Performance and Design of Cold Mix Asphalt

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Abstract— Hot mix technology has seen significant advances through many research programs. Cold mix technology is lagging behind in both research and application fields which is quite observable in a developing country like India. In the absence of uniformity in the laboratory cold mix design procedures followed by different researchers / agencies / organization, it is difficult to form reliable correlations and to have a comparative study between experimental results reported by them. The mix parameters selected for the present work are (i) Method of compaction, (ii) level of compaction, (iii) additives and (iv)aggregate gradation. The first three parameters are selected for their importance as presented in a number of previous research works. It is observed that Bailey method for gradation selection is the only method for HMA/SMA mixture which analyses the aggregate gradations both considering the blend by volume as well as blend by weight. In this study Bailey's concept has been considered for cold mix design. All the mix parameters have been selected to assess the effect on Marshall Properties of CMA mixture. Initially a suitable experimental methodology has been prepared and then the effects of selected mix parameters on performance of compacted mix are studied. Finally a comparative study for above results has been done on basis of the Marshall Stability and air void content of the cold mix. Considering all the selected mix parameters it is observed that only in case of gyratory compaction the adequate. Air void range (3 to 5 %) in cold mixes can be achieved. Besides, though each and every parameter has contributed to increase the Marshall Stability of cold mixes, cement and developed gradations have shown more significant increase in stability of cold mixes.

Key words: Cold Mix Method, Thanaya, MORTH, Binder, Marshall Stability, Gyratory

I. INTRODUCTION

Several ambitious road construction plans and activities primarily involve bituminous pavements with hot mix technology. Hot mix technology which is a very 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. Though performance wise this has been the most suitable for pavement structures, but their high use have several drawbacks like environmental degradation, high energy consumption, increase in carbon footprint, low output for mix production, low laying work in rains and cold weather, limited construction period in a year, oxidative hardening of binder, health and safety hazard to labour (Pundhir et al., 2012). Besides this, in some North and North Eastern parts of India like Jammu and Kashmir, Assam, Manipur, Meghalaya, Arunachal Pradesh and others, rural road projects involving several Lakhs and Crores of rupees are beyond time. Due to topographical and weather constraints, it is difficult to work with hot mix technology in such hilly regions, heavy rainfall and forest zones. So, it is desirable to find out a suitable alternative for hot mix technology. In the emulsion based cold mix technology, the addition of pre-wetting 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 (23ºC to 25ºC). In addition to this, field trials have proved that cold mix can be easily produced by using hot mix plant and laid in using similar techniques. It is also a labour friendly technology.

II. METHODOLOGY

A. Materials Used

1) Aggregates:

For preparation of cold mixes, two types of aggregate gradations such as dense gradation (BC) and gap gradation (SMA) were taken as per MORTH (2001) and IRC:SP:79 (2008) specifications.

2) Coarse Aggregates:

Raw materials consisted of stone chips were collected from a local source. Aggregates up to 4.75 mm are sieve size were used as coarse aggregate. Its specific gravity was found to be 2.75 as per IS: 2386 (Part-III) procedure.

3) Fine Aggregates:

Raw materials consisted of stone crusher dusts were collected from a local crusher. Aggregates with fractions passing 4.75 mm and retained on 0.075 mm IS sieve was used as fine aggregates. Its specific gravity was found to be 2.62 as per IS: 2386 (Part-III) procedures.

4) Filler:

Raw materials for stone crusher dusts were collected from a local crusher while fly ash, lime and portland slag cement (Grade 43) were collected from local market. Materials are passing 0.075 mm IS sieve was used as filler material. Specific gravity for stone crusher dusts, fly ash, lime and cement were found to be 2.7, 2.2, 2.3 and 3.07 respectively.

5) Binder:

Cationic medium setting (CMS) Bitumen emulsion collected from the reliable source was used in this investigation to prepare the samples. Its residual asphalt content was found to be 65.4%.

