Construction and Building Materials 191 (2018) 376–385

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

# Influence of mix parameters on design of cold bituminous mix

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## HIGHLIGHTS

- A comparative study on cold mix performance is conducted for various mix parameters.
- Mix parameters are: Aggregate gradation; Method and level of compaction; Variation in filler materials.
- The comparative study is made on basis of Marshall Stability and air voids content.
- Parameters resulting higher Marshall Stability and lesser air voids in cold mix is observed.

## ARTICLE INFO

*Article history:*
Received 17 February 2018
Received in revised form 25 July 2018
Accepted 1 October 2018

*Keywords:*
Cold bituminous mix
Cold mix design
Marshall properties
Marshall stability
Air voids

## ABSTRACT

In the absence of design uniformity, it is difficult to form reliable correlations between experimental results for Cold Bituminous Mixes (CBM) reported by different researchers/agencies/organizations. This paper presents a study on effects of various mix parameters such as aggregate gradation, method and level of compaction, variation in filler materials on performance of CBM. Dense (BC) and Gap (SMA) graded CBM were produced by both Marshall and gyratory method with varying level of compaction. Also, variations in filler materials (cement, lime, fly-ash) were done to evaluate the property of CBM. Finally, hot bituminous mixes were produced with same gradations (BC and SMA). A comparative study on test results has been made on basis of the Marshall Stability and air voids content of compacted mixes. It is observed that optimum residual bitumen content (ORBC) of cold mixes is not much affected by factors such as initial residual bitumen content (IRBC) and optimum total liquid content (OTLC). Rather, it mostly depends on the aggregate gradation. Considering all the selected parameters it is observed that only in case of gyratory compaction 3%–5% range of air voids can be achieved in CBM. Besides, though each and every parameter has contributed to increase the Marshall Stability of CBM, the most significant improvement as comparable with hot mixes is found to be caused by cement filler in comparison with other parameters. Also, higher load sustaining capacity of dense graded CBM is observed by its superior Marshall properties in comparison to gap graded CBM.



## 1. Introduction

Hot mix technology has seen significant advances in field applications as well as in the research level activities. Though it is quite popular among the paving engineers due to its satisfactory performance, there are also some difficulties associated with hot mixes such as emission of harmful gases from hot bituminous mix (HBM) plant, difficulty in construction of HBM during wet and humid condition, costly in case of a relatively small volume of work due to setting up of a hot mix plant, non-energy conserving because of involvement of sustained heating of aggregates, bitumen and bituminous mix. Considering this, the use of cold bituminous mix (CBM) in flexible pavement has gained importance in many developed countries. CBM is a mixture of unheated aggregates, mineral fillers and bitumen emulsion at ambient temperature. Though the cold mix technology has several advantages like safety, energy saving, non-emission of harmful gases and ease in laying of paving mix in any climatic condition, it is lagging much behind in both research and applications. Its use has mostly been limited to patch repairs and crack seals.

As per Asphalt Institute Manual Series No.14 (AI MS-14) [1], the engineering properties of CBM mainly depend on aggregate source, type of emulsion, curing condition and curing time. As per this method using empirical formula initial residual asphalt content (IRAC) and initial emulsion content (IEC) is obtained and then with IEC coating test is carried out by using all batches of aggregates and filler to determine optimum pre-wetting water content (OPWC). The optimum total liquid content (OTLC) is then found out based

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https://doi.org/10.1016/j.conbuildmat.2018.10.002
0950-0618/

on the maximum dry density result obtained as per dry stability test. Then the specimens are prepared with varying residual asphalt content (RAC), hence with varying emulsion content, maintaining the OTLC value same in all batches of RAC content and the optimum residual asphalt content (ORAC) is determined based on results obtained for maximum soaked stability and retained stability (ratio of soaked stability to dry stability).

MORTH [2] specification has almost followed the guidelines given by Asphalt Institute for cold bituminous mix design. It has recommended certain minimum requirements of the cold mix based on the Marshall test. The main difference between the two guidelines is that while the porosity target as specified by AI in MS-14 is 5%–10%, the same by MORTH is specified as 3%–5% only.

Thanaya [3] critically reviewed the cold mix design procedure of Asphalt Institute and reported the following limitations.

- It is difficult to achieve the porosity level of 5%–10% and there is no universally accepted specification on porosity requirements.
- The mix design procedure is not practicable in the field.

He recommended not to consider OTLC in the mix design and 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, which can be more efficient and economic.

