# A STUDY ON THE BEHAVIOUR OF SMA MIX DESIGN BY THE ADDITION OF BANANA FIBRE AND JUTE FIBRE

**Submitted in partial fulfilment of the requirement for the award of the degree of**

**MASTER OF TECHNOLOGY**

**in**

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**(Civil Engineering)**

**by**

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*Transforming Education Transforming India*

**School of Civil Engineering**

**LOVELY PROFESSIONAL UNIVERSITY, PHAGWARA**

**2017**

# DECLARATION

I, Umashankar Debnath(Regd. No. 11511785 ), hereby declare that this thesis report entitled **"A STUDY ON THE BEHAVIOUR OF SMA MIX DESIGN BY THE ADDITION OF BANANA FIBRE AND JUTE FIBRE"** submitted in the partial fulfilment of the requirements for the award of degree of Master of Civil Engineering, in the School of Civil Engineering, Lovely Professional University, Phagwara, is my own work. This matter embodied in this report has not been submitted in part or full to any other university or institute for the award of any degree.

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# CERTIFICATE

Certified that this project report entitled " **A STUDY ON THE BEHAVIOUR OF SMA MIX DESIGN BY THE ADDITION OF BANANA FIBRE AND JUTE FIBRE**" submitted individually by student of School of Civil Engineering, Lovely Professional University, Phagwara , carried out the work under my supervision for the Award of Degree. This report has not been submitted to any other university or institution for the award of any degree.

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I am also thankful to my classmates and those who directly and indirectly involves in completion of the present project.

**Signature of Student**

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# ABSTRACT

The improvement and use of the asphalt materials and mixtures is initially found and mostly utilized in the part of European nations and North America. The SMA blend is a Gap-evaluated blend which is characterized by more quantity of coarse aggregates, binder and fibre added as stabilising additives here. This research has been made to concentrate the designing property of blend of (SMA) among fibres and with no fibres. Here fibre which is going to be utilized is a non-traditional normal fibre, called as banana fibre and jute fibre. And as the stabilizing agent in search of asphalt mix, in which flow test will be analyzed parameters and stability, and mechanical properties of mix with banana fibre and jute fibre, mix also will point out to check compatibility. Here are the details for the SMA mixture based on MoRTH specification and bitumen content varied as 4%, 4.5%, 5%, 5.5%, 6% and 7% by the total weight of the mix and the fibres used as 0.3% (0.2% banana fibre and 0.1% jute fibre). The cement is used as a filler and bitumen 60/70 penetration grade (VG 30) as a binder.

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# LIST OF ABBREVIATIONS

| ABBREVIATIONS | FULL FORM |
|---|---|
| VG | Viscosity grade |
| Rpm | Rotation per minute |
| % age | Percentage |
| Cum | Cumulative |
| STD | Standard specifications |
| DBM | Dense bituminous macadam |
| SMA | Stone matrix asphalt |
| Min | minute |
| Cm | centimeter |
| Mm | millimeter |
| Gm | Bulk specific gravity |
| Kg | Kilogram |
| KN | Kilo Newton |
| Gm | Bulk specific gravity |
| Gt | Theoretical specific gravity |
| Va | Volume of air voids |
| VMA | Voids filled with mineral aggregates |
| VFB | Voids filled with bitumen |
| OBC | Optimum binder content |
| OFC | Optimum fiber content |
| HMA | Hot mix asphalt |
| IRC | Indian road congress |
| Mort&h | Ministry of road transport and highways |
| ASTM | American society for testing and materials |

# CHAPTER 1

# INTRODUCTION

## 1.1 General :

SMA is defined by a gap grade mix, which possesses superior stone with stone build up, furthermore gives enhanced quality to blend. Here MORT&H specifications are applied to present this work over SMA Mix. The mix is made by utilizing total with various types of materials such as cement as packing filler and bitumen of grade VG-30 at place of binder. Here fibres are utilized as stabilizers. The use of fibres is made for stabilising the mixture which helps in diminishing the draw down furthermore to build the quality of blend and soundness of the (SMA) blend. The test for these (SMA) is adopted by Marshall Device. In this analysis of SMA Mix among and with no use of fibre is finished. Several research mechanisms are finished primarily by utilizing cellulose fibre, manufactured fibre, poly-propylene fibre and polyester filaments. Cellulose filaments are for the most part utilized as a part of (SMA) prepared at Europe and USA. Combining top of the micro-fibre woven black asphalt film is structured to keep taking in order to extend the power and sturdiness of the mix (SMA), which combines enhanced features. Here is some of the pavilions cellulose, cellulose fibres, which is the same as that of jute fibre arts to be taken. It is a mixture of higher content of binder is built tough. Fibre or high temperature binder mixture is held. And the production, transport and extraction time to prevent failure. By adding fibres to SMA Mix increase is there in stability and durability of the mix. So, here we tried using the combination of two strong fibres, banana fiber and jute fiber to the mix to check the various Marshall properties.

Stone matrix asphalt (SMA) has been proved most cost effective than dense graded mixes for high volume roads. Brown (1992) observed that many number of factors will influence the performance of SMA mixtures, as changes in binder source and grade of mix, types of aggregate, environmental conditions, production and methods of construction etc. Good study of these factors would help to determine the long term performance of SMA and provides information so that changes can be made to suit different environmental conditions.

**1.2 Scope of the study:** In recent years, there has been rapid growth in the research and innovation in the natural fibre composition with the design mix for the purpose of laboratory test about the change in the property after mixing the natural fibre with the design mix and for partial replacement of the bitumen content. So by using combination of some natural fiber at place of synthetic fibers can be useful and cost efficient in pavement construction.

So, if we are using such kind of natural fibers in bituminous mix at place of synthetic polymers which are having high initial cost, it will reduce not only the initial cost of the construction but also maintenance cost, final cost, reduction in defects, less production of noise on pavements, protecting environment and human health, long life span of pavements etc.

## 1.3 Advantages of SMA over conventional mix:

The parameters like strength, longevity, and durability is better in SMA when it is compared to normal conventional mix. There are certain other factors which ensure good results in SMA over to conventional mix. Bose et al (2006) mentioned that in SMA there are very good results in resistance to rutting when traffic is slow, heavy and high. Good resistance to pavements where temperature fluctuation is very high and also at high temperature prone pavements. Resistance to skid factor is increased, in conventional mix pavements the degree of noise is high as compared to SMA pavements which produce less noise .SMA ensures good resistance to cracking and fatigue at low temperatures, durability of pavement is increased and also lowers the permeability rate and sensitivity to moisture. According to Brown and Manglorkar (1993) SMA Mix provides good resistance to plastic deformation when there is heavy traffic with high tire pressure. Due to rough texture in SMA it provides good friction between tires and pavement when the upper film of binder on pavement gets removed due to traffic and lowering the skid factor. Even though the cost of SMA Mix is 15 to 25 % more as compared to conventional mix, but it is acceptable if we compare with the life span of both mixes when used in pavements, so it is well justified. On the basis of these factors it can be well proved that a pavement made by SMA Mix is better as compared to HMA mix. Various types of fibers have been used yet in SMA as stabilizer. But many of the fibers are not easily available in India or they cost more. So here we used hemp fiber which is found abundantly in India and is considered as non conventional/waste fiber because its growth is illegal in India

## 1.4 Objectives:

- The foremost objectives for this study is to use a quantity of non-traditional fibres such as banana fibre and jute fibre at place of other conservative fibre or synthetic fibres like polymers which can be economical to the mix.

- Preparation of Marshall Specimens and to obtain ideal blend content thereby finding various Marshall Properties when combination of banana fiber and jute fiber used in SMA.

- To check the banana fibre with jute fibre and other functions associated with the type of test sample with the BM results.
- To find out the suitability of these two fibres in SMA Mix.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Previous studies:

During the 1980s, government and state roadway authorities in U.K perceived the requirement to design a road rut opposing mix. As an outcome, the American on the pitch in 1990, the Europe Study Tours, this participated in the investigation of SMA road. This is the first concentrated attempt to form out how to apply (SMA).

### Bradliy J. Putman and SerjiN. Amir khanian (2004)

They used waste fibers like carpet fibers, polyester fibres and tire and other materials which are produced from manufacturing processes to advance the stability and strength of mixture compared to cellulose fibre.

They presume that there is no huge distinction in moisture susceptibility or perpetual distortion in (SMA) contain fibers with no use,when contrasted with the (SMA) which posses cellulose fiber. And also conclude that the tensile strength ratio intended for the mixes containing waste fibers are more than 100%. Toughness of the SMA mixtures increases by addition of tire and carpet fibers.

### Punith V.S., Sridhar R., Bose Sunil, KumarK.K., Veer aragavan A (2004)

The stabilizing agent, such as the comparison of the use of polyethylene bags recovered LDPE bituminous concrete in the form of hand in (SMA) study (size 3 mm and 0.4 percent), the test outcomes showed that the property of the mixture is a mixture of two SMA ventilator has good elastic stabilizer resistant to regenerated plastic stains reinforced by the addition of resistance to damage caused by moisture, rutting, creep and aging.

### Pawan, Chandra Satish and Bose Sunil (2007)

Used traditionally imported fibers and cellulose fibers from the result of the low viscosity binder fiber material coated jute instead of taking an ethnic composition of SMA fiber tried to use good quality bitumen 60/70 and 0.3% at the optimum mixture of fibers per cent . The patented fiber jute fibers imported Marshall Stability test showed similar results, indicated by a permanent deformation test and fatigue life. Mix with aging patented fiber jute fibers showed better results.

