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A STUDY ON EFFECTOFAGGREGATEGRADATIONANDSIZEONCOLDBITUMINOUSMIX

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Abstract :

In India, about90%ofthetotalroadnetworkincluding airfieldpavementisof flexiblepavement,whichareconstructedusinghotmixtechnology.Hotmix technology hasnumerous drawbacks.Someofthemare liberation ofgreenhouse gases, highconsumptionofenergy,healthhazardstoconstructionlabours,etc.Hence, adoptionofalternativetechnologysuchascoldmixtechnologyisneededtoreducethe drawbacksofhotmixtechnology. InthisstudytwoaggregategradationsaretakenbasedontheNominal MaximumParticleSize(NMPS):NMPS13.2mmandNMPS19mmfromMinistry of RoadTransportandHighways(MoRTH)specification.Further,twomoreaggregate gradationswereformulatedforeachNMPSbasedonmodifiedFullerandThompson maximumdensity gradationandCooper’setal.equationwith4%filler.Thegradation ofMoRTHgradation,modifiedFullerandThompsonequationandCooper’setal. equationforNMPS13.2mmaredesignatedasM13.2,MFT13.2,andC13.2 respectivelyandforNMPS19mmgradationsasM19,MFT19andC19respectively. Mediumsettingcationictypebitumenemulsionwasusedforthisstudy.Thestudy methodologyincludescharacterizationofaggregatesandemulsion,determinationof pre-wettingwatercontent,volumetricanalysisofmixesbyMarshallStabilitytest, performanceevaluationbyRetainedMarshallStability(RMS)test.A parametercalledgradationratioiscorrelatedwithstrengthandperformanceparameters ofthemixtopredictlaterfromaggregategradationcurvealone.

Keywords - NMPS, MORTH, prewettingwatercontent, MarshallStabilitytest, RetainedMarshallStability.

1.INTRODUCTION

Intheemulsion-basedcoldmixtechnology,theadditionofpre-wettingwater totheaggregate,thereafteradditionofemulsiontoit,productionofthemix,layingand compaction,allprocesses aredoneattheroomtemperature(23ºCto25ºC) .Inaddition tothis,fieldtrialshaveprovedthatcoldmixcan

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beeasily producedby usinghotmix plantandlaidinusingsimilartechniques. Itisalso alabourfriendlytechnology. Itcan producemanuallyforsmall-scalejobslikepatchwork,potholes,andrepairs.It particularlysuitedfortheconstructionofroads intopographicalandweather constraints, remote and isolated areas. Coldbituminousmixture(CBM)iscomposed ofapproximately 95%byweight or80%byvolumewithmineralaggregate.Therefore,itisessentialtoseehow aggregategradationaffectstheperformanceofcoldbituminousmixes.Aggregates formtheskeletonofthebituminousmixtureandareresponsiblefortheloadcarrying capacityofpavement.Aggregategradationandsizeaffectstheworkability,layer thickness,ruttingresistance,fatiguecracking, permeability,surfacetextureand frictional resistance.

Coldbituminousmixture(CBM)iscomposed ofapproximately 95%byweight or80%byvolumewithmineralaggregate.Therefore,itisessentialtoseehow aggregategradationaffectstheperformanceofcoldbituminousmixes.Aggregates formtheskeletonofthebituminousmixtureandareresponsiblefortheloadcarrying capacityofpavement.Aggregategradationandsizeaffectstheworkability,layer thickness,ruttingresistance,fatiguecracking, permeability,surfacetextureand frictional resistance.

The propertiesofthebituminousmix including thedensity andstability are muchdependentontheaggregatesandtheirgrainsizedistribution.Gradationhasa profoundeffectonmixperformance.Itmightbereasonabletobelievethatthebest gradationistheonethatproducesmaximumdensity.Thiswouldinvolveaparticle arrangementwheresmallerparticlesarepackedbetweenlargerparticles,thusreducing thevoidspacebetweenparticles.Thiscreates moreparticletoparticlecontact,which wouldincreasestabilityandreducewaterinfiltrationofbituminouspavements. However,someminimumamountofvoidspaceisnecessarytoprovideadequate volumeforthebindertooccupy,promoterapid drainageandprovideresistancetofrost action for base and sub base courses.

