IRC:SP:101-2019

GUIDELINES FOR WARM MIX ASPHALT

INDIAN ROADS CONGRESS
2019

GUIDELINES FOR WARM MIX ASPHALT

Published by:

INDIAN ROADS CONGRESS

Kama Koti Marg,
Sector-6, R.K. Puram,
New Delhi-110 022

DECEMBER, 2019

Price : ₹ 400/-
(Plus Packing & Postage)

First Published : August, 2014
First Revision : December, 2019

Printed at India Offset Press, Delhi - 110 064
1100 Copies

CONTENTS

PERSONNEL OF THE HIGHWAYS SPECIFICATIONS AND STANDARDS COMMITTEE

(As on 20.07.2019)

1	Pandey, I.K. (Convenor)	Director General (Road Development) & Special Secretary to Govt. of India, Ministry of Road Transport and Highways, New Delhi
2	Balakrishna, Y. (Co-Convenor)	Additional Director General, Ministry of Road Transport and Highways, New Delhi
3	Kumar, Sanjeev (Member Secretary)	Chief Engineer (R) S, R & T, Ministry of Road Transport and Highways, New Delhi

Members

4	Behera, Bijan Kumar	Engineer-in-Chief (Civil) (Retd.), Odisha
5	Bose, Dr. Sunil	Head (Retd.), FPC Division, Central Road Research Institute, New Delhi
6	Chandra, Dr. Satish	Director, Central Road Research Institute, New Delhi
7	Gupta, D.P.	DG(RD) & AS (Retd.), Ministry of Surface Transport, New Delhi
8	Jain, R.K.	Chief Engineer (Retd.), PWD Haryana
9	Kapila, K.K.	Chairman & Managing Director, ICT Pvt. Ltd., New Delhi
10	Kukrety, B.P.	Associate Director, CEG Ltd., New Delhi
11	Kumar, Dr. Mahesh	Engineer-in-Chief (Retd.), PWD (B&R) Haryana
12	Lal, Chaman	Engineer-in-Chief (Retd.), PWD Haryana
13	Meena, H.L.	Secretary (Retd.), PWD Rajasthan
14	Nashikkar, J.T.	Secretary (Retd.), PWD Maharashtra
15	Nirmal, S.K.	Secretary General, Indian Roads Congress, New Delhi
16	Parida, Prof. (Dr.) M.	Deputy Director, Indian Institute of Technology, Roorkee
17	Patel, S.I.	Secretary (Retd.), PWD (Roads and Buildings) Gujarat
18	Prasad, R. Jai	Engineer-in-Chief (Retd.), PWD & Bangalore Mahanagar Palike, Karnataka
19	Rawat, M.S.	Executive Director, AECOM India Pvt. Ltd.
20	Reddy, Dr. K.S. Krishna	Secretary, Public Works, Ports & Inland Water Transport Department, Karnataka
21	Reddy, I.G.	Engineer-in-Chief (NH, CRF & Buildings), PWD Hyderabad
22	Reddy, Prof. (Dr.) K.S.	Professor, Indian Institute of Technology, Kharagpur
23	Sharma, S.C.	DG(RD) & AS (Retd.), Ministry of Road Transport and Highways, New Delhi
24	Shrivastava, A.K.	Additional Director General (Retd.), Ministry of Road Transport and Highways, New Delhi
25	Singh, Nirmaljit	DG(RD) & SS (Retd.), Ministry of Road Transport and Highways, New Delhi
26	Sinha, A.V.	DG(RD) & SS (Retd.), Ministry of Road Transport and Highways, New Delhi

27	The Chief Engineer (Basar, Toli)	PWD Arunachal Pradesh
28	The Addl. DGBR (North-West) (Kumar, Anil)	Border Roads Organisation, New Delhi
29	The Director (Tech.) (Pradhan, B.C.)	National Rural Infrastructure Development Agency, New Delhi
30	The General Manager (Projects) (Retd.) (Kaul, Satish)	National Highways and Infrastructure Development Corporation, New Delhi
31	The JICA Expert (Kitayama, Michiya)	Japan International Cooperation Agency, New Delhi
32	The Member (Projects) (Pandey, R.K.)	National Highways Authority of India, New Delhi
33	The Professor (Chakroborty, Dr. Partha)	Indian Institute of Technology, Kanpur
34	The Secretary (Vasava, S.B.)	Roads and Buildings Department, Gujarat
35	The Secretary (Roads) (Joshi, C.P.)	PWD Maharashtra
36	The Secretary (Tech.) (Tickoo, Bimal) (Retd.)	Roads and Buildings Department, Jammu & Kashmir
37	The Special Director General (Retd.) (Bansal, M.C.)	CPWD, Nirman Bhawan, New Delhi
38	Venkatesha, M.C.	Consultant
39	Wasson, Ashok	Member (Tech.) (Retd.), National Highways Authority of India, New Delhi

Corresponding Members

1	Jaigopal, R.K.	MD, Struct Geotech Research Laboratories (P) Ltd., Bengaluru
2	Justo, Prof. (Dr.) C.E.G.	Professor (Retd.), Emeritus (*Expired in June, 2019*)
3	Veeraragavan, Prof. (Dr.) A.	Professor, Indian Institute of Technology, Madras

Ex-Officio Members

1	President, Indian Roads Congress	(Basar, Toli), Chief Engineer, PWD Arunachal Pradesh
2	Director General (Road Development) & Special Secretary to Govt. of India	(Pandey, I.K.), Ministry of Road Transport and Highways, New Delhi
3	Secretary General, Indian Roads Congress	Nirmal, Sanjay Kumar

GUIDELINES FOR WARM MIX ASPHALT

1. INTRODUCTION

Warm Mix Asphalt technology has been in use in USA and a number of European countries for several years. A number of trials were also made in the recent past in India. This technology has inherent advantages in terms of reduction of greenhouse gas emissions and economy in construction (because of less fuel consumption in construction) as well as elimination of suspected health hazards to construction workers (according to some studies the fumes from hot bituminous mixes is a health hazard). Considering the importance and need of green technology, IRC published Interim Guidelines for Warm Mix Asphalt in the year 2014. This document presents the interim guidelines for the production and construction of Warm Mix Asphalt (WMA) pavement.

