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A Study on Asphalt Pavements by using RAP, Sand & UFS Mixtures as Replacements

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Abstract*: The centre of this study is concentrated on introducing the lean ideas in asphalt pavement construction particularly in the Quality control (QC) process in HMA. HMA comprises of nearly 95% of aggregate, gravel or sand, filler and these ingredients are binding together with bitumen a by-product from crude oil industry. The aim of the present study is to compare the strength in terms of stability and flow value of Conventional & Non-conventional mix by Marshal Stability test. The present study relates Usage of RAP to reduce the fresh aggregate in the proposed Mix without influencing the properties of mix, from the test results we are adopting 10 % RAP with 90 % fresh aggregate for NCM mixes.VG 30 grade bitumen is used as binder and Maximum aggregate size (MAS) 23.0 mm and Nominal Maximum Aggregate size (NMAS) 19.0 mm. Cement is used as filler for conventional mixes, while UFS, Sand is used as filler for NCM-II and NCM-III respectively. And finally, 1 % lime in the weight of bitumen used as antistripping agent to minimise moisture susceptibility or to increase the resistance to moisture sensitivity of the proposed mix. From this study we are observed NCM –II shows better results than other Non-conventional mixes, the stability values are slightly lesser than conventional mix, other Marshall properties are far better than conventional ones. The optimum binder content (OBC) is 5.68 for NCM – II, which is lesser than Conventional mix 5.72

Keywords: Bituminous concrete, Reclaimed Asphalt Pavement (RAP), Optimum Binder Content (OBC), Used Foundry Sand (UFS), Non-Conventional Mix (NCM).

I. INTRODUCTION

Hot mix asphalt consists of aggregates, binders and air voids. Out these aggregate having nearly 90-96 percent in total weight of the mix, most of the loads carried by the skeleton of aggregate structure. It is also noted that the amount of asphalt binder is 4-6% in the total weight of mix. Due to viscos-elastic property of bitumen it acts like adhesive and bind together all ingredients in the mix. Fillers are fine materials which are passed through 75-micron sieve having lot of advantages in HMA mix. They are not only reducing the voids but also increases the bond between aggregate and bitumen, increases the resistance to moisture susceptibility.

1.1 Lime in HMA

Hot mix Asphalt (HMA) mixtures containing lime having some benefits. Lime improves the resistance to moisture susceptibility and reduces the water damage [15].Lime acts as an-active filler and anti oxidant and also improves durability at low temperatures [20]. It reduces the plasticity of clay fines. Thus, hydrated lime is an additive with a purpose to increase pavement life and performance via multiple mechanisms [20].

1.2 RAP in Pavement construction

RAP is a scarified Asphalt pavement layer which is used as a pavement material with proper inspection [3].By Using RAP we can optimize the usage of Natural resources by partial replacement of aggregate which is a scarce commodity in some regions and can reduce the binder content in mix, since always some binder content present in the RAP [18].Studies proven that Pavements constructed with less than 30 % RAP having same performance compared with the Conventional pavements [18].

1.3 Used foundry sand as mineral filler in pavement construction

Used foundry sand as mineral filler in pavement creation Filler materials in asphalt concrete combinations have a whole lot of advantages. In addition to filling the voids, they decreasing moisture susceptibility, developing the bond of aggregate and asphalt and end result to increase the stiffness through which includes of inflexible materials in much less rigid matrix [10].

However, having too much filler in HMA mixture can lessen the cohesive among aggregates and binder as coating of the aggregates by way of way of fillers will growth the quantity of binders within the mix eventually weakening the aggregate [8]. High content material of fillers will stiffen the combination to a extremely good amount and the workability of the mix can also reduce. Foundry sand is uniform silica sand that is used to make moulds and cores for ferrous and nonferrous metal castings [25].

Recycling of used foundry sand can keep strength, lessen the need to mine new substances, and can lessen expenses for both producers and quit customers.

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Use of foundry sand as a excellent aggregate and filler in production applications offers task managers the ability to enhance green sustainable creation. Studies have established that used foundry sand can be used between eight to 25 percent in region conventional fillers in asphalt mixes [25].

