iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 10 **Issue:** VI **Month of publication:** June 2022

DOI: https://doi.org/10.22214/ijraset.2022.43697

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue VI June 2022- Available at www.ijraset.com

Experimental Evaluation on the Performance of Cold Mix Asphalt in Comparison with Hot Mix Asphalt for BC Layer

SantoshKumar[1], Ramesh B[2], Nagesh S[3], Panduranga B[4], Hariprasad G[5]
[1,2,3,4,]*Assistant Professor, Department of Civil Engineering, Navodaya Institute of Technology-Raichur-584103-India*
[5]*BE Civil Engineering, Navodaya Institute of Technology-Raichur-584103-India*

Abstract— Hot Mix Technology is used from many years in the construction of bituminous layer. It basically involves heating of aggregates and bitumen, mixing and laying of the mixture at a high temperature around 120°C - 165°C. Though it is well suited for all the types of roads because of its good performance, it has several dis-advantages such as degradation of environment, it consumes lot of energy, problems due to hardening of asphalt, and it cannot be laid in cold region and during rainfall season. There is an increasing demand for the Cold Mix Asphalt (CMA) due to its several advantages and also it is gaining importance nowadays specially in the cold areas. The main advantage is the elimination of heating of aggregates and bitumen; instead emulsion can be used in producing the bituminous mix. Also, Cold Mix Asphalt is eco-friendly and consumes less energy. In the present study, the main objective is to check the feasibility of cold mix asphalt for Bituminous Concrete layer. For Cold Mix Asphalt bitumen emulsion of grade SS-2 is used. The Marshall Test is carried out on CMA and Hot Mix Asphalt (HMA) by varying bitumen emulsion and bitumen content respectively.. The results obtained are comparable with Hot Mix Asphalt. Hence Cold Mix Asphalt is feasible for BC layer.
Keywords— Cold Mix Asphalt; Hot Mix Asphalt; Marshal Test; BC Layer; Emulsion;

I. INRODUCTION

In India, the main utilization of bitumen emulsion was found in the 1970s. The whole world utilized 12 million tons of emulsion mid-seventies, India devoured just 20,000 tons till 1996, out of the aggregate bitumen utilization of around 2 million tons. After 2005 there has been an unfaltering ascent in the utilization and request of bitumen emulsions. At exhibit, for all intents and purposes all the street development and upkeep necessities can be met with the utilization of bitumen emulsion. Prudent choice and fitting utilization of these innovations can yield huge economies, natural advantages and vitality security to the extent development and upkeep of streets are concerned. Many field trials and research work led from Central Road Research Establishment (CRRI) and other oil organizations on cold mix blend advances under various movements furthermore, climatic conditions have been observed to be empowering.

Cold mix is produced at ambient temperature (23°C to 25°C). It can be prepared in concrete or in the cold mix plant. In northern part of India, it has many weather restrictions. Also in hilly areas and in the areas where there is always heavy rainfall. In the states like Jammu and Kashmir, Assam, Manipur, Meghalaya and Arunachal Pradesh it very difficult to adopt hot mix technology. In such places cold mix technology can be used. Cold mix is beneficial in the construction of rural roads and also in case of high altitudes because hot mix requires heating of mixture at high temperature. Also in case of construction of rural roads it is difficult to maintain the temperature if the construction site is distance is greater. Simple concrete mixers can be used to produce cold mix and they can be even laid by small scale jobs. Due to all these reasons cold mix is gaining importance. Cold mix is beneficial in the construction of rural roads and also in case of high altitudes because hot mix requires heating of mixture at high temperature. Also in case of construction of rural roads it is difficult to maintain the temperature if the construction site is distance is greater. Simple concrete mixers can be used to produce cold mix and they can be even laid by small scale jobs. Due to all these reasons cold mix is gaining importance. In cold mix technology, emulsion and pre-wetting water content is added to aggregates. It's mixing, its production and its laying everything is done at ambient temperature i.e. 23°C to 25°C. Also it can be produced and laid in hot mix asphalt plant due to its similar techniques. It is also friendly technique for the labours.