Subsequent to the adoption and usage of the warm mix technology in India, the feedback received on the interim guidelines from various stakeholders and also considering the advancement in materials and technology, IRC decided to revise this document. The task was assigned to Flexible Pavement, Airfield & Runways (H-2) Committee of IRC during the tenure 2018-20. The initial document was prepared by Dr. Sunil Bose, Dr. Ambika Behl and Dr. Sridhar Raju. The draft was deliberated in various meetings of H-2 Committee and was finalized in its meeting held on 8th June, 2019.

The composition of H-2 Committee is given below:

Reddy, Prof. (Dr.) K. Sudhakar	……..	Convenor
Nirmal, Sanjay Kumar	……..	Co-Convenor
Shukla, Manoj Kumar	……..	Member-Secretary

Members

Basu, S.B.	Lal, Chaman
Bongirwar, P.L.	Murthy, D.V. Sridhar
Bose, Dr. Sunil	Panda, Prof. (Dr.) Mahabir
Director (Tech.), NRIDA (Pradhan, B.C.)	Pandey, I.K.
Garg, Sanjay	Pandey, R.K.
Ghai, Inderjit	Rep. of DGBR (Das, Brig. A.K. VSM)
Jain, N.S.	Sharma, S.C.
Jain, R.K.	Singh, V.K.
Jha, Bidur Kant	Sinha, A.V.
Krishna, Prabhat	Sitaramanjaneyulu, K.
Kumar, Prof. (Dr.) Praveen	Tyagi, B.R.

Corresponding Members

Justo, Prof. (Dr.) C.E.G. (*Expired in June, 2019*)	Seehra, Dr. S.S.
Rao, Prof. (Dr.) S.K.	Veeraragavan, Prof. (Dr.) A.

Ex-Officio Members

President, Indian Roads Congress	(Basar, Toli), Chief Engineer, PWD Arunachal Pradesh
Director General (Road Development) & Special Secretary to Govt. of India	(Pandey, I.K.), Ministry of Road Transport & Highways
Secretary General, Indian Roads Congress	Nirmal, Sanjay Kumar

The draft document was placed before the Highways Specifications and Standards Committee (HSS) in its meeting held on 20.07.2019. The HSS Committee decided that Co-Convenor, H-2 Committee will modify the document based on written comments and verbal comments offered during the meeting and submit the final document to IRC for placing in the IRC Mid-Term Council meeting. The Mid-Term Council in its meeting held on 9th and 10th August, 2019 at Goa approved the document for publishing.

The guidelines would need to be further refined and amended in course of time with experience gained with widespread use of the technology.

2. SCOPE

2.1 The Guidelines Describe

i. A range of warm mix technologies, which have the potential for use in bituminous construction like Dense Bituminous Macadam (DBM), Bituminous Concrete (BC) meeting the quality and performance requirements of IRC:111 and Recycled Asphalt Pavements (RAP).

ii. The essential requirements of collaborative effort between the technology provider/ the product supplier on the one hand and the contracting agency on the other with a view to promoting the use of the warm mix technology.

2.2 Since the WMA technology uses a variety of patented products as additives, which come in different forms such as solid, liquid and powder and use different processes for administering the additives and mixing, these guidelines do not prescribe any specific product or process except in a generic manner at the level of technology.

2.3 The guidelines further recommend that the contracting authorities may accept any technology that claims to meet the requirements of these guidelines provided such a claim is (a) substantiated by laboratory and field tests, and (b) backed by a collaboration between the contracting agency and the product/technology provider in a manner that ensures joint and several responsibility.

3. OVERVIEW OF WMA TECHNOLOGY

3.1 The basic principle of this technology is that by adding certain additives at the final stages of the mix production, the coating of the aggregates by the binder is greatly enhanced and can be achieved at a considerably less temperature (typically 30^{0}C less) compared to the hot mix process wherein bitumen is heated to a sufficiently high temperature to make it fluid enough to surround the aggregates and coat their surfaces. In hot mix process, it is the viscosity of bitumen alone, which is less at higher temperature, that plays the main role in coating of aggregates. In warm mix technology, this can be achieved in three different ways, viz. by increasing the volume of bitumen, by making the bitumen less viscous, by reducing the surface tension at aggregate bitumen interface etc.

3.2 Currently there are more than 30 different WMA technologies, using patented processes and products, which have capabilities of bringing reduction in mixing, laydown and compaction temperatures of bituminous mixes in one of the three different ways described above. Although the end effect of reduction of mixing, laydown and compaction temperatures is the same, different technologies work in different ways. This specification covers the Warm Mix Bituminous technologies currently adopted globally, classifying them into four main categories.

