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Quality Control of Cationic Emulsion Modified Cold Mix in Flexible Pavement

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Abstract: Several ambitious road construction plans and activities primarily involve bituminous pavements with hot mix technology. Hot mix technology which is a conventional method for road construction, has structurally satisfied the performance requirements over many years. The procedures generally followed by the hot mix technology are : heating of binder and aggregate, mixing, tack coating, laying of mix followed by the compaction process everything done at high temperature in a range of 120ºC to 165ºC temperature. So, it is desirable to find out a suitable alternative for hot mix technology. In India almost 90 percent road network is occupied by bituminous pavements only. Certain limitations associated with use of hot mix asphalt are like emission of greenhouse gases from it, shut down of plants during rainy season, problems in maintaining the paving temperature when hauling distances are more, etc. Field trials have proved that cold mix can be easily produced by using hot mix plant and can be laid in using similar techniques. Here the main objectives of the experimentation are to evaluate and improve the properties of the cold mixtures. Test results also show that the addition of additive significantly improved the performance of the cold mix. In this paper the performances of cold-mix, cold-lay emulsion mixtures is described with reference to its quality control.

Keywords: *Quality control, cationic emulsion, cold mix, flexible pavement*

1. Introduction

Bitumen emulsion is a liquid product in which a substantial amount of bitumen is suspended in a finely divided form of the size 4-10 microns, in water in presence of emulsifiers. In the emulsion based cold mix technology, the addition of pre-wetting with water to the aggregate, thereafter addition of emulsion to it, production of the mix, laying and compaction, all processes are done at the room temperature.

Use of emulsified cold mixes would eliminate the emissions and also reduce the fuel requirement at the mixing plant as energy conservation. Use of bitumen emulsion in India is very less (2.7%) as this may be due to the inexperience in this technology, non-availability of proper machinery and lack of quality bitumen emulsion. [1]

Cold mix asphalt should be tried in India for construction of rural roads in hilly areas having high rainfall and difficult terrain. Cold mix when used as paving mix can offer following advantages.

a) It eliminates heating of aggregate and binder.
b) It is environmental friendly and conserves energy. Cold mix pavement can provide energy savings of over 50% compared with hot mix. So it can be considered as green bituminous mix for rural road construction. [2]
c) It can be easily prepared using small set up on site. It can be produced manually for small scale job. Laying of hot mix asphalt for rural road construction sometimes is not economical because setting up of a hot mix plant for small scale job increases the project cost.
d) This paving mix is particularly suited for construction of roads in remote and isolated areas of a country where hot mix produced in plant would set before reaching site.
e) Cold mix can be laid during wet or humid condition also.
f) It is versatile also as a large number of grades of emulsion and cutbacks are available.

2. Scope of Work

Cold mix technology is lagging behind in both research and application fields which are quite observable in developing country like India. This is the primary motivation underlying selection of this cold mix technology as the present research area. Hence following objectives are chosen.

2.1. Objectives of the Work

The objectives of the work are as follows:

1) To develop mix design for modified cold mix and test it according to standards.
2) To study effect of additives on performance of cold mix.
3) To study quality control aspects of modified cold mix.

3. Literature Review

Head [3] reported the results of research on cement modified asphalt cold mixes. He indicated that

addition of cement had a very significant effect on mix stability; addition of 1% cement produced an increase in stability of 250-300% over that of untreated samples. Brown and Needham [4] indicated that emulsion droplet coalescence was affected by pressure, bitumen type, emulsifier level, cement and temperature. Pouliot et al. [5] indicated that mortars made with the cationic emulsion (CSS-1) gives higher strengths and elastic modulus than mortars made with anionic emulsion (SS-1).

Transportation research circular entitled "Asphalt Emulsion Technology" [6] has provided detailed information regarding bitumen emulsion. An emulsion is a dispersion of small droplets of one liquid in another liquid. Emulsions can be formed by any two immiscible liquids, but in most emulsions one of the bases is water. Bitumen emulsion is a liquid product in which a substantial amount of bitumen is suspended in a finely divided form in water in presence of emulsifiers. The bitumen droplets range from 0.1 micron to 20 micron in diameter. Standard bitumen emulsions is a brown liquid and contain 40% to 75% bitumen, 0.1% to 2.5% emulsifier, 25% to 60% water plus some minor components. During the literature review it was observed that Thanaya [7] provided some useful recommendations for the cold mix design procedure. Al-Busaltan et al. [8] used LJMU-FA1 which was a waste domestic fly ash, within the cold bituminous emulsion mixes to improve the mechanical properties, namely indirect tensile stiffness modulus and creep stiffness. Five percentages of the specific waste materials from 0.5 to 5.5% of aggregate mass in the mixture was incorporated in the cold bituminous emulsion mixtures.