1.4. Objectives of this study

1. To find the Suitability of RAP, Conventional Sand and Used foundry sand as an additive in Hot Mix Asphalt.
2. To evaluate the stability, flow value and volumetric properties of bituminous mixes with and without addition of RAP, Conventional Sand and Used foundry sand for BC grade1.
3. To determine the OBC by conducting Marshall Stability test for conventional, non-conventional mixes.
4. To examine resistance to moisture sensitivity of test specimens with and without antistripping agent (Lime).

II. MATERIALS

The materials used in this study are Aggregates, Bitumen, Mineral filler, RAP, Antistripping Agent (Lime)

2.1 AGGREGATES

The aggregates from crushed rocks passing from IS 23.0 mm sieve and retained on IS 0.75 mm sieve which is clean, hard, durable which is free from dust had been taken and is collected from sarubujjili, Srikakulam, India. The results after performing the tests as shown below.

Property	Test	Test method	Results obtained	Recommended values
Strength	Crushing value	IS:2386(IV)	25.3%	30% maximum
	Aggregate Impact value	IS:2386(IV)	17.7%	30% maximum
	Los Angeles Abrasion value	IS:2386(IV)	18%	30% maximum
Specific gravity	Coarse aggregate	IS:2386(III)	2.65%	2.6-2.8
	Fine aggregate		2.63%	
Water absorption	Water absorption test	IS:2386(III)	0.5%	2%maximum
Particle shape	Combined flakiness & Elongation index test	IS:2386(I)	26.7%	30% maximum

2.2 Bitumen:

Bitumen acts as a binding agent to the aggregates, fines and stabilizers in bituminous mixtures. Binder provides durability to the mix. Binder characteristics affect the bituminous mixture behaviour viz., temperature susceptibility, viscos-elasticity and aging. In this study VG-30 bitumen is used as binder. The bitumen of penetration grade 50/60 i.e. VG-30 grade used as binder. The bitumen is collected from R&B department Srikakulam and is used for preparation of test specimens. To ensure the use of VG-30 grade bitumen basic engineering tests are conducted as per IS 73:2013, which is significantly more rut resistant than the old 60/70penetration bitumen. The tests result of VG-30 bitumen AS tabulated below.

Bitumen test	VG-30	Requirements as per IS 73-2013
Penetration at 25^0C , mm	63	Min 45
Softening point (Ring & Ball) , ^{0} C	49	Min 47
Flash point , ^{0}C	251	Min 220
Fire point , ^{0}C	271	NA
Ductility @27^0C , cm	82	>75
Specific gravity	1.01	0.95-1.1

2.3 Filler:

Fillers are fine materials passing through 75-micron sieve. There are lot of advantages by using fillers in asphalt concrete. Following are advantages

i) They reduce moisture susceptibility, in addition to filling the voids

ii) Increasing the bonding between the aggregate and binder.

iii) When the filler particle size is smaller than the thickness of asphalt film, the filler particles are suspended in asphalt binder and become mastic.

Generally crushed stone dust, hydrated lime, cement is used as filler. But in this investigation cement used as filler for conventional mix, sand and UFS used for non-conventional mixes.

The properties of cement, Sand, UFS are Tabulated below

Si.no	Mineral filler	Specific gravity	Limitation of specific gravity
1	Cement	3.1	3.1-3.15
2	Sand	2.64	2.6-2.8
3	UFS	2.7	2.39-2.70

2.4 Reclaimed Asphalt Pavement Material (RAP)

Scarified material of existing Asphalt Pavement Removal is termed as RAP. In order to achieve required gradation we have to pulverised the RAP in crushers. Reuse of the waste materials after proper investigation should be a right solution for waste management. The tests which are performed on RAP as Tabulated below.

Property	Test	Results obtained	Recommended values
Strength	Crushing value	27.23%	30% maximum
	Aggregate Impact value	19.97%	30% maximum
	Los Angeles Abrasion value	21.5%	30% maximum
Specific gravity	Coarse aggregate	2.65%	2.6-2.8
	Fine aggregate	2.63%	
Water absorption	Water absorption test	1.42%	2%maximum
Particle shape	Combined flakiness & Elongation index test	29%	30% maximum

2.5 Antistripping agents for bituminous surfacing:

In Asphalt plant the aggregate is normally dried and heated then the mixed with bitumen. The mixing temperature varies between 120o-175o c for hot/warm mixes, depending mainly on the grade of bituminous binder. With moist and partly wet aggregate the desired adhesion can be achieved by addition of antistripping agent. The amount of antistripping agent to be added depends upon the type and viscosity of the bitumen and type and gradation of aggregate. In this investigation lime is used as antistripping agent.

