EVALUATION OF PERFORMANCE OF FLAX FIBER IN THE SMA MIX USING SLAG AS AGGREGATE REPLACEMENT

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EVALUATION OF PERFORMANCE OF FLAX FIBER IN THE SMA MIX USING SLAG AS AGGREGATE REPLACEMENT

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by
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Under the guidance
of
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Certificate

This is to certify that, the Project Report entitled "**EVALUATION OF PERFORMANCE OF FLAX FIBER IN THE SMA MIX USING SLAG AS AGGREGATE REPLACEMENT**" submitted by **Mr. SASWAT MOHAPATRA** in partial fulfillment of the requirements for the award of Bachelor Of Technology Degree in Civil Engineering at National Institute Of Technology, Rourkela is a bonafide research and authentic work carried out by him under my supervision and guidance.

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

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ABSTRACT

The technology of the asphalt material and their mixtures for paving of roads was first discovered and used to large extent in the European countries and North America. The SMA (Stone Mastic Asphalt or Stone Matrix Asphalt) mixture is a gap-graded mix that is often characterized by the presence of high coarse aggregate(may be of stone or slag), fiber additives(may be natural or artificial) as stabilizers and high asphalt content. In the present research work, an attempt has been made for studying the engineering properties of the SMA mix prepared with and without fiber and using slag in partial replacement of stone aggregate for the coarse aggregate grades. The fibers used for this project is a non-conventional natural fiber, namely flax fiber and another bitumen coated synthetic cellulose fiber. This research project was done to check the suitability of flax fiber as stabilizing agent in the SMA mixture by conducting tests in laboratory in which stability and flow parameters were analyzed, also the mechanical properties of the mixture was analyzed. And slag has been used in partial replacement of the stone aggregate for all the coarse aggregate grades for preparing SMA mixes and their properties were analyzed as well. Here for the stone matrix asphalt mix the aggregate gradation is taken based on IRC-SP-79 specification and the binder content is varied as 4%, 5%, 5.5%, 6%, 7% by weight of aggregates and fiber used is at optimum fiber content i.e. at 0.3% by weight of aggregate. Here stone dust has been used as filler and binder used is 60/70 penetration grade bitumen.

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EVALUATION OF PERFORMANCE OF FLAX FIBER IN THE SMA MIX USING SLAG AS AGGREGATE REPLACEMENT

CHAPTER-1

INTRODUCTION

1.1|GENERAL INTRODUCTION

Aggregates bound in addition with bitumen are conventionally used throughout the world in construction & maintenance of flexible pavements. The close , well, uniform , or dense graded aggregates bound with normal bitumen usually perform well in heavily trafficked roads when designed and executed properly and hence are very common in paving industry. However , it is not always possible to arrange dense aggregates available at the site. In such a situations, bituminous mix known as stone matrix asphalt (SMA) that is basically consisting of gap graded aggregates, 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. As SMA showed excellent rut-resistance and resistance to deformation caused by heavy traffic at high temperatures, its use became popular even after the ban of studded tires. SMA is a gap-graded mixture with 70-80% coarse aggregate of the total mass, 6-7% binder, 8-12% filler, and about 0.3-0.5% fiber or stabilizer or additives. The high content of coarse aggregate in the mixture makes a skeleton - type structure that provides a better stone-on-stone contact in between the coarse aggregates, that offers high resistance to rutting. Aggregate to aggregate contact, being one of the important parameters that is there in dense graded mixtures but happens to be in the fine aggregate. This is because the coarse aggregate floats in the matrix of fine aggregate, which don't give the same shear resistance since the coarse aggregate skeleton. Brown & Manglorkar (1993) reported that traffic loads for SMA are mainly carried by the coarse aggregate instead of the fine aggregate asphalt-mortar. The higher content of binder makes the mix durable. The fibers or stabilizer holds the binder in the mix even at a high temperature; this helps prevent factors like drainage during operations such as production, transportation and laying.

SMA has been yet proved to be more cost efficient than dense graded mixes for the roads with high volume. Brown (1992) observed a number of influencing factors for the performance of SMA mixes, such as

- changes in binder source and grade,
- types of aggregate,
- environmental conditions,
- Production and construction methods etc.

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.

From all these studies and observations, SMA can be defined as “A gap graded aggregate, hot mix asphalt that maximizes binder content, coarse aggregate fraction and provides a better and stable stone-on-stone skeleton which mainly is held together by a rich and consistent mixture of binder, filler and stabilizing additives”.

In this present research work aggregate calculation and consumption for use is as per the IRC-SP-79 specification. The samples are made with aggregate keeping in mind the different gradations, filler (stone dust) and binder (bitumen 60/70). Fibers are used for the purpose of stabilization. Fibers are used to decrease drain down and for increasing the strength and stability of SMA mix. The testing of the SMA samples is done in Marshall Apparatus. Here the comparison of SMA mixes with and without fiber was done. As we can see the SMA mix is having a better stone-on-stone contact than any other conventionally used mix for paving roads. This can be attributed due to the high percentage of coarse aggregate present in the mix design.

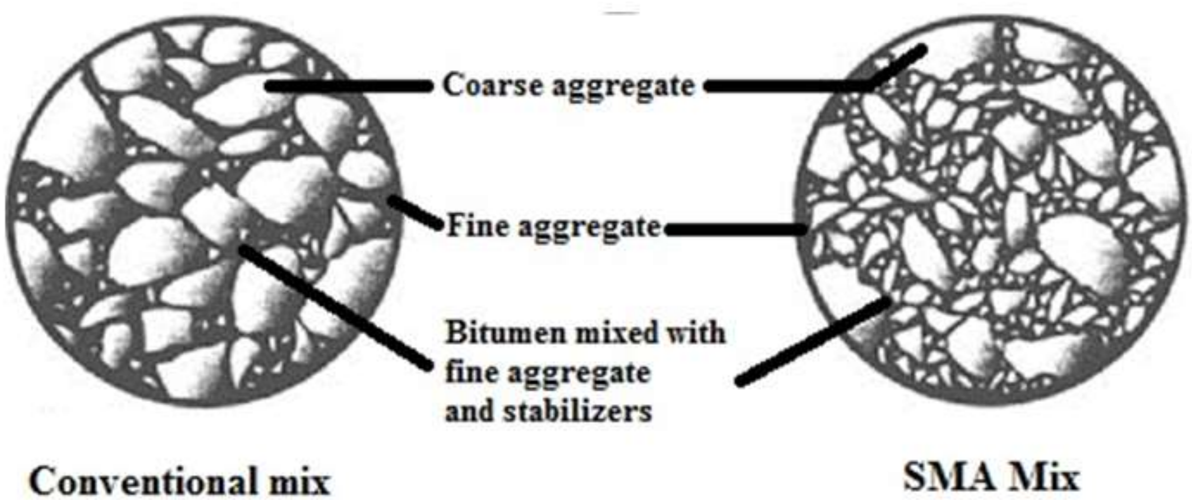

Fig 1|Comparison of the skeleton structure of SMA and HMA

1.2| ADVANTAGES OF USING SMA OVER OTHER CONVENTIONAL MIXES

- Higher strength, durability, reduced moisture permeability and longevity of SMA over conventional mixes.
- SMA provides better rut-resisting capacity caused due to slow, heavy and high traffic.
- Improved skid resistance, better resistance to deformation at high temperatures faced by the pavement, improved, noise reduction, improved fatigue-resistance are all the properties of SMA.
- SMA has a rough texture that provides good frictional properties after the surface film coating of the binder is removed by the traffic.

- Cost of production and laying SMA has been estimated to be more than conventionally used dense graded mixes, but this is justified by the increased life of the pavement layer.
- Keeping in view all these factors, SMA mixes are preferred over conventionally used HMA mixes these days.

1.3|STABILIZERS USED

1.3.1|FLAX FIBER

The natural fiber used for experimentation process was flax fiber. Flax fiber is obtained from the stem of the flax plant with the botanical name - *Linum usitatissimum***.** This plant in local Hindi language is called as "Alsi". From the fibre obtained from this plant, textile industry is largely dependent for making Linen, which is used for making clothes and different textile materials.

During the process of extraction of flax Fiber, the seeds are usually obtained and they are used to produce the linseed oil. This is an edible oil and has been a keen interest of research over the years to find its suitability as a natural substitute for petroleum.

Fig 2| Flax plant.

Fig|3 Flax fiber.

The flax fiber available was 300mm long having a diameter of .1mm and less when unsegregated. They are hence cut into smaller pieces for experimenting to a size of around 5-

7 mm and is used after being cleansed and is put into the sample at Optimum Fiber Content of 0.3% i.e. 3.6 grams.

1.3.2| EXTRAXTION OF FLAX FIBER FROM PLANT.

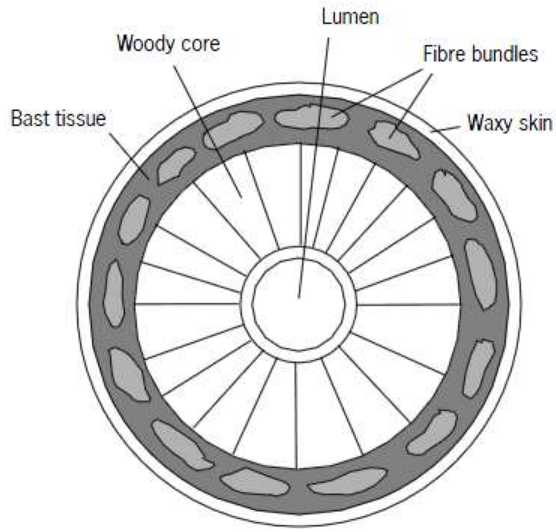

Fig 4| Cross sectional view of the stem

The process executed for extraction of the fiber is:

- Ripping- To extract the seed and for removal of the leaves and upper epithelium of the plant.
- Retting- Putting the ripped stems in water to soak the out in a concentrated solution.
- Scutching- Further refining and separation of strands.
- Hackling- preparing the bundles after subsequent refining.

