A REVIEW ON WARM AND HOT BITUMINOUS MIXES

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Abstract: Warm Mix Asphalt (WMA) innovation is one of the arrangements which join vitality investment funds and ecological advantages. It is a modification of the conventional method of construction of flexible pavements which is surfaced with Hot Mix Asphalt (HMA), which involves high mixing temperatures up to 1400C. In other hand, a bituminous mix essentially consists of coarse aggregates, fine aggregates, filler and bitumen which bind together all the constituents at high temperature. It is used in flexible pavements. The ease of construction, adequate strength, workability, durability and cost- effectiveness of flexible pavement is the reason it is so extensively used in road construction. In this work, comparison made between the Warm mix and bituminous mix technology.

***IndexTerms* - WMA, HMA, WM.**

1. INTRODUCTION

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1.2 Bituminous Mixes

A bituminous mix essentially consists of coarse aggregates, fine aggregates, filler and bitumen which binds together all the constituents at high temperature. It is used inflexible pavements. The ease of construction, adequate strength, workability, durability and cost- effectiveness of flexible pavement is the reason it is so extensively used in road construction. The design of flexible pavement is two folded, i.e.- calculating thickness required and mix design. The mix design consists of balancing the proportions of various constituents, achieving the desired requirements according to the type of pavement. The performance in service life of the mix is estimated by various laboratory tests. The work of an engineer is to make a precise design which may save considerable investments, give reliable performance and at the same time be environment friendly.

1.2.1 Constituents of bituminous mix

Coarse aggregates: Granular materials like crushed stones, gravels or sand may be used. They make up almost 90-95% part of the mix. They provide compressive strength and shear strength to the pavement and also show good interlocking properties.
Fine aggregates: Crushed gravels, crusher dust or fine sand (smaller than 2.36mm) are used. They are used to fill up the voids in coarse aggregates and also to stiffen the binder. Filler: Stone dust, cement, lime or fly ash can be used. They are used to fill the voids resulting in higher density, stability and toughness. Binder: Bitumen/Asphalt is used as a binder. It is a black viscous liquid or semi-solid obtained as a residue of petroleum distillation. It causes particle adhesion and binds together all the constituents.
Reclaimed Asphalt Pavement (RAP): Removed pavement materials from an existing pavement (for the purpose of reconstruction or resurfacing) can be processed and used in new pavement construction. It contains asphalt and asphalt coated aggregates, which otherwise is a waste. Recycling helps in achieving financial, as well as environmental benefits.

1.2.2 Layers in bituminous roads

A bituminous road is typically formed in a number of layers, each layer having its own functions and accordingly its composition is designed. The load is transferred from top layer to the bottom by grain to grain mechanism and then finally distributed on earth. Each layer demands different properties and hence the type of bituminous mix for that layer is carefully chosen.
The following figure shows the hierarchical structure of flexible pavement.

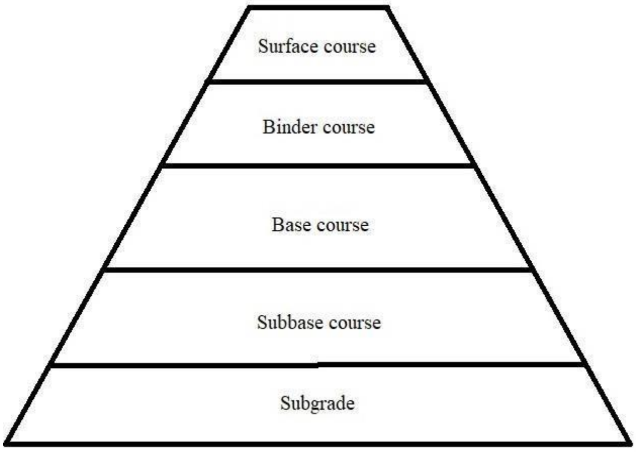

Figure 1.1 Layers of Bituminous Pavement

1.2.1 Surface course:

It is the topmost layer of the pavement, which is visible to the traffic. It directly takes up the vehicular load and transfer it to the layers below. It is responsible to provide smooth riding surface to the vehicles. Surface course must be composed of quality materials to resist distortion under traffic load and also ensure that there is no entry of water. Generally, dense graded bituminous concrete is used in this layer.

1.2.2 Binder course:

Its main purpose is to distribute load to the base course. It can be treated as a part of surface course only, but with less bitumen content and less quality materials, for a more economical design.