III. METHODOLOGY

Marshall mix design was done for conventional mixes with Marshall stability testing equipment to find the Stability, flow, Bulk specific gravity, Air voids, VMA, VFB etc. From these test results, the OBC determined by taking the average percentage of Bitumen for the maximum stability, maximum bulk specific gravity, and at 4% Air voids. Using RAP as partial replacement to fresh Aggregate in Marshall specimen preparation and compare the test results such as stability, flow, Bulk specific gravity, Air voids, VMA, VFB etc. with conventional mix. Using RAP and fine sand as partial replacements for aggregate and mineral fillers in the preparation of Marshall test specimen respectively and made comparisons with conventional ones. Again done the same procedure for Marshall specimen preparation but in this case UFS is used as partial replacement for mineral filler, and compare the results with conventional ones.

Fig. 1 Marshall specimen

Fig.2 Marshall apparatus

3.1 Aggregate Gradation

In a gradation and size analysis, a sample of dry aggregate of known weight is separated through a series of sieves with progressively smaller opening. Once separated, the weight of particles retained on each sieve is measured and compared to the total sample weight. Particle size distribution is then expressed as a percent retained/passing by weight on each sieve size.

Aggregate gradation influences almost every important property including:

Stiffness

- Stability
- Durability
- Permeability
- Workability
- fatigue resistance
- skid resistance and
- resistance to moisture damage

Aggregate gradation for BC Grade-I using MORTH Table 500-17

IS Sieve (mm)	Cumulative % by weight of total aggregate passing	Cumulative % by weight of total aggregate passing
	Range	Adopted
26.5	100	100
19	90-100	98.5
13.2	59-79	75.81
9.5	52-72	70.62
4.75	35-55	48.72
2.36	28-44	38.07
1.18	20-34	28.09
0.600	15-27	22.54
0.300	10-20	16.85
0.150	5-13	11.11
0.075	2-8	7.40
Pan	0	0

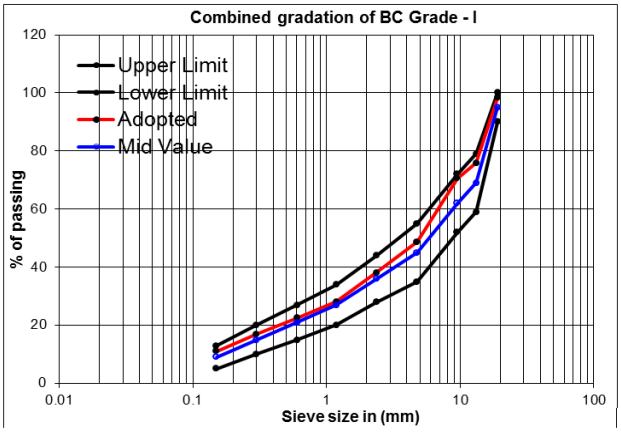


Fig -3 Aggregate combined Gradation

Aggregate gradation for BC (Aggregate + 10% RAP)

IS Sieve (mm)	Cumulative % by weight of total aggregate passing	Cumulative % by weight of total aggregate passing
	Range	Adopted
26.5	100	100
19	90-100	98.30
13.2	59-79	75.56
9.5	52-72	68.84
4.75	35-55	47.29
2.36	28-44	34.47
1.18	20-34	24.61
0.600	15-27	19.65
0.300	10-20	14.75
0.150	5-13	9.73
0.075	2-8	6.56