II. SCOPE AND OBJECTIVES OF THE STUDY

The aim of the present work is to study the Experimental Evaluation on the Performance of Cold Mix Asphalt in comparison with Hot Mix Asphalt and check the feasibility of cold mix for BC layer. Following are some of the objectives of the present work.

A. Laboratory evaluation of aggregates and bitumen emulsion for determination of physical and mechanical properties.

B. To arrive at the mix design of Cold mix asphalt (IRC:SP: 100) and Hot mix asphalt (MoRTH).

C. To test the behavior of Cold Mix Asphalt and Hot Mix Asphalt through Marshall Test.

D. To check the feasibility of Cold Mix Asphalt for BC layer.

III. MATERIALS USED IN THIS STUDY

Aggregates used in this study were procured from a quarry Bidadi road Bengaluru. Physical properties of aggregates were tested as per specified test procedure. Aggregates were graded as per the gradation requirement for BC grade 1 according to MoRTH (2013). Aggregates of size 20mm, 12mm, 6mm, dust and filler materials were used. Final mix proportion obtained is 24%, 25%, 24%, 25% and 2% of 20mm down, 12mm down, 6mm down, dust and filler respectively. In the present study cement of the grade OPC-43 was used as filler material. Bitumen of grade VG-30 was used in the present study for the preparation of hot mix asphalt. Bitumen VG-30 was procured from Civil Aid. Bitumen emulsion of the grade SS-2 cationic type was used for the preparation of cold mix asphalt. Emulsion was procured from HINCOL Company. Test on emulsion was carried out in accordance with IS: 8887. Properties of aggregates, bitumen VG-30 and bitumen emulsion is shown in the table 1, 2 and 3 respectively.

TABLE 1: PROPERTIES OF AGGREGATES

Properties Tested	**Test results on Aggregates**	**MoRTH Specifications clause table 500-16**	**Test conduction as per**
Aggregate impact value	26.15%	27%max	IS 2386(Part 4)
Specific Gravity of Coarse aggregate & Fine Aggregate	2.58 & 2.52	2.5-3	IS 2386(Part 2)
Elongation and Flakiness index	26.6%	35%max	IS 2386(Part 1)
Water Absorption	0.86%	2%max	IS 2386(Part 3)

TABLE 2: PROPERTIES OF VG-30

Sl.no	**Characteristics**	**Results**	**Requirements**	**BIS specifications**
1	Specific gravity	0.998	0.97-1.02	IS 1208-1978
2	Softening point	49 ° C	47°C(min)	IS1230-1978 R1988
3	Ductility test	72.5cm	75cm(min)	IS 1208-1978
4	Penetration test	67mm	60 (min.)	IS1230-1978 R1990
5	Viscosity test	9 seconds	-	IS 1206 1978 R 1988

TABLE 3: PROPERTIES OF BITUMEN EMULSION

Sl.no	**Characteristics**	**Results**	**Requirements of Slow Setting – 2 as per IS: 8887**
1	Residue on 600-micron IS Sieve (Percentage by mass)	0.035	0.05 (max.)
2	Viscosity by Say bolt Furol Viscometer, seconds at 25ºC	48	30 – 150
3	Storage Stability after 24 hrs, %	0.34	2 (max.)
4	Test on Residue		
	a) Residue by Evaporation, %	62	60 (min.)
	b) Penetration 25 ºC/100g/5sec	70	60 – 120
	c) Ductility 27 ºC/cm	88	50 (min)

IV. MIX DESIGN

Marshall Test is conducted to find out optimum bitumen emulsion content and optimum bitumen content. The mix design procedure for cold mix and hot mix is explained below.

A. Cold Mix Design

The design procedure is followed as mentioned in IRC: SP-100. Following steps are followed for the preparation of cold mix specimens.

