AN EXPERIMENTAL INQUIRY INTO BITUMINOUS CONCRETE AND STONE MATRIX ASPHALT-2

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ABSTRACT

Stone Matrix Asphalt (SMA) is a gap graded mix that has a substantial proportion of coarse aggregates that are kept together by a rich matrix of filler, fibre or polymer stabiliser in a thick asphalt film. This mix is also known as stone matrix asphalt. SMA is regarded as a premium mix by a number of state departments of transportation for use in regions that experience large volumes of traffic and have circumstances that need regular maintenance that may be expensive. The mixture receives a stabilising component such as cellulose fibre in order to prevent the binder from leaching out of the mixture while it is being transported and placed.

In the current investigation, an effort is made to evaluate two different bituminous mixes, namely Bituminous Concrete (BC-2) and Stone Matrix Asphalt (SMA-2). Both of these mixes are referred to as bituminous mixes. Within the context of this project, the additive ARBOCEL-ZZ8/1 serves the purpose of stabilising. In this project, a number of different types of tests, including the Marshall Stability test, the Drain down test, the Indirect Tensile Test, and the Rutting Test, are carried out.

I.INTRODUCTION

Transportation is the key infrastructure of a country. A country's economic status is mainly is depends upon the how well the country is by its roads. The rate of economic growth is inter-related with the rate at which the transport sector grows. The four major modes of transportation are roadways or highway for transportation, railways, waterwaysandairways.

Several thousand kilometers of highways are constructed or upgraded each year due to increase in the demand in transport sector of the country. Good roads are the symbol of a healthy economy and it helps the economy growth better. To reduce the vehicle operating cost (VOC) it is essential to have a road that gives smooth ride. The material quality, proper mix design, good construction practices are the main factors that determine the quality of the roads and its level of maintenance in future. The performance of newly constructed or upgraded roads is not all that satisfactory. Many highway pavements are suffering from premature failure, primarily in terms of cracking and rutting. There are many reasons for the premature failure of pavements including poor material choice, improper surface and sub-surface drainage, poor construction practice etc. Failure could be primarily in the form of cracking or rutting.

Bituminous pavements are prone to rutting due to failure of one or more of the layers. Rutting is the plastic strain resulting in permanent deformation caused in one or more layers of bituminous pavement. Rutting may occur on a pavement due to densification of bituminous layer or due to deformation of the lower layers generally on the more traversed wheel path. Very often shoving and rutting occur simultaneously. Shoving is the longitudinal displacement of bituminous material as load applied has a horizontal component in addition to vertical on the pavement surface. This phenomenon is common at curves and intersections and happens due to traction action of thewheel. Shoving ultimately results in heaving in the direction of horizontal component of the load applied and rutting on to the side.

Overlay on such roads which have sustained rutting despite adequate structure strength of lower layers does not resolve the problem and demands replacement of the affected bituminous layer.

The new materials to have better performance, though costly are available, but rarely used. Mixes are design such that they are more rut resistant and have been formulized and need to be tested for Indian conditions. This can happen only when these new materials are used in test sections and monitored for their performance. Gap graded mixes are known to be rut resistant due to stone-stone contact for better load dispersion and reduce the effect of flow of mastic available in the mix. Modified binder are also available and the bitumen standards have been amended from penetration grade to viscosity grade, however, choice of performance grade bitumen would yield betterresults.

The riding quality is bad at the rutted portion of the roads and also the vehicle operating cost increases. This will leads to road accident. Hence the countries demands for roads which is able to sustain the premature rutting and cracking.

Bituminous concrete (BC) which is widely used mix in India. BC mix is a dense graded mix and which is impermeable and it offers good compressive strength.

Stone Matrix Asphalt (SMA) has become more popular mix across the world for the surfacing of heavy traffic roads, airfield pavements and harbour in Europe. The surface that obtained from SMA that provides good riding comfort and its texture gives good skidding resistance to road users. The strong aggregate to aggregate contact provides resistance to permanent deformation and the rich bitumen content which fills the voids between the particles makes SMA highly durable.

1.2 Bituminous MixesRequirements

1.2.1 Flexibility

It is property of the bituminous pavements which undergoes deformation during the loading and it regains its original shape after the removal of the loads.

1.2.2 Durability

The term durability defined in terms of resistance against weathering such as heaving and thawing and also abrasion action. The examples of failure are pot holes, stripping, etc.

1.2.3 Stability

It is the resistance of the bituminous mix to deformation under wheel load. Stability is depend on the inter particle arrangement, aggregates and the cohesion offer by the binder and the coating of the bitumen to the surface of the aggregate.

1.2.4 SkidResistance

It is the resistance offered by the pavement to the skidding action. The skid occurs due to the lack of the friction between the pavement surface and vehicle tire. The skid resistance that can be achieved by providing good surface texture to the road surface.

