LABORATORY INVESTIGATION ON UTILIZATION OF RECYCLED MATERIALS IN SMA MIX

By

POKALA VAMSHI

110CE0385

DEPARTMENT OF CIVIL ENGINEERING
NATIONAL INSTITUTE OF TECHNOLOGY, ROURKELA

2014

LABORATORY INVESTIGATION ON UTILIZATION OF RECYCLED MATERIALS IN SMA MIX

A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of

BACHELOR OF TECHNOLOGY
IN
CIVIL ENGINEERING

by
Pokala Vamshi
110ce0385

Under the Guidance
of
Prof. Simantini Behera

DEPARTMENT OF CIVIL ENGINEERING
NATIONAL INSTITUTE OF TECHNOLOGY, ROURKELA

National Institute of Technology

Rourkela

Certificate

This is to certify that the Project Report entitled "**LABORATORY INVESTIGATION ON UTILIZATION OF RECYCLED MATERIALS IN SMA MIX**" submitted **by Mr. POKALA VAMSHI** in partial fulfillment of the requirements for the award of Bachelor of Technology Degree in Civil Engineering at National Institute Of Technology, Rourkela (Deemed University) is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in this Project Report has not been submitted to any other University/Institute for the award of any Degree or Diploma.

Date:

Prof. Simantini Behera
Dept. of Civil Engineering
National Institute of Technology
Rourkela

ACKNOWLEDGEMENT

I Extend my deep sense of gratitude and indebtedness to my guide **Prof. S. Behera** Department of Civil Engineering, National Institute of Technology, Rourkela for her kind attitude, invaluable guidance, keen interest, immense help, inspiration and encouragement which helped me carrying out my present work.

I am extremely grateful to **Prof. N.ROY**, Professor and Head of the Department of Civil Engineering and **Prof. A. KUMAR**, faculty advisor and members of Civil Engineering Department, National Institute of Technology, Rourkela, for providing all kind of possible help throughout the two semesters for the completion of this project work. I would like to thank to **Mr. S. C. Xess**, Lab Assistant and **Mr. H. Garnayak**, lab attendant, for their kind support in execution of experiment carried out

It is a great pleasure for me to acknowledge and express my gratitude to my classmates and friends for their understanding, unstinted support and endless encouragement during my study.

Lastly, I thank all those who are involved directly or indirectly in completion of the present project work.

Pokala Vamshi
110ce0385

ABSTRACT

SMA (stone matrix asphalt or stone mastic asphalt) was originally developed in European and German countries as impervious or highly durable wearing surface for bridge decks. But today, it is pavement surface of choice. Generally it consists of two parts, a coarse aggregate and a binder rich mortar. It is made by a mixture of crushed coarse and fine aggregates, stabilizer such as fibers or polymers, mineral filler, cement. In present research work, an attempt has been made to study the properties of SMA mixes with cellulose fiber and using recycled pavement material as well as slag in partial replacement of stone aggregates as coarse and fine aggregate grades. This research project was done to check the usage of recycled pavement material in SMA mixture by conducting Marshall test in the laboratory in which stability value and flow values was examined along with other properties of mixtures. Here IRC -SP-79 specification, aggregate gradation is taken for stone matrix asphalt. Binder used is 60/70 penetration grade bitumen. Binder content is varied as 4%, 5%, 5.5%, 6%, and 7% by weight of aggregates and fiber used is optimum fiber content at 0.3% by weight of aggregate.

Contents

Chapter-1
INTRODUCTION

Chapter-2
LITERATURE REVIEW

Chapter-3
EXPERIMENTAL INVESTIGATION

Chapter-4

Analysis of Results

Chapter-5
Conclusion

Chapter-6
References

LIST OF TABLES

LIST OF DIAGRAMS

LABORATORY INVESTIGATION ON UTILISATION OF

RECYCLED MATERIALS IN SMA MIX

CHAPTER-1
INTRODUCTION

1.1 INTRODUCTION

Generally Aggregates are used in addition with bitumen throughout the world in construction & maintenance of flexible pavements. Aggregates with uniform, close, well, or dense perform well with normal bitumen in heavily trafficked roads when designed and executed properly and also commonly used in paving industry. But it is not always possible to arrange dense aggregates available at the site positions. In such situations, bituminous mix known as stone matrix asphalt (SMA) that is basically consisting of gap graded aggregate, can be attempted.

SMA was developed in Germany for the very 1st time in the year 1960s by Zichner of Straubag -Bau AG central laboratory, to resist the damage being caused by studded tires. It showed very good resistance to deformation by heavy traffic at high temperatures. SMA is a gap graded mixture, which has better stone to stone contact by which it gives more and high strength to mixture. By using high capacity of coarse aggregate in the mixture makes a skeleton type structure gives better stone to stone contact by which it gives high resistance to rutting. . In this research work, aggregates with different gradations stone dust as filler and bitumen (60/70) as filler used. Here fibers are used as stabilizers. Here fiber helps in decreasing the drain down and also to increase the strength of mix and stability of the SMA mixes. here fibers hold binder in the mix even at high temperature by which it helps to prevent factors like drainage during operations such as production, transportation, laying. Evaluating all of these factors will help to find the long term performance of SMA and would provide information that would make changes as determining the long term performance of SMA mixes and provide information to make changes needed to suit for different environmental conditions.

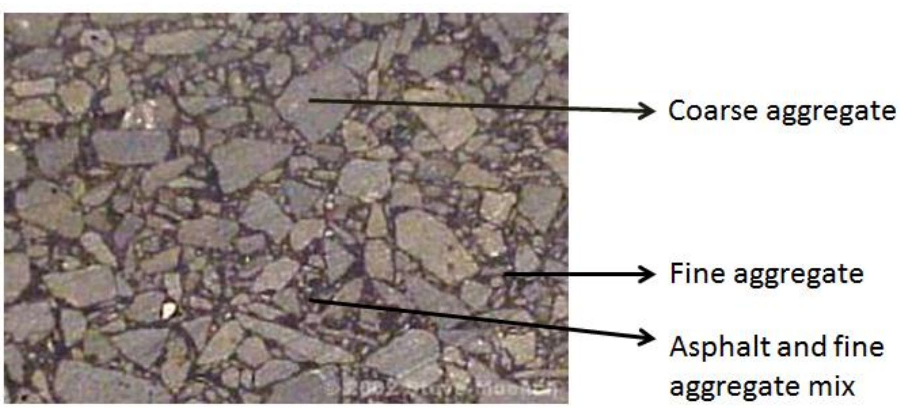


Fig1. Gap graded mix structure

Stone matrix asphalt has been proved, most expensive when compare to the dense graded mixes for high volume roads. Brown (1992) observed that many number of factor influenced the performance of SMA mixtures, as change in binder source and grade of mix, types of aggregates, environmental conditions, production and methods of construction etc. The FHWA SMA Technical Working Group defined SMA as “A gap graded aggregate hot mix asphalt which will maximize the binder content and coarse aggregate fraction and provides a stable stone-on-stone skeleton that is held together by a rich mixture of filler, binder and stabilizing additives”.

