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PERFORMANCE EVALUATION OF COLD BITUMINOUS MIX REINFORCED WITH COIR FIBRE

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ABSTRACT

In India, the flexible pavements acquire most of the total road network. Hot mix technology has numerous drawbacks. Some of them are the liberation of greenhouse gases, high consumption of energy, health hazards to construction labours, etc. Hence, the adoption of alternative technology such as cold mix technology is needed to reduce the drawbacks of hot mix technology. Cold Bituminous Mix (CBM) is defined as a mixture of bitumen emulsion and aggregate that is mixed together at ambient temperature. The cold bituminous mix is useful in areas, where there is a long distance between the job site and plant and temperature of climate is low and moderate. Cold mix can be mixed in-place at the job site as well as at a plant site and subsequently transported to the job site.

Compared to hot bituminous mixes, fewer studies have been done to ascertain the effect of fibre on the performance of cold bituminous mixes. This study aims to assess the performance of CBM by adding a natural fibre (coir), which is abundant and cheaper in India. The objectives of the study are to identify the Optimum Emulsion Content (OEC) for selected aggregate gradation, to identify the optimum length and optimum content of coir fibre for selected aggregate gradation, to evaluate the performance of CBM with and without coir fibre in terms of moisture susceptibility and rutting resistance and to compare the conventional CBM with CBM containing coir fibre.

In this study, aggregate gradation was taken based on the Nominal Maximum Particle Size (NMPS) 13.2 mm from Ministry of Road Transport and Highways (MORTH) specification (2013). In the present study, an attempt has been made to study the effect of coir fibre used as an additive in CBM. Bitumen emulsion content is varied from 7% to 9%, and fibre content is varied from 0.1% to 0.3%. The fibre length varied from 10 mm to 20 mm. The study methodology includes characterization of aggregates and emulsion, determination of pre-wetting water content, mix design by Marshall Stability test, performance evaluation of cold bituminous mix with and without coir fibre by Retained Marshall Stability test and rutting test by using Hamburg wheel tracking device.

Marshall Specimens are prepared for NMPS 13.2 mm gradation with and without coir fibre. Based on the results, Optimum Emulsion Content is 8%. Coir fibre free from moisture is added to the aggregates in a dry process to achieve homogeneity in dispersion and avoid the balling problem. Marshall parameters like Marshall stability, Flow value, Bulk density, Air voids, Voids filled with bitumen (VFB), Voids in mineral aggregates (VMA) were found out. When coir fibre is added to the mix, Marshall Stability was observed to be increased up to a certain level of coir fibre percentage. Maximum Marshall Stability is observed at 0.2% of 15 mm length coir fibre.

Retained Marshall Stability Test is also conducted on conditioned and unconditioned

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samples prepared with and without coir fibre to assess the resistance to moisture damage. It is observed that the addition of coir fibre had improved Retained Marshall Stability value. Rutting resistance is studied by conducting wheel tracking test with and without fibre. Rutting resistance of the mix is improving with the addition of coir fibre when compared to conventional mix.
Keywords: Cold bituminous mix, coir fibre, Nominal maximum particle size.

I.INTRODUCTION

1.1 GENERAL

From many decades in road construction, the hot bituminous mix is used predominantly as a paving mix. Over many years, hot mix technology is a conventional road construction method, which met the performance requirements structurally. Only bituminous pavements occupy nearly 90% of the road network in India (IRC: SP: 100-2014). 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 all are done at high temperature at a range from 120˚C to 165˚C. Although this method was the most suitable for pavement structures, its high use has several drawbacks, such as environmental degradation, high energy consumption and increased 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 etc.

Because of these constraints, in hilly regions and forest areas, it is difficult to work with hot mix technology. So, finding an appropriate alternative to hot mix technology is desirable. In this context of disadvantages of hot mix technology, a new innovative, and productive, flexible pavement construction technology has been brought into existence, i.e., the Cold mix technology.

1.2 COLD MIX TECHNOLOGY

Cold mix is the bituminous mixture containing mineral aggregate, water, and binder (bitumen emulsion) prepared by a suitable device like a concrete mixer or cold mix plant or a modified hot mix plant. In this technology, the mixing, laying, and compaction are done at ambient temperature. In cold mix technology, the bitumen emulsion comprising water will get coated on the surface of aggregates, and an adhesive bond is developed between the aggregates and binder

Cold mix, when used as paving mix, can offer the following advantages.