1.2.5 Workability

Workability is defined as how much easily the paving mix is laid and compacted. Workability is mainly depends on the aggregates gradation, shape and size of the aggregate and bitumen content.

1.3 Need for theStudy

Indian Government is spending the crores of money on the infrastructure development such as roads; bridged etc. Nearly 30% of money is spent on the road in every year for new construction, up gradation and maintenance of existing roads. Better pavements can be provided if the material quality and construction practice is good. Causes of pavements failure are the identified in the early stage and that are seriously consider and suitable measures are to taken. The usage of the new technology such as SMA for the road construction may solve the problems like permanent deformation, potholes, moisture damage etc. CRRI says that while BC breaks down frequently in areas where the drainage is not provided properly.

The various studies are to be conducted on the new technology and that are compared with the existing technology, the results are compared with standards and that can be adopted for the better performance of theroads.

III.MATERIALS AND METHODOLOGY

It is very important to design a road free from cracking and rutting for the safety purpose and also for the economy purpose. The construction of such roads involves huge capital investment and superior material quality and construction.

In this project investigation a laboratory study is conducted to know the performance of BC (grade-2) and SMA (grade-2) and also the physical properties of aggregates, binder properties and Job Mix Formula for BC-2 etc. The aggregate gradation is checked as per MORT&H specification and Marshall stability test is conducted on two mixes with varying amount of binder content to determine the optimum binder content (OBC).

Further, the mix is tested for the drain down to determine the amount of drain down of bitumen from the un compacted mix, the static indirect tensile strength for both the mixes is determined and also the rutting test is conducted on both BC and SMA to know the resistance of mixes against rutting.

3.2 Materials

The materials used in this project are the Mineral aggregates, Filler materials, Binder and the Stabilizing additive (cellulose fibers).

3.2.1 Mineral aggregates

The of role Mineral aggregate in the bituminous mix design is very important. The performance of the bituminous mix is depends on the physical and chemical properties of aggregates.

The aggregate used in this project which is from SRK Projects quarry (Lab) near Alur Kurnool District.

Figure 3.1 Mineral Aggregate

3.2.2 Stonedust

The crushed stone dust is used in this project which is from SRK Projects quarry Alur, Kurnool Dist.

Figure 3.2 Stone Dust

3.2.3 Binder

The binder used in this project is Viscosity grade 30 (VG-30) which is SRK Projects lab, Alur, Kurnool Dist.

Figure 3.3 Viscosity Grade 30 Bitumen

3.2.4 Stabilizing additive

The stabilizing additive used in this project is ARBOCEL ZZ8/1 as cellulose fiber which is brought from SMART (Strategic Marketing and Research Team) Bangalore in the mix to avoid the drain down of mix while transportation and placing.

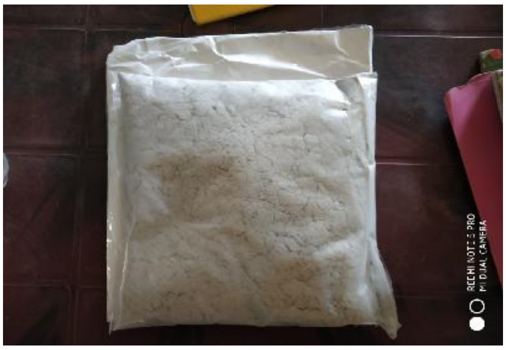


Fig 3.4 Stabilizing Additive (Cellulose Fibers)

3.3 Methodology

The following steps are adopted for the study:

(a) The literature review is collected related to the different industrial waste materials such as slag, fly ash as fillers and aggregates. Coir, sisal fibers, and plastic waste as additive are used in the BC as well as in SMAMix.

(b) The aggregates, fillers, additive and binder which are from different sources as mentioned in above. The basic properties for aggregates and for bitumen are carried out as per codal provision and the obtained results are compared with standards whether the results are satisfactory ornot.

(c) The materials are obtained from different sources are proportioned or Blended (Gradation) as per MORT&H and IRC: SP: 79-2008 specification to obtain a stable and dense mix.

(d) The proportioned materials are subjected to Marshall Stability Test to find the Optimum Bitumen Content (OBC) for both BC-2 and SMA-2 and also to find out the Marshall properties such as stability, flow value, air voids, voids in mineral aggregates (VMA), voids filled with bitumen (VFB), densityetc.

(e) The drain down test is conducted on SMA-2 mix with addition of fibers and without addition of fibers to check the drain down criteria for bothconditions.

(f) Indirect Tensile Strength test is conducted on both mixes to determine the tensile strength properties of bituminousmixes.

(g) The Rutting test is conducted using Immersion wheel Tracker Machine to determine the rutting performance of bothmix.

