IJARSE
ISSN (O) 2319 - 8354
ISSN (P) 2319 - 8346

Studies on Cold Bituminous mixes with NanoTac Additive

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ABSTRACT

There is an increasing trend for using cold mix design with bitumen emulsion all over the world because of several advantages such as elimination of heating of binder and aggregate while producing mixes, this helps in protection of environment and energy conservation. In the present study, the main objective is to study the behaviour and effect of pre compaction curing on grade-2 bituminous concrete (BC-2) mix using bituminous emulsions treated mixtures (BETM) by Modified Marshall Method of mix design. The specimen were prepared with and without NanoTac.Comparasion was made in terms of dry and wet Marshall Stability, Marshall Flow on Modified Marshall specimen prepared by cold mix method for BC-2 mix.

In the present investigation it was found that for mixes with and without NanoTac the Dry and wet Marshall Stability, Marshall Flow .

Based on this present study it has been found that mix with NanoTac 0.4% showed better results compared to mix without NanoTac.

Keywords: Dry and wet stability, Marshall Flow, NanoTac, Emulsion, Cold Mix

I. INTRODUCTION

The cold mixes can be prepared either by cutbacks or by emulsions. Cutback bitumen is brought into fluid state by adding petroleum solvent such as naphtha or kerosene oil. In the field, solvent evaporates as the curing of cutback

bitumen takes place. This technology has limited applications due to its inherent disadvantages and it is not environment friendly. Another type of bituminous binder, which is rapidly growing is the cationic bitumen emulsions. Emulsions are available in fluid state at ambient temperature and it is prepared by adding emulsifier’s in water and adding bitumen to it in a colloidal mill. The first trace of emulsion was developed in the 1900s and its use in pavement applications started in the 1920s. Earlier the bitumen emulsions were only restricted to spray applications and as dust palliatives. With the development in technology new types, grades, specifications, and availability of improved construction equipment’s and practices, emulsion based cold mix technology offered a wide range of solutions for construction and maintenance of roads. In India, the first use of bitumen emulsion was found in the 1970s. The entire world used 12 million tonnes of emulsion during mid-seventies

In the cold mix technology, the aggregates are premixed with water as pre-wetting water, there after emulsion is added to it in a predetermined quantity then the mix is produced, transferred to the mould and compacted, all the processes are done at room temperatures. Cold mixes in the field can be produced by using hot mix plants and laid and compacted by similar techniques.

IJARSE
ISSN (O) 2319 - 8354
ISSN (P) 2319 - 8346

II. OBJECTIVES AND SCOPE

The objectives of the present study are

- To select mix parameters and evaluate.their effects on properties of cold mix bitumen (CMB) mixtures.
- To determine the optimum dosage of the additive used and to study the effect on change in the mix parameters.
- To study and analyse the gain in the early strength by adding the additive and without adding
- To check the effect of the additive on the curing of cold mixes.

III. SELECTION OF COLD MIX DESIGN PROCEDURE

Currently, there are many mix design procedures for cold mixtures by different road authorities and research organizations. The Indian road congress gives the mix design procedure for cold mixes in IRC: 100 – 2014. But the design procedure do not consider the optimum total liquid content (OTLC) at the time of compaction and decides the optimum water content based on the coating of aggregates but it should be based on the density criteria. The majority of design and test procedures are based on American design procedures, e.g. The Bitumen Institute or AASHTO, with some modifications.

The Marshall method for cold mixtures uses the popular Marshall testing apparatus for stability and flow determinations, at ambient temperature. The detailed design procedure of MS – 14 is given in the section 3.3.1 and has been largely adopted in the present study. The mixing of aggregates, compaction and testing are all done at the ambient temperature. The mix is designed to meet the requirements as per the MORT&H specifications.

Table 1 Design Requirements of the CBM as per MORT&H

Mix Properties	Recommendations
Marshall Stability	2.2 kN
Minimum Flow	2 min.
Air Voids	3 – 5 %
Maximum Stability Loss	50 %
Level of Compaction	75 Blows
Emulsion Content	7 – 10 %
Voids in Mineral Aggregate	For Nominal Size of Aggregate 19mm**:** 14%

IV. AGGREGATE TESTING

The aggregates are tested as per IS 2386 for following properties.

A) Sieve analysis for coarse and fine aggregates.

B) Specific gravity and water absorption of coarse aggregate.

C) Specific gravity of fine aggregates

D) Aggregate impact value

E) Crushing value

F) Specific gravity of cement

G) Specific gravity of hydrated lime

International Journal of Advance Research in Science and Engineering
Vol. No.6, Issue No. 07, July 2017
www.ijarse.com
IJARSE
ISSN (O) 2319 - 8354
ISSN (P) 2319 - 8346