1. It eliminates heating of aggregate and binder.
2. It is environmentally friendly and energy conserving. Cold mix pavement can provide more than 50% energy savings compared to the hot mix so that it can be considered a green bituminous mix for rural road construction.
3. The cold mix can be prepared using a small set-up in the site. It can be produced manually for small-scale work. Sometimes it is not economical to lay hot mix for

rural road construction, as setting up a hot mixing plant for small-scale work increases the project cost.

4. This paving mix is especially suitable for road construction in remote and isolated areas of a country where a hot mix produced by a plant may have been set reaching the site.

1.3 OBJECTIVES OF THE STUDY

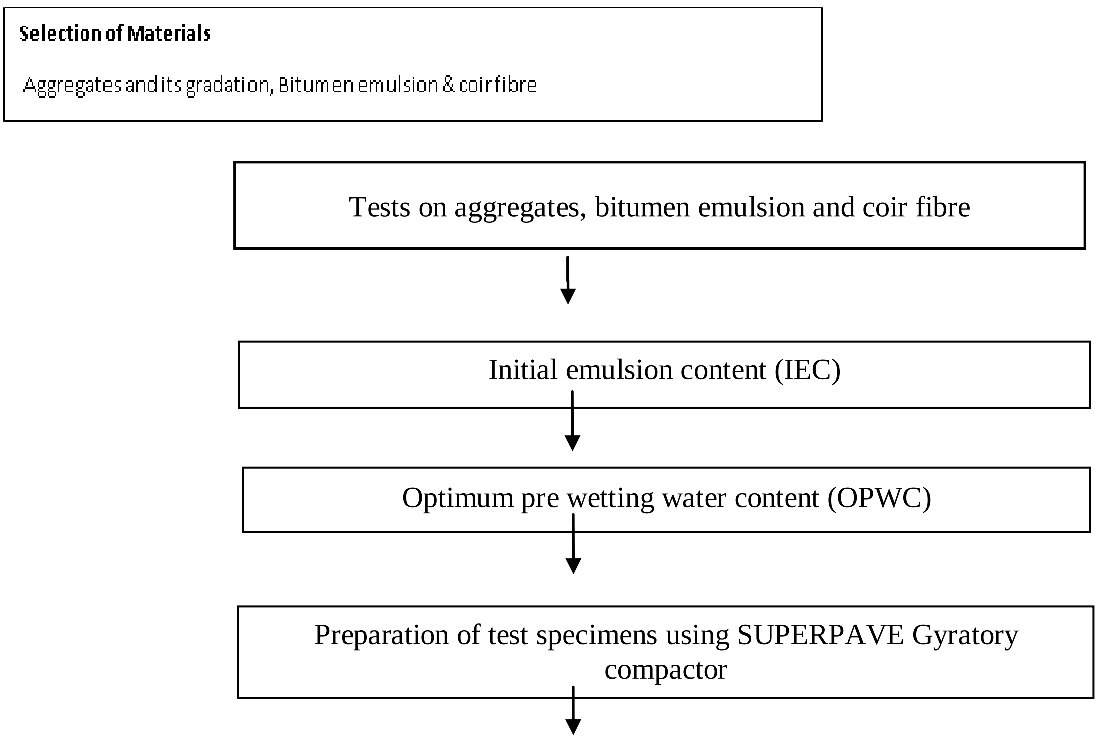
The objectives of the study are:

- To identify the Optimum Emulsion Content (OEC) for selected aggregate gradation
- To identify the optimum length and optimum content of coir fibre for selected aggregate gradation
- To evaluate the performance of cold bituminous mix with and without coir fibre in terms of moisture susceptibility and rutting resistance
- To compare the conventional cold bituminous mix with cold bituminous mix containing coir fibre.

II EXPERIMENTAL EVALUATION OF MATERIAL PROPERTIES

It describes the experimental methodology used for the study, laboratory testing of materials, namely aggregates, bitumen emulsion, and residual bitumen.

2.1 METHODOLOGY



Performance tests on CBM with and without coir fibre

- Marshall test – Mix design
- Retained Marshall Stability test – Moisture susceptibility
- Hamburg wheel tracking test - Rutting resistance

↓

Analysis of results

↓

Conclusions

2.2 TESTS ON AGGREGATES

In this project, to check the suitability of aggregates for use in pavement construction these are tested for strength, toughness, hardness, shape, and water absorption and their test results will be shown in the given below table.