2. OBJECTIVE

a. Tostudytheeffectofaggregategradation andsizeonperformanceofcold bituminous mix
b. Toselectsuitableaggregategradationswithinaspecifiedgradationlimitfor cold bituminous mixes
c. ToevaluateseveralCBM(ColdBituminousMix)specimensintermsof Marshall Stability
d. ToevaluatetheOptimumEmulsionContent(OEC)fordifferentaggregate gradations.
e. Toevaluatethemechanicalpropertiesofthemixlike RetainedMarshall Stability.

3.MATERIALS USED

A. Aggregate tests

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Table.1 Properties of aggregates

Experiment	Test Results
Specific Gravity (CA)	2.74
Specific Gravity (FA)	2.67
Aggregate Impact value (%)	28.72
Aggregate Crushing value (%)	29.20
Los Angeles Abrasion Test (%)	28.43
Combined Elongation and Flakiness index (%)	25.53
Water absorption (CA) (%)	0.44

B. Bitumen Tests:

Table.2 Properties of bitumen emulsion

Experiment	Sample No	Test Results
Residue on 600 micron (%)	1	0.0175
	2	0.0425
	3	0.035
	Average	0.031
Coagulation at low temperature	1	Nil
	2	
	3	
Viscosity by SayboltFurol Viscometer in Furol Seconds	1	236
	2	252
	3	205
	Average	231
Storage stability after 24 hours (%)	1	0.96
	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
	2	
	3	
Residue by evaporation (%)	1	65.48
	2	66.21
	3	65.63
	Average	65.77
Tests on residue		
Penetration, mm	1	110
	2	89
	3	105
	Average	101.33
Ductility, cm	1	65
	2	68
	3	76
	Average	69.67

Specific gravity	1	1.01
	2	1.03
	3	1.01
	Average	1.016

C. Aggregate gradation:

Table.3 Aggregate gradation for NMPS 13.2mm

	MoRTH	Modified Fuller andThompson Gradation	Gradation based on Cooper's et al. equation
Designation	M13.2	MFT13.2	C13.2
Sieve size(m	Percentageof passing (%)		
19	100	100	100
13.2	95	84.9	84.2
4.75	57.5	53.6	51.4
2.36	40	39.1	36.3
0.300	12.5	15.5	11.5
0.075	5.5	8.3	4

Table. 4 Aggregate gradation for NMPS 19mm

	MoRTH	Modified Fuller andThompson Gradation	Gradation based on Cooper's et al. equation
Designation	M13.2	MFT13.2	C13.2
Sieve size(m	Percentageof passing (%)		
26.5	100	100	100
19	95	86.1	85.6
9.5	70	63	61.8
4.75	50	46.1	44.3
2.36	35	33.7	31.4
0.300	11.5	13.3	10.4
0.075	5	7.1	4

4. EXPERIMENTAL WORK

A. Determination of Initial Emulsion Content (IEC)

$$IEC = 0.05A+0.1B+0.5C$$

Where, IEC = Initial emulsion content (%)
A = Percentage of aggregate retained on 2.36 mm sieve

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B = Percentage of aggregate passing 2.36 mm sieve and retained on 75-micron sieve
C = Percentage of aggregate passing on 75-micron sieve

IEC for NMPS 13.2 mm is 9.2%.

B. Optimum pre-wetting water content

Pre-wetting of the aggregate is necessary because by adding the water initially to aggregate, it will become an optimum moist state so if bitumen emulsion added to the aggregate, it will not absorb the water content in the emulsion. If aggregate absorb the water from the emulsion, workability will reduce and very difficult to mix, and it won't provide the better coating. The coated aggregates are then visually observed for the coated area of the aggregate by the binder. The optimum water content is the water content at which the maximum coating of aggregate occurs. After carrying out several trials with water contents of 1, 2, 3, and 4%, the Optimum Pre-wetting Water Content was found to be 2%. This OPWC was adopted in this investigation for preparing cold bituminous mix specimens.

C. Marshall mix

The mixes were prepared according to the IRC: SP: 100-2014 cold mix design procedure.

