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Characterization of Mastic Asphalt with Cold Mix

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Abstract— In the present study, an attempt has been made to use Cold Mix Technology as an alternative approach for preparation of Mastic Asphalt. Present work primarily aims to conduct a comparative study of Mastic Asphalt using hot mix as well as cold mix approach. In the present study 10/20 penetration grade bitumen has been used as binder for preparation of Mastic Asphalt in Hot Mix and Medium Setting (MS) emulsified bitumen has been used as binder for Mastic Asphalt in cold mix. Primarily the laboratory study has been conducted with recommended grading of coarse, fine aggregate and lime as filler in line with the provision of IRC: 107-2013 and MORTH specification for preparation of Mastic Asphalt with Hot mix Asphalt (HMA). Mastic Asphalt with Cold mix Asphalt (CMA) has been prepared with equivalent amount of emulsified bitumen corresponding to the bitumen taken for HMA Mastic with the same gradation and quantity of coarse & fine aggregate and lime as filler. The experimental results show that design binder content of Mastic Asphalt simply by replacing 10/20 Bitumen with equal amount of emulsified bitumen does not fulfill with the required parameters of relevant code guideline. Effort has also been made in this work to find out equivalent content of bitumen emulsion which will be effective as binder with respect to hot mix. Experimental results show that use of equivalent quantity of bitumen emulsion in cold mix for preparation of mastic asphalt does not yield desired hardness with respect to hot mix mastic with similar aggregate and filler quantity. However, replacement of lime as filler by cement has been found to be effective and satisfactory for preparation of Mastic Asphalt using CMA. It has also been found that the hardness number of such Mastic Asphalt using CMA increases with increase in curing period. The variation of hardness number with different filler content has also been studied in this work.

Index Terms—mastic asphalt; hardness number, bitumen emulsion, hot mix, cold mix.

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1 Introduction

Construction of new road and strengthening and widening of existing road are major thrust area in India in the area of its infrastructure development. Traditional materials and processes of road construction or repair presently involves large scale application of Hot mix asphalt with increasing level of green house gases, fumes and huge fuel consumption has raised serious question in sustainable development in road construction.

Flexible road pavement structure consists of multilayered system of granular materials, the stiffness of which reduces from top to bottom. The softest part of material in this system is soil sub grade, which rests at the bottom of pavement and the stiffest layer is the wearing course layer, which is directly subjected under the action of vehicle wheel load. The wearing course usually comprises bituminous mix with relatively high value of resilient modulus to withstand high abrasive forces developed during the acceleration or retardation of vehicles with huge axle loads. Therefore the design of such mix is done to satisfy the required stiffness and optimum permeability so that water on the top of pavement surface cannot percolate Through it , traditional bituminous mixes are hot mix in nature, which causes lot of energy and exits pollutants causes an environmental hazards for it production.

The word 'sustainable development' means the ability to make development to ensure the need of the present without compromising the ability of future. In this context, it's very much essential to develop a sustainable technology for road
In the present study, an attempt has been made to use Cold Mix Technology as an alternative approach for preparation of Mastic Asphalt. The work primarily aims to conduct a comparative study of Mastic Asphalt using hot mix as well as cold mix approach. The study includes 10/20 penetration grade bitumen as binder for preparation of Mastic Asphalt in Hot Mix and Medium Setting (MS) emulsified bitumen has been used as binder for Mastic Asphalt in cold mix. Primarily the laboratory study has been conducted with recommended grading of coarse, fine aggregate and lime as filler following the provision of IRC: 107-2013 [1] and MORTH [2] specification for preparation of Mastic Asphalt with Hot mix.Mastic Asphalt with Cold mix has been prepared with equivalent amount of emulsified bitumen corresponding to the bitumen taken for HMA Mastic and with the same gradation and quantity of coarse & fine aggregate and lime as filler.

2 LITARATURE REVIEW

During the last few decades the developments on the analysis of Cold Mixes Technology is notable and the related important works are briefly discussed in this section.