Experiment	Test Results	Permissible Value	IS Code
Specific Gravity (CA)	2.74	2.6-2.8	IS:2386 (Part III)-1963
Specific Gravity (FA)	2.67	2.6-2.8	IS:2386 (Part III)-1963
Aggregate Impact value (%)	28.72	Max. 30	IS:2386 (Part IV)-1963
Aggregate Crushing value (%)	29.20	Max. 30	IS:2386 (Part IV)-1963
Los Angeles Abrasion Test (%)	28.43	Max. 40	IS:2386 (Part IV)-1963
Combined Elongation and Flakiness index (%)	25.53	Max. 35	IS:2386 (Part I)-1963
Water absorption (CA) (%)	0.44	Max. 2	IS:2386 (Part III)-1963
Water absorption (FA) (%)	0.61	Max. 2	IS:2386 (Part III)-1963

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2.3 TESTS ON BITUMEN EMULSION

The bitumen emulsion sample which was chosen as per IS 8887-2004 Code provisions had tested according to the codal provisions and their test results will be shown in the given table below.

Experiment	Sample No	Test Results	Permissible Value	IS Code
Residue on 600 micron (%)	1	0.0175	Max 0.05	IS:8887-2004
	2	0.0425		
	3	0.035		
	Average	0.031		
Coagulation at low temperature	1	Nil	Nil	IS:8887-2004
	2			
	3			
Viscosity by Saybolt Furol Viscometer in Furol Seconds	1	236	30-300	IS:8887-2004
	2	252		
	3	205		
	Average	231		
Storage stability after 24 hours (%)	1	0.96	Max. 1%	IS:8887-2004
	2	0.97		
	3	0.97		
	Average	0.96		
Coating ability and water resistance a. Coating, dry aggregates b. coating, after water spraying	1	Good Fair	Good Fair	IS:8887-2004
	2			
	3			
Residue by evaporation (%)	1	65.48	Min 65%	IS:8887-2004
	2	66.21		
	3	65.63		
	Average	65.77		
Tests on residue				
Penetration, mm	1	110	30-150	IS:1203-1978
	2	89		
	3	105		
	Average	101.33		
Ductility, cm	1	65	Min 50	IS:1208-1978
	2	68		
	3	76		
	Average	69.67		
Specific gravity	1	1.01	Min 0.99	IS:1202-1978

	2	1.03		
	3	1.01		
	Average	1.016		

2.4 CHARACTERISTICS OF COIR FIBER

Coir fibre with different lengths such as 10mm, 15mm, and 20mm was used for this study. Fibre content was varied from 0.1% to 0.3%. The material used in this work was defibering coir fibre and the shape is of cylindrical. The diameter of the coir fibre is varied from 0.18 mm to 0.43 mm. The density of coir fibre is found to be 1.4 gm/cc by considering a cylindrical volume of the fibre.

2.5 AGGREGATE GRADATION AND SIZE

Cold bituminous mix with a nominal maximum size of 13.2 mm for the surface course with a nominal layer thickness of 36-50 mm is chosen for the study and the gradation of NMPS 13.2 mm mix is shown in the given below table.

Sieve size (mm)	Cumulative % by Weight of Total Aggregate Passing	Middle value
19	100	100
13.2	90-100	95
4.75	45-70	57.5
2.36	25-55	40
0.3	5-20	12.5
0.075	2-9	5.5

III SAMPLE PREPARATION AND TESTING PROCEDURE

The laboratory specimens were prepared to determine the optimum emulsion content and to test the performance of bituminous mix for its moisture susceptibility and rutting. The mixes were prepared according to the IRC: SP: 100-2014 cold mix design procedure. To determine the optimum binder content and quality of bitumen mixture by using the Marshall Test method. The Marshall specimens were prepared with the dimensions of diameter 100 mm and height 63.5 mm by using gyratory compactor. After casting, the specimens were kept at ambient temperature for a period of 24 hours. After that, the specimens were kept in the hot air oven for 72 hours at a temperature of 40˚C.

The CBM samples were prepared using varying emulsion content of 7.0%, 7.5%, 8.0%, 8.5%, and 9.0% for identifying the optimum emulsion content. Volumetric analysis was done using

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the result obtained, and optimum emulsion content was found out. The CBM samples were also prepared with coir fibre for Marshall Stability test to identify the optimum coir fibre content and optimum coir fibre length. The length of coir fibre was varied as 10 mm, 15 mm and 20 mm, and coir fibre content was varied as 0.1%, 0.2% and 0.3% by weight of the total mix.

