"MIX DESIGN PROPERTIES AND MOISTURE SENSITIVITY CHARACTERISTICS OF DENSE BITUMINOUS MACADAM MIXES MODIFIED WITH REDISET, A WARM MIX ADDITIVE"

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Abstract

Warm mix asphalt is a developing technology which allows the mixing, lay down and compaction of asphalt mixes at lower temperatures. Warm mix asphalt mixes can be produced at temperature about 120º C or lower which helps in saving the fuels and proves Eco friendly. A number of researchers evaluated various WMA mixtures using selected testing procedure in the laboratory. But only few of them varied both the temperature and additive dosage rate. In this study, the main objective is to study the effect of WMA additive Rediset on the viscosity of bitumen at different temperatures and to evaluate the properties like Marshal Stability, Indirect Tensile Strength and Moisture Susceptibility of DBM mix along with the warm mix additive.

The binder showed a decreasing trend in viscosity with increase in the temperature as well as additive dosage rate. The DBM mix with 2.5% WMA additive exhibits higher stability values even at 135° C or lower the temperatures. The specimens with additive showed the lowest value of air voids which were within the limit of 3-6%, which indicate WMA additives are effective in compacting mixtures at 120° C or lower. Indirect Tensile Strength and Tensile Strength Ratio values of the mixtures with WMA additive were found to be higher than the mixtures without additive Rediset. Based on the overall test results it can be concluded that WMA additive Rediset is effective in producing the mixtures with high strength at mixing temperatures of 135° C and 115° C.

Keywords: *WMA, DBM, Additive*

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1. INTRODUCTION

1.1 Background

The Warm mix asphalt technology was started in 1990's in Europe basically to reduce Green house effect. Aspha-min, Warm mix asphalt Foam, and Sasobit were the technologies developed as WMA additive. Some new technologies such as Evotherm, Rediset, LEA (Low Energy Asphalt) and Double Barrel Green were developed [5]. Even though Warm mix asphalt technology was started in Europe, the investigation on WMA was made very fast in US. National Asphalt Pavement Association (NAPA) started examining about WMA technologies in 2002 and National Center for Asphalt Technology (NCAT) started research on WMA technologies in 2003 [8]

1.2 Various Types of WMA Additives

1.2.1 Advantages

As the Warm Mix Asphalt technology found with many advantages, many agencies and manufacturers across the world started research on Warm mix asphalt technique. Depending upon the requirement, Different agencies started manufacturing different products of WMA with different properties. Some of the type of WMA additives is explained below.

Aspha-Min: It is the product of Eurovia Services GmbH based in Germany. Aspha-Min is the manufactured synthetic sodium aluminum silicate, also called as Zeolite. These are framework silicates with large empty spaces in their structures that allow the presence of large cat ions, such as sodium and calcium. It contains about 21% of water by mass, which is released at about temperature of 85°C-185°C. When Aspha-min is added to the mix at the same time as the liquid asphalt binder, water is released. Eurovia recommends that Aspha-Min to be added at the rate of 0.3 % by weight of the mix which reduces about 28ºC of temperature in a HMA [5].

Sasobit: It is the product of Sasol International, Germany. It is the paraffin wax derived from the coal gasification. This reduces brittleness at lower temperatures as compared to bitumen paraffin waxes. It helps in mix workability at lower temperature. Sasobit is designed as the flow improver for the asphalt, both during mixing process and lay down operation. Sasol recommends that it should be added at the rate of 0.8%

by of mass of the binder (Stacey and Amy 2008). Sasobit is available in two forms, flakes for molten addition or pills for direct addition to the mix.

Warm asphalt mix foam: This is a component of soft binder and hard foamed binder, which are added at different time during mixing. WAM-Foam is product of Shell petroleum company Ltd., U.K. and Kolo-veidekke, Norway. Initially soft binder is added at a temperature about 100ºC-120ºC to coat the aggregate. Later hard binder foam is mixed with the aggregate.

Revix: Revix is the technology based on chemical additive. It was developed in 2007 by Mathy Technology and Engineering Services and Paragon technical services in the US. This technology is not mainly related to the principle of foaming or viscosity reduction. Combination of surfactants, waxes, processing aids, polymers, etc. is used to reduce the internal friction between aggregate particles in the asphalt mixture.

