AN EXPERIMENTAL STUDY ON CATIONIC BITUMEN EMULSION BASED ON COLD MIX TECHNOLOGY

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ABSTRACT

Cold mix asphalt consists of unheated aggregate with emulsion or cutback as binder. Cold mix also offers advantages like; reduction in emissions, low fuel consumption, can be used in rainy seasons etc.This project presents the mix design of cold mixes for use in different courses of pavements. The project provides information on the different additives which are usually used to increase the performance of cold mix. It also gives the results of same earlier studies on cold mixes. It also highlights the scope of using cold mix in rural road construction.

INTRODUCTION

1.1 GENERAL

Hot Mix Asphalt (HMA) is used predominantly as a paving mix from many decades in road construction. In India almost 90 percent road network is occupied by bituminous pavements only. Certain limitations associated with HMA use are like emission of green house gases from hot mix plant, shut down of plants during rainy season, problems in maintaining the paving temperature when hauling distances are more, etc. Due to topographical constraints, rural roads projects in North Eastern States of India like Arunachal Pradesh, Assam, Manipur, Meghalaya and others are beyond

time. Indian government is undergoing a massive rural road development plan and is highly concerned for the rural road development projects in North East states.

1.2 NEED FOR COLD MIX TECHNOLOGY

Cold mix is a mixture of unheated aggregate and emulsion or cutback and filler. The main difference between cold mix and HMA is that aggregates and emulsion or cutbacks are mixed at ambient temperature (10°C-30°C) in case of cold mix and aggregates and binder are mixed at high temperature (138°C- 160°C) in case of HMA.

1.3 WHAT IS CATIONIC BITUMEN EMULSION

A stable dispersion of bitumen in water in continuous phase. The bitumen globules are positively charged due to the $NH3^{+}$ group cover which is formed around bitumen droplets and provide stability for emulsion by electrostatic repulsion. These bitumen droplets have an affinity with the negatively charged aggregate, which is usually available in India.

1.4 WHERE TO USE CATIONIC BITUMEN EMULSION?

Emulsions were first developed in the early 1900s. It was not until 1920s however, that emulsions, as we know them today came to the fore due to its ecofriendly behaviour & other advantages, the use of Cationic Bitumen Emulsion has had a steady rise in demand world wide including INDIA. The INDIAN ROADS CONGRESS & MINISTRY OF ROAD TRANSPORT & HIGHWAYS have recommended the use of Cationic Bitumen

Emulsion in several applications of Road Work like Tack Coat, Prime Coat, Surface Dressing work, 20 mm Premix Carpet, Sealing of cracks with fog seal etc

USE OF CATIONIC BITUMEN EMULSION BASED ON COLD MIX TECHNOLOGY IN RURAL ROAD CONSTRUCTION

Construction of rural road using conventional paving mix is sometimes not feasible in high rainfall area because it is difficult to produce and lay HMA. In case of high altitude or snow bound area, lower temperature of environment makes difficult to heat aggregate and binder at high temperature. In case of hilly roads, HMA is supplied from remote HMA plant; it is difficult to maintain mix temperature for long hauling distance.

LITERATURE REVIEW

DEVELOPMENT OF BITUMEN EMULSION BASED COLD MIX TECHNOLOGY FOR CONSTRUCTION OF ROADS UNDER DIFFERENT CLIMATIC CONDITIONS OF INDIA

Ref1

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To develop environment and eco-friendly cold mix technology, field trials were conducted using bitumen emulsion on Jammu-Srinagar Highway NH-IA near Patnitop (J&K) under snow bound arc a, Jowai-Badarpur Road NH-44 near Silchar (Assam) under heavy rainfall and H-S Road near Hanumangarh (Rajasthan) under desert climate. Specifications adopted were 25 mm semi dense bituminous concrete (SDBC) and 20 mm premix carpet (PM C) for laying test sections with bitumen emulsion and control section with paving bitumen 80/100. Laboratory mix design for SDBC with bitumen emulsion was developed using Marshall method. Marshall specimens or cold mix were prepared, cured at 40°C for 3 days and tested at 25°C for stability and low value. Post construction performance evaluation has been carried out at 6-month 'intervals for 5-6 years. SDBC and PMC with bitumen emulsion performed better or comparable with that of conventional paving grade bitumen.

