Comparative study of Hot mix asphalt to Warm mix asphalt containing plastic waste for sustainable development of roads

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Abstract – *Currently, majority of the Indian roads are paved with Hot Mix Asphalt (HMA), which consists of aggregates and bitumen mixed together at high temperature, approximately 160-170°C. The main concern with the production of HMA is, it requires large amount of energy and also releases enormous amount of emissions into the environment. Increased environmental awareness has led to a development of Warm mix asphalt (WMA) to reduce the high mixing temperatures of regular Hot mix asphalt (HMA). Warm mix asphalt (WMA) is a recent technology used to reduce the mixing and compaction temperatures by adding some additives. Moreover consumption of plastics is increasing day by day. Once used plastic material is generally thrown out as they do not undergo bio decomposition. Hence waste id either land filled or incinerated. Both are not eco-friendly processes as it pollutes the land and the air. In this study Stability – Flow analysis for the various bituminous concrete mixtures prepared with both the techniques that are WMA and HMA is reported and compared. It is found that 5.65 % is the optimum binder content and Marshall Stability is highest at 0.2% of zeolite with 8% replacement of bitumen with LDPE and also WMA fulfills the requirements specified by IRC29-1988.*

Key Words: warm mix, waste plastic, zeolite, Marshall Stability

1. INTRODUCTION

All India paved road network is constructed with traditional Hot Mix Asphalt (HMA) technology. The higher production and compaction temperature of the asphalt mix results emissions. The major source of emissions associated with the Hot Mix asphalt are the dryers, hot bins, and mixers, which emit particulate matter (PM) and a variety of gaseous pollutants. So, the road construction industry is looking for an alternate material or a technology that reduces the amount of energy required to produce the HMA, in order to combine energy savings and environmental welfare. Warm mix asphalt (wma) is one of the rising technologies developed by the transportation engineers, which is environment friendly as compared to the hot mix asphalt technology.

1.1 Warm Mix Asphalt

WMA refers to technologies which allow a significant reduction of mixing and compaction temperature of asphalt mixes, through the lowering of the viscosity of asphalt binders. WMA is amended HMA mixture that is produced, placed and compacted at a 30–50°C lower temperature than the conventional HMA mixture. In hot mix process absolute coating of mineral aggregates with binder is achieved at higher temperature, as the viscosity of binder is less at higher temperature. But in warm mixes, the proper mixing is achieved in three different ways that is by increasing the volume of bitumen, by making the bitumen less viscous, by reducing the surface tension at aggregate bitumen interface etc.

1.2 Technologies for WMA

Presently, there are more than 35 technologies which have the potential to bring reduction in mixing, laydown and compaction temperature of the bituminous mix in one of three ways as mentioned above. Warm mixes are majorly categorized into following technologies:

1.2.1 Foaming technologies

In this technology fine water droplets are used to increase the volume of binder in the mix. Small amount of water is injected into the hot binder or directly into the mixing chamber. Water expands approximately 1500 times when converted into steam at atmospheric pressure, and the steam is contained by viscous bitumen producing foam, which occupies a much greater volume compared to the original bitumen, ensuring improved coating and workability of the mix at lower temperatures. The water for creating the foam is either added as water through a water injections stem in specialized equipment, or from zeolites (which contain about 20 per cent water).

1.2.2 Organic additives

These organic additives when added cause reduction in viscosity of the bitumen. It has to be certain that the melting point of the selected organic additives must be higher than the anticipated in service temperature so that perpetual deformation should not occur. Paraffin wax is the common example of the organic additive.

1.2.3 Chemical additives

Chemical additives are comparatively new and rising group of warm mix additives. These products do not work on foaming or reduction of viscosity rather these are the surface active agents that reduces surface tension between polar aggregates and non-polar bitumen, improve wetting and reduce internal friction for lowering production and placing temperatures. These additives have little effect on rheological properties of bitumen. These agents are added at the rate of 0.20 to 0.70% to the weight of the binder.

1.2.4 Hybrid technologies

When two or more wma technologies are used to achieve the reduction in temperature then the technology is known as hybrid technology. Low energy asphalt is one of the hybrid technologies that employ chemical additive with water injecting technology to upgrade coating at lower temperature.

