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Warm mix asphalt: Paves way for energy saving

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Abstract
Road transport sector in India has expanded in the last sixty years after independence, both in terms of capacity and dimensions. Today, India is having thethird largest road network in the world, with over 4.236 million km of roadways spread across the country. Currently, majority of the Indian roads are paved with Hot Mix Asphalt (HMA),which consists of aggregates and bitumen mixed together at high temperature,approximately150-170°C. The production and placement of HMA pavements has evolved over the last 130 years and recognised as a high quality engineered paving material to produce good quality pavement. During all these years, the production of HMA has modernized from manual hand mixing and placement with rakes and shovels to computerized plants feeding, placement, and compaction equipment that track location and material quality.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. 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 benefits. Warm Mix Asphalt (WMA) technology is one of the solutions. WMA technologies allow producing the asphalt material at 30 to 40°C lower temperatures than conventional HMA. This paper presents a comprehensive literature review on various WMA technologies across the globe and advantages associated with WMA technologies.It also provides details of some of the attempts done with WMA technologies in India till now.

Keywords: Warm mix asphalt, Technology, HMA

INTRODUCTION

Construction sector is considered as one of the major sourcefor economic growth and development of a country. In India, after agriculture, construction sector forms the second largest economic activity which includes roadways, railways, water transport, ports, urban infrastructure etc. Out of them, roadconstruction is a predominant segment which plays an important role in the growth of country'seconomy.

Currently majority of the Indian roads are flexible pavements, which are surfacedwith Hot Mix Asphalt (HMA).HMA has evolved over the last 130 years and is recognised as a high quality engineered paving material. During all these years, the production and placement of HMA has modernized from manual hand mixing and placement with rakes and shovels to computerized plants feeding systems to maintain higher quality control, high precision pavers and compaction rollers which will track location and material quality for the placement and compaction respectively.

HMA is produced from a combination of well graded aggregates and bitumen mixed together at high temperature, approximately 150°C to 170°C. HMA is produced either by a batch mix plant or drum mix plant, through a sequential procedure like drying of aggregate, heating of bitumen, mixing of aggregate and bitumen, and finally the storage in silos. The main concern with the production of HMA is that it requires large amount of energy along with release ofgases into the environment. Production of one lakh tons of HMAin a year using batch mix plantrequires about 6.5 to 7.5 lakh liters of fuel and releases about 20 tons of carbon monoxide (CO), 0.7 tons of volatile organic compounds (VOC), 0.3 tons of sulfur oxides, 1.3 tons of nitrogen oxides and about 0.45 tons of total hazardous air pollutants into the atmosphere(USEPA Report, 2000).

Stringent environmental regulations and present need to reduce emissions, creates a need in the asphalt industry to look 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 benefits.Warm Mix Asphalt (WMA) technology is one of the solutions.WMArefers to technologies which allow a significant reduction of mixing and compaction temperature of asphalt mixes, through the lowering ofthe viscosity of asphalt binders (Lee *et al*., 2009). WMA is a modified HMA mixture that is produced, placed and compacted at a 10–40°C lower temperature than the conventional HMA mixture (Xiao *et al*., 2013).

Warm mix asphalt

Warm asphalt mixes are prepared over a wide range of temperatures. With the help of different WMA technologies. One way of classification of warm mixes is on the basis of the degree of temperature reduction. Mixes are divided into two groups: warm mixes and half warm mixes. If the production temperatures of the mixes are above boiling point of water andabout 10 to 20°C lower than the conventional HMA temperatures, then these mixes are known as warm mixes. Half warm mixes are the one which are prepared and laid at temperatures of 65-100°C (D'Angelo *et al.,*

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2008). Generalclassification on the basis of production temperaturesis as under(Zaumanis, 2010).

- Cold mixes (0-30°C);
- Half warm asphalt (65-100°C);
- Warm mix asphalt (100-140°C);
- Hot mix asphalt (above 140°C).

Warm mixes are further classified on the basis of technology or additive used for reducing the production temperatures into four major categories

1. Use of Foaming Technology
2. Use of Organic Additives
3. Use of Chemical Additives
4. Use of Hybrid Technology

Foaming Technology

In foaming technology, small amount of water is injected into the hot binder or directly into the mixing chamber(Larsen, 2001).Due to addition of water to hot binder, water evaporatesand gets encapsulated in the bitumen. This produces the foaming action that increases the volume of binder and condensesthe thickness of the binder,ensuing improved coating and workability of the mix at lower temperatures. It is important that the mix is prepared and compacted soon after the preparation of foamed binder, as foaming action is temporary in nature. Additional care need to be taken while adding water into the mixing chamber or hot binder, as excess amount of water may lead to the stripping problems.On the basis of the manner in which water is added (Zaumanis, 2010), foaming process are further divided into water-based (direct method) technologies and water-containing (indirect method) additives.