**Reddy et al (2004)** He used crumb rubber which is obtained from waste tires and binder of grade 80/100 to make the SMA Mix. In this mixture he made improvements over fatigue and permanent deformation and found that the mix he made showed more resistance to moisture as compared to normal mix.

**Hauxin Chen and Qinwuxu .** They added five types of polymers to SMA mix in which there was one part of polyacrylonitrile, one part he added of lignin, one part of asbestos and two parts of polyesters They study about the physical properties of fiber like what will be the difference in drain down characteristics of mix and moisture absorption value when such polymers are added to the mix. They observed that rutting performance and flow value got significantly improved of the asphalt binder.

**C.S Bindu, Beena K.S 2010**, they prepared one mix in which he added shredded plastic waste to SMA as stabilizing agent and one mix was prepared without any stabilizing agent. On both these mixes he performed Marshall Test, tensile strength test, compressive strength Test, tri axial test at different quantity of bitumen(6-8) %, and at different proportion of plastic wastes (6-12) % by weight.

**Esmail Ahmadinia, Mohd Rehan Karim, Mahrz Abdelaziz, Majid Zargar and Payam Shafi** has considered the waste influence of synthetic bottles like Poly-ethylene Terephthalate in SMA Mix by fluctuating the amount and then by detecting its engineering properties. The outcome of this observation was positive. It improved the quality of SMA and also proved that the use of waste plastic bottles is environmental friendly.

**Chuei-Te Chiu, Li Cheng Lu, (2007)** Asphalt rubber (AR), ground tire rubber (GTR) (i) @ 20 sieve, and (ii) a fine of a maximum size of 20% with a maximum size of a thick mixture produced by GTR 30% is used in step 30 Riddle, SMA and available as a binder for moisture sensitivity in terms of the combination, but not significantly different from the conventional mixture of SMA conventional dense graded better than that showed resistance to rutting.

**Manglokar and Browne** in 1993, they have studied about the use of granite and siliceous as aggregates on SMA and DGM. They specially added the fiber to mix which have more cellulose called as cellulose fiber. Drain down test, Indirect tensile test and Marshall test were performed on the mix. They had more concerned about the type of aggregates because SMA main content of more coarse aggregates. The high content of these aggregates make the mixture firm with more use of stone to stone contact.  Due to this property, SMA posses to achieving good value for load distribution providing good resistance to rutting and also good resistance to plastic deformation under heavy load of traffic. SMA posses a tough texture, so friction between tiers and pavements gets increase which leads to better skid resistance.

## Munandy R. Huat B.B.K. (2006)

The fiber palm cellulose and binder used in the fiber-modified cellulose fibers by weight of the rheological properties showed improved 0.2%, 0.4%, 0.6%, 0.8% and 1.0%, with ratio of fiber aggregates were premixed in PG64-22 binder. He showed that it could promote the modified binder PG64-22 and PG70-22 degree. Palm oil cellulose fibers SMA diameter improves fatigue performance. 0.6% increase in fatigue life of the fiber content, while the maximum tensile strength and rigidity performance also made a alike trend. At the content of 0.6% fibers was showed the lowest initial strains.

## K.L. Pickring, M.G. Aruan, T.M. Le (2015)

They have done the research work on the ordinary fibres and artificial fibres. and evaluate the mechanical performance of different fibres and what are the changes in mechanical properties due to fibre composites. Much effort has been made toincrease mechanical performance to extend the capability and application of this assemblage of materials. They discussed about the main factors about the mechanical performance of NFCs, which are:

**Table 2.1** Mechanical properties of normal and artificial fibre

| Fibre | Density | Length | Failure Strain | Tensile strength | Stiffness / young's modulus | Specific tensile strength | Specific Young's modulus |
|---|---|---|---|---|---|---|---|
| Ramie | 1.6 | 900-1220 | 2-3.8 | 400-938 | 44-128 | 270-620 | 29-85 |
| Flax | 1.6 | 5-910 | 1.2-3.2 | 345-1832 | 27-80 | 230-1220 | 18-58 |
| Hemp | 1.05 | 5-65 | 1.6 | 550-1112 | 58-70 | 370-740 | 39-48 |
| Jute | 1.3-1.5 | 1.5-122 | 1.5-1.8 | 393-805 | 10-55 | 300-610 | 7.1-40 |
| Sisal | 1.3-1.5 | 900 | 2-2.5 | 507-855 | 9.4-28 | 362-610 | 6.7-20 |
| Alfa | 1.4 | 350 | 1.5-2.4 | 188-308 | 18-25 | 134-220 | 13-18 |
| Cotton | 1.5 | 10-60 | 3-10 | 287-800 | 5.5-13 | 190-530 | 3.7-8.4 |
| Coir | 1.2 | 20-150 | 15-30 | 131-220 | 4-6 | 110-180 | 3.3-5 |
| Silk | 1.3 | Conts. | 15-60 | 100-1500 | 5-25 | 100-1500 | 4-20 |
| Wool | 1.3 | 38-152 | 13.2-35 | 50-315 | 2.3-5 | 122-226 | 3.3-11 |
| E-glass | 2.5 | Conts. | 2.5 | 2000-3000 | 70 | 800-1400 | 29 |

## 2.2 Types of mix design:

**HMA (hot mix asphalt concrete):** This mixture is prepared by providing more heat to reduce the viscosity of the binder. Aggregates are present in the mixture is dried to remove moisture. When the aggregates are mixed at a temperature of 150 C sufficiently warm mix asphalt paving and compaction is made. Most of the road where the traffic rate as high as HMAC used in highways and tracks and is used for air.

**Dense-Graded Mixes:** Dense-Graded Mixes: BC of all the elements such a well-graded HMA has the best ratio is more dense bituminous macadam. Fine grade mix is more restrained than that of sand and particle size. It is for all levels and in all traffic conditions are suitable for the pavement. It’s give great compressive strength. Well-graded agg. and bitumen binder are used (with binder and without modifying agent)

**SMA (Stone matrix Aphalt):** SMA, referred to as stone mastic asphalt, graded HMA rutting resistance, and heavy traffic on the road in Europe developed to maximize stability. SMA is a stone skeleton that resists deformation of a high fat content of their sum is not a permanent structure. Typically SMA 70-80 percent coarse aggregate composition, 8-10 percent filler, binder 6.0-7.percent, and 0.3 percent of the fibers. SMA resistance to deformation of a coarse stone to stone on stone skeleton is more conventional dense asphalt (DGA).

The higher the content of bituminous binder material to improve the stability of a thicker film of asphalt and is a result of low air gaps. This flexibility has also developed a high tar content. The addition of a small amount of cellulose or mineral fiber placement during transport and prevents the bitumen extraction. There are no specific guidelines for the design of SMA mixtures. A key feature, which is the skeleton of the coarse aggregate, and mastic composition, and is compatible surface texture and blending stability, essentially zero, and the type of aggregate and the choice is determined by the ratio of filler and binder. SMA enhanced stain resistance and durability.It is good in fatigue and tensile strength.SMA almost exclusively used for high-volume performance of pavement. Graded aggregates used for SMA vacuum, modified asphalt, the fiber filler. SMA advantage humid weather conditions of friction, less tire noise and less severe in reflective cracking. Mineral fillers and additives, asphalt drainage during manufacture to minimize the increase in the amount of asphalt binder used in the mixture and the mixture is used to improve stability.

**Open Grade Mixes**: Stereotypes are graded and SMA mixtures, an open-graded HMA mixture are designed to be permeable to water. Open-graded crushed stone (or gravel), and treated using a small amount of sand. Open graded mixes the two most common are:

- ✓ Generally a maximum of 15% of air voids and air pockets certain by the friction course of open-grade.
- ✓ Asphalt treated permeable base (ATPB). OGFC smaller amount requirements, since it is only for pumping stereotypes graded HMA, SMA or Portland concrete used below. OGFC - only used for surface courses. The dip of the tires / spray in wet

weather conditions and generally reduce the surface is smoother than the stereoscopic graded HMA. ATPB - stereotypes graded HMA, PCC below SMA or used as a drainage layer. Using materials in total, asphalt (with fibers). OGFC per ton pricier than stereotypes graded (HMA), but when mixed much less than the weight of the unit, which was partly offset by increased costs per ton. Gradient open hole in the mixture, the mixture is essential for proper functioning. Some of them, such as their low velocity resources, clogs, and excessive dirt road performance to degrade.