1.3.3|CHARACTERISTICS OF FLAX FIBRE:

- Flax fiber is a natural fiber which has a look in the likeness of jute fiber. But this fiber is used extremely in textile industries for its rough texture and has higher cellulose content and has better elasticity and strength.
- The chemical composition includes cellulose, lignin and hemicellulose.
- Strength of this fiber is very high and this property makes it a chief geo-synthesizer fiber for it has smaller elongation coefficient.

1.3.4|CELLULOSE FIBER (TOPCEL)

Cellulose fiber provided by Organo Chemical Farm was also used for the experimentation process in addition to stone aggregates for preparing the SMA mixes. The cellulose fiber was coated with bitumen to give better strength to the sample prepared with them. They used to be granular formed and when they were added into the sample and bitumen is added to them, they get spread in the sample after heat is applied on them.

Fig 5| TOPCEL cellulose used during experiments.

1.4|OBJECTIVES OF THE PROJECT

The objectives of this project are:

- The main and foremost objective of the project is to check the suitability of preparing SMA mixes using some non-conventional fibres such as flax fiber with slag replacement and compare the results obtained by using some conventional fibers like cellulose and to study their effect on various properties of SMA.

- To study the various properties of slag aggregates to be used in the experimentation process for the project.

- 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|GENERAL REVIEW

Majority of the roads, all over the world are being made up of flexible pavements. The flexible pavements consist of the bituminous layer generally applied on the surface course and sometimes also in base course followed by some granular layers in base and sub base courses over the Sub-grade. Asphalt Concrete Pavements or Hot Mix Asphalt pavements are the layers of a flexible pavement structure present on the surface course. 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. Several different types of HMA mixes are present. These include

- Conventional Dense Graded Mixes (DGM)
- Stone Matrix asphalt (SMA)
- and various Open graded HMA.

The HMA mixes differ from each other in a variety of ways of preparation, properties, but mainly in maximum aggregate sizes, aggregate gradation and the binder content or type of binder being used.

Stone Matrix Asphalt is a tough, very stable, rut-resistant mixture that depends chiefly on aggregate to aggregate contact that provides strength in this case and a rich mortar binder that provides durability. SMA mixture is composed mainly of mineral aggregates (stone or slag), mineral fillers (stone dust, slag, cement, fly ash etc.), asphalt binder and stabilizing additives in the form of natural or artificial fiber. It is designed to maximize the rutting resistance and durability. When the Mineral aggregates were bound with asphalt mortar it forms a stone on stone contact framework that impart the strength and toughness to the structure for carrying the applied load. Mineral fillers plays an important role in defining the properties of SMA mixes in terms of air voids, void in mineral aggregate and for determining the optimum binder content in the mix. Stabilizing additives like polymers and fibers are added to the mixture to reduce drain-down characteristics of the binder material during the conditions of high temperature of production and placement of the mix.

The literature survey done has been described in brief underneath-

Brown and Mallick (1994) studied the properties of SMA related to mix design by using Marshall Mix design method. A compactive effort of 50 blows of the mechanical fixed base Marshall Hammer was given to the mix for preparing the mix and proper compaction. They showed an increase in the density of the mix prepared, if higher compactive effort was used, but this may result in crushing of the coarse aggregate due to which stone to stone contact may be lost. Hence they recommended that SMA mixtures be designed with 50 blows rather than blows as high as 75 and they suggested that drain-down of binder in the mix gets significantly affected by the types of fillers used. Presence of higher percentage of filler in the mix lowers the drain-down of the binder.

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.

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

Punith V.S., Sridhar R., Bose Sunil, Kumar K.K., Veera ragavan A (2004) adopted Marshall mix design at 60°C, 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.

Neubauer and Partl (2004) investigated the nature of SMA mixes with different filler/ binder combination to do a comparative study in between Marshall and Gyratory Methods. They found out and observed that the optimum binder content (OBC) value determined using Marshall compactor were bit higher than those found using the Gyratory compactor. They **also** used two different binders, one of penetration grade bitumen 50/70 and another was the polymer modified bitumen with SBS modifiers. And from the experiments they observed that the polymer modified bitumen gives better performance in terms of deformation and stability than the other unmodified bitumen.

Putman et al. (2004) followed a Super-pave mix design guide-lines to design the SMA mixes using PG 76-22 binder and stabilizers like waste fibers such as waste tires as additives. They were compacted the specimen with the 50 gyrations of Super-pave Gyratory Compactor as per SC DOT procedures.

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

Muniandy and Huat (2006) studied the nature and characteristic Fatigue Performance of SMA with COPF using the Marshall mix design procedure using 50 blows of compaction on each side and they obtained the desired results of their experiments with the use of Cellulose Oil Palm Fiber (COPF) to investigate the fatigue performance of SMA mixes. They produced COPF by various methods of pulping. They observed that the SMA mixes with cellulose oil palm fibers showed a higher and better performance in terms of stability, flow and the resilient modulus

Kamaraj et al. (2006) used three different types of cellulose additives called Technocel, Topcel and Genicel for preparing samples of SMA. They observed that SMA mixes with the polymers as stabilizers performed very well in terms of drain-down charecteristics, resistance to moisture damage and the permanent deformation characteristics. They hence concluded that these mixes have a suitability for road paving subjected to heavy traffic and in wet weather conditions.

Kumar et al. (2007) used 60/70 penetration grade bitumen and Crumb Rubber Modified Binder- CRMB without any stabilizing additives to study the performance and results on SMA mixes. They concluded that the use of CRMB without fibers in SMA mixes has a performance similar to or better than the conventional SMA.

Chiu and Lu (2007) studied the feasibility of using Asphalt Rubber i.e. AR, as a binder for SMA. They produced AR by blending ground tire rubber (GTR) along with AC-20 asphalt. And they termed it to be AR-SMA. Its performance for moisture susceptibility was evaluated. It was found that this AR-SMA mixes were no different from the conventional SMA mixes in terms of moisture susceptibility.

Xue et al. (2008) utilized solid waste incinerator fly ash as a partial replacement of fine aggregate or mineral filler in SMA mixes. They made a comparative study on the performance of the design mixes using Super-pave and Marshall mix design procedures. These mixes were evaluated for dynamic stability, water -sensitivity and fatigue life. They concluded that nearly 8-16% of the incinerated fly ash substitution in replacement for aggregates and filler meets the SMA specifications.

Ravi Shankar et al. (2009) used stone dust as well as cement as the filler material for SMA mixes. They used a filler content of 10% by dividing it into 8% stone dust and 2% cement and for their studies used conventional 80/100 penetration bitumen in their performance study of SMA mixtures using waste plastics as modifier.

Perviz Ahmedzade, Burak Sengoz(2009) Conducted the Evaluation of steel slag as coarse aggregate in SMA along with polypropylene and found that According to the results obtained from Marshall stability and flow tests, it should be noted that the mixtures with steel slag have better results than mixtures with stone with increased stability and decreased flow-values.

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.

Behnood, M. Ameri (2012) conducted Experimental investigation of stone matrix asphalt mixtures containing steel slag. According to the results obtained from Marshall stability it was found that mixtures with steel slag have shown encouraging results in comparison with those containing stone. Also, replacing the coarse portion of stone aggregate with steel slag leads to some better results in comparison with mixtures that contain steel slag as the fine portion. Steel slag used as the coarse portion in SMA mixtures increased Marshall Stability and decreased the flow values

T. Subramani , (2012) used coir fiber as the stabilizing agent in SMA mix and found that fibre reinforcement in bituminous mixes will lead to an economic mix with lower binder content. And There was a significant increase in the Marshall stability value on addition of coir fibre. This addition of coir fubre results in an increase in stability by nearly 13% that will help achieve stronger pavement sections.

CHAPTER-3

Experimental investigation

3.1|MATERIALS USED

1. Mineral aggregate – both coarse and fine aggregates(Stone and Slag)
2. Mineral filler (Stone dust)
3. Binder (Bitumen of penetration grade 60/70)
4. Stabilizers (Natural stabilizer- Flax fiber and Artificial stabilizer- TOPCEL cellulose)

3.1.1|MINERAL AGGREGATES

The mineral aggregates constitute of coarse and fine aggregates.

Aggregate plays a very important role for providing strength to the prepared SMA mixtures as they contribute most of the part in the matrix with 70-80 percent coarse aggregate content out of the total stone content. The higher proportion of this coarse aggregate in the mixes usually forms a skeleton type structure that provides a better stone-on-stone contact in between the coarse aggregate particles that results in a good shear strength and a high resistance to rutting.

There are different types of mineral aggregates that can be used to form the bituminous mixes.The aggregates that are used to manufacture bituminous mixes are obtained from different natural sources which may be glacial deposits or mines. These are called natural aggregates and can be used in making the mixes with or without any further processing. Also different types of artificial or man-made wastes are being used as mineral aggregates e.g. slag, a byproduct of the steel industries.

Slag is a by-product from the blast furnace obtained while the extraction of iron ore or during the formation of steel. Significant quantities of steel slag are produced as by-product every year from steel industries in throughout the world. Although it can be used as an artificial source of aggregates, it is hence sent to landfills for disposal. The disposal of these steel slag occupies a significant portion of landfills and causes many serious environmental problems every-where. This study aims to investigate the feasibility of utilizing steel slag aggregates in Stone Matrix Asphalt (SMA) mixtures Here we have attempted using slag for the making of SMA mixes. Slag has been used in partial replacement of the stone aggregates for all the coarse grain aggregate grades i.e. from 19-2.36mm.

The coarse aggregate should consist of crushed rocks retained on a 2.36 mm sieve. It should be clean, cubic shaped and rough texture to resist rutting and movements And hardness which can resist fracturing under heavy traffic loads.

The fine aggregate shall consist 100% of fine crushed sand passing the 2.36 mm sieve and retained on .075mm sieve. Preferably it should be clean, hard, durable, cubical in shape and free from soft pieces.

