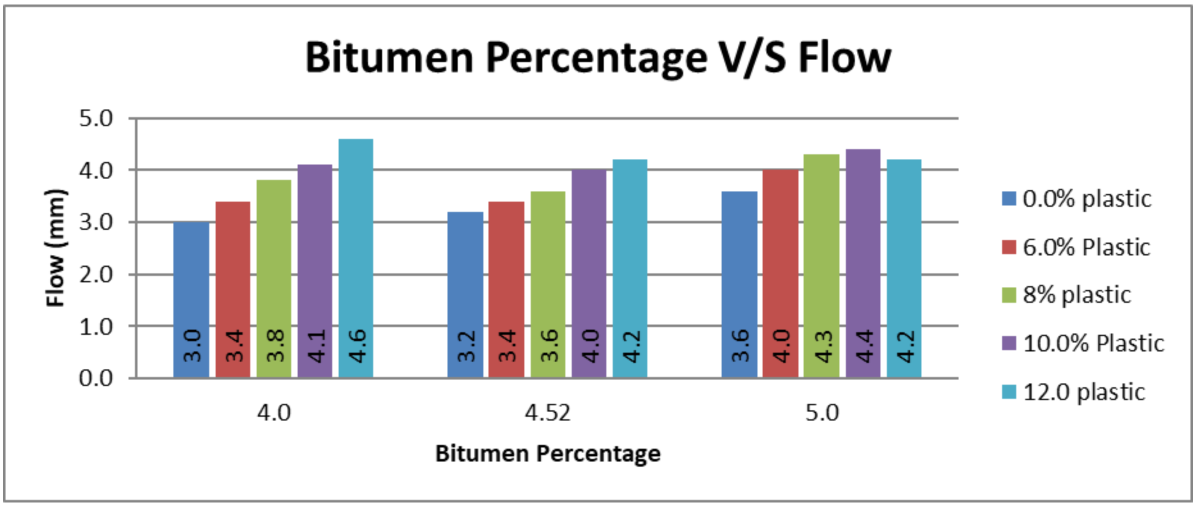

Fig: 3.3 Graph between Bitumen % Vs Flow

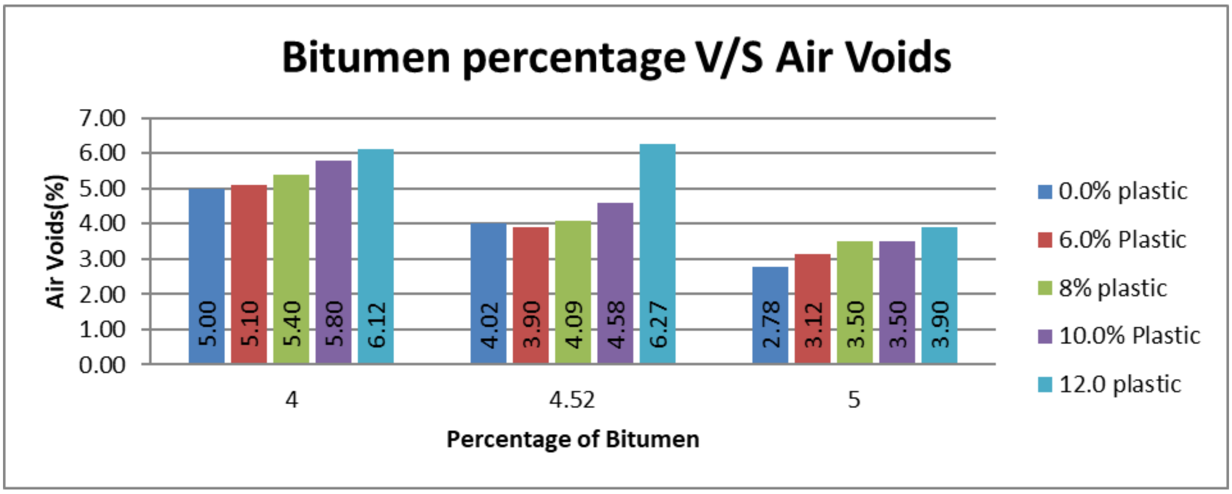

Fig: 3.4 Graph between Bitumen % Vs Air Voids

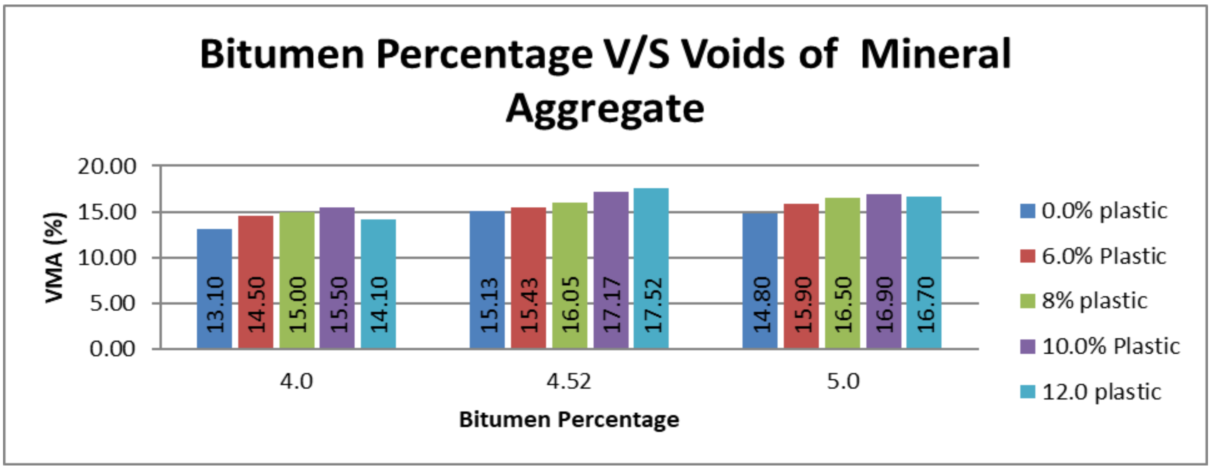

Fig: 3.5 Graph between Bitumen % Vs VMA

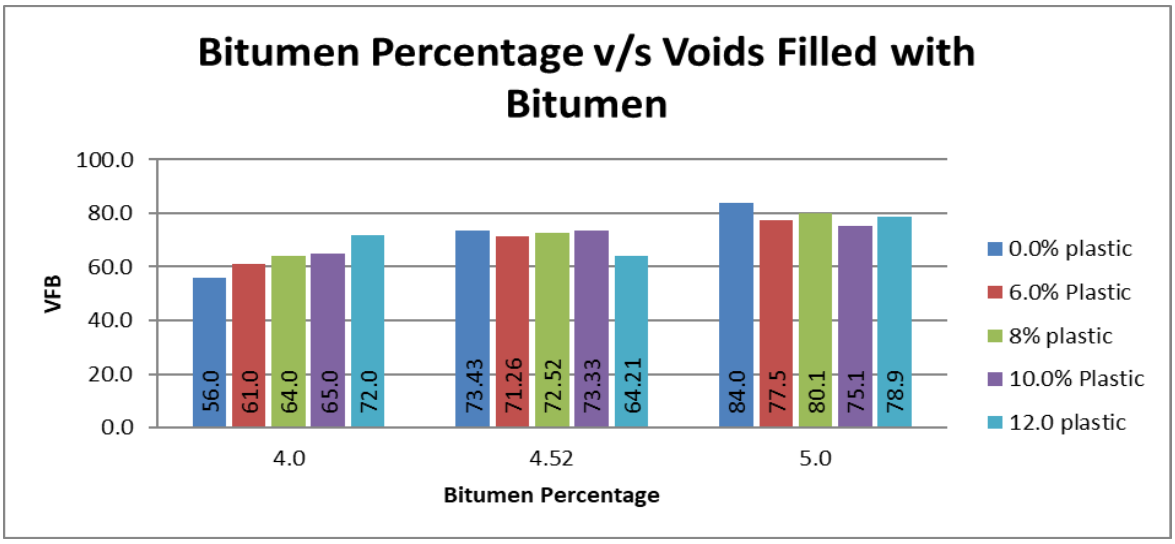

Fig: 3.6 Graph between Bitumen % Vs VFB

Table 3.1: Range of properties as per MoRTH & IRC SP : 92:2020

<table>
<tr><th>Range/ Limit</th><th>Stability (Kg)</th><th>Flow</th><th>% Air Voids</th><th>%VMA</th><th>%VFB</th></tr>
<tr><td>MoRTH Vth Revision / Without Plastic Mix</td><td>Min.- 900 Kg</td><td rowspan="2">2-4</td><td rowspan="2">3-5</td><td>Min.12</td><td rowspan="2">65-75%</td></tr>
<tr><td>IRC SP: 92: 2020 / Plastic Mix</td><td>Min.-1200 kg</td><td>Min.15</td></tr>
</table>

Table 3.2 The final proportion of materials for optimum bitumen content & with plastic waste

S.N.	Materials	Proportion
1	(a) Reclaimed Asphalt Pavement (RAP)	25.00%
2	(b) 20 mm	25.00%
3	(c) 13- 6 mm	15.00%
4	(d) Stone Dust	35.00%
5	(e) Bitumen (Gb) (Total = RAP+ Plastic + Virgin)	4.52%
6	(f) waste Plastic content by weight of Bitumen	8%

Discussion

1. **Density:** Density of Specimen decreases with increase in bitumen or plastic content ratio. (Specific gravity of Specimen (Gmb) decrease with increase bitumen or plastic content ratio & theoretical Specific gravity (Gmm) also simultaneously decreases.) Gmb < Gmm.