1.2 Advantages

- It improves skid resistance, reduces noise when compared to conventional alternative pavement surfaces.
- SMA also shows improved resistance to fatigue effects and cracking at low temperatures, also increases durability, and reduces permeability and sensitivity to moisture.
- SMA provides excellent resistance to rutting due to slow, heavy and high volume traffic, and resistance to deformation at high pavement temperatures.
- SMA has a rough texture which gives good friction properties after the upper surface film of the binder is removed by the traffic.
- Higher strength, durability, reduced moisture permeability and longevity of SMA over conventional mixes.

1.3 STABILIZERS USED

CELLULOSE FIBER (TOPCEL)

Cellulose fibers are obtained from wood pulp which dissolved in liquid and treated with chemicals. Cellulose fibers are used in experimentation process with coarse aggregates for preparing SMA mixes. These fibers are coated with bitumen by which it gives high strength to the sample prepared with them. Cellulose fiber provided by Oregano Chemical Farm. Cellulose fiber can absorb and release moisture without any loss of thermal resistivity.

Fig 2.Cellulose fiber used during experimentation process

1.3.1CHARACTERISTICS OF CELLULOSE FIBER:-

- Cellulose fiber is natural fiber and it has its own chemical and physical properties like other fibers
- It has lighter weight and has high absorption quality.
- It quickly absorbs and releases moisture.
- The chemical composition includes hemicellulose and lignin.
- Strength of the fiber is high but has small elongation.

1.4 Recycle Asphalt Pavement (RAP)

Recycle Asphalt material is a removed material consists of aggregates and asphalt. It has been grown widely reducing the virgin materials and helping in preserving land space. Recycle pavement materials are formed when asphalt pavement materials are removed from construction or resurfacing. The use of RAP in road construction, by which it reduces waste, preserves natural environment, better performance.

1.4.1 Benefits:-

- It reduces creep and improves modulus of RAP.
- It increases the stiffness.
- It reduces compression of base coarse
- It reduces bituminous asphalt concrete of pavements.
- Perform well.

1.4.2 Benefits in economic:-

- It reduces structural pavement layer thickness.
- It reduces time and cost.
- It reduces maintenance cycles and life cycle costs.
- Enables on site recycling of asphalt pavement.

1.4.3 Benefits in Environmental:

- It reduces energy, hauling and aggregate usage.
- It eliminates need for processing rap.

Fig3. Recycle pavement sample used during experiments

1.5 OBJECTIVE OF THE PROJECT

- The main objective of this project is to check the suitability of preparing SMA mixes using fiber and to study their effect on various properties of SMA.
- Preparation of several Marshall Specimens and to achieve optimum binder content by using Marshall Method.
- To compare the various engineering properties of the SMA samples with other similar type test results.

CHAPTER-2

LITERATURE REVIEW

2.1 LITERATURE REVIEW

In the year 1980's federal and state highway officials in the United States recognized the need to design stiffer, more rut resistant pavements. As a result, American professionals participated in the European Asphalt Study Tour in 1990, where SMA pavements were investigated. This was the first concerted effort to figure out how to use SMA. Most common type of flexible pavement surfacing that is used in India is the Hot Mix Asphalt (HMA). It is a mixture of coarse as well as fine aggregates and a specific asphalt binder. HMA, as the name suggests is mixed and compacted at a higher temperature. HMA is usually applied in layers, where the lower layers support the top layer, usually referred to as surface course or friction course. Aggregates used in the lower layer are implied at preventing rutting and the aggregates in the top layer are selected on the basis of frictional properties and durability.

Al-Qadi and Imad L (2007) tried to develop an understanding of the interaction between aged and virgin asphalt binders in RAP. Based on this understanding, they determined the appropriate level of contribution that should be given to the residual asphalt binder in RAP. The level of interaction between aged and virgin binders will then be used to investigate the influence on the performance and the durability of the mixtures as compared to virgin HMA. RAP material into hot-mix asphalt (HMA) since 1980, RAP HMA design provides 100% contribution for the residual asphalt binder from the RAP based on solvent extractions. This means that the amount of virgin asphalt binder is reduced by the full amount of asphalt binder in the RAP for the percentage specified. This has recently been reported to be inaccurate and could result in an erroneous HMA job mix formula and may cause dry HMA. Hence, the HMA may become vulnerable to durability cracking and premature failure.

Yue Huang and Roger N.Bird studied on construction and maintenance of UK roads consumes large amounts of quarried aggregates. The use of secondary (recycled), instead of primary (virgin), materials helps easing landfill pressures and reducing demand of extraction. However, concerns over inferior road performance and additional costs have hindered the widespread use of secondary aggregates in such applications. This is especially the case in surface layers of asphalt pavements that may represent a value application for recycled solid waste materials (SWM). Waste glass, steel slag, tires and plastics are selected for technical requirements, as well as the performance of asphalt pavements constructed using such recycled materials. Waste arising and management indicates that although there is a large potential for supplying secondary materials, a few factors have effectively depressed such recycling activities. Such barriers are described and may also apply to the secondary use of other SWM. After identifying and quantifying such barriers a brief discussion suggests ways of their removal.

Kandhal, P S (1997) studied on brief overview of the recycling of asphalt pavements. Five recycling methods are present: (1) cold planning; (2) hot recycling; (3) hot in-place recycling; (4) cold in-place recycling; and (5) full depth reclamation. Strategies for selecting an appropriate recycling method and also performance of different recycling processes have been explained. Economics, legislation/specification limits, and structural design associated with recycling of asphalt pavement are explained.