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

Test description	Coarse aggregates	Fine aggregates	Standard values
Flakiness index (%)	17	-	< 20
Elongation index (%)	12	-	<15
Specific gravity	2.76	2.64	2.6-2.9
Los Angeles abrasion value (%)	25.4	-	< 30
Impact value (%)	19.4	-	< 18
Aggregate Crushing value (%)	18	-	<30
Angularity number	10	-	0-11
Water absorption	0.9	-	1.3

Table 1| Physical properties of stone aggregates.

The filler used in our experiment is stone dust which has passed through 0.075 mm sieves and these are used as the filler material with a specific gravity of 2.7 g/cm^3

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

- Mineral fillers tend to increase the stiffness of the asphalt and mortar matrix.
- Mineral fillers also affect the workability, aging characteristics and moisture resistance of SMA mixtures.
- Mineral fillers help to reduce the drain-down in the mix during construction which improves the durability of the mix by properly maintaining the amount of asphalt used in the mix.
- It also helps in maintaining adequate amount of void in the mix.

Properties of coarse and fine aggregates of slag.			
Properties	Value		
	Stone	Iron slag	Steel slag
Coarse aggregate			
Bulk sp. Gr. (gr/ cm^3)	2.64	3.44	3.51
Apparent sp. Gr. (gr/ cm^3)	2.69	3.63	3.74
Water absorption (%)	0.9	1.7	1.6
L.A. abrasion (%)	25.4	20.7	19.5
Soundness in (%)	4.5	3.2	2.4
Fine Aggregates			
Bulk sp. Gr. (gr/ cm^3)	2.43	2.91	2.98
Apparent sp. Gr. (gr/ cm^3)	2.77	3.68	3.86
Plasticity index	Non-plastic	Non-plastic	Non-plastic

Table 2| Comparison for physical property of stone and slag aggregates.

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

1) Stone dust,
2) Ordinary Portland cement (OPC),
3) Slag cement and slag dust,
4) Fly Ash
5) Hydrated lime etc.

Brown and Mallick (1994**)** reported that drain-down of binder in the mix gets significantly affected by the types of fillers used. Presence of higher percentage of filler in the mix lowers the drain-down of the binder.

<u>3.1.2| BINDER</u>

Bitumen along with different additives (fibers, polymers etc.) acts as a stabilizer for the SMA mix. The bitumen for fibre-stabilized SMA shall be Viscous grade VG-30 complying with Indian Standard Specification for paving bitumen IS:73 Bitumen acts as a binding agent to the aggregates, fines and stabilizers in SMA mixtures. SMA mixes are rich in mortar binder which provides durability to the mix.

Bitumen acts as a binder for the aggregates, fines and stabilizers inside the SMA mixes that are rich in mortar binder that which provides desired durability to the mix. The various characteristics of bitumen that affects the bituminous mix behavior are susceptibility to temperature, visco-elasticity and aging.

The behavior of bitumen depends on temperature and also on the time of loading. It is stiffer at low temperature and under a short loading period. Bitumen must be treated like a visco-elastic material as it shows both viscous and also the elastic properties at normal pavement temperatures. Even though at low temperature it behaves as if it were an elastic material and at high temperature its behavior is like a viscous fluid.

Bitumen, with different additives (such as fibers, polymers etc.) acts as a stabilizer for the SMA mixes. Polymer modified bitumen can also be a stabilizer with or without additives in the mix. Penetration grade bitumen like bitumen of penetration 60/70, modified bitumen like CRMB, PMB, and Super-pave performance grade bitumen are often used to evaluate SMA mixes and their properties.

The bitumen used for the experiments is of grade of penetration60/70.

Table 3|Properties of binder

Test description	Results	Standard values
Penetration at 25ºC (1/10 mm)	65	50 to 89
Softening point ºC	65.2	>48 ºC
Ductility, cm	> 90	>50
Specific gravity	1.025	-

3.1.3| SELECTION OF STABILIZER

SMA is a gap-graded mix, with higher amount of void in the mix. So stabilizing additives are used in the mix in order to prevent mortar drain-down and to provide a better binding between the constituents. Initially SMA was developed using artificially produced asbestos fibers. Although it was perfect from technical point of view its use was gradually restricted for health reasons. Fibers commonly used now-a-days are materials like polypropylene, minerals, polyesters and cellulose. The important stabilizing additives used in the SMA mixes can be classified into four different groups;

- Fibers (Cellulose Fibers, Different Chemical Fibers and Mineral Fibers)
- Polymers
- Powder and flour like materials (Special Filler and Silicic acid)
- Plastics (Polymer Powders or Pellets)

As per MoRTH specification usually 0.3%-0.5% fiber is used in SMA mixtures. In this research study, we used 0.3% fiber by weight of aggregate. The flax fibers were cleaned and cut in to small pieces of 15-20 mm in length to ensure proper mixing with the aggregates and binder during the process of mixing.

PROPERTY	VALUE
Density(gm/ cm^3	1.5
Elongation(%)	2.0-2.5
Tensile Strength(Mpa)	500-900
Young Modulus(Mpa)	9.4-2.0
Cellulose (%)	66-78
Heli-cellulose(%)	10-13.8
Lgnin(%)	10.5-14
Pectin(%)	10
Moisture Content(%)	10-22.3
pH	5.7-6.2

Table 4| Properties of flax fiber.

3.1.4|MIX DESIGN

The main objective of the bituminous mix is to get the mix to have;

- Sufficient bitumen to ensure the durablablity of the pavement,
- Sufficient strength that will be used to resist the shear deformation under the traffic at higher temperature.
- Sufficient air void in the compacted bitumen so as to allow further additional compaction by the imposed load caused due to heavy traffic.
- Sufficient workability of the mix to permit easy placement and transpotation without segregation.
- Sufficient flexibility is needed to avoid premature cracking of the pavement caused due to repeated bending by traffic; and
- Sufficient flexibility at lower temperatures to promote better frost and thaw resistance and prevent shrinkage cracks.

3.2| PREPARATION OF MIXES

Sampling of coarse and fine aggregates is carried out for 13mm STONE MATRIX ASPHALT composition as specified by **IRC:SP-79**. Sampling was done and then the sample was allowed to be heated in an oven kept at 160 degree Celsius for 1 hour. It is then taken out, mixed with bitumen and is compacted with **Marshall Compaction Molds.** And they are 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 mold with the help of **Sample Ejector.** Its weight in air, radii and thickness/ height is calculated and then a paraffin coating is put over them.

3 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, flow, VA and VMA respectively.

The various samples prepared were-

1. Samples with stone aggregate as coarse and fine aggregate without fibre.
2. Samples with slag as coarse and stone as fine aggregate without fibre.
3. Samples with stone as coarse and fine aggregate with fiber.
4. Samples with slag as coarse and stone as fine aggregate with fiber.
5. Samples with stone as coarse and fine aggregate with cellulose fiber(TOPCEL)

IS Sieve	**Cumulative%**	**Mean**	**%retained**	**4%**	**5%**	**5.5%**	**6%**	**7%**
26.5	-	-	-	-	-	-	-	-
19	100	100	0	0	0	0	0	0
13.2	90-100	95	5	57.6	57	56.6	56	55.8
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	34.0	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	34.0	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

Table 5|Composition of 13mm SMA mix

3.3|FINISHING THE MARSHALL SPECIEMEN

After casting of the samples is done, we remove the sample from its mould with the sample extractor. After it is removed from the mould, its weight, radii, height are measured and then is coated with wax. After the coat of wax is provided the weight of the sample in air and water is taken for computing the volume of sample. Before conducting the Marshall test, each of the samples were kept in hot water bath for 30 min. at 60 degree temperature. Filler used was stone-dust.

Fig 6| Preparation and mixing of the SMA mix

Fig 7|Hammer Fig 8| Marshall Mould Fig 9| Marshall testing machine

Fig 10| Samples before and after wax coating.

3.4| VARIOUS TESTS PERFORMED

3.4.1|MARSHALL TEST

After preparation of the sample and its initial treatments we remove the samples from the hot-water-bath and take them for testing. It is then placed in the Marshall stability testing machine and loaded at a constant rate of deformation of 5 mm per minute until failure.

The total maximum load in kN(that causes failure of the specimen) is taken as Marshall Stability. The stability value hence obtained is corrected for volume by using correlation ratio table.

The total amount of deformation is units of 0.25 mm which occurs at maximum load is recorded as Flow Value.

Care should be taken so that the sample does not stays in the water bath for more than 30 minutes or at a temperature greater than 60 ºC. If such case happens, the bitumen that has been used as binder will loose it’s properties and the sample will be worth-less as after that it won’t give good stability and will not be able to carry the applied load.

Fig 11| Samples kept in hot water bath

Fig 12| Marshall test being conducted with the Marshall apparatus.

3.4.2| DRAIN DOWN TEST:

Drain down test was done on stone matrix asphalt (SMA) mixes to find out the drain-down percent of the binder which has been used in the mix. It was observed from the drainage tests conducted on SMA mixes that there is apparently no drain down of binder for all the mixes with fiber. Mixes of 60/70 bitumen yields some better results with further addition of fiber.

Drain-down results shows that upon addition of slag as coarse aggregate drain-down also reduces phenomenally and is absent sometimes at a bitumen content below 7%.

Fig 13| No drain down in case of samples with fiber.

CHAPTER-4

ANALYSIS OF RESULTS

4.1| GENERAL DISCUSSION

As it has been discussed above we have prepared 5 types of samples. And they are.

1. Samples with stone aggregate as coarse and fine aggregate without fiber.
2. Samples with slag as coarse and stone as fine aggregate without fiber.
3. Samples with stone as coarse and fine aggregate with fiber.
4. Samples with slag as coarse and stone as fine aggregate with fiber.
5. Samples with stone as coarse and fine aggregate with cellulose fiber(TOPCEL)

So for this analysis section we are going to compare all the results obtained from different tests conducted on the sample. Results will be compared in between,

1. Stone as both coarse and fine aggregates for the cases of without fiber, with fiber, and with cellulose.
2. Slag in partial replacement for the coarse aggregates with stone as fine aggregate for the cases of with and without flax fiber.
3. Samples with slag as coarse aggregate with that of samples where stone is the coarse aggregate.