Table 2 Test Results of Properties of Aggregates

Sl. No.	Property	Test method	Test Result	MORT&H Specification
1	Aggregate Impact Value	IS: 2386 (Part-IV)	23.86 %	Max. 24%
2	Crushing Value	IS: 2386 (Part-IV)	23.01	Max. 30%
3	Combined Index	IS: 2386 (Part-I)	23.10	Max. 30%
4	Specific Gravity	IS: 2386 (Part-III)		
	Coarse Aggregate		2.65	-
	Fine Aggregate		2.61	-
	Quarry Dust		2.75	-
	Cement	IS: 4031 (Part 11)	3.14	-
5	Water Absorption	IS: 2386 (Part-III)		
	Coarse Aggregate		0.14	Max. 2%
	Fine Aggregate		0.41	
	Quarry Dust		1.66	
6	Stripping Value	IS: 6241	3 %	Minimum 95% Retained

Table 3 Test Results of Properties of 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)

Table 4 Adopted Gradation for BC Grade – 2

IS Sieve,mm	Material A	Material B	Material C	Filler	Obtained Gradation	MORT&H (Vth Rev. Table 500 – 17)
	6 %	**30 %**	**62 %**	**2 %**	**100 %**	
	20 mm down	**12.5 mm down**	**4.75 mm down**	**Filler**		
19	6.00	30.00	62.00	2.0	100	100
13.2	5.71	29.78	62.00	2.0	99.50	90-100
9.5	2.11	2093	62.00	2.0	87.03	70-88
4.75	0.03	1.75	61.94	2.0	66.12	53-71
2.36	0.00	0.49	52.14	2.0	55.20	42-58
1.18	0.00	0.23	36.15	2.0	37.86	34-48
0.6	0.00	0.19	26.47	2.0	28.22	26-34
0.3	0.00	0.16	22.94	2.0	24.96	18-28
0.15	0.00	0.12	16.24	2.0	18.13	12-20
0.075	**0.00**	**0.00**	**4.96**	**2.0**	**7.14**	**4-10**

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ISSN (O) 2319 - 8354
ISSN (P) 2319 - 8346

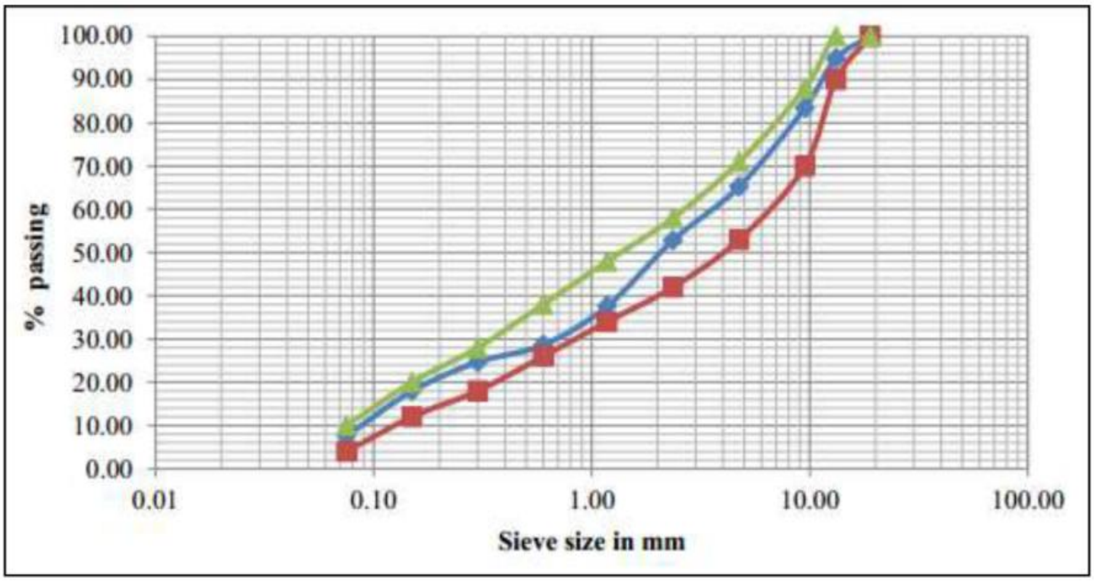


Table 5 Determination of Pre Wetting Water Content

Initial Emulsion Content %	Water %	Density g/cc
7.86	1.00	2.20
7.86	2.00	2.24
7.86	3.00	2.26
7.86	4.00	2.23
7.86	5.00	2.21

