WARM MIX TECHNOLOGY- A REVIEW

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ABSTRACT

All around the world efforts are made and being forward to protect the environment. At present the main emphasis is on reducing $_{CO2}$ emissions in the view of reducing the greenhouse gases and effect. Nowadays the construction of roads can be done by using the hot mix asphalt (HMA) technique which consists of aggregates and bitumen mixed at the higher temperature approximately 150° to 170° C. The objective of the study is to find out the various advantages of Warm Mix Asphalt Technology (WMA) as compared with the Hot Mix Asphalt Technology (HMA) with the help of different research Papers Published in National and International Journals. From our research we have come to the conclusion that Warm Mix Asphalt Technology can be better option as compared to the HMA Technology in term of its environmental benefits and other properties. The optimum binder content to produce the bituminous mix using the WMX additive will be achieved by the Marshall test. Then after optimum dosage of WMX additive and favorable temperature for WMX additive at which it can perform successfully. Qualified study can be done to know the stability of WMX additive with binder. As of late when fuel costs surpass record boiling records and exhaustion of greenhouse gases are restricted for makers there are new solutions for bitumen makers. The bitumen paving industry is continually investigating innovative upgrades that will improve the material's performance, expand development proficiency, save resources and development environmental stewardship. It is also found out that with certain modifiers the performance of WMA is further increased.WMA has significant effect on different parameters such as Marshall stability, Indirect Tensile Strength (ITS), Tensile Strength Ratio (TSR), rut depth, deformation, toughness, moisture resistance etc. This paper describes different techniques of obtaining WMA and different Warm Mix Chemicals that are available.

Keyword: - *Warm mix Asphalt (WMA), Warm Mix chemical, Indirect Tensile Strength (ITS)*

1. INTRODUCTION

From the considerations to protect the Earth humans are on path of searching better technologies which are environmental friendly and economical. In search of such environmental friendly techniques Highway Engineers have developed Warm Mix Asphalt Technology which is an alternative to Hot Mix Asphalt Technology. There are four types of Mixes:

- Hot Mix
- Warm Mix
- Half Warm Mix
- Cold Mix

Warm mix asphalt is produced at temperatures in the range of 20 to 40ºC lower than conventional hot mix asphalt (HMA). Hot mixes are produced by heating the aggregate and bitumen to high temperature in order to achieve the desired viscosity, such that it can adequately coat the aggregate and mix with other ingredients. The objective of WMA is to obtain desired binder viscosity and perform the same objective at lower mixing temperature without compromising on performance. Desired viscosity to fully coat the aggregates is obtained by adding certain

chemicals or additives. These chemicals can either be in powder form or in liquid form. With the reduction in production temperature there are some additional benefits, such as reduced greenhouse gas emissions, fumes, and odors generated at the plant and the paving site. The current industrial tendency is trying to improve the working systems in order to reduce the emissions of harmful components to the atmosphere and the consumption of energy as well. Until recent years the two fundamental criteria uses in deciding the best pavement to be uses are economical and technical considerations whereas today the environmental impact must also be taken into consideration. In the road sector the main research goal is the development of new systems which allow reducing the manufacturing and the application temperatures of the bituminous mixes. Bituminous mixes are most commonly use all over the world in pavement construction. Most of the highway in India is flexible pavements, within which are included surfacing of various types and thickness. Various studies are under taken to improve the strength characteristics of bituminous surfaces by modifying bitumen grades, aggregate gradation mix proportion and by adding different additives to the bitumen.