IV.EXPERIMENTAL INVESTIGATION

The experimental investigation deals with the laboratory investigation of materials which are used in this project and laboratory study evaluation of bituminous concrete (BC-2) and Stone matrix asphalt (SMA-2) using ARBOCEL ZZ8/1 as a stabilizer. The aggregate gradation is carried out using MORT&H specification for both BC-2 and for SMA-2. Marshall Stability tests, Static Indirect Tensile Test, Drain down and rutting test is carried out as per standard codes on both BC-2 andSMA-2.

4.2 Laboratory Test Carried Out on Basic Properties of Materials

4.2.1 Coarse Aggregates

Table 4.1 Test Results on Physical properties of Aggregate

Name of tests	Specification limit	Test Results
Cleanliness (%)	5% Max	0.8 %
Impact test (%)	24% Max	12.8 %
Los Angeles Abrasion Value (%)	35% Max	15.7 %
Flakiness& Elongation Index (%)	35% Max	27.2 %
Water absorption test (%)	2% Max	0.99 %
Water Sensitivity (Retained Tensile Strength)	Min 80 %	94.66 %

4.2.2 Fine Aggregate

Table 4.2 Test Results on Physical properties of Fine Aggregates

Name of tests	Specification limit	Test Results
Sand Equivalent value	50% Min	58.50 %
Plastic Index (%)	4% Max	Non Plastic

4.2.3 Mineral Filler

Table 4.3 Test Results on Physical properties of Mineral Filler

Name of tests	Specification limit	Test Results
Gradation	As per MoRT&H Table-No-9	Satisfactory
Plasticity Index (%)	4% Max	Non Plastic

4.2.4 Binder

Table 4.4 Basic properties of Binder VG-30

Name of test	Specification limit	Test Result
Softening point Ring & Ball ,^{0}C	47 min	54
Specific gravity test	-	1.02
Penetration test at 25^{0}C in mm	45 min	65
Flash Point, ^{0}C	220 min	232
Absolute Viscosity at 65 ^{o}C (Poises)	2400-3600	3190
Kinematic Viscosity at 135 ^{o}C (Centistokes)	350 min	520
Ductility test in cm	40 min	95

4.2.5 Stabilizing additive (Cellulose Fibers)

As per MoRT&H Stabilizing Additives/Cellulose Fibers shall be following

Requirements.

Maximum Fiber Length - 8 mm

Moisture Content - Less than 5 % by weight.

Ash Content - Max.20 % nonvolatile

Oil absorption - More than 4 times of by weight.

Table 4.5 Properties of stabilizing additive(Cellulose Fibers) ARBOCEL-ZZ8/1

Density	g/cc	1.5
Average Fiber length	µ m	45
Average Fiber Diameter	µ m	3.5
PH value	---	7.5 ±1
Temperature resistance	^{0}C	up to 200 ^{0}C
Solubility	---	Insoluble in water
Resistivity	---	Resistance to dilute acids and to alkalis
Moisture	---	Equilibrium moisture content up to 4-8%

4.3 Gradation

The aggregate gradation is carried out for both BC (grade-2) and SMA (grade-2) as per MORT&H specification fifth revision and IRC: SP 79-2008 that are shown in the table 4.4

Table 4.6 Aggregate gradation Specification for BITUMINOUS CONCRETE-2 (BC-2) as per MORT&H -2013

IS Sieves sizes in mm	JMF Limits	As per MoRT&H Limits
19	100	100
13.2	91.5-100	90-100
9.5	73.9-85.9	70-88
4.75	53.0-59.2	53-71
2.36	42.0-48.2	42-58
1.18	34.1-42.1	34-48
0.600	27.3-35.3	26-38
0.300	18.0-23.9	18-28
0.150	12.0-17.0	12-20
0.075	4.0-6.5	4-10

Table 4.7 Aggregate gradation Specification for STONE MATRIX ASPHALT-2 (SMA-2) as per MORT&H-2013

IS Sieves sizes in mm	As per MoRT&H Limits
19	100
13.2	90-100
9.5	50-80
4.75	20-35
2.36	16-24
1.18	13-21
0.600	12-18
0.300	10-15
0.075	1-12

4.4Bituminous Mix Design by MarshallMethod

Marshall Stability Test is conducted to find out the Optimum Bitumen Content (OBC) on compacted cylindrical bituminous mix specimens whose diameter is 101.6 mm and whose thickness is 63.5 mm. The load is applied perpendicular to the axis of the cylindrical specimen through a testing head consisting of a pair of cylindrical segment, at a constant rate of deformation of 51 mm per min at the standard test temperature of 600C.

Fig 4.1 Marshall Moulds

Fig 4.2 MarshallTestingMachine

4.6 Drain down Test

This test is conducted to determine the amount of drain down in an un compacted asphalt mixture sample when the sample is held at elevated temperature, which is encountered during the production, transportation, and placement of the mixture. This test is especially applicable to open graded mix and gap graded mixture such as SMA.