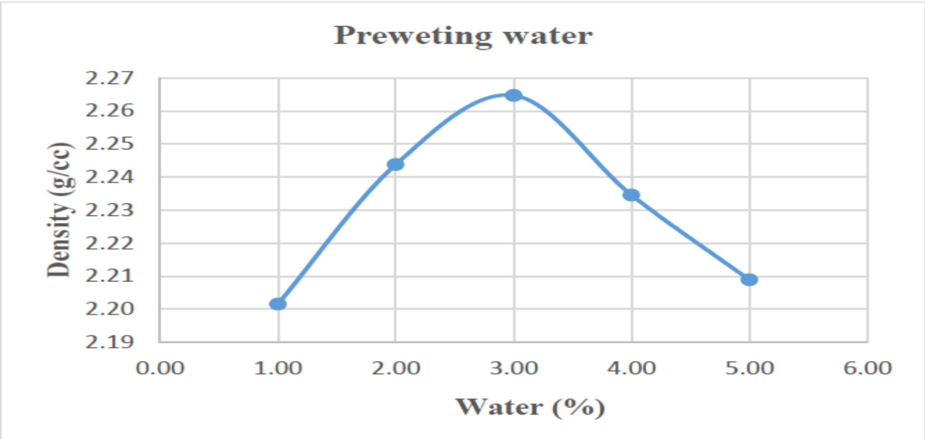
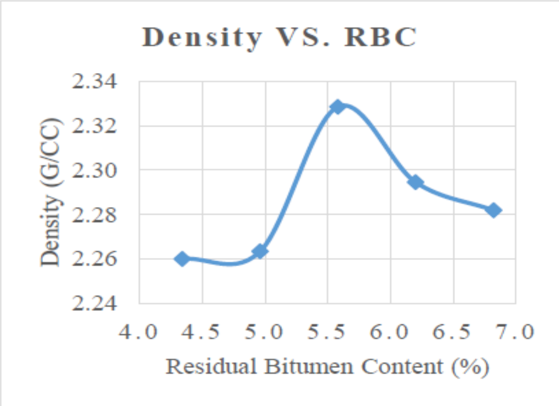
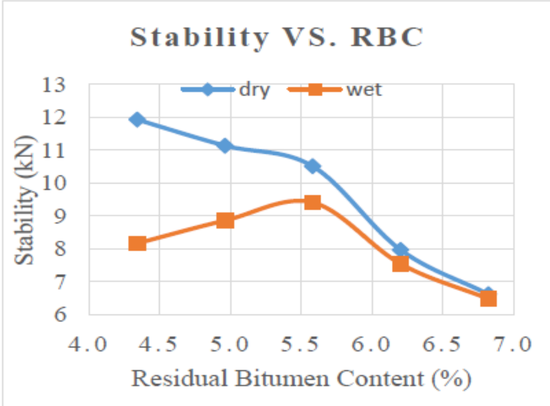


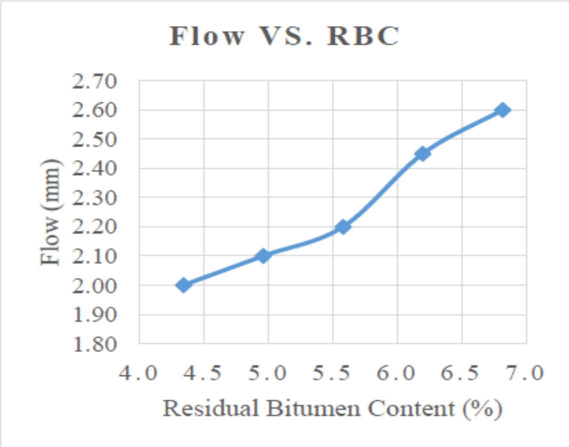
Table 6 Marshall Properties of Conventional Emulsion Mix

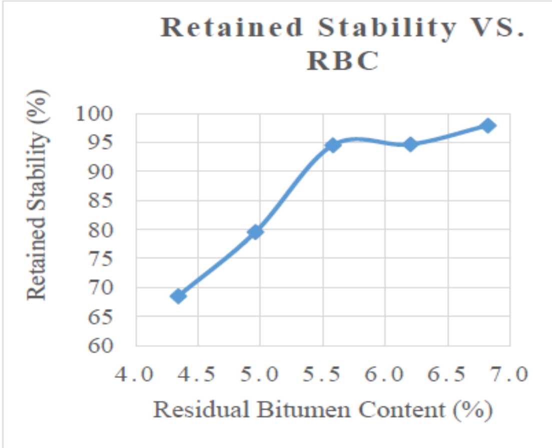
Emulsion Content (%)	RBC (%)	Dry Stability (kN)	Wet Stability (kN)	Density (g/cc)	Retained Stability (%)	Flow (mm)	VMA (%)	Water Absorption (%)	Voids (%)
7	4.34	11.93	8.17	2.26	68.48	2.00	17.99	3.5	8.19
8	4.96	11.14	8.86	2.26	79.56	2.10	18.92	2.7	7.57
9	5.58	10.51	9.93	2.33	94.51	2.20	19.75	2.2	7.28
10	6.20	7.97	7.55	2.29	94.65	2.45	20.67	0.8	6.49
11	6.82	6.62	6.48	2.28	97.91	2.60	21.91	0.7	6.11

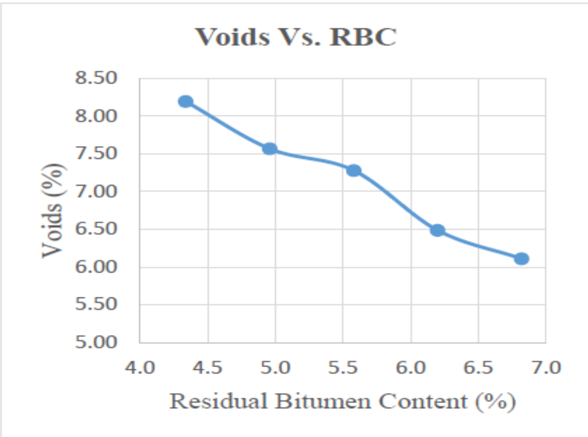
IJARSE
ISSN (O) 2319 - 8354
ISSN (P) 2319 - 8346