The Marshall Stability and flow test is the performance prediction measure for the Marshall mix design method. The resistance of a compacted cylindrical sample of the bituminous mixture to plastic deformation is measured in this method when the sample is loaded diametrically at a rate of 50 mm per minute. There are two significant features of the Marshall method of mix design. (i) density-voids analysis and (ii) stability-flow tests. The Marshall Stability of the mix is defined as the maximum load carried by the specimen at the specified standard test temperature. The flow value is the deformation undergone by the test specimen while loading up to the maximum load. The apparatus consists of the mould assembly, sample extractor, compaction pedestal, and hammer, breaking head, loading machine, flow meter, and water bath. Three compacted samples are prepared for each binder content in the Marshall mix design test method. To get the optimum binder content, at least five binder contents are to be tested. The following tests are carried out on all compacted specimens: determination of bulk density, stability and flow test and analysis of density and voids of the mix.

Table.5 Optimum pre-wetting water content for all gradations

	M13.2	MFT 13.2	C13.2	M19	MFT 19	C19
IEC (%)	9.5	10	8.5	9	9.5	8

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OPWC(%)	2	2	1	2	2	1

D. Retained Marshall Stability (RMS) Test

It is well known that the presence of moisture in a bituminous mix is a critical factor, which leads to premature failure of the flexible pavement. The loss of adhesion of aggregates with bitumen emulsion is studied by utilising Retained Stability Test to examine the effect of additive on resistance to moisture induced damage. Retained Marshall Stability is the ratio of soaked stability to dry stability. Both soaked stability and stability samples are prepared at OEC. After having been subjected to oven curing as explained for dry stability samples.Thedrysampleswerewaterconditioned(capillarysoaking).Inthisprocedure, half the thickness of each compacted specimen is soaked in water at roomtemperature for24hours,thespecimenistheninverted,andtheotherhalfwassoakedforafurther24hours. During soaking, the samples would rest on a bed of approximately 15 to 20 mm coarse sand. The samples are subsequently towel dried then tested for Marshall Stability at room temperature. The Marshall Stability test results obtained are referred to as Soaked Stability values.

$$\text{Retained Marshall Stability} = \left(\frac{\text{Soaked Stability}}{\text{Dry Stability}}\right) * 100$$

5. RESULTS & DISCUSSIONS

A. MARSHALL STABILITY TEST

The optimum composition of all six gradations was determined using the Marshall method for cold mix design as per the IRC:SP:100-2014. Marshall values for all gradations with different percentage of emulsion as shown in Below figures. The Marshall properties of such mixes with respect to the variation in residual bitumen content was studied. OEC for M13.2, MFT13.2, and C13.2 gradations were obtained as 8%, 9%, and 7% respectively. Also, OEC for M19, MFT19, and C19 gradations were obtained as 7.5%, 8%, and 7% respectively. OEC content decreased for an increase in the size for MoRTH and modified Fuller and Thompson gradations because the filler content is more in M13.2 and MFT13.2 than the M19 and MFT19 respectively and OEC remained same for Cooper's et al. gradations because of same filler content in the C13.2 and C19 gradations. High filler content have high surface area which requires more residual bitumen for coating. Marshall Stability values of M13.2 and M19 were found to be the highest among gradations under the categories of NMPS 13.2 mm and 19 mm respectively. The quantity of aggregate on NMPS sieve size is more for modified Fuller and Thompson and Cooper's et al. gradations than the MoRTH gradation. Among NMPS 13.2 mm gradations, Marshall Stability was found to be higher for MoRTH gradation, and it forms a dumbell shape with an increase in bitumen emulsion. Bulk density increases and then decreases after reaching a peak value for MoRTH gradation and