Water Based Technologies

i. Foaming

In essence, the “water technologies” use fine water droplets to expand the volume of binder in the mix by causing it to foam. This has the effect of increasing the volume of the bitumen, enabling it to coat aggregate at lower temperatures. The foaming technology can be further sub-divided into two classes, foaming additives and water injection system. The foaming process works by creating foamed asphalt that improves coating and compaction at lower temperature. Water expands 1,600 times when converted into steam at atmospheric pressure, and the steam is encapsulated by viscous bitumen producing foam, which occupies a much greater volume compared to the original bitumen. The water for creating the foam is either added as water through a water injection stem in a specialized equipment, or from zeolites (which contain about 20% water). Water is added at a rate of 1.25 to 2.0% by weight of bitumen (about 500 ml of water per ton of mix), whereas the zeolites are added a rate of 0.1 to 0.3% by weight of the mix. Foaming by water allows 18ºC to 30ºC reduction in temperature whereas foaming by zeolites allows a reduction of 30ºC to 40ºC.

ii. Water Carrying Chemical Additives

Natural and synthetic zeolites are mineral additives used to introduce water into the mix thereby creating “in-situ” foaming within the bitumen.

Zeolites in general are added to the mix with the filler during mixing process. As the mixing temperature increases the zeolites slowly release their absorbed water into the bitumen, which is dispersed throughout the mixture in the form of very fine foam droplets. This causes an increase in the volume of the bitumen and leading to improvement in its ability to coat the aggregate.

iii. Wet Fine Aggregate Addition Systems

In this process the bituminous binder is added to the heated coarse aggregate in the mixer. Once the coarse aggregate are well coated, fine aggregate at ambient temperature with moisture content of around 3% is introduced. The moisture vaporizes, causing the binder coating the coarse aggregate to foam, which in turn encapsulates the fine aggregate.

Chemical Additives

WMA technologies utilize chemical additives that have little effect on rheological properties of the binder. These products may be supplied in pellet, powder or liquid form, and then mixed into the binder or directly added to the mix. Chemical additives are Surfactants (surface active agents) that reduce surface tension between the polar aggregates and non-polar bitumen, improve wetting and reduce internal friction, and allows a reduction of 28^0C-50^0C in mixing and compaction temperatures. Typically they are added at the rate of 0.20 to 0.75 percent by weight of bitumen.

Rheological Modifiers

The wax based products can be described as viscosity modifying organic additives that reduce binder viscosity at high temperatures and thus allow lower mixing and paving temperatures. The additives, which are either waxes or other hydrocarbon modifiers improve lubrication by reducing the viscosity of bitumen and allow a reduction of 28ºC to 40ºC in mixing and compaction temperatures. Typical dosage amounts are 2 to 4% by weight of bitumen. Sometimes these additives are also added as modifiers for increasing the stiffness of asphalt mixes, for specialty applications, such as in racing tracks.

Hybrid Technologies

Hybrid technologies utilize a combination of two or more WMA technologies to achieve the reduction in temperature. For example, Low Energy Asphalt (LEA) utilizes a chemical additive with a water injection system to improve coating at lower temperatures.

The additives come in different forms, such as liquid, powder, pellet and are administered in the mix production process at different stage. Accordingly, some modification in the bituminous mixing plants is necessary to administer the controlled dosage of the additives. Some additives in liquid form can be pre-blended with bitumen and would need no modification in the conventional mixing plant provided the blended bitumen contains the right dose of additive. Other additives, which are administered in the mix at certain stage during the mix production process, would require some modification in the conventional mixing plants. These modifications would generally require a separate material (additive) feed system and a material metering system (to ensure the right dosage) which should be integrated with computerized plant control system of the mixing plant. The water-based WMA technologies would additionally need a water injection system as well.

3.3 Apart from such plant modification as required to administer the additives (described above), some modifications are needed for recalibrating the fuel burner, aggregate drying system, bitumen heating system and to take care of the possible consequences of lower temperature operation, such as contamination of the mix by un-burnt fuel and trapped moisture, condensation of bag house fines, etc to operate the plant at reduced temperature compared to that adopted for the conventional hot mix production.

4. BENEFITS OF WARM MIX ASPHALT

(1) *Environmental Benefits:* The single most important justification for use of this technology is that it reduces the emission of green house gases by around 25 to 30% and controls thereby global warming. This would earn tradable carbon credit. Secondly, the technology is quite compatible with Reclaimed Asphalt Pavement technology, which reduces the requirement of fresh aggregates and reduces the environmental hazard associated with dumping of damaged pavement materials.

(2) *Health Benefits:* The fumes from Hot Mix Asphalt are known to be potential health hazards, especially for the construction workers. Reduced temperature of the mix avoids this health hazard.

(3) *Technical advantages:*

a. Lower mixing temperature reduces the oxidation and ageing of bitumen and thereby gives long lasting pavement by delaying fatigue cracking.

b. Much improved workability of the mix at lower temperatures gives better compactability and larger compaction window.

c. Reduced rate of cooling of the mix (due to low initial temperature of the mix) permits longer haul distance from the plant to work sites and better cold weather construction opportunities.

(4) *Cost benefits:* WMA is most likely to have long term cost advantages, though its estimation should be case specific. The cost advantage is a trade-off between the additional cost of using the additives and technologies (including plant modification) and cost savings achieved through reduced fuel consumption, longer life of pavement and use of recycled material.