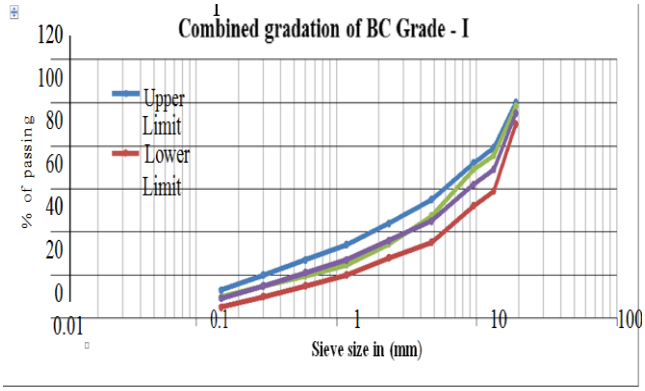


Fig- 4 Aggregate + 10 % RAP combined gradation

IV. EXPERIMENTAL RESULTS

4.1 Fixing the optimum RAP content for Non-conventional mixes

Properties	FreshMix (0%RAP)	RAP			Criteria as perMORT&H
		10%	15%	20%	
OBC, %	5.5	5.5	5.5	5.5	--
Stability KN	15.257	14.6	12.9	10.3	Min 9 KN
Flow, mm	3.9	3.82	3.4	2.85	2 to 4 mm
Air Voids, %	3.4	3.08	3.6	3.95	3 to 6 %
Bulk specific gravity,	2.281	2.305	2.298	2.288	--
VMA, %	14.86	15.12	15.2	15.45	12.0-18.0 %
VFB, %	74.43	74.82	74.9	75.32	65 – 75 %

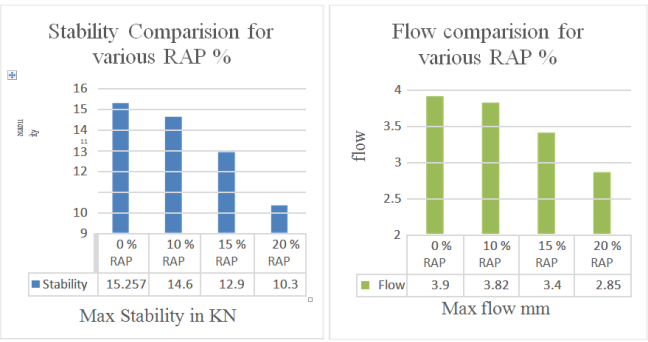


Fig -5 Stability and flow values for 0%, 10 %, 15 %, 20% RAP Specimens

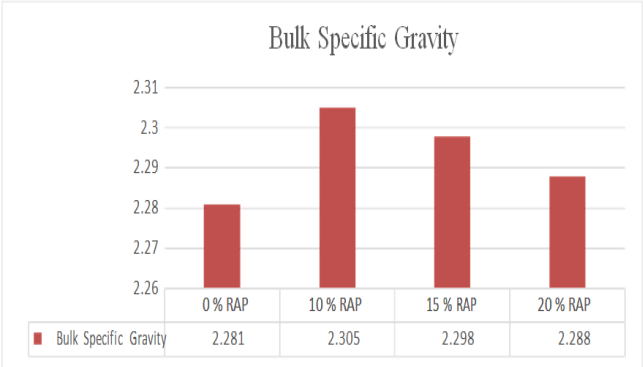


Fig -6 Bulk Specific Gravity values for 0%, 10 %, 15 %, 20% RAP Specimens

From the fig.5,6 we can clearly have observed that specimens with 10% RAP having higher Stability value compared to 15 %, 20% RAP respectively, and there is similarity between the flow values for 0%,10%,15%,20% RAP specimens. The Bulk specific gravity for 10% RAP specimen is greater than 0 % ,15 %,20% RAP specimens. The performance of a Pavement increase with Higher Bulk specific gravity values. From the above results we are restricting the RAP to 10 % as partial replacement for fresh aggregate.

4.2 Finding the optimum antistripping agent percent in bitumen content

Take 200g Coarse Aggregate of 13.2 mm (22.4 passing-11.2 mm retaining) shall be heated to 150oc and mixed with 8 grams of Bitumen and Antistripping agent blend at 150oc time of coating noted. The material should be heated till mixing is completed to maintain 150oc mixing temperature.

After complete coating the mixture shall be transferred to any tray and allowed to condition at 135oc for 2 hours and then transferred to 500ml beaker and allowed to cool at the room temperature for about 2 hours. Distilled Water shall then be added up to 500ml mark of beaker.