Thanaya (2002) [1] studied the performance of waste material incorporated Cold Bituminous Emulsion Mixtures (CBEM) to enhance the volumetric as well as mechanical properties. The cationic bitumen emulsion having 62 percent residual bitumen of 100 pen grade was used as binder. The aggregate gradation considered for the study was wearing coarse gradation which consists limestone, red porphyry sand a byproduct of stone crusher (waste material) and limestone filler. Void ratio was reduced to meet the desired viscosity by using medium to heavy compaction effort. It has been found from the study that 2% cement by weight of aggretgate will help to gain early strength and thereby increase in the stiffness of CBEM. It was suggested that, when CBEMs are carefully designed and are allowed to achieve a full curing condition; the performance of CBEMs can be comparable to hot asphalt mixtures with the same penetration grade binder. It also came out from the study that the CBEM can be carried out during dry season or summer.

Serfass et al (2004) .[2] observed the mechanical performance of two type's cold mix after curing it for diverse situation. Cold mixes were produced namely 0/10 mm dense graded asphalt concrete made of crushed gneiss with 5 percent of 70/100 residual bitumen and 0/14 mm grade emulsion, made of semi crushed alluvial aggregate and 4 percent of 70/100 residual bitumen. It was found that to get mature state of cold mix it should be cured for 14 days at 35°C and 20 percent Relative Humidity (RH).

Alvaro Garcıa, et al (2012) [3] found the effect of cement content and prevailing humidity on the performance of asphalt emulsion and cement composites.A dense asphalt concrete mixture was used in this study .The quarry materials as aggregates was used to make cold mix asphalt concrete. The findings revealed that, rigidity can be improved with the replacement of Portland cement as filler material with different curing environment. The basic limitation of these mix relate to duration of curing and preparation of mix.

S F Brown et al. [4] reported preparation of mix an improved understanding of the enhancement of stiffness modulus, permanent deformation resistance and fatigue strength of cement modified emulsion mixture. It can be further concluded that mechanical properties are comparable with equivalent hot mix, even at lower compaction level.

D.Kar (2012) [5] conducted laboratory study of bituminous mixes using a natural fiber with two type of mix namely Stone Mastic Asphalt (SMA) and Bituminous Concrete (BC). SMA and BC were prepared with 60/70 penetration grade bitumen as binder. A naturally available fiber called sisal fiber was used with varying concentration (0 to 0.5%). Optimum Bitumen Content (OBC) and Optimum Fiber Content (OFC) were found out by Marshall Method of mix design. Generally by adding 0.3% of fiber properties of mix was improved. From Drain down test, indirect tensile strength and static creep test it was concluded that SMA with using sisal fiber gives reasonable very good result and can be used in flexible pavement.

Anderson et al (1992) [6] used three types of polymers such as Neoprene, Styrene-Butadiene-Styrene (SBS) and Styrene-Butadiene-Rubber (SBR) to study the rheological properties of polymer modified asphalt emulsion residue. It was found that the polymer modification had little effect on the low temperature stiffness of the emulsion residue. It was concluded that some of the polymer modified emulsions slightly increase the consistency of the residue at high temperature.

F. Khodary et al (2013) [7] developed a new methodology to enhance physical, chemical, and rheological properties of Asphalt modifier in carriageway by introducing Nano size Cement Bypass. Experiments show that 15% of nano-sized cement bypass is the optimimum one to give the highest penetration, softening point and compressive strength in comparison to unmodified ahphalt mix.

MarekIwańskia et al (2014). [8] Studied with Foamed Bitumen Mixtures to enhance its mechanical properties by Cold recycling technology. The effect of, foamed bitumen and Portland cement as binding agent on Marshall Stability and resilient modulus were evaluated at 25°C. The detrimental effect of water was also measured by comparing indirect tensile strength both in soaked and unsoaked condition. It was reported that 2.5% of Foamed bitumen and 2.0% of Portland cement is optimum dose to achieve the required physical and mechanical properties and moisture resistance.

Serif Oruc et al (2006) .[9] studied the effect of cement on emulsified asphalt mixture. In their study, it was found that by adding OPC mechanical properties, resilient modulus, and susceptibility to temperature, creep, resistance to water damage and resistance to permanent deformatuion can be substantially increased.

Chavez Valencia et al. (2007) [10] showed compressive strength of cold mix asphalt can be substantially increased (31%) by using polyvinyl acetate in comparison with unmodified cold mix. In this study polyvinyl acetate emulsion was added to a quick set emulsified asphalt to obtain a modified asphalt emulsion.

