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Design of Mastic Wearing Course Using Reclaimed Asphalt Pavement (RAP)

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Abstract

Mastic Asphalt Surfacing is a plastic, void less and impermeable surface which is laid manually mainly over bridge decks and on difficult locations such as intersections and roundabouts as wearing surface in India. Under the present study, 100% Reclaimed Asphalt Pavement material was used instead of virgin aggregates for the design of Mastic Asphalt Surfacing. This would reduce the cost of construction and emissions, and also conserve energy associated with quarrying and transporting of aggregates. Five types of gradation (Grading-I to Grading-V) using different proportions of Reclaimed Asphalt Pavement, fine aggregate, lime powder and binder content were formulated and tested for its Hardness Number. It was found that 16% binder content made the bitumen puffy in the mastic asphalt design though the hardness number was high. Amongst all the bitumen types evaluated, only Viscosity Grade 40 bitumen with 13% binder content for Grading- V alone met the requirements of mastic asphalt pavement as per IRC 107:1992. The mix was found to be best suited for Indian conditions because the skid resistance value lies within the limit specified by Indian Roads Congress.

Key Words: *Mastic Asphalt Surfacing, Reclaimed Asphalt Pavement, Wearing Surface, Hardness Number, Skid Resistance.*

1. Introduction

In India, about 15,000 tons of aggregates are used for construction of one kilometre of highway. The demand for road construction materials has increased tremendously owing to huge road construction programs including new construction and relaying of existing deteriorated pavements. The road construction industry consumes enormous amount of natural occurring resources and is responsible for 22% of the global energy consumption, 25% of the fossil fuel burning across the world and 30% of the global air pollution and Green House Gases (GHG) production[1]. Also, there is a huge shortfall in the availability of good quality construction materials especially aggregates which is obtained from quarries for the purpose of road construction. Keeping in view the current trends of the road development activity in India, there is an urgent need to consider adopt the concept of green highways wherein the road pavements are constructed using materials that emit no or low concentration of pollutants and are environment friendly so as to create a sustainable development.

One such initiative is the reuse or recycling of milled out old pavement material usually know as Reclaimed or Recycled Asphalt Pavement (RAP), in the design of new pavement layers which considers RAP as a potential product for the construction of new pavement layers, rather than as a waste material [1,4]. Several studies have been carried out successfully in the past [2, 3, 15,17,18,] where high content of recycled asphalt (up to 60%), have been recommended but its use is mainly limited due to practical considerations related to the production of mixtures in the asphalt plant. The environmental and economic benefits of using RAP in Hot Mix Asphalt (HMA) applications could be pushed up to the maximum limit, by producing totally recycled HMAs (i.e. 100% RAP) [7,16].

In Chennai the old pavement material are dumped into the landfills (in Egmore) and subsequently degrade the environment. Only less than 15% of old pavement materials are used as RAP in road construction along with conventional aggregate and a large quantity of it remains as waste materials in the dumpyard. Hence,

there is a need to optimally and effectively utilize the old pavement's material for road construction.

Areas with braking, stopping, acceleration, deceleration and turning of slow moving heavy vehicles especially on intersections, induce some of the highest stress levels found on the bituminous pavements [5]. Giving special attention to the above mentioned aspects can ensure that high-stresses induced at such locations delivers the same performance as other asphalt pavements by providing void less and water proofing pavements called Mastic Asphalt Surface (MAS) as wearing course in the flexible pavements [11]. MAS has been used worldwide over many decades and is a plastic, void less and impermeable surface which is laid manually mainly over bridge decks and on locations such as bus-stops, intersections and roundabouts as wearing surface in India. Under the present study, 100% RAP material was used instead of virgin aggregates for the design of MAS. This would reduce the cost of construction and emissions, and also conserve energy associated with quarrying and transporting of aggregates.

2. Properties of Reclaimed Asphalt Pavement (RAP)

During repair and reconstruction of new pavements, the deteriorated pavement material is milled out using CIR (Cold In-Place Recycling) train and is usually dumped in landfills. This milled out material having considerable amount of aggregates and bitumen, can be further used as RAP in the construction of new pavements. The properties of RAP are given in Table 1.

