# EVALUATING THE VIABILITY OF HEMP FIBRE IN STONE MATRIX ASPHALT

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

**MASTER OF TECHNOLOGY**

**In**

**Transportation Engineering**

**(Civil Engineering)**

**By**

**CHANDER SEN DUTT**

**(11512393)**

**SUPERVISOR**

**MR. NITIN BHARDWAJ**

*Transforming Education Transforming India*

**School of Civil Engineering**

**LOVELY PROFESSIONAL UNIVERSITY, PHAGWARA**

**2017**

# DECLARATION

**I, Chander Sen Dutt** hereby declare that the project report entitled, **"EVALUATING THE VIABILITY OF HEMP FIBRE IN STONE MATRIX ASPHALT"** is submitted in the partial fulfillment of the requirements for the award of degree of Master of Civil Engineering , in the school of Civil Engineering at Lovely professional University Phagwara. This is my own work and the results are presented in this report. The material is not copied from any source or from any institution.

**Date:** **Chander Sen Dutt**

**Place:** **(11512393)**

# CERTIFICATE

Certified that this project report entitled **" EVALUATING THE VIABILITY OF HEMP FIBRE IN STONE MATRIX ASPHALT",** submitted individually by Chander Sen Dutt student 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/institution for the award of any degree**.**

**Signature of Supervisor**

Nitin Bhardwaj

Assistant Professor

School of Civil Engineering

## ACKNOWLEDGEMENT

I am profoundly thankful to my dissertation mentor who took interest on my project work and helped me all along for its completion by providing the required information for acquiring some authentic results in my report. I am thankful to get a regular support from all my teaching staff of the department of civil engineering. I thank to all my colleagues, my friends, my parents who helped me all along to complete my research and thesis work which would not be possible without their support. I also thank to my HOD Mrs. Man deep Kaur and our Dean Dr V. Rajesh Kumar for their esteem support. At last I thank to my university management for making this project successful by providing necessary information and resources.

**Signature of student**

**Chander Sen Dutt**

# ABSTRACT

SMA Mix is a mixture which differs from a normal bituminous mix on the basis of quantity of coarse aggregates. In SMA the assemblage of coarse aggregates is kept high and the materials other added are binder, filler and fibers. The basic purpose of adding fiber to SMA Mix is to make the mix stabilized. Various fibers which are added to SMA can be some natural fiber, polymer or synthetic fibers. Because of high amount of coarse aggregates in SMA, it makes the structure's skeleton more firms and there is efficient allocation of load distribution network. The thick asphalt film with binder exhibits durability of the mix. The fibers helps in averting the drain down of the mix and make the pavement's texture rough enough to achieve friction attribute when the top binder film gets removed by the action of traffic. On the basis of structural behavior of SMA it makes the mix resistant to rutting, more durability and hence increases the service life of the pavement.

In this project an effort is made to go through the various engineering properties of the SMA by adding some non conventional fiber called hemp fiber to it. This fiber made from Cannabis plant is generally considered as waste in India and is of no use yet here. According to the previous research various fibers added to SMA Mix were taken as per MORT&H specifications when 0.3 % of fiber was added to SMA. In this research the fiber added was Hemp fiber and various engineering properties of SMA Mix were studied and checked by conducting Marshall Test to meet the desirable standards for the mix.

# TABLE OF CONTENTS

# LIST OF FIGURES

# LIST OF TABLES

# 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

In mid 1960 European black-top production companies was in necessitate of a surface course to oppose rutting, scraped area and troubles because of overwhelming movement of traffic and studded tires. Therefore SMA was produced. It was initially created in Germany and because of its predominant exhibitions SMA was in the long run included as an institutionalized mix class in their asphalt details. Because of its higher groove resistance and sturdiness it is widely utilized as a part of other European nations for more than two decades. As an after effect of this extensive achievement accomplished by Europe, different nations as well as India have begun utilizing SMA or looking into on its usage and reasonability for their asphalt mixes.

Different reviews uncovers that utilization of SMA for surfacing street asphalts is required to fundamentally expand the toughness and groove confrontation of the mixes.SMA is a mix contains 70-80 percentage coarse total of aggregate with little fine aggregates in overall mass, 5-7 percentage of binder, 8-12 percentage of filler, and around 0.3-0.5percentage of fiber or modifier. Since coarse aggregates don't distort as much as black-top folio under load, this stone-on-stone contact incredibly decreases rutting. In this manner utilization of high coarse total give better rut resistance and skid resistance .Due to high substance of bitumen it fills the voids between the totals affectively and ties them together, consequently adding to its solidness from untimely splitting and raveling. A potential issue connected with SMA is drainage and bleeding. Draining is brought about because of trouble in getting the vital compaction. More bitumen content causes seepage, and as capacity and situation temperatures cannot be brought down and it remain a noteworthy issue connected with SMA .Therefore balancing out added substances, for example, fibers , rubbers and polymers are being utilized to harden the framework along these lines lessening the drawdown, bleeding altogether .

The diverse types of stabilize agent which are used in SMA are by and large costly consequently there exist a need to acquire an alternative, bring down cost stabilizers that will essentially serve a similar goal, likewise as got by utilizing other regularly utilized stabilizing additive substances. Henceforth here we attempted to utilize a common fiber, in particular the hemp fiber in SMA Mix.

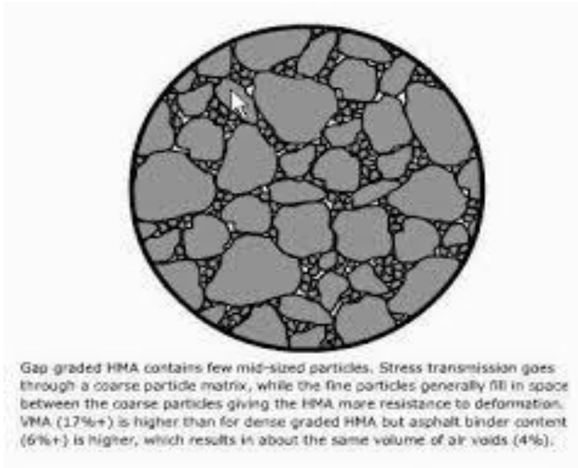


**Fig 1.1** Gap graded mix structure (SMA)

## 1.2 Scope of the study:

The purpose of this study is to enhance the properties of bituminous mix using natural waste fibers. As we all know that the bitumen is a petroleum product and it is obtained from the fractional distillation of crude oil. So, at high temperature the bitumen gets heated during hot climatic conditions and due this the SMA losses its properties like increase in air voids due to use of more coarse aggregates and by this bitumen gets drained off from the mix. So if we are using the Hemp fiber which is a natural fiber having high growth rate in every part of the world, this hemp fiber is having some good qualities like water adsorption that is not allowing water to percolates from the wearing coarse to sub grade and thus allowing SMA to make more sustainable and durable during its overall construction life span. 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 of study:

- The main purpose in this project work is using non conventional/common fibers as here hemp fiber is used in place of other conventional fibers and to study its viability in SMA.
- To prevent the drain down property of water in SMA.
- Preparing the Marshal specimens and to check the various Marshall properties by adding fiber.
- To determine the satisfactory results of hemp fiber when used in SMA.
- To evaluate the various properties of Stone matrix mix samples by further related test type results.

