UTILIZATION OF RECLAIMED ASPHALT PAVEMENT (RAP) WITH PLASTIC WASTE (Dry Process) AS ROAD PAVEMENT MATERIAL IN FLEXIBLE PAVEMENT USING HOT MIX ASPHALT (H.M.A.) TECHNIQUE (Marshall Stability Method)

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Abstract –.

The Reclaimed Asphalt Pavement Material (RAP) is obtained from the reclamation process from the bituminous roads, which are not commonly used for further construction, and dumped near the site. The RAP can be used as an aggregate. RAP also contains bitumen binder, which can be utilized in pavement construction. Since a decade plastic waste is used in road construction. Plastic waste safe disposal is also a big challenge to humans for protecting our environment and eco-system. There is no literature or research on the combined uses of RAP with Plastic waste. This project uses two waste materials, Reclaimed Asphalt Pavement Material (RAP) and Plastic waste for the construction of flexible pavement. Designing Dense Bituminous Macadam (DBM) Grading-II, which is now commonly used for flexible pavement on National Highway (NH), and State Highway (SH). Prepared samples with Reclaimed Asphalt Pavement material (RAP) and virgin aggregate, satisfying grading and specifications of aggregate as per MoRTH recommendations using Job mix formula (JMF). Bitumen Grade VG-30 used for binder. Adding Plastic waste as per IRC SP:98 2022[2] on hot aggregate (Dry Process) starting from 6% and increment of 2% up to 12% by weight of Optimum Bitumen Content (OBC). Assuming plastic will function as a binder. Comparing samples properties i.e., density, Marshall stability, flow value, air voids, voids in mineral aggregate, [VMA], and voids filled by bitumen [VFB]. From comparison found that RAP - 25% and Plastic waste 8% has satisfied all criteria of design & showed higher stability. The use of Reclaimed Asphalt Pavement Material (RAP) can save mines and disposal problems. Plastic waste uses in road construction also solves plenty of problems for the environment. The use of both waste materials can reduce the construction cost of the highway project.

***Key Words*:** Plastic waste, Marshall, stability, flow, energy, . environment ,Reclaimed Asphalt Pavement, RAP.

1.INTRODUCTION

Road Transport Network in India is vast. India has 1,32,500 km of National Highway (NH) (Ministry of Transport, 2020), 1,81,531 km of State Highway (SH), 6,14,028 of District Road, 44,04,404 km of Rural Road, 5,31,608 km of Urban Road, and 3,46,505 km of Project Roads [25]. A Good Alternative solution for road construction is the recycling of old bituminous surfaced pavement. There is lacking in the consumption and utilization of natural resources. The disposal of RAP product is a tedious job, so it might be useful to adopt these materials in the construction of new road pavement or re-surfacing (maintenance). The road pavement requires a considerable high amount of binder and aggregate, for this purpose the RAP proves highly economical in the new road construction with the use of natural resources to an extent. It has been observed that the heavy quantity of RAP material is generated from the Strengthening and widening of existing roads and consequently in maintenance work. The RAP properties depend not only on the composition of the old pavement but also on the milling process [3]. if processed correctly, can be a good source for fine and coarse aggregates [27]. The RAP collection reduces the shortage of material also the disposal issue of RAP materials generated during the process of maintenance of the road. In addition, energy savings can be achieved using RAP material by reducing the process and transport activities of new aggregates. India has limited experience with recycling and reuse of RAP [26] in road construction. The object of this paper is to study the collective effect of the use of RAP materials for the Sustainability of its usage in road construction.

Reclaimed Asphalt Pavement (RAP) is nothing but an old flexible pavement material of top surface which is not at end of its service life, large quantity of RAP materials is produced during construction and maintenance of highway projects. Being composed of two valuable non-renewable resources, i.e., aggregates and bituminous binder **[4]. to** obtain a coarse aggregate fraction with a high environmental benefit, by reducing the use of natural resources [35]. In previous decades, the RAP materials were either stored near the construction site for a longer time or disposed of as waste landfills, which was often costly. Nowadays, the construction industries are emphasizing materials conservation, reuse, and recycling in order to move towards better environmental quality and sustainable development. The materials from existing pavement are recycled to produce fresh pavement layers resulting in significant saving of materials, money, and energy [29].