B. Laboratory Tests

1) Marshall Test:

The specimen is loaded diametrically at a deformation rate of 50 mm per minute. There are two major features of the Marshall method of mix design. (i) density-voids analysis and (ii) stability-flow tests.

2) Gyratory compaction:

The parameters used in the present study are the 100 mm diameter mould, 1.25° gyratory angle 30 rpm gyration rate, 4.711kN vertical load on 100mm diameter specimen.

3) Static Indirect Tensile Strength Test:
A loading rate of 50 mm/minute was adopted. The load was applied and the failure load was noted from the dial gauge of the proving ring. The tensile strength of the specimen was calculated by using the formula given in ASTM D 6931 (2007) and mentioned in equation below.
$St = (2000 \times P) / (\pi \times t \times D)$
4) Static Creep Test:
In this case there are two stages: 1) a vertical load of 0.55 kN was applied for 60 minutes. The deformation was registered during 10 minutes intervals using a dial gauge graduated in units of 0.002 mm. 2) its deformation was registered during next 10 minutes at 5 minutes interval of time.

C. Cold Mix Design Method Procedure

All the processes are clearly elaborated in following steps are given below.
1) Determination of Aggregate Gradation:
This simply follows standard specifications for aggregate gradation selection. Determination of Initial Residual Asphalt Content (IRAC) and the Initial Emulsion Content (IEC):
Initial Residual Asphalt Content (IRAC) is calculated utilizing an empirical formula:
$IRAC = (0.05\ A + 0.1\ B + 0.5\ C) \times (0.7)$.IEC is calculated using formula: $IEC = IRAC / [X\ (\text{in}\ \%)]$.
2) Test and Determination of optimum pre-wetting water content (OPWC):
Using the IEC value coating test is carried out by mixing dry aggregates and filler with varied amount of water.
3) Dry Stability Test and Determination of Optimum Total Liquid Content at Compaction (OTLC):
Utilizing the IEC, the mix is compacted at the predetermined compaction level (50 Marshall blows on each side of the sample).This test gives the OTLC at which the dry stability of the sample is maximum.
4) Soaked Stability Test and Variation of Residual Asphalt Content (RAC):
By maintaining a constant OTLC value, the RAC is varied in a range of 7 to 10 % emulsion content (EC) value with 0.5 % increment in RAC. Specimens are mixed, compacted at each of these RAC values.
5) Determination of Optimum Residual Asphalt Content (ORAC):
ORAC is determined by optimizing the parameters such as soaked stability, air void, flow value for soaked samples of all residual asphalt content (RAC) variation.
Determination of Retained Stability: Retained stability is the ratio of soaked stability to dry stability.

Marshall compaction	Gyratory compaction
Determination of Aggregate gradation (As per Specifications) IRAC and IEC (As per MS 14 formula) OPWC (Coating Test) 50 blows of compaction level.(as per MORTH) OTLC(Dry Stability Test)	Determination of Aggregate gradation (As per Specifications)IRAC and IEC (As per MS 14 formula) OPWC (Coating Test) Compaction Level i.e. number of gyrations to achieve air void target (Dry Stability Test) OTLC (Dry Stability Test) ORAC (Soaked Stability Test)
ORAC (Soaked Stability Test)Retained Stability (Dry Stability Test at ORAC)	Retained Stability (Dry Stability Test at ORAC)

III. Analysis of Results and Discussion

Marshall compaction (50 blows)		Gyratory compaction (40 gyrations)	
Dense graded mix	Gap graded mix	Dense graded mix	Gap graded mix
Marshall Stability= 5.88kN	Marshall stability= 3.46kN	Marshall Stability= 6.02kN	Marshall Stability= 4.54kN
Air void=8.32%	Air void = 9.22 %	Air void = 4.82 %	Air void = 4.91 %

Table 2: Marshall Stability and Air Void Results of Cold Mixes for Marshall and Gyratory Compaction

Comparative study between dense graded and gap graded cold mixes: From the comparative study it was observed that though gyratory compaction method did not show much influence on the Marshall Stability but it was highly effective to reduce the air void content in cold mix asphalt and to get the adequate air void range (3 to 5 %) even at 40 numbers of gyrations.