5. CHOICE OF AN APPROPRIATE WMA TECHNOLOGY

In the Section dealing with ‘overview’, the principles behind various alternative technologies and different additives have been presented. They provide the general guideline for an appropriate choice of technology. Secondly, since the plants and equipment used for producing WMA mixes would remain essentially the same (at least till such time the technology proliferates and its use becomes widespread) as that for HMA mix, it would be necessary to ascertain the nature and feasibility of as well as commitment to these modifications/changes. Thirdly, the suppliers of the products to be used in works should be willing to take responsibility along with the main contractor not only for their products but for the entire technological solution.

All technologies and all commercial additives should be allowed to compete for acceptance on a work if the following conditions are satisfied:

- Technology and/or product suppliers provide evidence of :
  - (a) achieving the reduction of at least 30^0C in mixing and laying temperatures demonstrated based on some actual work done in the past. The evidence should be in the form of a certificate from the owner/owner's representative of the said work,
  - (b) additives proposed to be used not having any harmful effects on human health and environment. This evidence should be in the form of test certificates from reputed laboratory,
  - (c) complete understanding of the technological solution such as dosage of additives, the process of administering the additives in a controlled manner (weight, volume, pressure, temperature, etc.), adequacy of the plant and equipment proposed to be used on the work and if not, the modifications required, quality assurance in the process, etc. This evidence should be in the form of a written quality statement.
- The main contractor provides evidence of understanding of the technological requirement, including modifications in the plant and equipment and acceptance of these requirements. This evidence should be in the form of a written joint commitment statement.

The selection of the best WMA technology depends on many factors, and in most cases is dependent on the monetary incentives and benefits of using WMA. Important factors to consider include the reduction in temperature that is desired, the tonnage of mix that is anticipated and whether or not to invest in plant technology that are needed for certain additives. It should also be pointed out that the "green" benefits of adopting WMA technologies should not be overlooked, and that a reduction in emission through a reduction of temperature can help contractors/ agencies receive significant amount of "carbon credits."

6. DESIGN OF WMA MIXES

The quality and performance of the WMA mix shall be the same as specified for HMA in IRC:111 except for mixing and laying temperatures, which should be at least 30^0C less than those specified for HMA. The threshold of 30^0C is considered technologically feasible as well as desirable from the point of view of fuel savings of some significance.

Design of mix, quality of inputs (except the additives) and tests required to be performed shall follow the same procedures as specified in IRC:111. In addition, the following WMA specific tests shall also be performed:

- Coating
- Compactability
- Moisture Sensitivity

The viscosity-temperature plots shall not be used to find the mixing and compaction temperatures of warm asphalt mixes. Since not all WMA additives effect the viscosity of bitumen and mainly work on the bitumen-aggregate interface and improve the workability of the asphalt mix at lower temperatures. Volumetric properties should be used as the criteria for optimizing the mixing and compaction temperatures for warm mixes. The above parameters should be verified first in the laboratory and after the criteria are satisfied a field trial section of at least 500 m length shall be constructed, and the parameters obtained in the laboratory may be verified.

6.1 Aggregate Coating

- WMA samples shall be prepared as per AASHTO T195 (Refer **Annex 1**) at a temperature of at least 30°C lower than conventional hot-mix.
- The warm-mix shall be evaluated for coating as per AASHTO T195.
- Minimum 95% of the coarse aggregate particles shall be fully coated at a temperature of at least 30°C lower than conventional hot-mix.

6.2 Compactability

Since the mixing and compaction temperatures of the warm-mix samples are lowered by at least 30°C compared to the conventional hot-mix, it is important for the warm-mix samples to attain specified mix densities at adopted lower temperatures. In order to verify that the warm-mix samples attain sufficient density when prepared at temperatures which are at least 30^{o}C lower than those of conventional hot-mix:

- Three hot-mix specimens shall be prepared conforming to the JMF as per AASHTO T245 (also adopted in MORTH Section 500 Table 10). (Refer **Annex 1**)
- Similarly, three more warm-mix specimens shall be prepared conforming to the JMF. In all cases the JMF shall be made in the same procedure as per conventional mixes except at a temperature at least 30°C lower than the hot-mix samples as per AASHTO T245. The compactive effort should be similar for both mixes. In case there is a specific change required by an additive manufacturer to suit the JMF requirements the same shall be permitted except that the Specified Properties in the Guidelines shall have to be adhered to.
- The bulk specific gravity (G_{mb}) of all the specimens shall be determined as per AASHTO T166.
- The theoretical maximum specific gravity (G_{mm}) of the bituminous mixture of HMA and WMA shall be determined as per AASHTO T209.
- The air voids of both the mixes shall be determined as per the following equation:

$$V_a = \frac{G_{mm} - G_{mb}}{G_{mm}} \times 100$$

- The ratio of the air voids shall be as per the following equation:

$$R_{Va} = \frac{V_a \; of \; WMA}{V_a \; of \; HMA}$$

- The ratio shall be such that $0.9 < R_{Va} < 1.1$

In most of the cases, improved workability of warm asphalt mixes at low temperatures leads to improved and early coating of aggregates and reduced compaction effort to achieve densities; this should not be accepted as a parameter to reduce the binder content in the mix.