Prices of asphalt pavement materials have been increasing tremendously, which led to attempts to find alternative cheap materials. In addition, more concerns are directed to reserving natural resources and reducing environmental impacts of using virgin asphalt binders, thus more attention is focused on the use of recycled materials in pavement designs. [36]

Disposal of plastic waste in an environment is considered to be a big problem [28]. plastic waste has many bad impacts on soil, surface water, groundwater, and air (due to burning). Scientists and researchers are doing a major concentration on this area to use/reduce plastic waste. Govt. had a ban on the single use of plastic. Now being fashion on packed food, online food ordering, and packed drinking water bottles. Some packages of food as necessary to protect from moisture and time duration which cannot be stopped instantly. Daily plastic waste collection is in millions of tones. which is a major issue to manage and dispose by municipals. Plastic use in road construction is not new [24]. It also increases the strength and performance of the road [23]. Using Reclaimed Asphalt pavement and the use of waste plastic in road construction can shove environmental problems up to great extent.

The use of Reclaimed Asphalt Pavement (RAP) in various road projects becomes now more popular. The materials present in old asphalt pavements have residual value even when the pavements themselves have reached the ends of their service lives [11]. The use of RAP has proven to be economical and environmentally sound. RAP rates between 10% and 30% are commonly used in hot recycled bituminous mixes [14]. The environmental and financial restrictions are forcing the researchers to incorporate a high percentage of RAP in pavement construction. One of the main barriers to achieving this goal is the increased stiffness of the RAP binder. The objective of this paper is to study RAP with other major environmental solid waste / waste. The paper gives a brief overview of the recycling of existing Methods of bituminous pavement, advantages of using RAP Materials, sources, processing of RAP, and use of plastic waste in flexible road construction. The durability of the roads laid out with shredded plastic waste is much more compared with roads with asphalt with the ordinary mix [2].

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.

2. Methodology

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

In Indian conditions, the most suited type of pavement used in Indian Highways is flexible pavements in which bituminous materials such as dense bitumen macadam are used widely. For the construction of the pavements, the standardized specifications are set by IRC (Indian Road Congress) and mixed designs as directed by the Ministry of Road Transport and Highways (MoRTH) were followed. MoRTH continuously brings about required amendments to improve the quality of pavements and provide the design life of pavements as long as possible.

Mix design objectives are to provide sufficient Workability to permit easy placement without segregation, sufficient flexibility to avoid premature cracking due to repeated bending by traffic, sufficient air voids in the compacted bitumen to allow for additional compaction by traffic, sufficient strength to resist shear deformation under traffic at higher temperature, sufficient bitumen to ensure a durable pavement and sufficient flexibility at low temperature to prevent shrinkage cracks. [17]

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.

Marshall test was conducted on a Dense bituminous concrete Grade-II. In the test taken blending of 25% Reclaimed Asphalt Pavement (RAP) with virgin aggregate from job mix. Bitumen VG-30 is used as a binder. Founded out 4.50 % as optimum bitumen content (OBC) for the mix. Residual bitumen binder available on Reclaimed Asphalt Pavement (RAP) would be used. The required balance binder will be fulfilled with the virgin binder. The assumption is that Plastic waste will partially replace bitumen binder. Waste Plastic as per IRC: SP:98-2020 "Guidelines for the Use of waste plastic in hot bituminous mixes (Dry Process) [2]. spread uniformly on heated blending which would form a priming layer over the aggregate. Samples were made with plastic content of from 6 to 12 % at an increment of 2.0% of the weight of the total required bitumen binder. The test specimen is prepared with a combination of plastic waste with varying bitumen content of 4.0%, 4.5% & 5.0 % to measure the effect on physical properties i.e. density, marshal stability, flow value, air voids, voids in mineral aggregate [VMA] and voids filled by bitumen [VFB]. Subsequently Marshall stability test was performed on a prepared cylindrical sample of 101.6 mm in diameter and 63.5 mm thick with the compacted help of a specified hammer 75 no. blows on each face. The load was applied perpendicular to the axis of the sample by a test head consisting of a set of cylindrical segments at a constant strain rate of 51 mm/min at a standard test temperature of 60°C (arrangement of water-bath maintaining temperature 60°C for 30-40 minutes.) Marshall stability of the bitumen mixed sample was defined as the maximum load supported at a standard test temperature of 60°C. When a load is applied under the specified test conditions, the flow value is the total deformation of the Marshall test at maximum load and is expressed in mm. The Marshall stability value of the compacted specimen of the bitumen mixture indicates the resistance to deformation under the applied incremental load, and the flow value indicates the amount of deformation received by the load or its flexibility.

3. Martials & Process:

3.1 Materials source: -

Coarse Aggregate: - The aggregate 20mm & 10mm Collection Sample Stone Crusher.