The results illustrated a comparative enhancement in the mechanical properties of the new cold mixtures. M.S.Ranadive et.al. [9] Studied effect of fly ash in flexible pavements and found that fly ash along with e-waste as filler cannot improve strength. Further, M.S.Ranadive et al. [10] studied effect of lime as filler material on performance of mastic asphalt and found that percentage of binder increases with increase in lime as filler content for obtaining permissible range of hardness number. From the above literature review it is observed that the quality control of cold mix is missing in the research works. Also, study of effect of additive has to be studied in greater depth hence herein attempt is made for the same.

4. Research Methodology

The overall methodology of experimental program is described as follows.

1) Preparation of test samples
2) Testing program
3) Comparison of results of all cases
4) Conclusion

4.1 Preparation of Test Samples

Samples were prepared according to IRC: SP: 100-2014[11]. Bitumen emulsion used was of the grade MS-65 as per ASTM D 244 [12]. Following materials are used for the preparation of cold mix in varying proportion as described in *Table 1*, *3* and *5*.

1) Aggregates as per IRC:SP:100-2014
2) Fly ash as per IS 3812 (Part 2) : 2013
3) Lime as per IS 1514 : 1990
4) Portland cement (Grade 43)

4.2. Testing Program

Following tests were conducted in the Transportation Engineering laboratory of College of Engineering Pune for evaluation of the material properties.

a) Marshal stability test
b) Indirect tensile strength test
c) Water resistance test
d) Workability test
e) Binder content test
f) Bond test

In the following section the above tests are described in brief.

5.1. Marshal Stability

The Marshall Stability test was conducted as per ASTM D 6927 [13] of bituminous mix is the ability of the mix to resist deformation under the action of load. For emulsion based cold mixes, the stability requirements are given for paving only.

5.2. Indirect Tensile Strength Test

The test was conducted as per ASTM D 6931 [14]. Indirect tensile test is used to determine the indirect tensile strength (ITS) of bituminous mixes. In this test, a compressive load is applied on a cylindrical specimen (Marshall Sample) along a vertical diametrical plane through two curved strips which radius of curvature is same as that of the specimen. A uniform tensile stress is developed perpendicular to the direction of applied load and along the same vertical plane causing the specimen to fail by splitting. This test is also otherwise known as splitting test. *Image 1* shows the test set up.

Image1. *Test setup for indirect tensile strength test*

5.3. Water Resistance Test

The test was conducted as per IRC: SP: 100-2014. This test is used to check the water resistance capacity of the cold mix. Fifty grams of patching mix, were heated at 120°C in a laboratory oven for 4 hours, and then cooled to 95°C in laboratory by air, and then placed in 400 ml of boiling water in a 600-ml glass beaker and stirred at 95°C with a glass rod at the rate of 1 revolution per second for 3 minutes. The water was decanted and the mix was spread on an absorbent paper for visual observation of the coating. The aggregate observed at least 90 percent coated with a bituminous film.

5.4. Workability Test

The test was conducted as per IRC: SP: 100-2014. Approximately 2.5 kg of the patching mix was cooled to -7°C in a freezer. After cooling, the mixture was capable of being broken up readily with a spatula that has a blade length of approximately 200 mm. This test shall be performed when the mix is produced and thereafter anytime during storage. If the mix is not workable at -7°C, it shall be rejected and the composition of the mix shall be properly modified (for example, by increasing the bitumen content and/or gradation changes). This test is also applicable in areas with hot climate because it amplifies the workability characteristics of the mix by using a lower test temperature.

5.5. Binder Content Test

The test was conducted as per IRC: SP: 100-2014. This test is used for determining the amount of binder content in cold mix. First 600 gm of cold bituminous mixture is taken in preweighed bowl and placed in a hot air oven for4 hours at 120°C. Cool the mix to room temperature and weigh to nearest 0.1 gm. Place cooled mix in a tray at 100°C for about 1 hour and take 500 gm (W1) of mix in a bowl of bitumen extractor, while the temperature of mixture is 50-60°C. Close the lid of extraction bowl and allow the contents to remain is submerged condition in solvent (TCP) for about 1 h. Repeat this process till TCE is clear of colour and aggregate is free from bitumen. Dry aggregate in an oven at 120°C for about 2 h. Take the weight of bowl+ aggregate for determination of bitumen content (W2). The difference in W1 and (W2+ weight of filler) indicate weight of residual bitumen in mixture. *Image 2* shows test set up.