Brown and Haddock (1997) has remarked that, due to the fact that the strength of SMA relies mostly on the stone-on- stone aggregate skeleton, steps should be taken as to design the mix and place it with a strong coarse aggregate skeleton that would provide the desired strength and stability to the mix.

Kumar Pawan, Chandra Satish and Bose Sunil (2007) tried to use an indigenous fiber in SMA Mix by taking low viscosity binder coated jute fiber instead of the traditionally used fibers and compared the result with the imported cellulose fiber, using 60/70 grade bitumen and found optimum fiber percentage as 0.3% of the mixture. Jute fiber showed equivalent results to imported patented fibers as indicated by Marshall stability test, permanent deformation test and fatigue life test. Aging index of the mix prepared with jute fiber showed better result than patented fiber

Bradely et.al. (2004) studied on Utilization of waste fibers in stone matrix asphalt mixtures. They used carpet, tire and polyester fibers and other materials to improve the strength and stability of mixture compared to cellulose fiber. They found no difference in the moisture susceptibility and permanent deformation in SMA Mix containing waste fibers as compared to the SMA Mix which contains cellulose or mineral fiber.

Punith V.S., Sridhar R., Bose Sunil, Kumar K.K., Veera ragavan A (2004) adopted Marshall mix design at 60^0C, using 50 blows of compaction per side and did a comparative study of SMA with asphalt concrete mix utilizing reclaimed polythene in the form of LDPE carry bags as stabilizing agent (3 mm size and 0.4%) .The test results indicated that the mix properties of both SMA and AC mixture are getting enhanced by the addition of reclaimed polythene as stabilizer showing better rut resistance, resistance to moisture damage, rutting, creep, aging and better drain-down properties as well.

Yongjie Xue, Shaopeng Wu, Haobo Houa, Jin Zha (2006) used basic oxygen furnace slag in place of aggregate in asphalt mixture. By testing and analyzing, BOF steel slag was found to be suitable to be used as asphalt mixture aggregate in expressway construction.

Bindu C.S. et. al.(2010),Plastic coated graded aggregates were used for the SMA mix and the Marshall Stability value of stabilized SMA mix was found to be higher than the prescribed value along with the values of retained stability. Excessive drain-down too was reduced by a great factor.

CHAPTER-3

EXPERIMENTAL INVESTIGATION

3.1 MATERIALS USED:-

- RAP (recycle asphalt pavement), SLAG, STONE as coarse and fine aggregate.
- Mineral filler-Stone Dust
- Binder (Bitumen of penetration grade 60/70)
- Stabilizers (TOPCEL cellulose fiber)

3.2 MINERAL AGGREGATES

Generally aggregate represents coarse and fine aggregates. There are various types of mineral aggregates which form the bituminous mixes. Aggregates play a very crucial role, which provides strength to SMA mixtures with 70-80 percent coarse aggregate content out of the total stone content. The aggregates that are used to manufacture bituminous mixes are obtained from various natural resources such as mines or glacial deposits.

Due to the high quantity of coarse aggregate in mixes forms a skeleton type structure and provides stone on stone contact which gives high resistance and high shear strength for rutting. Various types of artificial or manmade wasters are used as natural aggregates used in making the mixes example as slag, a byproduct of steel industries. Here Slag and RAP are used in partial replacement of stone aggregate for all coarse aggregate grades from 19-2.36mm.

Slag is obtained from blast furnace during the process of formation of steel. It can be used as artificial source of aggregates. In this project work, slag and RAP has been used for making of SMA mixes. Whereas RAP which changes in construction materials economics, stricter environmental regulations, and an emphasis on “green” technologies (e.g., warm mix asphalt) and sustainable pavements, the highway community is reassessing the economic and environmental benefits of allowing higher percentages of reclaimed asphalt pavement (RAP) in premium pavements and asphalt surfaces while maintaining high-quality pavement infrastructure. Coarse aggregate should have crushed rocks retained on 2.36mm sieve. It should be clean, cubical shaped and rough texture to resist rutting and hardness by which it can resist fracturing under heavy traffic loads.

The physical properties of the mineral aggregates are obtained by testing Impact value, crushing value and Los Angeles abrasion value test for the stone aggregates.

Table1 Physical properties of stone aggregates

Test description	Coarse aggregates	Fine aggregates	Standard values
Impact value	15.6	-	<18
Water absorption	0.7	-	1.3
Angularity number	10	-	0-11
Aggregate crushing value (%)	18	-	<30
Flakiness index (%)	17	-	<20
Specific gravity	2.76	2.64	2.6-2.9
Los Angeles abrasion value (%)	22.8	-	<30
Elongation index (%)	12	-	<15

Mineral fillers play significant impact over the properties of SMA mixes.

- It helps in maintaining adequate amount of void in mix.
- During construction it reduces the drain-down in mix and improves the durability of mix.
- It increases the stiffness of asphalt and mortar.
- It also effects the moisture resistance, workability

Table 2 Comparison for physical properties of stone and slag aggregates.

Properties of coarse and fine aggregates of slag			
Properties	Value		
	Steel Slag	Stone	Iron Slag
Coarse aggregate			
Soundness in (%)	2.4	4.5	3.2
Water absorption (%)	0.9	0.6	1.7
BULK sp. Gr.(gr/ cm^3	2.64	2.64	3.44
L.A. abrasion (%)	12.5	15.6	20.7
Apparent sp. Gr. (gr/ cm^3)	3.74	2.69	3.63
Fine Aggregates			
Plasticity index	Non plastic	Non plastic	Non plastic
Bulk sp. Gr	2.98	2.43	2.91
Apparent sp. Gr	3.86	2.77	3.68

Various types of mineral fillers are used in the SMA mixes such as

- Stone dust,
- Ordinary Portland cement (OPC),
- Slag cement and slag dust,
- Fly Ash
- Hydrated lime etc.

3.3 BINDER:-

Many researchers used various types of binders one being, conventional 60/70 penetration grade bitumen and other modified binders like

- Polymer Modified Binder(PMB)
- Crumb Rubber Modified Binder(CRMB)
- Natural Rubber Modified Binder (NRMB) etc.

In this research work 60/70 bitumen is used as binder.