1) Determination of Initial Bitumen Emulsion

For the calculation of Initial Bitumen emulsion following equation 1 is used. Purpose of calculating initial bitumen emulsion is to find out optimum pre-wetting water content.

$P = 0.05A+0.1B+0.5C$ Eq (1)

P= the quantity of bitumen emulsion (%)

A= the percent of Aggregate retained on the 2.36mm sieve.

B= the percent of aggregate passing through 2.36mm sieve and retained on the 90-micron sieve.

C= Percent Aggregate passing through the 90-micron sieve.

2) Determination of Optimum Pre-Wetting Water content

The Initial bitumen emulsion content calculated from equation 1 is kept constant and water content is varied from 2% to 4% with difference of 1%. Specimens are prepared with the water content 2%, 3% and 4% and calculated initial bitumen emulsion content. Densities of all the specimens are checked. The specimen which gives maximum density that water content is chosen. This per-wetting water content is kept constant for the calculation of optimum bitumen emulsion content.

3) Variation of Bitumen Emulsion content

Around 1200 gm of graded aggregates are taken and are mixed with optimum pre-wetting water content for about 1-2 minutes. Emulsion content are varied from 6% to 10%. For each % of bitumen emulsion three trial specimens are prepared. After mixing with optimum pre-wetting water content bitumen emulsion is added and is mixed thoroughly so that all the aggregates are coated with emulsion. The mixture is left for drying under fan for 2 hours and in oven at 40°C for further 2 hours. After drying the mixture is transferred to Marshall mould and is compacted with 50 blows on both the sides. After compacting the specimen is left in the mould for 24 hours. Next day the specimen is extruded from the mould. After demoulding the specimen is kept for 3 days for curing, 24 hours in oven at 40°C and last 48 hours it is cured in air at room temperature. After curing specimens are subjected for testing in Marshall Apparatus to determine the bulk density, stability and flow value of dry specimens and wet specimens. For dry stability, specimens after curing is directly subjected to testing. For wet stability specimens before testing are conditioned under vacuum pressure for one hour and are subsequently immersed in water for further one hour at room temperature.

Below table 4 shows the Marshall Test results of dry specimens. From the Marshall results graphs are plotted between Stability Vs Bitumen emulsion, Flow Vs Bitumen emulsion, Density Vs Bitumen emulsion, Air voids Vs Bitumen emulsion and VFB Vs Bitumen emulsion to find out the Optimum Emulsion content.

Figure 1, figure 2, figure 3 and figure 4 shows the graphical representation between the Stability Vs Bitumen emulsion, Flow Vs Bitumen emulsion, Density Vs. Bitumen emulsion and Air voids Vs Bitumen emulsion respectively. From all the graph optimum emulsion is chosen 8%.

TABLE 4: MARSHALL TEST RESULTS OF CMA (DRY SPECIMENS)

Emulsion (%)	**Gb (g/cc)**	**Gt (g/cc)**	**Vv (%)**	**Vb (%)**	**VMA (%)**	**VFB (%)**	**Stability (kg)**	**Flow (mm)**
6%	2.28	2.50	8.8	13.5	22.42	60.5	1144	2.2
7%	2.31	2.47	6.3	16.0	22.44	71.5	1489.7	3.2
8%	2.34	2.44	4.0	18.5	22.61	82.0	1584.9	3.36
9%	2.32	2.40	3.6	20.6	24.32	85.0	1428.5	4.233
10%	2.29	2.37	3.4	22.7	26.19	86.8	1387.7	4.5

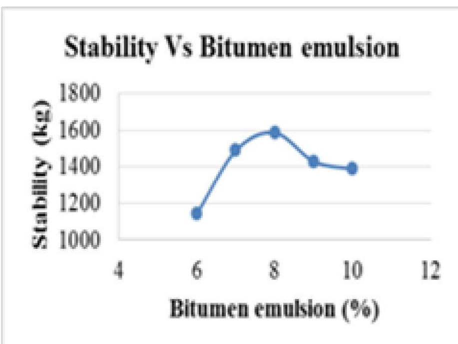

Fig. 1: Stability Vs Emulsion (Dryspecimen)