3. Properties of Mastic Asphalt as per IRC 107:1992

The bitumen mastic is composed of suitably graded mineral filler, coarse aggregates, fine aggregates and hard grade of bitumen as to form a coherent, void less, impermeable mass which is solid or semi-solid under normal temperature conditions, but sufficiently fluid when brought to a suitable temperature to be spread by means of a float in manual construction and by paver in mechanized construction [9].

Mastic asphalt is used as a wearing course for any pavement requiring high durability and stability. In the mineral structure of mastic asphalt mix, there should be minimum voids and any voids that do remain are filled with bitumen. 30-40 grade bitumen and 8mm size coarse aggregates are conventionally used in mastic asphalt pavement for Indian condition. Mastic asphalt pavement considerably reduces construction time, since it can be used as soon as it has cooled. It is a durable material and therefore economical.

Table 1: Physical and Mechanical Properties of Reclaimed Asphalt Pavement (RAP)

Properties	RAP Property	Typical Range of Values
Physical Properties	Unit Weight	1940 - 2300 kg/m^3 (120-140 lb/$ft^{3)}$
	Moisture Content	Normal: up to 5% Maximum 7-8%
	Asphalt Content	Normal: 4.5-6% Maximum Range: 3-7%
	Asphalt Penetration	Normal: 10-80 at 25°C (77°F)
	Absolute Viscosity or Recovered Asphalt Cement	Normal: 4,000 - 25,000 poises at 60°C (140°F)
Mechanical Properties	Compacted Unit Weight	1600 - 2000 kg/m^3 (100-125 lb/ft^3)
	California Bearing Ratio (CBR)	100% RAP: 20-25% 40% RAP and 60% Natural Aggregate: 150% or higher

Source:U.S Department of Transportation and Federal Highway Administration.

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4. Materials

4.1 RAP Material

The RAP material for this study was collected from Egmore landfill and was tested for its physical and consensus properties for evaluation. The bitumen content from 5 random samples of RAP material was extracted using the trichloroethylene as solvent in the Centrifuge Extractor as per IRC SP11-1988 [8] and the average binder content was obtained as 3.75%.

4.2 Bitumen

Four different types of bituminous binders (CRMB-55, PMB-70, VG-30, and VG-40) have been used under this study for the design of MAS. The physical properties of various types bituminous binders used in this design were tested and the results are given in Table 2[6, 9, and 10].

4.3 Filler

Mineral filler is one of important materials affecting the properties and quality of asphalt mixtures. Hydrated lime which has the property to increase the tensile strength and improve the water sensitivity of a mix [10], is commercially available in the market and the same has been used in this study as the filler.

4.4 Aggregates

Since the RAP from the Egmore dump yard was already crushed, its initial weight was taken and directly sieved to get the required amount of aggregate of size passing 19mm and retained on 2.36mm sieve without any segregation in size between 19mm and 2.36mm. This formed part of coarse aggregate (Table 3).

Table 2: Physical Properties of Different Bituminous Binder Used

Types of Binder	Penetration @25°C, 1/100, cm	Softening Point (R&B), °C	Ductility @27°C, cm	Loss on heating, %	Solubility in Carbon disulphide, %
CRMB-55	60	55	72	0.1	99
PMB-70	70	55	76	0.1	99
VG-30	68	46	78	0.1	99
VG-40	32	60	82	0.1	99

Notes:CRMB: Crumb Rubber Modified Bitumen, PMB: Polymer Modified Bitumen, VG: Viscosity Grade

Table 3: Gradation of Coarse Aggregate in RAP as per IRC107:1992

Type of Work	IS Sieve	% Passing IS Sieve	Thickness of Finished Course (mm)	% of Coarse Aggregates
Wearing course for road pavement and bridge decks	19 mm	100	25 – 40 or 41 - 50	30 – 40 or 40 -50
	13.2 mm	88-96		
	2.36 mm	0-5		

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4.4.1 Gradation of Fine Aggregate

The fine aggregate consists of crushed hard rock or natural sand or a mixture of both. For the fine aggregate, the sand passing 2.36mm and retained on 75 micron was taken. The grading of fine aggregates inclusive of filler material passing 75 micron shall be as given in Table 4.