Drain down (%) = (C-A)/(B-A)

Fig 4.3 Drain down test

Fig 4.4 Drain down of mix

4.7 Rutting Test by Using Immersion Wheel Tracking Equipment

Rutting is a longitudinal depression along the wheel path. The ruts are usually of the width of wheel path. Swerving from a rutted wheel path at high speed can be dangerous. Accumulation of water in this depression causes skidding resistance.

This test is conducted is to determine the rutting performance of bituminous mixes such as BC-2 and SMA-2 at room temperature using Immersion wheel tracking equipment and the binder used is VG-30grade.

Fig 4.5 SMARutting Mould

Fig 4.6 BC RuttingMould

Fig 4.7 Immersion Wheel Tracking Machine for Conducting Rutting Test

CHAPTER 5

ANALYSIS OF TEST RESULTS

This chapter deals with different test carried out on Bituminous Concrete grade 2 (BC-2) and Stone Matrix Asphalt grade 2 (SMA-2) mixes prepared using VG-30 grade bitumen. The optimum bitumen content (OBC) is determined using Marshall Test procedure. Static indirect tensile strength test were carried out at room temperature. Drain down test was carried out on SMA with fiber and for SMA without fiber and rutting test were carried out on both the mixes.

5.1 Studies on Marshall Properties of Bitumen Mixes

• The purpose of Marshall Test is to determine the optimum bitumen content for a blended aggregates and bitumen. The optimum bitumen content for BC is found by taking stability, flow, bulk density, air voids and VFB are plotted along the Y-axis and bitumen content along X-axis by taking the average of these values the optimum bitumen content isdetermined.

- For SMA the optimum bitumen content is determined for 17.3 % VMA.
- The type of binder used in the study isVG-30.
- The Marshall properties for both BC-2 and SMA-2 at different percentage of bitumen are tabulated in table 5.2 and 5.5.The Stability, Air voids, Density, Flow, VMA, and VFB are also shown in tables.
- The gradation for both BC-2 and SMA-2 are showed in the table 5.1 and in 5.4 respectively. And the gradation curves are shown in graphs 5.1 and in5.8.

5.2 Test Result of Coarse Aggregate

STRIPING VALUE TEST.(IS:6241-1971)

Table 5.1 Striping Value Test Result (BC-2 & SMA-2)

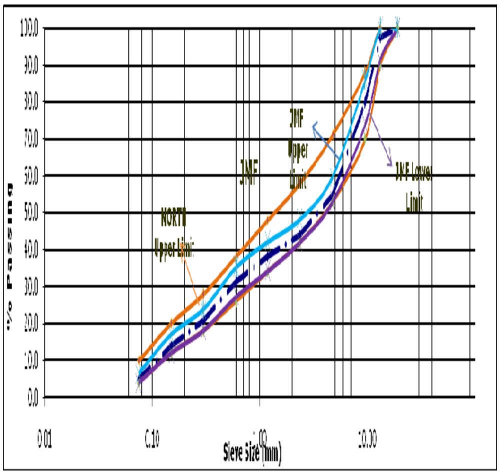
S.N	Size of Aggregates	Type of Test	Observed Value	Specification Limit as Per MoRT&H
1	20 mm passing 12.5 mm retained sample	Coating & striping value test of bitumen mixed agg.in %	98.50%	Minimum retained coating 95 %

Table 5.2 Blending of Hot Bin Aggregate(BC-2)

BLENDING OF HOT BIN AGGREGATES

Description :Bituminous Grade-02

Sieve Size	Hot Bin 16.0-6.0	Hot Bin 6.0-3.0	Hot Bin 3.0-0.0	Ultra-Fine Aggregate	46.0% 16.0-6.0	9.0% 6.0-3.0	43.0% 3.0-0.0	2.0% Ultra-Fine Aggregate	JMF %	JMF Lower Limit	JMF Upper Limit	MORTH Table No:17 Specification Limits
19.0	100.00	100.00	100.00	100.00	46.00	9.00	43.00	2.00	100.0	100.0	100.0	100
13.2	94.7	100.00	100.00	100.00	43.54	9.00	43.00	2.00	97.5	91.6	100.0	90-100
9.5	56.4	100.00	100.00	100.00	25.93	9.00	43.00	2.00	79.9	73.9	85.9	70-88
4.75	3.0	92.6	100.00	100.00	1.39	8.33	43.00	2.00	54.7	53.0	59.7	53-71
2.36	0.0	0.7	98.0	100.00	0.00	0.06	42.13	2.00	44.2	42.0	48.2	42-58
1.18	0.00	0.00	83.9	100.00	0.00	0.00	36.09	2.00	38.1	34.1	42.1	34-48
0.600	0.00	0.00	68.1	100.00	0.00	0.00	29.28	2.00	31.3	27.3	35.3	26-38
0.300	0.00	0.00	44.0	100.00	0.00	0.00	18.92	2.00	20.9	18.0	23.9	18-28
0.150	0.00	0.00	27.9	100.00	0.00	0.00	12.00	2.00	14.0	12.0	17.0	12-20
0.075	0.00	0.00	7.1	99.60	0.00	0.00	3.05	1.99	5.0	4.0	6.5	4-10