2. Literature Review

Goh et al. (2007) evaluated the properties of WMA with the addition of Aspha-min (synthetic zeolite) based on the Mechanistic-Empirical Pavement Design Guide (MEPDG). They found that the addition of Aspha-min did not have any effect on the dynamic modulus values for any of asphalt mixtures examined. The rut depths predicted from the MEPDG simulations showed that WMA could decrease rutting and the greatest difference of rutting between WMA and its control could be up to 44%.

Wielinski et al. (2009) conducted a study based on laboratory tests and field evaluations of foamed WMA. They found that the Hveem and Marshall properties of HMA and WMA were almost similar, and all met the Hveem design requirements and the mixture property requirements. The in-situ densities were also almost similar.

Khan et al. (2001) studied the comparative performance of properties of bituminous mixes containing plastic/polymer (PP) (8% and 15% by weight of bitumen) with conventional bituminous concrete mix (prepared with 60/70 penetration grade bitumen). Improvement in properties like Marshall Stability, retained stability, indirect tensile strength and rutting was observed in Plastic modified bituminous concrete mixes.

Karim and Mohagdam (2012) stated that the application of waste material in asphalt pavement would be beneficial in order to find a substitute solution to upturn service life of asphalt pavement and decrease environmental pollution as well. Form their study it is decided that Polyethylene Terephthalate (PET) reinforced mixtures hold higher stability value, flow, fatigue life in comparison with the mixtures without PET.

2.1 Methodology

1.	Blending of aggregates (satisfying the gradation limits of BC grade 1 specified in IRC: 29-1988)
2.	Preparation of Marshall Specimens of BC mix with conventional Hot Mix technology to calculate optimum binder content and stability characteristics.
3.	Preparations of warm mix asphalt (WMA) Specimens of BC mix with waste plastic and zeolite as WMA additive and calculate the flow values and stability characteristics.
4.	Comparison between stability characteristics and volumetric analysis of BC mixes prepared with both techniques.

3. Experiments and Results

3.1 Job mix formula for bituminous concrete mix grade I (40mm)

Aggregate blend

Type 1 aggregate (20 mm) = 42%

Type 2 aggregate (10mm) = 27%

Type 3 aggregates (local sand) = 31%

3.2 Marshall Stability Test

As per Indian Standards in IRC 29-1988 when the specimens are compacted with 75 blows on either side, the designed mix should accomplish following requirements:

Marshall Stability value (in Kg at 60° C)
918

Marshall Flow value, (0.25mm units)
2 to 4

Voids in total mix, (V_v %) 3 to 6

Voids in mineral aggregates filled with bitumen, (VFB %)
65 to 75

The highest value of Marshall Stability (possible) in the mix is meant to be consistent with the other three requirements written above. If the designed mix does not fulfil any one or more of the requirements, the gradation of the filler content or aggregates or bitumen content or their combination are altered and the design tests are done again till all the requirements are fulfilled simultaneously.

3.3 Discussion on result of BC grade I mix prepared with hot mix technique

- Stability- flow and volumetric analysis result and graphs of BC mix prepared with traditional hot mix technique have been shown in table 3.7 to 3.9 and from figure 3.16 to figure 3.21.
- Test samples were prepared starting from bitumen content of 4% to 6.5%. Three test specimens were prepared for each bitumen content. Bitumen content was increased by 0.5% in each next set of specimen.
- It is observed that stability value increases from 4% to 5.6% and then decreases till 6.5% bitumen content. Stability value is always above the minimum requirement of 9kN according to MORTH. Maximum value of corrected stability is 17.88 kN at just above 5.6 % bitumen content.
- Flow value will keep on increasing from 4% to 5.6% bitumen content. Flow criteria of 2to4 mm for BC grade I is satisfied for bitumen content from 4% to 5.5%
- Bulk density value increases sharply from 4% to 5.6% and then decreases sharply when bitumen content increases from 5.5%. maximum value of bulk density is 2.406 at 5.5% bitumen content
- Air voids decreases sharply from 4% to 5.6% and then increases upto 6% then decreases afterwards. Nearly minimum air voids achieved in total mix is 3.15% at 5.5% bitumen content lying within limits 3 to 6%.
- Voids filled with bitumen remain constant from 4% to 5.5% then increases to 6% and decreases afterwards. It is remain in range of 65% to 85%.
- Voids in mineral aggregates (VMA) increases throughout increase in bitumen content. Minimum value of VMA is found to be 14.5% at 5%bitumen content.