Table 3 Properties of binder

Test description	Standard values	Results
Ductility (cm)	>50	>90
Penetration at 25 ºC(1/10mm)	50 to89	65
Specific gravity	-	1.025
Softening point ºC	>48 ºC	65.2

3.4 FILLER:-

In SMA Mix, filler is used for the proper binding of materials. Fillers such as slag dust, rock dust, stone dust, hydrated lime, hydraulic cement, mineral filler, fly ash etc. are used in SMA Mix. We can even use fine aggregate less than 75 micron as filler. But in this research work, stone dust and cement is taken as filler which gives proper binding with fiber, bitumen and aggregate.

3.5 STABILIZER:-

SMA is gap graded mix, which means it has more air void content and high concentration of binder. So to prevent them stabilizing additives are added to the mixture such as cellulose fiber, mineral fibers and many polymers, waste materials such as tires, carpet fibers, natural fiber etc. are used in various SMA mixes. Here in this research work Cellulose fiber is used as stabilizing agent.

Many research works are carried before to check the influence of fiber in stone matrix asphalt (SMA) mix. Chui-Te Chiu and Li-Cheng Lu (2006) did a laboratory study on stone matrix asphalt (SMA) by using ground tire rubber. Asi Ibrahim M (2003) used mineral fiber of 0.3 percentages in Laboratory comparison study for the use of stone matrix asphalt in hot weather conditions. Also

(Bradley J. Putman and Serji N.Amirkhanian, 2004) both done research on Utilization of waste fibers in SMA mixtures. (Huaxin Chen, Qinwu Xu) done a laboratory study on fibers in stabilizing and reinforcing asphalt binder.

As per MORTH specification usually 0.3%-0.5% fiber is used in SMA mixtures. In this research study, 0.3% fiber is used by weight of aggregate.

3.6 MIX DESIGN:-

The main objective of bitumen mix is

- To promote good frost ,thaw resistance and to prevent shrinkage cracks sufficient flexibility is required
- To ensure durability of pavement enough bitumen is required
- Sufficient flexibility is needed to avid premature cracking of pavement caused due to repeated bending's by traffic.
- To allow further additional compaction by imposed load caused due to traffic sufficient air void in compacted bitumen is required.

3.6.1 PREPARATION OF MIXES:-

First sieving is done to coarse and fine aggregates.
Sampling of coarse and fine aggregates is carried out for 13mm STONE MATRIX ASPHALT composition as specified by **IRC:SP-79**.Total sample weight is 1200gm including filler, binder .After sampling is done the sample was allowed to be heated in an oven at 160 degree Celsius for 12 hours. It is then taken out, mixed with bitumen and is compacted with a hammer with a falling weight of 4.54kg falling from a height of 40cms, by giving 50 blows on each side for compaction. The sample is allowed to dry for the next 24 hr. and then it is taken out of the mould with the help of Sample Ejector. Its weight in air, radii and thickness/ height is calculated and then a Wax coating is put over them. Before conducting the Marshall test, each of the samples was kept in hot water bath for 30 min. at 60 degree temperature. Weight in water also Calculated.2 Samples each of 4%, 5%, 5.5%, 6% and 7% bitumen were prepared respectively for bituminous course and Marshall Test was carried out to calculate their Stability.

The various samples are:-

1. Sample with fiber using stone as coarse aggregate and fine aggregate.
2. Sample with fiber using slag as coarse aggregate and fine aggregate.
3. Sample with fiber using RAP (recycle asphalt pavement)as coarse aggregate and fine aggregate.

Table4 Composition of 13mm SMA mix

IS Sieve	Cumulative%	Mean	%retained	4%	5%	5.5%	6%	7%
19	100	100	0	0	0	0	0	0
13.2	90-100	95	5	57.6	57	56.6	56	55.58
9.5	50-75	67.5	32.5	374	370.5	373	369.4	362.8
4.75	20-28	24	38.5	443	438.9	436.5	435.1	434.1
2.36	16-24	70	4	45.8	45.6	45.4	45.1	45.12
1.18	13-21	17	3	34.5	34.2	34	33.7	33.5
0.6	12-18	15	2	23	22.8	22.5	22.2	22.3
0.3	10-20	15	3	34.5	34.2	34	33.7	33.5
0.75	8-12	10	2	23	22.8	22.5	22.4	22.3
Total				1162	1140	1134	1128	1116
Binder used				48	60	66	72	84

3.6.2 FINISHING THE MARSHALL SPECIMEN:-

After casting is done to all the samples, samples are removed from its mould by extractor.
After samples are removed from mould its weight, height, radii are measured and then coated with wax. After coating of wax is done, the weight of samples in air and in water is measured for computing volume of sample. And finally samples are kept in hot water bath for 30 minutes. at 60 degree temperature. Later Marshall Test is conducted.

Fig4.Preparation and mixing of SMA during experimentation process.

Fig5.Sample before and after coated with wax.

Fig6. Water bath

Fig7. Samples in water

3.7 Marshall Test:-

- After preparation of samples we remove samples from hot water bath and supposed to undergo Marshall Test.
- It is kept under testing machine and loaded at constant rate of deformation of 5mm per minute till failure. Hence stability value and flow values are obtained by Marshall Test.
- Here samples should be treated well during, when they are in hot water bath should not keep more than 30 minutes and also not more than 60 degree temperature.
- If no proper care is taken then bitumen will lose its properties and we will not get good stability value and not be able to carry applied load.
- The total maximum load is taken in KN.

Fig8.Marshall Test Apparatus

Fig9. Material in mould

Fig10.Marshall mould

Fig11.Cylindrical Hammer

CHAPTER-4

ANALYSIS OF RESULTS

In this project work, 3 types of samples are prepared. They are:-

- Sample with fiber using stone as coarse aggregate and fine aggregate
.
- Sample with fiber using slag as coarse aggregate and fine aggregate.
- Sample with fiber using RAP (recycle asphalt pavement) as coarse aggregate and fine aggregate.

Table5 Nomenclatures and their full forms

VFB	Voids filled with bitumen
G_{mm}	Theoretical maximum specific gravity of mix
G_{sb}	Bulk specific gravity of aggregates
VA	Air void
G_{se}	Effective specific gravity of aggregate of mix
VMA	Voids in mineral aggregates
G_{mb}	Bulk specific gravity of mix

4.1 MARSHALL STABILITY:-

Stability value increases with increase in bitumen content up to some point theoretically and then decreases .The reason is due to increase in bitumen content there will be high bonding with aggregate and gets strong, but with further increase in bitumen, the applied load is transmitted and hydrostatic pressure keeps the aggregates immobilized. By this it makes weak against plastic deformation and stability decreases. Stability value increases with fiber than without fiber. Here fiber acts as stabilizer in mix, fiber not only fill the voids but also reduces the drain down and hold with binder and gives good result.