Table 4. Gradation of Fine aggregate as per IRC107:1992

Passing IS Sieve	Retained on IS sieve	Percentage by weight
2.36 mm	600 micron	0-25
600 micron	212 micron	May-25
212 micron	75 micron	Oct-20
75 micron	-	30-50

Five different grading for various proportions of coarse and fine aggregates were adopted as shown in Table 5. It may also be noted that the amount of filler is kept constant at 10% for all the grading.

Table 5. Different Types of Grading Adopted for Mastic Asphalt

Mix Proportions				
Types of Grading	Coarse Aggregate %	Fine Aggregate %	Lime Powder %	Binder Content %, mix
Grading I	80	10	10	16
Grading II	70	20	10	16
Grading III	60	30	10	13
Grading IV	50	40	10	13
Grading V	40	50	10	13

5. Laboratory Investigation

5.1 Mix Design Method for Mastic Asphalt Using RAP

The manufacture of bitumen mastic in this study involves replacement of coarse aggregates by 100% RAP material with various grades of bitumen, fines and filler. The preparation of the mastic asphalt mix consists of different stages of preparation. Initially the filler alone was heated to a temperature of 170°C to 200°C in a mechanically agitated mastic cooker and half the required quantity of the heated bitumen was added and cooked for one hour. The second stage involves the addition of fine aggregate and the remaining bitumen in the cooker and heating up to 170°C to 200°C and further mixed for another one hour. In the final stage the course aggregates was added and heating of mix was continued for another one hour. Prolonged heating should be avoided. Thus a total period of minimum three hours is appropriate to prepare the mastic asphalt mix. During mixing and cooking, care shall be taken to ensure that the contents in the cooker area at no time heated to a temperature exceeding 200°C.

Since mastic asphalt is overlaid on wearing course, its thickness is maintained to 25mm to 50mm. The prepared mix is then poured into a standard mould having a diameter of 100 mm and depth of 25.4 mm and is then allowed to cool and set. No compaction is given as in the conventional mix design. After casting, the mould is kept undisturbed for 24 hours for curing in room temperature. The mould is then dismantled for the testing its Hardness Number [10]. The hardness of mastic asphalt can be varied over a wide range by changing the formulation of bitumen and aggregates during manufacture. The hardness can also be increased by the addition of coarse aggregate on site.

5.2 Hardness Number Test

Hardness Number is defined as the number, denoting the depth in hundreds of a centimeter, to which a flat ended indentation pin in the form of a steel rod (6.35 mm in diameter) will penetrate the Mastic Asphalt under a load of 31.7 kg applied for 60 seconds, the temperature being maintained at 35ºC. Hardness tester unit for Mastic Asphalt is complete with load release mechanism and is fabricated to meet the requirements of IS 1195 – 2002[10]. The values of Hardness Number of MAS tested for various gradings are given in Figure 1. The hardness of mastic asphalt can be varied over a wide range by changing the formulation of bitumen and aggregates during manufacture.

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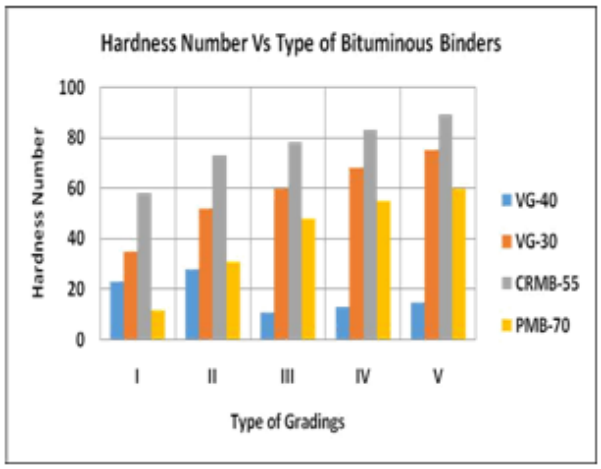

Figure 1. Hardness Number of MAS for various Gradings and Binders

5.3 Skid Resistance Testing of Mastic Asphalt Sample Using British Pendulum Tester (BPT)

Skid resistance is an important pavement parameter because inadequate skid resistance would lead to higher skid related accidents. Skid resistance depends on pavement surface texture. Since mastic asphalt samples have very smooth finishing, the chances for skidding of vehicles are very high when compared to that of other pavements.

