STUDIES ON WARM RECYCLED DENSE BITUMINOUS MIXES

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Abstract - ***In the present study, an attempt is made to understand the Performance of warm dense bituminous mixes by conducting, indirect tensile strength and tensile strength ratio.VG-30 is used as binder and Sasobit as WMA. DBM -II mix is selected for the present study. The recycled pavement material (RAP) was added at different percentages to the conventional DBM-II mixes. Integrating WMA, and RAP in bituminous mixes optimizes the advantages towards durable and sustainable pavements.***

***Key Words**: Recycled pavement materials, DBM, Sasobit.*

1. INTRODUCTION

An asphalt mix method that is environmentally friendly, inexpensive, economical, and protective of people's health and safety is necessary for sustainable road construction practises. Hot Mix Asphalt (HMA) technique is used in India and many other nations to buildasphalt roads. HMA has a number of drawbacks, including high manufacturing temperatures (155°C to 165°C), which raise GHG emissions. These gases contribute to global warming and have a negative impact on paving crew members' respiratory systems. When compared to HMA, Warm Mix Asphalt technology can lower the temperature of mixing and compaction by about 30°C. WMA provides various benefits over HMA, including decreased emissions, better site visibility, and more use of reclaimed asphalt pavement[1].

1.1 Dense Graded bituminous Mixes

Bitumen, fine and coarse mineral filler, and continuously graded aggregates make up dense grade asphalt. When hot, it is laid and compressed. In order to account for the greater traffic loading, highways, major, industrial, and distributor roads typically utilize a stiffer, denser grade of asphalt. Dense-graded mixes that have been properly planned and built are largely impermeable, making them appropriate for all types of traffic and pavement layers. The size of the majority of the aggregate particles in the mix distinguishes the two types of dense-graded mixes fine-graded and coarse-graded. Both surfaces and asphalt repairs can be made with these mixtures. Mixtures of dense graded airport asphalt developed by Marshall typically comprise 5.4 to 5.8% of bitumen and 4 to 6 % of aggregates that pass through sieve size of 75μ.

1.2 Recycling of Asphalt Mixes

A technique that is currently under research but has shown to be very promising from an economic and environmental standpoint is warm mix recycled[1]asphalt with bitumen emulsion. By increasing the amount of recovered materials and enabling recycling at lower temperatures, this technique conserves energy and lowers CO_2 emissions. It makes it possibleto make use of the basic materials already present on the worn-out pavement and to use less energy to create the new combination[2].

There are several advantages to recycling extensively used binders of asphalt into fresh asphalt pavements. The production of recycled asphalt mixtures using RAP and recycled asphalt shingles (RAS) along with manufactured waste asphalt shingles (MWAS) and tear-off asphalt shingles (TOAS), can be cost effective, maintain depleting natural resources, save priceless landfill space &benefit the environment. While retaining acceptable pavement durability, it is difficult to mix the materials in significant amounts obtained from RAS and RAP into new asphalt pavements [4].