So for the analysis of results, we need to deal with some basic abbreviations.

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

Table 6| Nomenclatures and their full forms

4.1.1| MARSHALL STABILITY

Stability of a mix is obtained after deciding the load taken by the sample and after that multiplying by a suitable factor called as the correlation ration which is obtained by comparing the thickness/ height of the sample or the volume of the sample. On increasing bitumen content the stability value, increases upto some point theoretically and then falls.

This is due to the reason that with the initial increase in bitumen content, the aggregate and bitumen bond gradually goes on getting stronger, but with any further increase in the content of bitumen, the applied load is transmitted. This transmission of load is through hydrostatic pressure, keeping that fraction across the contact point of aggregates immobilized. This makes the mix very weak against plastic deformation and hence the stability falls.

The very same principle is applied to mix with fibers, but in this mix there exists a higher stability value at the very same binder content in comparison with the mix without fibers. This is due to, the fibers in the mix act as stabilizer that not only fills the voids up in the sample, but also reduces the drain down quite significantly, and hence holding up the binder in the mix for good results. This method of addition of fibers also provides a homogeneity to the mix.

4.1.2| FLOW VALUE

Flow in general terms is defined as the deformation undergone by the sample at the condition of maximum load where failure usually occurs. The flow value increases with an increase in bitumen content for both cases of the mix with and without fibers .The increase is initially slow, but later the rate of increase of flow value increases with increase in bitumen content. The flow value of the mix prepared with fibers should theoretically be low as compared to the flow of samples without fiber.

But sometimes it has been observed that the flow value may increase at higher bitumen content for samples with fiber. This may be due to formation of lumps of bitumen and the fiber.

4.1.3| AIR VOIDS

During the process of casting of the sample, use air voids get in between the sample due to improper compaction and heating. The Air Voids (VA) decreases as we go on increasing the bitumen content. This is because; with an increase in bitumen content bitumen fills the air voids continuously.

The VA of mixes, with fiber is much lesser to that without fiber theoretically. This happens as the fibers tend to fill up some voids in the sample as well.

4.1.4| VOIDS IN MINERAL AGGREGATE

The value of VMA, for a given aggregate should remain constant theoretically. However, it is sometimes observed, that at low bitumen content, VMA keeps on slowly decreasing with an increase in bitumen content and then it remains constant, and finally increases with the higher bitumen content. The initial fall of VMA value is because of the reorientation of aggregates in the presence of the bitumen. At a high bitumen content, this is due to a thicker bitumen film, that repels the aggregates slightly apart increasing the VMA value theoretically.

4.2| COMPARISON OF RESULTS OF STONE AS BOTH FINE AND COARSE AGGREGATE, WITH AND WITHOU FLAX FIBER AND WITH CELLULOSE

4.2.1| SAMPLES WITHOUT FLAX FIBER

Sample No.	Bitumen content	Wt. before paraff. Coating	Wt. aftr paraff coating	Wt in water	height	flow	Load taken	stability
S-4-1	4%	1194	1210	709	64.5	3.1	300	5.84
S-4-2	4%	1183	1199	699	65	2.4	250	6.13
S-4-3	4%	1187	1202	703	65	3.1	280	5.74
S-5-1	5%	1185	1197	709	63.2	3.6	355	6.93
S-5-2	5%	1182	1196	701	63	4.8	290	7.84
S-5-3	5%	1198	1209	719	62.5	4	315	7.12
S-5.5-1	5.5%	1183	1192	750	57	3.9	230	8.157
S-5.5-2	5.5%	1179	1186	755	56	4.2	280	7.11
S-5.5-3	5.5%	1181	1189	754	61.7	4.8	340	7.48
S-6-1	6%	1201	1208	740	59	4.7	275	6.76
S-6-2	6%	1186	1194	757	56.25	5.4	250	7.3
S-6-3	6%	1193	1201	753	59	4.3	320	7.2
S-7-1	7%	1180	1210	707	60	5.4	455	5.52
S-7-2	7%	1186	1215	712	61	4.8	480	6.4
S-7-3	7%	1184	1212	710	60.5	5.7	470	5.8

Table 7|Flow, stability and general characteristics of samples without flax fiber

Gmb	Volume	ps	Gmm	VA	GSB	VMA
2.41	506.58	0.97	2.62	8	2.727	15.27
2.39	510.51	0.98	2.62	8.65	2.727	15.88
2.4	510.51	0.98	2.62	8.22	2.727	15.48
2.45	496.37	0.96	2.58	7.3	2.755	15.66
2.41	494.8	0.96	2.58	6.75	2.755	16.96
2.46	490.87	0.95	2.58	6.82	2.755	15.14
2.69	443	2.57	2.95	5.96	3.2	20.12
2.75	431.78	2.64	2.95	5.66	3.2	18.45
2.73	435.89	2.62	2.95	7.46	3.2	19.02
2.58	468.78	2.38	2.87	7.35	3.21	22.42
2.73	437.89	2.55	2.87	4.91	3.21	21.09
2.68	448.89	2.49	2.87	6.51	3.21	22.57
2.39	471.24	0.95	2.53	5.4	2.763	22.58
2.4	479.09	0.94	2.53	4.99	2.763	23.58

Table 8| Physical characteristics of sample type-1, i.e. without fiber

4.2.2| SAMPLES WITH FLAX FIBER WITH STONE AS COARSE AND FINE AGGREGATE.

Sample No.	Bitumen content	Wt. before paraff. Coating	Wt. aftr paraff coating	Wt in water	height	flow	Load taken	stability
F -4-1	4%	1182	1189	709	60	2.3	370	6.01
F -4-2	4%	1178	1186	706	63	3.2	355	5.89
F -4-3	4%	1183	1192	705	61	2.1	430	6.01
F -5-1	5%	1202	1210	721	55.5	3.9	420	10.29
F -5-2	5%	1186	1194	713	56	4.3	475	8.43
F -5-3	5%	1194	1204	715	56.5	3.9	450	7.52
F-5.5-1	5.5%	1176	1189	742	57	4.8	420	9.18
F-5.5-2	5.5%	1180	1192	740	58.5	5.4	465	7.63
F-5.5-3	5.5%	1189	1201	749	58	4.9	400	8.47
F-6-1	6%	1196	1209	756	56	5.7	360	7.41
F-6-2	6%	1204	1214	740	61.5	5.1	410	8.08
F-6-3	6%	1203	1212	748	60	5.9	330	8.23
F-7-1	7%	1185	1192	752	58.5	4.9	340	6.32
F-7-2	7%	1178	1186	754	57	5.4	365	6.52
F-7-3	7%	1185	1191	759	62	5.9	330	7.89

Table 9| Flow, stability and general properties of sample with fiber

BVS	GMB	Volume	PS	GMM	VA	GSB	VMA
480.78	2.47	480.78	2.42	2.99	15.12	3.17	19.68
480.89	2.47	480.89	2.42	2.99	16.98	3.17	22.08
488.00	2.44	488.00	2.38	2.99	15.09	3.17	18.68
489.89	2.47	489.89	2.33	2.95	15.67	3.20	19.61
481.89	2.48	481.89	2.37	2.95	14.95	3.20	18.15
490.11	2.46	490.11	2.33	2.95	15.32	3.20	17.94
448.44	2.65	448.44	2.54	2.95	10.58	3.20	18.36
453.33	2.63	453.33	2.51	2.95	12.86	3.20	18.33
453.33	2.65	453.33	2.51	2.95	12.02	3.20	19.85
454.44	2.66	454.44	2.48	2.93	10.03	3.24	20.15
475.11	2.56	475.11	2.37	2.93	11.59	3.24	21.65
465.00	2.61	465.00	2.43	2.93	8.95	3.24	23.49
440.78	2.70	440.78	2.53	2.87	5.69	3.21	24.58
432.89	2.74	432.89	2.58	2.87	6.84	3.21	23.02
432.67	2.75	432.67	2.58	2.87	6.37	3.21	21.08

Table 10| Physical properties of sample with fiber

4.2.3| SAMPLES PREPARED WITH CELLULOSE AND AGGREGATES

Bulk volume sample (BVS)	Gmb	Volume	ps	Gmm	VA	GSB	VMA
447.11	2.69	447.11	2.6	2.99	10.07	3.17	18.35
474.22	2.56	474.22	2.45	2.99	14.44	3.17	22.32
463.11	2.61	463.11	2.51	2.99	12.68	3.17	20.71
489.33	2.45	496.37	0.96	2.58	8.17	2.755	15.66
496.56	2.41	494.8	0.96	2.58	12.63	2.755	16.96
491.22	2.46	490.87	0.95	2.58	10.83	2.755	15.14
447.11	2.69	447.11	2.52	2.93	8.17	3.24	20.20
474.22	2.56	474.22	2.38	2.93	6.63	3.24	24.08
463.11	2.61	463.11	2.44	2.93	6.83	3.24	22.51
447.11	2.69	447.11	2.52	2.93	7.3	3.24	18.54
474.22	2.56	474.22	2.38	2.93	6.75	3.24	23.36
463.11	2.61	463.11	2.44	2.93	6.82	3.24	20.96
439.56	2.71	439.56	2.54	2.87	5.51	3.21	22.86
436.78	2.72	436.78	2.56	2.87	5.31	3.21	23.88
444.89	2.72	444.89	2.51	2.87	5.08	3.21	21.72