Water-Based Technologies

In water based technologies, water is injected directly into the hot binder through special nozzles. Injected waterevaporates rapidly and produces large amount of foamed binder which slowly collapses (Zaumanis, 2010). This category can been further sub-divided on the basis of types of products used to make the mix (Rubio *et al*., 2012). In one case, water is directly injected into the hot binder using different equipment's which creates foaming action (eg: Double Barrel Green, Ultrafoam GX, and Aquablack WMA). Whereas in the second case,a softer binder is first mixed with the aggregate and then a foamed binder which is produced by injecting the cold water into hard binder is added into the mix (eg: WAM foam).

Water-Containing Additive

Water-containing or Water-bearing additives are finely powdered artificial zeolites that are hydro-thermally crystallized and contain about 21% of water by mass. Water is released from the crystalline structure at temperatures above 85°C(Zaumanis, 2010). Zeolites have a porous structure that can accommodate, absorband lose the water without damaging the crystalline structure. Aspha-Min and Advera are some of the examples of water containing or water bearing additives. Details of few foaming technologies used along with the respective production temperature are given in Table 1.

Table 1. Dosage and Production Temperatures in Foaming Technologies

Product	Company	Description	Dosage of additive	ProductionTemperature
Double Barrel Green	Astec	Water-based	2% of water by mass of bitumen	116-135°C
Ultrafoam GX	Gencor Industries	Water-based foaming process	1-2% water by mass of bitumen	Not specified
LT Asphalt	Nyas	Foaming of bitumen with hydrophilic additive	0.5-1% by mass of bitumen	≈ 90°C
WAM-Foam	Shell &Kolo-Veidekke	Soft binder coating followed by foamed hard binder	2-5% water by mass of hard binder	100-120°C
LEAB	Royal Bam Group	Mixing of aggregates below water boiling point	0.1% of bitumen weight of coating & adhesion additive	≈ 90°C
Aspha-Min	Eurovia	Water-containing	0.3% by total weight of mix	20-30°C lower than HMA
Advera	PQ Corporation	Water-containing	0.2% by total weight of mix	10-30°C lower than HMA

Use of Organic Additives

Organic additives used for producing WMA have high molecular weight hydrocarbon chains with a melting point of 80-120°C. When these additives are added to binder, reduction in viscosity of the binder is observed beyond melting point temperatures of these additives. As it cools down below the melting point, these additives solidify into microscopically small and uniformly distributedparticles, which increase the stiffness of the binder in the same way as fiber-reinforced materials (Rubio *et al*., 2012).While selecting the organic additives, it has to be ensured that the melting point of the additives is higher than the pavement service temperature. This process was developed in 1980's and has given rise to three technologies which differ by the type of wax used; Sasobit®, AsphaltanB and Licomont BS 100.

Use of Chemical Additives

Chemical additives are relatively new and emerging group of warm mix additives.These products do not work on foaming or reduction of viscosity for lowering production and placing temperatures (Rubio *et al*., 2012). Chemical additives helps to reduce the frictional forces at the microscopic interface ofthe aggregates and bitumen (EAPA, 2010). They usually include a combination of emulsification agents, surfactants, polymers and additives to improve coating,mix workability, and ease of compaction. Evotherm®, CecabaseRT®andRediset WMX are few examples of chemical additives used for production of WMA.

Use of Hybrid Technology

It is a combination of two or more WMA technologies, developed by the producers to address some weaknesses in technologies; using a chemical additive with water injection system. This helps to improve the coating at lower temperatures. Low Energy Asphalt is one of the marketed products under this head.

Advantages of wma mixes

WMA offers many advantages over conventional HMA. The specific benefits and the degree of the benefits depend upon the WMA process used. Some of the commonadvantages associated with the use of WMA are:(Xiao *et al*., 2012; Xiao *et al*., 2013; You and Goh, 2008, Khandhal, 2010).

i. **Energy savings:** One most important benefit of WMA is the reduction in the fuel consumption, is used for drying and heating of aggregates and bitumen. Energy savings associated with WMA ranges from 20 to 30% (You and Goh, 2008;Khandhal, 2010).

ii. **Decreased emissions:** Use of WMA lowers the visible and non-visible emissions by 20 to 30% (You and Goh, 2008). This would permit the asphalt plants in and around non-attainment areas that have air quality restrictions(Khandhal, 2010).