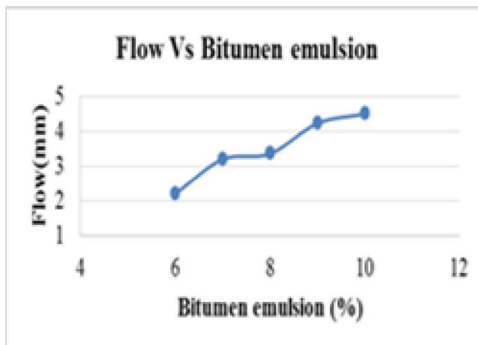

Fig. 2: Flow Vs Emulsion (Dryspecimen)

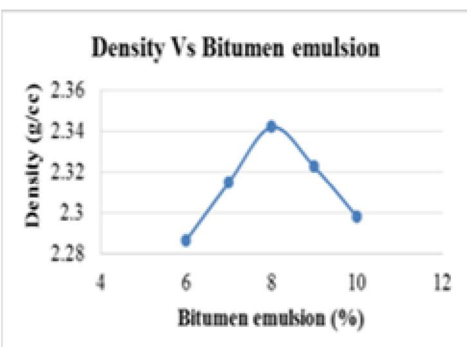

Fig. 3: Density Vs Emulsion (Dryspecimen

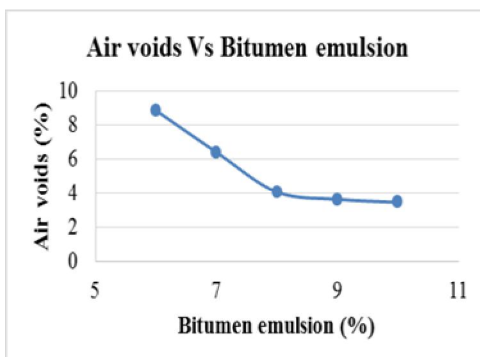

Fig. 4: Air Voids Vs Bitumen (Dry specimen)

Below table 5 shows the results of Marshall Stability of wet specimens. From the Marshall results graphs are plotted between

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ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
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Stability Vs Bitumen emulsion, Flow Vs Bitumen emulsion, Density Vs Bitumen emulsion, Air voids Vs Bitumen emulsion and VFB Vs Bitumen emulsion to find out Optimum Emulsion content.Figure 5, figure 6, figure 7 and figure 8 shows the graphical representation between the Stability Vs Bitum enemulsion, Flow Vs Bitumen emulsion, Density Vs. Bitumen emulsion and Air voids Vs Bitumen emulsion respectively. From all the graph optimum emulsion is **8%**

TABLE 5: MARSHALL TEST RESULTS OF CMA (WET SPECIMENS)

Emulsion (%)	**Gb (g/cc)**	**Gt (g/cc)**	**Vv (%)**	**Vb (%)**	**VMA (%)**	**VFB (%)**	**Stability(kg)**	**Flow (mm)**
6%	2.27	2.50	9.36	13.5	22.8	59.0	1540.6	2.1
7%	2.31	2.47	6.27	16.0	22.3	71.9	1756.8	2.73
8%	2.32	2.44	4.72	18.4	23.1	79.5	1868.9	3.1
9%	2.31	2.40	3.78	20.6	24.4	84.5	1855.2	4.56
10%	2.29	2.37	3.38	22.7	26.1	87.0	1584.4	4.68