# CHAPTER 2

# LITERATURE REVIEW

**2.1 Previous studies:** Lot of researches has been done and are still proceeding for the advancement and enhancements in SMA. A brief survey of writing examined and connected for the combination of this venture is being depicted beneath. Ever since the advancement of SMA in Germany in mid 1960 and its achievement in European nations, numerous nations world wide have used the theory of SMA. It was institutionalized in numerous nations worldwide and turned into a part of the transportation powers for the nations, as well as India.

**Manglokar and Browne** in 1993, studied about SMA and DGM mixes where they used granite and siliceous gravel as aggregates. The fiber which they added to the mix was cellulose fiber. They performed Marshall Test, Indirect tensile test, Drain down test on the mix. They concentrated on the type of aggregates because SMA posses more content of coarse aggregates. The high content of these aggregates make the mixture firm with more use of stone to stone contact. This property of SMA helps in achieving good value for load distribution providing good resistance action against rutting and to the plastic deformation under heavy load of traffic. SMA posses a ought to texture so friction between tiers and pavements gets increased which leads to better skid resistance.

**Bradley et al** (2004) used carpet fiber and waste tires at the place of cellulose fiber for improving the stability and strength of the mix. He concluded a significant decrease in drain down characteristics of SMA Mix. He also found that when fiber added to mix is exposed to moisture, don't tends to decrease or weakens the mix properties, but helps in increasing toughness of the SMA mix.

**Kama raj et al (2004)** studied about SMA mixes by adding rubber powder to it. He used bitumen of grade 80/100. Other mix he made was dense grade mix in which he added filler stone dust and lime, fiber added was cellulose fiber and found stability of mix by performing different tests.

**Reddy et. al (2004)** He made use of crumb rubber which is taken 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.

**Muniandy and Haut (2006)** used a cellulose fiber derived from palm oil tree. It showed that the rheological properties of this modified mix when added to PG 64-22; binder gets modified to PG 70-72. It also increases fatigue performance of the mix. The amount of fiber taken was 6% at which it shows maximum fatigue life of SMA.

**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 and compressive strength 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** have 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.

**Punith et al** in the year 2004 have done a relative study of SMA with asphalt concrete mix. They did this by using reclaimed polythene which is present in the type of some carry bags. These act as stabilizing agents having size 3 mm and 0.4 %. The outcome of the test specified that mix property of AC and SMA Mix got improved by adding reclaimed polythene which are used as a stabilizer and it displayed the properties like enhanced rut resistance, creep and aging.

**Kumar et al** in the year 2007 studied the two types of fibers. In his study of SMA Mix, he used the jute fiber which was covered with low viscosity binder. He then related his observation with an imported cellulose fiber which was imported from Germany. 60/70 grade bitumen was used and he came to the conclusion that 0.3% is the optimum fiber percentage of the mixture. The equivalent results of import were shown by the Jute fiber.

**Xue et al (2008)** partially replaced fly ash incinerator by fine aggregates and mineral filler. He took Basic Oxygen slag as a component of coarse aggregates with polyester fiber of length 6.3 mm in SMA Mix. PG 76-22 was taken as binder and he carried test like Marshall test, super pave method for design purpose. He found it suitable for SMA Mix.

**Jony Hassanet at al** in the year 2010 has studied the influence of fillers which used waste powder made from glass as mineral filler on the Marshall property in SMA by relating it with SMA in which usual Portland cement, lime stone was used as space filler which vary in its content by 4-7%. The ideal content of the glass power was found to be 13%. The usage of glass power as filler in SMA leads to increase in its stability up to 13%. There is a decrease in its flow value up to 39%. Comparing to SMA Mix, the density is also decreased as it contains cement layer and lime stone.

## 2.2 Bituminous mix Design:

A bituminous mix design is a combination in which aggregates, binder (bitumen), filler are added to prepare a mix up which should be effective, strong and durable and also should be economical. The content of bitumen is added as such it provides good elastic properties, effectively impervious and also acceptable dissipative property. The main requirements of the mix are to provide various components which are as follows:

- An adequate content of bitumen to make a long lasting pavement's life.
- Better in opposing shear deformation usually at high temperature pavements.
- Bitumen should be as compacted that there should be sufficient air voids for additional compaction by traffic.
- Mix should be having adequate workability so that it can be easily place without segregation.
- It should be enough resistant to premature cracking which is due to repeated bending of traffic.
- It should avert shrinkage cracks which are at low temperatures pavements.

## 2.3 Bituminous mix properties:

- **Stability**: It can be demarcated as the resistance which is offered by the paving mix to deform beneath the transfer traffic load. Two cases of failure:

  - **Shoving defect** - It refers to the oblique stiff deformation which arises at the areas focusing severe acceleration.
  - **Grooving defect**- It refers to the longitudinal folding which occurs because of channelization of traffic present on roads. Stability is dependent upon the inter-particle rubbing, predominantly of aggregates and consistency that is given by the bitumen. There should be appropriate binder that has to be accessible to cover whole particles at the similar time that would offer sufficient liquid friction. When the particles are away from each other and the binder content is high, there is decrease in stability.

- **Durability:** Durability refers to the amt. of resistance of the mix in contrast to weathering action and abrasion actions. Weathering leads to harden, which occurs due to the loss of volatiles. Tensile strain is caused by wheel loads which lead to abrasion. Distinct examples of failure are:

  - **Pot-holes**- It refers to the weakening of local pathways.
  - **Stripping**- It refers to the binder loss from the aggregates which lead to the exposure of aggregates.

  Disintegration is reduced by more binder content as they leads the mix to be filled air and water proof and the asphalt film is more resistance to strengthening.

- **Flexibility:** To stabilize traffic loads and to prevent cracking of surface, flexibility is a quantity which is used to measure the level of bending strength of the surface. Fracture leads to the formation of cracks like hair shape cracks, alligator cracks present. The main reason behind the fracture is the shrinkage of the binder and fragility of the binder. The shrinkage cracks are formed due to the change in quantity of binder volume because of ageing. The frequent bending of the plane due to transfer loads leads to the fragility. If the content of bitumen is high, it will provide superior elasticity and less breakage.

- **Skid resistance**: Resistance which for reducing the skidding action which depends on texture provided and binder’s content used. It is an essential element in speedy traffic. Generally, a coarse surface type of texture is required at the top surface.

- **Workability:** It is defined as the way by which the mix can be positioned and packed down to design the needed conditions and its shape. It is dependent upon the degree of aggregates, aggregate's shape and quality, content of used binder and its type. Flaky, angular and stretched aggregate's workability. Rounded aggregates, leads to improvement in workability.
- **Some Prudent properties:**

➢ To meet traffic demand there should be stability.
➢ For proper binding and water proofing bitumen content should be made certain.
➢ Due to traffic there should be well voids compaction.
➢ Traffic load should meet up flexibility particularly in cold season.
➢ For construction purpose there should be an adequate workability.
➢ It should be a cost effective mix.

## 2.4 Bituminous mix design concrete:

**HMA (Hot mix asphalt concrete)** it is the mix which is prepared by providing more heat to binder for decreasing the viscosity of it. Aggregates are dried for removing the moisture if present in the mix. Aggregates are mixed at a temperature of 150 C. When asphalt is suitably hot the paving and compaction of mix is done. HMAC is used mostly pavements where traffic rate is high such as at highways and also used at race tracks and air fields.

**WMA (Warm mix asphalt)** this type of asphalt concrete is made by the addition of zeolites waxes, asphaltic emulsions and water is also added sometimes to asphalt binder prior to mixing. A temperature of 20C is maintained when it is processed. It is laid at lower temperatures with lower rate of mixing so it requires less consumption of fuels thereby producing fewer amounts of volatiles like carbon dioxide, vapors and other effluents which can cause pollution.