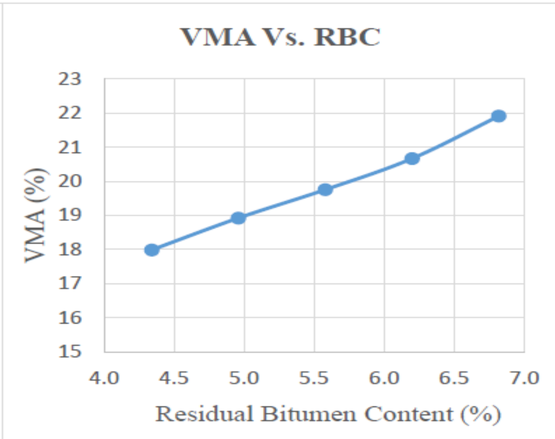












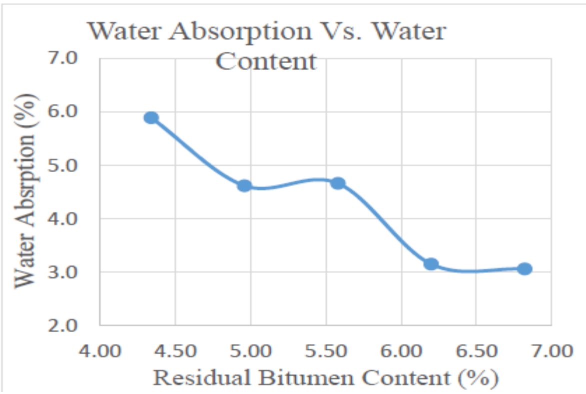


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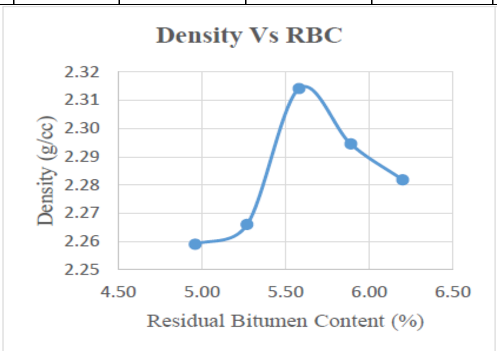
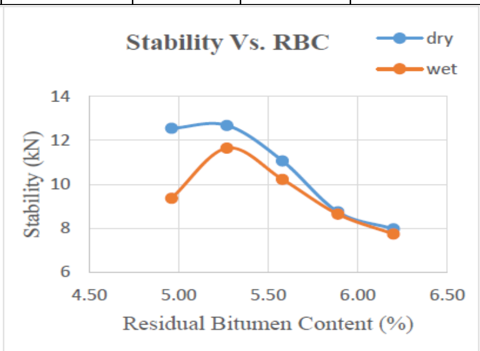
Table 7 Marshall Properties of Conventional Cold Mix at Optimum Residual Bitumen Content For BC - 2

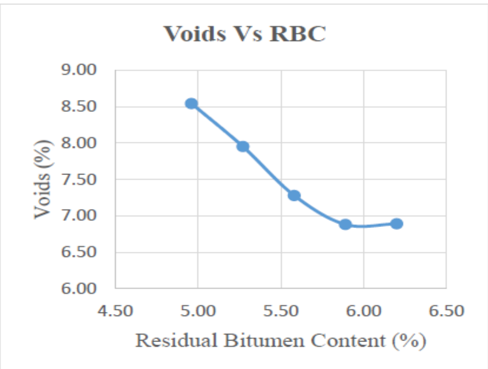
Marshal Properties	Results	MORT&H Specifications as per Table 500-45 for Dense graded mixes
Wet Stability (kN)	9.93	2.22
Dry Stability (kN)	10.51	-
Stability Loss (%)	5.49	50
Density (g/cc)	2.33	-
Flow (mm)	2.2	2
Percent Air Voids	7.3	3-5
Water Absorption (%)	5	
VMA (%)	19.75	
VFB (%)	65	65-75

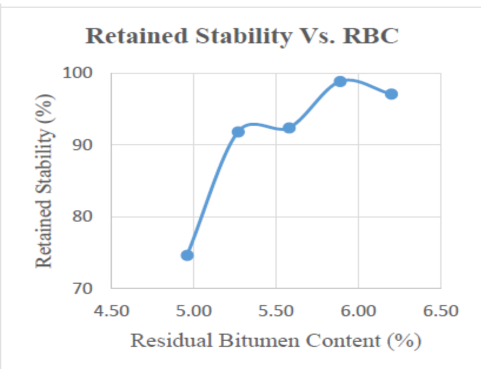
Table 8 Marshall Properties of Cold Mix With 0.2% NanoTac Additive