Performance of cold bituminous mixes with and without coir fibre was evaluated by the Retained Marshall Stability and Wheel tracking tests. Wheel tracker is designed for measuring the rut depth of bituminous mixtures in either water or air by following the procedures detailed in the AASHTO T324 standard. Retained Marshall Stability specimens were prepared with and without coir fibre at optimum emulsion content of 8%. The length of coir fibre was varied as 10 mm, 15 mm and 20 mm, and coir fibre content was varied as 0.1%, 0.2% and 0.3% by weight of the total mix.

IV ANALYSIS OF RESULTS AND DISCUSSIONS

4.1 OPTIMUM EMULSION CONTENT

The optimum emulsion content was found to be 8% for NMPS 13.2 mm gradation. Marshall values for NMPS 13.2 mm gradation with different percentages of emulsion are shown in table 4.1, and the graphical representation of the results are shown in Figure 4.1.

Table 4.1 Marshall Stability test results for NMPS 13.2 mm gradation

Bitumen emulsion (%)	Sample No.	Marshall Stability (kN)	Flow (mm)	Bulk density (gm/cc)	Air Voids (%)	VMA (%)	VFB (%)
7	1	11.34	3.41	2.190	13.836	23.423	40.930
	2	11.23	4.29	2.209	13.070	22.742	42.530
	3	11.21	3.81	2.212	12.970	22.654	42.745
Average		**11.26**	**3.84**	**2.204**	**13.292**	**22.940**	**42.068**
7.50	1	11.89	4.63	2.188	13.491	23.723	43.129
	2	12.27	3.96	2.233	11.741	22.179	47.065
	3	11.76	3.20	2.245	11.248	21.744	48.274
Average		**11.97**	**3.93**	**2.222**	**12.160**	**22.549**	**46.156**
8	1	12.63	5.07	2.261	10.190	21.432	52.452
	2	13.07	5.21	2.260	10.230	21.466	52.344
	3	11.89	4.23	2.230	11.422	22.509	49.257
Average		**12.53**	**4.84**	**2.250**	**10.614**	**21.802**	**51.351**
8.50	1	9.63	5.15	2.255	9.991	21.869	54.312
	2	11.40	5.68	2.261	9.768	21.675	54.934
	3	10.99	5.93	2.230	11.005	22.749	51.623
Average		**10.67**	**5.59**	**2.249**	**10.255**	**22.098**	**53.623**

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9	1	9.84	6.96	2.210	11.393	23.678	51.883
	2	10.35	6.80	2.290	8.186	20.915	60.863
	3	10.96	6.21	2.220	10.992	23.333	52.889
Average		**10.38**	**6.66**	**2.240**	**10.190**	**22.642**	**55.212**