Fine Aggregate: - 4.75 mm Down materials Stone Dust collection Stone Crusher.

RAP Materials: RAP material sample collected from National Highway (NH-53) Kolkata-Surat Highway section of km 322+400 to 405+000 of which is also known as Asian Highway (AH-46), cold process milling at the controlled depth of 40mm. (fig: 1.1)

Bitumen: Bitumen conforming IS: 73 VG-30 shall be used. The Bitumen was obtained from the storage tank.

Plastic waste: - The Sample Collection from garbage. Before using plastic cleaning & cutting as per IRC: 98:2020. Waste plastic shall size passing sieve 2.36 mm and retained 600 microns.

Filler: - cement is used as filler.

Figure 3.1: Cold Removal Process (control-Depth) in NH-53 Ch 345+200 (Rajnadgaon, Chattisgarh)

3.2 Materials Properties: -

All materials assessed for Physical Properties

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

A). Water Absorption & Specific gravity: - Water absorption & specific gravity test conducted as per IS: 2386 Part-III. The Required equipment –wire basket, Oven (300 ºC), Container for filling the water & Suspending Basket, balance-0-10 kg & tray, clothes. The limit of water absorption is less than 2.0%.

B) Aggregate impact value: Aggregate impact value Conducted IS: 2386 part-IV- 1963 The Sample passing on 12mm Sieve and retained on 10mm has taken oven-dried. the limit of impact value should be less than 27% for use on the pavement.

C). Combined Flakiness and Elongation: According to IS: 2386 part-I sample collection, the tested.

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 %

3.3 Combined Grading- Combined grading Followed by Individual Grading of RAP and aggregate to be used.

3.4 Blending of Materials: Aggregates Blended by Trial & Error procedure, for determining the designed Bitumen content, Specimens of the compacted paving mixture were prepared as per ASTM D 6926-10. The bulk-specific gravity of the compacted paving mixture was measured as per ASTM D2726.

Material taken for Finding Blending ratio:

Coarse Aggregates: (i) 20 mm Aggregate,
(ii) 13- 6mm size aggregate
Fine aggregate: Dust.
Reclaimed Aggregate (RAP) material

3.5 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.

Theoretical Bitumen Content @4 % Air Voids= 4.52 %

% Optimum Binder (Bitumen content) = 4.52%

Table 3.1 : The proportion of materials with Bitumen: -

Materials	Proportion
a) Reclaimed Asphalt Pavement (RAP)	25.00%
b) 20 mm	25.00%
c) 13- 6 mm	15.00%
d) Stone Dust	35.00%
e) Bitumen (Gb)*	4.52%

*Table **Error! No text of specified style in document.**.2: 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

3.6 Preparation Marshall mold Casting with plastic waste: -

Taken 1200 gm of Blended aggregate as per the above table and material is heated with maintaining the temperature between 150ºC to 170ºC As (per MoRTH - Vth Revision Table-500-02). Plastic has been introduced to the hot aggregate and the weight of plastic waste is taken as per the weight of total required bitumen to the mix. The preparation of the sample waste plastic specification as per IRC SP 98: 2020 is spread over heated aggregate, which creates a base /prime coat on the aggregate surface for the Mix. From literature review /review /earlier studies, our assumption in this practice is that the amount of plastic will replace the bitumen content. No rejuvenating agent/material is added to the mix. The Optimum bitumen content (OBC) is calculated 4.52% for the mix considering RAP as aggregate, The available bitumen in RAP was used. The required added binder will be fulfilled by virgin bitumen as per MS-2 Asphalt Mix Design method (11.5.4). Bitumen temperature should be between 150ºC-165º C (table-500-02).

Samples were made with plastic content of from 6 to 12 % at an increment of 2.0% of the weight of the total required bitumen binder. The test specimen is prepared with a combination of plastic waste with varying bitumen content of 4.0%, 4.52% & 5.0 % to measure the effect on physical properties i.e., density, marshal stability, flow value, air voids, voids in mineral aggregate [VMA] and voids filled by bitumen [VFB]. Subsequently Marshall stability test was performed on a prepared cylindrical sample of 101.6 mm in diameter and 63.5 mm thick with compacted help of a specified hammer 75 no. blows on each face. The load was applied perpendicular to the axis of the sample by a test head consisting of a set of cylindrical segments at a constant strain rate of 51 mm/min at a standard test temperature of 60°C (arrangement of water-bath maintaining temperature 60°C for 30-40 minutes.) Marshall stability of the bitumen mixed sample was defined as the maximum load supported at a standard test temperature of 60°C. When a load is applied under the specified test conditions, the flow value is the total deformation of the Marshall test at maximum load and is expressed in mm. The Marshall stability value of the compacted specimen of the bitumen mixture indicates the resistance to deformation under the applied incremental load, and the flow value indicates the amount of deformation received by the load or its flexibility. The stability value so obtained by specimens with a thickness other than 63.5 mm is corrected by multiplying the stability value with the correlation ratios given in the Asphalt Institute manual (Asphalt Institute MS-2).