Emulsion Content (%)	RBC (%)	Dry Stability (kN)	Wet Stability (kN)	Density (g/cc)	Retained Stability (%)	Flow (mm)	VMA (%)	Water Absorption (%)	Voids (%)
7	4.96	12.55	9.37	2.26	74.67	2.65	16.23	57.57	8.54
8	5.27	12.68	11.65	2.27	91.83	2.73	18.63	66.341	7.95
9	5.58	11.07	10.23	2.31	92.39	2.83	19.49	68.314	7.28
10	5.89	8.74	8.64	2.29	98.83	2.93	20.35	67.619	6.88
11	6.20	7.97	7.74	2.28	97.06	3.10	21.28	69.400	6.89









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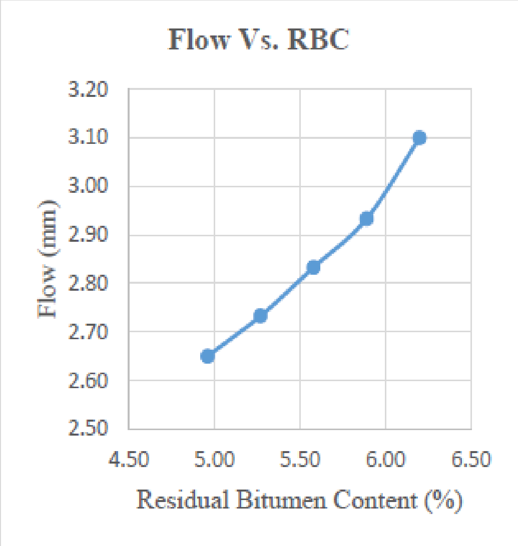

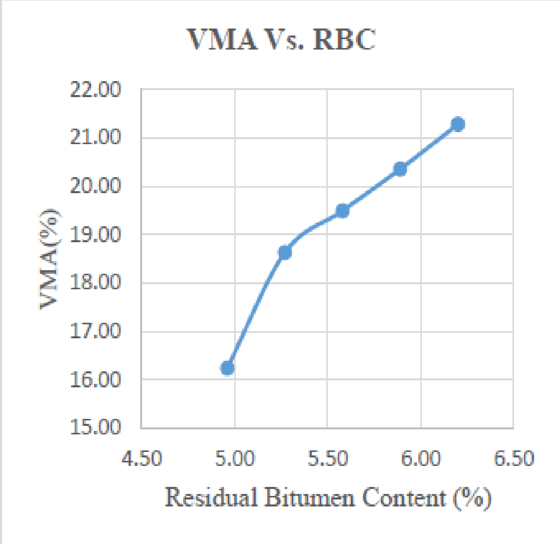

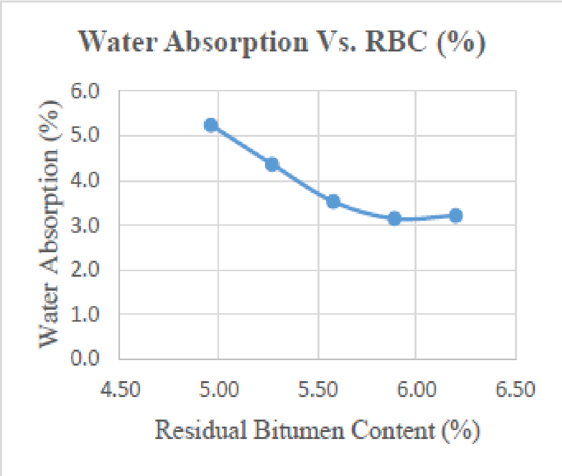

Table 9 Marshall Properties of Cold Mix at Optimum Residual Bitumen Content For BC - 2 With 0.2% NanoTac Additive

Marshal Properties	Results	MORT&H Specifications as per Table 500-45 for Dense graded mixes
Wet Stability (kN)	11.65	2.2
Dry Stability (kN)	12.68	-
Stability Loss (%)	9.27	50
Density (g/cc)	2.31	-
Flow (mm)	2.73	2
Percent Air Voids	7.95	3-5
Water Absorption (%)	4.4	
VMA (%)	18.63	
VFB (%)	66.34	65-75