**Cold mix asphalt mixture:** It is formed by an emulsion of water and soap. It is less viscous when it is in emulsified state so it is easy to work and compaction. It takes the properties of HMAC as he emulsions break out after sufficient removal of water from it. This concrete used acts as a patching material mostly and on the roads where traffic is less.

**Cut back asphalt concrete** It is prepared when kerosene or any other lighter fraction material like petroleum is dissolved in it. In dissolved form it is having less viscosity and the mix is very workable. After laying the mixture the lighter fractions present gets evaporated. The cut back asphalt is replaced by asphalt because it produces volatile organic compounds which also lead to pollution

**Natural asphalt concrete** The naturally readied black-top cement is prepared from bitumen rocks where the nearness of sedimentary rocks up well bitumen close to its surface .SMA is additionally named as stone mastic black-top which was produced in Europe to conquer issues like rutting and to make the asphalts more tough where on streets movement is high . In SMA the content of coarse totals is high so it shapes a stone skeleton sort of structure in which stones get interlocked to each other in this manner coming about imperviousness to permanent distortion. It is loaded with folio (bitumen), filler and fibers. Fiber here acts as stabilizer which avoid draw down of bitumen as it is having more number of air voids in view of more utilization of coarse totals. Structure of SMA is coarse totals (70-80) %, filler (10-12) %, binder (5-7) %, fiber (0.3) %. . The reason for adding fiber is to minimize the drain down of bitumen mortar; it additionally gives better grating in wet climate conditions.

## CHAPTER 3

## RESEARCH METHODOLOY AND MARERIAL CHARACTERIZATION

### 3.1 Methodology

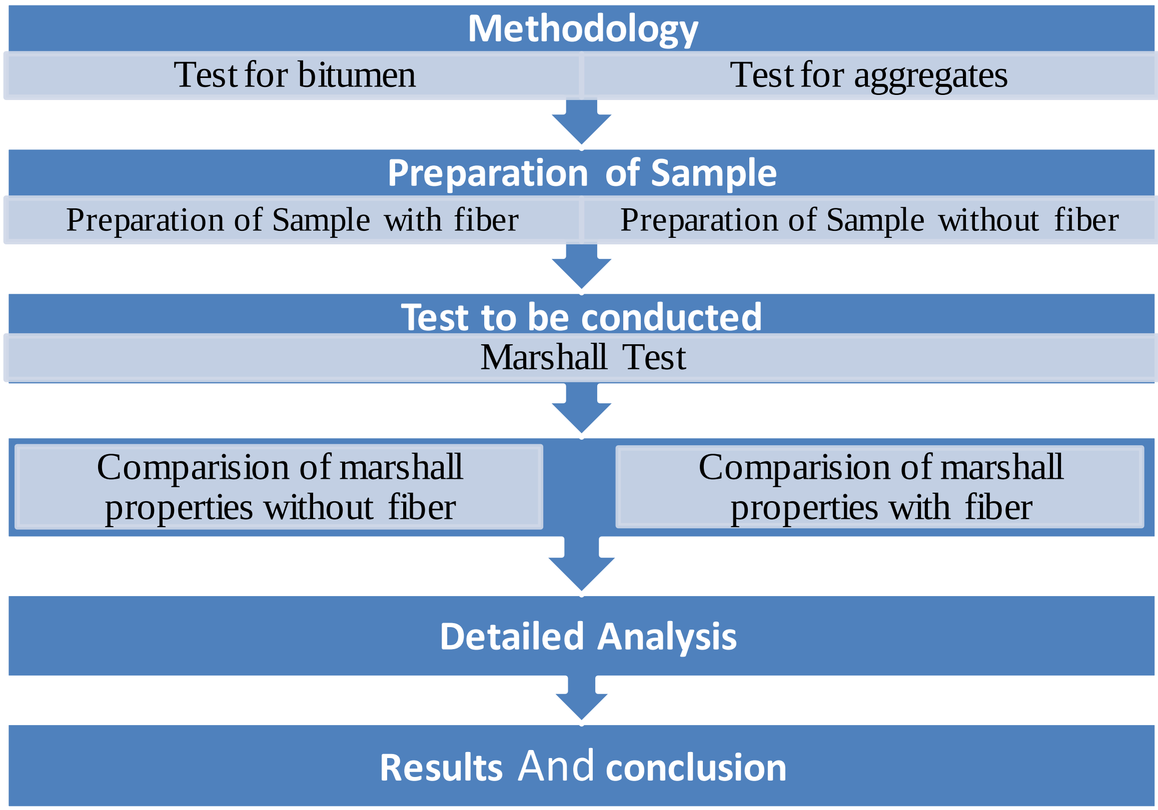


**Fig 3.1** Methodology to be adopted

A large portion of research activities made on SMA incorporates the Marshall test for deciding the flow value and for making SMA a stable mix.

### 3.2 Material characterization:

### 3.2.1 Mineral Aggregate:

In bituminous mixes the mineral aggregates which can be used are of many types. For the manufacturing of bituminous mixes the aggregates can be taken from different types of naturally available sources like glacial deposits- mine. These aggregates collected naturally can be used without or with processing. A better performance result can be obtained by further processing and finishing. With the help of industrially available by products like glass furnace slag, steel slag etc. are used with these aggregates to improve the quality characteristics of the mix. As we know in SMA matrix aggregates used play necessary role in giving good strength to mixture because 70- 80 percent of coarse aggregates are totally present in the mix, These coarse aggregates results better in case of shear strength and show a good resistance factor to rutting resistance when compared to normal BC because this stone to stone contact of coarse aggregate form a firm skeleton type of structure. Aggregates should be:

- Rough in texture for resisting rutting and other movements.
- It should be cubical in shape.
- The degree of hardness should be as such that under heavy traffic it can resist fracture.
- More resistant to polishing and other factors like abrasion and attrition.

**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 Mineral filler:

In SMA matrix the mineral fillers have a measure impact on its properties. It adds to the increase in the stiffness of the matrix. Fillers in case of HMA mixture have an effect on its workability, aging and moisture resistance. In general these fillers have measure impact over the properties like air void presence and voids in aggregates present. Various mineral fillers such as OPC, slag cement, hydrated lime, fly ash etc. Stuart and Mogawar in 1996 made study over mineral fillers in SMA. Both they selected 8 type of fillers on their performance basis, gradation etc. They checked drain down of the mastic, low temperature cracking, moisture susceptibility, rutting, and workability of SMA mixture. So here we are used to use fly ash as a filler material to determine our work and to check the various engineering properties of SMA. In this research we used Class F fly ash because of its cementitious properties.

**Fig 3.2** Fly ash

**Table 3.2** Properties of Fly Ash (Class F)

| Component | Bituminous | Sub-Bituminous | Lignite |
|---|---|---|---|
| $SiO_2$ (%) | 20-60 | 40-60 | 15-45 |
| $Al_2O_3$ (%) | 5-35 | 20-30 | 20-25 |
| $Fe_2O_3$ (%) | 10-40 | 5-10 | 4-15 |
| CaO (%) | 1-12 | 4-30 | 15-40 |
| LOl (%) | 0-15 | 0-3 | 0-5 |

### 3.2.3 Bitumen as 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 tried using VG-30 grade of bitumen in SMA.

The grade of the bitumen is adopted as per the SMA considerations and heavy traffic conditions, as per the IRC and Mort&h specifications that is **VG-30** grade which was taken from the bitumen agency situated in **Jalandhar Jyoti Chowk**. The tests which we need to perform before using the bitumen in bituminous mix design that are penetration test, viscosity test, softening point, ductility etc.