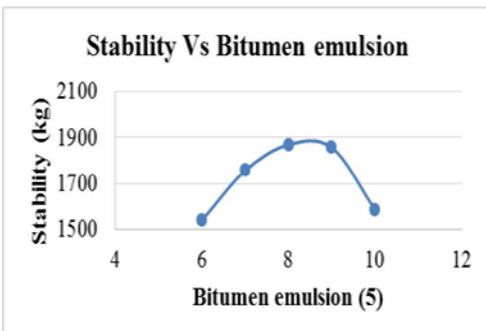

Fig. 5: Stability Vs Emulsion (Wetspecimen)

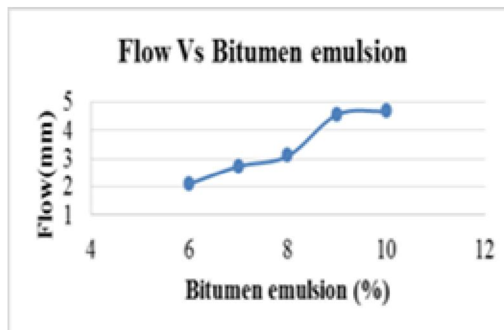

Fig. 6: Flow Vs Emulsion (Wetspecimen)

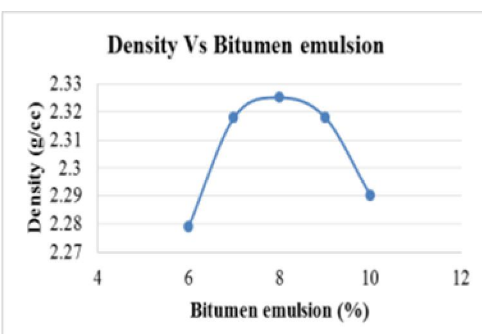

Fig. 7: Density Vs Emulsion (Wet specimen)

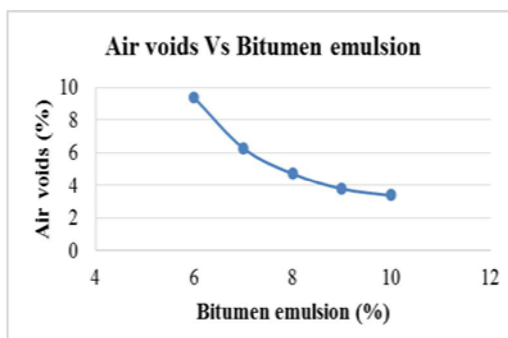

Fig. 8: Air Voids Vs Bitumen (Wetspecimen)

B. Hot Mix Design

The design procedure is followed as mentioned in MoRTH (2013). Following steps are followed for the preparation of hot mix specimens. 1200 gm of graded aggregates are taken and heated at 175°C, bitumen content is varied from 5%, 5.5%, 6%, 6.5% and 7%. Moulds are preheated at 95 °C to 100°C temperature. After heating the aggregates bitumen is added and is mixed with aggregate. Mixing is continued till the temperature reaches to 160°C. After mixing, the mixture is transferred to Marshall mould and is tamped 75 times on both sides. The specimen is left in mould for 24 hours and is extruded from the mould the next day. Specimens after de- moulding are subjected to Marshall testing. Before testing specimens are kept in water bath at 60°C for 45 minutes. Bulk density, stability and flow value are found out. Graphs are plotted and optimum bitumen content is found out from graphs. Test results are tabulated in the table 6 below. From the Marshall results graphs are plotted between Stability Vs Bitumen content, Flow Vs Bitumen content, Density Vs Bitumen content, Air voids Vs Bitumen content and VFB Vs Bitumen content to find out Optimum Bitumen content. Figure 09, figure 10, figure 11, and figure 12 shows the graphical representation between the Stability Vs Bitumen content, Flow Vs Bitumen content, Density Vs. Bitumen content and Air voids Vs Bitumen content respectively.