Pundhir et al (2010) [11] studied the effect of OPC cement (2%) on SDBC with cold mix and compared the stability value at different curing conditions. The cold mix with cement showed higher stability value with respect to the specimen without cement.

AliAzhar Butt (2009) [12] studied low temperature performance of wax modified mastic asphalt. This study reveals that 4% Montan wax can improve the performance of modified mastic asphalt at low temperature. It was found that Wax modification has no negative effect on the storage stability as well as crack susceptibility.

3 MATERIAL

This chapter in three parts describes the experimental works carried out in present investigation. First part of the chapter deals with the gradation and experiments carried out on the materials, where as the second part deals with the preparation of mastic asphalt and its properties in Hot Mix and the third part deals with the preparation of mastic asphalt and its properties in Cold mix.

Materials Characteristics of each and every component leaves its imprint on the properties of asphaltic mix. In this backdrop, the materials used in the present study have been characterized using Indian Standard specifications as far as possible. However, specifications of other countries have been adopted only in cases where Indian guideline is unclear. For the present investigation, the following ingredients have been characterized.

(1) Coarse aggregate
(2) Fine aggregate
(3) Lime
(4) Cement

Coarse Aggregate

The characteristics of aggregate which is significant for producing bituminous mix are porosity, grading, moisture absorption, shape; crushing strength and the type of deleterious substance present (Mehta & Monteiro, 2006) [13]. These properties mainly depend on mineralogical composition of the parent rock, exposure condition and the type of equipment used for producing the aggregate.

The coarse aggregates used in this study are derived from a metamorphic rock named Amphibolites. The physical properties of coarse aggregate are given through table 1 to table 6. Since commercial aggregates vary in grading from batch to batch, a specific grading is fixed and followed throughout the experiment and presented below for coarse and fine aggregate.

Table 1: Grading of Coarse Aggregate for Mastic Asphalt.

Sieve Size	% passing				Limits as per table 500-40 of MORTH(5th revision)
	Sample 1	Sample 2	Sample 3	Average	
19	100	100	100	100	100
13.2	95.2	92.5	95.2	95.2	88-96
2.36	3.5	5.4	4.4	4.4	0-5

Table 2: Physical Requirements of Coarse Aggregates for Mastic Asphalt

Properties	Values (in %) as per IRC	Limits as per table 500-40 of MORTH(5th revision)
Los Angeles Abrasion Value	19.3	Max 40%
Aggregate Impact Value	10.8	Max 30%
Flakiness Index	28.3	Max 30%
Stripping Value	0.82	Min coating 95%
Water absorption	Nil	Max 2%

Table 3: Grading of Fine Aggregate for Mastic Asphalt (Inclusive of Filler)

IS sieve	65% of fine aggregate and 35% of lime	Limits as per table 500-41 of MORTH(5th revision)
Passing 2.36 mm but retained on 0.60 mm	24.8	0-25
Passing 0.60 mm but retained on 0.212 mm	19.5	10-30
Passing 0.212 mm but retained on 0.075mm	15.3	10-30
Passing 0.075 mm*	40.4	30-55

Table 4: Grading of Filler.

Sieve Size	% retained			
	Sample 1	Sample 2	Sample 3	Average
0.212mm	00	00	00	00
0.075mm	12.2	11.8	10.5	11.5
Passing 0.075mm*	87.9	88.3	89.5	88.56

Table 5: Physical Properties of Bitumen used for Mastic Asphalt

Specification	Test Result		
	Industrial grade bitumen	VG 30	Requirement as per IS Specification
Penetration at 25°C	10	60	20/40
Softening Point	85°	47°C	50°C to 90°C
Ductility at 25°C	3	100	10
Loss on Heating	1%	<1%	1%

Table 6: Requirements for physical properties of binder in mastic asphalt

Property	Requirement	
Penetration 25°C	IS: 1203	15±5
Softening Point °C	IS: 1205	65±10
Loss on heating for 5h at 163°C, per cent by mass	IS: 1212	Max 2.0
Solubility in trichloroethylene, per cent by mass	IS: 1216	Min 95
Ash (Mineral Matter), per cent by mass	IS: 1217	Max 1.0

4 EXPERIMENTAL PROGRAM

Trial-1

Initially hot mix mastic asphalt specimen has been prepared as reference material in this study with recommended material composition which is presented through table 1 to table 11.