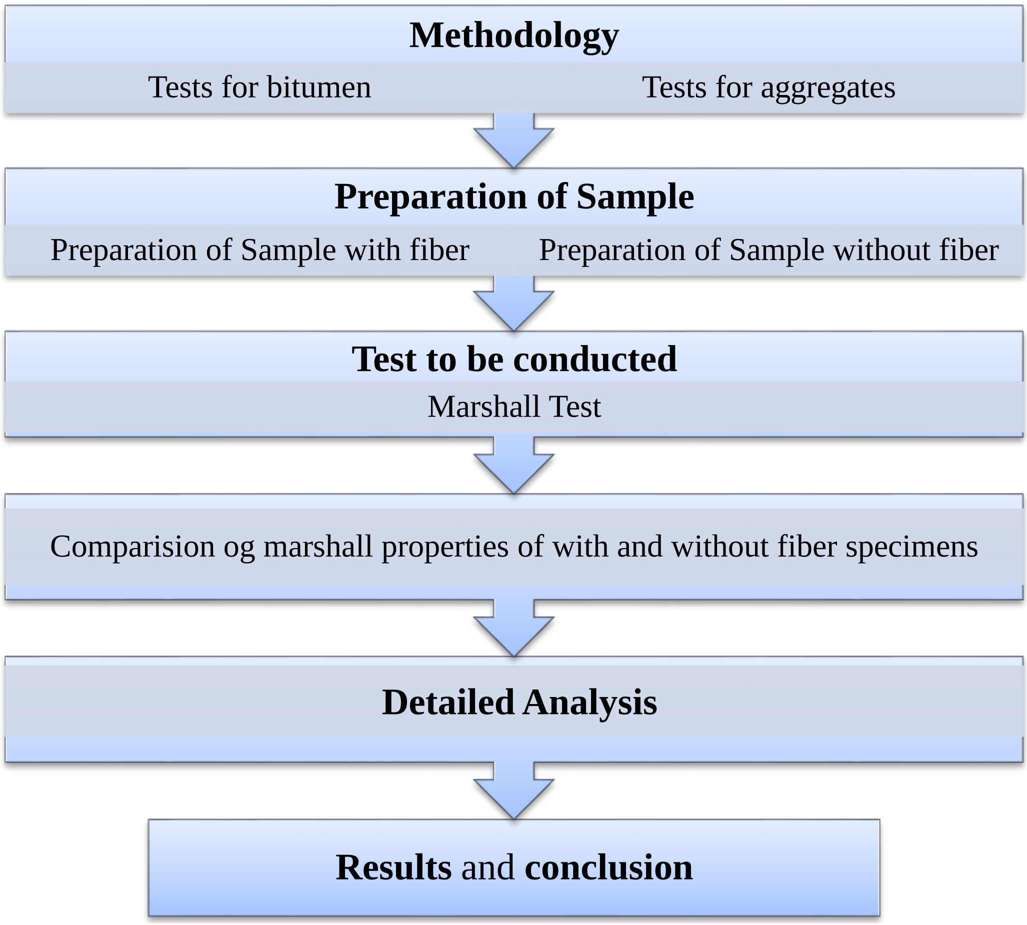
**Table 2.2 Standard aggregate Gradation for SMA (IRC SP 079)**

| **SMA Designation** | **14 mm SMA** |
|---|---|
| Course where used | Wearing course |
| Nominal aggregate size | 14 mm |
| Nominal layer thickness | 40-50 mm |
| IS Sieve (mm) | Cumulative % by weight of total aggregates passing |
| 26.5 | — |
| 19 | 100 |
| 13.2 | 90-100 |
| 9.5 | 50-75 |
| 4.75 | 20-28 |
| 2.36 | 16-24 |
| 1.18 | 13-21 |
| 0.600 | 12-18 |
| 0.300 | 10-20 |
| 0.075 | 8-12 |

# CHAPTER 3

# RESEARCH METHODOLOGY AND MATERIAL CHARACTERISATION

## 3.1 Methodology:




Banana fibre and jute at different percentage in bitumen has to be check. Marshall Stability test is considered to simulate with field conditions. The samples were made with mix in which bitumen, banana fibre and jute will be taking at different percentages in each sample. Test will perform on bitumen sample and then the test will conduct with bitumen banana fibre and jute fibre.

## 3.2 Characteristics of Materials used:

1. Aggregates
2. Bitumen (VG-30)

3. Fibre as additive and partial replacement of bitumen ( banana and jute fibre)
4. Cement as filler

### 3.2.1 Aggregates:

Mix design (SMA) for the preparation of consolidated according to the registration requirements as given below MoRTH amounts of fiber and binder mixture according to the rules to be a special kind of Marshall Procedure

**Table 3.1** Physical requirements of coarse aggregates for Stone Matrix Asphalt

| **Property** | **Test** | **Method** | **Specifications** |
|---|---|---|---|
| Cleanliness | Grain size Analysis | IS:2386 P-1 | < 2% passing 0.075 mm sieve |
| Particle Shape | Combined Flakiness and Elongation Index | IS:2386 P-1 | < 30% |
| Strength | Los Angeles Abrasion value and impact value | IS:2386 P-4 | < 25% and < 18% |
| Durability | Soundness test | IS:2386 P-5 | < 18% |
| Water Absorption | Water absorption | IS:2386 P-3 | < 2% |

### 3.2.2 Binder

In bituminous mixture binder helps in binding the aggregates filler, fines and stabilizer and act there as a binding agent. The durability of the mix is achieved by adding binder to it. The bitumen is that part of the mix which affects various characteristics of bituminous mixture. Characteristics like aging, temperature susceptibility, viscous elastic properties are affected by the use of binder. At low temperature it solidifies so can’t be used for longer loading period. Bitumen acts as a viscous elastic material at normal temperature as it shows both the properties of viscosity and elasticity at normal pavement’s temperature. It acts like material elastic in nature elastic at low temperatures and when high temperature is there, it behaves like a viscous fluid. Bitumen behaves like a stabilizer for bituminous mix which contains various additives like fibers, polymers etc. As we know the primary agent which is used for binding of aggregates with filler and fiber is bitumen, so here we are trying using the bitumen of penetration grade VG-30 in SMA

### 3.2.3 Fibres:

Fiber is categorized according to the type origin: animal, plant or mineral. All the main structural component of plant fiber as their head, and contains cellulose; from animal protein fibers. However, based on natural mineral mineral asbestos fibers into existence of the group, but this is due to health problems avoided.

Generally, the higher stiffness and strength than fibers animal fibers are accessible by high-performance trousers. Silk has a very high strength, rigidity and low but relatively expensive and not readily available. Moreover, many countries have also developed a series of fiber to fiber is obtained after a short time.

**Natural fiber** grouped into 3 classes on the basis of the piece of plant from where it is extracated these are (a) Stem fiber (banana and jute). (b) Leaf fiber (pineapple and sisal). (c)Fruit fiber (coir, cotton and oil palm)

Here for this research work banana fiber and jute fiber is selected due to its physical and chemical properties as defined by different researchers.

**Banana fibre:** Banana plant gives a textile fibre called as, banana fibre. It is most usually found in hot climates and tropical. Once the harvesting of the fruits is done the fibres are extracted from the plant and it regard as in the set of bast fibers. Nearly all types of banana plants include fibre in great quantity. Banana fibre’s Extraction, the drawing out methods has been varying from every place and country but mainly well-liked and India has established the easy ways.

**Fig 3.1** Banana Fiber

**Description of banana fibre:** Banana fiber is ordinary bast fibers and erstwhile fibers are all comparatively own chemical and physical properties and other properties of the fiber, such fiber are an excellent quality.

1. It seems like almost ramie fiber and bamboo fiber fineness and rotation capability, but betters.
2. Chemical synthesis of lignin, cellulose and hemicellulose is included.
3. It has a small elongation and a very strong fiber.
4. Has a strong moisture absorption value. Quickly absorb and release moisture.
5. It is environment friendly and has no negative consequence on the surroundings since it to be bio degradable.
6. Banana fibre has usual fine-ness is around 2400 nm.

**Banana fiber's extraction:** Particular attention is required to collect from the natural fiber to stay away from harm. The banana plant is cut from the plant comes from, and then move slowly to expel plenty of moisture. Removal of impurities in the fibers, for example, have broken fibers, cellulose coating, etc. for manual methods have been displaced from the brush, and then clean and dry the fibers. Mechanical and manual extraction of fiber arts tedious, tiring and damage the fiber

Therefore, this type of system can be recommended for mechanical applications. And an engineer to describe a single machine has been developed for the extraction of fiber banana. It consists of two flat bars, whereby an excellent brush connected to a car, which basically can be moved forward and backward. Just fiber extraction machine using this strain method banana standing on stage can be performed by setting a clear part of the face, and by the end of cinched. The three hours at 200 ° C followed by purification and drying of the fibers in a chamber. These fibers are then identified and prepared for coating handle.

**Fig 3.2** Main banana Stem


**Fig 3.3** Banana fiber extractor Source: Internet

## Jute fiber:

The fibres that come from the inner bark of the plants are known as bast fibre. And jute is a bast fibre.

**Fig 3.4** Jute plant

**Fig: 3.5** Jute fiber

## Characteristics of jute:

The chemical and physical properties of jute can vary region to region. Temperature and atmospheric condition has a great effect on the properties of jute.

1. Jute fibers are composed of ligin, cellulose and hemi-cellulose.
2. It has ultimate length of 1.5-4mm
3. It has Ultimate diameter of 0.015- 0.020mm
4. Fiber length is 5-12 ft
5. Resistance bleaching agents (eg. NaOCl, $H_2O_2$, $CH_3COOH$ )
6. 100% bio-degradable and environment friendly
7. It has high tensile strength, low extensibility.

## 3.3 EXPERIMENTS TO BE PERFORMED:

### 3.3.1 Tests done for aggregates:

### Los Angeles abrasion test:

There is mutual abrasion and attraction of tires with respect to the pavement and to determine the percentage wear due to that action, the Los Angeles Abrasion test is used. The machine comprises a hollow cylinder which is closed at both ends, having an inner diameter 700 mm, 500 mm length and cast iron balls having approximately 48 mm in diameter and all individually having 390 to 445 gram weight which is used to abrasive charge up.

Aggregate sample with specified weight is placed inside the cylinder with steel balls. Machine is rotated at 30-33 rpm. Aggregates are sieved with 1.7mm sieve and weighted to determine rate of wear and tear in terms of percentage. Standard value for Los Angeles test should not be more than 30 percent.