Graph 5.1.Hot Bin Gradation (BC-2)

Table5.3 Marshall Properties of BC-2 Mix

Table5.4 Marshall Properties of BC-2 Mix to Determine Optimum Binder Content

ANALYSIS OF COMPACTED MIXTURE BY USING MARSHALL STABILITY - OBC CONFIRMATORY

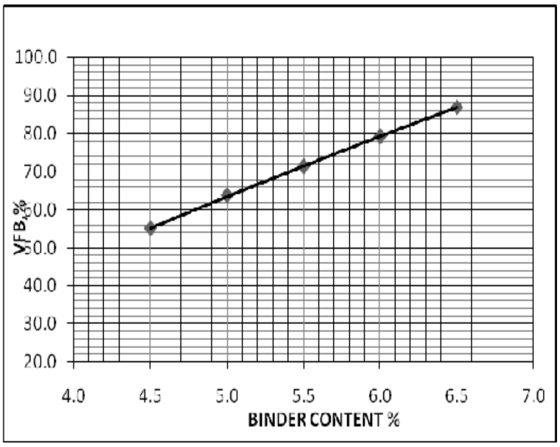
Proportion : 46:9:43:2 — TypeofBitumen : VG-30

SampleDescription : BCGrading-II — Compaction : 75blows

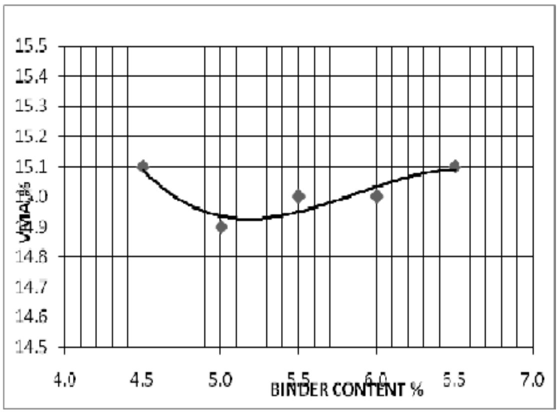
TestMethod : ASTM D 2726 & ASTM D1559 — ProvingRingFactor : 7.13

EffectiveSpecificGravityofAggregate(G_{se}): 2.651 — Bulk Specific Gravity of Aggregate (G_{sb}) : 2.592 — Specific Gravity ofBitumen: 1.020

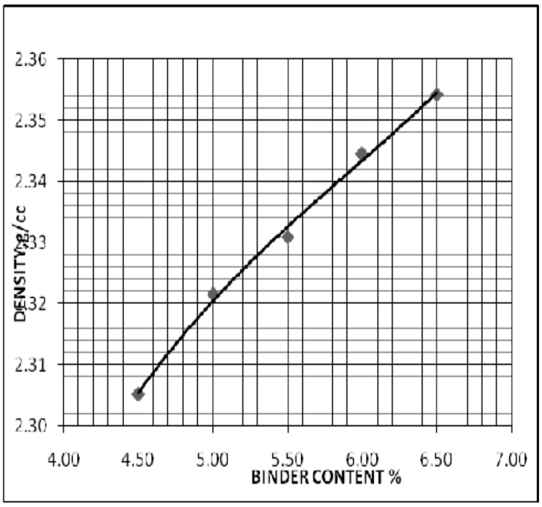
% of Bitumen By Weight of Mix	Mould ID	Weight of mould in Air (gms)	Weight of mould in water (gms)	SSD weight in Air (gms)	Bulk Volume (cc) 7=(6-5)	Bulk Sp Gravity (G_{mb}) gm/cc 8=(4/7)	Maximum Specific Garavity of Asphalt Mixture (G_{mm})	% Air Voids (Va)	VMA	VFA	Stability (KN) Measured	C.Factor	Adjusted	Flow (mm)	Marshall Quotient (Stability/Flow)	Remarks
1	2	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
5.60	1	1266.4	725.8	1267.9	542.1	2.336					245	0.93	16.2	3.4	4.5	
	2	1264.5	724.8	1267.2	542.4	2.331					230	0.93	15.3	3.2	4.8	
	3	1263.2	725.1	1264.8	539.7	2.341					240	0.93	15.9	3.1	4.6	
	4	1266.9	725.3	1267.8	542.5	2.335					215	0.93	14.3	3.6	4.0	
	5	1262.4	723.5	1264.5	541.0	2.333					230	0.93	15.3	3.2	4.8	
	6	1265.8	725.4	1266.9	541.5	2.338					220	0.93	14.6	3.2	4.6	
Average						2.336	2.433	4.01	14.9	73.2			15.3	3.3	4.55	



