Comparative Study on Properties Of Bitumen Hot Mix And Bitumen Emulsion Mix

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Abstract

This study involves preparation of mix samples of bitumen hot mix and bitumen emulsion mix (cold mix) by adopting Marshall Method procedure. The Method involves use of cationic medium setting emulsion and bitumen 80/100 penetration grade as binder. The investigation is carried out in places with relative temperature, to see effect of temperature on the properties of mix samples for both cold and hot mix. In this study, set of test is carried out in one of the laboratory in Thimphu and another set in college laboratory (Phuentsholing). Comparative study on results of the different mix sample produced at different places and at the same lab between cold and hot mix is done, based on the volumetric properties: Bulk density, Air voids in compacted mix, voids filled with bitumen (VFA) as well as Marshall stability and flow.

Keywords: *Cold Mix, Hot mix, Marshall Method, temperature, volumetric properties*

1. INTRODUCTION

Bitumen is a dark brown to black viscous liquid or solid, consisting essentially of hydrocarbons and their derivatives. It is substantially non-volatile, softens gradually when heated and soluble in carbon disulphide and in carbon tetra chloride. It possess, strong, readily adhesive, highly waterproof and durable material. It also provides some flexibility to mixtures of mineral aggregates with which it is usually combined. It is highly resistant to the action of most acids, alkalis and salts. The paving bitumen grades available are classified into two categories (Singh, 1978): 1.Paving bitumen from Assam Petroleum, denoted as A-type and designated as grades A 35, A-55, A-65 and A 90, 2.Paving bitumen from other sources denoted as S-type and designated as grades S-35, S-45, S-55, S-65 and S-90.

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 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. The emulsion in general is of two types cationic and anionic. Cationic emulsion have bituminous droplets which carry a positive charge. Anionic emulsions have negatively charged bituminous droplets. Based on their setting rate, which indicates how quickly the water separates from the emulsion, both anionic and cationic emulsions are further classified into rapid setting (RS), medium setting (MS), and slow setting (SS).

1.1 Bitumen Hot Mix

The material most often used to make bitumen bound layers is known as 'hot mix' because it is produced and laid at elevated temperatures. Although bitumen are manufactured to have range of viscosities, the grade used in the structural layers of roads are most solid at ambient temperature. In order to mix with the aggregate mixture, bitumen must first be liquefied by heating. In the manufacture process, hot bitumen is added to the hot aggregate mixture in a large blender and mixed until full coating of aggregate is achieved. The bitumen and aggregate temperatures necessary for this are in the range of 110^{0} to 180^{0}C depending on the hardness grade of bitumen being used. The hot material is then

1.2 Bitumen Emulsion Mix

It is alternative binder for bitumen that can be applied at relatively low temperature compared to that of hot mix. Needham (1996) stated that although cold mix generally manufactured at ambient temperatures, some processes could also use the emulsion warmed to around 60°C. Till now there is no universally accepted cold mix design method and therefore no thumb rule that can be followed. There is no general existing equipment made specifically for the design of cold mixes, hence those for hot mixtures are most frequently used. Marshall Method has been popularly used to design cold mixes.

1.3 Status of Hot and Cold mix

Hot mix does an excellent job when manufactured and laid. Hot mix technology is well developed even though they are based on empirical laboratory and field data rather than fundamental principles (Needham, 1996). On the other hand workers are much experienced and enable them to have confidence in the performance of a structure comprised of hot mix. The problems stated by Needham, with the case of cold mix are shortfall in performance in terms of mechanical properties. Cold mix has very little stiffness during its early life and can be damaged if trafficked. And, emulsion mixture have an inherent susceptibility to water damage, due the fact that unset bitumen emulsion are partially water soluble and binder can therefore be washed away by rain fall resulting in very weak material.

transported to laying site in drum trucks and must be laid and compacted while still hot. If the mixture is allowed to cool down too much, the bitumen viscosity becomes too high and mixture gets solidifies. Below a certain temperature, depending on the grade of bitumen a mixture will become unworkable, meaning that it can be neither placed nor compacted in the required way. After laying, a hot mix pavement can be opened to traffic as soon as it has cooled to ambient temperature and the bitumen has harden.

On the other hand, benefits of using bitumen emulsion mixtures are: since the aggregate need not have to be dried for use in emulsion mixture, dust emission are eliminated. Hot mix leads to emission of harmful gases from polycyclic aromatic compounds (PAC's) at higher temperature, which are considered to be powerful carcinogens (SABITA, 2007). Needham (1996) stated that, use of cold mixture can lead to energy at the same time cost saving. The data from CSIR-Central Road Research Institute, New Delhi (2010), shows that, construction of rural road 930km using bitumen emulsion in Assam, saved around 1.4 Million liters of fuel and 4.5 million kgs of CO_2 emission. Emulsion mixture offer potential improvement in performance. It avoids formation of embrittlement and cracking due to hardening of binder through oxidation during the heating process. Dittmar found out that cold mix gain its strength over time and cracks that forms over time repairs themselves due to its flexibility.