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continuously increases for other two gradations. Air voids fall in the range of 8 to 12 %, 10 to 12 % and 11 to 19 % for Fuller and Thompson, MoRTH and Cooper's gradations respectively. VMA decreases to lower peak and then increases and VFB increases for all gradations with the increase in bitumen emulsion as shown in fig 5.7. Among the NMPS 19 mm gradations, Marshall Stability was found to be higher for MoRTH gradation and varies rapidly with the increase in bitumen emulsion. These gradations also followed the same trend as NMPS 13.2 gradations in bulk density. Air voids fall in the range of 5 to 10 %, 11 to 14 % and 11 to 16 % for Fuller and Thompson, MoRTH and Cooper's gradations respectively as shown in fig 5.8. Marshall Stability values for C13.2 and C19 gradations showed a similar trend with closer values, but MoRTH and modified Fuller and Thompson not followed the same trend as size of aggregate increases as shown in figure below Bulk density increases and then decreases after reaching a peak value for M13.2 and M19 gradations, but increases for all other gradations with an increase of RBC shown in fig 5.9(b). Air voids decreases and flow value increases for all gradations with an increase in RBC as shown in fig 5.9(c) and 2(d). Air voids fall in the range of 5 to 14 %, 11 to 19 % and 10 to 14 % for Fuller and Thompson, Cooper's and MoRTH gradations respectively. It was observed that Marshall Stability decreases and VMA increases with increase in aggregate size for MoRTH gradation.

Gradations	Optimum Bitumen em	Optimum Residual Bitum	Marshall Stabil	Flow valu	Bulk speci	Air voids	V b	VMA	VFB
	%	%	kN	mm					
M13.2	8	5.23	8.13	4.19	2.214	10.62	11.46	22.08	51.90
MFT 13.2	9	5.88	7.06	5.00	2.211	9.79	12.87	22.66	56.79
C13.2	7	4.57	6.95	4.85	2.121	15.26	9.6	24.86	38.62
M19	7.5	5.55	7.44	5.63	2.180	11.67	11.98	23.65	50.66
MFT 19	8	5.23	7.32	5.25	2.271	8.28	11.76	20.04	58.68
C19	7	4.57	7.15	4.97	2.153	14.02	9.74	23.76	40.99

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Table.6 MarshallStability test results for all gradations at ORBC