**Table 3.3** Showing desirable properties of bitumen (VG-30)

| Tests | Standard specifications |
|---|---|
| Penetration test (mm) | 60-70 |
| Viscosity (poise) @60°C | 2400 |
| Ductility (cm) | 40 cm/min |
| Softening point (degree) | 47 |
| Specific gravity | 0.9-1.06 |

### 3.2.4 Stabilizing additives:

To enhance better binding and to avert drain down from mortar stabilizing additives are added in the mixture like Polyester, cellulose, minerals. Different properties of stabilizing additives which are introduced to the mix are categorized as follows:

- Fibers like cellulose, chemical fibers, and other mineral fibers.
- Polymers
- Materials which are present in the form of flour like powder e.g. Silicic acid, special filler etc.
- Plastics like pellets and powdered polymers.
- Natural fibers: Fibers which are obtained from the stem of plants are bagasse fibers, hemp fiber, jute fiber, banana fiber etc. Cotton, oil palm, coir are some examples of fruit fiber.

Here, hemp fiber is used as additive whose length is kept after cutting and cleaning around 15-30 millimeters and dia. from 0.3 to 0.5 mm (l/d) ratio. It is ensured that fiber should get mixed properly with aggregates and binder during mixing process.

## 3.3 Hemp Fiber:

Hemp fiber is extracted from cannabis tree. This fiber is possessing very good tensile strength, stiffness and stresses easily. The moisture absorbing capacity of this fiber is very good when compared to other natural fibers like cotton linen etc. In India the production or use of hemp is illegal so it can be considered as a waste in India. But if this waste which we know grows here on a very large scale can be utilized for some useful purposes can be prove very useful. In India this hemp plant grows almost in every state and because of its illegalization it remains as a waste for us. Outside India this hemp is used in textile industries and they are utilizing this fiber effectively. So, here in this research paper hemp fiber is used which is appraised as waste in India**.**

### 3.3.1 Extraction of Hemp Fiber:

The extraction of hemp fiber from cannabis plant can vary at different countries of the world. This crop takes only 90 days to grow and extraction of this fiber is simple like first cultivation is done after it followed by harvesting and the in final stage fiber processing is done.

**Fig 3.3** Hemp fiber (Stabilizer)

### 3.3.2 Characteristics of Hemp Fiber:

- Hemp fiber is having high moisture content, so if used in bituminous mix can be used as stabilizer to increase run off over pavement reducing wetting of surface.
- Hemp fiber is yellowish grey to deep brown
- This fiber is very strong fibrous material and is having good tensile strength
- This fiber is having high wax content in it, so in presence of water it does not allow it to percolate within into the pavements surface. So it can be said that this fiber is having very good moisture absorbing capacity.
- Very resistant to deterioration under heat and does not get effected under sunlight.
- Excellent resistance to alkalis and organic solvents.

- It is not attacked by moth-grubs or beetles.

**Table 3.4** Chemical Composition of Hemp fibers

| | |
|---|---|
| Cellulose | 77.5 % |
| Hemi cellulose | 20 % |
| Lignin | 6-8 % |
| Pectin | 3 % |
| Wax | 1.9 % |
| Water soluble materials | 1.8 % |

**Table 3.5** Chemical composition of various natural fibers

| Fibers | Cellulose (Wt. %) | Lignin (Wt. %) | Hemi cellulose (Wt. %) | Pectin (Wt. %) | Wax (Wt. %) | Moisture content (Wt. %) |
|---|---|---|---|---|---|---|
| Jute | 62-72 | 12-13 | 13.6-20.4 | 0.2 | 0.5 | 12.6 |
| Hemp | 71-78 | 3.5-7.5 | 18-22.41 | 2.9 | 1.9 | 10.8 |
| Ramie | 68-76 | 0.6-0.7 | 13.1-16.7 | 1.9 | 0.3 | 8.0 |
| Sisal | 64-76 | 8-11 | 10.0-14.2 | 10.0 | 2.0 | 11.0 |
| Flax | 70 | 2.2 | 18.0-20.6 | 2.3 | 1.7 | 10.0 |

## 3.4 Experiments to be performed

### 3.4.1 Tests done for coarse aggregates:

### Los Angeles abrasion test:

This test is used to determine % age wear and tear due to mutual abrasion and attrition of tires with respect to pavement. It consists of a hollow cylinder closed at both ends with inner diameter 70cm and 40cm and weighs 390-446 gm.

Aggregates are 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 25 percent.

### Impact test for Aggregates:

It consists of a cylinder cup of internal diameter 102 mm, depth 50mm and thickness 6.4 mm. A hammer of weight 14kg is made with a freefall of 38cm. Aggregates passing from 12.5 mm sieve and retained on 10mm sieve are used. Aggregates filled in cylinder are given 15 blows for three layers and then hammered aggregates are sieved by 2.36 mm sieve.

## Crushing value test:

Amount of aggregates passed from 12.5 mm are sieve and retained on 10 mm IS sieve are taken.

Aggregates crushing value is given by (B/A)*100

Where B = fraction of weight passing from appropriate sieve.

A = Weight of SSD sample

## Flakiness and Elongation index:

The flakiness index for aggregates is the %age of the total wt. of the passing aggregates though various gauges of thickness gauge to the total sample wt.

The elongation index for aggregates is the %age of the total wt. of the retained aggregates though various gauges of length gauge to the total weight of the sample taken.

## 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:

$$\frac{W3}{W3-(W1-W2)} * 100$$

## Water Absorption test for aggregates:

Water absorption is determined by equation:

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

Here,

W1= Dry saturated weight

W2= Combined weight of material and basket in water

## 3.4.2 Test done 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).

### 3.4.3 Test done 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:

Viscosity test determines 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.

### 3.4.4 Test done for filler:

#### Specific gravity test:

Specific gravity of filler material was calculated by Le Chatlier Apparatus. The specific gravity of filler was found 2.1 and standard range is 1.9 to 2.8 for class F fly ash.

### 3.4.5 Test for bituminous mix:

**Table 3.6** Composition of SMA Mix (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 |

### Marshall Mix design

- **Preparation of sample:**

Various steps involved for the preparation of sample are as follows

**Weight of samples:**

In weighting process 3 samples with binder content 4 %, 4.5 %, 5 %, 5.5 %, 6%, and 7 % of each were made. Each sample weighs 1200 gm without the use of fiber and fibers added to samples also weight same with 0.3 % of fiber content added to samples.

**Heating of aggregates:**

After weighting the aggregates, the aggregates taken by gradation are mixed together and are kept for heating at 130 centigrade for 24 hrs.

**Heating of bitumen:** Bitumen was heated at a high temperature so that it gets liquefied easily when mixed with aggregates and fiber.

- **Mixing the components:**

A homogenous mix is prepared when all components are mixed with each other. These components like aggregates, bitumen, fly ash and fiber are mixed manually and care should be taken so that fiber doesn't get burnt in it.

**Fig 3.4** Mixing for the samples

**Putting in mould:** The mixture made by mixing is transferred to the moulds. This mould is a standard mould of Marshall Apparatus and is cylindrical having diameter of 100mm. This mould is also kept for heating for 24 hours and care should be taken that this mould and mixture may not get cold before hammering.