2. METHODOLOGY

This section highlights the experimental works conducted throughout the project. It presents the methodology of experimental program to accomplish the overall framework of the study carried out and also deals with experiments carried out on the procedures.

2.1 Selection of materials

Total of three materials are selected as per the aims of the project namely Aggregate, Bitumen and Bitumen Emulsion. Collections of the materials are done according to the availability within the locality keeping in view of their strength and usage. Aggregate was collected from the ongoing highway construction site (Phuntsholing-Samtse highway via Amohchu). Bitumen emulsion and Bitumen are collected from the Bhutan Bitumen Industries Private Limited, Pasakha and Department of Road, Phuentsholing respectively.

2.2 Material Testing

Various properties of the aggregate are conducted and their results were recorded and compared with the standard specification (SBRW/IS) to examine their feasibility to use in road construction. Various tests conducted are: Los Angeles Abrasion Tests, Impact Value Test, Crushing Test, Specific gravity and Water Absorption Test.

2.3 Preparation of Aggregate

After qualifying various quality test, aggregate preparation was done. Aggregate preparation is done in order to standardize the aggregate that is similar type of aggregate with regard to its shape, sizes and amount, to carry out comparative studies between bitumen and emulsion mix.

Preparation of aggregate was done in three phases; Phase-I: Sorting out of aggregate that are retained on particular size of IS sieve by sieving it through different sizes of sieves (20mm, 16mm, 12.5mm, 10mm, 8mm, 6.3mm, 4.75mm, 2.36mm); Phase-II: Sorting out visually the elongated and flat aggregates; and Phase-III: Advanced sorting by using instrument like length gauge, thickness gauge and Vernier caliper. The process is shown in pictorial form below.

2.3.1 Aggregate proportioning

After the completion of the aggregate preparation, proportioning for mix design is carried out. Unlike usual blending method, proportioning of aggregate is developed by trial and error method. Various sizes of aggregate were taken to get required aggregate weight and mixed with binder, and sample is produced. Likewise varied amount of different aggregate is mixed until stable sample is produced, which can be used for testing purpose. Various theoretical and field knowledge and also specification were researched, in order to produce suitable proportion. The required proportion obtained for the mix is shown in the figure below.

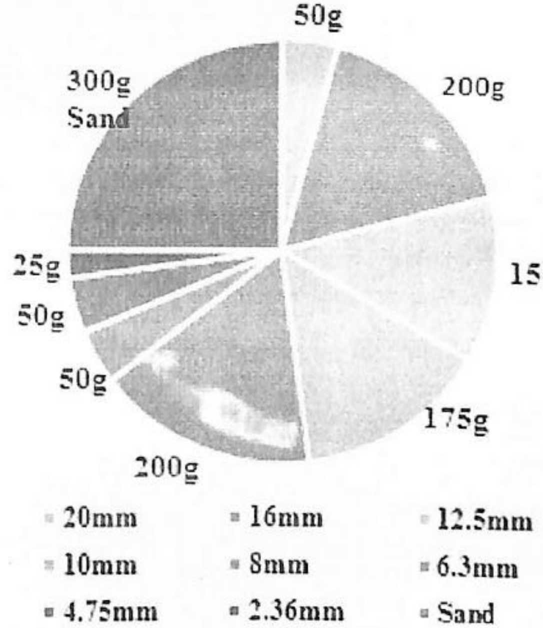


Fig. 2.2 : Aggregate proportions for the mix.

2.4 Marshall Mix Design

In the Marshall Tests method of mix design three compacted samples are prepared for each binder. Total of five binder contents are considered for test to get the optimum binder content (i.e. 5%, 5.5%, 6%, 6.5% and 7%). All the compacted specimens are subjected to the following tests: Bulk density determination, Stability and Flow test and Density and Voids analysis. The bulk density of the sample was determined by weighting the sample in air and in water.

The proposed design steps for the design of bituminous mix are as follows : 33.33% course aggregate, 39.58% fine aggregate and 27.08% filler are used as the grading in the mix design. The trial specimens with varying bitumen contents ranging from 5% to 7% by weight of aggregate are prepared and the stability test is conducted in each specimen for each location i.e. Phuentsholing and Thimphu.