EXPERIMENTAL PROGRAMME

GENERAL

In this chapter, the experimental investigations on the various physical and other properties of all the materials used in the preparation of cationic bitumen emulsion based on cold mix technology. And type of tests conducted on bitumen emulsion and test procedures also discussed.

3.2 MATERIALS USED:

The different materials used in this investigation are:

- Cationic bitumen emulsion
- Aggregates

3.2.1 CATIONIC BITUMEN EMULSION :

Bitumen emulsion is a dispersion of small droplets of bitumen in water. Bitumen emulsion consists of three basic ingredients; bitumen, water and an emulsifying agent. Based on specifications it may contain other additives, such as stabilizers, coating improvers, antistripping or break control additives

•Anionic–with negatively charged globules;

$$RCOOH + NaOH \rightarrow RCOO^- + Na^+ + H_2O$$

• Cationic – with positively charged globules.

$$RNH_2 + HCl \rightarrow RNH_3^+ + Cl^-$$

The main grades for cationic bitumen emulsions are classified as follows:

• **Rapid setting.**

Designed to react quickly with aggregate and revert from the emulsion to the bitumen. Primarily used for spray applications, like surface dressing.

• Medium setting.

Formulated not to break immediately upon contact with aggregate and will remain workable for a few minutes to several months depending on formulation and application (tack coat, production of stockable asphalt mixes and etc.

• Slow setting.

Designed for mixing stability . Primarily used with high fine content aggregates. Very often used in Cold recycling technology.

In this present study **Cationic bitumen emulsion** based on cold mix technology is used with different settings.

PRODUCTION OF BITUMEN EMULSIONS

Bitumen emulsions are usually made using a colloid mill, although other dispersion devices are possible, too. In the colloid mill energy is applied to the system by passing the mixture of hot bitumen and water phase between a rotating rotor and stator.

Bitumen emulsions can be produced either in a batch or an in-line process plant.

The batch type

the batch process involves at least two process steps: water phase (soap), bitumen preparation and the actual emulsion production.

The in-line type

In the in-line process the water heating and all material dosing are done continuously using individual dosage pumps for each material.

3.2.1.1 COMPONENTS OF THE CATIONIC BITUMEN EMULSION

A)Bitumen

The binder type used in emulsions is usually bitumen 160/220 penetration, however specialised applications may require the use of polymer and other additives to enhance the emulsion and binder performance. For production of polymer modified bitumen emulsions, SBS modified bitumen can be used, too.

B) Calcium chloride

Calcium chloride or other soluble salts are often included in the water phase of cationic emulsions at level of 0,05 - 0,1%. Calcium chloride helps to reduce the osmosis of water into the bitumen and the increase in viscosity during storage.

C) Additives to improve bitumen adhesion to aggregate

Water resistance is an important property of mixes and seals. Often bitumen emulsions may not have sufficient adhesion on aggregates, in which case adhesion promoters can be added to the bitumen before emulsification or to the finished emulsion.

3.2.2 AGGREGATES :

In India aggregates should conform the physical requirement laid by MoRTH specification (2001). Testing of aggregate like sieve analysis, specific gravity, aggregate impact value and soundness were conducted and results were tabulated below.

S.No	TEST DESCRIPTION	RESULT
1.	Specific gravity	
	10mm size	2.63
	Stone dust	2.7
2.	Water absorption	0.9%
3.	Aggregate impact value	17

Table 3.1 Properties of aggregates

3 PREPARATION OF CATIONIC EMULSION :

The actual preparation of cationic emulsions of the present invention does not involve any unusual or complex procedures. Ordinarily, the predominantly water soluble cationic quaternary nitrogen-base halide salt emulsifier is dissolved in the aqueous phase, and the predominantly oil-soluble high molecular weight unsaturated alcohol capable of

prolonging the time of mixing the emulsion with the aggregate is added to the oil (bituminous) phase. Thereupon, emulsions can be formed in the conventional manner by intensive agitation of the combined two phases in a suitable piece of equipment, such as a colloid mill.