**Compaction:** For compaction purpose of the mix a fixed attached arrangement is there in which the mould filled with mix is placed. Compaction is mainly done by hammering the mould. The hammering is performed by giving 70 blows on each side of the mould or on both faces of specimen. Oiling is done to the interior of the mould and to the facing side of the hammer.

**Fig 3.5** Hammering of mould

**Fig 3.6** Cylindrical hammer

- **Finalizing the sample:** After hammering the sample on both sides the sample is extracted from the mould and according to the binder content provided to that sample is named so that the sample can be recognized later on. The sample is kept at room temperature for cooling down and then kept in water bath.

**Fig 3.7** A typical sample

**Fig 3.8** Samples prepared

- **Experiments performed:**

After the sample preparation the next step is to perform Marshall test which was done according to ASTM D 6927-06. According to this test we obtain flow values and stability for the specimens. Before performing the dry weight of samples used is calculated and are recorded. The sample's weight kept in water is noted down.

**3.4.6 Marshall test:** This method for the testing purpose of bituminous mixes by Marshall Apparatus is given by ASTM D 6927-06. Its various parts are

- **Breaking Head:** It consists of two segments one upper and other lower cylindrical segment made of cast iron or steel. The lower segment is provided with a base with two perpendicular rods of 12.5 mm extending upwards. Upper segment is having two guide sleeves for adjusting the binding or losing of the breaking head.

**Fig 3.9** Breaking head with sample

- **Compression loading machine:** It consists of a screw jack which is mounted on a frame and is designed to give a vertical uniform load of 50.6 mm/minute.
- **Load measuring device:** Calibrated ring of 20 KN with dial value indicator is used to measure deflection which is shown by ring applied at different loads. The sensitivity of ring is min about 50N. The dial indicator has an increment of 0.0025 millimeters. The ring is then attached to the test frame for transmitting the load to the breaking head.

- **Flow meter**: A dial gauge is used for measuring the flow. The initial and the final values are obtained by this dial gauge and the difference of the two values I taken as flow value for the sample.

**Fig 3.10** Sample without fiber (left) sample with fiber (right)

**3.4.7 Test procedure:** The inside surfaces of the breaking head and the guide rods are thoroughly cleaned before conducting the test**.** The upper test head the guide rods are lubricated for its free movement over them. If in case water is present, should be wiped from test head of the apparatus.

A specimens kept in water bath are to be taken and is placed in lower part of the breaking head. Then after the upper head segment over the specimen kept on lower head is properly adjusted over it in position of the loading machine. The dial gauge is kept on the guide rods.

The time for the sample from water bath to the final load determination should not exceed 30 seconds. The proving ring of the dial gauge measure the values and the readings are thus taken. In this case 100kg load is equal to the 36 divisions of the proving ring.

### 3.4.8 Parameters used:

1. Theoretical specific gravity of the mix ($G_t$):

$$G_t = W_1+W_2+W_3+W_b / (W_1/G_1+W_2/G_2+W_3/G_3+W_b/G_b)$$

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):

$$Gm = Wa / (Wa-Ww)$$

Here,

Wa = weight of sample in air.

Ww = wt. of sample in water.

3. Air voids (Vv):

$$Vv = (Gt-Gm) /Gt * 100$$

Here,

Gt = Theoretical sp. Gravity of the mix.

Gm = Bulk sp. Gravity of the mix.

4. Percentage of volume of bitumen (Vb):

$$Vb = (Wb/Gb)/(W1+W2+W3+Wb)/Gm$$

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

$$VMA = Vv + Vb$$

6. Voids filled with bitumen (VFB):

$$VFB = Vb * 100 / VMA$$

## CHAPTER 4

## RESULTS AND DISCUSSIONS

### 4.1 Laboratory investigation:

#### 4.1.1 Gradation of aggregates:

**Table 4.1** Gradation of aggregates

| Sieve size | Upper limit | Lower limit | Adopted |
|---|---|---|---|
| 19 | 100 | 100 | 100 |
| 13.2 | 100 | 90 | 95 |
| 9.5 | 75 | 50 | 63 |
| 4.75 | 40 | 25 | 33 |
| 2.36 | 28 | 20 | 25 |
| 1.18 | 26 | 18 | 21 |
| 0.6 | 22 | 15 | 18 |
| 0.3 | 20 | 12 | 15 |
| 0.15 | 15 | 8 | 12 |
| 0.075 | 12 | 8 | 11 |

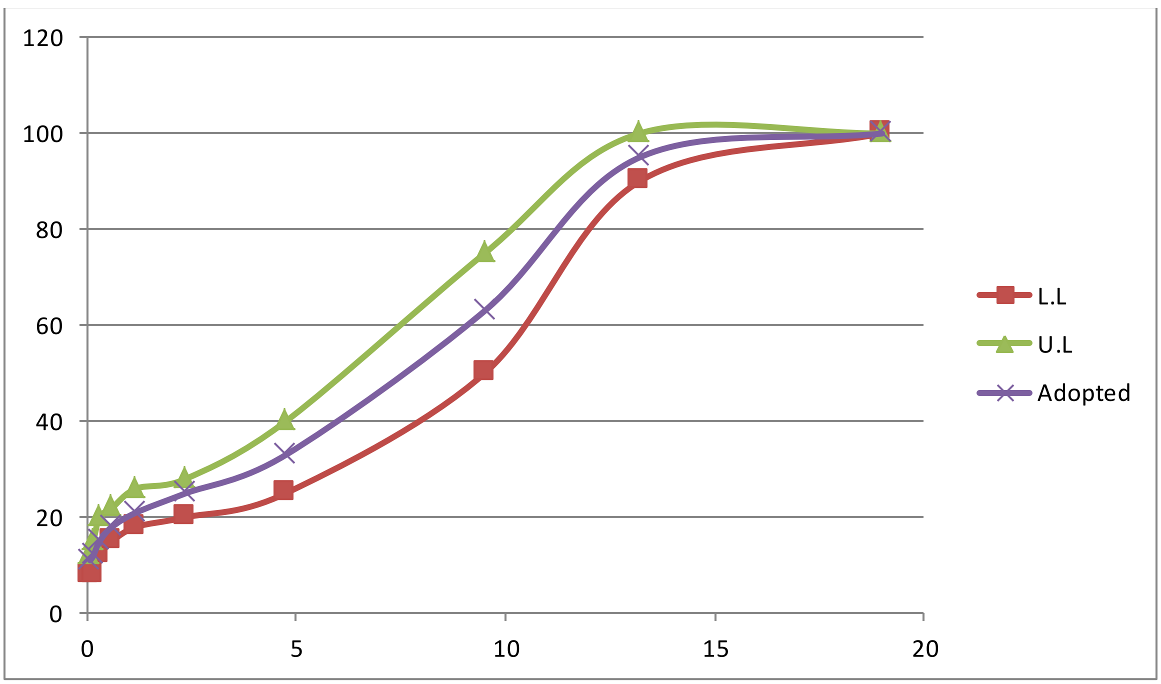


**Fig 4.1** Gradation of aggregates

### 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 (w1) | 2.5 kg |
| Weight of aggregates retained (w2) | 1952 gm |
| Weight of aggregates passing from 1.7mm sieve (w3) | 540 gm |
| Abrasion value = w1-w2/w1*100 | 22 % less than < 25 %, satisfactory value. |