The percentage of voids, VMA, percent voids filled with bitumen and bulk density in each

2.4.1 Preparation of test specimen

The specimen for the test is prepared with Marshall Mix method. Prepared proportions of aggregate and binder are taken so as to produce a compacted bituminous mix specimen of thickness 63.5 mm approximately. Summary of procedure involved in preparing the mix is given in the table below:

Table 3.1: Sample Production

Sample Production	
Cold Mix	Optimum moisture for mixing. Addition of emulsion and mixing. Marshall Compaction (50 blows). Curing (one day each in mould, oven and air respectively).
Hot Mix	Aggregate drying(175°C to 190°C) Bitumen Heating(120°C to 130°C) Mixing and Compaction Cooling in room temperature (30 min). Water bath for 40 minutes (50°C to 60°C)

2.5 Sample Test

Different Marshall Test conducted are as mentioned below:

2.5.1 Specific Gravity of Compacted Specimens

From the determined value of specific gravity and weight of coarse aggregates, fine aggregate, filler and bitumen, the theoretical specific gravity (G_t) of the mix is given by following equation.

$$Gt = \frac{100}{\left(\frac{w1}{G1}\right) + \left(\frac{W2}{G2}\right) + \left(\frac{W3}{G3}\right) + \left(\frac{W4}{G4}\right)}$$

W_1 = percent by weight of coarse aggregates.
W_2 = percent by weight of fine aggregate.
W_3 = percent by weight of filler.
W_4 = percent by weight of bitumen in total mix.
G_1, G_2 and G_3 are apparent specific gravity values of the coarse aggregates, fine aggregates and filler respectively and G_4 is the specific gravity of bitumen.

2.5.2 Density and Voids Analysis

Soon after the compacted bituminous mix specimens have cooled to room temperature, the weight average thickness and diameter of the specimen are noted. The specimens are also weighed in air and then in water.

The bulk density value G_b of the specimen is calculated from the weight and volume using following equation.

$$Gb = \frac{Wm}{Wm - Ww}$$

Where : W_m: Dry weight of the sample.

W_w: submerge weight of the sample. The voids analysis is made using the following respective equations.

$$Vv,\% = \frac{100(Gt - Gb)}{Gt}$$

$$Vb,\% = Gb\text{x}\left(\frac{W4}{G4}\right)$$

$$VMA,\% = Vv + Vb$$

Where: $$\text{VFB},\% = 100\text{x}\left(\frac{\text{Vb}}{\text{VMA}}\right)$$

V_v: air voids in the mix in percent.
V_b: volume of bitumen in percent.
VMA: voids in mineral aggregates in percent.
VFB= voids filled with bitumen in percent.

2.5.3 Marshall Stability flow value

The specimen to be tested is kept immersed under water bath maintained at 50° ± 5°C for 40 minutes. After 40 minutes it is taken out and let it dry for some time. Then the specimen is placed in the Marshall Testing machine and the Marshall Stability value (maximum load carried in kg, before failure) and the flow value (the deformation the specimen undergoes during loading up to the maximum load in 0.25 mm units) are noted.

2.5.4 Determination of Optimum Bitumen Content

Optimum Bitumen Content is determined by considering optimum value of following properties.

i. Density G_b, g/cm^3
ii. Marshall stability, kg
iii. Voids in total mix, V_v %

Let the bitumen contents corresponding to maximum density be B_1, corresponding to maximum stability be B_2 and that corresponding to the specified voids content be B_3. Then the optimum bitumen content for the mix design is given by:

$$Bo = \frac{B1 + B2 + B3}{3}$$

The val[illegible]rom the graphs, corresponding to bitumen content B_0. All the design values of Marshall Stability, Flow, Voids and VFB are checked at the optimum bitumen content B_0, with the specified design requirements of the mix.

3. RESULT AND DATA ANALYSIS

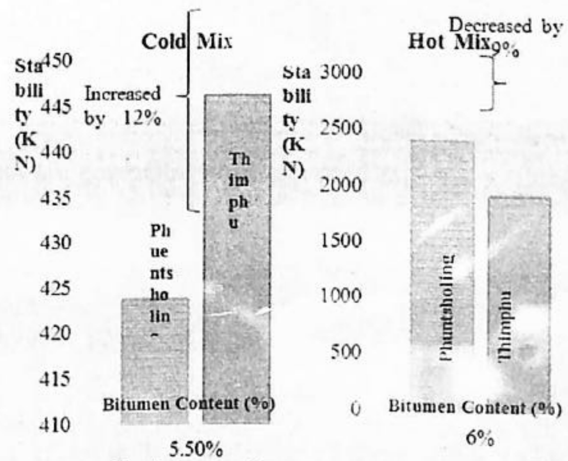
The results obtained for different compacted samples, which is for cold and for hot mixes in Phuentsholing and in Thimphu with corresponding optimum bitumen content is shown under this section. The attempt to analyze effect of temperature on the mixes at two places on the stability is also discussed. Comparative study on different properties of two mixes are done with respect to each other under same place and at different places.