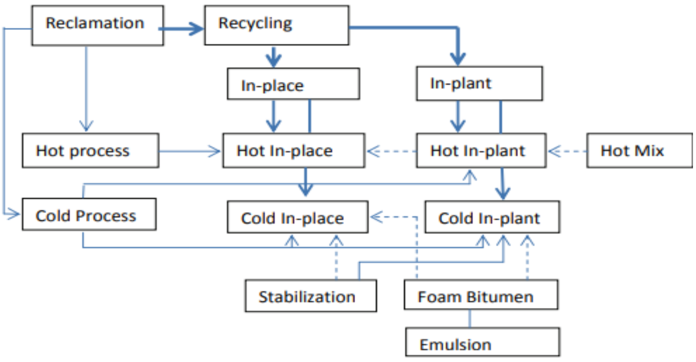

FIG. 1 Different recycling methods based on processes

1.3 Warm Mix Asphalt Technology

Heat between 150°C and 190°C is used to mix and compact conventional HMA. The main objectives of using the WMA are to conserve fossil fuels and reduce energy demand and GHG emissions. As a result, the researchers have created new WMA technologies for asphalt materials that require lower production temperatures. The same goals lower binder viscosity, increased workability, and decreased emissions are shared by WMA solutions despite the relatively wide range of options available to them and the variety of ways in which they can function[6]. When compared to HMA, which must be mixed and compacted at temperatures ranging from 140 &160 degrees Celsius, WMA is a mixture whose performance attributes are not considerably affected by the lower temperature at which it can be done. The effectiveness of WMA technologies in reducing energy use and emissions during production has been demonstrated. WMA is currently produced using a variety of additives and foaming techniques. A scientific classification is important because WMA technologies come in so many different forms. WMA technologies are now categorized in a variety of ways, and one popular system among them is on the basis of classification of additives. And this methodology allows for the classification of WMA technologies into three groups: organic additive technology, foamed bituminous technologies, and chemical additive technologies[7].

1.4 Types of Warm Mix Asphalt Technology

1. Foaming technology

Foamex a foam based additive was developed by Mobil of Australia, where steam was substituted with 1-2% freezing water into hot asphalt in 1968. To avoid stripping problems, sufficient water needs to be added during process of foaming. Shell Bitumen filed a patent in 1995 for a two-component binder system known as WAM-Foam, which made use a soft binder and a hard foamed binder at varying stages of plant production. Aspha-min, Advera, WAM -Foam, Terex, Gencor, Ultrafoam GX, Stansteel, and AquablackTM are few of the water-foaming WMA technologies [16].

2. Organic technology

The additives here are mixed with the binder or directly added to the asphalt mixture. Generally, organic additives melt between 80° to 120°C and they modify the viscosity-temperature interaction of the asphalt binder chemically. They are a long chained synthetic wax formed in the presence of a catalyst using the Fischer- Tropsch paraffin wax process by treating hot coal with steam. The viscosity of the binder is reduced by paraffin wax and it also allows mixing at lower temperature. Selection of suitable additives must be carefully done such that the melting point of the additive is greater than the in-service mix temperature and also care should be taken that at low temperatures, brittlement of asphalt mixtures is reduced. lists organic based additives such as Evotherm, Sasobit, Ecoflex Asphaltan-B, and fatty acids amides [16].

2.MATERIALS

Conventional Aggregate: Basic physical examinations were performed in accordance with IS: 2386-1963-Part III & Part IV [18-19], 2386-1963-Part I [17]. Granite aggregates using thicknesses that range from 26.5 mm to 4.75 mm, according to MORTH, 2013[22], are utilized in the asphalt mixtures. Sieve analysis is performed in accordance withIS: 383-1978[21].

Binder : Bitumen VG30 grade (60/70) was used for the investigation and its fundamental characteristics were examined in accordance with IS 73:2013 [22].

Recycled materials: It was retained on a 26.5mm filter was employed. Basic physical testing was done using IS: 2386-1963-Part I [17], IS: 2386-1963-Part III& Part IV [19][20]. The MORTH-V revision,2013 [21] states that the coarse particles used in asphalt mixes range in size from 26.5 mm to 4.75 mm

Warm mix Additive

Sasobit

Sasobit was used as an organic WMA addition and was purchased from Sasobit Industries India. The bituminous mix for this investigation had 3 percent of these additives added to it per the supplier's instructions. Sasobit is a synthetic hard wax which is ideal for the production of warm mix asphalt plus it enhances workability, reduces rutting and extends service life.[16]

3. TEST

3.1 Extraction of Bitumen

The RAP materials were subjected to solvent (benzene) extraction method by centrifuge extractor as per IRC-SP11:1988

3.2 Test on Conventional and RAP Aggregate

According to IS:2386-1963-PART VI (mechanical properties of aggregate and IS:2386-1963-PART I (partical size and shape),the properties of aggregate are listed below.