## Impact test for Aggregates:

The machine consists of a cylinder cup of 10.2 cm inner diameter, 5 cm depth and metal base of 0.64 cm thickness. A hammer of weight 14kg is made with a freefall of 38cm. Aggregates passing through 12.5 mm sieve and retained on 10mm sieve are used. Aggregates filled in cylinder in three layers by giving 25 blows and then again give 15 blows to compacted aggregates by raising the hammer at 38 cm and are allowed to freefall, crushed aggregates are sieved by 2.36 mm sieve.

## Crushing value test:

Apparatus composes 152 mm diameter steel cylinder with plunger and base plate.

Dry aggregates passing by 12.5 mm sieve and retained on 10 mm IS sieve are taken.

Aggregates crushing value is given by $\frac{W_2}{W_1}$ x 100

Where,

$W_1$ = Weight of SSD sample

$W_2$ = fraction of weight passing from appropriate sieve

## Specific gravity of aggregates:

This test is determined to find out strength and quality of aggregates. Specific gravity for coarse aggregates is determined by equation:

$$\frac{W_4}{W_3-(W_1-W_2)} \text{ x } 100$$

## Water Absorption test for aggregates:

Water absorption is given by equation:

$$\frac{w2-W1}{W1}*100$$

Here,

W1= Dry saturated weight

W2= Combined weight of material and basket in water

**Test for fine aggregates:** These are the aggregates which passes through 4.75 mm IS sieve and retain on 0.075 mm IS sieve. The test for fine aggregates was performed to obtain specific gravity and was found 2.8 which lies in between 2.5 to 3 (range of specific gravity for fine aggregates).

**3.3.2 Test for bitumen:** In this research various bitumen tests were performed corresponding to that penetration, ductility, softening point, viscosity for taken bitumen was calculated.

## Penetration test:

This test is used to examine consistency of bitumen by determining the penetration of a standard needle at specified conditions of time and temperature. This distance is measure of $1/10^{th}$ of a mm. Penetration value for grade 60/70 means that penetration lies between 60 to 70.

## Ductility test:

Ductility test measures stretching/adhesive property of bitumen. A good ductility of binder forms a thin film with aggregates and improve interlocking of aggregates. It is measured in centimeters when two clips of standard briquette are forced apart @50mm per minute.

## Viscosity test:

This test is used to determine the resistance against flow of bitumen. It greatly influences the strength of pavement at the application of temperature. At low temperature the binder simply lubricates the aggregates rather than providing a thin film for binder action. Similarly at high temp resist the compaction effort and results in heterogeneous mix.

## Softening point:

It is the temperature at which the substance attains a particular degree of softening. This test is also termed as Ring and ball apparatus method. It tells us about the energy required to soft the bitumen before its application on roads surface.

### 3.3.3 Test for filler:

**Specific gravity test:** Specific gravity of filler was determined by Le Chatlier Apparatus. The specific gravity of the cement used for this is found to be 3.14 g/cc and the stand range is 3.11 g/cc – 3.19 g/cc.

## 3.4 Test for SMA mix:

### 3.4.1 Marshall mix design:

- **Preparation of sample:**

The various steps involved in the preparation of the sample are given below:

- **Weighing of sample:**

Here samples were made with binder content of 4 %, 4.5 %, 5 %, 5.5 %, 6%, and 7 % and each of binder content has 3 samples. 0.3 % of fiber content added to the sample having weighs 1200 grams.

- **Heating of aggregates:**

After preparing the gradation for aggregates with the fiber, they were thoroughly mixed with weight 1200 grams. They were heated in oven for 24 hrs at 130°c. And over heating is avoided.

- **Heating of bitumen:**

VG 30 bitumen is heated to a high temperature of the liquid. So that would be mixed with the aggregates and fiber easily.

**Fig. 3.6:** Heating bitumen

- **Mixing of components**All materials (aggregate, cement, bitumen and fiber) were mixed to form a homogeneous sample of SMA mix.

**Fig.3.7:** Mixing of materials

The mixture is placed in moulds prepared for sample preparation. A typical mould is a cylindrical mould made of iron having a diameter of 100 mm. Mould was also used to heat before hammering so that the mixture cannot get cold. A typical mould is shown in Fig below:

**Fig.3.8:** A typical mould

- **Compaction**

After filling in the mould hammering is performed. A standard Hammer is used for hammering. Usually 50 or 75 blows are given to the each side of sample by hammering. Each sample of this study is to provide 50 blows on both faces. The first hammering a fixed system for the mould was attached to make sure that the mould will not be staggered during hammering. Fitting the mould by placed on a piece of paper having size of the mould so that the mixture is not glued to the fitting. For the same purpose, oiling and hammer at the bottom of the mould is done in the internal faces.

**Fig.3.9:** Hammer used in sample preparation

**Fig.3.10:** Compaction of sample by hammering

- **Finalization of the sample**

After hammering out the sample was taken from the mould. Stick a piece of paper on sample with the details of binder content and sample number. Then the sample was left open to cool down to room temperature. The figure below shows a sample.


**Fig.3.11:** SMA sample with and without fiber

**Fig.3.12:** Sample prepared

## 3.4.2 EXPERIMENT PERFORMED

Samples will be ready to go under the Marshall test. This test is performed in accordance with ASTM D-6927 06. Test gives the flow and stability value. All of the dry weight of the sample was recorded in the first set. Sample weight in water is also recommended. It is because, if voids present in the sample can filled with the water. After weighing of the samples before water bath for 40-60 minutes at maximum temperature of 60°C and water bath temperature maintained throughout. After the samples are heated up to the temperature of 60°C for 40 minutes, it's ready for the Marshall test.

### 3.4.2.1 Marshall Test

The method of testing of Marshall Test is given in ASTM D 6927-06. Marshall

Apparatus which is used for testing has following parts:

- **Breaking Head:**

The breaker head comprises upper and lower cylindrical portions of the casting of gray or ductile cast iron or cast steel. The lower section having two vertical guide rods of 12.5 mm in diameter extending upwards and lower section was mounted on a base. Guide sleeves in the upper section directing the two parts together, without appreciable connection or loose movement up to the guide rods.

**Fig.3.13:** Breaking head with sample

- **Compression loading machine:** It comprises a screw jack mounted on a test frame and a uniform vertical movement is designed to provide load at the rate of 50.8 mm/min.

- **Loading measuring device:** A calibrated ring of 20 KN with dial gauge for measuring deflection of ring at different applied loads and having a minimum sensitivity of 50 N. The dial indicator has an increment of 0.0025 mm. The ring connected to the testing frame and an adopter is provided for transmitting load to the head breaking. Ring is also called as proving ring.

- **Flow value:** A dial gauge is used for measuring the flow. The initial and final value of the dial gauge and the difference of initial and final are taken for the flow value.

**3.4.2.2 Test procedure:** The inner surfaces of breaking head and guide rods are cleaned thoroughly prior to testing. The lubrication of the guide rods are done so that upper test head move freely on them. The excess water wiped from the testing head section.

A sample is removed from the water bath and placed in the lower portion of the testing head. The upper portion of the test head on the sample is placed, and the complete assembly is paced at the position of the loading machine. The dial gauge is disposed at a position over one of the guide rods.

The time elapsed since the removal of test samples from the water bath to the final determination load must not exceed 30 s. The dial gauge and proving ring readings are recorded. In this case 100kg load is equal to the 36 divisions of the proving ring.

## 3.5 Parameters used:

1. Theoretical specific gravity of the mix (Gt):

$$Gt = \frac{W_1 + W_2 + W_3 + Wb}{\frac{W_1}{G_1} + \frac{W_2}{G_2} + \frac{W_3}{G_3} + \frac{Wb}{Gb}}$$

Here,

$W_1$ = Wt. of Coarse aggregates.

$W_2$ = Wt. of fine aggregates.

$W_3$ = Wt. of filler material.

$W_b$ = Wt. of bitumen.

$G_1$ = Specific gravity of coarse aggregates.

$G_2$ = Specific gravity of fine aggregates.

$G_3$ = Specific gravity of filler.

$G_b$ = Specific gravity of bitumen.

2. Bulk specific gravity (Gm):

$$Gm = \frac{Wa}{Wa - Wb}$$

Here,

Wa = Weight of sample in air.

Ww = Weight of sample in water.

3. Air voids (Vv):

$$Vv = \frac{Gt - Gm}{Gt} \times 100$$

Here,

Gt = Theoretical Sp. Gravity of the mix.

Gm = Bulk Sp. Gravity of the mix.