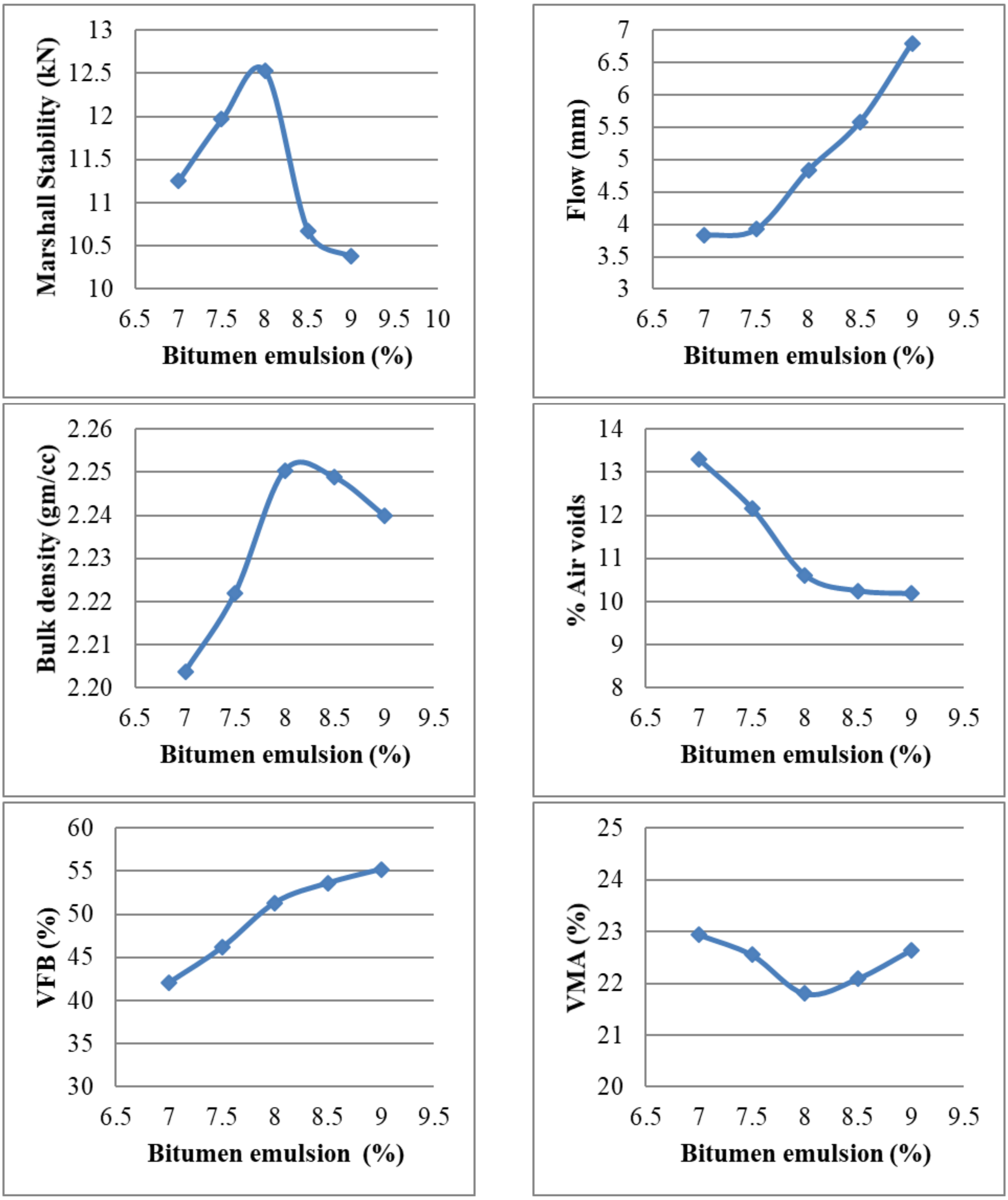

Figure 4.1 Marshall graphs for NMPS 13.2 mm gradation

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The Marshall Stability results of CBM with coir fibre are shown in table 4.2, and the graphical representation of the results are shown in Figure 4.2.

Table 4.2 Marshall Stability test results of CBM with coir fibre

Coir fibre Content (%)	Sample No.	Marshall Stability (kN)		
		Coir Fibre length of 10 mm	**Coir Fibre length of 15 mm**	**Coir Fibre length of 20 mm**
0.00	1	12.63	12.63	12.63
	2	13.07	13.07	13.07
	3	11.89	11.89	11.89
Average		**12.53**	**12.53**	**12.53**
0.1	1	12.71	13.57	12.01
	2	12.46	12.96	12.69
	3	12.51	13.07	12.05
Average		**12.56**	**13.20**	**12.25**
0.20	1	12.48	16.75	12.62
	2	13.05	15.35	10.82
	3	12.54	14.55	12.69
Average		**12.69**	**15.55**	**12.04**
0.30	1	11.96	13.64	11.79
	2	12.23	11.92	11.30
	3	12.31	12.43	12.96
Average		**12.17**	**12.66**	**12.02**
0.40	1	15.37	11.84	11.57
	2	11.68	11.54	12.19
	3	12.11	11.88	11.71
Average		**13.05**	**11.75**	**11.82**

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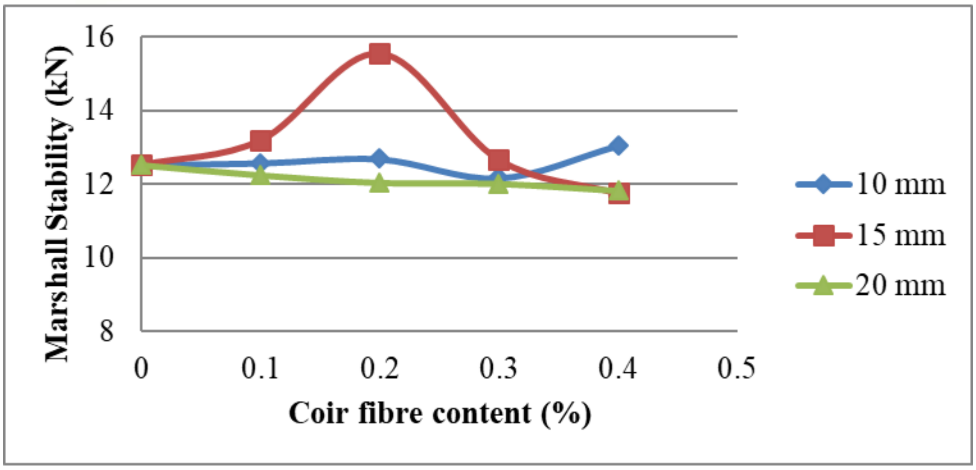