6.3 Moisture Susceptibility

Since Warm-mixes are typically prepared at least 30°C lower temperatures, it is likely that the aggregate can retain some residual moisture, especially when the aggregate are porous and when the moisture content in the aggregate is high due to recent rains. It is recommended that the warm-mix additives or processes should also function as anti-stripping agents, and should be able to improve the resistance of the mix to moisture susceptibility even when produced at temperatures at least 30°C lower than conventional mixes. If the warm-mix additives cannot perform as an anti-stripping agent, it must be mandated to add either hydrated lime or a liquid anti-stripping agent to the mix to improve resistance to moisture damage. However in case of WMA using foaming technology use of anti-stripping agent or lime may be detrimental. The following procedure may be adopted for evaluating the moisture damage resistance of Warm-mix asphalt mixes:

- Six samples of the compacted HMA mix conforming to the JMF as per AASHTO T245 (Refer **Annex 1**) shall be prepared in the first instance.
- The specimens shall have 7.0±0.5% air voids.
- Six samples of warm-mix specimens conforming to the JMF shall be prepared at a temperature at least 30°C lower than the hot-mix samples as per AASHTO T245. The compactive effort shall be either similar for both mixes or adjusted in such a way that both the mixes have similar air voids (7.0±0.5%).
- The Tensile Strength Ratio (TSR) of the hot-mix and the warm-mix shall be determined as per AASHTO T283. The TSR value of HMA shall meet the requirement of minimum 80% as specified in IRC:111. A TSR of above 80% for the warm-mix that is prepared at least 30°C below corresponding hot-mix will ensure sufficient resistance against moisture susceptibility.

7. PRODUCTION OF WARM MIX ASPHALT

7.1 Mixing Plant Requirements

WMA requires mix temperatures to be significantly reduced. The two basic types of bituminous mixing plant most commonly used are the batch type mixing plant and the continuous drum type plant, both of which types can be adapted to manufacture WMA.

For production of warm mixes that also contain reclaimed bituminous mixes, mixing plant design should include adequate features. When any of the various types of mixing plants are used, it should be ensured that the Recycled Asphalt (RA) and the virgin aggregates are properly blended together; the blending process shall facilitate proper heat transfer and shall prevent both physical and thermal segregation.

As with any new technology, there are a few concerns about the production of WMA, specifically because of the lower temperatures that are utilized during production. Fortunately, all of these problems are expected and solvable in many cases through the adoption of techniques that could also be utilized for improving conventional HMA production.

The first concern is about incomplete drying of aggregates (specifically the internal moisture) at the reduced temperatures. It has been seen that for aggregates with an absorption value of less than 1%, drying of aggregate has not been reported to be a problem at WMA temperatures. To prevent the incomplete drying of aggregates, it is suggested that stockpiles be kept as dry as possible by sloping sides, paving surrounding areas, and keeping them under cover. To dry aggregates with high moisture content the retention time in the dryer drum could be increased and the dryer shell should be insulated properly. Ways to detect incomplete drying include a greater than 20ºC fall in temperature in mix between discharge and loading, dripping water from silos and excessive steam from slat conveyors and a loss of more than 0.5% of the weight of mix during moisture content test.

The second concern is regarding incomplete combustion of fuel at the reduced temperature and the resulting risk of getting unburnt fuel in the mix.

Evidence of such a problem includes brownish color of mix and higher than normal emissions. Proper maintenance and tuning of burner and preheating of burner fuel are recommended solutions to this problem. The last but not least problem is the potential of condensation of baghouse fines, leading to the clogging and decreased efficiency of the emission control system.

Recommended solutions include proper preheating of baghouse, sealing of leaks, adjusting flights and slopes of the dryer to increase baghouse exhaust temperature, insulation of baghouse and ductwork and addition of duct heaters to increase baghouse temperatures, if needed. A high-pressure drop within a range greater than 0.28 to 0.35 kg/cm^2 across the bags is an indicator of caking due to condensation.

7.2 WMA Technology Addition Systems

For WMA Technologies, both rheological modifier and chemical additive types that are blended into the binder shall be added through the mixing plant's normal binder addition system. These may also be blended at terminals and supplied to project sites through conventional transportation system.

Water carrying chemical additives, which are in powdered form, can be added manually into the pugmill of batch type mixers either through the filler system, or by intruding it through the RA collar.

Equipment to produce foamed bitumen may be installed on both batch and continuous drum mixing plant types. The systems obviously operate differently, with separate generations of foamed bitumen for each batch in the former type of plant and a continuous production of foam in the latter plant type's case.

Conventional types of bituminous mix plants shall have the following monitoring and control systems:

- Binder storage tank heating temperature
- Integrated individual cold feed hopper (new aggregate and RA) and burner fuel flow
- Burner fuel flow meter
- Infrared temperature monitor
- Infrared silo discharge temperature monitor

Foaming systems should include integrated flow metering and pressure sensing systems for both the binder and the water used to produce the foam.

7.3 RAP and WMA

WMA (Warm Mix Asphalt) and RAP (Recycled Asphalt Pavement) present their own individual benefits and costs. WMA has the ability to reduce production costs and environmental impacts by reducing fuel consumption and emissions production by reducing the asphalt mix production and compaction temperatures. Furthermore, certain types of WMA additives or processes have the ability to improve permanent deformation resistance, fracture resistance, and moisture sensitivity. The use of RAP can also reduce costs and ecological production effects by utilizing a recycled material. However, the increased stiffness of RAP asphalt binder as compared to HMA and WMA asphalt binder could be problematic if it is used excessively. Combining WMA and RAP can offer potential improvements in pavement performance compared to using either material alone. AASHTO M320 recommends the use of a softer virgin binder grade for higher (greater than 25%) RAP contents. Adding warm-mix is the perfect solution, as lower mixing temperatures result in less binder aging during production and consequently, a softer binder. A RAP mix produced at warm-mix temperatures should then have ample stiffness to resist rutting, as well as sufficient viscoelastic behavior to resist cracking. Plant operations are also improved when WMA and RAP are used together. As per IRC:120, for hot in plant recycling a maximum of 30% RAP content is recommended to be used, whereas with the use of warm mix additives this 30% rap content can be increased to 40-50%.