Also several researches have been conducted using various additives/waste products/other materials with cold mixes which have shown improvement of properties of modified cold mixes. Oruc et al. [4] suggested that the cement modified asphalt emulsion mixes might be used as a structural pavement layer. Thanaya et al. [5] reported that the addition of 1%–2% of rapid-setting cement accelerated the early strength obtained as well as enhanced the mechanical performance of the modified (cement treated) cold mixes. Pundhir et al. [6] prepared bitumen emulsion treated mixtures of semi-dense bituminous concrete (SDBC) by cold mix method under varying test conditions and observed that increase in curing time results in improvement in cold mix properties. Similarly use of 2% cement enhances the normal and soaked stability values. Al-Busaltan et al. [7,8] used waste materials such as LJMU-FA1 and domestic fly ash with the cold mix in different studies and the results illustrated a comparative enhancement in the mechanical properties of the modified cold mixes. Al-Busaltan [9] also investigated the effect of waste materials (various ash and slag) individually and observed increase in stiffness as well as porosity level of cold mix with the increase in the waste materials level. Abbas Al-Hdabi et al. [10] studied the effect of cement on gap graded cold mix asphalt and observed improved mechanical properties of cold mix comparable with the conventional hot mix within one day curing period. Also, optimisation approach using response surface methodology was found to be an effective method for cold bituminous mix design [11]. Various research works reflected that cold mixes with binary and ternary blended fillers as well as with alkali-activated forms of these fillers resulted in improvement of mechanical properties of the mixes [12,13,14].

Goyer et al. [15] presented a comparative study between the cold mix technique and conventional techniques such as hot mix asphalt based on the environmental impact. It was observed that for construction of 10 cm thick pavement, the rate of energy consumption and greenhouse gas emissions was nearly two times higher for hot mix manufacturing in comparison to cold mix manufacturing. By cost analysis N.K.S. Pundhir [16] estimated road construction with cationic bitumen emulsion to be cheaper by about 15%–20% in comparison to that with 60/70 and 80/100 bitumen. Also performance of road with emulsion was found satisfactory after 5 years pavement service life. From field studies by Ostlund and Soenen [17], it is observed that roads with cold mix technology have sustained excellently for 10–15 years and even more after the construction. Also evaluation of binders recovered from the roads has shown remarkably little ageing of the bitumen in spite of high void content of paving mix.

Though CBM can be a suitable alternative of HBM, the reported lesser stability and higher air voids of CBM relative to traditional HBM presents a challenge for cold mix technology. This may be one of the limiting causes for more widespread usage of CBM in the field up to date.

## 2. Research objectives

Unlike in hot mix design, universally accepted cold mix design procedure is not seen. The laboratory procedures followed by different researchers/agencies vary widely in terms of method of compaction, curing conditions and other mix parameters for evaluation of the mix in terms of relevant engineering properties. Hence, it becomes difficult to form reliable correlations and to make an absolute comparative study of the experimental results reported by different researchers/agencies. This is the primary motivation underlying selection of cold mix technology in this research work. The research objectives which are aimed to study the cold mix design procedure are mentioned below.

- To evaluate the Marshall properties of cold bituminous mixes (CBM) with various mix parameters.
- To make a comparative study on the effect of mix parameters on CBM design based on two important desired cold mix properties such as Marshall Stability and air void.
- To evaluate the performance of cold mixes in comparison to that of hot mixes from the point of view of Marshall properties and to recommend some most suitable mix parameters for consideration in cold mix design.

The mix parameters selected in the present work are: i) aggregate gradation, ii) method and level of compaction, and iii) variation in filler materials. These mix parameters have been selected considering scanty literature involving these parameters in cold mix design.

## 3. Materials used

The materials used for production of the cold mixes and their physical properties are given in Tables 1 and 2 respectively. Cationic medium setting (CMS) bitumen emulsion with 65.4% residual bitumen content was used as binder. CMS was chosen as it was believed that the setting time involved in the emulsion would suit most appropriately the traffic behaviour during execution in India,

**Table 1**
Materials used for bituminous mix production.

| Material | Specific gravity |
|---|---|
| (a) *Aggregate (Stone chips) (BIS Test Method)*[a] | |
| Coarse aggregate > 4.75 mm size | 2.75 |
| Fine aggregate < 4.75 mm and > 0.075 mm size | 2.62 |
| (b) *Filler < 0.075 mm (ASTM Test Method)*[b] | |
| Stone crusher dust | 2.7 |
| Cement | 3.07 |
| Lime | 2.3 |
| Fly ash | 2.2 |
| (c) *Binder (BIS Test Method)*[c] | |
| Cationic Bitumen emulsion (65.4% Residual bitumen) | 1.01 |
| VG30 Bitumen | 1.01 |

[a] From BIS Test Method: IS 2386 (Part – III) [18].
[b] From ASTM Test Method: C188 [19].
[c] From BIS Test Method: IS 1202 [20].