3.1 Result Discussion

So, from various data analysis of mix samples, it was observed that undoubtedly, Marshall Stability strength of hot mix both in Phuntsholing and Thimphu is comparatively higher than that of cold mix. It is illustrated in graphical figure below.

As shown in figure 3.1, it is observed that the strength of bitumen hot mix is effected by mix temperature, in which strength gets reduced by 9% when test is conducted in cold region, having relatively lower temperature than Phuntsholing. Reason for this is that the mixing and compaction temperature is not being able to meet due to immediate lowering of heat and viscosity of bitumen being high in cold places results to inadequate coating.

Fig 3.1: Stability comparison between mixes in two places



3.2 & 3.3. It's observed that that there is slight variation in bulk density of the both the samples in different places. So, it means that the density gets less effected with the change in temperature, although slight decrease was expected from hot mix sample due to difference created in mix temperature in Thimphu. At the same time the void contain being inversely related to density, lower void content was observed in Thimphu than that is observed in Phuntsholing.

For the case of VFB which is expressed as a percentage of the VMA that contains binder, as it's known that VMA is the void spaces that exist between the aggregate particles in the compacted paving bituminous mixture, including the space filled with the binder. So, from this it is understood that if VFB is higher than air void content is less and vice versa. It is observed that VFB is higher for the test that is conducted in Thimphu, so it can be

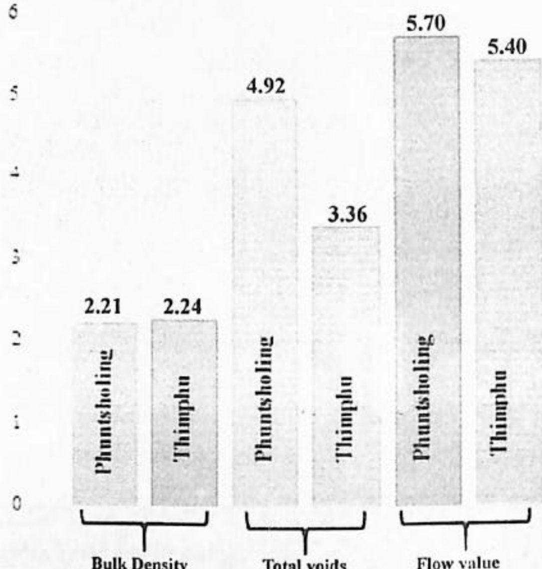
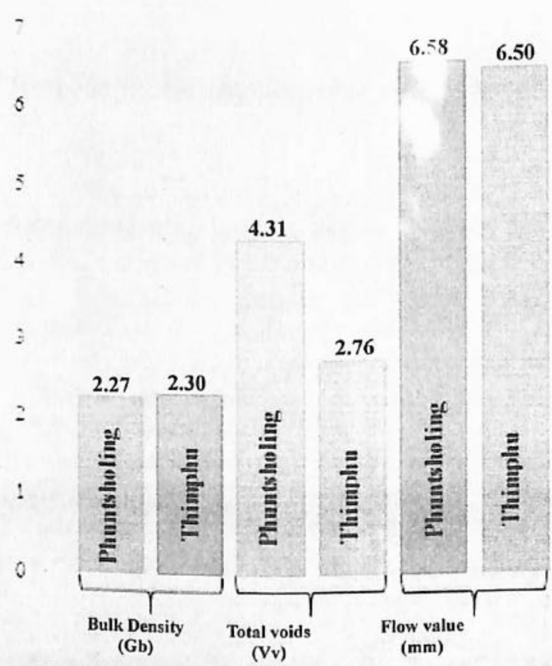


Fig 3.2: Comparison of properties of cold mix



4. CONCLUSION

With the results obtained for stability through this study, it can be concluded that cold mix is still inferior to hot mix to be used in High Traffic Volume Roads. But it can be used in Low Traffic Volume Roads as its stability and other properties confines to values given in the specification. From this research it has been understood that cold mix is advantageous than hot mix for the Low Traffic Volume Roads and maintaining of potholes in colder region due to:

i. Increase in its stability with decrease in temperature.

ii. Decrease in the stability of hot mix with decrease in temperature.

iii. Minimum rainfall intensity in higher region, since heavy rainfall intensity affects the strength of the cold mix.

In general, use of cold mix will have minimum effect on environment (i.e. production of heat and greenhouse gases will be minimum) and also it will have no safety issue to laborers and can be beneficial both in terms of cost and energy consumption point of view.

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