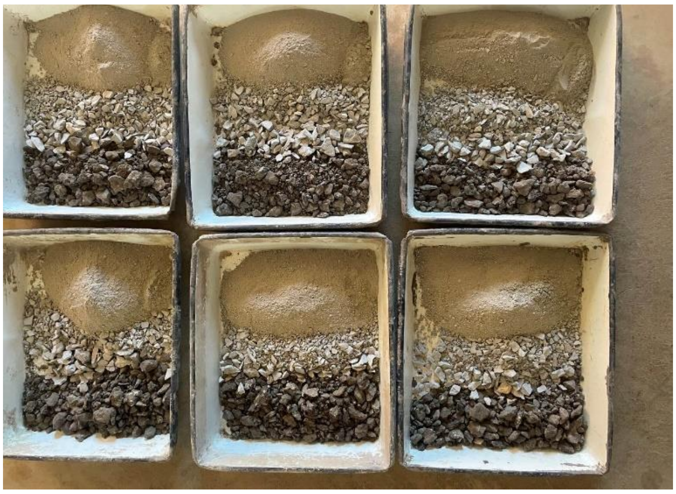

Figure.3.2 : Blending of aggregate with RAP

Figure Error! No text of specified style in document.3: Samples for Marshal stability and Flow test.

Figure 3.4 Marshall l Equipment with water bath arrangement

3.7 Determination of new virgin binder quantity as per the MS-2 Asphalt Mix Design method (11.5.4)

3.7.1 Determining new virgin binder quantity:

$$\text{Virgin Binder Weight} = \text{Total Agg. Weight} \times \frac{P_b}{P_s} - (RAP \text{ Batch Weight} - \text{RAP Agg Weight})$$

…………Equation.1

Where:

Virgin Binder Weight = the weight of binder to be add
Total Agg. Weight = the total weight of virgin and RAP aggregates

Pb = desired asphalt binder content, percent

Ps = aggregate content, percent (100 – Pb)

RAP batch weight = total weight of RAP that was batch

RAP Aggregate Weight = weight of RAP aggregate in the blend

3.7.2 Determining RAP stockpile:

$$\text{RAP stockpile} = \text{RAP Blend} \times 1 - \frac{P_{b,\ RAP}}{100}$$

……… Equation.2 form MS-2(11.25)

Where:
RAP stockpile = the stockpile percentage of RAP used in aggregate blending calculations
RAP blend = the total amount of RAP used in the mixture, in Percent
Pb, RAP stockpile = asphalt binder content of the RAP, expressed in percent.

RAP stockpile = 25× {1- (4.52/100)} = 23.87 %

3.7.3 Determining Virgin aggregate stockpile:

$$\text{VirginAgg}_{stockpile} = \text{virginAgg}_{Blend,n} + \frac{\text{virginAgg}_{Blend}}{\left(\sum_{1}^{n} VirginAgg_{blend,n}\right)} \times (\text{RAP}_{blend} - \text{RAP}_{stockpile}$$

Equation.3 ------ from MS-2 (11.26)

20 mm Aggregate
Virgin Aggregate stockpile =25+ [{25/ (25+15+35)} *(25-23.87)] = 25.37 %

13mm - 6 mm Aggregate
Virgin Aggregate stockpile = 15+ [{15/ (25+15+35)} *(25-23.87)] = 15.23 %

fine Aggregate
Virgin Aggregate stockpile = 35+ [{35/ (25+15+35)} *(25-23.87)] = 35.53 %

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

Table Error! No text of specified style in document..3 : Weight of material for 1200-gram sample/one mold:

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

3.7.5 Determine RAP batch weight:

$$\text{RAP batch Weight} = \text{RAP Aggregate Weight} \times \frac{RAP_{blend}}{RAP_{stockpile}}$$

Equation 4 MS-2 (11.27)

= 286.44*(25/23.87)
= 300.00 gram

3.7.6 Determining new virgin binder quantity:

$$\text{Virgin Binder Weight} = \text{Total Agg. Weight} \times \frac{P_b}{P_s} - (RAP \text{ Batch Weight} - \text{RAP Agg Weight})$$

Equation 5 From MS-2

Virgin Binder Weight = (1200 × (4.52/95.48) − (300−286.44)]

= (56.81) − (13.56)

= 43.25 gram

3.8 Summary of data obtained:

Optimum Bitumen Content (OBC) for the Mix: 4.52 %

Bitumen available on Reclaimed Asphalt Pavement (RAP) Material: 3.88%

Total Binder Weight Required for the Mix: 54.24 gram

Virgin binder weight Required for Mix = 43.25 gram

Available old Bitumen weight for the mix: (C-D) = 10.99 gm.