3.4 Discussion on Results of BC grade I mix containing low density polyethylene waste (LDPE) prepare with the Warm Mix Asphalt (WMA) technique.

- Stability- flow and volumetric analysis result and graphs of BC mix containing LDPE waste prepared with warm mix technique have been shown in table 3.10 to 3.12 and from figure 3.25 to figure 3.30.
- It is observed that stability value increase from 0.1% of zeolite to 0.2% zeolite and then further decreases a bit on more dosage of zeolite. Minimum stability value achieve is 12.3 kN which is more than minimum requirement of 9kN according to IRC 29-1988.
- Unit weight of the sample remains constant for the dosage of 0.1 to 0.2% of zeolite and after then it decreases when zeolite quantity is increased.
- Flow criteria for WMA mix of 2 to 4mm is satisfied throughout all the specimen prepared and is shown in figure.
- Air voids (%) is minimum at 0.2% of synthetic zeolite, after that value of air voids start increasing on increasing zeolite content (%).
- The required value of Voids in Mineral aggregates (VMA) and voids filled with bitumen (VFB) is achieved at zeolite content of 0.2% of bitumen
- From the above analysis zeolite at the rate of 0.2% of the weight of binder satisfying all the requirements (as per MORTH) of bituminous concrete mix

4. Comparison between results of Hot Mix Asphalt samples and Warm Mix Asphalt samples

4.1 Stability value comparisons

A comparison of stability value of BC mix prepared at OBC with hot mix technology (HMA) and warm mix technology (WMA) is shown in figure

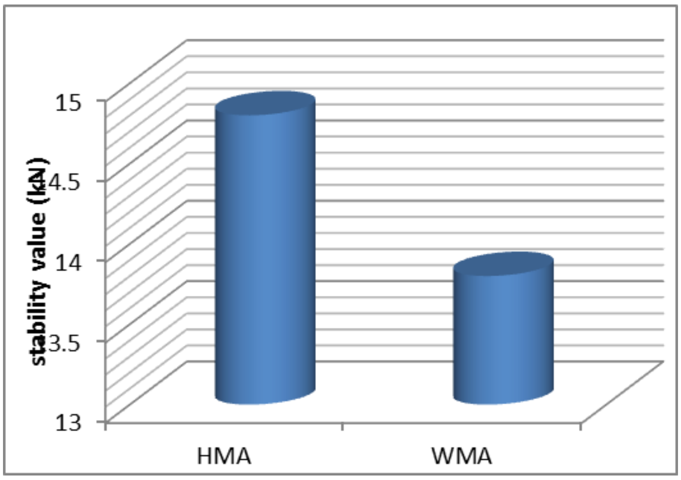

Figure 4.1: Stability value comparison between HMA and WMA

4.2 Flow value comparison

A comparison of flow value of BC mix prepared at OBC with hot mix technology (HMA) and warm mix technology (WMA) is shown in figure 4.2

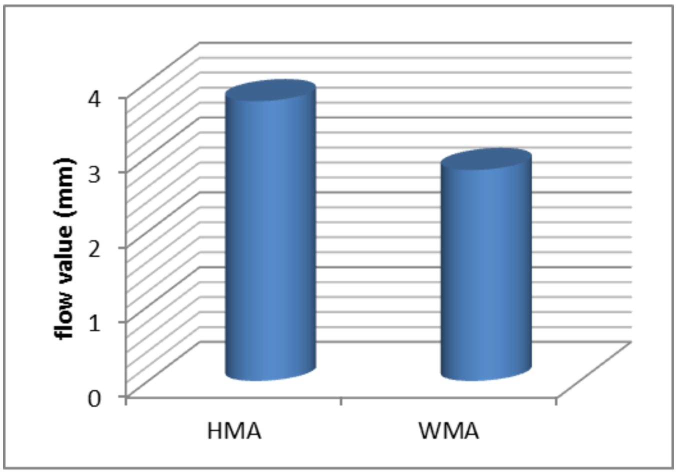

Figure 4.2: Flow value comparison between HMA and WMA

4.3 VMA value comparison

A comparison of VMA value of BC mix prepared at OBC with hot mix technology (HMA) and warm mix technology (WMA) is shown in figure 4.3