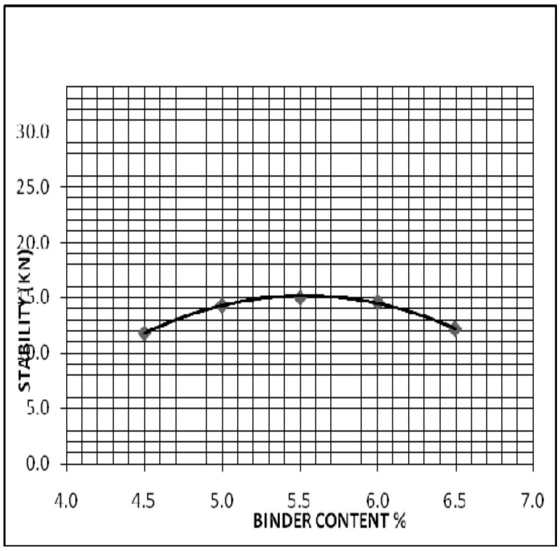
Graph.5.2 VFB vs Binder Content



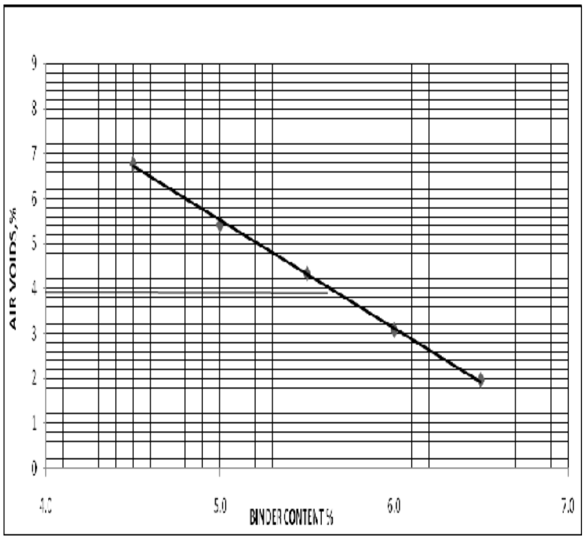
Graph 5.3 VMAvs Binder Content



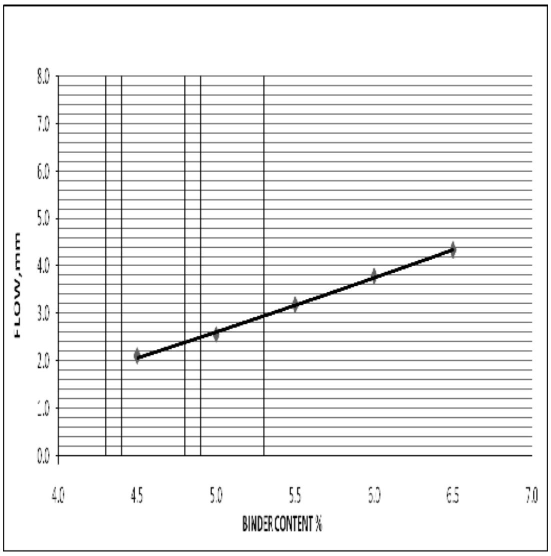
Graph.5.4Densityvs Binder Content



Graph.5.5 Stability vs Binder Content



Graph.5.6 Air Voidsvs Binder Content



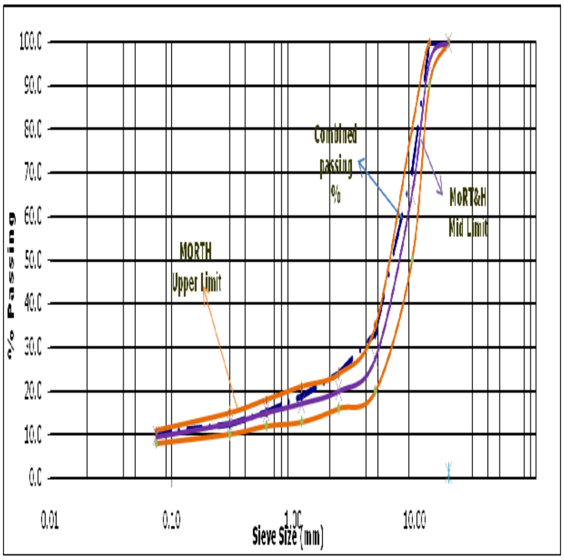
Graph.5.7 Flowvs Binder Content

Table 5.5 Blending of Hot Bin Aggregate(SMA-2)