As per MoRTH - Section 509, bituminous concrete for wearing course should be made with bitumen of viscosity grade-30 (VG-30) for nominal aggregate size 19mm with bitumen content 5-6% having layer thickness 50-65mm and for nominal aggregate size of 19mm with bitumen content 5-7% having layer thickness 30-45mm. Bitumen VG-30 improves the performance of the binder to minimize the stress cracking that occurs at low temperature and plastic deformation at high temperature. Use of binders is a logical, practical and economical approach to meet required performance standard for pavement today. This enhances durability of existing road surfacing which results in reducing maintenance and surfacing operations

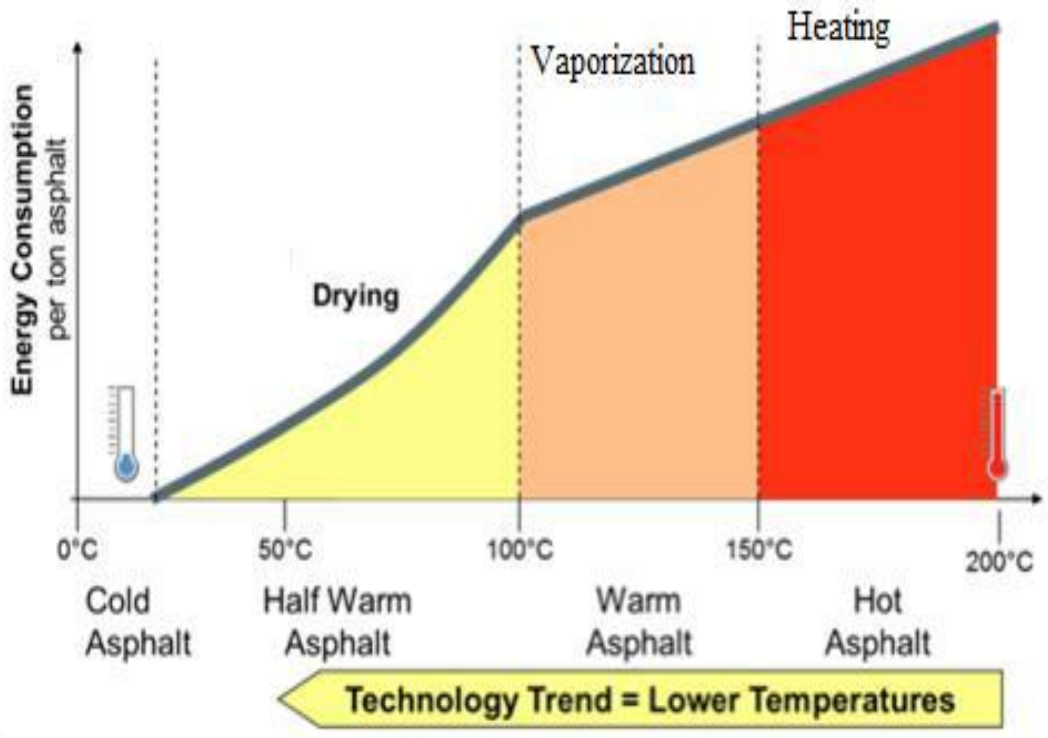

Fig. 1 classification of technologies related to various temp.