4. Percentage of volume of bitumen (Vb):

$$Vb = \frac{\frac{W_b}{G_b}}{\frac{W_1 + W_2 + W_3 + W_b}{G_m}}$$

5. Volume of voids in mineral aggregates (VMA):

$$VMA = V_v + V_b$$

6. Voids filled with bitumen (VFB):

$$VFB = \frac{V_b}{VMA} \times 100$$

# CHAPTER 4

# RESULLTS AND DISCUSSION

## 4.1 Laboratory investigation:

### 4.1.1 Gradation of aggregates:

**Table 4.1** Aggregate gradation

| Sieve size | Upper limit | Lower limit | Adopted |
|---|---|---|---|
| 19 | 100 | 100 | 100 |
| 13.2 | 100 | 90 | 94 |
| 9.5 | 75 | 50 | 63 |
| 4.75 | 40 | 25 | 33 |
| 2.36 | 28 | 20 | 24 |
| 1.18 | 26 | 18 | 22 |
| 0.6 | 22 | 15 | 18 |
| 0.3 | 20 | 12 | 16 |
| 0.15 | 15 | 8 | 11.5 |
| 0.075 | 12 | 8 | 10.5 |

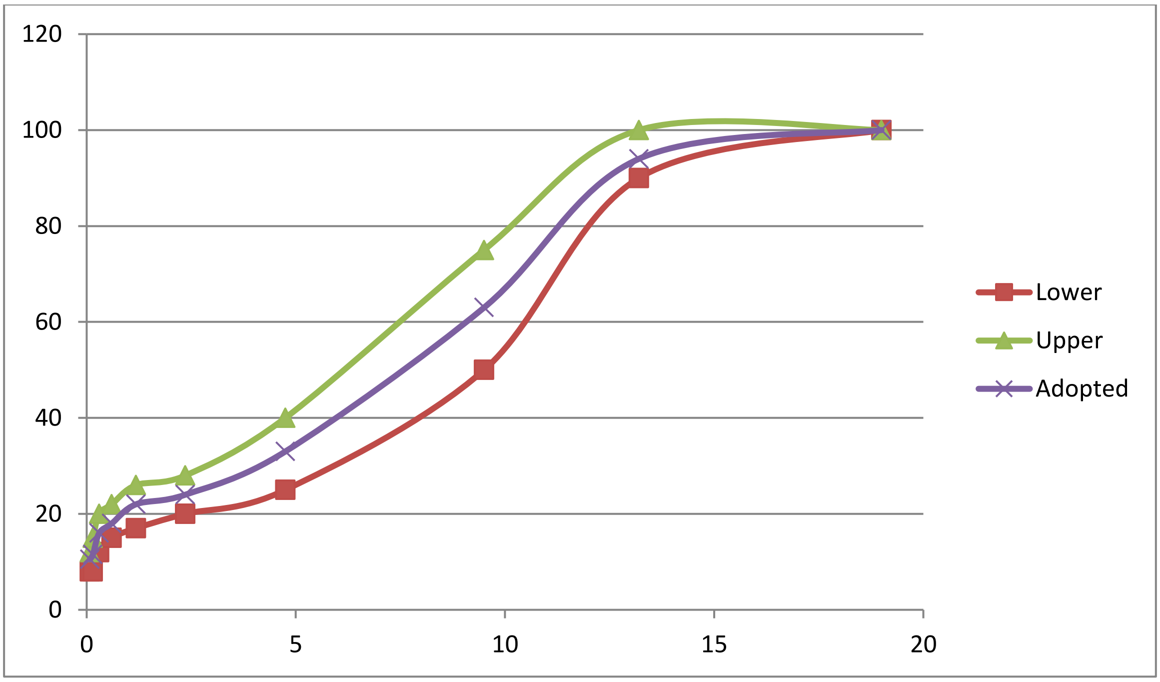



**Fig.4.1:** Aggregate gradation

### 4.1.2 Aggregates testing results:

**Table 4.2** Test for Los Angeles abrasion as per IS: 2386 (P-4):

| | |
|---|---|
| Total weight of aggregate sample ($w_1$) | 2.5 kg |
| Weight of aggregates retained ($w_2$) | 1968 gm |
| Weight of aggregates passing from 1.7mm sieve ($w_1 - w_2$) | 532 gm |
| Abrasion value = $w_1$-$w_2$/$w_1$*100 | 21.28 % < 25 %, satisfactory value. |

**Table 4.3:** Flakiness and Elongation index for aggregates:

| Sieve size (mm) | Wt. of sample (gm) | Aggregates passing in gauge (gm) | Flakiness index | Avg. Flakiness index | Aggregate retained in length gauge (gm) | Elongation index | Avg. Elongation index |
|---|---|---|---|---|---|---|---|
| 25-20 | 390 | 60 | 15.38 | 19.468 | 131 | 33.58 | 25.97 |
| 20-16 | 732 | 136 | 18.57 | | 128 | 17.48 | |
| 16-12.5 | 549 | 94 | 17.12 | | 101 | 18.39 | |
| 12.5-10 | 277 | 80 | 28.88 | | 56 | 20.21 | |
| 10-6.3 | 92 | 16 | 17.39 | | 37 | 40.21 | |

**Table 4.4** Impact test as per IS: 2386 (P-4):

| | |
|---|---|
| Weight of mould | 1.275 kg |
| Weight of mould with sample | 1.994 gm |
| Weight of sample (Oven dried) | 719 gm |
| Aggregate retained on 2.36 mm sieve ($w_1$) | 656 gm |
| Aggregate passing from 2.36 mm sieve after 15 blows by hammer ($w_2$) | 63 gm |
| Impact value = $w_2$/w1*100 | 9.60 % < 18 % , satisfactory |

**Table 4.5** Crushing value test:

| Weight of oven dried sample in gm ($W_1$) | Weight of retained aggregates on 2.36 mm sieve in gm | Weight of passing aggregates in gm ($W_2$) | Abrasion value |
|---|---|---|---|
| 10000 | 8583 | 1417 | 14.17 < 25% |

**Table 4.6** Specific gravity test:

| | |
|---|---|
| Total weight of aggregates | 2.0 kg |
| Weight of submerged bucket ($w_2$) | 0.7 kg |
| Wt. of bucket + aggregates (submerged) (w1) | 2.09 kg |
| Surface dried weight of aggregates (w3) | 2.01 kg |
| Oven Dried weight of aggregates (w4) | 1.9 kg |
| Specific Gravity = w4/w3-(w1-w2) | Specific gravity= 2.88 , should be 2.5 to 3 |

**Table 4.7** Water Absorption test:

| Dry saturated weight W1 in grams | Combined weight of material and basket in water W2 in grams | Water absorption % |
|---|---|---|
| 1996 | 2014 | 0.90 |

## 4.1.3 Binder test results:

Binder used is VG-30 grade for sample preparation and various test results are as follows.

**Table 4.8** Bitumen test results:

| Tests | Test methods | Value obtained |
|---|---|---|
| Penetration test (mm) | IS:1203-1978 | 68.1 |
| Softening test (degree) | IS:1203-1978 | 48.9 |
| Specific gravity | IS:1203-1978 | 1.01 |
| Ductility (cm) | IS:1203-1978 | 41.6 cm/min |

**4.2 Sieve Analysis:** Aggregates are taken from different places and sieved by sieve analysis method and the purpose is to attain the aggregates gradation which is given for SMA Mix according to MoRTH specifications. The weight of each sample is 1200 grams.

**Table 4.9** Gradation of samples without fibers:

| Sieve Size in mm | Intermediate | adopted | %age retained | Amount of aggregates taken in this binder content | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | 4% | 4.5% | 5% | 5.5% | 6% | 7% |
| | | | | 1152 | 1146 | 1140 | 1134 | 1128 | 1116 |
| 19 | 100 | 100 | | 0% | 0% | 0% | 0% | 0% | 0% |
| 13.2 | 90-100 | 94 | 6 | 69.12 | 68.76 | 68.40 | 68.04 | 67.68 | 66.96 |
| 9.5 | 50-75 | 63 | 31 | 357.12 | 355.26 | 353.4 | 351.54 | 349.68 | 345.96 |
| 4.75 | 25-40 | 33 | 30 | 345.6 | 343.8 | 342 | 340.2 | 338.4 | 334.8 |
| 2.36 | 20-28 | 24 | 9 | 103.68 | 103.14 | 102.6 | 102.06 | 101.52 | 100.44 |
| 1.18 | 17-26 | 22 | 2 | 23.04 | 22.92 | 22.8 | 22.68 | 22.56 | 22.32 |
| 0.6 | 15-22 | 18 | 4 | 46.04 | 45.84 | 45.6 | 45.36 | 45.12 | 44.64 |
| 0.3 | 12-20 | 16 | 2 | 23.04 | 22.92 | 22.8 | 22.68 | 22.56 | 22.32 |
| 0.15 | 8-15 | 11.5 | 4.5 | 51.84 | 51.57 | 51.3 | 51.03 | 50.76 | 50.22 |
| 0.075 | 8-12 | 10.5 | 1 | 11.52 | 11.46 | 11.40 | 11.34 | 11.28 | 11.16 |
| Filler | 0 | 0 | 10.5 | 120.96 | 120.33 | 119.7 | 119.07 | 118.44 | 117.18 |
| Binder | | | | 48 | 54 | 60 | 66 | 72 | 84 |

**Table 4.10** Gradation table for samples with fibers:

Total weight of sample = 1200 gm

| Sieve Size in mm | Intermediate | adopted | %age retained | Amount of aggregates taken in this binder content | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | 4% | 4.5% | 5% | 5.5% | 6% | 7% |
| | | | | 1148.4 | 1142.4 | 1136.4 | 1130.4 | 1124.4 | 1112.4 |
| 19 | 100 | 100 | | 0% | 0% | 0% | 0% | 0% | 0% |
| 13.2 | 90-100 | 94 | 6 | 68.904 | 68.544 | 68.184 | 67.824 | 67.464 | 66.744 |
| 9.5 | 50-75 | 63 | 31 | 356.004 | 354.144 | 352.284 | 350.424 | 348.564 | 344.844 |
| 4.75 | 25-40 | 33 | 30 | 344.520 | 342.71 | 340.92 | 339.12 | 337.32 | 333.72 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 2.36 | 20-28 | 24 | 9 | 103.356 | 102.816 | 102.276 | 101.736 | 101.196 | 100.116 |
| 1.18 | 17-26 | 22 | 2 | 22.968 | 22.848 | 22.728 | 22.608 | 22.488 | 22.248 |
| 0.6 | 15-22 | 18 | 4 | 45.936 | 45.969 | 45.456 | 45.216 | 44.976 | 44.496 |
| 0.3 | 12-20 | 16 | 2 | 34.452 | 22.848 | 22.728 | 22.608 | 22.488 | 22.248 |
| 0.15 | 8-15 | 11.5 | 4.5 | 51.678 | 51.408 | 51.138 | 50.868 | 50.598 | 50.058 |
| 0.075 | 8-12 | 10.5 | 1 | 11.484 | 11.424 | 11.364 | 11.304 | 11.244 | 11.124 |
| Filler | 0 | 0 | 10.5 | 120.582 | 119.952 | 119.322 | 118.692 | 118.062 | 116.802 |
| Binder | | | | 48 | 54 | 60 | 66 | 72 | 84 |
| Fiber (gm) | | | | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 |

### 4.3 Marshall test results:

Various Marshall Properties determined during performing the experiment are stability and flow value. The stability portion of the samples is calculated by providing the samples a supported load which is given at 50.8 mm/min. As the sample starts to show failure and the maximum load measured at dial gauge till failure is stability for the sample.