2. **Stability:** Marshall stability of the mix increases from 0% plastic to 10% plastic and starts decreasing in 12% plastic by weight of bitumen mix.
3. **Flow:** Marshall Flow of the mix increases with increase with bitumen % and plastic %. As flow increase with stability but seems after range stability decreases.
4. **Air Voids:** Air voids inversely proportionate to bitumen percentage, **but air Voids increases with increase in plastic content of mix.** Air Voids inversely proportionate to Specific gravity (Gmb) & theoretical Specific gravity (Gmm).
5. **Voids in Mineral Aggregate (VMA):** VMA directly proportionate to bitumen content, and here directly proportionate to plastic content of mix. As VMA increases Density of Mix Decreases.
6. **Voids Filled by Bitumen (VFB):** VFB increases with increasing in Binder content/plastic content. VFB ranges 65-75% gives higher Stability. Flow also increases with increase in VFB. VFB is inversely proportionate to density of Mix.
7. **Retained Stability**: plastic mix specimen is more durable than normal mix (without Plastic). Retained Stability found 92.62% for Plastic mix RAP & 86.50% for only RAP mix.
8. **Relative Compaction:** Achieved over 95% compaction (specific gravity to theoretical specific gravity) on all Specimens.
9. Bulk specific gravity of total aggregate (Gsb) less than effective specific gravity (Gse) Gse < Gsb.