TESTS ON BITUMEN EMULSION

4. TESTS ON CATIONIC BITUMEN EMULSION

There are a number of tests to assess the properties of bituminous materials. The following tests are usually conducted to evaluate different properties of bituminous materials.

1. Penetration test
2. Ductility test
3. Softening point test
4. Specific gravity test
5. Viscosity test
6. Flash and Fire point test
7. Float test
8. Water content test
9. Loss on heating test

4.1 Penetration test

It measures the hardness or softness of bitumen by measuring the depth in tenths of a millimeter to which a standard loaded needle will penetrate vertically in 5 seconds. BIS had standardized the equipment and test procedure. The penetrometer consists of a needle assembly with a total weight of 100g and a device for releasing and locking in any position. The bitumen is softened to a pouring consistency, stirred thoroughly and poured into containers at a depth at least 15 mm in excess of the expected penetration

4.2 Ductility test

Ductility is the property of bitumen that permits it to undergo great deformation or elongation. Ductility isdefined as the distance in cm, to which a standard sample or briquette of the material will be elongated withoutbreaking. Dimension of the briquette thus formed is exactly 1 cm square. The bitumen sample is heated andpoured in the mould assembly placed on a plate. These samples with moulds are cooled in the air and then inwater bath at 27^{o} C temperature.

4.3 Softening point test

Softening point denotes the temperature at which the bitumen attains a particular degree of softening underthe specifications of test. The test is conducted by using Ring and Ball apparatus. A brass ring containing testsample of bitumen is suspended in liquid like water or glycerin at a given temperature. A steel ball is placedupon the bitumen sample and the liquid medium is heated at a rate of 5^{o} C per minute.

4.4 Specific gravity test

In paving jobs, to classify a binder, density property is of great use. In most cases bitumen is weighed, butwhen used with aggregates, the bitumen is converted to volume using density values. The density of bitumen isgreatly influenced by its chemical composition. Increase in aromatic type mineral impurities cause an increasein specific gravity.The specific gravity of bitumen is defined as the ratio of mass of given volume of bitumen of known contentto the mass of equal volume of water at 27^{o} C.

4.5 Viscosity test

Viscosity denotes the fluid property of bituminous material and it is a measure of resistance to flow. At theapplication temperature, this characteristic greatly influences the strength of resulting paving mixes. Low orhigh viscosity during compaction or mixing has been observed to result in lower stability values. At highviscosity, it resist the compactive effort and thereby resulting mix is heterogeneous, hence low stability values.And at low viscosity instead of providing a uniform film over aggregates, it will lubricate the aggregate particles.Orifice type

viscometers are used to indirectly find the viscosity of liquid binders like cutbacks and emulsions.

4.6 Flash and fire point test

At high temperatures depending upon the grades of bitumen materials leave out volatiles. And these volatilescatches fire which is very hazardous and therefore it is essential to qualify this temperature for each bitumengrade. BIS defined the flash point as the temperature at which the vapour of bitumen momentarily catches firein the form of flash under specified test conditions. The fire point is defined as the lowest temperature underspecified test conditions at which the bituminous material gets ignited and burns.

4.7 Float test

Normally the consistency of bituminous material can be measured either by penetration test or viscosity test.But for certain range of consistencies, these tests are not applicable and Float test is used. The apparatusconsists of an aluminium float and a brass collar filled with bitumen to be tested. The specimen in the mouldis cooled to a temperature of 5^{o}C and screwed in to float. The total test assembly is floated in the water bathat 50^{o}C and the time required for water to pass its way through the specimen plug is noted in seconds and isexpressed as the float value.