TABLE 4: MARSHALL TEST RESULTS OF HMA

Bitumen (%)	Gb (g/cc)	Gt (g/cc)	Vv (%)	Vb (%)	VMA (%)	VFB (%)	Stability(kg)	Flow (mm)
5	2.38	2.54	6.34	11.7	18.1	65.03	1018.7	2.54
5.5	2.39	2.52	5.09	13.0	18.1	71.92	1209.6	3.42
6	2.40	2.50	3.96	14.3	18.2	78.30	1231.6	3.60
6.5	2.37	2.49	3.52	15.3	18.8	81.25	1099.9	3.80
7	2.36	2.47	2.27	16.3	19.6	83.32	944.63	4.54

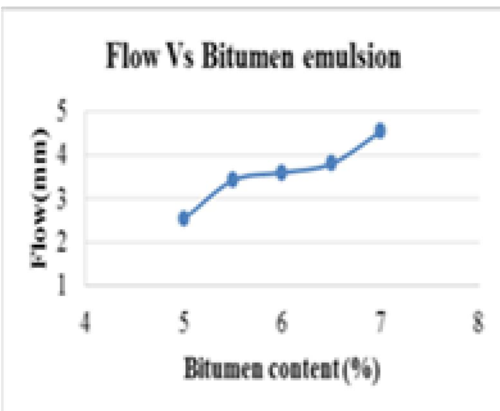

Fig. 9: Stability Vs Bitumen

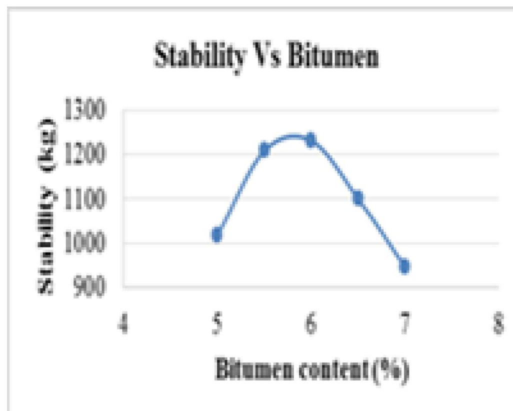

Fig. 10: Flow Vs Bitumen

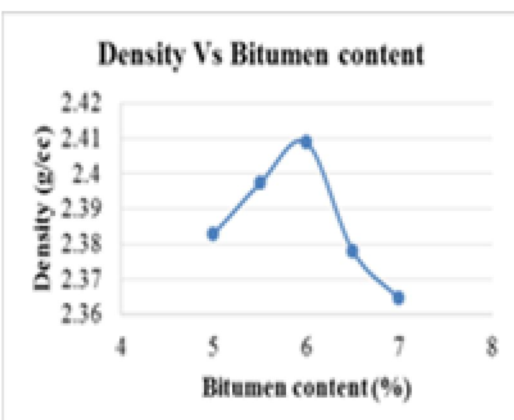

Fig. 11: Density Vs Bitumen

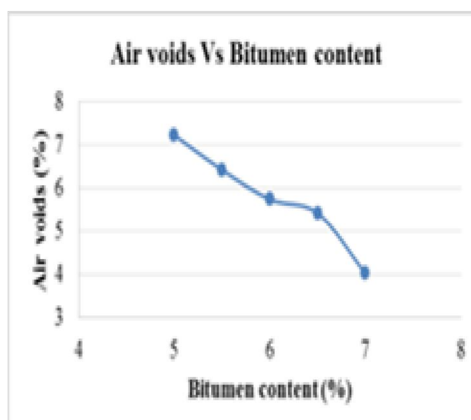

Fig. 12: Air Voids Vs Bitumen

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V. RESULTS AND DISCUSSION

Tests were conducted on both CMA and HMA. The results of the tests conducted on both are compared below. Fig. 13 shows the comparison of stability values between CMA and HMA. The stability of CMA is found greater than the stability of HMA. Fig. 14 shows the comparison of flow values between CMA and HMA. The deformation of HMA is more in comparison with CMA. Fig. 15 indicates the comparison between CMA and HMA. Form the figure it is seen that the density of cold mix asphalt is less than the density of hot mix asphalt. Fig. 16 shows the comparison of Air Voids between CMA and HMA. Air voids of HMA are more than CMA. The range of air voids according to MoRTH specifications is 3- 5%; cold mix asphalt is within the specified range.