4.2 FLOW VALUE

Flow value defined as deformation of sample where failure occurs. Flow value increases with increase in bitumen content using with fiber or without fiber. Generally increase is slow, but later with increase in bitumen content flow value increases. Flow value prepared with fiber show low when compare to without fiber. But in some situations, flow value increases with fiber due to formation of lumps of bitumen and fiber.

4.3 AIR VOIDS

While preparing the samples, due to improper compaction and heating air voids are formed between the samples. Here air voids goes on decreasing on increasing the bitumen content. This is due to increase in bitumen content air voids get filled up. The air voids with fiber shows less than without fiber due to fibers fill up some voids in sample.

4.4 VOIDS IN MINERAL AGGREGATES

With increase in bitumen content, VMA goes on slowly decreasing and then it remains constant, and then finally increases with increase in bitumen. The slowly decreasing in VMA is due to reorientation of aggregates in bitumen. Whereas at high bitumen content, due to a thick bitumen film repels the aggregates and increases the VMA value theoretically.

4.5 COMPARISON OF RESULTS OF STONE, SLAG, RAP (recycled asphalt pavement) USING FIBER.

4.5.1 SAMPLE WITH FIBER USING STONE AS COARSE AGGREGATE AND FINE AGGREGATE.

Sample No.	Bitumen Content	Weight before paraffin Waxing	Weight after paraffin Waxing	Weight in water	Height	Flow	Load taken	Stability
C-4-1	4%	1194	1204	758	57	2.8	350	7.1
C-4-2	4%	1186	1197	742	60	2.8	340	6.25
C-5-1	5%	1195	1206	750	54	3.1	290	8.3
C-5-2	5%	1185	1192	751	57	3.23	260	8.4
C-5.5-1	5.5%	1187	1194	731	58	3.2	300	8.25
C-5.5-2	5.5%	1186	1193	736	56	3.4	280	8.3
C-6-1	6%	1192	1198	771	54	4.2	230	7.2
C-6-2	6%	1188	1194	767	52	4.4	250	7.5
C-7-1	7%	1186	1191	752	58	4.8	355	6.84
C-7-2	7%	1175	1186	750	58	4.6	375	6.6

Table-6 Stability, Flow value and general properties of sample with fiber

GMB	BVS	PS	Volume	GMM	VA	GSB	VMA
2.46	481.88	2.41	481.88	2.88	10.71	3.21	18.61
2.48	482.31	2.42	482.31	2.88	13.16	3.21	19.78
2.67	443.77	2.53	451.3	2.77	11.94	3.26	19.72
2.73	451.66	2.58	455.4	2.77	10.01	3.26	18.13
2.60	455.22	2.43	455.2	2.73	8.61	3.22	17.31
2.64	449.22	2.43	449.8	2.73	6.03	3.22	19.31
2.73	433.44	2.58	433.4	2.71	6.72	3.24	21.23
2.72	441.55	2.58	441.5	2.71	7.32	3.24	20.49
2.82	433.33	2.61	433.6	2.66	6.31	3.21	23.61
2.83	427.77	2.61	427.7	2.66	5.35	3.21	24.73

Table-7 Physical properties of sample with fiber

GMB – Bulk specific gravity of mix.

GSB – Bulk specific gravity of aggregates.

GMM - theoretical maximum specific gravity of mix

VA – Air Voids

VMA – Voids in mineral aggregates.

4.5.2 SAMPLE WITH FIBER USING SLAG AS COARSE AGGREGATE AND FINE AGGREGATE.

SAMPLE No.	Bitumen Content	Weight before paraffin coating	Weight after paraffin coating	Weight in water	Height (mm)	Flow	Load Taken	Stability
C-4-1	4%	1182	1183	709	60	2.3	370	6.8
C-4-2	4%	1178	1186	706	63	3.2	355	7.2
C-5-1	5%	1186	1195	721	55.5	3.5	420	8.3
C-5-2	5%	1185	1196	713	56	2.15	475	7.85
C-5.5-1	5.5%	1176	1189	742	57	3.6	420	8.7
C-5.5-2	5.5%	1180	1192	740	58.5	2.5	465	8.4
C-6-1	6%	1196	1209	756	56	3.8	360	7.5
C-6-2	6%	1192	1204	740	61.5	3.4	410	8.08
C-7-1	7%	1185	1192	752	58.5	4.2	340	6.32
C-7-2	7%	1178	1186	754	57	3.8	365	6.52

Table-8 Stability, Flow value and general properties of sample with fiber

BVS	GMB	volume	PS	GMM	VA	GSB	VMA
470.4	2.57	470.4	2.49	2.77	10.78	2.95	18.71
467.2	2.54	467.2	2.47	2.77	9.63	2.95	17.55
464.0	2.55	469.6	2.48	2.66	9.45	2.97	18.33
470.7	2.51	470.1	2.48	2.65	8.82	2.97	15.97
432.55	2.71	440.2	2.56	2.63	8.42	2.95	19.72
438.6	2.69	438.6	2.54	2.63	7.65	2.95	18.35
438.6	2.7	438.6	2.55	2.61	6.45	2.98	21.31
440.4	2.72	440.4	2.57	2.61	7.31	2.98	20.65
432.22	2.71	432.2	2.55	2.56	6.55	2.95	22.69
433.7	2.7	433.7	2.55	2.56	6.02	2.95	21.85

Table-9 Physical properties of sample with fiber

GMB – Bulk specific gravity of mix.

GSB – Bulk specific gravity of aggregates.

GMM - theoretical maximum specific gravity of mix

VA – Air Voids

VMA – Voids in mineral aggregates.