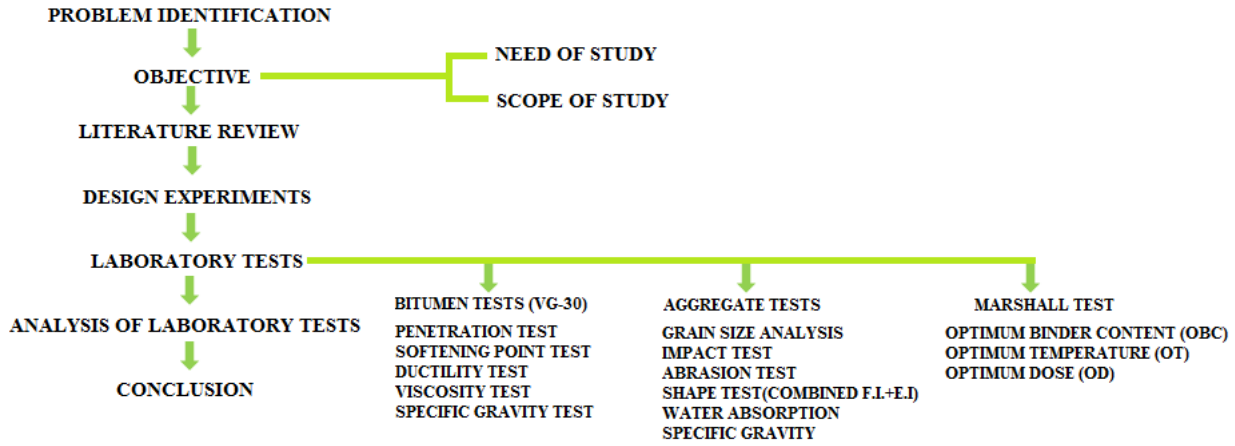

Fig. 2 study methodology

2. ADVANTAGES OF WMA:

In order to prove that Warm Mix Asphalt Technology is better than HMA Technology we have to find out certain advantages of WMA over HMA. These are listed below:

i) **Emission**: the first and the most palpable benefit is lower emission. As compared to HMA, WMA produces lower emissions because of reduced temperature. According to various studies and surveys it is observed that there is a reduction of 20-35% in the emissions.
ii) **Fumes:** due to temperature reduction WMA yields less fumes as compared to HMA.
iii) **Workability:** by achieving the same viscosity at lower temperature the workability may improve, leading the better compaction.
iv) **Binder aging:** due to high mixing temperature volatile compounds present in bitumen are lost it is called Binder ageing and because of that pavement develops cracks after some time.
v) **Energy:** reduced burner fuel led to energy saving.
vi) **Plant Wear:** due to lower temperature there is less wear and tear in the plant
vii) **Proximity to site**: due to less emissions and fumes WMA plants can be located within or near residential societies.
viii) **Compaction**: compaction is easier in warm mixes than HMA.
ix) **RAP:** the future use of pavement in terms of RAP is increased because of decreased binder ageing.

3. TECHNIQUES TO PRODUCE WMA AND WARM MIX CHEMICAL AVAILABLE

The Most common techniques for producing WMA are organic additives, chemical additives and foaming techniques.

i) **Organic additives:** Those techniques which use certain organic additives such as organic waxes, or fatty amides having melting points slightly higher than those of in service temperatures. Due to these organic additives observed reduction in temperature is 20-30◦ C.
ii) **Foaming techniques:** Those techniques which uses water for reducing binder viscosity. This is done by converting water into steam which increases the volume of binder thereby reducing its viscosity. The water then evaporates.
iii) **Chemical Additives:** Those techniques which use certain chemical additives which act as surfactants and reduce the frictional forces between aggregate and binder. Due to these chemical additives observed reduction in temperature is 20-30◦C Sasobit, Asphaltan-B, Licomont BS and Aspha-Min chamicals are widely used in Germany. Aspha-Min, EOMAC, Ecoflex, LEA, Warm-Foam, Evotherm are used in France. Advera, Double barrel Green, Evotherm, LEA, Aspha-Min, Asphaltan-B are used in U.S.

Sasobit, WMA, Asphamin are used in European countries. Some other Chemicals are: Asphaltan A and Romonta, Evotherm DAT, Evotherm 3G, Rediset WMX, Revix, Cacabase, LT Asphalt etc.