Table 11| Physical properties of samples with cellulose fiber

Sample No.	Bitumen content	Wt. before paraff. Coating	Wt. aftr paraff coating	Wt in water	height	flow	Load taken	stability
C-4-1	4%	1194	1202	759	57	2.8	350	6.87
C-4-2	4%	1206	1215	741	60	2.8	340	6.53
C-4-3	4%	1201	1213	747	61	2.7	380	7.33
C-5-1	5%	1185	1197	709	59	3.6	420	8.75
C-5-2	5%	1182	1196	701	58	4.2	470	7.81
C-5-3	5%	1198	1209	719	57.5	4	480	8.165
C-5.5-1	5.5%	1192	1204	757	56	4	470	8.697
C-5.5-2	5.5%	1204	1211	742	60	4.6	425	8.55
C-5.5-3	5.5%	1199	1211	746	61	3.7	495	7.94
C-6-1	6%	1196	1206	758	58	4.3	380	7.75
C-6-2	6%	1202	1210	743	61	5.6	400	8.052
C-6-3	6%	1205	1213	748	60	4.5	375	7.204
C-7-1	7%	1186	1191	752	58	5.7	355	6.84
C-7-2	7%	1179	1186	750	58	4.8	375	7.56
C-7-3	7%	1203	1211	767	59	6.2	350	6.34

Table 12| Flow, stability and general properties of samples with cellulose

4.2.4| COMPARISON OF RESULTS

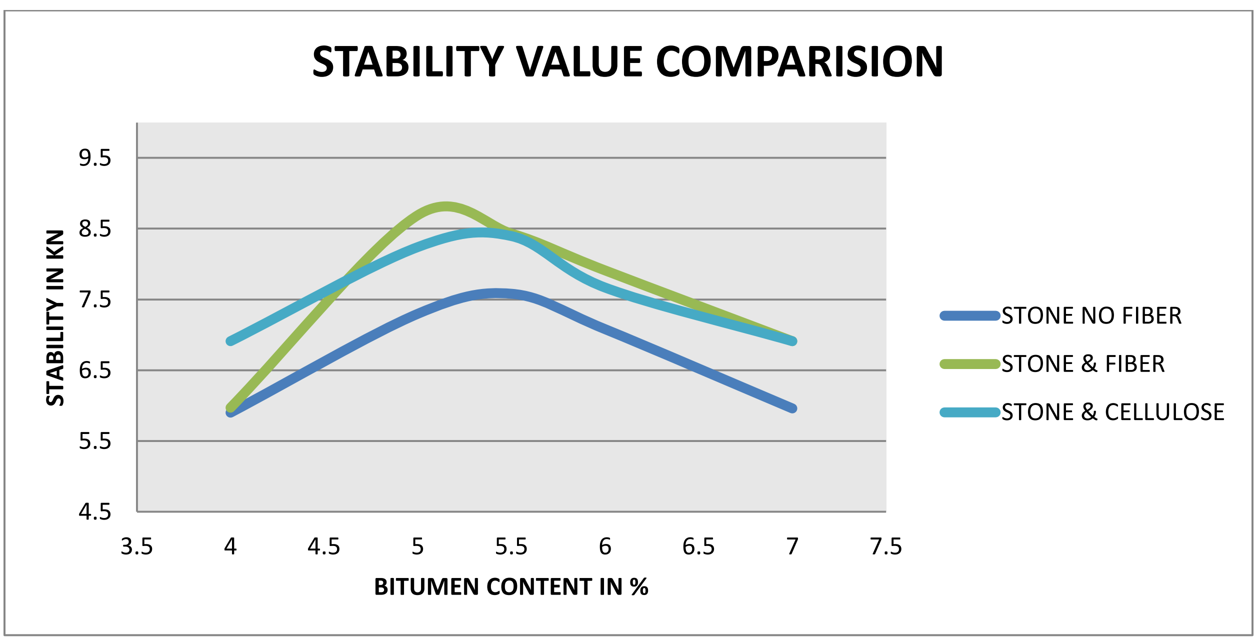

Fig 14|Avg. Stability value comparison for stone aggregates

	BITUMEN CONTENT	STONE NO FIBER	STONE & FIBER	STONE & CELLULOSE
STABILITY	4	5.9	5.97	6.91
	5	7.297	8.69	8.24
	5.5	7.58	8.43	8.395
	6	7.08	7.91	7.668
	7	5.96	6.91	6.91

Table 13| Avg. Stability value comparison

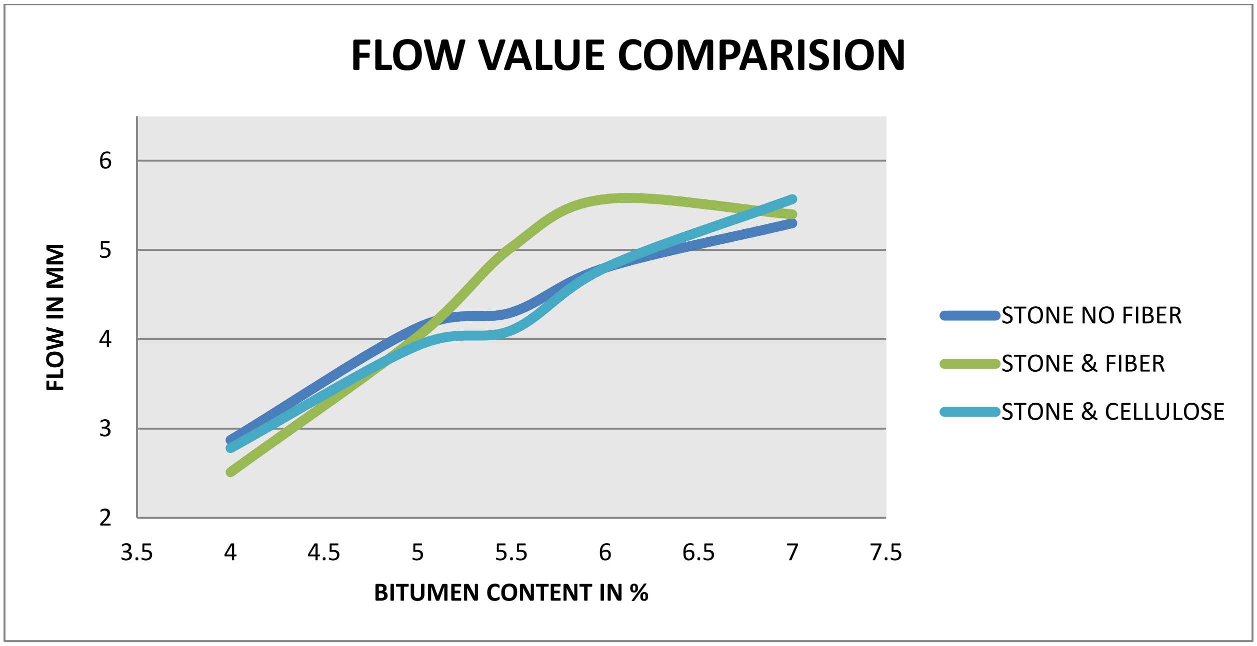

Fig 15| Avg. Flow value comparison for stone aggregates

	BITUMEN CONTENT	STONE NO FIBER	STONE & FIBER	STONE & CELLULOSE
FLOW	4	2.87	2.51	2.78
	5	4.13	4.03	3.93
	5.5	4.3	5.03	4.1
	6	4.8	5.57	4.8
	7	5.3	5.4	5.57

Table 14| Avg. Flow value comparison

	BITUMEN CONTENT	STONE NO FIBER	STONE & FIBER	STONE & CELLULOSE
VA COMPARISON	4	8.3	11.97	12.4
	5	6.96	5.59	10.54
	5.5	6.36	9.62	7.21
	6	6.26	8.78	6.9
	7	5.13	6.39	5.3

Table 15| Comparison of data for avg. VA

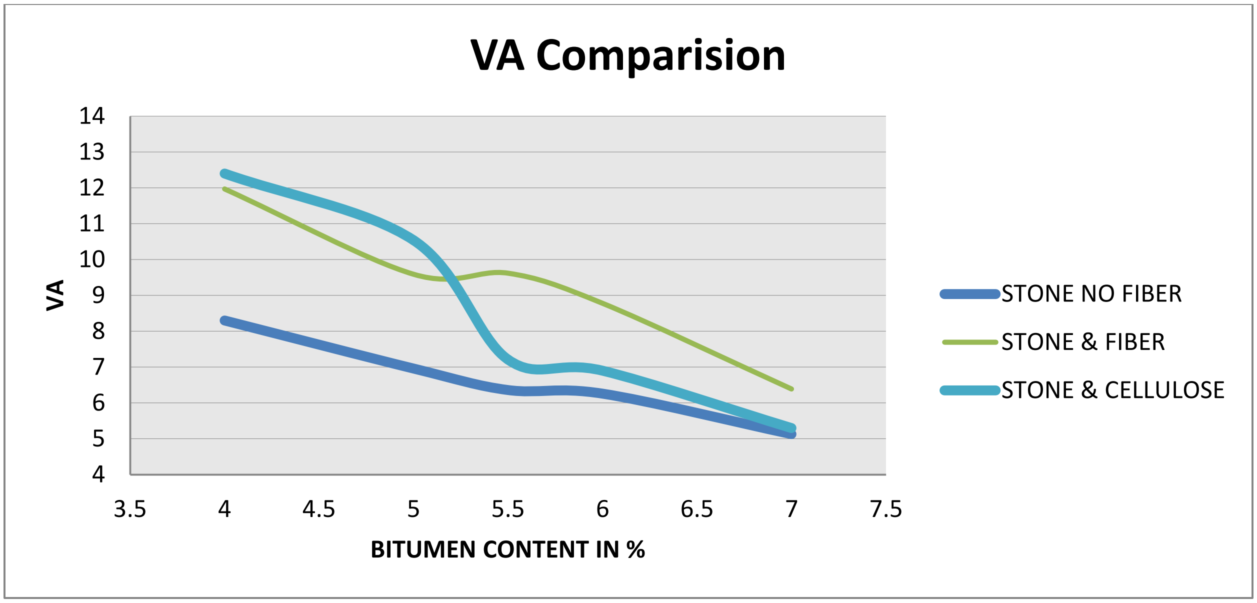

Fig 16| Comparison of data for avg. VA

	BITUMEN CONTENT	STONE NO FIBER	STONE & FIBER	STONE & CELLULOSE
VMA COMPARISON	4	19.2	20.15	20.46
	5	15.9	18.57	15.92
	5.5	16.12	18.85	22.2
	6	19.24	21.76	20.9
	7	13.7	22.89	22.8