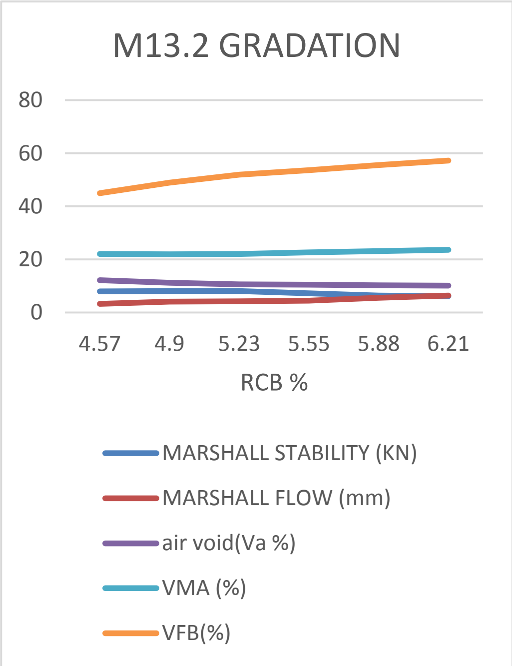

Fig.1 Marshall graphs for M13.2 gradation

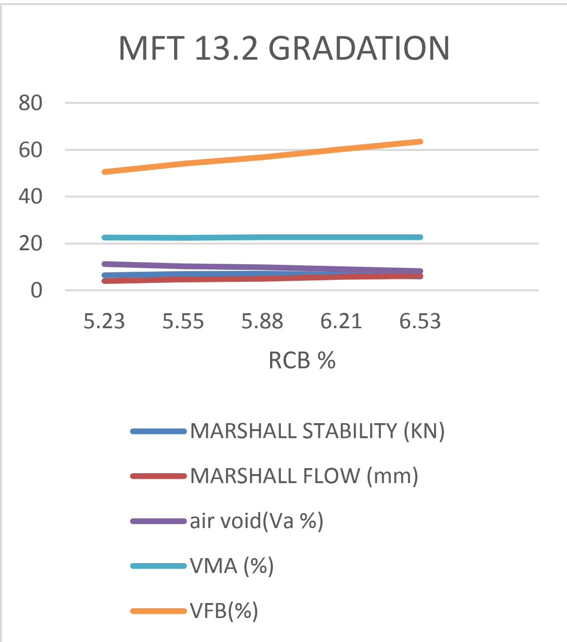

Fig .2 Marshall graphs for MFT13.2 gradation

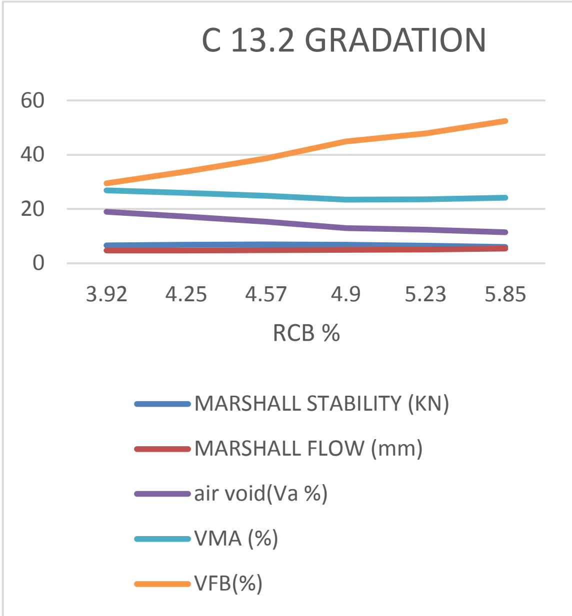

Fig .3 Marshall graphs for C13.2 gradation

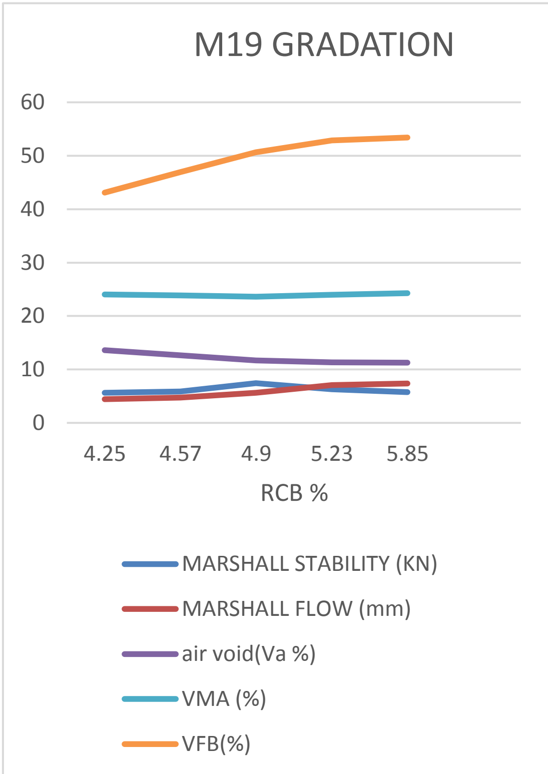

Fig .4 Marshall graphs for M19 gradation

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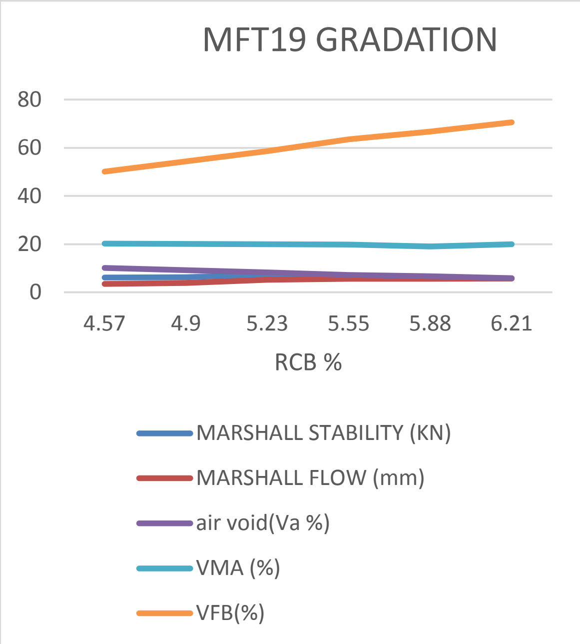