Rediset-WMX: This technology was developed in 2007 by Akzo Nobel Surfactants. This additive is in a solid form and consists of cationic surface active agents. Rediset-WMX helps in improving wetting of the aggregate surface and provides good aggregate adhesion. By using this additive it is possible to reduce a temperature up to 30%.

Rediset-WMX is the solid additive which can be blended in liquid asphalt binder. The recommended dosage is that 1.5 to 2.5 % by weight of the asphalt binder. The additive can be blended into asphalt before mixing or can be added just before as the asphalt enters the mixers. Asphalt treated with Rediset-WMX can be stored before use [13].

Advantages of warm mix asphalt technologies are mentioned below.

- Warm mix asphalt technology helps in reducing the fuel consumption which is used to dry and heat the aggregate, thereby saving the energy. According to studies it is observed that the energy consumption is reduced up to 30 percent.
- Emission from the fossil fuels can be comparatively reduced as compared to hot mix asphalt (HMA).
- By using WMA technology, the fumes and odor can be reduced at the plant and paving area. This helps in working condition at both places.
- By producing WMA at normal HMA temperatures, it may be possible to extend the paving season into the colder months of the year since WMA additive act as a compaction aid.

At the Bitumen Forum of Germany in 1997, warm mix asphalt (WMA) technology was identified as one of means to lower emissions. The WMA technology was introduced in the United States in 2002 when the NAPA sponsored an industry scanning tour to Europe for asphalt paving contractors (John Angelo et al. 2008). In 2004, the World of Asphalt convention featured a demonstration project of WMA, and since then, WMA additive manufacturers have successfully performed many demonstration projects throughout the United States [8].

1.3 Effect of WMA Additives on Binder Viscosity

It has been well established that the rheological properties of any new binder should be studied extensively in order to decide whether this binder is applicable to be utilized or not. Traditionally, the most common rheological characterization of a binder has been reported using viscosity. Viscosity is the physical material characteristics or property that can be employed and utilized to describe the resistance of liquids to flow [1`]. Viscosity is defined as the ratio of shear stress to shear strain rate at any given temperature and shear rate [14].

The concept of warm mix technology is to reduce the asphalt binder viscosity, which helps the asphalt to attain the required viscosity to coat the aggregates and thus compact the mixes at lower temperatures [2].

Viscosity of binder after short term aging for WMA and HMA. The obtained viscosity of the plain binder without any additive is normalized. Rotational viscometer was used to measure all the viscosities at 135° C. Result indicated that, the binders with no warm mix asphalt additives had the highest viscosities than the binder with warm mix asphalt additive [14].

1.4 Mix Design of WMA

The design methods followed by different agencies vary due to the usage of different WMA additives and different binder. Some of the mix design practiced by different agencies is discussed.

Aspha-Min use in Warm Mix Asphalt. Two aggregates, granite and limestone were used. The Super pave gyratory compactor was used to determine the mixture compatibility at different temperatures. Mixes were compacted at 149° C, 129° C, 110° C and 88° C, with mixing temperature about 19° C above the compaction temperature. The additive Aspha-min was added at rate of 0.3% by mass of the mix [5].

Warm mix asphalt technology by using Sasobit. In this study the nominal maximum aggregate size of Super pave 9.5mm and 12.5mm were used. The mix is produced using penetration grade 64-22 binder, designated by VDOT SM-9.5A mixture and VDOT SM-12.5A mixture. Mix production was carried out at different temperatures of 149ºC, 162ºC and 121ºC. WMA additive Sasobit was added at a rate of 1.5% by weight of the binder [11].

Laboratory test conducted for the CECABASE Warm Mix Additive using an aggregate of a size 19.0mm as specified by Caltrans Standard specification and NDOT specification for Road and Bridge construction. PG 64-28 polymer modified asphalt binder was used for the study. Temperature of 160ºC and 132ºC were maintained for the preparation of HMA and WMA mixes respectively. CECABASE warm mix additive was added to asphalt binder at a rate of 0.4% by weight of binder. Mix design was carried out according to Caltran and NDOT specification for the HVEEM design method [3].

1.4.1 Volumetric Properties of WMA Mixes

The volumetric properties of warm mix asphalt vary with the addition of different types of WMA additives at different rate and temperature, all technologies improved the compatibility of the asphalt mixture and resulted in lower air voids compared HMA [4].

Strength of the WMA mix using PG 64-22 binder and the granite and limestone aggregates. Mixture strength was evaluated based on indirect tensile strength at 25° C. Indirect tensile strength of the mixture is sensitive to binder. The result indicate that although the strength varied over the different aging times, there were no change in strength for either the control mix or for the warm mix at particular age time[5].