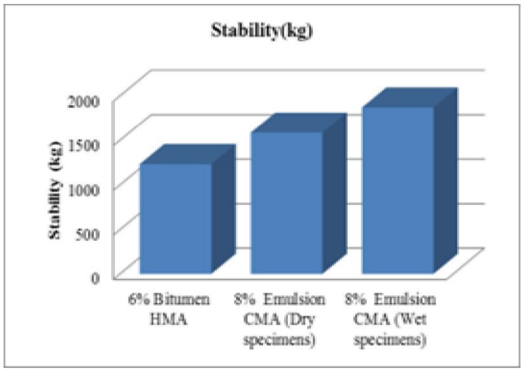

Fig. 13: Comparison of Stability between HMA and CMA

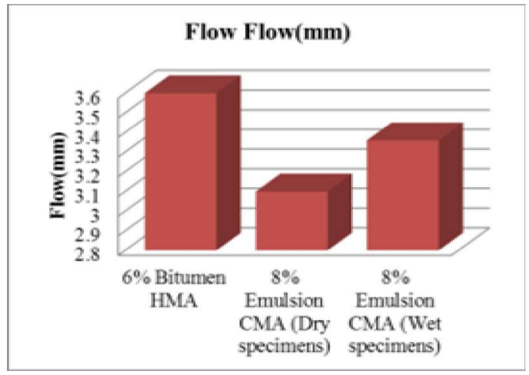

Fig. 14: Comparison of Flow between HMA and CMA

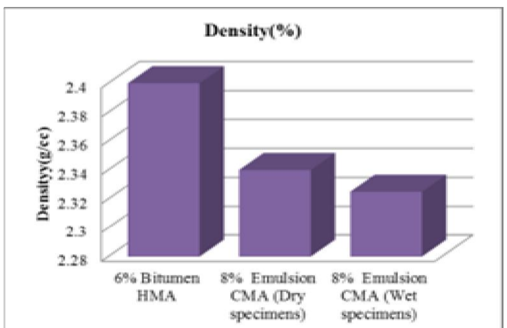

Fig. 15: Comparison of Density between HMA and CMA

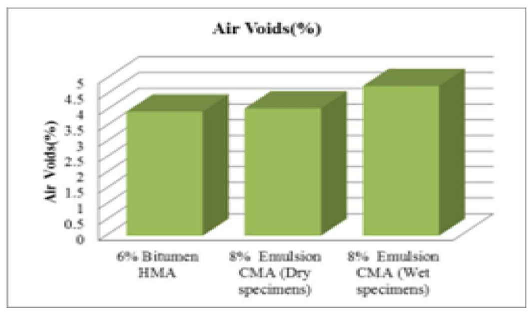

Fig. 16: Comparison of Air Voids between HMA and CMA

VI. CONCLUSIONS

The study was conducted on the experimental evaluation on the performance of CMA and HMA. Various tests were conducted and conclusions are drawn. It was seen that cold mix asphalt has met all the requirements that are required for bituminous concrete layer.

Following are the some of the conclusions drawn from thisexperimental study.

A. Physical properties of Aggregates, bitumen emulsion and bitumen used in this experimental study were within the specifications mentioned.
B. Material gradation obtained has met the specifications given by MORTH clause table 500-17.
C. Results of Marshall Stability of cold mix asphalt were found 34.09% greater than hot mix asphalt.
D. Flow value of cold mix asphalt was found within the specified range. Deformation of cold mix asphalt was found 13.87% less than hot mix asphalt.
E. Density of cold mix asphalt was found 3.12% less than hot mix asphalt.
F. For 8% optimum emulsion content the air voids obtained is between 3-5%. Hence cold mix has met the air voids requirement given by the MORTH specifications.