5.6. Bond Test

The test was conducted as per IRC:SP:100-2014.Adequate bonding between bound layers is necessary for pavement performance. The degree of bonding at the pavement interfaces affects the stress distribution within the materials that constitute a layer. This stress distribution is predominantly, affected by the Interface bonding condition between upper pavement layers; the surface course and the underlying base course. In the laboratory, Marshall Samples are to be prepared by 50 blows on one side, such that the thickness of the sample is about 30-35 mm.

Image2. *Test set-up for binder content*

Once the samples are taken out from the mould, tack coat is applied at the specified rate on the samples and allowed to cure for 24 hours at room temperature. After the curing period, the other half part of the Marshall sample is prepared by applying 50 blows. The sample should be such that half of the sample is of the one type of material and the other superimposed half is of other type of the material and tack coat membrane is interlayer between two layers. The sample is taken out and allowed to cure for 24 hours. After the completion curing period, the sample shall be placed in the shear mould assembly Marshall testing machine. Test setup for testing of bond strength of tack coat between two bituminous layers is shown in *Image 3*.

Image 3 *Test set-up for bond strength*

6. Observations and Interpretations

Results obtained are tabulated as follows.

6.1. Marshall Stability Number

Following *Table 1* shows Marshall Stability Number in KN obtained by addition of cement, lime, and fly ash independently for different percentage in each case.

Table 1: *Effect of additive on Marshall Stability Number*

Sample No.	Addition (%)	Marshall stability number (KN)		
		Cement	Lime	Fly ash
1	1	12	5.2	6
2	2	15	6.4	8.8
3	3	17	7.8	9.1
4	4	25	8	9.2
5	5	24	9.2	9.2

Table 1 shows that cement modified mix gives better stability. 4% Cement gives maximum stability.

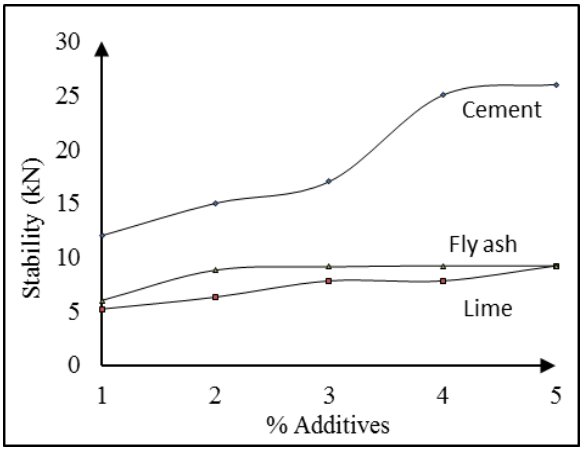

Figure1. *Stability v/s % additive*

From Figure 1 it is observed that addition of cement significantly improved the stability of modified mix as compared to fly ash and lime.

Table 2 explains the effect of strength by Marshall Stability number in percentage for different additive. Cement modified binder gives maximum stability as compared to lime and fly ash.

Table 2: *Percentage increase in stability*

Sample No.	% Cement	% Lime	% Fly ash
1	56.7	0	13.3
2	58.0	1.56	28.4
3	47.0	-15.51	1.0
4	63.2	-15	0.0
5	61.7	0	0.0

6.2. Flow Value

Table 3: *Percentage Increase in Flow value*

Sample No.	Addition (%)	Flow value (mm)		
		Cement	Lime	Fly ash
1	1	2.5	3.2	3.2
2	2	2.3	3.4	3.1
3	3	2.1	3.6	3.3
4	4	2	3.7	3.5
5	5	2.2	3.5	3.7

It was observed that addition of additives improves the flow value. Table 3 shows the results of flow values which are in between 2 to 4 mm. As per MORTH [15] guidelines the range of flow value is between 2mm and 4 mm which is observed from Figure 2.