International Journal of Advance Research in Science and Engineering
Vol. No.6, Issue No. 07, July 2017
www.ijarse.com
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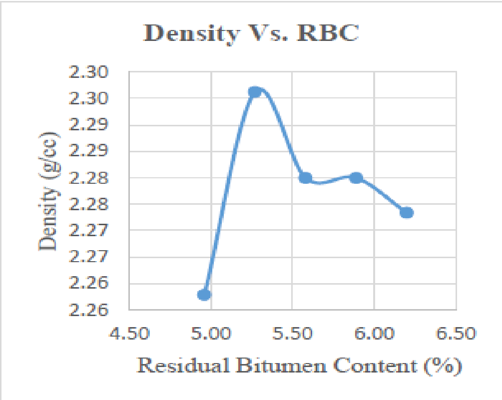
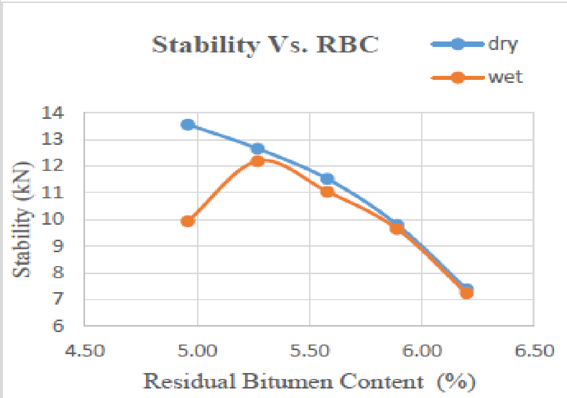
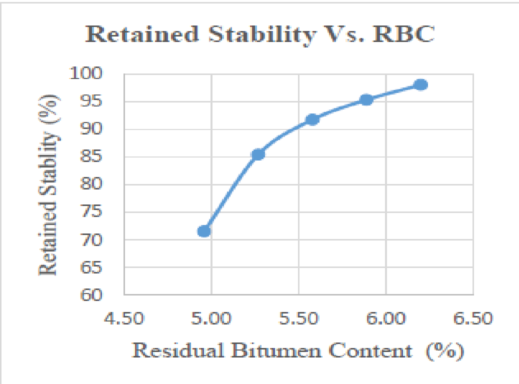
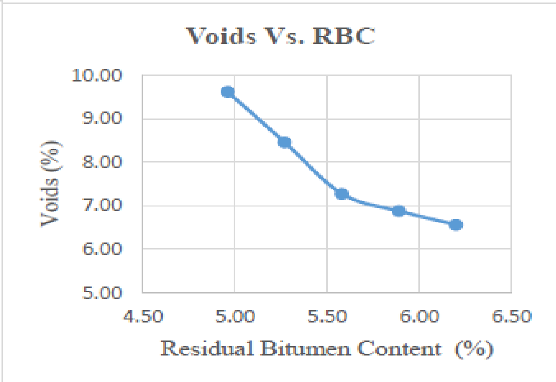
Table 10 Marshall Properties of Cold Mix With 0.4% NanoTac Additive

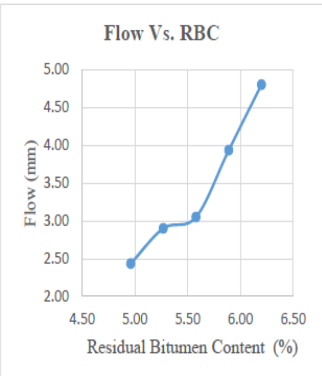
Emulsion Content (%)	RBC (%)	Dry Stability (kN)	Wet Stability (kN)	Density (g/cc)	Retained Stability (%)	Flow (mm)	VMA (%)	Water Absorption (%)	Voids (%)
7	4.96	13.55	9.69	2.26	71.52	2.43	18.40	56.05	9.62
8	5.27	12.15	10.38	2.26	85.43	2.90	19.42	67.30	8.03
9	5.58	11.52	10.57	2.33	91.74	3.05	19.61	68.85	7.28
10	5.89	9.80	9.35	2.29	95.34	3.93	20.35	66.21	6.88
11	6.20	7.38	7.24	2.27	98.05	4.80	20.87	67.76	6.57

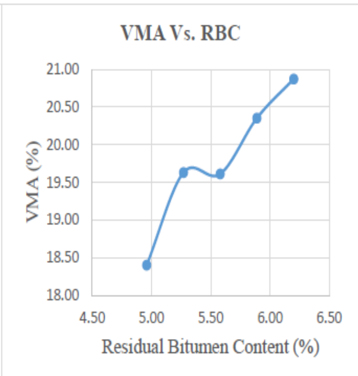


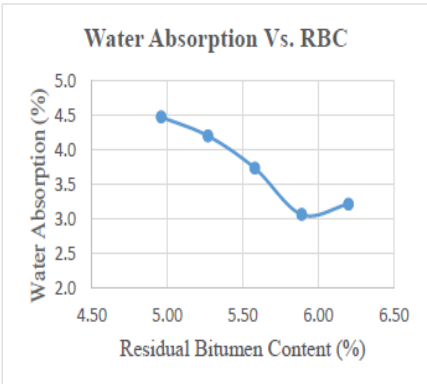












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ISSN (O) 2319 - 8354
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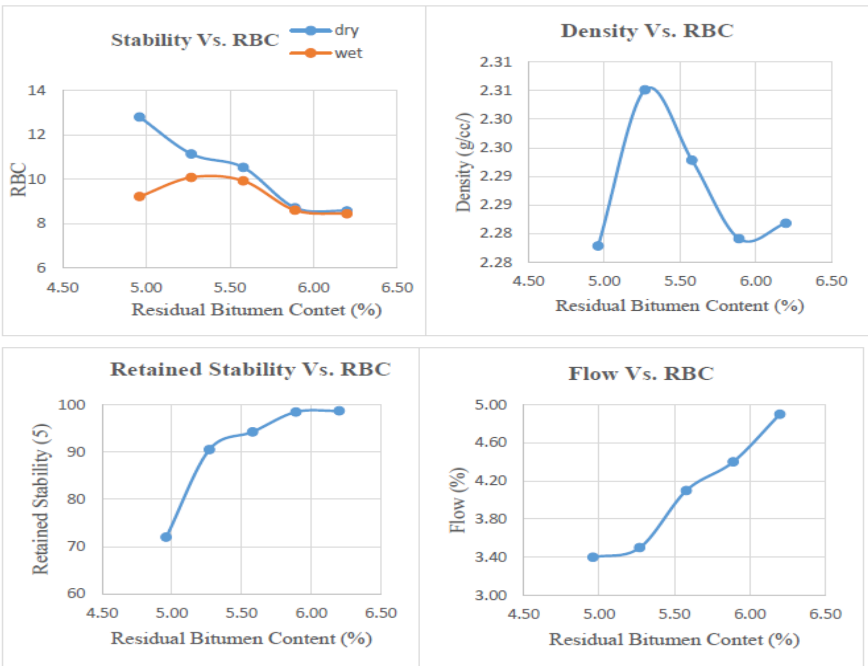
Table 11 Marshall Properties of Cold Mix at Optimum Residual Bitumen Content For BC - 2 With 0.4% NanoTac Additive