4.8 Water content test

It is desirable that the bitumen contains minimum water content to prevent foaming of the bitumen when itis heated above the boiling point of water. The water in a bitumen is determined by mixing known weightof specimen in a pure petroleum distillate free from water, heating and distilling of the water. The weight ofthe water condensed and collected is expressed as percentage by weight of the original sample. The allowablemaximum water content should not be more than 0.2% by weight.

4.9 Loss on heating test

When the bitumen is heated it loses the volatility and gets hardened. About 50gm of the sample is weighed and heated to a temperature of 163^{0}C for 5hours in a specified oven designed for this test. The sample specimen is weighed again after the heating period and loss in weight is expressed as percentage by weight of the original sample. Bitumen used in pavement mixes should not indicate more than 1% loss in weight, but for bitumen having penetration values 150-200 up to 2% loss in weight is allowed.

MIX DESIGN & TEST RESULTS

1.1 COLD MIX DESIGN

Properties of cold mixes are varied by many parameters like; source of aggregate, curing condition and curing time, etc. Hence there is no universally accepted mix design method for cold mixes. This method is applicable to base course mixture for low volume traffic load. Cold mix is used in surface course also for low to medium traffic volume road. The cold mix design is carried out to optimize water and emulsion content for aggregate in the mix. The parameters involved in mix design of cold mix asphalt are having following steps in Cold mix design of cationic bitumen emulsion:

1. Evaluation of Bitumen Emulsion
2. Gradation and Properties of Aggregates
3. Premixing Optimum Water Content
4. Preparation of Cold mix
5. Application of track coat
6. Transportation of Mix
7. Spreading cold mix
8. Laying Premix Carpet with Emulsion
9. Preparation of Road Surface-
10. Seal Coat on Premix Carpet –
11. Laying of Control Sections
12. Problems and Remedial Measures During Construction

1. Evaluation of Bitumen Emulsion :

Selection of emulsion depends on aggregate type and aggregate gradation and ability of emulsion to coat

the aggregate. According IS 8887:2004 specifications, five grades of emulsion; RS-1, RS-2, MS, SS-1 and SS-2 are used to prepare cold mix. Quality tests should be carried out on the selected emulsion according to IS 8887:2004.

2. Gradation and Properties of Aggregates

Characterisation-Aggregates supplied byVaragali Cross Road ChillakuruMandal in Spsr Nellore District of Andhra Pradesh State, were subjected to sieve analysis and tested as per IS: 2386. Properties of aggregates has been found as: specific gravity, aggregate (11.2 mrn size), 2.63; stone dust, 2.71; aggregate Impact Value, 17; and water absorption value, 0.9%.

3. Determination of Premix Water Content:

Quantity of emulsion (p) is determined as:

P=0.05A+0.1B+0.5C

Where,

A= Percent aggregate retained as 2.8 mm sieve

B= Percent aggregate retained on 90micron sieve

C= Percent aggregate passing on 90micron sieve

4. Preparation of Cold mix

Construction of bituminous road with bitumen emulsion requires significantly different procedures from those used for hot-mix hot laid construction. Drums of emulsion were rolled to 5-6 m to and fro for twice or thrice to make emulsion homogeneous before its use. The graded aggregates after blending different size of aggregates were charged into concrete mixer driven with diesel engine. Optimum water content as determined in the laboratory was added and mixed to wet the aggregate surface

5. Application of Tack Coat-

Tack coat with bitumen emulsion of MS or SS grade was applied @5.0kg for 10m^2 area by means of perforated cans as per IRC specification. Holes of cans were cleaned with water whenever tack coating was discontinued to avoid choking of the holes with residual bitumen. Cold mix was spread when tack coat turned black from brown after 15-20 min.

6. Spreading Cold Mix-

In half of road width, cold mix was laid over tacky surface and spread uniformly in required thickness (33mm loose mix) by manual method. Cold mix turns black from brown after some time when water of emulsion exudes after breaking of emulsion. Cold mix was aerated for 2 h and then rolled with 8-10 tons three-wheel roller to compact the mix.