Table 16| Comparison of data for avg. VMA

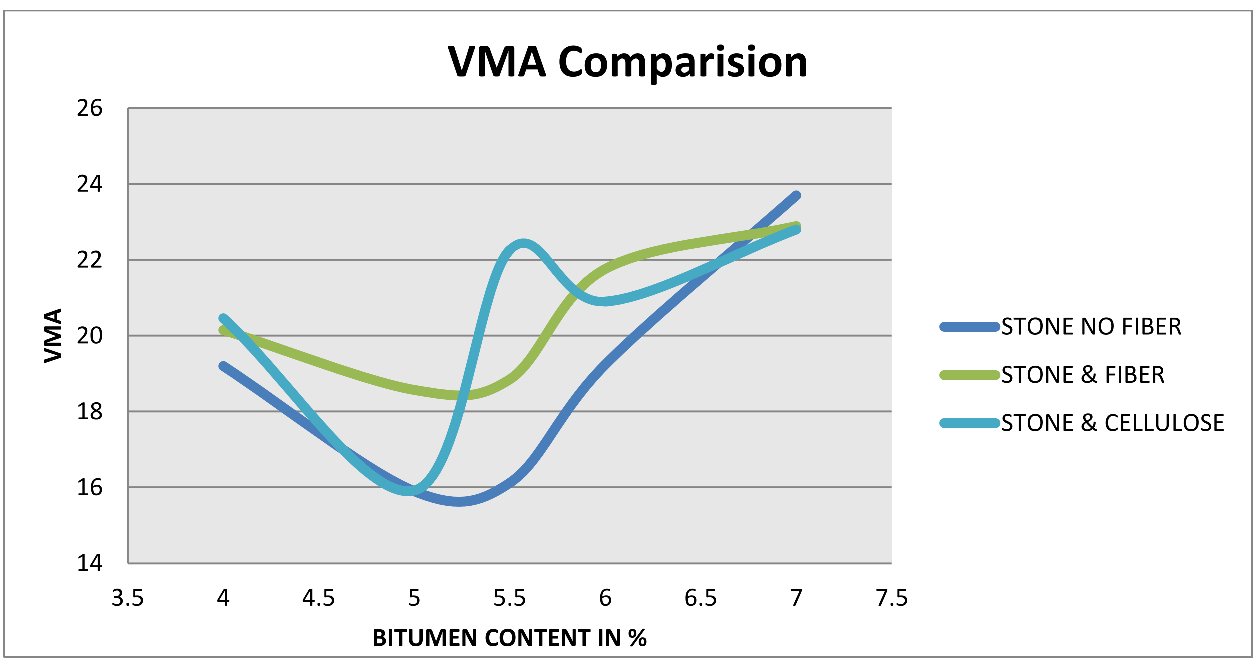

Fig 17| Comparison of data for avg. VMA

4.3| COMPARISON OF RESULTS OF SAMPLES PREPARED BY PARTIAL REPLACEMENT WITH SLAG WITH AND WITHOUT FIBER

4.3.1| SAMPLES PREPARED WITHOUT FLAX FIBER

Sample No.	Bitumen content	Wt. before paraff. Coating	Wt. aftr paraff coating	Wt in water	height	flow	Load taken	stability
L-4-1	4%	1191	1201	759	57	2.8	440	6.53
L-4-2	4%	1201	1215	742	60	2.8	430	5.86
L-4-3	4%	1201	1214	746	61	2.7	400	6.33
L-5-1	5%	1183	1194	751	57	3.6	230	8.157
L-5-2	5%	1179	1186	754	56	3.2	280	7.11
L-5-3	5%	1181	1187	757	61.7	3.7	340	6.48
L-5.5-1	5.5%	1195	1204	757	57	4	415	8.25
L-5.5-2	5.5%	1205	1212	743	60	4.6	395	7.22
L-5.5-3	5.5%	1203	1210	747	61	3.7	330	7.39
L-6-1	6%	1185	1192	750	57	5.2	380	7.378
L-6-2	6%	1179	1187	755	58	4.8	360	6.52
L-6-3	6%	1186	1189	754	63.5	5.6	320	6.94
L-7-1	7%	1201	1208	740	59	6.1	275	6.76
L-7-2	7%	1186	1194	757	56.25	5.4	250	6.36
L-7-3	7%	1193	1201	753	59	6.3	320	7.206

Table 17| Flow, stability and general properties of samples without fiber

Bulk volume sample (BVS)	Gmb	Volume	ps	Gmm	VA	GSB	VMA
447.11	2.69	447.11	2.6	2.99	10.07	3.17	18.35
474.22	2.56	474.22	2.45	2.99	14.44	3.17	22.32
463.11	2.61	463.11	2.51	2.99	12.68	3.17	20.71
443	2.69	443	2.57	2.95	8.72	3.2	20.12
431.78	2.75	431.78	2.64	2.95	6.82	3.2	18.45
435.89	2.73	435.89	2.62	2.95	7.46	3.2	19.02
447.11	2.69	447.11	2.52	2.93	8.17	3.24	20.20
474.22	2.56	474.22	2.38	2.93	6.63	3.24	24.08
463.11	2.61	463.11	2.44	2.93	6.83	3.24	22.51
443.00	2.69	443.00	2.52	2.87	6.17	3.21	23.12
431.78	2.75	431.78	2.58	2.87	4.21	3.21	23.97
435.89	2.73	435.89	2.56	2.87	4.88	3.21	24.01
468.78	2.58	468.78	2.38	2.87	10.14	3.21	25.42
437.89	2.73	437.89	2.55	2.87	4.91	3.21	23.01
448.89	2.68	448.89	2.49	2.87	6.7	3.21	24.84

Table 18| Physical properties of samples without fiber

4.3.2| SAMPLES PREPARED WITH FLAX FIBER

Sample No.	Bitumen content	Wt. before paraff. Coating	Wt. aftr paraff coating	Wt in water	height	flow	Load taken	stability
F -4-1	4%	1179	1187	731	60	3.2	375	7.12
F -4-2	4%	1183	1191	743	59	2.9	350	6.73
F -4-3	4%	1182	1189	740	59.5	2.7	400	8.12
F -5-1	5%	1176	1186	745	58	4.5	490	8.51
F -5-2	5%	1177	1187	747	56	2.3	475	8.43
F -5-3	5%	1194	1201	753	59	3.2	425	8.925
F-5.5-1	5.5%	1181	1193	751	57.5	3.6	500	8.87
F-5.5-2	5.5%	1181	1188	753	56.5	4.5	425	9.375
F-5.5-3	5.5%	1183	1189	754	58	4.9	490	8.51
F-6-1	6%	1196	1204	759	58	3.7	415	8.58
F-6-2	6%	1190	1197	751	60.5	4.9	370	7.15
F-6-3	6%	1200	1211	760	58	4.2	330	8.62
F-7-1	7%	1185	1193	754	58.5	4.7	355	7.12
F-7-2	7%	1181	1189	752	57.5	4.8	375	7.56
F-7-3	7%	1204	1214	766	58	5.1	350	6.13

Table 19| Value of flow, Stability and other physical properties

BVS	GMB	Volume	PS	GMM	VA	GSB	VMA
456.9	2.6	456.0	2.54	2.99	11.78	3.17	17.86
448.9	2.7	450.0	2.59	2.99	9.85	3.17	19.55
449.8	2.6	449.8	2.58	2.99	9.65	3.17	18.36
442.1	2.7	442.1	2.58	2.95	8.99	3.20	16.59
441.1	2.7	441.1	2.58	2.95	8.71	3.20	18.38
448.8	2.7	448.8	2.54	2.95	9.21	3.20	16.94
443.0	2.7	443.0	2.57	2.95	5.96	3.2	20.12
431.8	2.8	431.8	2.64	2.95	8.36	3.2	18.45
435.9	2.7	435.9	2.62	2.95	7.46	3.2	19.02
445.9	2.7	445.9	2.53	2.93	7.92	3.24	20.85
446.8	2.7	446.8	2.52	2.93	6.78	3.24	20.61
452.2	2.7	452.2	2.49	2.93	8.68	3.24	21.69
439.9	2.7	439.9	2.54	2.87	6.92	3.21	21.98
437.9	2.7	437.9	2.55	2.87	5.31	3.21	23.88
449.1	2.7	449.1	2.48	2.87	5.74	3.21	22.65

Table 20| Physical properties

4.3.3| COMPARISON OF RESULTS

	BITUMEN CONTENT	SLAG WITHOUT FIBER	SLAG & FIBER
STABILITY	4	6.24	7.32
	5	7.25	8.62
	5.5	7.62	8.92
	6	6.95	8.11
	7	6.78	6.94