1.2.3 Base course:

It further distributes the load from layer above to the sub base and adds to sub-surface drainage.

1.2.4 Sub-base course:

Primary functions are to provide structural support, improve drainage and to reduce the intrusion of fine aggregates from below sub grade.

1.2.5 Subgrade:

It is a layer of natural soil, prepared to receive load from above and disperse it safely. Generally, it is made by compaction of naturally occurring soil to desired thickness.

1.3 Warm mix asphalt

The idea of warm mix was first presented in Europe in late 1990‟s with the expansion in ecological mindfulness. The primary target of this innovation is to lessen the destructive outflows shaped by traditional hot mix. WMA is created at temperatures 20 to 50oC lower than HMA. Holding same quality, toughness and execution at diminished temperature is accomplished by including certain added substances, emulsions or by changing the philosophy of generation. In future, warm mix innovation would adequately replacehot mix innovation, because of disturbing natural consumption occurring at present. As the innovation is new and creating, consistent research is going on the determination and appropriateness of the added substances utilized. As indicated by the innovation or added substance utilized, WMA can be grouped into four classifications, as talked about underneath.

2. RELATIED WORK

Graham C. Hurley *et al* **,** assessed the use of Evotherm® as an additive in WMA. The author concluded that there is an improvement in compaction using Evotherm® at temperature as low as 88^{O}C. The optimum binder content may be reduced as there is a reduction in air voids upto 1.4%. No direct influence on resilient modulus and rutting potential was observed. But there was an overall increase in rutting potential at lower temperature, may be due to decreased aging of binder. Care should be taken for susceptibility of moisture damage due to low production temperature.

Animesh Das , gave a brief overview about the warm mix technology. The production temperature ranges from 100 to 140^{O}C. The author discussed comparison and advantages of WMA over HMA. Simple modifications of hot mix asphalt plant can tackle WMA production and provide a mix which is environmental friendly and consumes less energy.

Graham C. Hurley *et al* **,** conducted a laboratory study to determine applicability of Aspha-min®, Sasobit® and Evotherm® as additives in WMA. There was an overall reduction in air void content in all three mixes, which suggests a lower binder content may be adopted. A reduction of 0.77% of air voids was noted in mix using Aspha-min®, 0.89% in Sasobit® and 1.53% in Evotherm® at temperature as low as 88^{O}C. There was no effect on the resilient modulus and rutting potential. There was no difference in strength gain with time as compared with HMA, suggesting no extra time for curing is required. ITS value for mix containing Sasobit® was lower than control mix, which may be due to anti-aging properties of Sasobit®. Overall, all three additives appear to be suitable for use in WMA. Extra care for moisture susceptibility must be taken due to lower production temperature.

Nishant Mukeshkumar Sheth , evaluated fundamental characteristics of WMA mixtures with four types of additives, Cecabase®, Aspha-min®, Advera and Kumho. Parameters used for comparison were tensile strength, moisture susceptibility, flow number and dynamic modulus. All WMA mixtures show similar compaction but lower tensile strength as compared to HMA. Dynamic modulus of only Cecabase® was found to be more than HMA. Resistance to permanent deformations was observed maximum in mix prepared using Aspha-min®, followed by HMA mix, whereas Cecabase® and Advera failed repeated loading test.

Feipeng Xiao *et al* **,**investigated moisture susceptibility of mixes made using anti- stripping additives (ASA) and warm mix additives. The study compared properties of mixes produced by using PG 64-22 binder with three different types of ASA additives (hydrated lime and two liquid type), virgin WMA and two WMA additives (Aspha-min® and Sasobit®) and using three aggregates from three different sources.. Use of hydrated lime exhibit best moisture resistance. Use of WMA additives gave lesser indirect tensile strength than mix without additives. Liquid ASA offered more ITS value but at the cost of lower moisture resistance.

Feipeng Xiao *et al***,** investigated moisture susceptibility and rutting resistance of WMA prepared using foaming technology. Comparison was made between various mixes prepared with different moisture contents, with and without anti-stripping additives and moist aggregates from different sources. Gyration number increased with increase in foaming water content. Rut depths reduced in HMA, it also depends majorly on source of aggregates. Increase in ITS value was noticed, regardless of foaming water content, ASA or aggregate moisture content. Liquid ASA has no effect on rutting resistance. The author concluded that binders containing 2% water content is suitable.