Fig .5 Marshall graphs for MFT19 gradation

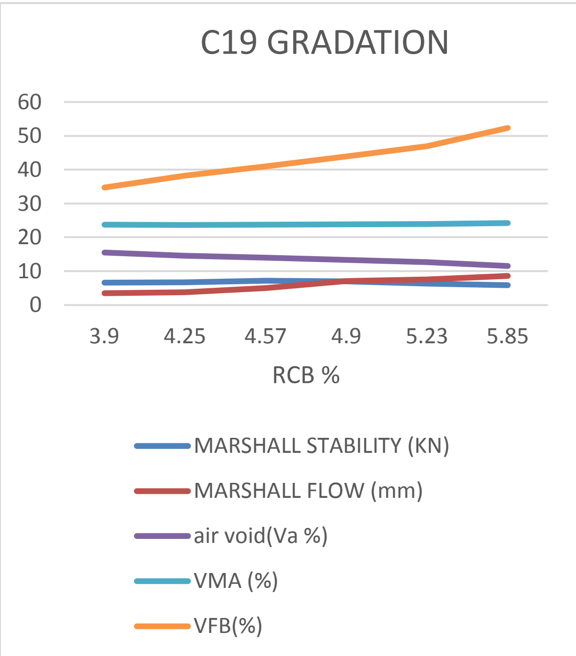

Fig..6 Marshall graphs for C19 gradation

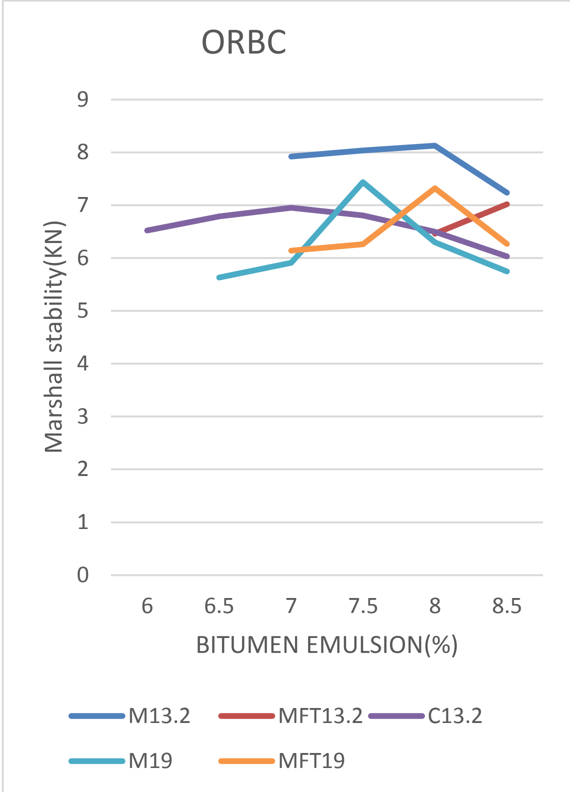

Fig .7 Marshall stability for various gradation

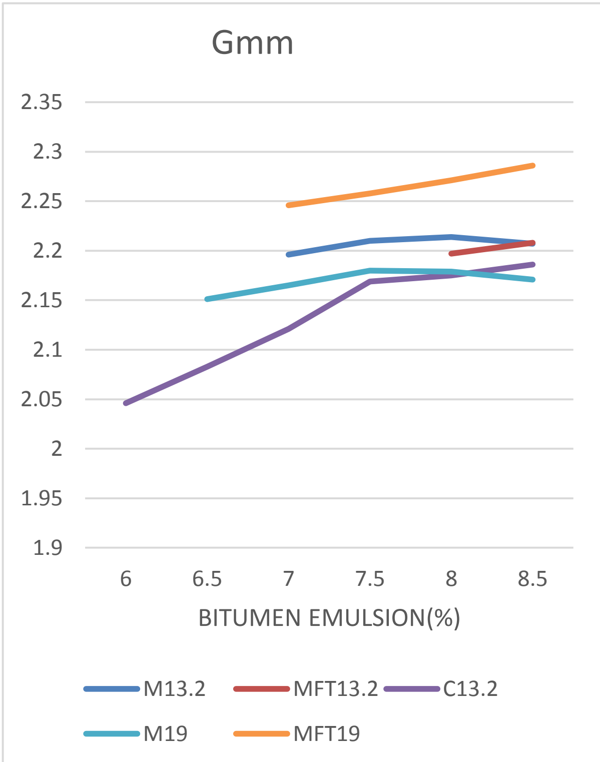

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Fig .8 Bulk specific gravity (Gmm) for various gradation

B. RETAINEDMARSHALL STABILITY

Soaked stability test conducted after soaking half thickness of the sample in water for one day and reversed for one day. Soaked stability values was found to be higher than the dry stability values because of the possible reaction of emulsifiers with water. Retained Marshall Stability was calculated for all gradation at OEC. RMS was found to be higher than the 100% for all gradations and the results are shown in below table.