4.5.3 SAMPLE WITH FIBER USING RAP (recycle asphalt pavement) AS COARSE AGGREGATE AND FINE AGGREGATE.

Sample No.	Bitumen content	Weight before paraffin waxing	Weight after paraffin waxing	Weight in water	Height	Flow	Load Taken	Stability
C-4-1	4%	1148	1158	653	5.4	2.5	270	7.3
C-4-2	4%	1130	1144	648	5.5	2.45	250	7.11
C-5-1	5%	1167	1180	659	5.3	2.65	260	8.75
C-5-2	5%	1154	1167	755	5.5	2.7	275	8.2
C-5.5-1	5.5%	1173	1188	663	5.5	2.8	278	8.87
C-5.5-2	5.5%	1183	1196	669	5.4	2.75	260	8.9
C-6-1	6%	1153	1166	656	5.5	3.2	264	7.9
C-6-2	6%	1162	1174	661	5.6	2.8	207	7.8
C-7-1	7%	1185	1197	679	5.4	3.9	260	7.1
C-7-2	7%	1174	1189	673	5.5	3.95	210	6.5

Table-10 Stability, Flow value and general properties of sample with fiber

BVS	GMB	VOL	PS	GMM	VA	GSB	VMA
493.7	2.32	493.7	2.41	2.71	13.4	2.95	23.07
480.5	2.35	484.6	2.46	2.71	13.11	2.95	22.5
485.4	2.30	485.4	2.44	2.66	11.6	2.95	18.3
483.2	2.31	483.2	2.48	2.63	12.6	2.95	19.5
479.6	2.38	479.6	2.55	2.65	9.5	2.96	21.6
480.1	2.30	482.1	2.55	2.63	9.8	2.96	20.3
477.3	2.36	477.3	2.57	2.61	8.7	2.95	21.6
477.1	2.4	477.1	2.59	2.61	7.4	2.95	22.8
469.4	2.30	469.4	2.6	2.56	7.8	2.95	22.9
472.1	2.4	472.1	2.6	2.53	7.2	2.95	23.5

Table-11 Physical properties of sample with fiber

GMB – Bulk specific gravity of mix.

GSB – Bulk specific gravity of aggregates.

GMM - theoretical maximum specific gravity of mix

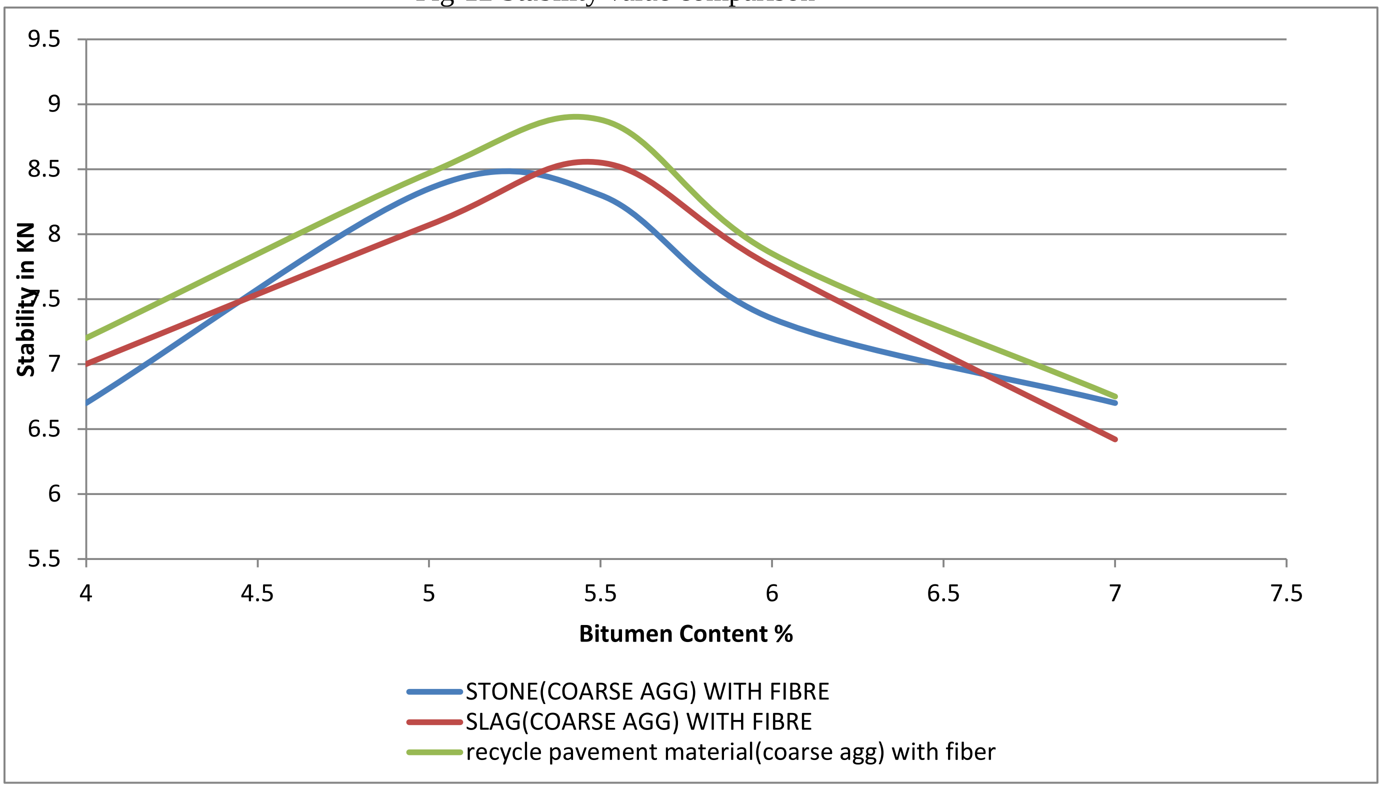
VA – Air Voids

VMA – Voids in mineral aggregates.