Marshal Properties	Results	MORT&H Specifications as per Table 500-45 for Dense graded mixes
Wet Stability (kN)	12.19	2.2
Dry Stability (kN)	12.65	-
Stability Loss (%)	3.66	50
Density (g/cc)	2.30	-
Flow (mm)	2.9	2
Percent Air Voids	8.4	3-5
Water Absorption (%)	4.18	
VMA (%)	19.63	
VFB (%)	66.52	65-75

Table 12 Marshall Properties of Cold Mix With 0.6% NanoTac Additive

Emulsion Content (%)	RBC (%)	Dry Stability (kN)	Wet Stability (kN)	Density (g/cc)	Retained Stability (%)	Flow (mm)	VMA (%)	Water Absorption (%)	Voids (%)
7	4.96	12.81	9.22	2.28	72.01	3.40	18.89	60.11	7.84
8	5.27	11.14	10.09	2.31	90.51	3.50	19.33	62.71	7.74
9	5.58	10.54	9.93	2.29	94.27	4.10	20.30	63.37	7.28
10	5.89	8.72	8.61	2.29	98.46	4.40	20.35	64.80	6.88
11	6.20	8.58	8.45	2.28	98.69	4.90	22.11	67.20	6.89



International Journal of Advance Research in Science and Engineering
Vol. No.6, Issue No. 07, July 2017
www.ijarse.com
IJARSE
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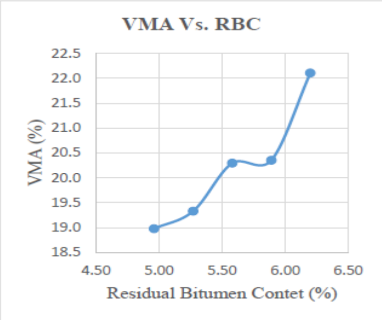
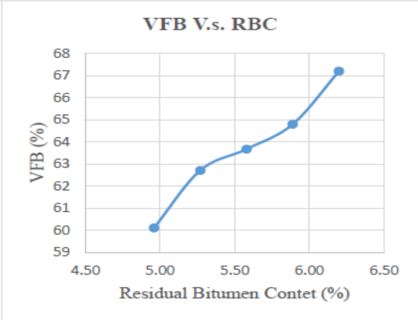




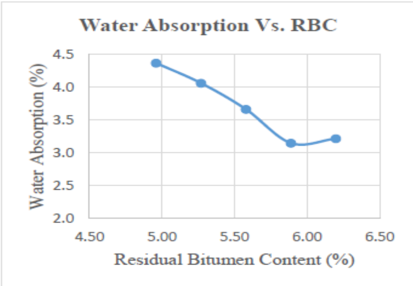
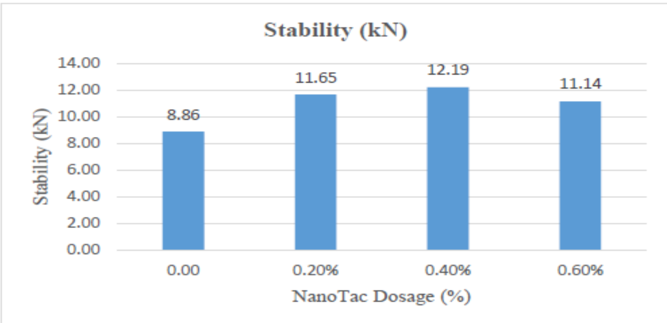
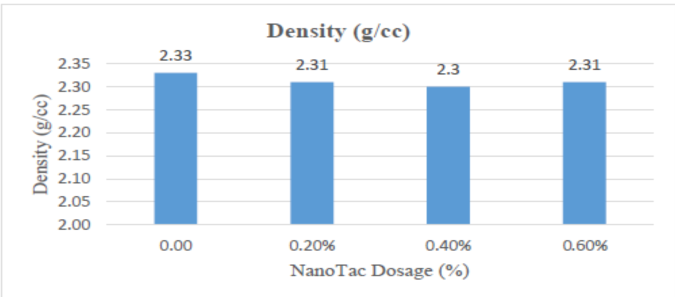