**Table 4.11** Stability and flow values for samples without fibers:

| Bitumen (%) | Wsa | Wsw | flow | stability | Avg. flow | Avg. Stability |
|---|---|---|---|---|---|---|
| 4 | 1206 | 722 | 2.1 | 6.9230 | 2.07 | 6.8949 |
| 4 | 1208 | 728 | 1.8 | 6.7810 | | |
| 4 | 1207 | 724 | 2.3 | 6.9807 | | |
| 4.5 | 1197 | 706 | 3.1 | 8.5290 | 3.10 | 8.5575 |
| 4.5 | 1200 | 719 | 3.3 | 8.3124 | | |
| 4.5 | 1205 | 722 | 2.9 | 8.8310 | | |
| 5 | 1203 | 717 | 3.2 | 9.3801 | 3.43 | 8.9428 |
| 5 | 1199 | 709 | 3.8 | 8.4903 | | |
| 5 | 1205 | 716 | 3.3 | 8.9573 | | |
| 5.5 | 1207 | 726 | 4.6 | 7.3990 | 4.13 | 8.4633 |
| 5.5 | 1206 | 718 | 3.8 | 9.1056 | | |
| 5.5 | 1210 | 730 | 4.0 | 8.8854 | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 6 | 1209 | 726 | 4.5 | 8.5039 | 5.10 | 7.8792 |
| 6 | 1198 | 704 | 5.8 | 7.3007 | | |
| 6 | 1205 | 724 | 5.0 | 7.8330 | | |
| 7 | 1198 | 718 | 5.8 | 6.9064 | 6.06 | 6.6561 |
| 7 | 1195 | 708 | 6.3 | 6.7602 | | |
| 7 | 1192 | 702 | 6.1 | 6.3019 | | |

**Table 4.12** stability and flow values for the samples with fibers:

| Binder (%) | Wsa | Wsw | Flow | stability | Avg flow | Avg stability |
|---|---|---|---|---|---|---|
| 4 | 1202 | 714 | 3.0 | 6.8090 | 2.933 | 6.9277 |
| 4 | 1205 | 718 | 3.1 | 6.5540 | | |
| 4 | 1201 | 720 | 2.7 | 7.4201 | | |
| 4.5 | 1196 | 708 | 2.9 | 8.8903 | 3.13 | 8.4666 |
| 4.5 | 1199 | 706 | 3.4 | 8.0814 | | |
| 4.5 | 1204 | 714 | 3.1 | 8.4281 | | |
| 5 | 1200 | 720 | 3.2 | 10.1035 | 3.30 | 9.9824 |
| 5 | 1198 | 714 | 3.7 | 9.7108 | | |
| 5 | 1202 | 710 | 3.0 | 10.1329 | | |
| 5.5 | 1204 | 715 | 4.0 | 8.7210 | 4.07 | 8.7154 |
| 5.5 | 1202 | 712 | 3.7 | 9.8110 | | |
| 5.5 | 1207 | 724 | 4.5 | 7.6144 | | |
| 6 | 1205 | 726 | 4.3 | 8.7019 | 4.87 | 7.8343 |
| 6 | 1203 | 716 | 5.7 | 6.5710 | | |
| 6 | 1200 | 720 | 4.6 | 8.2301 | | |
| 7 | 1198 | 712 | 5.3 | 7.1436 | 5.8 | 6.5217 |
| 7 | 1195 | 706 | 6.2 | 6.1095 | | |
| 7 | 1197 | 702 | 5.9 | 6.3122 | | |

**Marshall Parameters for samples with fibers:**

| Binder content (%) | Avg. VMA | Avg. Vv | VFB | Stability (KN) | Flow (mm) |
|---|---|---|---|---|---|
| 4 | 14.05 | 4.64 | 71.29 | 6.9277 | 2.933 |
| 4.5 | 13.87 | 3.83 | 76.73 | 8.4666 | 3.13 |
| 5 | 13.98 | 3.95 | 85.47 | 9.9824 | 3.30 |
| 5.5 | 14.57 | 2.97 | 86.79 | 8.7154 | 4.07 |
| 6 | 15.23 | 2.87 | 90.68 | 7.8343 | 4.87 |
| 7 | 16.17 | 2.19 | 94.68 | 6.5217 | 5.8 |

## 4.4Graphs obtained:

### 1. Stability vs. binder content:

A graph between stability and bitumen content is plotted in which the bitumen content is in x-axis and stability of the samples is plotted in y-axis. Here stability is in kN and binder content is in percentage.

**Table: 4.13** Stability values for samples with and without fibers:

| Binder | 4 | 4.5 | 5 | 5.5 | 6 | 7 |
|---|---|---|---|---|---|---|
| Without fiber | 6.8949 | 8.5575 | 8.9428 | 8.4633 | 7.8792 | 6.6561 |
| With fiber | 6.9277 | 8.4666 | 9.9824 | 8.7154 | 7.8343 | 6.5217 |

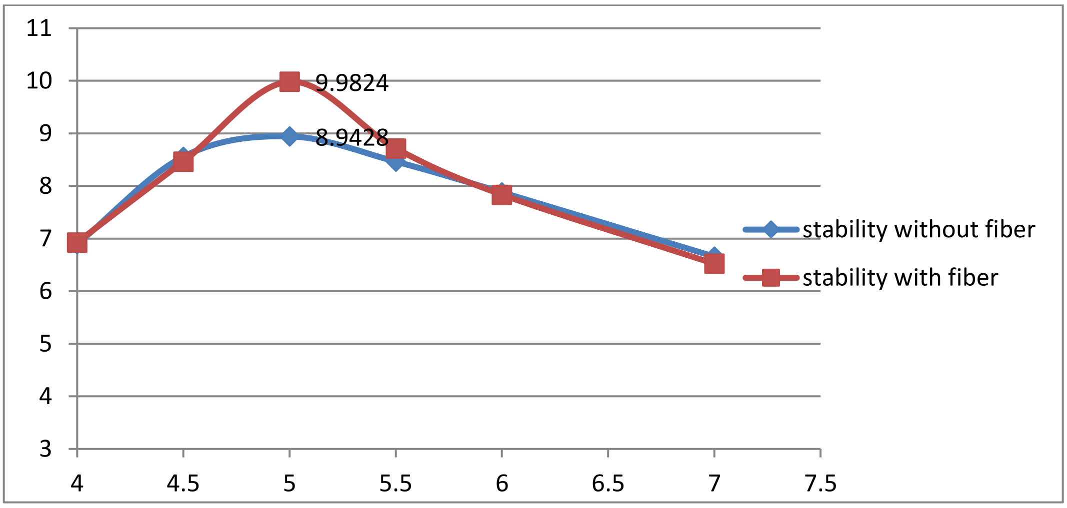



**Fig.4.2** : Comparision of stability with and without fibers at different binder content.

**2. Flow value vs. binder content:**

A graph between flow values in **mm** vs bitumen content in percentage for the fibers. Bitumen content is in **x-axis** and flow values are in **y-axis** for the samples with and without fibers

**Table: 4.14** Flow values of samples with and without fibers at respective binder contents.

| Binder | 4 | 4.5 | 5 | 5.5 | 6 | 7 |
|---|---|---|---|---|---|---|
| Without fiber | 2.20 | 3.03 | 3.56 | 4.1 | 5.03 | 6.2 |
| With fiber | 2.966 | 3.163 | 3.366 | 4.00 | 4.8 | 5.7 |