Gui-juan Zhao *et al* **,**evaluated the workability of Sasobit® mixed WMA by workability testing instrument. The results showed that it gave same workability at 145^{O}C as HMA gave at 175^{O}C. When using workability testing instrument, workability was influenced by the mixing frequency, best workability appeared at 30Hz.

Rosolino Vaiana *et al* **,**evaluated the workability of laboratory prepared WMA with addition of synthetic zeolite by water-containing methodology. Considering the reaction time required for proper foaming, three types of mixes were prepared and compared, HMA at 130^{O}C, WMA at 90^{O}C compacted immediately after preparation and same mixes compacted at 1-2 hours after preparation. After 1 hour of storage, the air voids of WMA reduced more than HMA at 150^{O}C. The ITS value of both mixes were close enough, which may be due to better compaction. Further research needs to be done on the type of compaction as it significantly affects the results.

Prasanta Kumar Patra , evaluated suitability of bitumen emulsion (cationic medium setting type) as an additive in WMA for use in stone mix asphalt and dense bituminous macadam. Optimum binder content by Marshall test came out to be 5.93% for SMA and 5.33% for DBM. Overall, properties improved by using emulsion. Flow value increases with increase in bitumen content whereas air voids decreases.

Shu Wei Goh *et al* **,** evaluated performance of WMA prepared using different percentages of Cecabase® RT. The author compared mixes at 0.2%, 0.35% and 0.5% Cecabase® RT at temperatures 100°C, 115°C and 130°C. The aging factor of WMA was significantly lower than control HMA. Dynamic modulus, fatigue life, tensile strength ratio were not noticeably affected by the production temperature and the amount of additive used. Rutting potential increased with the increased additive content and the reduction in production temperature.

Rajan Choudhary *et al* **,** focused on the need for adopting WMA in India over conventional HMA. There is a decrease of temperature of about 30-40^{O}C in production of WMA. Other environmental and economic benefits were briefly discussed by the author. Significant amount of research on the additives and methodology used in warm mixes is required to extract its many benefits for use on Indian roads.

Monu *et al* **,** discussed the advantages of WMA. There is 20-30^{O}C decrease in temperature and 20-30% reduction in emission of greenhouse gases using thistechnology. Different techniques and types of additives used to produce WMA have been briefly discussed by the author, namely organic additives, chemical additives and foaming techniques. Using certain bitumen modifiers, properties such as stability, density, indirect tensile strength, tensile strength ratio, resilient modulus, binder aging, and moisture resistance can be improved.

Monu *et al* **,** studied properties of WMA prepared by using zeolite as additive. Comparison was made between Marshall samples of HMA and WMA at four different binder contents using 1% zeolite content in WMA. A total of 48 samples were prepared. It was found out that optimum binder content in HMA is 5.75% and there is no change in optimum binder content in warm mixes, there is an increase in Marshall Stability Value and Flow value in WMA mixes, whereas the density is decreased.

Muhammad Rafiq Kakar *et al* **,** analyzed adhesive failure susceptibility of WMA using imaging technology. The specimens were fractured using direct and indirect tensile strength (ITS) tests and stripping of bitumen over the aggregate surface was examined. Mix with PG-76 binder showed more resistance against stripping as compared to PG-64 binder. Most of the failure was concentrated at the portions where the load was applied.

3. CONCLUSION

Most of the additives studied are patents of companies abroad. Extensive research and development is needed in this field so that technology becomes viable in India. The temperature of production can be reduced to as low as 88^{O}C. Addition of any type of additive lowers the air voids of mix. No direct effect on resilient modulus or rutting potential, but lower production temperature, in general increases the rutting potential, due to decrease in binder aging.There is a slight decrease in ITS value in all WMA mixes. Aspha-min® and Advera showed greatest decrease in ITS value. In every type of WMA, due to reduction in temperature, asphalt may be susceptible to stripping action and moisture failure. Care should be taken for the water. Suitability and modification of bitumen, for use in WMA has not been studied specifically. No specific study for the optimum content of additive used with respect to various grades of bitumen is done. Very less study for variation in aggregates, its shape, size, moisture content for suitability for WMA has been done. Little work on reduction of binder content to compensate for the addition of warm mix additives is done. WMA technology enables reduction in temperatures by 30-50^{o}C. Study for the solution for moisture susceptibility, especially when temperature goes far below boiling temperature of water needs to be done. Little work has been done for the suitability and content of anti-stripping additives along with the addition of warm mix additives.

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