The mix was prepared following the recommendations as stated in IRC: 107-2013. The bitumen content for preparation of mix during present investigation was ranged between 14% -17% After heating and mixing the above mix for some time, the fine aggregate and bitumen are added and further cooked at a temperature of 180-200 C for one hour. After cooking the mix, the required quantity of coarse aggregate was added in the mix for further cooking at same temperature to get a homogenous mix. Base mastic of Mastic asphalt comprises fine aggregate, filler and binder which are shown through table 1 to table 10.In Mastic asphalt with hot mix, the proportion of Base mastic and Coarse aggregate by weight was 60: 40. Therefore bitumen content equal to 15% weight of base mastic has been considered as design binder content in this section, which in other way means a binder content of 9% of total weight of mix. The results of hardness test conducted on those hot mix mastic asphalt specimens using Mastic Asphalt tester machine have been presented in table 9.

Trial 2.

The same gradation of aggregates in preparing hot mix mastic asphalt has been used for preparation of cold mix mastic asphalt. The process of sample preparation was done following the guide-

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line of IRC: SP 100-2014 [14]. Initially the filler, fine aggregate and 2.5% pre wetting water is added and mixed for one minute to get maximum aggregate coated with water. The quantity of binder in the form of Bitumen emulsion remained same with respect to the bitumen used in preparation of hot mix mastic asphalt. The bitumen emulsion and the wet aggregate was mixed for 1-2 minutes for achieving uniform binder coating and a homogeneous mixture.

The experimental program conducted in the laboratory may be illustrated with the following block diagram.

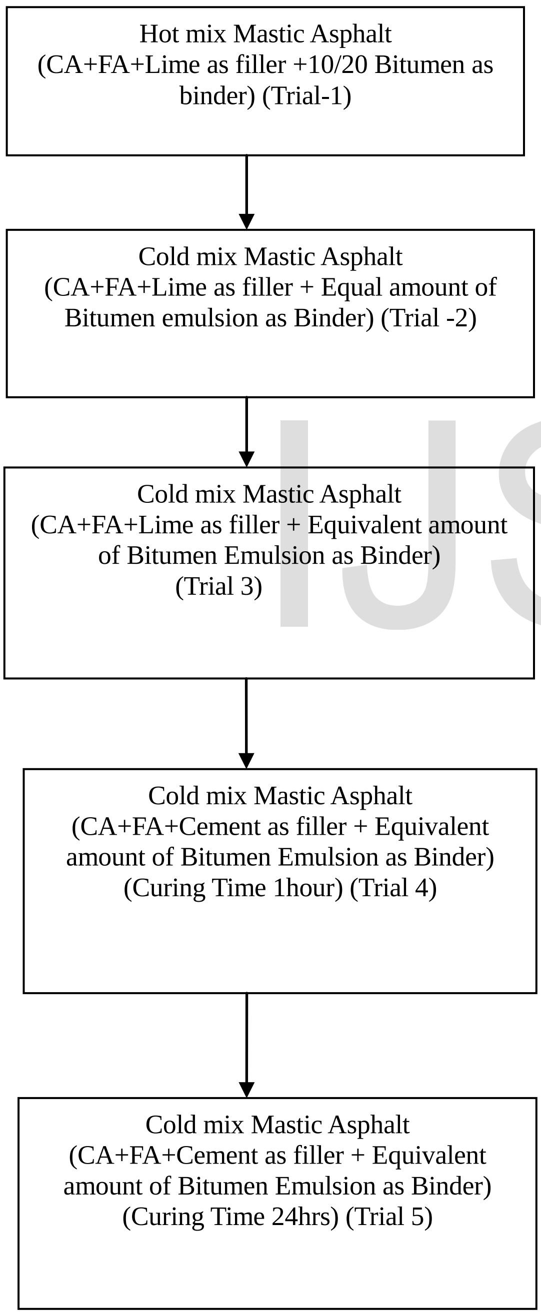

Figure 1. Flow chart of Experimental Program.