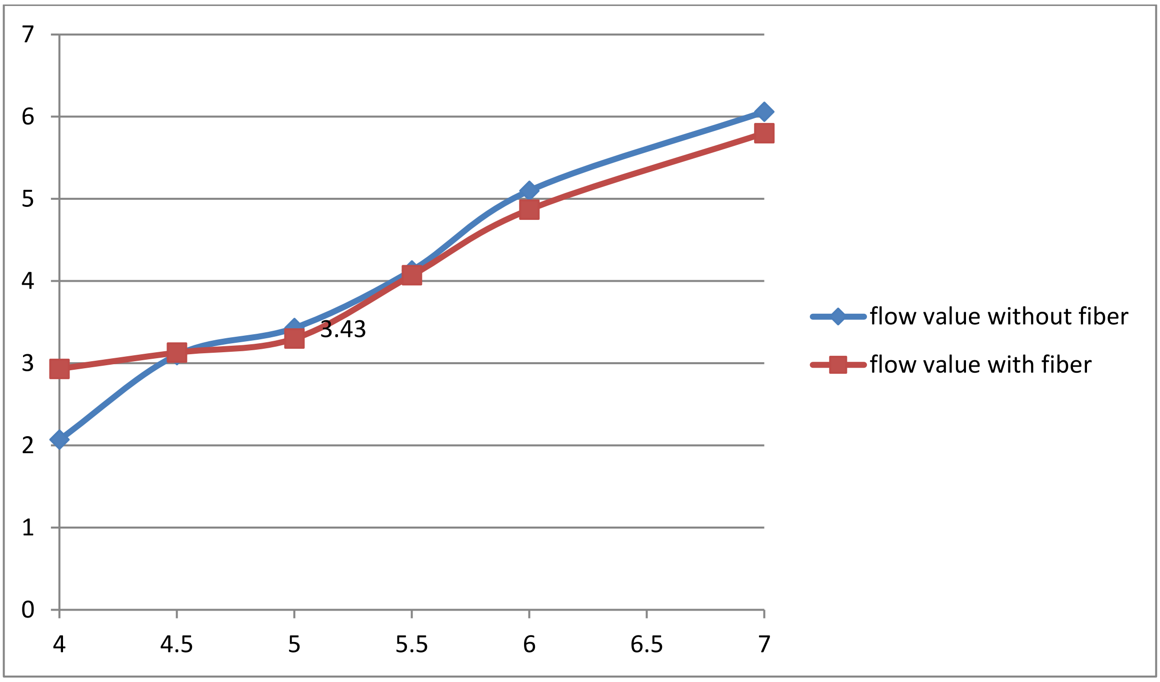



**Fig.4.3:** Comparison of flow value at different binder contents with fiber and without fibers

**3. VMA vs. binder content:**

**Table 4.15** VMA vs. Binder content for samples without and with fiber:

| Binder (%) | 4 | 4.5 | 5 | 5.5 | 6 | 7 |
|---|---|---|---|---|---|---|
| Without fiber | 14.02 | 13.83 | 14.41 | 14.48 | 15.07 | 16.27 |
| With fiber | 14.05 | 13.87 | 13.98 | 14.57 | 15.23 | 16.17 |

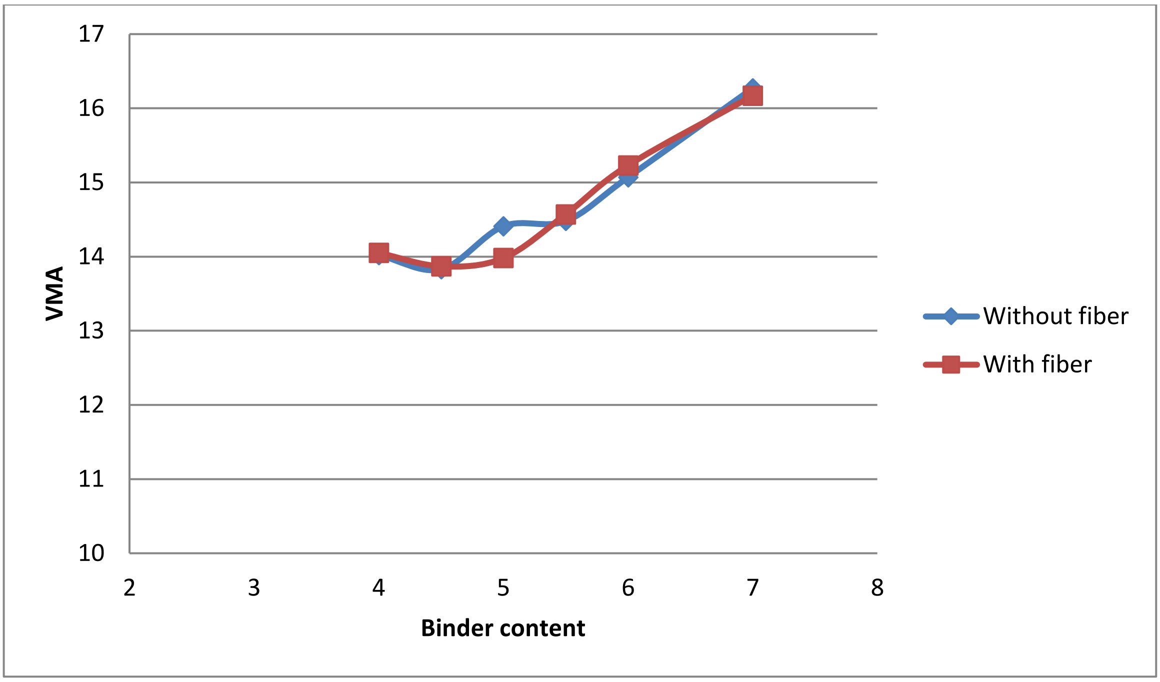



**Fig.4.4** Graph between VMA vs. binder content

4. **VFB vs. binder content:**

**Table 4.16** VFB vs. Binder content without and with fiber:

| Binder (%) | 4 | 4.5 | 5 | 5.5 | 6 | 7 |
|---|---|---|---|---|---|---|
| Without fiber | 73.1 | 77.68 | 82.74 | 84.98 | 89.32 | 93.12 |
| With fiber | 71.29 | 76.73 | 85.47 | 86.79 | 90.68 | 94.65 |

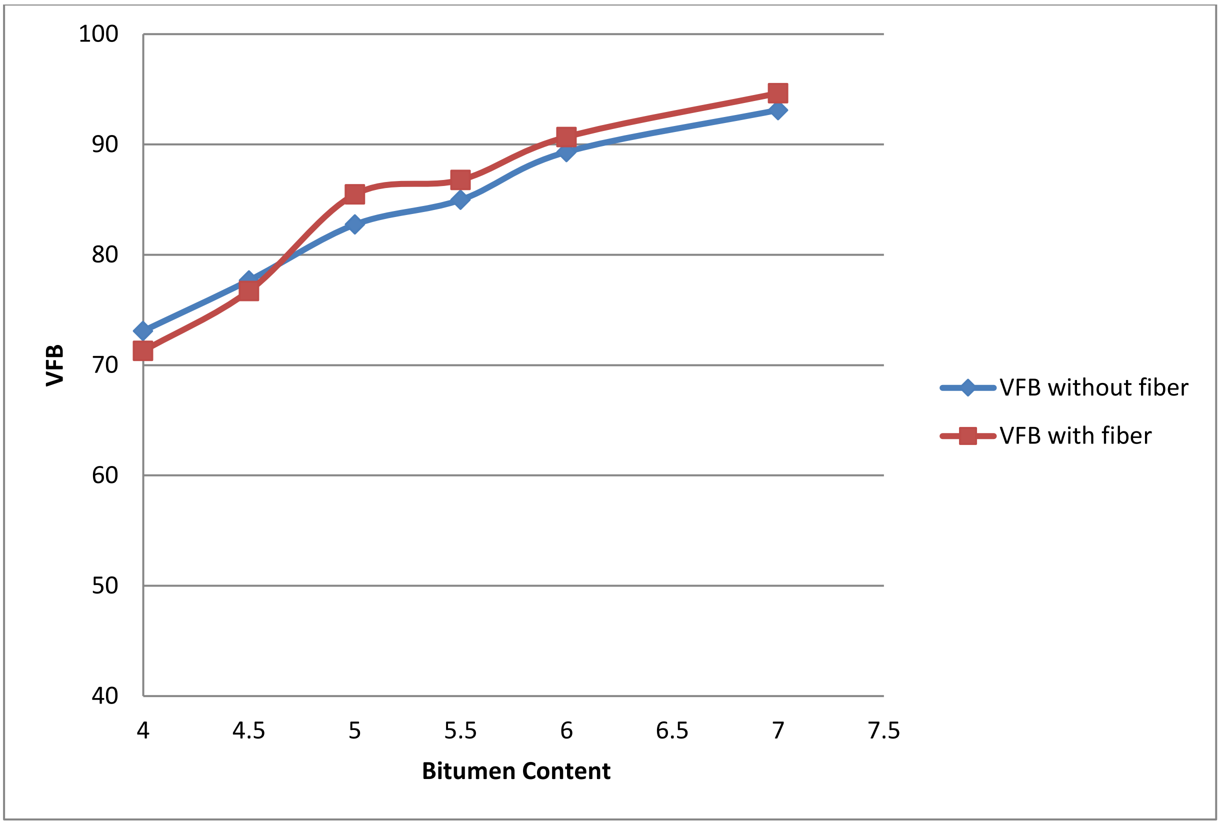



**Fig.4.5:** Graph between VFB vs. Binder Content

**5. Volume of voids (Vv) vs. binder content:**

**Table 4.17** Vv vs. Binder content without and with fibers:

| Binder (%) | 4 | 4.5 | 5 | 5.5 | 6 | 7 |
|---|---|---|---|---|---|---|
| Without fiber | 4.41 | 3.63 | 3.32 | 2.97 | 2.62 | 2.36 |
| With fiber | 4.64 | 3.83 | 2.95 | 2.79 | 2.87 | 2.19 |