BLENDING OF HOT BIN AGGREGATE

Description: SMA-2 — Cellulose Fiber 0.3 %

Sieve Size	Hot Bin 10 mm	Hot Bin Crushed Stone dust	Mineral Filler	74.0% 16.0-6.0	18.0% Stone dust	8.0% Filler	Combined Passing Percentage	MoRT&H Mid Limits	MoRT&H Table No: 17 Specification Limits
19.0	100.00	100.00	100.00	74.00	18.00	8.00	100.0	100.0	100
13.2	100.0	100.00	100.00	74.00	18.00	8.00	100.0	95.0	90-100
9.5	60.0	100.00	100.00	44.40	18.00	8.00	70.4	65.0	50-80
4.75	10.0	99.6	100.00	7.40	17.93	8.00	33.3	27.5	20-35
2.36	0.8	85.0	100.00	0.59	15.30	8.00	23.9	20.0	16-24
1.18		60.00	100.00	0.00	10.80	8.00	18.8	17.0	13-21
0.600		40.00	100.00	0.00	7.20	8.00	15.2	15.0	12-18
0.300		25.00	100.00	0.00	4.50	8.00	12.5	12.5	10-15
0.075		13.00	99.5	0.00	2.34	7.96	10.3	9.5	8-12



Graph.5.8 Blending of Hot Bin Aggregate (SMA-2)

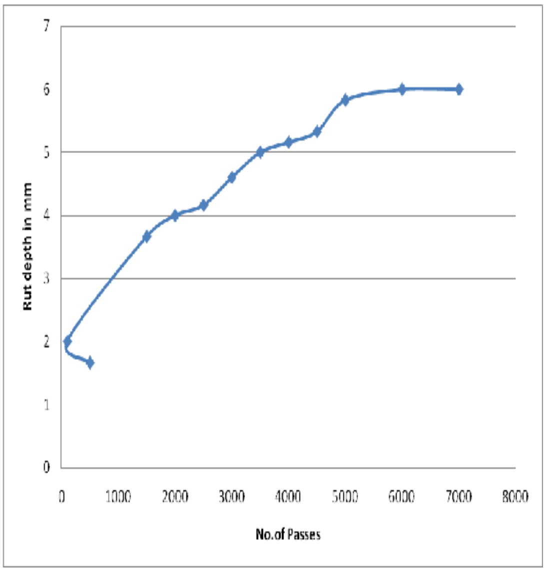
Table5.6 Marshall Properties of SMA-2 Mix

ANALYSIS OF COMPACTED MIXTURE BY USING MARSHALL STABILITY

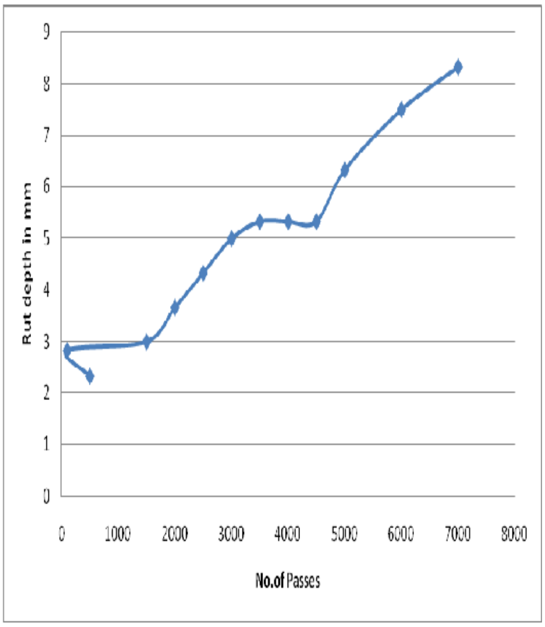
Proportion : 74:18:8 — Bitumen : VG 30
Compaction : 50 blows
Sample Description : SMA Grading-II — Cellulose Fiber : 0.3 %

Effective Specific Gravity of aggregate(Gse): 2.711 — Bulk Specific Gravity of Aggregate Gsb 2.510 — Specific Gravity of Bitumen: 1.020