**Table 4.3** Impact test as per IS: 2386 (P-4)

| | |
|---|---|
| Weight of mould | 1.275 kg |
| Weight of mould with sample | 1.794 kg |
| Weight of sample (w1) | 535 gm |
| Percentage retained | 500 gm |
| Percentage passing from 2.36 sieve after 15 blows by hammer (w2) | 40 gm |
| Impact value = w2/w1*100 | 10 % < 18 % , satisfactory |

**Table 4.4** Crushing value test

| Weight of oven dried sample in gm (A) | Weight of retained aggregates on 2.36 mm sieve in gm | Weight of passing aggregates in gm (B) | Abrasion value |
|---|---|---|---|
| 10000 | 8502 | 1498 | 14.98 < 25% |

**Table 4.5** 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 4.6** Specific gravity test

| | |
|---|---|
| Total weight of aggregates | 2.0 kg |
| Weight of bucket in air | 0.9 kg |
| Weight of submerged bucket (w2) | 0.7 kg |
| Weight of bucket + Aggregates | 2.9 kg |
| Weight of bucket + aggregates (submerged)/ w1 | 1.9 kg |
| Dry weight of aggregates (w3) | 1.8 kg |
| Specific Gravity = w3/w3-(w1-w2) | Specific gravity= 2.9 , 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 waterW2 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 in mm | IS:1203-1978 | 67.9 |
| Softening test (degree) | IS:1203-1978 | 48.6 |
| Specific gravity | IS:1203-1978 | 1.03 |
| Ductility in cm | IS:1203-1978 | 41.5 cm/min |

### 4.1.4 Sieve analysis for Mix:

Total weight of sample = 1200 gm

**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 | 95 | 5 | 57.6 | 57.3 | 57.00 | 56.7 | 56.4 | 55.8 |
| 9.5 | 50-75 | 63 | 32 | 368.64 | 366.72 | 364.8 | 362.88 | 360.96 | 357.12 |
| 4.75 | 25-40 | 33 | 30 | 345.6 | 343.8 | 342 | 340.2 | 338.4 | 334.8 |
| 2.36 | 20-28 | 25 | 8 | 92.16 | 91.68 | 91.2 | 90.72 | 90.24 | 89.28 |
| 1.18 | 18-26 | 21 | 4 | 46.08 | 45.84 | 45.6 | 45.36 | 45.12 | 44.64 |
| 0.6 | 15-22 | 18 | 3 | 34.56 | 34.38 | 34.2 | 34.02 | 33.84 | 33.48 |
| 0.3 | 12-20 | 15 | 3 | 34.56 | 34.38 | 34.2 | 34.02 | 33.84 | 33.48 |
| 0.15 | 8-15 | 12 | 3 | 34.56 | 34.38 | 34.2 | 34.02 | 33.84 | 33.48 |
| 0.075 | 8-12 | 11 | 2 | 23.04 | 22.92 | 22.8 | 22.68 | 22.56 | 22.32 |
| Filler | 0 | 0 | 10 | 115.2 | 114.6 | 114.0 | 113.4 | 112.8 | 111.6 |
| Binder | | | | 48 | 54 | 60 | 66 | 72 | 84 |

**Table 4.10** Gradation of samples with fiber

| 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 | 95 | 5 | 57.42 | 57.12 | 56.82 | 56.52 | 56.22 | 55.62 |
| 9.5 | 50-75 | 63 | 32 | 367.48 | 365.568 | 363.648 | 361.72 | 359.80 | 355.968 |
| 4.75 | 25-40 | 33 | 30 | 344.52 | 342.72 | 340.92 | 339.12 | 337.32 | 333.72 |
| 2.36 | 20-28 | 25 | 8 | 91.872 | 91.392 | 90.912 | 90.432 | 89.952 | 88.992 |
| 1.18 | 18-26 | 21 | 4 | 45.936 | 45.696 | 45.456 | 45.216 | 44.976 | 44.496 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0.6 | 15-22 | 18 | 3 | 34.452 | 34.272 | 34.092 | 33.912 | 33.732 | 33.372 |
| 0.3 | 12-20 | 15 | 3 | 34.452 | 34.272 | 34.092 | 33.912 | 33.732 | 33.372 |
| 0.15 | 8-15 | 12 | 3 | 34.452 | 34.272 | 34.092 | 33.912 | 33.732 | 33.372 |
| 0.075 | 8-12 | 11 | 2 | 22.968 | 22.848 | 22.728 | 22.608 | 22.488 | 22.248 |
| Filler | 0 | 0 | 10 | 114.84 | 114.24 | 113.64 | 113.04 | 112.44 | 111.24 |
| Binder | | | | 48 | 54 | 60 | 66 | 72 | 84 |
| Fiber (grams) | | | | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 |

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

| Bitumen (%) | Wsa | Wsw | flow | stability | Avg. flow | Avg. stability |
|---|---|---|---|---|---|---|
| 4 | 1207 | 724 | 2.2 | 6.4230 | 2.20 | 6.834 |
| 4 | 1204 | 710 | 1.9 | 6.8910 | | |
| 4 | 1202 | 713 | 2.1 | 7.1907 | | |
| 4.5 | 1198 | 709 | 3.0 | 8.6190 | 3.03 | 8.7594 |
| 4.5 | 1200 | 723 | 3.2 | 8.7084 | | |
| 4.5 | 1206 | 722 | 2.9 | 8.9510 | | |
| 5 | 1205 | 717 | 3.5 | 8.8021 | 3.56 | 8.899zaa |
| 5 | 1199 | 707 | 3.9 | 8.1103 | | |
| 5 | 1205 | 715 | 3.3 | 7.9573 | | |
| 5.5 | 1207 | 726 | 4.5 | 7.3691 | 4.1 | 8.5237 |
| 5.5 | 1201 | 711 | 3.8 | 9.3076 | | |
| 5.5 | 1210 | 730 | 4.0 | 8.8945 | | |
| 6 | 1201 | 702 | 4.7 | 8.3920 | 5.03 | 7.8762 |
| 6 | 1199 | 704 | 5.5 | 7.9537 | | |
| 6 | 1203 | 721 | 4.9 | 7.3430 | | |
| 7 | 1197 | 716 | 5.9 | 6.3964 | 6.2 | 6.5042 |
| 7 | 1190 | 704 | 6.1 | 6.1682 | | |
| 7 | 1196 | 708 | 6.4 | 6.9480 | | |

**Table 4.12** Stability and flow value for the samples with fibers

| Binder (%) | Wsa | Wsw | Flow | stability | Avg. flow | Avg. stability |
|---|---|---|---|---|---|---|
| 4 | 1204 | 716 | 2.9 | 6.4190 | 2.966 | 6.8764 |
| 4 | 1202 | 713 | 3.1 | 6.8854 | | |
| 4 | 1199 | 709 | 2.9 | 7.3248 | | |
| 4.5 | 1203 | 711 | 3.0 | 8.1123 | 3.16 | 8.4408 |
| 4.5 | 1198 | 720 | 3.3 | 8.8854 | | |
| 4.5 | 1200 | 717 | 3.2 | 8.3248 | | |
| 5 | 1205 | 706 | 3.3 | 9.8105 | 3.366 | 9.909 |
| 5 | 1199 | 713 | 3.6 | 9.7808 | | |
| 5 | 1207 | 709 | 3.2 | 10.1359 | | |
| 5.5 | 1204 | 715 | 3.9 | 9.9210 | 4.01 | 8.5088 |
| 5.5 | 1208 | 717 | 3.8 | 8.8014 | | |
| 5.5 | 1196 | 711 | 4.3 | 7.704 | | |
| 6 | 1202 | 714 | 5.6 | 8.379 | 4.8 | 7.860 |
| 6 | 1207 | 713 | 4.6 | 6.710 | | |
| 6 | 1200 | 716 | 4.2 | 8.501 | | |
| 7 | 1198 | 703 | 5.2 | 7.0124 | 5.7 | 6.5389 |
| 7 | 1203 | 705 | 6.1 | 6.492 | | |
| 7 | 1204 | 715 | 5.8 | 6.1121 | | |

## 4.2 Marshal test results:

Various Marshall Properties determined during performing the experiment are stability, flow values. The stability portion for 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.