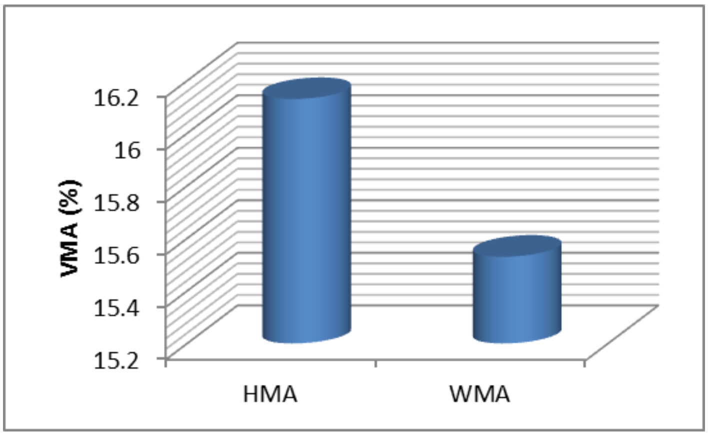

Figure 4.3: VMA (%) value comparison between HMA and WMA

4.4 Some of the major advantages by using warm mix asphalt (WMA)

4.4.1 *Environmental benefits*

In wma requirement of fuel is lower as production temperature is lower than the hma. This lead to lower emission of the asphalt plant. The reduced fuel and energy usage gives a reduction of the production of greenhouse gases and reduces the CO2.

This technology is compatible with reclaimed asphalt pavement technology which lead to reduction in requirement of the fresh mineral aggregates which is again beneficial to our environment

4.4.2 *Health benefits*

The fumes release from hot mix asphalt are hazardous to health but that are minimum in case of warm mix asphalt due to temperature reduction. reduced emissions are specially beneficial to densely populated areas

4.4.3 *Extended paving season*

One of advantages of this technology is paving in colder region as the mixing and laying temperature required is less in case of wma which is aided by warm mix asphalt additives.

4.4.4 *Energy*

Warm mix asphalt technology lead to reduction in use of fuel. So it is energy saving method

5. CONCLUSIONS

The major conclusions drawn from the study carried out on stability characteristics of bituminous concrete mixes containing waste plastic using warm mix asphalt technique are as under.

- In case of HMA Stability value of Bituminous Concrete (BC) mix at optimum binder content (OBC) came out 15.4 kN and at same binder content stability value came out 13.8 kN in case of WMA containing waste plastic. In both the cases it was more than 9kN which is the minimum requirement as per IRC 29-1988 specifications.
- Warm Mix Asphalt (WMA) containing Low Density Polyethylene waste (LDPE) (8% replacement of binder content) performs equally well as compared to conventional Hot Mix Asphalt by fulfilling all the requirements such as stability value, flow value etc. of the Bituminous Concrete Mix as prescribed by MORTH.
- In a stretch of 1 km long and 3.5m wide road paved with 40mm Bituminous Concrete layer, WMA encapsulated with LDPE saves about 40 tons of bitumen i.e. 8.3% saving in bitumen cost.
- Plastic waste is non-biodegradable and is either landfilled or incinerated which causes air, land and water pollution. So its utilization in construction of roads is eco-friendly method for waste use.
- As per European Asphalt Pavement Association (EAPA) fuel consumption for HMA is 2.0 gallon per ton of asphalt mix and in WMA it is 1.6 gallon per ton of asphalt mix. .i.e. fuel savings in WMA ranges from 20- 30%.
- Reduction in consumption of fuel will lead to reduction of emissions of greenhouse gases, which will be beneficial in earning carbon credits under the cap of Kyoto Protocol.

Above positive result conclude that WMA is a sustainable way of paving and lead to the development of Green Highways

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