Put the beaker on hot plate and start heating bring the water to boiling and note the time continue boiling for 30 minutes at 10,20,30 minutes remove the floating bitumen from the top by spatula to avoid redisposition.

For this test we used 0.2, 0.4, 0.6, 0.8, and 1.0 percent of antistripping agent in bitumen content, and got optimum at 1.0 % Lime is used as Antistripping agent.

Moisture sensitivity test Visual inspection:

➢The aggregate will be taken out and allowed to dry to room temperature.

➢The brownish surface as well as completely stripped surface will be considered as stripped area.

➢Only glossy black or dull black portion of the aggregate shall be considered as coated surface

Fig - 7 Without Antistripping Agent

Fig – 8 With anti-stripping agent

Terminology and Designation

CM = Conventional Mix

NCM = Non-Conventional Mix

CM = Aggregate + Bitumen + Filler (cement)

NCM – I = (Aggregate + 10 % RAP) + Bitumen + Filler (cement) + ASA NCM – II = (Aggregate + 10 % RAP) + Bitumen + Filler (10 %UFS) + ASA NCM – III = (Aggregate + 10 % RAP) + Bitumen + Filler (10%Sand) + ASA

4.3 Marshall stability test results

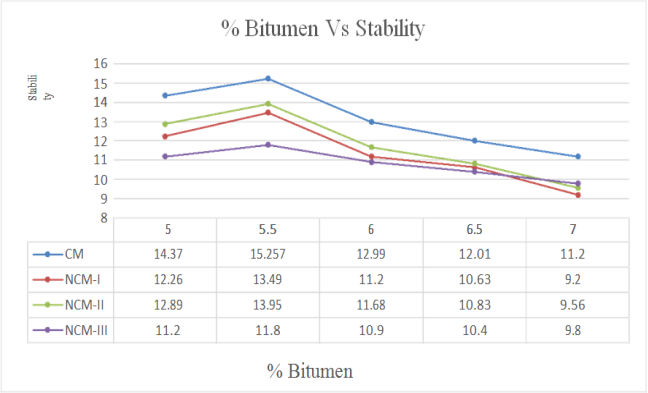


Fig -9(a) Marshall stability vs percent Bitumen values

Figures shows that variation of stability, flow, Air voids%, Bulk specific gravity, VMA, VFB with change in percentage of bitumen for Bituminous Concrete Grade –I mix. From the results which are shown in Graphs we can clearly conclude that the stability values increase with increase in binder content up to 5.5 % Bitumen Content after that it starts decreasing. We also conclude that the stability values for specimens with Fresh aggregate (CM), Aggregate with 10% RAP (NCM-I), Aggregate &10% RAP with UFS (filler)(NCM-II), Aggregate with 10% RAP and sand (filler) (NCM-III), the stability values were decreases but the values are above than the minimum Marshall stability values. We can also observe that the stability values for Aggregate with10% RAP and UFS (filler) is greater than Aggregate with 15% RAP, Aggregate with 10% RAP and sand (filler) and closer to the Virgin aggregate sample specimens. The maximum stability values obtained at 5.5 % Bitumen content in each case.