Table 13 Marshall Properties of Cold Mix at Optimum Residual Bitumen Content For BC - 2 With 0.6% NanoTac Additive

Marshal Properties	Results	MORT&H Specifications as per Table 500-45 for Dense graded mixes
Wet Stability (kN)	10.10	2.2
Dry Stability (kN)	11.14	-
Stability Loss (%)	5.49	50
Density (g/cc)	2.31	-
Flow (mm)	3.5	2
Percent Air Voids	7.74	3-5
Water Absorption (%)	4.1	
VMA (%)	19.33	
VFB (%)	62.11	65-75



Comparison of Stability at different NanoTac Dosages



Comparison of Density at different NanoTac Dosages

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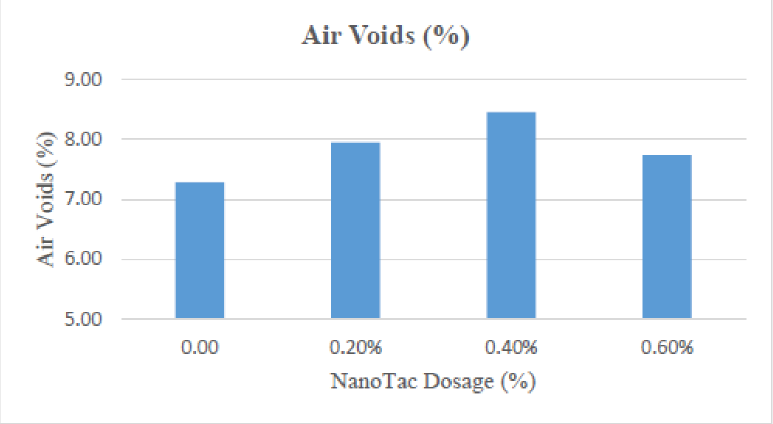
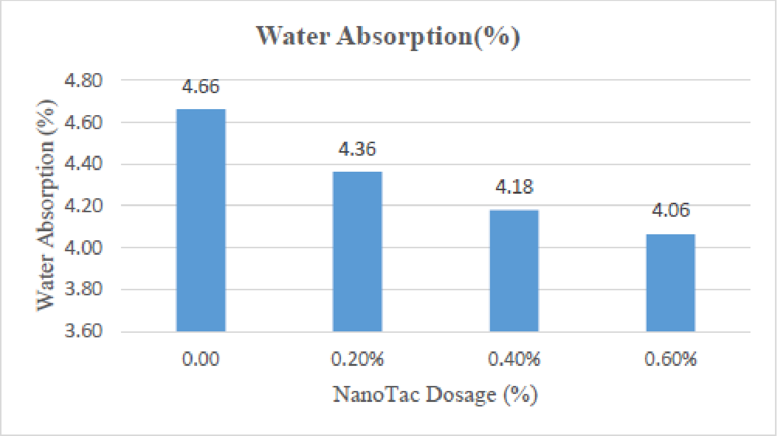
ISSN (O) 2319 - 8354
ISSN (P) 2319 - 8346



Comparison of Air Voids at different NanoTac Dosages



Comparison of Water Absorption at different NanoTac Dosages

V. RESULTS

[1] The cold mix for BC – 2 was prepared by varying emulsion content for constant pre-wetting water content to obtain optimum residual bitumen content. The optimum residual bitumen for the cold mix without additive was found out to be 5.58%.

[2] The optimum residual bitumen content by addition of additive with 0.2, 0.4 and 0.6% was 5.5 % lesser than the cold mix without additive.

[3] From the figure 4.7, stability of the conventional cold mix is 8.86 kN and those with the additive with 0.2%, 0.4% and 0.6% Nanotac additive are 11.65 kN, 12.19 kN and 11.14 kN respectively.

[4] The stability of the cold mix with 0.2% Nanotac additive was maximum among other mixes which was 27.31% more than the conventional cold mix.

[5] The density of the mixes with additives was same for all dosages but the density of the conventional cold mix was 0.8% higher.

[6] The water absorption of the mixes reduces with the increased percentage of additive.

[7] The retained stability of the cold mix with 0.2 % additive was 2.43 % higher than the cold mix without additive.

[8] The retained stability of the cold mix with 0.4 % additive was 6.8 % higher than the cold mix without additive.

[9] The retained stability of the cold mix with 0.6 % additive was 1 % higher than the cold mix without additive.

VI. CONCLUSION

From the analysis of the results the following conclusions were drawn

a. The mixes which are added with NanoTac additive with different dosages had more stability than those without additive. But all the mixes were satisfying the minimum stability criteria as specified by the MORT&H

b. The mixes with additives had less density than without additives. It may be due to decreased optimum binder content.

c. The coating of the aggregate was better with the increase in the addition of the additive.

d. By the addition of the additive the there was a decrease in the optimum bitumen content required by the mixes.

e. Form the results obtained from the retained stabilities, it shows that the mixes with additives were less prone to moisture susceptibility which will be helpful in the moist seasons.

f. From all the results obtained, the Mixes with 0.4% of Nanotac additive showed better results and improvements in most of the properties than any other mixes with additive.

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