Skid resistance is generally quantified using some form of friction measurement such as a friction factor or skid number which is tested using the British pendulum equipment, which follows the Izod principle. This test method provides a measure of a frictional property, micro texture, of surfaces, either in the field or in the laboratory (ASTM: E303-93.) The skid resistance for the mastic asphalt was tested in the laboratory by preparing samples of mastic asphalt pavement.

The RAP materials, fine aggregate, lime powder and bitumen were heated in a mastic cooker for 3 hours at a temperature of 170°C to 200°C. The prepared sample was casted in the mould to the size of 10cm x 6cm x 2.5cm.

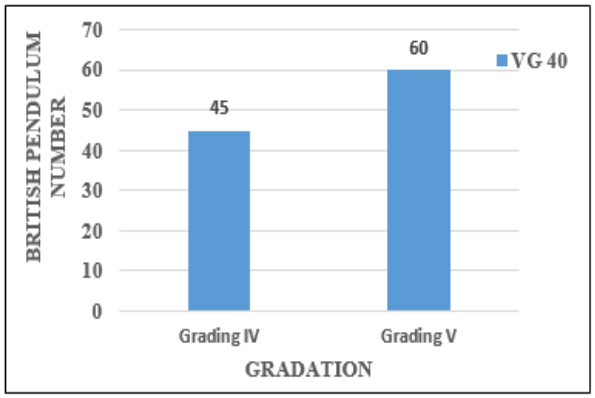

Figure 2. Skid Resistance Value

6. Discussion of Results

As can be seen from figure-1 the values of Hardness Numbers are 58 and 73 and 12 and 31 with gradings I and gradings II using CRMB-55 and PMB-70 respectively. Using VG-30 and VG-40 as the binder, the Hardness Number values were 35 and 52 and 23 and 28 respectively. These values appear to be erratic which may be because of excess binder and less amount of fine aggregate. Keeping these values into consideration, the binder content was reduced from 16% to 13% and new grading (grading- III) was adopted.

In grading-III, the Hardness Number varied from 11 to 78 with various types of binders. This could be because of increased RAP content and reduced binder content. Further changing the RAP contents, two grading i.e. grading-IV and V was formulated. Hardness Number for grading IV ranges from 13 to 87. The Hardness Number of VG-40 was in the range of 11 to 28, confirming to IRC specification limits.

Special attention was given to grading IV and V. Sample of slab was casted for testing of skid resistance using VG-40 as the binder. The values of skid resistance measured by using British Pendulum Tester on the sample of slab of MAS prepared by using Grading IV and V with the use of VG-40 are given as Figure 2. As seen in figure 2, the skid resistance values are in the range of 45 to 60 for Grading IV and V respectively.As per "Guidelines for Maintenance Management of Primary, Secondary and Urban Roads"[14], the minimum skid resistance specified is 55. Therefore, Grading V using VG-40 as

binder may be used for Indian conditions.

7. Conclusions

- Reclaimed Asphalt Pavement (RAP) materials were used to design Mastic Asphalt Surfacing.
- Percentage of binder content extracted by Centrifuge extractor was 3.75%.
- Mix design for Mastic Asphalt was done using aggregates passing 19mm and retained on 0.075 mm sieve without any segregation in size.
- Four types of bitumen viz. CRMB-55, PMB-70, VG-30 and VG-40 were used for the same gradation (mix proportion) of mastic asphalt.
- Five types of gradations of different proportions of RAP, fine aggregate, lime powder and binder content were tested for hardness number.
- 16% binder content made the mastic asphalt puffy though the hardness number was high.
- Amongst all types of bituminous binder VG-40 alone met the requirements of mastic asphalt surface, as per IRC 107:1992.
- The mix proportion with 40% RAP, 50% fine aggregate, 10% lime powder and 13% binder content (i.e. Grading V of Table 1) was found to be best suited because the skid resistance value lies within the limit specified by IRC.
- With 100% replacement of coarse aggregates by RAP, the materials cost can be greatly reduced during construction of roads and conservation of scarce resources leading to better environment and savings in energy consumption.

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