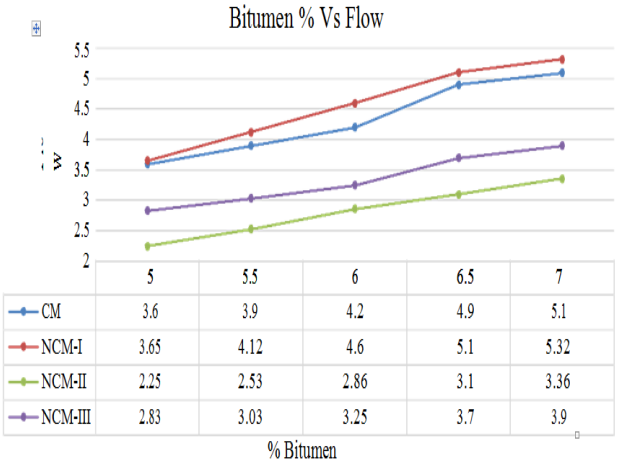


Fig.9-(b) Flow vs Percent Bitumen

Fig 9-(b) shows that the flow values regarding various bituminous contents for conventional and non-conventional mixes. The flow values are increases with increase in binder content. When compared with conventional specimens the flow values were decreases for, non-conventional specimens particularly in the case of NCM-II, NCM-III and are exactly lies within the Marshall flow value Range i.e. 2mm – 4 mm, the maximum flow value for NCM-II is 3.36 % at 7 % Bitumen and for NCM –III the maximum flow value is 3.9 at 7 % Bitumen, from that we can conclude that NCM-II, NCM-III having higher resistance to deformation increases resulting in low flow value, compared to CM, NCM –I.

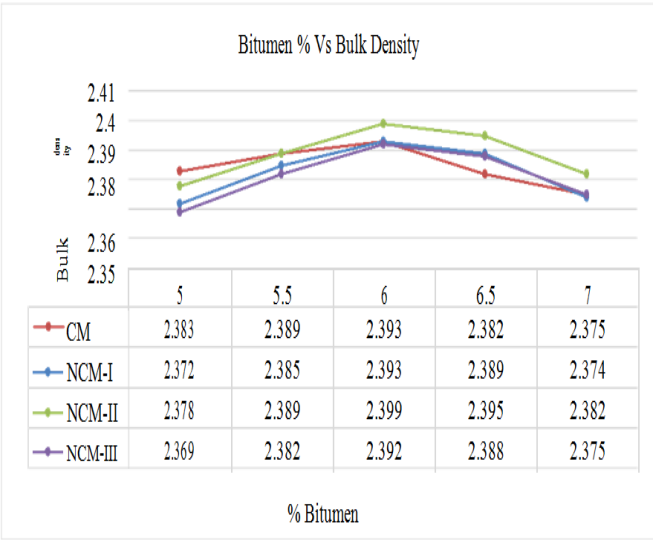
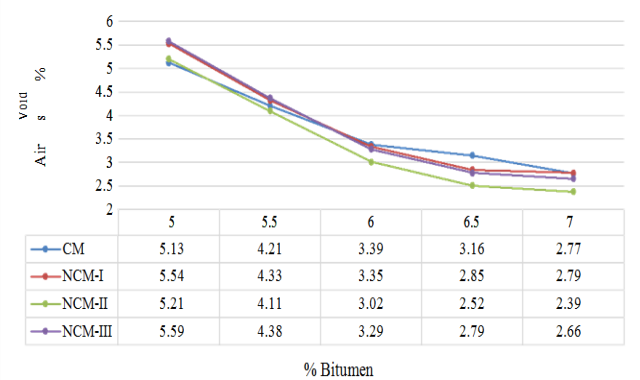


Fig – 9 (c) Bulk density vs Percent Bitumen

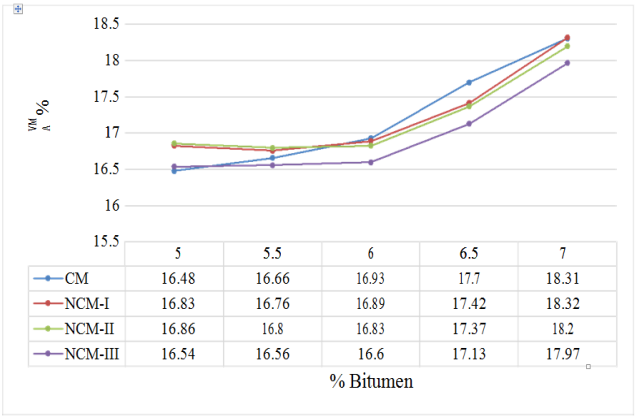
Fig – 9 (c) shows the bulk specific gravity is maximum at 6.0 % bitumen content for conventional mix, NCM-I, NCM-II, NCM-III respectively. It is the fact that Higher the Specific gravity values will increase the pavement performance. From the results it is clearly notify that NCM-II having higher specific gravity 2.399, compared to other Conventional and Non-conventional mixes, may have better performance than others.