1.5 Moisture Sensitivity

The ability of the mixes to resist moisture damage was measured using two tests. Tensile strength ratio (TSR) and Hamburg wheel–track tests. Each test measures moisture sensitivity differently. The TSR test compares conditioned and unconditioned indirect tensile strength of specimen sets. The Hamburg wheel-track test subjects submerged samples to a simulated traffic load based on the theory that moisture damage cause rutting [11].

Moisture sensitivity of WMA mixtures using the modified Lottman test following AASHTO T283. Six samples (three for dry condition and three for wet condition) for control WMA mixtures and WMA mixtures were prepared with 20 gyrations. For wet conditioning, three samples were saturated at between 70% and 80% were placed in freezer at -18° C for 16 hours and in water bath at 60°C for one day followed by conditioning in water bath at 25° C for two hours. The tensile strength ratio values of WMA samples ranged between 58.6% and 69.1%, all below the Super pave specification of 80%.

2. MATERIALS AND METHODOLOGY

Various tests were conducted to determine the physical properties of Bitumen and the coarse aggregate. Penetration test, Softening point test, Specific gravity test and Ductility test were conducted to know the physical properties of Bitumen while Abrasion test, Crushing test, Shape test, Specific gravity test and Impact test were conducted on the aggregates to know its physical properties. Dense bituminous macadam grading-2 was selected as a gradation. Different temperatures of 155° C, 135° C and 115° C and additive rate of 1.5% and 2.5% by weight of binder were selected. [6].

Samples of plain bitumen and bitumen with WMA additive at 1.5%, 2.0%, 2.5% and 3.0% dosage rate were tested for viscosity using brook field viscometer at 95, 105, 115, 125, 135 and 155° C. Specimens were prepared for DBM Grading-2 at 155, 135 and 115° C. Specimens with warm mix additive were prepared at a rate of 1.5% and 2.5% of the binder at 135° C and 115° C. The specimens were prepared with same variation of 4.5, 5.0, 5.5 and 6.0 percent of bitumen content. The casted specimens were tested for Marshall Stability, Indirect Tensile Strength and Moisture Susceptibility.

2.1 Warm Mix Asphalt Additive

Rediset WMX 8017 was used as a Warm Mix Asphalt additive obtained from Akzo Nobel Coatings IPL, Mumbai. This additive developed by Akzo Nobel Surfactants in US. Rediset WMX is in solid form which is added to bitumen before mixing. The recommended dosage rate is 1.5 to 2.5 per cent by weight of the asphalt binder. Rediset WMX is shown in Fig1.

Fig1. Rediset WMX-8017

2.2 Dense Bituminous Macadam Gradation

Dense Bituminous Macadam grading-2 is selected as base layers. The bituminous mix design is done as per Marshall Mix design of MS-2, and the gradations for these mixes were obtained from MoRTH (2001).

3. RESULTS AND DISCUSSIONS

3.1 Viscosity Test Results

A rotational viscometer was used to compare the viscosity of the virgin binder and the binder with WMA additive Rediset. The viscosities of the binders were measured at different temperature such as 95, 105, 115, 125, 135, and 155°C as per ASTM D 4402 (2006). For all the viscosity tests 10.5 grams of binder was tested with a SC4 - 27 spindles maintaining a constant rotational speed of 20 RPM.

Viscosity of the binder was reduced with the increase in the temperature as well as with the addition of the WMA additive Rediset. Viscosity was reduced from 2480cP to 2000cP with the addition of 3.0% additive at 95° C temperature corresponding to mixing and compaction at minimum and maximum viscosity level shows that, difference in the mixing and compaction temperature is higher for plain bitumen when compared to the bitumen with warm mix asphalt additive Rediset.

3.2 Design of DBM Mix

The Marshall Stability specimens were prepared with plain bitumen by varying the binder content from 4.5 per cent to 6 per cent by an increment of 0.5 per cent. Three specimens were prepared for each binder content. In the conventional Marshall Mix design 1.2 kg of aggregates were used to prepare the specimen.