Table 1 : Mechanical properties of aggregate

Properties (%)	**Limits as per MORTH (V) revision**
Impact value	27
Crushing value	24

Specific gravity (a) Coarse (b) fine	2.5-3
Combined index	30

3.3 Test on Conventional and Recovered bitumen

Bitumen VG30 grade (60/70) was used for the investigation and its fundamental characteristics were examined in accordance with IS 73:2013.

Table 2: properties of bitumen

properties	**Limits as per MORTH**	**Test method**
Penetration in mm	60-70	IS-1203:1978
Softening pt in degree Celsius	45-50	IS-1205:1978
Ductility in cm	75	IS-1208:1978
Specific gravity	0.99	IS-1202:1978

3.4 Mix Design

Superpave, Marshall and Hveem mix design procedures are commonly used around the world. Almost all WMA studies have used a mix design protocols comparable to traditional HMA, but also, minor changes to HMA plant may be required for WMA. Asphalt mix design methods for WMA include five major choices- a) selection of materials, binder grade & type of aggregates, b) additional additives, c) gradation of aggregates, d) curing and conditioning of WMA mixing and e) mixing & compaction temperature. Following this, volumetric analysis, optimum binder content determination, and workability assessment are performed. Range of production temperature of HMA and WMA technique are shown in fig 2 [23].

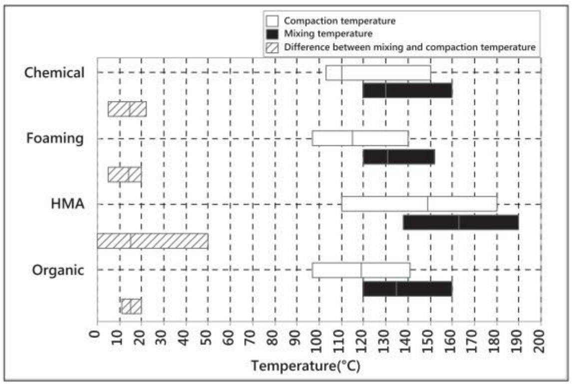

FIG. 2 Range of production temperature of WMA technique

3.4.1 Aggregate gradation

Table 3 : Specification of aggregate gradation for DBM Grade II as per MoRTH-V revision

IS sieve (mm)	**Cumulative % by weightof total aggregate passing**	**% Passing for middle limit (ML)**
37.5	100	100
26.5	90-100	95
19	71-95	83
13.2	56-80	68
4.75	38-54	46
2.36	28-42	35
0.3	7-21	14
0.075	2-8	5
Bitumen (%)	Min 4.5%	

3.4.2 Determination of volumetric properties

Following properties are determined for each specimen

Bulk specific gravity or density of the mix (Gm)

When air voids are taken into account, the bulk specific gravity of the mix (Gm) is obtained.It's given by,

$$G_m = \frac{W_m}{W_m - W_w}$$

Theoritical specific gravity (G_T)

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

Percent air voids (V_v)

The following formula is used to determine the percentage of air voids by volume in the specimen

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

Percent volume of Bitumen (Vb)

The Volume of Bitumen (Vb) is the volume of bitumen divided by the total volume,computed as follows

$$V_b = \frac{\frac{W_b}{G_b}}{\frac{W_1+W_2+W_3+W_b}{G_m}}$$

Voids in Mineral Aggregate (VMA)

The following formula is used to compute the volume of voids in mineral aggregates (VMA),

$$VMA = V_v + V_b$$

Voids Filled with Bitumen (VFB)

Voids Filled with Bitumen are the voids in the mineral aggregate frame work that are filledwith bitumen (VFB).

$$VFB = \frac{V_b \times 100}{VMA}$$

Where,

W_m - is the weight of the mix in air;

W_w - is the weight of the mix in water;

W_1, W_2, W_3 etc., are the weights of different sizes of aggregates used in the mix;

W_b - Weight of the bitumen used;

G_1, G_2, G_3 etc., are the apparent specific gravity of different sizes of aggregatesused in the mix;

G_b - Apparent specific gravity of the bitumen used;

G_m – Bulk Specific Gravity.