Figure 4.2 Marshall Stability graph for different lengths and contents of coir fibre

From the above Figure 4.2, for coir fibre length of 15 mm and the coir fibre content of 0.2%, the Marshall Stability value was more compared to other combinations with and without coir fibre. Therefore, based on Marshall Stability value, optimum coir fibre content and optimum coir fibre length is 0.2% by the total weight of mix and 15mm length, respectively.

4.2 RETAINED MARSHALL STABILITY TEST

The test results for variation of retained marshall stability with coir fibre content is shown in figure 4.3 . RMS was found to be higher than the 80 % for all variations with and without coir fibre in CBM. These results show that the presence of coir fibre in cold bituminous mix leads to increases the moisture resistance of CBM.

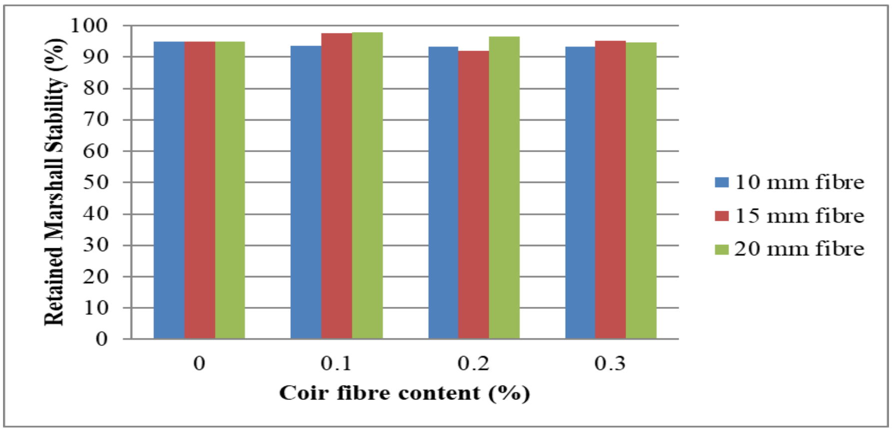

Figure 4.3 Variation of Retained Marshall Stability with coir fibre content (%)

4.3 HAMBURG WHEEL TRACKING TEST

The graphs were plotted between the rut depth and the number of passes for all variations of CBM with and without coir fibre. The graphical representation of `wheel tracking test results of CBM with and without coir fibre are shown in Figure 4.4 to Figure 4.8.