Then the Cold mix is poured in to the mould of 100 mm diameter up to a thickness of 25 mm. Specimens were then air dried for 1 hour using fan in room temperature of 28 C and oven dried at 35 C for two hours before placing in Mastic Asphalt tester machine for determination of hardness number. Five type's specimens with varying emulsion contents of 14.5%, 14.7%, 14.9%, 15.0%, and 15.5% weight of base mastic were used for trial in this section. The results obtained for the respective specimens of cold mix mastic asphalt have been presented in Figure 4. It is evident from the hardness number obtained for different specimens that the present mix does not seem to be an alternative of hot mix mastic asphalt for laying in wearing coarse.

Trial 3.

In trial 3, gradation of coarse aggregate, fine aggregate and filler material are kept unchanged. The process of sample preparation of samples was done following the guideline of IRC: SP100-2014 [14]. Initially the filler , fine aggregate and 2.5% pre wetting water are added and mixed it for one minute to get maximum aggregate coated with water there after equivalent quantity of Emulsified Bitumen(MS) was added and mixed it thoroughly for 1-2 minute for achieving uniform binder coating and a homogeneous mixture.

Figure 2. Air curing of Cold Mix

The equivalent quantity of Emulsified bitumen in this paper has been defined as the effective bitumen content in a bitumen emulsion having the proportion of bitumen and emulsifier as 60:40. The Cold Mix is thus prepared was poured in to the mould of 100 mm dia up to a thickness of 25 mm. Specimens of different bitumen contents thus prepared were air dried for 1 hour using air blower and oven dried for 2 hours at 35^0 C temperature before placing in the Mastic Asphalt tester machine for determination of Hardness number. The values of Hardness number obtained on the cold mix mastic asphalt specimen with different bitumen content based on equivalence criteria are presented in figure 5.It is relevant to mention that the strength of mix thus prepared for mastic asphalt also does not comply with the required hardness number.

Figure 3. Mastic Asphalt Test Machine with Specimen

Trial 4.

In this case the same gradation of coarse aggregate, and fine aggregate was taken but filler material was replaced by Portland Pozzolona Cement (PPC) conforming to IS-1489 (Part-I) [15]. The process of sample preparation was done following the guide-line of IRC: SP100-2014. At first pre-wetting water of 2.5% was added in to the mixture of coarse aggregate and fine aggregate and mixed it for two minutes to get maximum aggregate coated with water and then half the required quantity of Emulsified Bitumen (MS) measured in the form of equivalent binder content was mixed thoroughly for 1-2 minute. Cement as filler and remaining quantity of Emulsified Bitumen were then added and mixed for 5 minutes to get uniform binder coating and a homogeneous mix-ture. The mixture thus prepared was poured in to the mould of 100 mm dia up to a thickness of 25 mm. and temped with flat ended 12mm dia of rod to compact. Specimen air dried for 1 hour using blower in room temperature at 28C before placing to the Mastic Asphalt tester machine for determination of hardness num-ber. The values of hardness number obtained after one hour and 24 hour curing the sample in air have been presented in Figure 6 and Figure7 respectively.

5 RESULTS AND DISCUSSION

It has been observed that the mix prepared using cold mix with emulsified bitumen content simply by substituting the cut back bitumen percentage with bitumen emulsion does not comply with requirement of Mastic asphalt in terms of its hardness and there-fore cannot be treated suitable for roadwork. The higher percen-tage of bitumen from 14.5% to 15.0% reduces the hardness num-ber from 201 to 190. However, further increase in bitumen content reduces the rate of change in hardness number. The higher pene-tration of the needle in the hardness test shows that poor strength of the mix due to lack of effective binder to be present in the mix with comparable quantity and gradation of aggregates and filler in hot mix. The inadequacy of the binder content as revealed in this section can be removed if the effective bitumen content present in bitumen emulsion can be determined and added in the mix.