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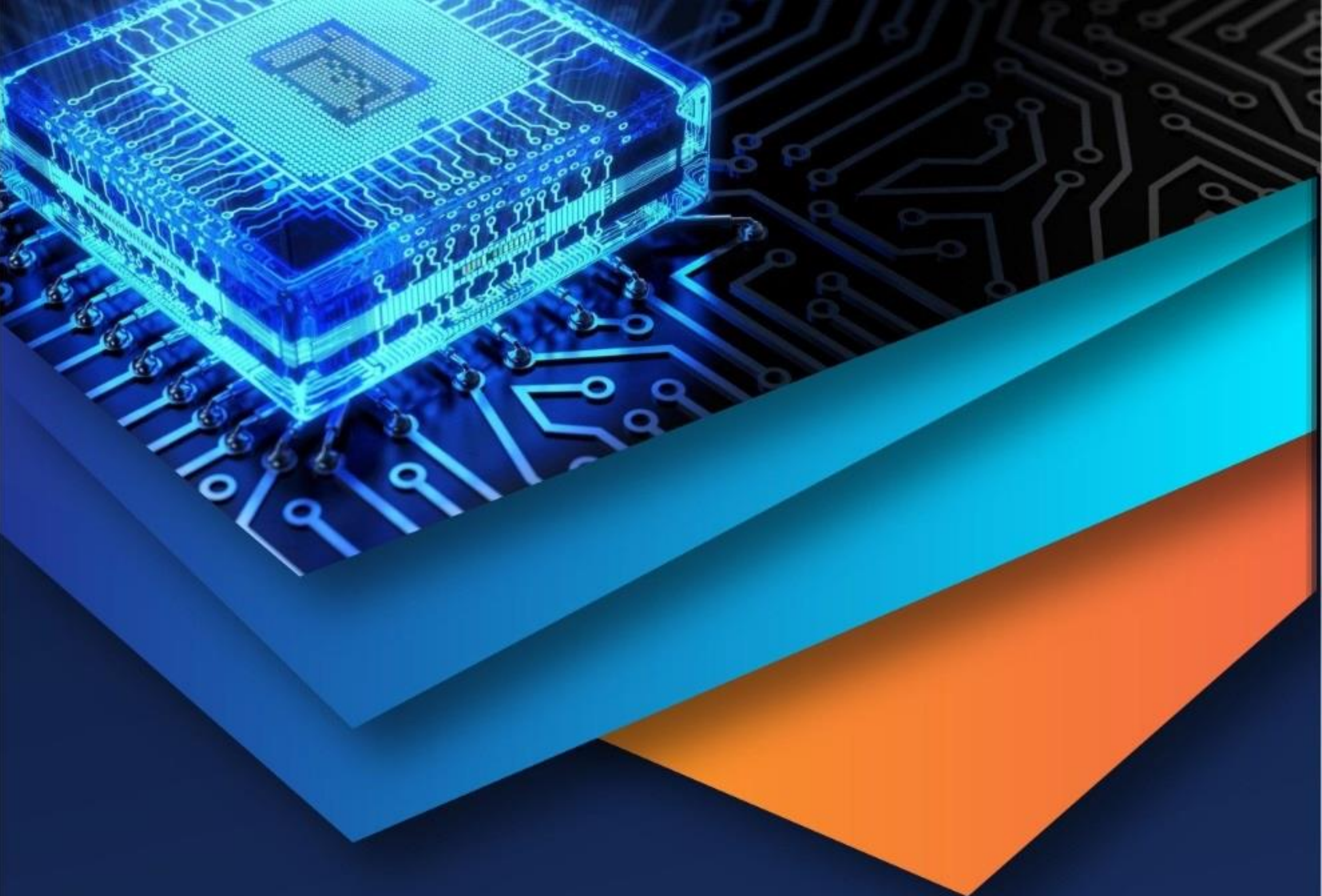

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