3.1 Various researches carried out in different parts of the world revealed that

i) After 46 months of service both HMA and WMA have similar International Roughness index.
ii) WMA have better workability than HMA.
iii) Both WMA and HMA have similar cost because cost of fuel saved counter balance the cost of Warm Mix Chemical.
iv) There is no significant effect on moisture susceptibility of Warm Mix additives when compared to control mixes.
v) The energy saving using WMA is equivalent to approximately 1.5-2 liters of fumes/tons of material.
vi) WMA reduces the total air pollutants such as CO, NOx, SOx and volatile organic compounds.
vii) WMA technology is suitable for cold regions because of lower temperature requirements.
viii) By using Rediset a mix of high strength is achieved at a temperature of 115◦C and 135◦C
ix) At maximum additive content of 4% only Sasobit can change the viscosity of binder with the reduction in mixing temperature of 10◦ C.
x) Only Casabas act as surfactant it do not affect the viscosity of bitumen.
xi) After 3 month of service Indirect Tensile Strength (ITS) values of WMA mixture had higher than the HMA mixture. However after 46 months HMA exhibit the higher ITS value.
xii) Normal dosage of Sasobit used is 4-5%.
xiii) It was noticed on allowing reduction of mixing temperature of about 10◦CSasobitchanges the viscosity of the binder when the maximum additive of 4% was used.
xiv) WMA has better performance than HMA in general.
xv) Reduction in fuel consumption by adding organic, water based foaming and chemical additives are 35%, 11-20% and 50% respectively.

Overall from this study we have concluded that WMA have good performance than HMA.

3.2 Additional technology of WMA & their different products.

After the first evolution of warm mix asphalt technology in 1959 by Prof. Ladis Csanyi at Iowa State University, till now there are many technologies have come on rise. The additional technologies available for the pavement construction are divided in to three categories which are listed below.

- Use of Chemical Technologies
- Use of Foaming Technologies
- Use of Organic(Wax) Additives

4. PREVIOUS STUDIES ON WARM MIX ASPHALT TECHNOLOGY

- **Hurley and Prowell, 2005** evaluated three different WMA additives: Aspha-Min® (synthetic zeolite), Sasobit® (wax) and Evotherm™ (emulsion) and concluded that all three technologies improved the asphalt mixture compatibility and resulted in reduction of air voids as compared to HMA. They stated that the addition of Aspha-min lowered the air voids in WMA measured in the rotating compactor. This can also improve the compatibility of both the rotating compactor and a vibratory compactor. Arithmetical analyses of test results indicated an average reduction in air voids of 0.65% using the vibratory compactor. Aspha-min did not have any significant effect on the resilient modulus of asphalt mixtures.

- **Dr. Sunil Bose, Mrs. Ambika Behl, Mr. M.N.Nagabhushna, Mr. Gajendra Kumar, Mr. Girish Sharma, Mrs. R. Uma Devi- Laboratory Evaluation of Evotherm Additive in Warm Mixes (2011)** carried out study on use of Evotherm Additives to design Warm mix design of Bituminous concrete with 13 mm nominal size of aggregate by adding 0.5% by weight of binder (60/70 Grade).The Marshall sample prepared at 95-100°C, 105-110°C, 115-120°C and 125-130°C temperature gives the OBC 5.7%. The performance Evaluation tests also carried out at each of above temperature such as Retained Stability, Indirect Tensile Strength and Tensile Strength Ratio, Hamburg Wheel Tracking Rutting test to obtain

Temperature at which the Warm mix satisfactorily gives its performance. The Retained stability for Control mix is 82.5% and 85.15%, 79.33%, 78.4% and 77.27% respectively for above temperature which is higher than required 75% as per MORTH section 500 clause 509. Tensile Strength Ratio for Control mix is 85.2% and 86.3%, 85.2%, 83.8% and 77.8% respectively in which the Tensile Strength Ratio at temperature 95-100°C is lower than required 80% as per MORTH section 500 clauses 509. Rutting test indicate that the rutting at 125-130°C temperature is 1.8 times lesser than the Control mix. At the end of Research they concluded that the There is no saving in OBC using Evotherm as additive.