Ratio of reclaimed Bitumen Vs Virgin Bitumen on Mix = 1:3.94

% of virgin bitumen (43.25/54.24) *100= 79.74%

4. Result:

Table 4.1 Result For 4.52% Bitumen with Various Plastic Content ratio

Plastic content %	Density	Stability (Kg)	Flow	% Air Voids	%VMA	%VFB
0.0%	2.371	1128.78	3.2	4.02	15.13	73.43
6.0%	2.362	1245.70	3.4	3.90	15.43	71.26
8.0%	**2.345**	**1396.09**	**3.6**	**4.09**	**16.05**	**72.52**
10.0%	2.314	1361.22	4.0	4.58	17.17	73.33
12.0%	2.304	1215.00	4.2	6.27	17.52	75.11
Range/ Limit (without Plastic Mix) MoRTH		Min.- 900 Kg			Min.- 12	
Range/ Limit (Plastic Mix) SP: 92: 2020		Min. - 1200 kg			Min.- 15	

From the above analysis for the specimen made for Dense Bituminous Macadam Gr. II with:

4.52 % bitumen with 8% Plastic gives higher Marshall Stability with satisfying all criteria of MoRTH table 500-11 (requirements for Dense Bituminous macadam 5th revision) and IRC:98-2020 (Guidelines for the use of waste plastic in hot bituminous mixes (Dry Process) in Wearing Courses (first revision)).

Summary of Result :

Table Error! No text of specified style in document..21 :Test Result Summary with 4.52 % Bitumen and RAP 25% with Plastic 8% (by weight of bitumen) As per MoRTH Table 500-11 & IRC SP 98: 2020

SL NO	Description	AS Per Results	Specification (MoRTH 5th Revision) 500-11	IRC SP 98:2020 Table 2
1	Compacted Density of Mix (g/cc)	2.345	-	-
2	Minimum stability (at 60 ⁰C) (kg)	1396	1200	
3	Flow (mm)	3.2	2.5 – 4	2-4
4	Marshall Quotient (Stability/Flow)	3.88	2.5 – 5	
5	Air voids in total Mix (%)	4.09	3 – 5	
6	Voids Filled with Bitumen (% (VFB)	73.54	65-75	
7	Coating Of aggregate particle	100 %	Minimum 95%	-
8	Bitumen Content (%) i/c (RAP+ Plastic)	4.52	As per MoRTH Table 500.3.2 at 4% air void	
9	Quantity of waste plastic (% by weight of bitumen)	8%	-	8%
10	Voids in Mineral Aggregate (%) VMA	16.05	Min.12	Min.15

11	Retained Marshall stability (%) Minimum	92.62%	Min. 80%	Min. 90%

5. Conclusion:

Marshall Stability of Dense Bituminous Macadam RAP mixed with Plastic content resulted approx. 20% more Strength than only RAP mixed Dense Bituminous Macadam.
Bulk Density of Dense Bituminous Macadam RAP mixed Plastic content at optimum bitumen content resulted 1.09 % lesser value than only RAP mixed Dense Bituminous Macadam.
The volume of Dense Bituminous Macadam RAP mixed with Plastic content sample resulted 1.06 % higher value than only RAP mixed with Dense Bituminous Macadam.
Voids in Mineral Aggregate (VMA) and Voids Filled by bitumen (VFB) values for DBM Gr. II both ranges between limit specified in the current MoRTH & IRC SP :98-2020
Plastic waste over on hot aggregate form a primer base for bitumen.
Retained Stability of Dense Bituminous Macadam RAP mixed with Plastic content at optimum bitumen content resulted 6.12 % higher fromvalue than only RAP mixed Dense Bituminous Macadam.
In this analysis Dense Bituminous Macadam RAP mixed with 8% Plastic content gives a higher value for Marshall Stability. Hence 25 % RAP with 8% plastic mix may be recommended. However, further lab research and field test investigations are requiring backing this viewpoint.

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