The limit in the use of Reclaimed Asphalt Pavement material (RAP) proportion is restricted due to stiffness and workability issues related to RAP. This problem is addressed with the help of Warm Mix Asphalt (WMA) which increases the proportion of RAP used by producing mixes having same/better properties viz., better workability, reduced viscosity than Hot Mix Asphalt (HMA) at lower temperatures.

For this purpose the RAP mix shall be designed as per IRC:120, the RAP proportion may be increased up to 40% with the addition of warm mix additives.

8. CONSTRUCTION OPERATION

The construction operation for WMA shall be the same as that prescribed for HMA and shall be in accordance with the IRC:111 except that the mixing, laying and rolling temperatures for WMA shall be as indicated in **Table 1**.

Table 1 Mixing, Laying and Rolling Temperatures for WMA*

Bitumen Grade	Mix Temperature (ºC)	Laying Temperature (ºC)	Rolling Temperature (ºC)
VG-40	135 max	120 min	100 min
VG-30	130 max	115 min	90 min
VG-20	125 max	115 min	80 min
VG-10	120 max	110 min	80 min
Modified Bitumen**	135 Max	120 min	100 min

*In case of special conditions including but not limited to long hauls, cold paving conditions, etc. the recommendations of the WMA technology supplier shall be followed.

**The properties of modified binder shall conform to IRC:SP:53.

9. QUALITY ASSURANCE

The extent and level of quality control of Warm Mix Asphalt shall be same as that of HMA and specified in IRC:111. In addition, one test each for coating, compactibility, moisture susceptibility shall be carried out for each mix design. Further, when the WMA mixes include reclaimed bituminous mixes, additional testing shall be required.

The properties of the binder contained in the RA (Recycled Asphalt) have to be taken into account at mix design stage and the consistency of the recovered binder properties shall be checked regularly.

Typically the moisture content, grading and binder content of each RA fraction shall be checked prior to the start of the day's mix production.

A proposed job mix formula for a WMA must be evaluated for its fatigue cracking resistance (with the mix incorporating WMA additive, specifically for wax based additive) prior to being approved for construction.

Warm mix additives can be used with all types of mixes (BC, DBM and SMA etc.) and with all types of binders i.e. PMB, rubber modified and viscosity grade binders. It is advised to perform lab trial for asphalt mix design to check the volumetric properties before field application.

10. COLLABORATIVE EFFORTS BY CONTRACTING AGENCY, TECHNOLOGY PROVIDER AND THE CONTRACTING AUTHORITY

10.1 WMA technology will actually be applied in works by the Contracting agency. While the quality and performance of the work is the responsibility of the Contracting agency, the product technology provider has to take responsibility for the efficacy of the product and the technology. It is essential, therefore, that both contractor and the product/technology provider come to an understanding or agreement with regard to their respective roles and formalize them in the form of Joint Venture or Contractor-Subcontractor or Contractor-Supplier arrangements, delineating therein their respective roles, committing themselves to joint and several responsibilities, and accepting these arrangements to be made a part of the contract for work to the extent it involves WMA work.

10.2 The product/technology provider should give reasonably detailed information in narrative form supported by sketches, diagrams, process flow charts, laboratory and field test evidences, etc., with regard to but not limited to the following:

(i) The trade name of the product and the form in which available (such as liquid, powder, pellet,etc)

(ii) Technology description (such as water-based, rheological modifier, surfactants, etc.)

  a) Recommended dosage and target reduction in mixing and laying temperatures
  b) The additive feed system (such as pre-blended with binder, water injection system, separate feed system)
  c) The stage of mix production process at which the additive is to be administered (such as with hot binder before mixing, hot aggregate before mixing, pug mill during mixing)
  d) The additive metering system (volumetric, gravimetric, temperature, pressure, etc),
  e) The controls required (manual, centralized computer control or parallel computer control for additive feed system) for administering the recommended dosage
  f) Whether the mixing plant to be used on the work has these systems and controls or not, and if not, the modifications required in the plant
  g) Safety and precautions in material (i.e. the additives) storage, handling and processing

10.3 The contracting agency should undertake to procure the materials, bring out modifications required in the plant and equipment as required specifically for administering the additives in a controlled and safe manner and also for the general requirement of operating the mixing plant at reduced temperature. The general requirements would be but not limited to:

(i) Tuning the burners (to prevent un-burnt fuel getting mixed with warm mix)

(ii) Modifying dryer flight configuration (to ensure proper drying of aggregates),

(iii) Modifying dryer drum inclination (to ensure proper drying of aggregates)

(iv) Preventing condensation of bag house fines (to ensure efficiency of emission system)

(v) Preventing un-burnt fuel and moisture getting mixed with the warm mix produced

(vi) Maintaining computer control of plant operation and not allowing any overriding manual control

(vii) Carrying out a trial run of plant operation

(viii) Constructing a test section of suitable length

11. ROAD MAP FOR WMA TECHNOLOGY

It is necessary that every user of the technology monitors and evaluates the performance of the WMA technology, creates a database in a standard format (e.g. like one suggested in **Annexure**) and uploads it on its website to make it accessible to any interested party. Over time the success stories will lead to the wide spread use of the technology, lessons can be learnt from not so successful ones and the unsuitable ones would fall by the way side. In order to assess fossil fuel, emission and energy use reductions, it is suggested that beginning and end fuel usage data be recorded for test run. This may be accomplished with direct fuel usage meter readout, wherever available or by tank gauging as appropriate.