7. Laying Premix Carpet with Emulsion

Preparation of Cold Mix-The blended aggregates as per required grading were charged in the concrete mixer and uniformly wet the aggregate with optimum quantity of pre mixing water. Emulsion of MS grade in required quantity was added in to wet aggregate gradually and mixed for 2 minutes to get uniform coating. Prolonged mixing was avoided, as it will decoat the aggregate.

8. Preparation of Road Surface-

Pavement surface was cleaned of dirt, dust and loose materials. Tack coat (5 kg/10m2) with SS grade emulsion was provided.

9. Seal Coat on Premix Carpet –

Sand seal coat material was prepared with aggregate passing 2.36mm and retained on 180µm. Fine aggregate was taken in the concrete mixer and water (3%) was added to wet the aggregates uniformly. The emulsion of SS grade was poured gradually in to the mixer and mixed from uniform coating. Decorating starts when mixing time is increased in excess of about 2 min.

10. Laying of Control Sections

The control (reference) sections with specification of 25mm semi dense bituminous concrete with bitumen (IRC: 95-1987) and 20mm PMC with bitumen were also laid as controlled section as per IRC 14:1977, using mini hot mix plant.

TEST RESULTS

5.2.1 Penetration test results:

Actual test temperature = 27°c

Penetrometer dial reading	**Trail (1)**	**Trail (2)**	**Trail (3)**
a) Initial reading	120	135	115
b) Final reading	210	195	195
Penetration value	90	60	80

Table 5.2.1 Penetration test results

Average of penetration value = $\frac{90+60+80}{3}$ = 76.6mm

5.2.2 Ductility test results:

Readings	**Briquette no's**	
	1	2
a) Initial reading	0	0
b) Final reading	73.2	74.0
c) Ductility(b-a)	73.2	74.0

Fire point	358	347	351	352

Table 5.2.6 Flash and Fire pointtest results

5.2.8 Float test results:

	Min	Normal	Max
Weight of float, g	37.70	37.90	38.10
Total height of float, mm	34.0	35.0	36.0
Height of rim above lower side of shoulder, mm	26.5	27.0	27.5
Thickness of shoulder, mm	1.3	1.4	1.5
Diameter of opening, mm	11.0	11.1	11.2

Table 5.2.8 Float test results

5.2.9 Water content test results:

Water collected	**Repeatability**	**Reproducibility**

Table 5.2.2 Ductility test results

The ductility value of the bitumen sample = 73.6cm

5.2.3 Softening pointtest results:

	Trail (1)	**Trail (2)**
Temp. when the ball touches bottom ˚c	46	45

Table 5.2.3 Softneing point test results

The softening point value of bitumen sample = 45˚c

5.2.4 Viscosity test results:

Test	Trails		Mean value
	1	2	230
Viscosity in sec	230	230	

Table 5.4 Viscosity test results

The viscosity of bitumen sample=230 sec.

5.2.6 Flash and Fire point test results:

Test	Trails			Mean value
	1	2	3	
Flash point	305	308	311	308

0 – 1.0ml	**0.1ml**	**0.2ml**
1.1 – 25ml	**0.1ml or 2 % of the mean whichever is greater**	**0.2ml or 10% of the mean whichever is greater**

Table 5.2.9 Water content test result

CONCLUSION

This review paper has focused on the use of cold mixes in rural road construction. The following overall conclusion can be justified.

- Cold mix can be laid on low to medium volume road as a green paving mix. Mixture can be produced by using conventional plant or by hand. So it can be laid as surface course or bituminous base course for rural road construction.
- Additive can be used in cold mix to make its properties comparable to the properties of HMA.
- Curing rate and mechanical properties of cold mix can be improved.
- Cold mix can be tried for paving mix in north east region of India.
- Large scale laboratory and field trials studies should be carried out to develop better understanding on the performance of cold mixes in rural road construction for different traffic, climate and terrain conditions

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