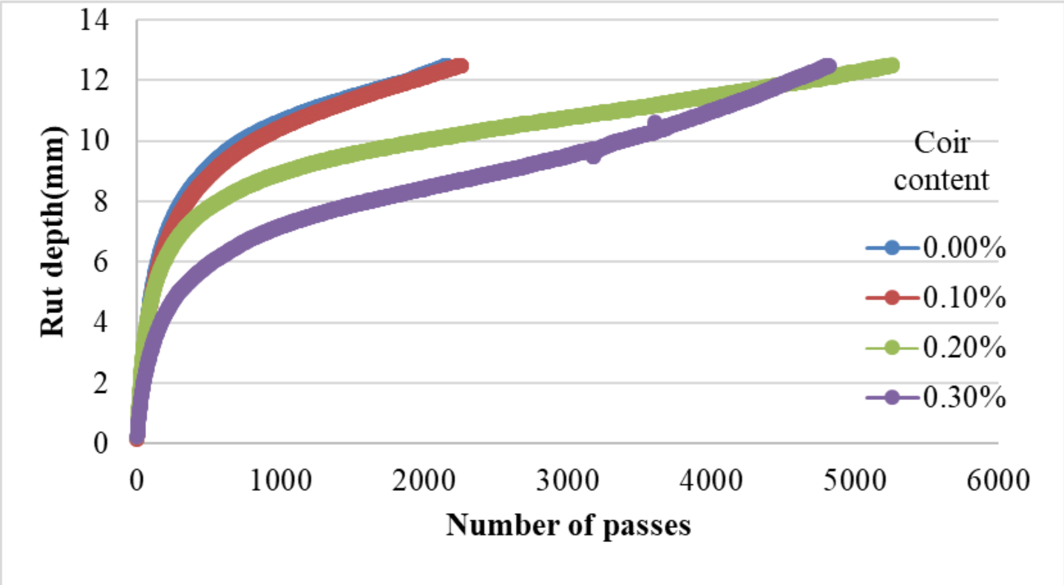

Figure 4.4 Rutting characteristics of CBM with a coir fibre length of 10 mm

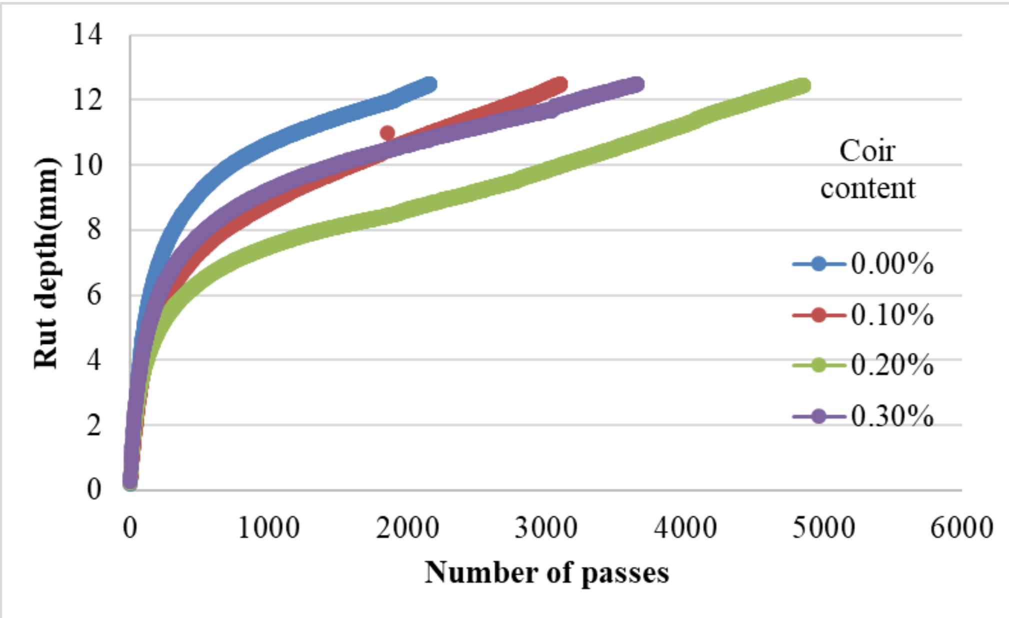

Figure 4.5 Rutting characteristics of CBM with a coir fibre length of 15 mm

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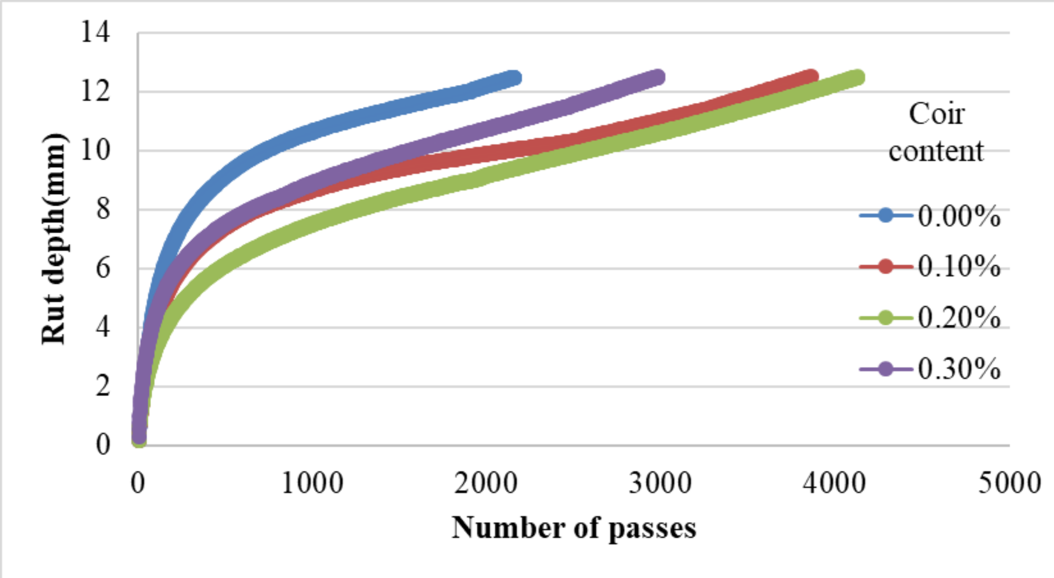