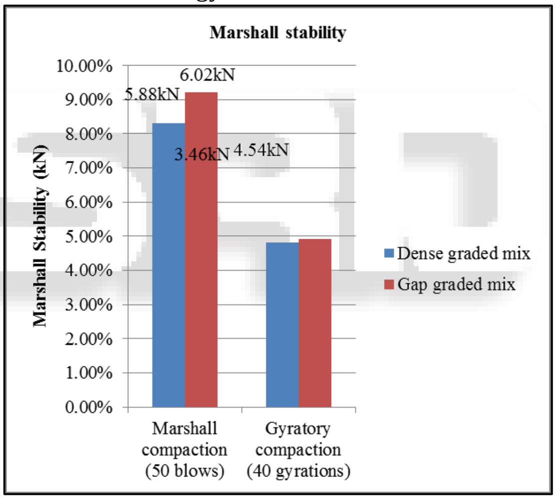

Fig. 1: Marshall Stability Results of Cold Mixes for Marshall and Gyratory Compaction

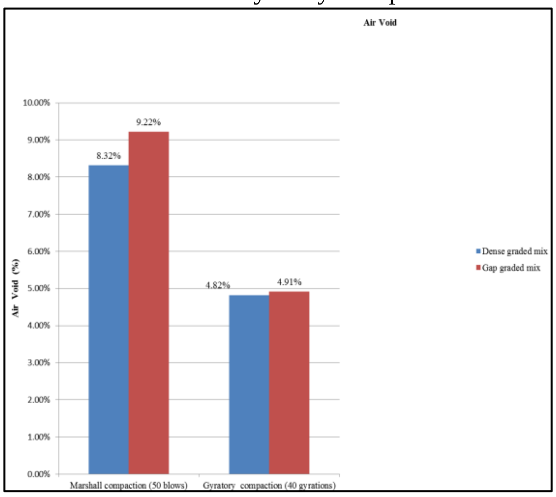

Fig. 2: Air Void Results of Cold Mixes for Marshall and Gyratory compaction

IV. LITERATURE REVIEW

Ministry of Road Transport and Highways (MORTH, 2001) specification for Road and Bridge Works (Fourth Revision) introduced the procedures for bituminous cold mix. The design guidelines were based on those of Asphalt Institute Manual Series 14 (MS 14). During the literature review it was observed that Thanaya (2007) provided some useful recommendations for the cold mix design procedure. The main difference between the procedures provided by MS 14 and Thanaya is the optimum total liquid content (OTLC) and optimum residual asphalt content (ORAC) determination process. To determine the ORAC value, MS 14 suggested to conduct both dry stability and soaked stability test at each residual asphalt content (RAC) while Thanaya suggested to conduct only soaked stability test at each RAC and to find out the dry stability value only at ORAC to determine the retained stability. Later one is more efficient and economic.

V. CONCLUSIONS

1) Initial stability of the mix is dependent on optimum total liquid content (OTLC) of the compacted mix. At same binder content higher the total liquid content, greater is the curing time to obtain full strength of the mix.
2) Increase in number of gyrations has resulted in the increased stability and reduced air void content of compacted cold mixes.
3) Comparing lime and fly ash as substituted for filler, greater stability but higher air void content is noticed in case of cold mixes modified with lime.
4) The Bailey method for gradation selection has been found to be effective for improving the stability of both dense and gap graded cold mixes even without addition of cement.

   In between dense and gap graded cold mixes, though the dense graded mixes has resulted in higher stability value.
5) Considering all the selected mix parameters it is noticed that only in case of gyratory compaction the adequate air void range (3 to 5 %) in cold mixes has been achieved.

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