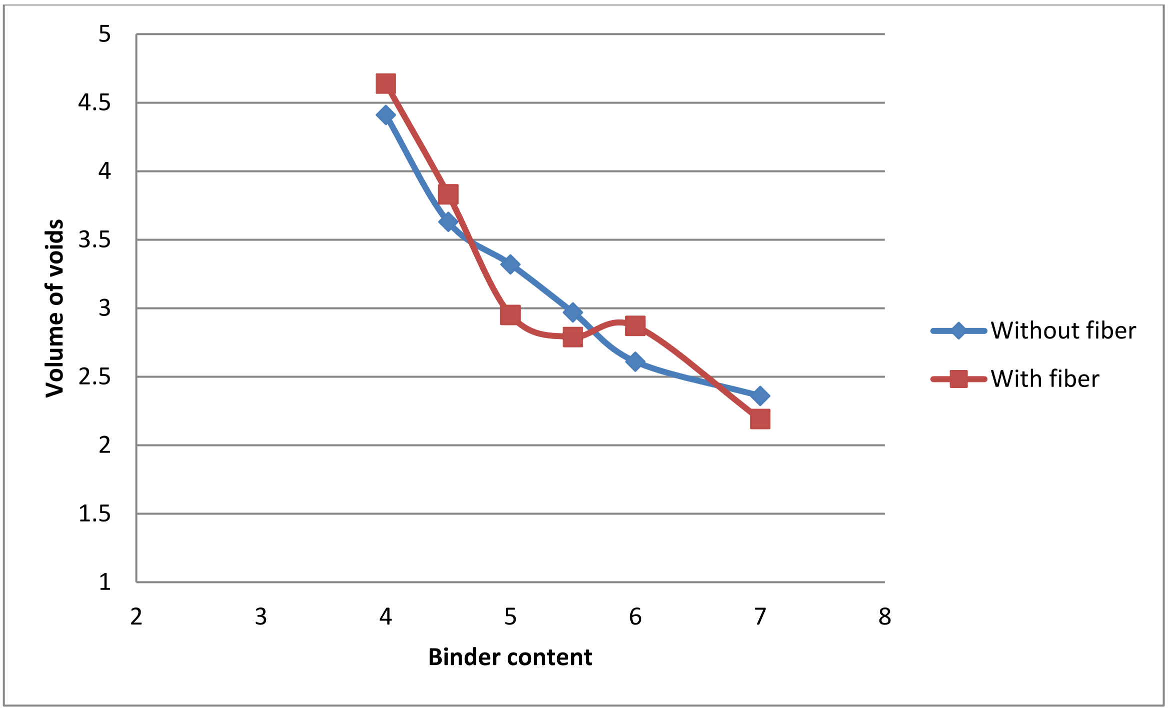



**Fig.4.6:** Graph between Volumes of voids vs. binder content

**Table 4.18** Unit weight vs. binder content:

| Binder (%) | 4 | 4.5 | 5 | 5.5 | 6 | 7 |
|---|---|---|---|---|---|---|
| With fibers | 2.45 | 2.50 | 2.53 | 2.59 | 2.62 | 2.59 |

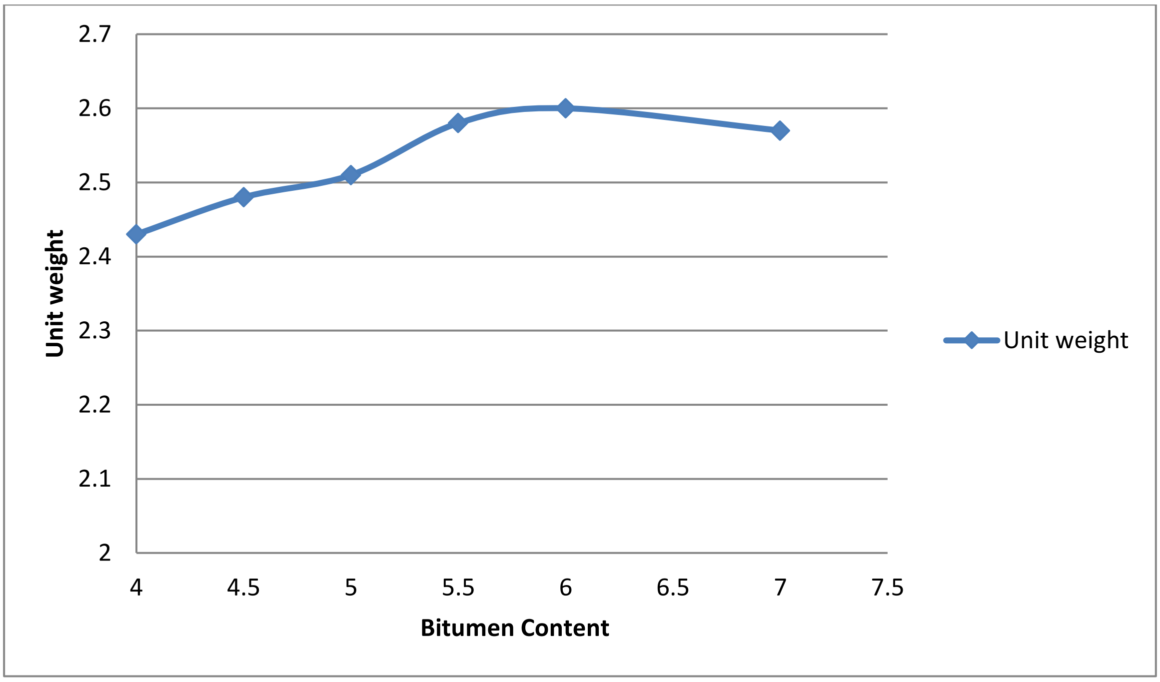



**Fig.4.7:** Unit weight vs. binder content:

## 4.5 Determination of mix design's parameters:

From the above curves the mix properties at 4% air voids are as follows in the table:

**Table 4.19** Various mix properties at 4% air voids:

| | Without fiber | With fiber |
|---|---|---|
| Asphalt content (%) | 5.10 | 5.10 |
| Stability (KN) | 8.8469 | 9.7289 |
| Flow (mm) | 3.58 | 3.45 |
| VMA (%) | 14.24 | 14.09 |
| VFB (%) | 83.18 | 85.73 |

## 4.6 Interpretation of results:

1. For stability value the Marshall samples were made at different binder contents as 4%, 4.5%, 5%, 5.5%, 6% and 7%. These samples showed a gradual increment in their stability values at their initial stage and by further increase of binder to these samples, they showed decreasing stability value. This was due to facts that with increase of binder content the bond between aggregates and bitumen gets stronger and with further addition it decreases and the bond got weaker showing plastic deformation and stability falls.

The same is the case with samples made with fiber but, instead of it they showed greater stability value when compared with samples made without fiber at same binder content. This proves that by adding fiber as stabilizer to SMA Mix which not only increases stability but also helps in decreasing the air voids present in mix. By adding fiber the drain down of the binder also decreases from the asphalt film. It enables a sought of homogeneity to the mix and also has proved less noise production of pavements made of SMA Mix.

2. Flow value of Marshall Samples is the value when samples go through deformation under load at failure. Flow value of samples without fibers showed a constant increase in flow, but the samples with fibers showed a little increase in initial binder content and then later showed a gradual increase in flow value. This was due to the fact that at initial stages the fibers helps in maintaining homogeneity of the mix but later on it gets lost with the increase of binder content. The flow value for SMA Samples or mix lies between 2 to 4 mm.

3. VMA values for mix samples should show a constant increase theoretically, but here it was observed that when bitumen content was low starting from initial addition, the VMA values gets decreased and after with more addition of bitumen it finally starts increasing at high bitumen content. The VMA value at initial falls because of the reorientation of the aggregates

with the binder added which is low. With high binder content the VMA value gets increased because aggregates starts moving a bit form a thick film and fiber starts forming lumps resulting increase VMA value.

4. VFB is basically computed as fraction of VMA. The VFB of the mixture shows an increment in its value as the binder content is increased. In our results we also found the VFB of samples with fibers and also the samples without fibers showed a gradual increase in VFB with increase in binder content. This is because as the binder content is increased the voids present in the mix get filled by bitumen or binder.

5. The air voids decreases with the increase in the bitumen content, because it goes on filling the voids present in the mix. The air voids of the sample with fiber  was found less near OBC which was due to fact that on addition of bitumen and fiber the voids present in mix got filled up. If there is any increase in air voids after OBC is due to improper mixing of samples.

# CHAPTER 5

# CONCLUSION AND FUTURE SCOPE

## 5.1 Conclusion:

In recent years, there has been rapid growth in the research and innovation in the natural fibre composition with the design mix for the purpose of laboratory test about the change in the property after mixing the natural fibre with the design mix and for partial replacement of the bitumen content. Here SMA is prepared by using bitumen of grade VG 30. Additionally a normally accessible fibre called banana fibre and jute fiber is utilized with the percentage 0.2% and 0.1% respectively. At OFC 0.3%, OBC has discovered by Marshall Method of mix plan. Cement is used as filler which is highly recommended as per MoRTH. From various tests like Marshall Test were analyzed in SMA with utilizing banana fibre and jute fibre gives a great outcome. Here maximum stability obtained is 9.7289 KN at OBC @5.10%. When compared to other fibres it is a bit higher. So because of this combination of banana fibre and jute fibre can be used in case of general heavy traffic requirements and it would be suitable for severe traffic situations also.

## 5.2 Future Scope:

Numerous properties of SMA, for example, Marshall Properties has considered in this examination. As its VG30 bitumen and an adjusted common fiber called banana fiber and jute fiber are used in this examination. Be that as it may, a portion of the properties, for example, moisture vulnerability qualities, imperviousness to rutting behaviour can further be researched. Some other natural or synthetic fibres can also be used to check the viability of SMA properties. Banana fiber is utilized as a part of this review is a minimal effort material, along these lines money saving advantage investigation can be made to know its impact on cost of development. Additionally, to guarantee achievement of this fresh material, trial extends might be built and intermittent exhibitions observed**.**

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