**4.13 Table:** Marshall Parameters for samples with fibers

| Binder Content (%) | Avg. VMA | Avg. Va | VFB | Stability (KN) | Flow (mm) |
|---|---|---|---|---|---|
| 4 | 14.04 | 4.66 | 70.78 | 6.876 | 2.96 |
| 4.5 | 13.97 | 3.90 | 78.68 | 8.440 | 3.16 |
| 5 | 13.88 | 2.96 | 84.56 | 9.909 | 3.36 |
| 5.5 | 14.78 | 2.81 | 86.55 | 8.508 | 4.01 |
| 6 | 15.72 | 2.88 | 89.92 | 7.860 | 4.8 |
| 7 | 16.19 | 2.11 | 93.02 | 6.538 | 5.7 |

## 4.3 Graphs obtained:

### 4.3.1 Stability vs. binder content

Graph between stability and bitumen (%age) is plotted in which the bitumen content is in x axis and stability of the samples is plotted in y axis. Stability is in kilo Newton and binder content is in percentage.

**Table 4.14** Stability values for samples without and with fibers

| Binder | 4 | 4.5 | 5 | 5.5 | 6 | 7 |
|---|---|---|---|---|---|---|
| Without fiber | 6.834 | 8.7594 | 8.899 | 8.5237 | 7.8762 | 6.5042 |
| With fiber | 6.8764 | 8.4408 | 9.909 | 8.5088 | 7.860 | 6.5389 |

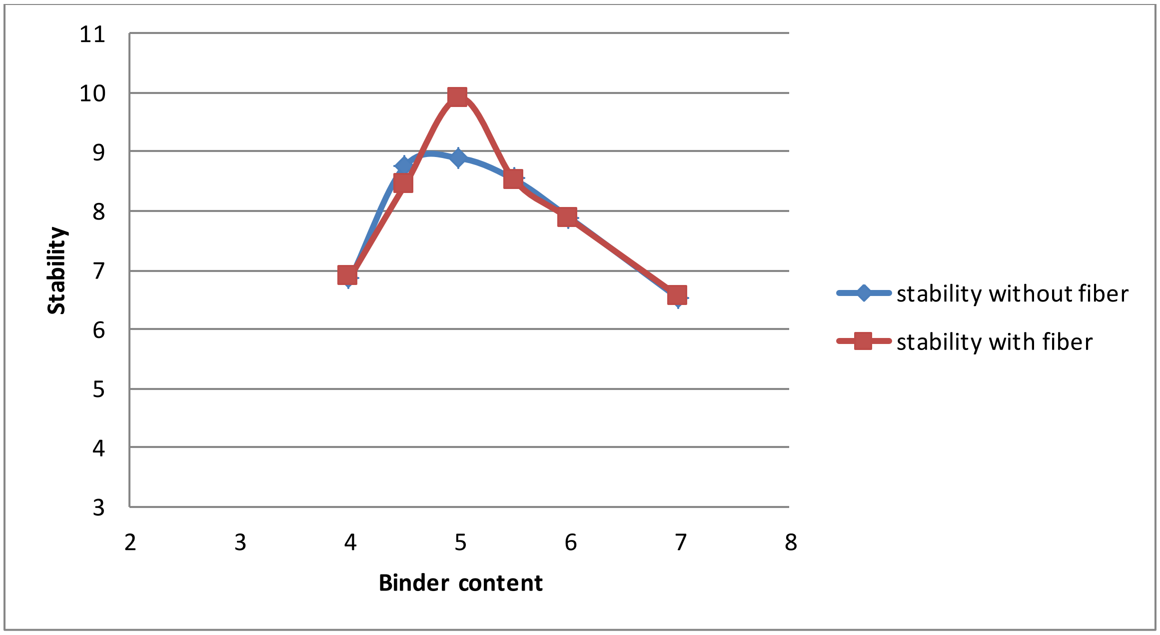


**Fig 4.2** Comparision of stability with and without fibers at differenr binder contents.

### 4.3.2 Flow value vs. bitumen content

Graph between flow values (mm) vs bitumen content for the fibers. Bitumen content is in x axis and flow values are in y axis for the samples with and without fibers

**Table 4.15** Flow value 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 | 3.36 | 4.01 | 4.8 | 5.7 |

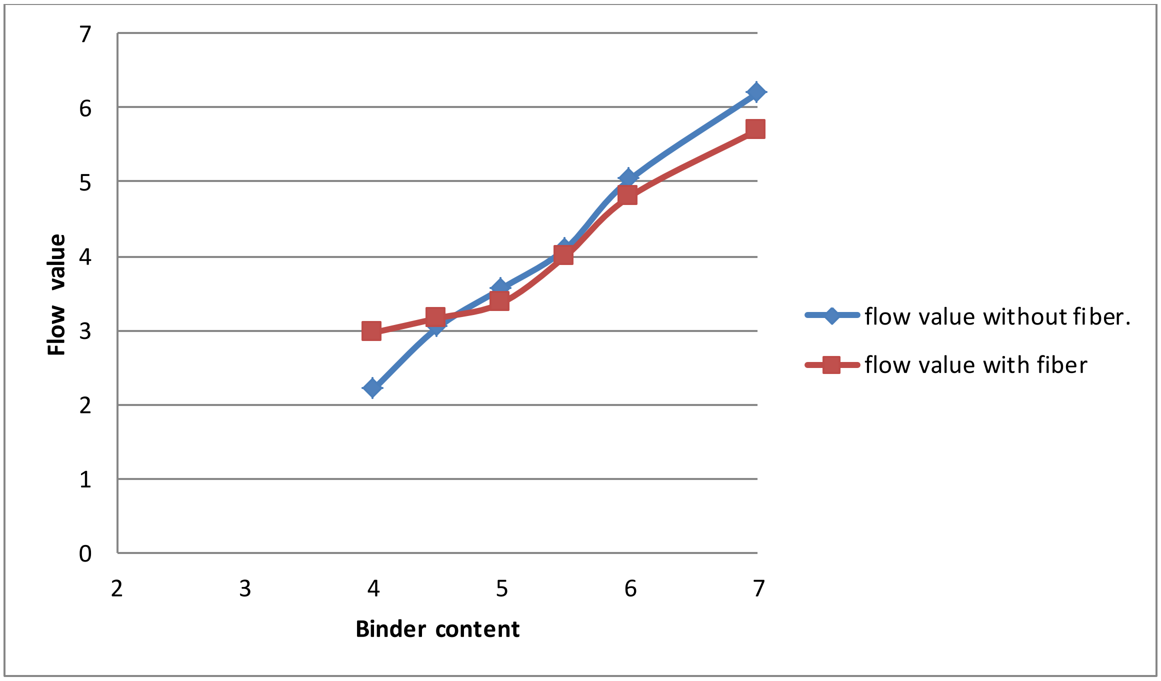


**Fig 4.3** Comparison of flow values at respective binder contents with fiber and without fibers

### 4.3.3 VMA Vs. binder content.

Graph of VMA in (%age) and binder content in (%age) are plotted in which VMA is in y axis and binder content is in x axis.