Table 21| Avg. Stability value comparison

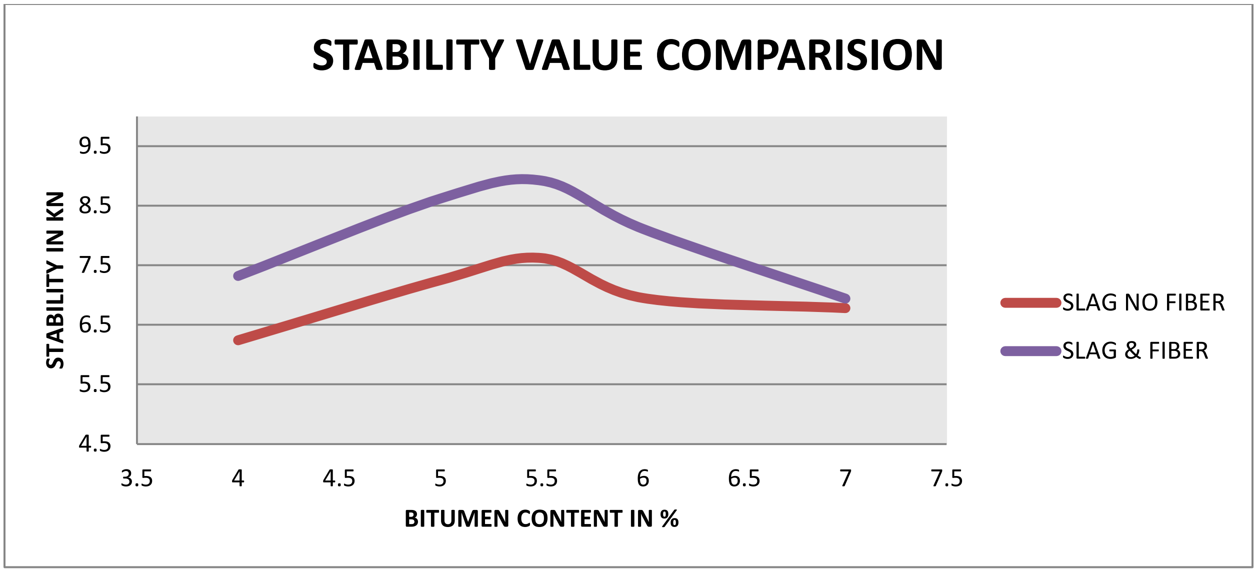

Fig 18| Comparison of avg. stability

	BITUMEN CONTENT	SLAG WITHOUT FIBER	SLAG & FIBER
FLOW	4	2.78	2.93
	5	3.5	3.33
	3.5	4.1	4.33
	4.1	5.2	4.27
	5.2	5.94	4.87

Table 22| Avg. Flow result comparison

	BITUMEN CONTENT	SLAG WITHOUT FIBER	SLAG & FIBER
VA	4	12.4	10.43
	5	7.7	9.33
	3.5	7.2	7.26
	4.1	5.1	7.8
	5.2	7.25	5.77

Table 23| Comparison of results of avg. VA

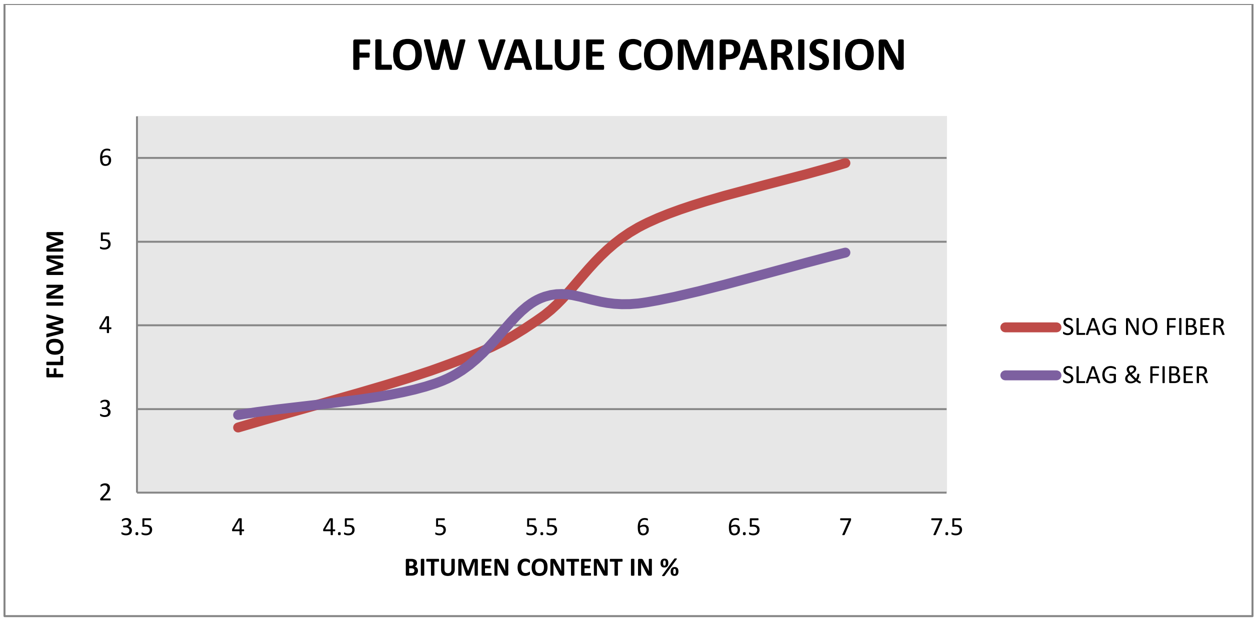

Fig 19| Avg. Flow result comparison

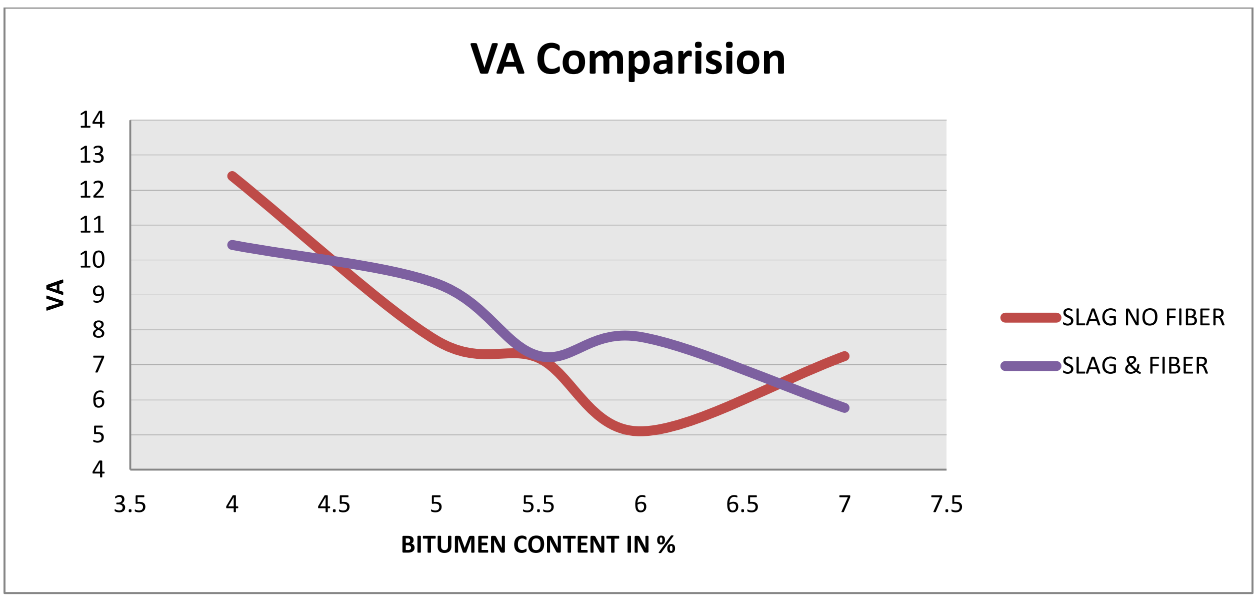

Fig 20| Comparison of results of avg. VA

	BITUMEN CONTENT	SLAG WITHOUT FIBER	SLAG & FIBER
VMA	4	20.5	18.66
	5	19.2	17.3
	3.5	22.2	19.2
	4.1	23.7	21.18
	5.2	24.4	22.84

Table 24| Comparison of results for avg. VMA

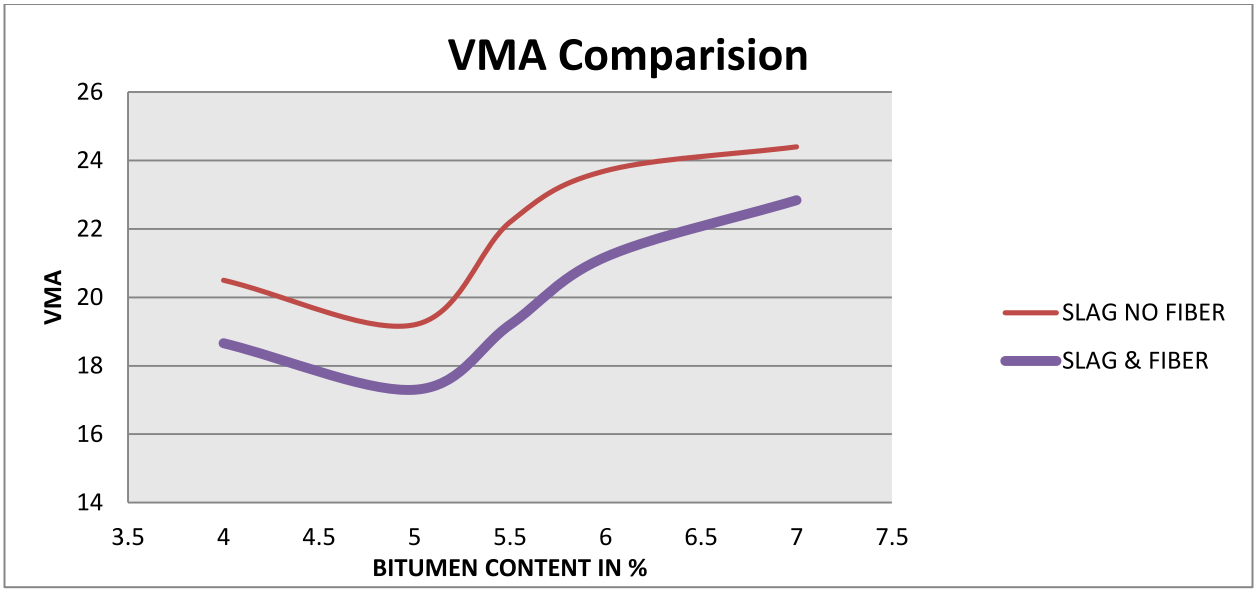

Fig 21| Comparison of results for avg. VMA

4.4| COMPARISON OF RESULTS INVOLVING SAMPLES WITH STONE AGGREGATE AND SLAG AGGREGATE AS COARSE AGGREGATE WITH FLAX FIBER BEING USED AS STABILIZER.