Gradations	OEC	Dry Marshall stability	Soaked Marshall stability	Retained Marshall Stability
	%	KN	KN	%
M13.2	8	8.13	9.23	113.53
MFT13.2	9	7.06	7.15	101.27
C13.2	7	6.95	7.88	113.38
M19	7.5	7.44	8.11	109.01
MFT19	8	7.32	8.19	111.89
C19	7	7.15	9.15	127.97

Table .7 Retained MarshallStability for all gradations

6. SUMMARY

Two aggregate gradations were taken based on the NMPS: NMPS 13.2 mm and NMPS 19 mm from Ministry of Road Transport and Highways (MoRTH) specification. Further, two more aggregate gradations were formulated for each NMPS based on modified Fuller and Thompson maximum density gradation and Cooper's et al. equation. The study methodology included characterization of aggregates and emulsion, determination of pre-wetting water content, volumetric analysis of mixes by Marshall Stability test, performance evaluation by Retained Marshall Stability (RMS). A parameter called gradation ratio was correlated with strength and performance parameters of the mix to predict later from aggregate gradation curve alone.

7. CONCLUSION

a. Aggregate gradation affects the Marshall design parameters. The quantity of coarse aggregate equal to NMPS sieve size is more in the modified Fuller and Thompson and Cooper's et al. gradation compare to MoRTH gradation. It leads to less

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interlock by the presence of filler quantity. For, both NMPS 13.2 mm and 19 mm categories, MoRTH gradations gave the peak stability values.

b. Marshall Stability value increases with the increase in the size of the aggregate for modified Fuller and Thompson gradation and Cooper's gradation but decreases with increase in the size of aggregate for MoRTH gradation.

c. For MoRTH gradations, as NMPS increases VMA increases, but for Fuller and Thompson and Cooper's gradations as NMPS increases VMA decreases.

d. From the above two points, it can be concluded that as the size of the aggregate increases, Marshall Stability increases and VMA decreases, and vice versa.

e. As the size of the aggregate in a particular gradation increases, optimum residual bitumen content decreases for MoRTH and modified Fuller and Thompson gradation, but remains same for Cooper's et al. gradation. This is because, the filler content in NMPS 13.2 mm gradation of MoRTH and modified Fuller and Thompson is higher than NMPS 19 mm gradations, and filler content is same for Cooper's gradation. Surface area is high for higher filler quantity. Higher surface area requires high emulsion content for full coating.

f. Air voids also changes with change in gradation and NMPS. Air voids for MFT 13.2 is 9.79 and for MFT 19 is 8.28% at OEC. These values are less compared to other gradation because of higher filler quantity.

g. Cooper's gradation shows better rutting resistance among three gradations of NMPS 13.2 mm and NMPS 19 mm.

h. Retained Marshall Stability is above the 100% for all gradations.

8. FUTURE STUDY

a. The **s**ame study can be conducted with different filler variations in the Cooper's et al. equation.

b. Comparison of CBMs with Hot Mix Asphalt (HMA) can be studied by conducting the performance tests with all the six gradations using HMA.

c. Study with CBMs using RAP material can be conducted to save the material and save money.

d. The study can be extended with different curing temperatures and curing period.

e. Wheel tracking test can be performed with & without the presence of water.

f. The other mix performance studies can be conducted to understand the fatigue behaviour of the mixture.