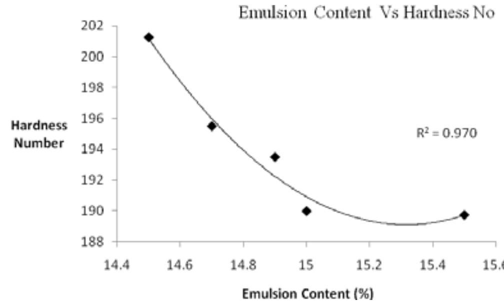

Figure 4. Variation of Hardness Number with Varying % of Emulsion Content

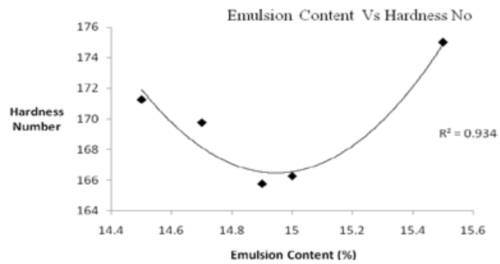

Figure 5. Variation of Hardness Number with Varying % of Emulsion Content

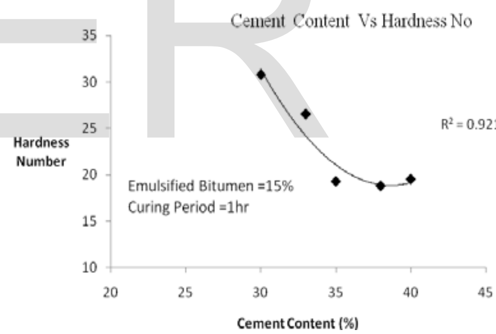

Figure 6. Variation of Hardness Number with different percentage of Cement Content as filler

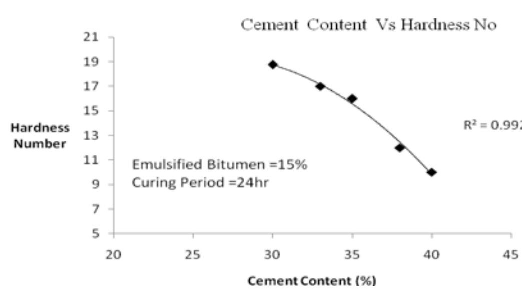

Figure 7. Variation of Hardness Number with different percentage of Cement Content as filler

In order to do so equivalent quantity of binder was used in trial -2. The equivalent quantity of bitumen content of Emulsified bitumen has been defined as the effective bitumen content in a bitumen

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emulsion having the proportion of bitumen and emulsifier as 60:40. Enhancement of quantity of emulsified bitumen in the form of equivalent bitumen has been used in trial-2 samples and results of hardness numbers are reported in figure 5. It is evident from such variation that the cold mix mastic asphalt prepared with equivalent quantity of emulsified bitumen fails to conform requirement of hardness of hot mix asphalt. The major reason of poor performance of the mix was due to presence of lime as a filler, which in presence of more water in emulsifier bitumen reacts and forms hydroxides of calcium thereby reducing in strength of the mix. It is interesting to note that the average value of reduction in hardness number using equivalent quantity of binder with respect to binder used in trial-1, is in the range of 10%. The highest reduction in hardness number was observed as 14.9% for the binder content of 14.5% and the lowest reduction was observed as 7.4% corresponding to the binder content of 15.5%.

In order to overcome the limitation of lime as a filler in cold mix, use of Portland Pozzolona Cement (PPC) conforming to IS-1489 (Part-I) was explored in this study. The results are presented in figure 6. and figure 7. For samples prepared with PPC as filler by replacing lime shows reasonable good performance of mix with respect to hot mix mastic asphalt. It has been observed that increase in cement content as filler from 30% to 35% , the value of hardness number decreased 37.4% but further increase in cement content the performance of mix does not improve much, thereby pointing out an optimum dose of cement as filler at this stage. It has further been observed that hardness number decreases with the increase in curing period in air for different cement content. This change can be explained with the reaction time of cement with water, which comes from break of emulsion structure during its final setting time period. It can be concluded from the study that 35.0% filler as PPC may be considered as an optimum binder content for preparation of mastic asphalt using cold mix with medium setting emulsified bitumen.

6 CONCLUSION

It can be concluded from the present study that, design of Mastic asphalt cannot be done simply by substituting the bitumen required for hot mix by emulsified bitumen. The bitumen content required for preparation of cold mix shall be based on the concept of equivalent binder quantity for a specific ratio of water and bitumen, as defined in this paper. Lime as a filler in cold mix does not exhibit desired performance in terms of hardness of the mix. Present investigation recommends use of PPC as substitutions of lime as filler in cold mix. The results show that the hardness number of mastic asphalt mix with curing time in air thereby indicating gain in strength of the mix.

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