4.6 COMPARISON OF RESULTS

4.6.1 STABILITY VALUE COMPARISON

Fig-12 Stability value comparison



	Bitumen content (%)	Stone	Slag	RAP
STABILITY VALUE	4%	6.7	7.0	7.2
	5%	8.35	8.07	8.5
	5.5%	8.27	8.55	8.88
	6%	7.35	7.75	7.85
	7%	6.73	6.42	6.7

Table-12 Avg. stability value comparison

4.6.2 FLOW VALUE COMPARISON

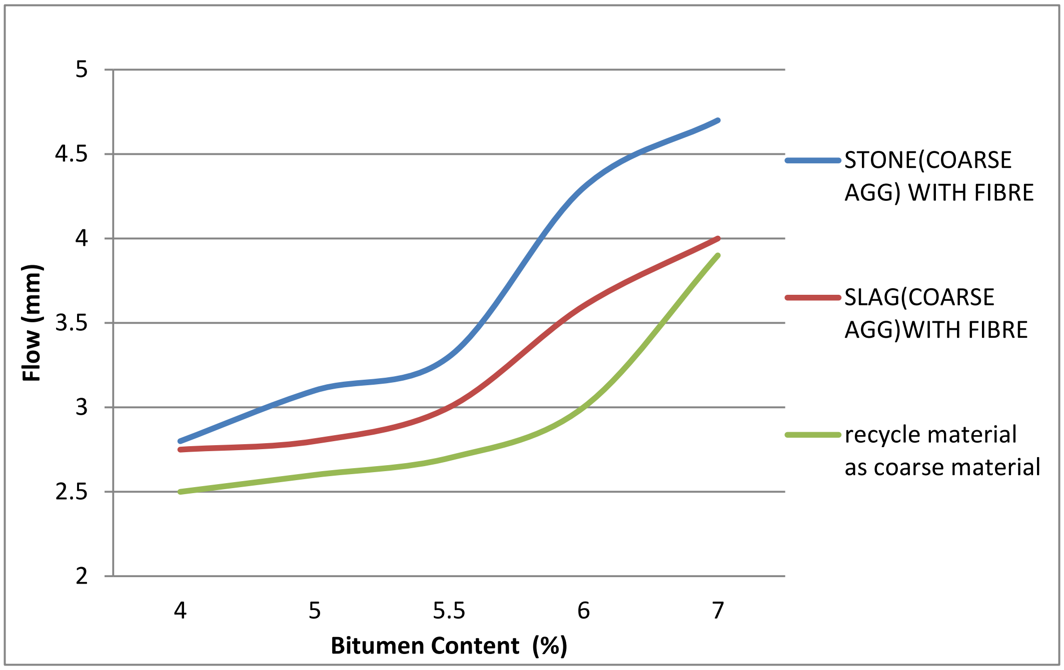


Fig-13 Flow value comparison

	Bitumen Content	Stone	Slag	RAP
FOLW VALUE	4%	2.8	2.75	2.56
	5%	3.1	2.8	2.68
	5.5%	3.4	3.0	2.73
	6%	4.3	3.6	3.0
	7%	4.7	4.0	3.92

Table-13 Avg. Flow value comparison

4.6.3 AIR VOID COMPARISON

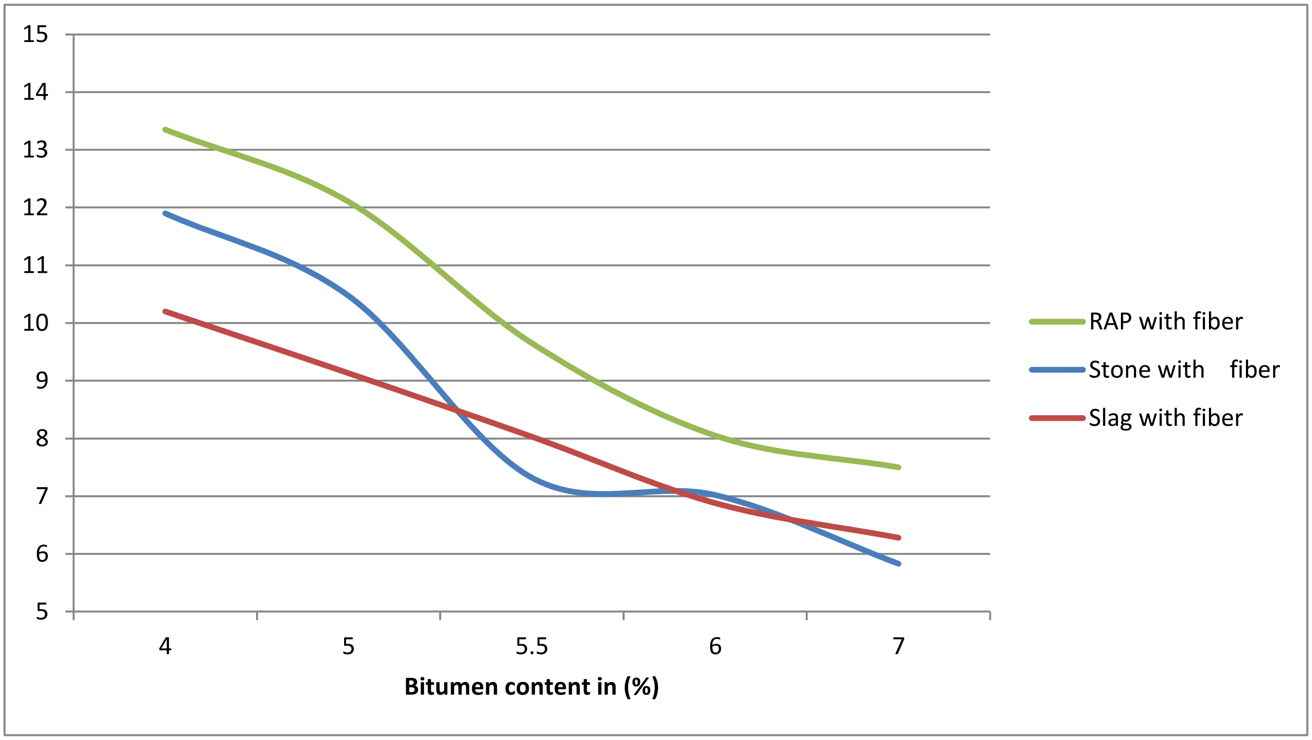


Fig14 Air void comparison

	Bitumen content	Stone	Slag	RAP
AIR VOIDS COMPARISON	4%	11.9	10.20	13.35
	5%	10.47	9.13	12.1
	5.5%	7.32	8.03	9.65
	6%	7.02	6.88	8.05
	7%	5.83	6.28	7.5