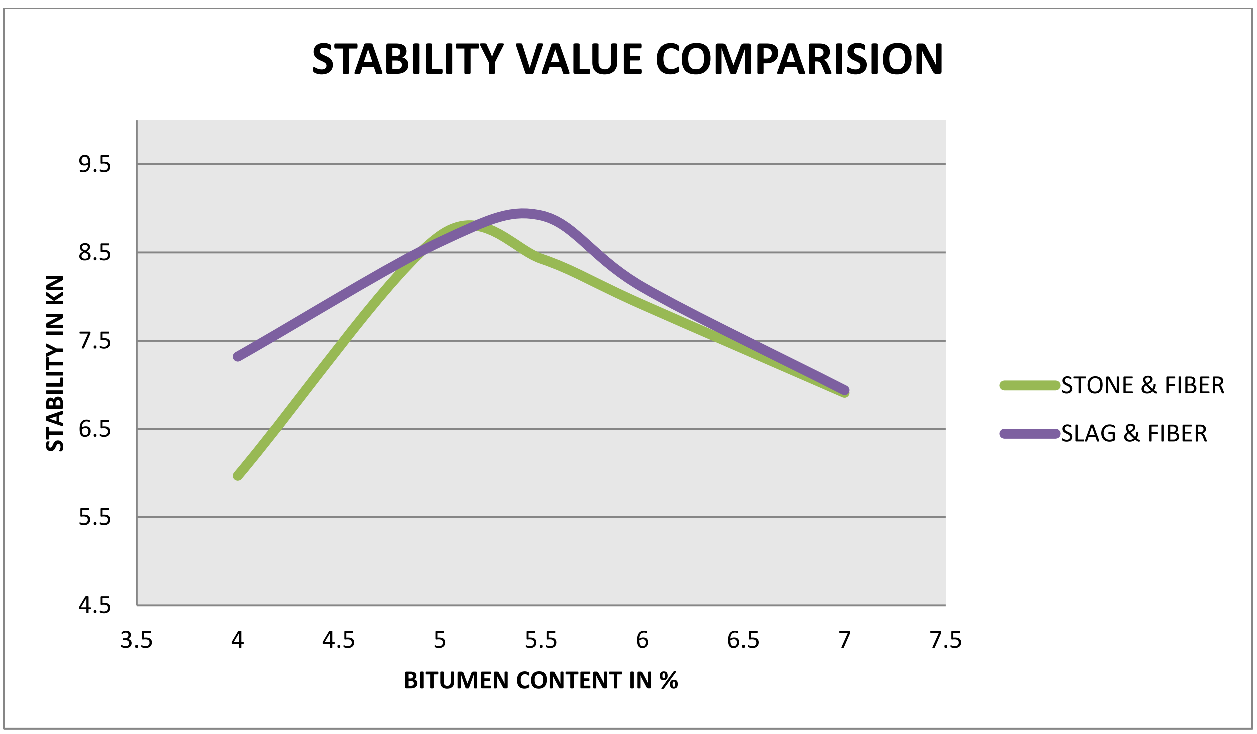

Fig 22| Comparison of stability results

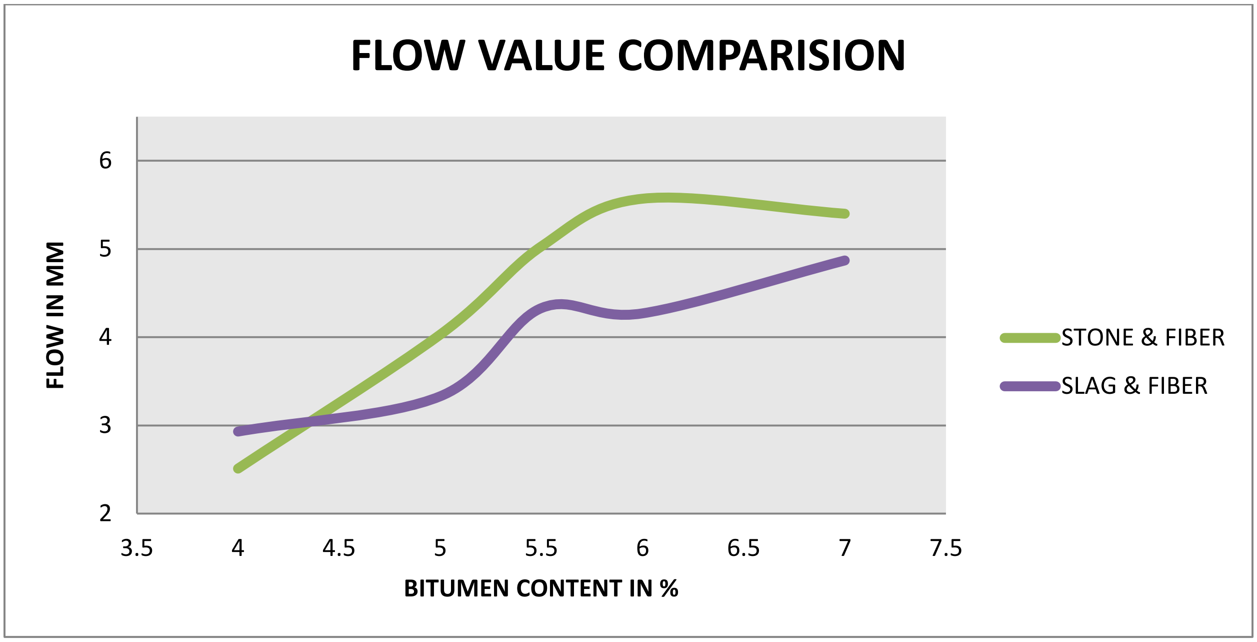

Fig 23| Comparison of flow results

CHAPTER-5

Conclusions AND DISCUSSIONS

CHAPTER 5| CONCLUSIONS AND DISCUSSIONS

5.1|MARSHALL STABILITY

The SMA samples were prepared using varying bitumen content of 4%, 5%, 5.5% and 7%. This was done to find out the effect of increasing bitumen content on the stability value. The plot obtained also helps us to find the Optimum binder content for this mix. The plot indicates that the stability value increases initially with increase in bitumen content but then decreases gradually. The same principle applies to mix with fibers, but this mix shows higher stability value at the same binder content than the mix without fibers.

SMA samples prepared with slag as coarse aggregate shows better stability values as compared to the samples with stone as the coarse aggregate. This is due to the strength of the slag, being used in the higher fraction to stone.

From experiments it was obtained that

- At optimum binder content of 5% for the stone aggregate being used in coarse as well as fine grades there is an **increase of 19.04% stability values** when flax fiber is used as the stabilizing agent.

- At an optimum binder content of 5.5% for slag aggregate being used in partial replacement for the coarse grades and stone being used as fine aggregates there is an **increase of 17.06% stability values** upon addition of stabilizing agent i.e. flax fiber.

    - When cellulose fiber is used there is also an **increase of 10.68% of stability values** as compared samples without addition of cellulose fibers.

    - When slag is used as coarse aggregate,

        - There is an **increase of 3% stability** values when no fibers are added to the mix as compared with the samples that use only stone as aggregates.

        - There is an **increase of 7.52% of stability** after addition of flax fiber as compared to the samples that use only stone as aggregates.

5.2| FLOW VALUE

The flow value increases with the increase in the bitumen content for both the mixes with and without fibers .The increase is slow initially, but later the rate increases with the increase in the bitumen content.

The flow value of mixes with fibers is more than that without fibers initially. But as the bitumen content increases this homogeneity is lost , due to which the fibers forms lumps with bitumen and make the sample loose its homogeneity, reducing stability and increasing deformation under load.

5.3|VOIDS IN MINERAL AGGREGATE

The VMA value at low bitumen content slowly decreases with the increase in bitumen content, then remains constant over a range, and then finally increases at high bitumen content. The VMA values are quite similar in both the mix with and without fiber, but at larger bitumen content of 6%, VMA of mix with fiber is slight more.

5.4| DRAIN DOWN TEST RESULTS

With the use of fibers no drain down was obtained. Hence we can easily observe that use of fibers significantly reduce the drain down in a SMA Mix that otherwise would have caused a problem.

5.5| AIR VOIDS

The Air Voids (VA) decreases with increase in the bitumen content because with increase in bitumen content it goes on filling the air voids gradually. The VA of mix with fiber is less than that without fiber. This is because the fiber already filled up some portion of air voids (VA) which further decreases as the bitumen goes on filling the air voids with increase in bitumen content.

5.6|OPTIMUM BINDER CONTENT (OBC)

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. It is also found that addition of flax fiber lowers the optimum binder content of the mix as for the sample with stone as coarse and fine aggregates it is found that after addition of Flax fiber the OBC reduced from 5.5% binder content to 5% binder content.

5.7|OPTIMUM FIBER CONTENT

It is seen from the Marshall test results that at a fiber content of 0.3% all the mixes show their best and utmost properties at optimum binder content. So, 0.3% fiber content in the mix is taken as the OFC for all the SMA mixes with 60/70 bitumen as binder.

5.8| CONCLUDING REMARKS

Maximum stability obtained in this case after addition of fiber is 10.29 kN. When compared to other fibers obtained and prepared naturally it is has a higher value. So because of this reason flax fibre can be used for general heavy traffic load taking requirements and it would also be very much suitable for severe traffic conditions also.

From the experiments conducted it is evident the stability and flow values have improved significantly to a higher value which makes this fiber liable to be used for paving roads.
It is also found that the drain down property of the sample improve as after addition of the flax fiber we don’t find any drain-down.

CHAPTER-6

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Chapter 6|references

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