9. REFERENCES

a. Asphalt Institute: Asphalt Cold Mix Manual, Standard Manual Series No. 14

b. (MS-14), Third Edition, KY 40512-4052 USA, 1997.

c. Banerji, A. K., et al.(2014), "Comparative Evaluation on the Properties of HMA with Variations in Aggregate Gradation of Laboratory and Field Produced Mixes", Vol. 3, pp 1-9.

d. Brown E.R and Basaett C.E. (1989), "The Effects of Maximum Aggregate Size on Properties of Asphalt Aggregate Mixes", *Highway Research Center Harbert Engineering Center*, Auburn University, Alabama.

e. Brown, S. F., and Needham, D. (2000), "A Study of Cement Modified Bitumen Emulsion Mixtures" *Annual Meeting of the Association of Asphalt Paving Technologists*.

f. Bureau of Indian Standards, BIS IS 1202-78: Indian Standard Methods for Testing Tar and Bituminous Materials: Determination of Specific Gravity, New Delhi, India, 1978.

g. Bureau of Indian Standards, BIS IS 2386(Part-I)-1963: Methods of Test for Aggregates for Concrete, Part I: Particle Size and Shape, New Delhi, India.

h. Bureau of Indian Standards, BIS IS 2386(Part-IV)-1963: Methods of Test for Aggregates for Concrete, Part IV: Mechanical Properties, New Delhi, India.

i. Bureau of Indian Standards, BIS IS 8887-2004: Bitumen Emulsion for Roads (Cationic Type) – Specification, Second Revision, New Delhi.

j. Cooper, K.E., Brown, S.F., and Pooley, G.R., (1985), "The Design of Aggregate Gradings of Asphalt Base Courses", *Proceedings of Conference of Association of Asphalt Pavement Technologists*, Vol. 54, pp 324-346

k. Campen et al. (1963), "Factors that Control Asphalt Requirement of Bituminous Paving Mixtures and a Method for Determining the Proper Asphalt Content", *Proceedings AAPT*, Vol. 32, pp. 530-544.

l. Dash, S.S and Panda, M., (2015), "Effect of Aggregate Gradation on Cold Bituminous Mix performance", *Advances in Civil Engineering Materials*, Vol.4, No. 1, pp 155-174.

m. Dilliprathap G. (2011), "Effect of Aggregate Gradation and Moisture on Performance of Modified Bituminous Mixes", *Unpublished M.TechThesis submitted to Department of Civil Engineering, NIT Calicut*.

n. Fuller W. B and Thompson S.E., (1907), "The Laws of Proportioning Concrete", *Transactions of the American Society of Civil Engineers*, Vol. 59, No. 2, pp 67-143.

o. Harshavardhan C. B. (2017), "Performance Evaluation of Cold

Bituminous Mixes", *Unpublished M.Tech Thesis submitted to Department of Civil Engineering, NIT Calicut*.

p. Hongying L, Peiwen H and Jinzhi X, (2017), "Effects of Nominal Maximum Aggregate Size on the Performance of Stone Matrix Asphalt", *Applied Sciences*, Vol 7, No.126, pp 1-9.

q. Haider H.A., Yassir N.A.K., and Satish Chandra, (2012), "Effect of Aggregate Gradation on Moisture susceptibility and Creep in HMA", *International Journal of Civil and Environmental Engineering*, Vol.6, No.12, pp 1082-1087.

r. Huber, G. A., and Heiman, G. H., (1987), "Effect of Asphalt Concrete Parameters on Rutting Performance: A Field Investigation", *Proceedings, Association of Asphalt Paving Technologists*, Vol. 56, pp 33-61.

s. I.N.A Thanaya, (2007), "Review and Recommendation of Cold Asphalt Emulsion Mixtures (CAEMs) Design", *Civil Engineering Dimension*, Vol. 9, No.1, pp. 49-56

t. Indian Roads Congress, Use of Cold Mix Technology in Construction and Maintenance of Roads using Bitumen Emulsion, Standard IRC:SP:100-2014, IRC, New Delhi.

u. Ministry of Road Transport and Highways(MoRTH), Specifications for Road and Bridge Works, Fifth Revision, Ministry of Road Transport and Highways, New Delhi, 2013.

v. Needham, D. (1996), "Developments in bitumen emulsion mixtures for roads", Thesis submitted to the University of Nottingham for the degree of Doctor of Philosophy, pp 1-203.

w. Priyansh S, Aravind K. S, (2015), "Influence of Aggregate Gradation on Permanent Deformation Characteristics of Asphalt Concrete", *3rd Conference of Transportation Research Group of India, Kolkata*.

x. RajanChoudhary, AbhijitMondal and Harshad S. K, (2012), "Uses of Cold Mixes for Rural Road Construction", *International Conference on Emerging Frontiers in Technology for Rural Area (EFITRA)*, pp 20-24