3.4.2 Optimum binder content determination for DBM mix

(a)Plot the graphs

- Density vs. asphalt binder content.
- Marshall stability v/s asphalt binder content.
- Asphalt binder content vs. flow.
- Asphalt binder content vs. air voids. Percent air voids should decrease with increasing asphalt binder content.
- Asphalt binder content vs. VMA. Percent VMA should decrease with increasing asphalt binder content, reach a minimum, and then increase.
- Asphalt binder content vs. VFA.Percent, VFAincreases with increasing asphalt binder content.

(b) Calculate the amount of asphalt binder needed for the mix design by averaging. the following three bitumen contents derived from the graphs created in step one.

- Binder content corresponding to maximum stability.
- Binder content corresponding to maximum bulk specific gravity (Gb)
- Binder content corresponding to the median of designed limits of percent air voids (Vv) in the total mix (i.e., 4%)

3.5 Moisture Susceptibility of Bituminous Mixes Indirect Tensile Test

ITS test is a measure of tensile strength of bituminous mixes and is commonly used for determining tensile strength ratio (TSR) of bituminous mixes. As per the MoRTH-V revision, the minimum TSR requirement for DBM-II mixes is 80%. The test is conducted as per ASTM D 6931-12. Marshall specimens were prepared at 7% air void level and Tensile strength ratio (TSR) was determined as per AASHTO T283 for conditioned and unconditioned samples. Overall, it can be said that adding RAP with a lower RAP percentage (< 30%) could reduce the HMA mix's dry strength, but adding RAP with a greater RAP content could increase dry strength (>30 percent). Additionally, the strength in dry conditions may not be diminished by the addition of RAP to WMA mixes [22]. Along with that sasobit(3%) is added to mixes conduct the moisture resistance test.

$$St = 2P/\pi DT$$

Where,

St - Horizontal stress (N/mm^2)

P - Load at Failure or maximum load (N) L - Specimen height (mm)
D - Specimen diameter (mm) T - Thickness (mm)

The tensile strength ratio is computed using the formula below.

$$TSR = S1/S2$$

Where,

TSR - Tensile Strength Ratio, %

S1 - stresses of unconditioned state in, kpa

S2 - stresses of conditioned state in, kpa

3.6 Fatigue and rutting properties of WMA mixes

Fatigue cracks typically happen at intermediate temperature condition. Different approaches are used by researchers to evaluate the fatigue cracking due to repeated load for similar climatic and environmental conditions. These approaches include fracture mechanics, energy-based techniques, and stiffness reduction criteria. At three different strain levels fatigue life of organic and chemical WMA mixes was analysed. The study also showed fatigue resistance is improved with addition of Sasobit to native binder improved. The type of WMA additives also influences the fatigue performance of mixes. Based on the field studies in France, Germany and Norway, it is observed that Sasobit exhibited better cracking resistance to HMA[22].

Permanent deformation or rutting is another factor that determines the performance of bituminous mixes. Rutting of mixes depends on binder grade, aggregate gradation, tyre pressure and test temperature. Studies indicated that rutting resistance of bituminous mixes reduced with addition of WMA additive. This is due to less ageing of mix. However, several researchers reported that some warm mix additives increase the rutting resistance of bituminous mixes due to after crystallization of additives in binder The inconsistency in results indicate that that the rutting performance is depending on the type of WMA additive or method.[24].

4. Conclusion

- Based on the Marshall test results, Marshall Stability increased with increase in RAP percentage less than 30% for warm bituminous mixes
- The indirect tensile strength increased with increase in RAP content and Sasobit when compared to conventional mixes.
- The tensile strength ratio increased with addition of warm mix additive to conventional and RAP mixes indicating, better resistance to moisture resistivity.
- Addition of sasobit as a warm mix additive to the warm mixes gives better fatigue and rutting resistance property.
- Thus, integrating WMA, and RAP in bituminous mixes optimizes the advantages towards durable and sustainable pavements.

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