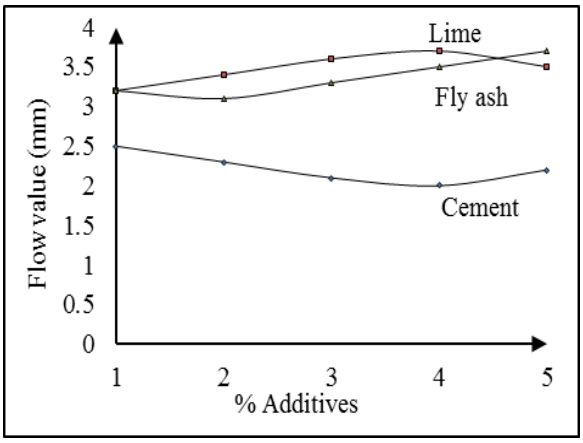

Figure 2 *Flow value v/s % additive*

6.3. Indirect Tensile Strength (IDT) Results

Table 4: *Results of indirect tensile strength test*

Sample	Maximum Load, N	ITS (kPa)	% Increase
with 2% cement	2.28	239.6	14.48
with 5% lime	2.06	216.5	5.35
with 3% fly ash	2.01	211.2	2.98

Table 4 shows the results of indirect tensile strength test results. It is observed that 14.48% increase in indirect tensile strength case of cement is observed. While lime and fly ash shows 5.35% and 2.98% increase respectively. Figure 3 shows the combined values of cement lime fly ash in one graph.2% Cement gives maximum value of indirect tensile strength which comes out to be 239.6 kPa.

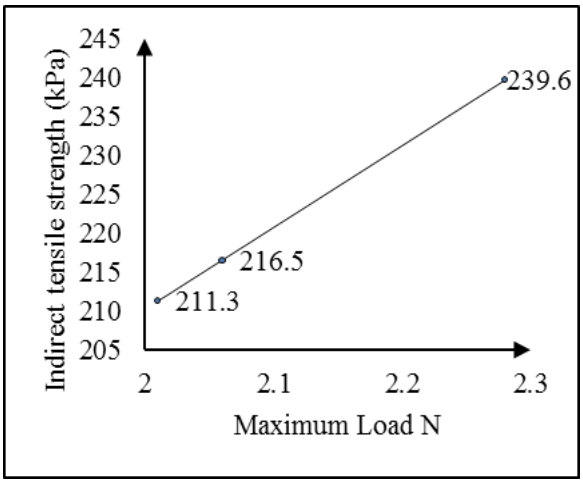

Figure 3 *Indirect tensile strength v/s maximum load*

6.4. Bond Strength

Table 5: *Results of bond strength test*

Sample No.	Addition (%)	Bond strength (kg/cm^2)		
		Cement	Lime	Fly ash
1	1	1.006	0.880	1.094
2	2	1.132	1.006	1.132
3	3	1.258	1.069	1.195
4	4	1.396	1.132	1.258
5	5	1.522	1.157	1.384

Table 5 explains the effect on bond strength in percentage for different additive. These values are in between 0.880 kg/cm^2 to 1.522 kg/cm^2. As per Naby and Easa [16] the range of bond strength is between 0.427 kg/cm^2 to 1.450 kg/cm^2 which is observed from Figure 4.

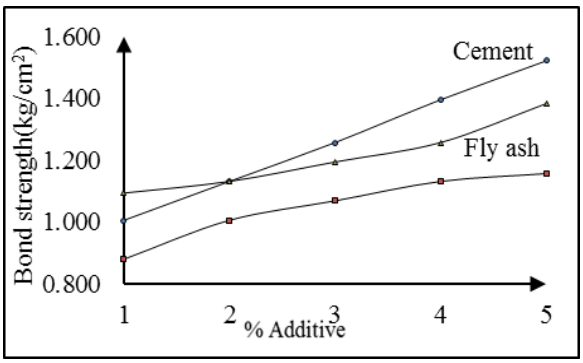

Figure 4. *Bond strength v/s % additive*

From Figure 4 it is observed that addition of cement significantly improved the stability of modified mix followed by fly ash and lime. Also it is observed that the values of bond strength test fall within prescribed range.

7. Conclusion

Following conclusions are drawn based on the experimental study:

a) Among the additives, though the stability value has been found to be improved by addition of fly ash, lime and cement, stability of cement modified binder was maximum with 56.7 to 61.7 % increase.

b) It is observed that with the addition of fly ash, lime and cement indirect tensile strength increases by 2.98%, 5.35% and 14.48% respectively with respect to conventional mix.

c) The mix also satisfies the quality control tests. The results of quality control fall within the permissible range.

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