- **MUNSHI RAMIZRAJA, from SVNIT, Surat (2011)** conducted a study on warm mixed design on bitumen concrete using modified binders. In this study he was carried out polymer modified binder (PMB) and crumb rubber modified binder (CRMB) used as a modified binder. The grade of this modified binder is PMB 40 and CRMB 60 used. In this study, he used 2% Rediset WMX with this modified binders. The reduction of 30°to 40°C has been documented in mixing and compaction temperature of bituminous mixes by adding 2% additive and fulfilled all volumetric requirement for both binders resulting in better performance at lower temperature of bituminous mixes. Bituminous mixes are less vulnerable to entrance of water or moisture damage than conventional mixes because of increasing in retained stability and tensile strength ratio of warm mix using both binders. Under static loads the permanent deformation of warm mix is lower than the control mix and have higher rate of recovery at higher temperature indicating better resistance to permanent deformation. Warm Bituminous mix with Polymer as well as Crumb rubber modified bitumen having higher fatigue life than conventional mix due to higher initial stiffness which indicate higher resistance to fatigue failure which occur at lower temperature. Warm Bituminous mix with Polymer modified bitumen exposed to lesser rutting than conventional mix which entitles the higher resistance to the deformation under wheel path.

5. LABORATORY TESTS

The warm mix design of the bituminous concrete starts with the laboratory tests originated by finding the physical properties of aggregate and bitumen which must satisfied the requirement of MORTH specification and relevant IS codes. Subsequently this determination of physical properties the Marshall Stability test for the determination of OBC as well as optimum temperature and optimum doses of the Rediset for making the BC is carried out. At last the testing for certain engineering properties of controlled along with warm mix using binder of VG-30 can be carried out for checking the specification.

5.1. Aggregate testing

Aggregates used in this study of designing the BC is crushed aggregate collected from the quarry. Before using the aggregate in design of bituminous mix it has been tested for their physical properties consist of Hardness, Toughness, Cleanliness, Particle shape, Water absorption, Stripping etc. These test should be performed as per procedure revealed in the applicable IS codes. The tests performed on the aggregate in the laboratory are as follows:

- Grain size analysis, IS: 2386 (Part 1)-1963
- Impact value test, IS: 2386 (Part 4)-1963
- Shape test, IS: 2386 (Part 1)-1963
- Abrasion test IS: 2386 (Part 4)-1963
- Water absorption and Specific Gravity test, IS: 2386 (Part 3)-1963

5.2 Bitumen tests

Bitumen used in the warm as well as control design of BC is VG-30. Bitumen is used to bind the material together. Before use of bitumen in design mix it has been tested for their physical properties. All these test should be performed as per procedure in relevant IS codes. The tests to be performed are enlisted as follows:

- Penetration test, IS: 1203-1978
- Softening Point test, IS: 1205-1978
- Ductility test, IS: 1208-1978
- Viscosity test, IS: 1206-1978
- Specific Gravity test, IS: 1202-1978

5.3 Marshall stability test

The Marshall Stability and flow test provides the performance and prediction measure for the Marshall mix design method. The stability portion of the test measures the maximum load supported by the test specimen at a loading rate of 50.8 mm/minute. Load is applied to the specimen till failure, and the maximum load is designed as stability. During the loading, an attached dial gauge measures the specimen's plastic flow (deformation) due to loading. The flow value is recorded in 0.25mm (0.01 inch) increments at the same time when the maximum load is recorded. The properties incorporated with the test are stability, flow value, bulk specific gravity, air voids, voids filled with bitumen, voids in mineral aggregates. The marshall test also gives the final blend of the materials to be used. The Marshall Stability Test gives the following:

- Optimum Binder Content
- Optimum Dose of Rediset-WMX
- Optimum Temperature

Low energy asphalt Low energy asphalt (LEA) WMA technology is developed by LEA-CO and distributed in the USA by McConnaughay Technologies. Furthermore, it uses wet fine aggregate and is essentially based on foaming process. A key to energy savings in this process is that it takes five times more energy to turn water into steam than it takes to heat aggregate from 0 to 1008C. Furthermore, the coarse aggregate and a portion of fine aggregates are heated to normal HMA temperatures (approximately 1508C) and are then blended with the binder which contains coating and adhesion agents. After being coated with the binder, the coarse aggregate will be combined with the cold wet fine aggregate. Therefore, foaming action will be resulted which facilitates the fine aggregate coating (D'Angelo et al. 2008, Bueche 2009, Perkins 2009). This method reduces the production temperatures to about 908C. In this process, similar to the WAM-Foam method, coating and adhesion additives are introduced to enhance the performance of the mix. A separate cold feed bin is required for adding the cold wet fine aggregates in the case of batch plants. However, these aggregates are added to the middle of the drum, similar to RAP, in the case of drum plants. Basically, in contrast to other WMA technologies, the LEA method requires major plant modifications (D'Angelo et al. 2008, Bueche 2009, Middleton and Forfylow 2009). The low emission asphalt is similar to LEA and is a combination of both chemical and foaming method. In the first stage, the binder is modified with certain modifiers and then is introduced to the heated aggregates. In the second stage, the wet fine aggregates are added and foam is produced. This method was introduced in 2007 by McConnaughay (Hamzah et al. 2010b).

6. SUMMARY AND CONCLUSIONS

WMA technology is a newer technology which enables us to prepare a bituminous mix at significantly lower temperature than HMA technology by adding certain external agents. This technology helps to reduce the emissions of greenhouse gases by 20-30%. It has significant effect on Bituminous mix characteristics for example Stability, density ITS, TSR, resilient modulus, fatigue behavior etc.

The emissions reduction is an important advantage but how beneficial it really is in practice for asphalt producers and buyers is entirely reliant on environmental consciousness and guidelines in each country. Within each country, reduced emissions are especially advantageous for paving projects in heavily inhabited areas and for non-open air paving.

This technology also helps to reduce the environment degradation by emission of toxic gases and fume generation. In the hot mix plant the fumes has been observed while mixing the aggregate and bitumen mixture together while using warm mix asphalt there is no such fumes has been observed.

7. REFERENCES

[1]. IS: 2386 (Part 1)-1963: Grain size analysis, Shape test
[2]. IS: 2386 (Part 4)-1963: Impact value test, Abrasion test
[3]. IS: 2386 (Part 3)-1963: Water absorption and Specific Gravity test
[4]. IS: 1203-1978: Penetration test
[5]. IS: 1205-1978: Softening Point test
[6]. IS: 1208-1978: Ductility test
[7]. IS: 1206-1978: Viscosity test
[8]. IS: 1202-1978: Specific Gravity test

[9]. IS: 73-2013: Paving Bitumen- Specification
[10]. MORTH section- 500 clause 509: Design of bituminous concrete
[11]. Khanna S.K. and Justo C.E.G. (2001), "*Highway Engineering*", Nem Chand and Bros, Rookie, pp315-321.
[12]. *Warm mix Asphalt Technologies: An Overview*, Journal of Indian Roads Congress, Vol. -2 (2010).
[13]. *The asphalt hand book*, MS-04
[14]. Dr. Sunil Bose, Mrs. Ambika Behl, Mr. M.N.Nagabhushna, Mr. Gajendra Kumar, Mr. Girish Sharma, Mrs. R. Uma Devi- *Laboratory Evaluation of Evotherm Additive in Warm Mixes (2011).*
[15]. Ramizraja Munshi, *"Mechanistic evaluation on warm mix design of bituminous mixes using modified binders"* SVNIT Surat.
[16]. Hurley, G.C. and Prowell, B.D. Evaluation of Aspha min for use in Warm Mix Asphalt. Auburn, Alabama: *National Center for Asphalt Technology, 2005. NCAT Report 05-04*.
[17]. Hurley, G.C., and Prowell, B.D., (2006), *"Evaluation of Potential Process for use in Warm Mix Asphalt", Journal of the Association of Asphalt Paving Technologist, Volume 75, pp 41 – 90.*
[18]. Prowell, B.D., Hurley, G.C. and Crews, E. *Field Performance of Warm Mix Asphalt at the NCAT Test Track. Washington D.C.: Transportation Research Board, 2007.*