Annex 1

PROPERTIES OF WMA TO BE VERIFIED IN ACCORDANCE WITH TESTING PROCEDURE AS PER AASHTO/ASTM STANDARDS

i. Coating - (AASHTO T195/ASTM D2489)

ii. Compactibility - (AASHTO T245/ASTM D1559)

iii. Moisture Sensitivity - (AASHTO T283/ASTM D1075)

AASHTO T195/ASTM D2489

The standard method of test for “Determining degree of particle coating of Asphalt Mixture”, helps in determining the particle coating in asphalt mix based on the percentage of fully coated aggregate present in a mix. The specification also helps in determining the mixing time required for satisfactory coating of aggregate in the asphalt mixture.

After producing WMA mix by lowering the temperature by at least 30°C lower than conventional hot-mix, samples of the mix are taken immediately after discharge from the pug mill. Coating is only measured on aggregate retained on 9.5 mm sieve. So the material is sieved on a 9.5 mm sieve while still hot and roughly 200-500 gram of sieved sample is collected.

The percentage of coated particles is determined by

$$\%\,Coating = \frac{No.of\ completely\ coated\ particles}{Total\ No.\ particles} \times 100$$

At least 95% of the coarse aggregate particles shall be fully coated at a temperature at least 30°C lower than conventional hot-mix.

AASHTO T245/ASTM D1559

The standard method of test for “Resistance to Plastic flow for bituminous mixture using Marshall Apparatus” covers the measurement of resistance to plastic flow of cylindrical bituminous mixture samples by the means of a Marshall apparatus.

This test method is specified to verify that the warm-mix samples attain equivalent resistance to plastic deformation relative to conventional mixes at temperatures at least 30°C lower than conventional hot-mix. The specification details the procedure for preparing a cylindrical bituminous mixture sample of 100 mm diameter consisting of around 1200g of material. The sample is prepared by compacting using a standard Marshall hammer. The samples are checked for Marshall Stability and flow under a constant displacement rate testing using a Marshall Apparatus after being immersed in water at 60±1°C for 30 to 40 minutes.

WMA mixes shall have at least 9kN Marshall Stability value (12kN if sample prepared with PMB) and flow between 3-6 mm.

AASHTO T283/ASTM D1075

The standard method for "resistance of compacted asphalt mixture samples to moisture-induced damage" covers preparation of specimens and the measurement of the change of diametrical tensile strength resulting from the effects of water saturation and accelerated water conditioning, with a freeze-thaw cycle, of compacted asphalt mixtures. The results may be used to predict long-term stripping susceptibility of the asphalt mixtures and evaluate liquid anti-stripping additives that are added to the asphalt binder.

The test is performed by compacting cylindrical bituminous mixture specimens to an air void level of six to eight percentages. Three specimens are selected as a control and tested without moisture conditioning, and three specimens are selected to be conditioned by saturating with water undergoing a freeze cycle (-18°C for at least 16 hours), and subsequently having 60±1°C water soaking cycle for 24 hours. The specimens are then transferred to a 25±1°C water bath for two hours and then tested for indirect tensile strength by loading the specimens at a constant rate and measuring the peak force required to break the specimen. The tensile strength of the conditioned specimens is compared to the control specimens to determine the tensile strength ratio (TSR).

$$\% \, TSR = \frac{Tensile\ strength\ of\ conditioned\ samples}{Tensile\ strength\ of\ unconditioned\ samples} \times 100$$

The Tensile Strength Ratio (TSR) of the hot-mix and the warm-mix shall be determined as per the AASHTO T283. A TSR of above 80% for the warm-mix that is prepared at least 30°C below corresponding hot-mix will ensure sufficient resistance against moisture susceptibility.

Annexure

LIST OF WMA TRIALS IN INDIA

S. No	Time of Trial	Area	Length	Binder/ Mix	Stretch	Mix Temp reduced by	Fuel Savings	Key Benefits Observed
1	Aug, 2009	Bawana, DSIIDC	400 m	CRMB-60 (BC)	Industrial area	by 25-30^{0}C	Not measured. Small stretch	CRMB-60 could be compacted even at 100^{0}C. Less odour, comfortable working for paving crew.
2	Feb, 2010	Chandannagar, WB	300 m	VG-30 (SDBC)	Village Road	30^{0}C	Not measured. Small stretch	Less smoke. Improved adhesion between binder and aggregate.
3	Jan, 2011	Delhi-Rohtak	400 m	CRMB-60(DBM and BC)	NH-10	30^{0}C	Fuel consumptions reduced by 25%.	Reduced fuel consumptions, compaction at lower temperature, improved density / reduced number of roller passes, longer hauls under cold climate, quicker opening to traffic.
4	Apr, 2011	Halol-Godhra	1 km	VG-30 (BC)	SH-5, Gujarat	25^{0}C	Burner opening reduced, indicating fuel saving of 25%	Reduced fuel consumptions, higher productivity, improved density, better surface texture
5	Dec, 11 to May, 12	Delhi-Rohtak	15 km	CRMB-60(DBM and BC)	NH-10	30^{0}C	Fuel saving reported by M/s ERA as 23%.	Reduced fuel consumptions, compaction at lower temperature, improved density / reduced number of roller passes, longer hauls under cold climate, quicker opening to traffic.
6	June, 11 and Dec, 11	Project Shivalik	200 m + 200 m	VG-10 (50 mm thk BM)	NH-58	30^{0}C	Burner opening reduced, indicating fuel saving of 25%	Mixing temp reduced by 30^{0}C, rolling at 70^{0}C, achieving density at a low temperature