iii. **Decreased fumes and odour:**Reduction in production temperatures provides smart working conditions behind the paver which allows the workers to inhale far less smoke and dust at construction site.WMA mixes give better paving conditions inside the tunnels where ventilation is less.

iv. **Extended paving season:** By producing WMA at normal HMA temperatures, it is possible to extend the paving season into the colder months of the year since the WMA additives or processes act as a compaction aid.

v. **Longer haul distance:** As the difference between production and ambient temperature is smaller for warm mixes compared to HMA, the rate of drop in temperature is less for WMA with time, allowing a longer time for paving and compaction.

vi. **Less binder ageing:** Lesser binder ageing takes place due to lower production temperatures of WMA.This will help to get long lasting pavements andwill also help to reduce the need for maintenance, thereby cutting downthe cost and wastage of energy.

vii. **Use of Higher Percentage of Reclaimed Asphalt Pavement (RAP) in Asphalt Recycling:**Studies (Mallick *et al*., 2008; Doh *et al*., 2010)haveshown that WMA additives, acts as a rejuvenators and helps to increasethe percentage of RAP used during recycling of pavements. The increased use of RAP increases the savings to contractors, and thus will lead to sustainable pavements by cutting down the natural resources requirements of bitumen and virgin aggregates.

Evaluation ofwma technologies in India

WMA technologies gained popularity in European countries and USA by tasting the benefits of it. But in India,WMA is a relatively new technique. Limited studies and field trials are available in India with different WMA technologies. Behl *et al*. (2011) studied the moisture susceptibility and rutting characteristics of warm mixes with a chemical additive using VG 30 grade binder and quartzite aggregates. Bituminous Concrete (BC) mixes were prepared at standard temperature (155 to 160°C) and at four different temperature ranges (95 to 100°C, 105 to 110°C, 115 to 120°C and 125 to 130°C). Retained Stability of warm mixes produced below 125°C was observed to be lower than that of the control mixes. Warm mixes prepared at 120°C showed better resistance towards rutting than control mixes (relative rutting life of warm mix produced at 120°C was 1.6 times more than the conventional hot mixes).A WMA field trail stretch of length 500m was constructed at Bawana industrial area in Delhi(Behl *et al*., 2011). Ingredients viz. CRMB 60, and 0.6% chemical additive was used for the construction. Conventional CRMB-60 mix was produced, laid and compacted at 160°C, 150°C and 130°C respectively. Whereas WMA with CRMB-60 produced at 125°C, laid at 113°C and compacted at 100°C. With warm mix very less amount of fumes and odours was observed compared to control mix. The performance of the trail stretch was under evaluation.

Kakade *et al*. (2011) developed a foaming chemical additive which can be used to produce Warm Mix Asphalt (WMA) and Half Warm Mix Asphalt (HWA). WMA mixes were prepared by using chemical foaming agent at a rate of 6%, 8%, and 10% whereas, HWAwas prepared by adding 6% of water along with the chemical agent. WMAshowed a greater resistance toward moisture susceptibility than HMA mixes. Energy savings estimated with WMA and HWA were 13.5% and 52.5% respectively.Effect of mixing and compaction temperatures on the volumetric properties of warm mixes with Sasobit® were studied with two modified binders (Choudhary and Julaganti, 2013) Polymer Modified Bitumen and Crumb Rubber Modified Bitumen were used to prepare warm mixes with Sasobit® (an organic additive). Warm mixes produced and compacted at four loweredtemperatures 0°C, 20°C, 30°C, and 40°C. Warm mixes produced at same temperatures of control mixes,showed higher density and Marshall Stability values. Warm mixes m*et al*l the mix design requirements after lowering the production temperatures by about 30°C.

CONCLUSIONS AND RECOMMENDATIONS

WMA technology is an environment friendly technology that allows a reduction in mixing and compaction temperature of asphalt mixes either through lowering of viscosity of asphaltbinders or by increasing the workability at lower temperatures without compromising the quality or properties of the mix. It also offers many other advantages like cost savings, energy savings, cutting of natural resources requirement, etc. Since the start of developing WMA technologies, a lot of research studies have been carried out at laboratory and field scale to identify the potential benefits of using WMA in Europeancountries, and USA. Many manufacturers and researchers are continuouslylooking into development of new additives and technologies which gives more enhanced performance.

India has a limited level of experience in WMA. The need of today is to evaluate and analyzethis technology in order to extract the various benefits associated with it.Some trail stretches arealso constructed using WMA in India and also some WMA technologies or WMA additives are accredited by IRC for trials in India.Considering the research and exploration of WMA in India, the technology is still in its infancy stages. In order to adoptWMA on

Indian roads, significant amount of efforts will berequired in terms of studies, research and proper implementation.

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