Marshall Stability test was conducted and properties like stability, flow, bulk density, volume of voids and voids filled with bitumen are found for plain bitumen and for bitumen with WMA additive Rediset varying dosage rate of 1.5% and 2.5% at a temperature of 135° C and 115° C

3.3 Comparison of Marshall Properties

Marshall Properties of specimens prepared at different temperatures and with different additive rate is compared each other. The graphical representation of comparison of Marshall properties for DBM at 155° C, 135° C, 115° C, 1.5% and 2.5% additive at 135°, 115° C are shown in Figure 2 .

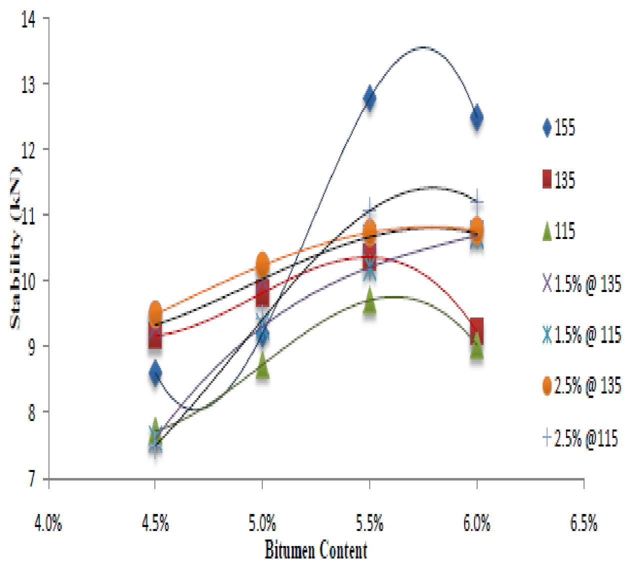

Fig 2 stability varies with different grades 0f bitumen

4. CONCLUSIONS AND RECOMMENDATION

4.1 Conclusions

Following conclusions are made based on the results obtained in the present investigation:

- Viscosity of binder found using Brookfield Rotational Viscometer was maximum at lower temperature of 95° C. Further with the increase in temperature up to 155° C, viscosity was reduced to lower values. The value of Viscosity was still lower when the binder was tested with 1.5, 2.0, 2.5 and 3.0% additive dosage rate. Viscosity was minimum for the binder with 3.0% additive rate at 155° C. It was seen that the, viscosity reduced with the increase in the temperature as well as with the addition of WMA additive Rediset.
- From the results of Marshall Properties, for the DBM Grade-2 mix, WMA additive Rediset added at a rate of 2.5% weight of the bitumen shows the maximum stability against the DBM mix at 135 and 115° C. Mix with additive of 1.5% dosage rate also showed improved stability at 135 and 115° C than the mix without WMA additive.
- Flow value was seen to be increased with the increase in additive rate but decreased with decrease in temperature.
- The increase in bitumen content initially increased the bulk density but further increase in bitumen content decreases the bulk density. The addition of WMA additive Rediset improved the Bulk Density of the mix. It was also seen that there was very less difference between the densities of 1.5% and 2.5% additive rate specimens.
- The percentage air voids in the mix were found to decrease with the increase in the bitumen content. Air voids of DBM mix with WMA additive Rediset at 135° C was the lowest when compared to the mix without additive at 155° C which indicate that, WMA additives are effective in compacting mixtures at a lower temperature. The voids filled with bitumen (VFB) in the mix were found to increase with the increase in the bitumen content.
- The indirect tensile strength of a mix with WMA additive was higher than the mix without WMA additive. This shows that the WMA additive play important role in increasing the strength of the specimen.

The Tensile strength ratio (TSR) values for all the DBM mix were above the specification 80%. TSR of the mixes with WMA additive were higher when compared to the mixes without additive. These results indicate that the mixes with WMA additive are more susceptible to moisture damage.

4.2 Recommendations

Warm mix additive Rediset added at 2.5% dosage rate showed better stability for DBM mixes when compared to mixes with 1.5% additive dosage rate. So in terms of stability, it is better to use 2.5% of WMA additive Rediset to DBM mix. Air voids was low as 3.94% in the mix with 2.5% additive at 135° C when compared to mixes with 2.5% additive at 115° C and 1.5% additive at 135° C and115° C. So in terms of air voids, it is better to use 2.5% WMA additive for DBM mix at 135° C.

4.3 Scope for Further Research

The conclusions drawn in the above sections are based on the laboratory studies performed on DBM Grade-2 mixes, at different temperatures and different additive rate. After the analyses of results at different stages of this study, it was found that the following issues needs to be addressed as part of the future scope of study.

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