S. No	Time of Trial	Area	Length	Binder/ Mix	Stretch	Mix Temp reduced by	Fuel Savings	Key Benefits Observed
7	Sept, 11	Project Beacon	400 m	VG-10 (50 mm thk BM)	NH-1	30^{0}C	Burner opening reduced, indicating fuel saving of 25-30%	Mixing temp reduced by 30-35^{0}C, rolling at 70^{0}C, achieving density at a low temperature
8	Apr, 2012	Guwahati--Shillong	500 m	VG-30 (DBM)	NH-44	25^{0}C	Burner opening reduced, indicating fuel saving of 20%. Very moist aggregates.	Reduced fuel consumptions, improved density/less compaction effort resulting in less number of roller passes, anti-strip properties.
9	Dec, 12	Bewar-Pali-Pindwara	650 m	VG-30 (DBM)-90 mm	NH-14	25^{0}C	From actual measurement in plant- 20%	Reduced fuel consumptions, improved density/less compaction effort resulting in less number of roller passes, replaced lime as anti-strip agent.
10	Jan, 13	Reengus-Sikar	4.19 km	VG-30 (DBM)-100 mm	NH-11	25-30^{0}C	From actual measurement in plant- 22%	Reduced fuel consumption, lesser no of roller passes, improved productivity, anti-strip properties
11	Jan, 13	Jammu Bypass	245 m	VG-30 (DBM)-60 mm	NH-1A	25-30^{0}C	Burner opening reduced, indicating fuel saving of around 20%.	Reduced fuel consumption, achieving density at a very low compaction temp.

Three of these sections were evaluated for 3 year field performance in comparison of hot mix asphalt section, by CSIR-CRRI. The field performance of WMA sections was found to be comparable to the HMA sections. The detailed reports may be obtained from CSIR-CRRI.

REFERENCES

1. Rajib B. Mallick and A.Veeraragavan, 'Warm Mix Asphalt a Smart Solution for Building Sustainable Pavements in India, NBM & CW September, 2013.
2. Ambika Behl, Dr. Sunil Bose, Girish Sharma, Gajendra Kumar," Warm Bituminous Mixes: The wave of future", Journal of IRC, Volume 72-2, pp 101-107, 2011
3. Ambika Behl, Dr. Sunil Bose, Girish Sharma, Gajendra Kumar, "Warm Bituminous Mixes: Way to Sustainable Pavements", presented and published in the proceedings of 9th International Transportation Specialty Conference held in Edmonton, Canada 6-9th June, 2012 organized by Canadian Society of Civil Engineering.
4. Ambika Behl, Gajendra Kumar, Dr. P.K. Jain, "Performance of Low Energy Crumb Rubber Modified Bituminous Mixes", 14th REAAA (Road Engineering Association of Asia & Australasia) Conference held in Malaysia in September, 2013.
5. Ambika Behl, Prof. Satish Chandra, Prof. V.K. Aggarwal, "Rheological Characterization of Bituminous Binder containing Wax based Warm Mix Asphalt Additive" Journal of Mechanical & Civil Engineering, Volume 9, Issue 1, PP 16-22, 2013
6. First Field Performance Evaluation Report of (WMA) Trial Section at DSIIDC Industrial Area Bawana, New Delhi, April, 2012, CRRI Report.
7. First Field Performance Evaluation Report of (WMA) Trial Stretch on Halol Godhra-Samlaji Section Gujarat, August, 2012, CRRI Report.
8. Laboratory Evaluation of Wax Additive in Warm Asphalt Mixes, 2011,CRRI Report.
9. Laboratory Evaluation of Additive in Warm Mixes, 2010, CRRI Report.
10. Mexico City Warm Asphalt Specifications, 2010, CRRI Report.
11. Local Standards of Jiangxi Province, Specifications of Warm Mix Asphalt for Pavement Construction, January 11, 2011.
12. California WMA Specifications, August, 2012.
13. Best Practice Guideline and Specification for Warm Mix Asphalt – South Africa.
14. National Cooperative Highway Research Program, NCHRP Report 691, Mix Design Practices for Warm Mix Asphalt, 2011.
15. AASHTO T 168. Warm Mix Asphalt Mixes.
16. Warm Mix Asphalts English version published by dav (German Asphalt Paving Association), Bonn, Germany, July, 2009.
17. Ambika Behl, Prof Satish Chandra, Dr. S. Gangopadhyay, "Durability and Performance Characteristics of Warm Asphalt Mixes", Journal of Indian Road Congress, Volume: 77-1, pp 323-332, 2016.
18. Ambika Behl, Prof. Satish Chandra, V.K. Aggarwal, Dr. S. Gangopadhyay, "Zero Shear Viscosity of Bitumen-Filler Mastics of Warm Mix Binders", ASCE Journal of Material Science in Civil Engineering, USA, 2015.
19. Ambika Behl, Prof. Satish Chandra "Aging Characteristics of Warm Mix Asphalt Binders" ASCE, Journal of Materials in Civil Engineering, USA Vol. 29, Issue 10, 2017.

(The Official amendments to this document would be published by the IRC in its periodical, 'Indian Highways' which shall be considered as effective and as part of the Code/Guidelines/Manual, etc. from the date specified therein)