10. Bitumen Content and Plastic percentage increase as well as Flow, VMA, VFB increase, but density decrease.

4. Conclusion:

- *Marshall Stability of Dense Bituminous Macadam RAP blended with plastic content produced about 20% higher strength than RAP mixed alone.*
- *Dense bituminous macadam bulk density Only RAP mixed Dense Bituminous Macadam had a value that was 1.09% lower than RAP mixed Plastic Content at Optimal Bitumen Content.*
- *RAP mixed with Dense Bituminous Macadam produced a volumetric value that was 1.06% greater than RAP mixed with Dense Bituminous Macadam alone.*
- *For DBM Gr. II, the values for Voids in Mineral Aggregate (VMA) and Voids Filled by Bitumen (VFB) range between the upper and lower limits set out in the present MoRTH & IRC SP:98-2020.*
- *A primer base for bitumen is formed by spreading plastic trash over heated aggregate.*
- *The value of the retained stability of the Dense Bituminous Macadam RAP combined with*

Plastic content at the ideal bitumen content was 6.12% greater than that of the Dense Bituminous Macadam RAP mixed alone.

- *Dense Bituminous Macadam RAP combined with 8% Plastic Content provides a higher Marshall Stability rating in this research. Therefore, mixing 25% RAP with 8% plastic may be advised. However, this perspective has to be supported by more laboratory study and field test studies.*

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