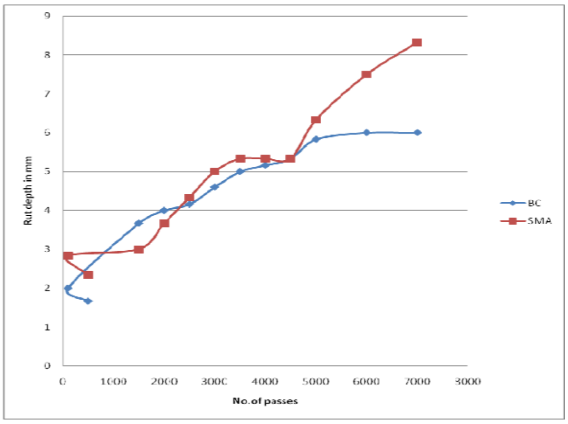
% of Bitumen by Weight of Mix	Mould ID	Weight in Air (gms)	Weight in water (gms)	SSD weight in Air (gms)	Bulk Volume (cc) 7=(6-5)	Bulk Sp Gravity (G_{mb}) gm/cc 8=(4/7)	Max. Sp.Gr. (ASTM D 2041) (G_{mm})	% Air Voids (Va)	VMA 100-(G_{mb}P/Gsb)	VFA 100(11-10)/11	Stability (KN) Proving Ring Reading	Stability C.Factor	Stability Adjusted	Flow mm	Marshall Quotient (Stability/Flow)	Remarks
1	2	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
5.0	1	1233	689	1241	552	2.234										
	2	1230	686.5	1237.5	552	2.228										
	3	1236	690	1241	551	2.243										
Average						2.235	2.503	10.7	17.8	61.8						
5.5	1	1240	692	1243	551	2.250										
	2	1238	696	1241	548	2.259										
	3	1212	686.2	1217	530.8	2.254										
Average						2.254	2.484	9.3	17.5	46.9						
6.0	1	1216	709	1250	541	2.278										
	2	1218	709	1257	540	2.289										
	3	1250	701.6	1262	551.5	2.268										
Average						2.271	2.468	7.9	17.4	54						
6.5	1	1251	706	1263	547	2.287										
	2	1247	706	1266	541	2.289										
	3	1248	706	1251	546	2.290										
Average						2.289	2.447	6.6	17.1	62.0						
7.0	1	1250	712	1266	548	2.302										
	2	1248	708.5	1252.5	543	2.298										
	3	1251	710.0	1254	543.2	2.303										
Average						2.301	2.429	5.3	17.2	69.2						



Graph .5.9 Rut depth vsNo. of Passes for BC



Graph.5.10. Rut depth vs No.of Passes for SMA



Graph.5.11Comparison of BC-2 and SMA-2

FUTURE SCOPE OF WORK

The Marshall Properties, Drain down characteristics, Tensile Strength characteristics and Rutting characteristics of BC-2 and SMA-2 have been studied in this investigation VG-30 grade binder. However some of the properties such as fatigue, moisture susceptibility, resistance dynamic creep behavior can be studied. The usage of other binder PMB, CRMB, VG-40.etc,That can be studied and also usage of different stabilizing additive such as sisal fibers, waste plastic fibers, coir fibers that can be studied further.

Recently Indian Govt. i.e., Ministry of Road Transport & Highways (MoRT&H) has released circular (24th .Aug.2018) regarding the use of Bitumen in DBM/BM shall be VG-40 Grade for the National Highways. And BC/Wearing coat shall be modified bitumen (using PMB/CRMB/NMB) or VG-40 grade has to be used. In some projects especially those related to expressways / green-fields projects and traffic more than 150 MSA, SMA shall be used.

DISCUSSION AND CONCLUSION

1) The aggregates used in the project are tested for its Physical properties the obtained results are in line with the standards and the results are satisfactory as perMoRT&H specification 2013 (5TH Revision).

2) The Binder VG-30 used in the project satisfies all basic requirements as per IS: 73-2006. The Marshall Test results of BC-2 and SMA-2 are within the specified limits as per IRC: SP: 79-2008 and MoRT&H specification 2013 (5ThRevision).

3) From the test results it was observed that the Optimum Binder Content (OBC) for BC-2 and SMA-2 are 5.6% and 6.0% respectively. The OBC for SMA-2 is 7.14% more than BC- 2.

4) The Marshall Stability of BC-2 is 14.8 KN and The Flow values of BC-2 is 3.3.

5) The Density of BC-2 and SMA-2 are 2.336 and 2.274gm.\cc respectively. And the air voids for BC-2 and SMA-2 are 4.01 and 7.8. The density of SMA-2 is 2.68% lesser than BC-2 and air voids are lesser for BC-2 thanSMA-2.

6) The Voids in Mineral Aggregates (VMA) for BC-2 and in SMA-2 is 14.9% and 17.3 % respectively. Voids filled in mineral aggregate in BC-2 is 16.10 %

lesser than SMA-2. The Voids Filled with Bitumen (VFB) in BC-2 and in SMA-2 are 73.2% and 54.80 % respectively. Voids filled with Bitumen in SMA-2 are 33.57% less thanBC-2.

7) IndirectTensileStrengthofBC-2andSMA-2are 94.66 % and 88.5 % respectively.

The Indirect Tensile Strength of SMA-2 is less than BC-2 and hence the moisture susceptibility damage is less in case of SMA-2 mix.

8) From the Fig 5.11 the SMA-2 mix at 1500 passes shows lesser rut depth when compared to BC-2. After increase in the number of passes BC shows better results thanSMA.

9) Finally we observed that the approximately cost of SMA-2 is nearly 8 to 10 % of higher than BC-2.

10) From this project we studied and observed that the Bituminous Concrete (BC) is cost effective than SMA. But in India upcoming projects the use of bitumen Modified Bitumen (PMB/CRMB/NMB)/VG-40 grade shall be used.

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