Figure 4.6 Rutting characteristics of CBM with a coir fibre length of 20 mm

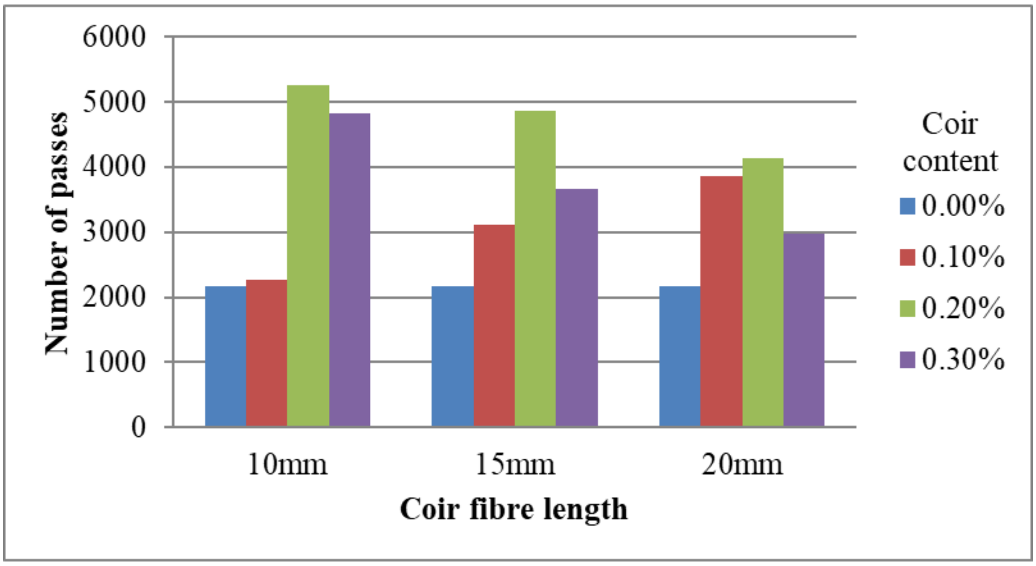

Figure 4.7 Variation in the number of passes for 12.5 mm rut depth in CBM

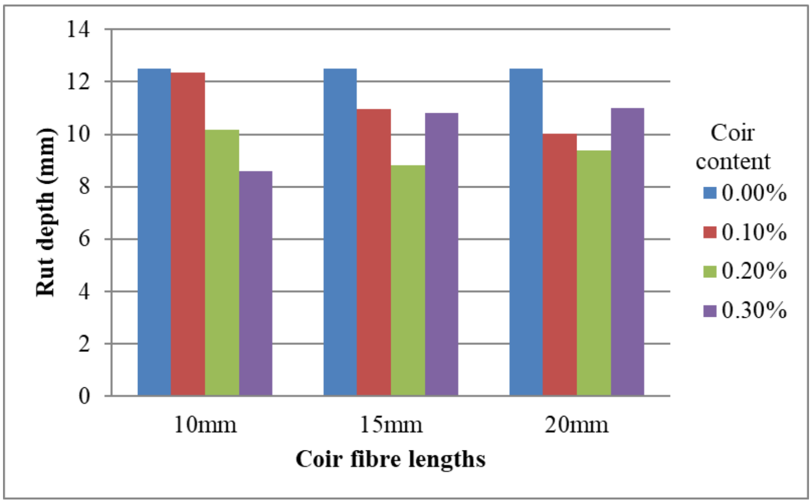

Figure 4.8 Deformation after 2162 passes

V CONCLUSIONS

Based on laboratory tests, the following conclusions were drawn:

1. Optimum emulsion content of cold bituminous mix based on Marshall Stability is 8% by weight of the total mix for selected gradation.
2. Use of coir fibre resulted in an increase of Marshall Stability value by 14.55% when compared with the conventional CBM.
3. The optimum coir fibre content is 0.2% by weight of total mix, and optimum fibre length is 15 mm based on Marshall Stability value.
4. Moisture resistance is found to be more than 90 % for all variations with coir fibre.
5. Rutting resistance of the mix is improving with the addition of coir fibre when compared to conventional mix. The rutting resistance is more at 0.2% of coir content at all lengths (10 mm, 15 mm&20 mm).
6. Based on Marshall Stability results and wheel tracking test results, the optimum length of coir fibre is 15 mm, and the optimum coir fibre content is 0.2%.

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