Table-14 Avg. Air voids comparison

4.6.4 VMA COMPARISON

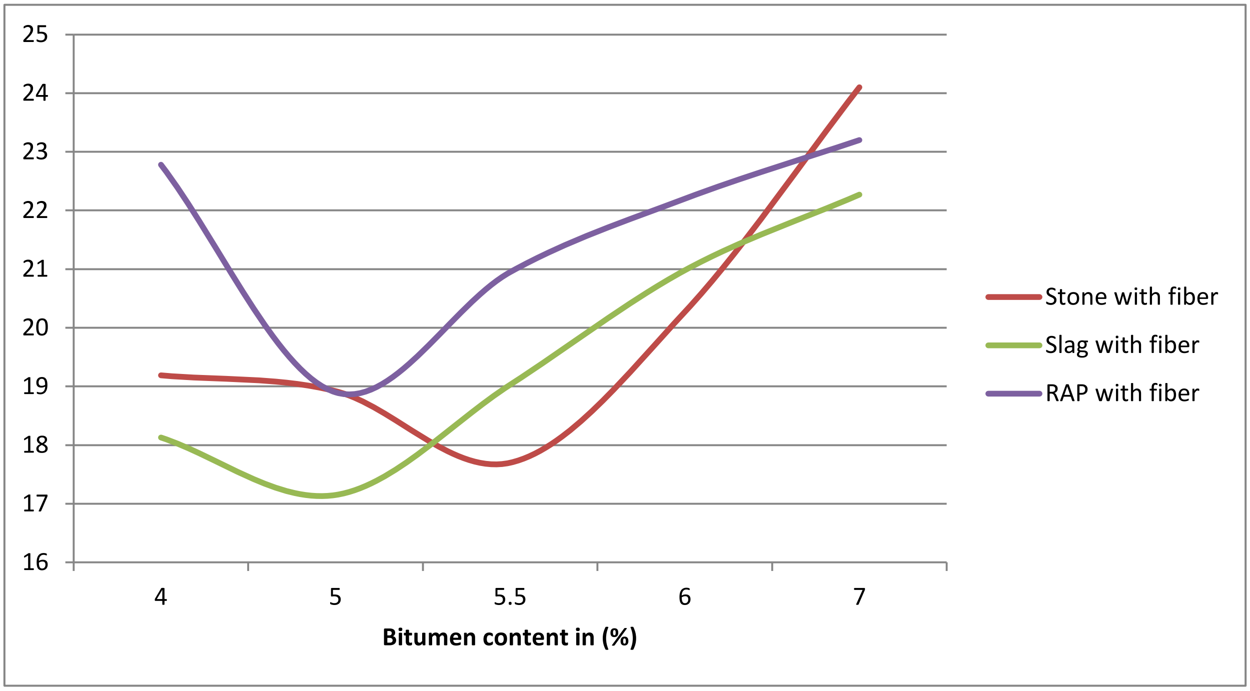


Fig15 VMA comparison

VMA COMPARISON	BITUMEN CONTENT	Stone as coarse aggregate	Slag as coarse aggregate	RAP as coarse aggregate
	4%	19.19	18.13	22.78
	5%	18.92	17.15	18.9
	5.5%	17.7	19.03	20.95
	6%	20.27	20.98	22.2
	7%	24.1	22.27	23.2

Table-15 Avg. VMA comparison

Chapter-5
CONCLUSIONS

5.0 Conclusions

5.1 Marshall Stability:-

SMA samples prepared with stone, slag and RAP as coarse aggregate. In this project work ,RAP shows better stability value shows better when compare to stone and slag aggregate. This is due to in RAP material already bitumen is mixed by which it gives more strength to material.

The maximum stability value is obtained for RAP as coarse aggregate i.e. 17.77 KN at 5.5% bitumen content when compare to stone and slag as coarse aggregate.

5.2 Flow Value:-

Flow value increases with increase in bitumen content . Generally increase is slow, but later with increase in bitumen content flow value increases. SMA mix with RAP material shows less flow value in comparison with SMA mix with slag and stone aggregate.

5.3 Air Voids:-

While preparing the samples, due to improper compaction and heating air voids are formed between the samples. Here air voids goes on decreasing on increasing the bitumen content. This is due to increase in bitumen content air voids get filled up. The air voids with RAP shows more value than other two types.

5.4 Voids in mineral aggregates:-

The VMA value, for a given aggregate should theoretically remain constant. However, in this case, it is sometimes observed that, at low bitumen content, VMA slowly decreases with the increase in bitumen content, then remains constant over a range, and finally increases at high bitumen content. The initial fall in VMA value is due to the re-orientation of the aggregates in the presence of bitumen. At very high bitumen content, due to a thicker bitumen film, the aggregates slightly moves apart resulting in an increase in VMA.

5.5 OPTIMUM BINDER CONTENT:-

The optimum binder content of the SMA mix, based on the results of Marshall test taking 3% air voids as the main criteria are observed to be increasing with the increase in stiffness of the binder. RAP shows optimum binder content of 5.5% which is same as that of SMA samples with slag where as SMA mix with only stone aggregates gives optimum binder content of 5%.

Capter-6

REFERENCES

6.1 References:-

1. Manual for construction and supervision of bituminous works, MORTH, IRC, New Delhi, 2001.
2. Chakraborty Partha, Das Animesh , Principals of transportation engineering, PHI 2003, pp-294-309 .
3. Putman B.J. and Amirkhanian S.N. (2004), “Utilization of Waste Fibers in Stone Matrix Asphalt Mixtures”, Resources, Conservation and Recycling, Volume 42, Issue 3, pp 265-274.
4. Y. Xue, S. Wu, H. Hou, J. Zha “Experimental investigation of basic oxygen furnace slag used as aggregate in asphalt mixture”- J. Hazard. Mater. 138 (16) (2006), pp. 261-268.
5. IRC: SP: 79-2008-Tentative specifications for stone matrix asphalt, Published by Indian Roads Congress.
6. MORTH, Specifications for Road and Bridge Works, up gradation of Third Revision, Ministry Of Road Transport and Highways.
7. Brown E.R. and Mallick R.B. (1994), “Stone Matrix Asphalt Properties Related to Mixture Design”, *NCAT Report 94-02.*
8. D-6927-06, Standard Test Method for Marshall Stability and Flow of Bituminous Mixtures.
9. Kumar Pawan, Chandra Satish and Bose Sunil, 'Laboratory investigations on SMA mixes with different additives', International Journal of Pavement Engineering, Volume 8, Issue1, March 2007, Pages11-18.
10. Bindu C.S. et. al.,”Waste plastic as a stabilizing additive in Stone Mastic Asphalt”, International Journal of Engineering and Technology Voume-2 (6), 2010, 379-387.