	5	5.5	6	6.5	7
CM	5.13	4.21	3.39	3.16	2.77
NCM-I	5.54	4.33	3.35	2.85	2.79
NCM-II	5.21	4.11	3.02	2.52	2.39
NCM-III	5.59	4.38	3.29	2.79	2.66

Fig – 9 (d) Air voids % vs Percent Bitumen

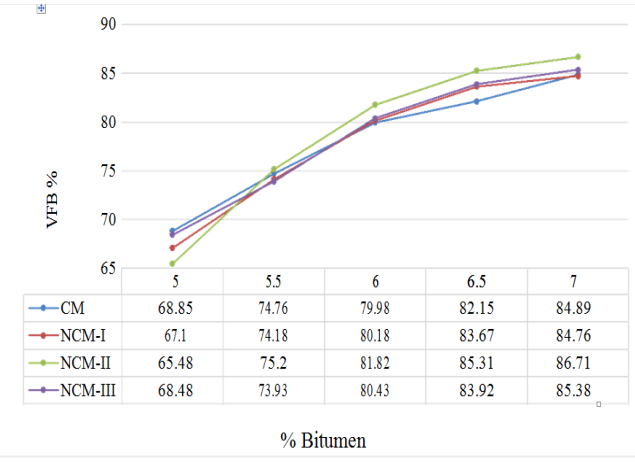
Mixes with excessive air voids would results cracking because of lack of bonding between binding material and the aggregate, and too less voids results more plastic flow (rutting), bleeding. From the test results we can conclude that NCM-II having better Air voids % compared to others. The Maximum % Air voids obtained at 5.0 % bitumen content at each case and these values are lies below than the maximum %Air voids values.



	5	5.5	6	6.5	7
CM	16.48	16.66	16.93	17.7	18.31
NCM-I	16.83	16.76	16.89	17.42	18.32
NCM-II	16.86	16.8	16.83	17.37	18.2
NCM-III	16.54	16.56	16.6	17.13	17.97

Fig – 9 (e) VMA % vs Percent Bitumen

VMA values are lesser for NCM – II when compared to other mixes and also these values are greater than minimum VMA values which is 12 % and these values are lesser than the maximum VMA limit 18 %. But in the remaining cases the values cross maximum limit. VMA of 16.78%,16.817%,16.574%,16.183% were achieved for Conventional mix, NCM-I, NCM-II, NCM-III at an optimum binder content of 5.7%,5.72%,5.68%,5.72% respectively.



	5	5.5	6	6.5	7
CM	68.85	74.76	79.98	82.15	84.89
NCM-I	67.1	74.18	80.18	83.67	84.76
NCM-II	65.48	75.2	81.82	85.31	86.71
NCM-III	68.48	73.93	80.43	83.92	85.38

Fig – 9 (f) VMA % vs Percent Bitumen

VFB values for CM, NCM-I, NCM-II, NCM-III are 76.848,76.82,75.79,77.583. for an optimum bitumen content of 5.7,5.72,5.68,5.72 respectively. VFB of 74.76%, 74.18%,73.93%,68.48% for conventional mix and NCM-I, NCM-II, NCM-III respectively which are greater than minimum voids filled with bitumen and are below than the maximum values at 5.5,5.5,5.0,5.5 percent bitumen contents respectively.

V.CONCLUSIONS

i) Marshall specimens with RAP 10 % reducing the usage of fresh binder content and the Stability values are greater than minimum Marshall Stability values.

ii) The Stability values for NCM-II is very near to the Conventional ones.

iii) The flow values regarding NCM-II, NCM-III are shown very much satisfactory results compared to Conventional mix i.e. The values lie between 2mm-4mm which is exact range for Bituminous concrete grade–I.

iv) Mixes without antistripping agents shows lesser moisture resistance compared to mixes with antistripping agents at an optimum of 1 % antistripping agent in the weight of bitumen.

v) The optimum binder content (OBC) for NCM-II is 5.68 % which is lesser than Conventional (5.7 %), NCM-I (5.72 %), NCM-III (5.72 %).

vi) From the above conclusions we can clearly conclude that NCM-II is showing better results i.e. these specimens not only reducing the optimum binder content but also satisfies the Marshall Stability and flow values to a great extent.

vii) NCM-II reducing the construction cost by partial replacement of fresh aggregate with 10% RAP and filler with used foundry sand (UFS).

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