**Table 4.16** VMA vs. Binder content for samples without and with fiber

| Binder (%) | 4 | 4.5 | 5 | 5.5 | 6 | 7 |
|---|---|---|---|---|---|---|
| Without fiber | 14.03 | 13.93 | 14.39 | 14.48 | 15.50 | 16.33 |
| With fiber | 14.04 | 13.97 | 13.88 | 14.78 | 15.72 | 16.19 |

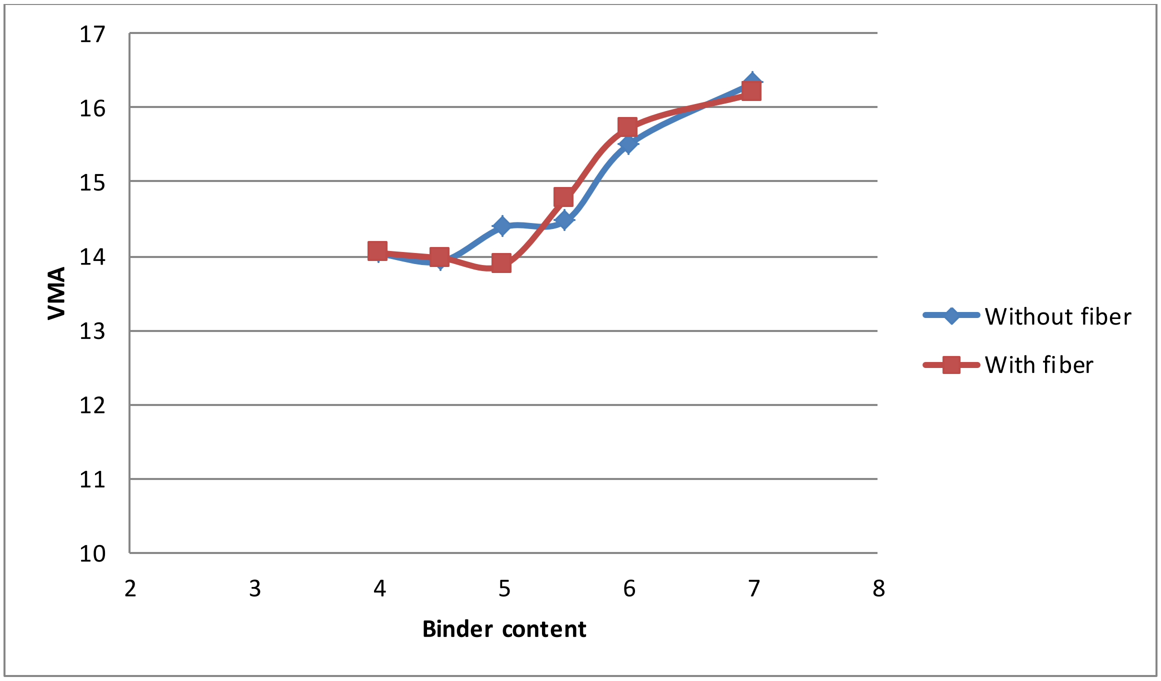


**Fig 4.4** Graph between VMA vs. binder content

### 4.3.4 VFB vs. binder content:

Graph between voids filled with bitumen VFB (% age) and bitumen content (% age) are plotted with VFB in vertical axis and bitumen content in horizontal axis.

**Table 4.17** VFB vs. Binder content without and with fiber

| Binder (%) | 4 | 4.5 | 5 | 5.5 | 6 | 7 |
|---|---|---|---|---|---|---|
| Without fiber | 72.26 | 79.12 | 82.09 | 84.23 | 88.35 | 91.24 |
| With fiber | 70.78 | 78.68 | 84.56 | 86.55 | 89.92 | 93.02 |

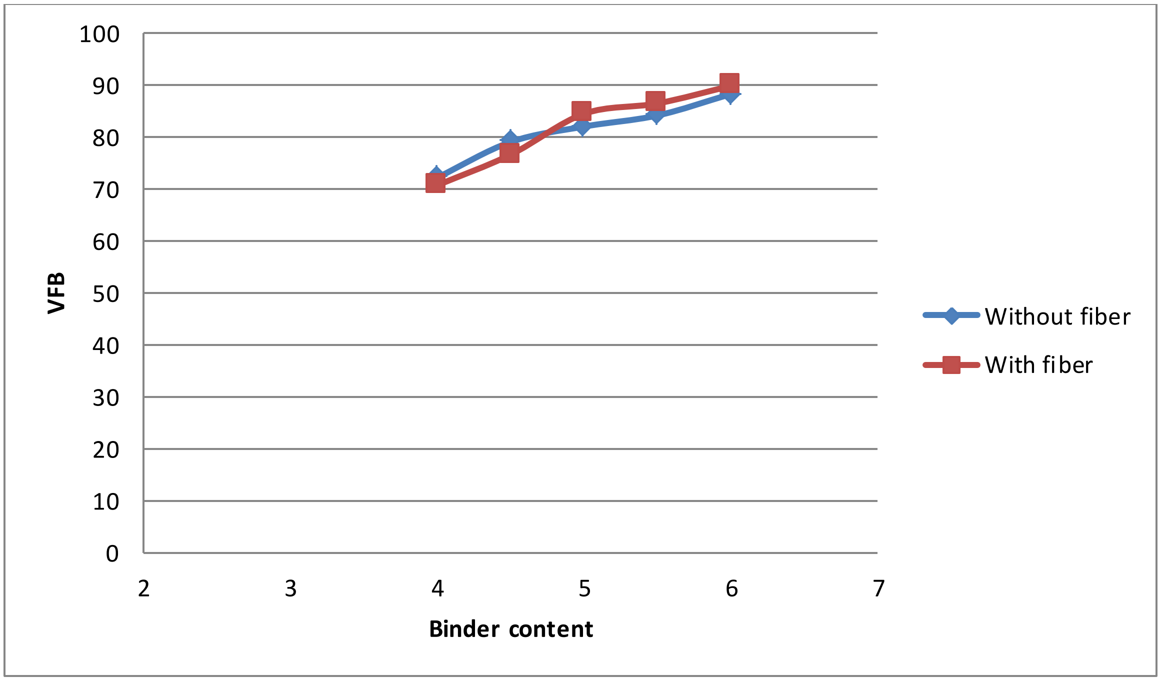


**Fig 4.5** Graph between VFB vs. binder content

### 4.3.5 Volume of voids vs. binder content:

Graph for volume of voids at different binder content is plotted in which volume of voids is shown in y-axis and binder content in x-axis.

**Table 4.18** Volume of voids vs. Binder content without and with fibers

| Binder (%) | 4 | 4.5 | 5 | 5.5 | 6 | 7 |
|---|---|---|---|---|---|---|
| Without fiber | 4.51 | 3.71 | 3.33 | 2.96 | 2.62 | 2.29 |
| With fiber | 4.66 | 3.9 | 2.96 | 2.81 | 2.88 | 2.11 |

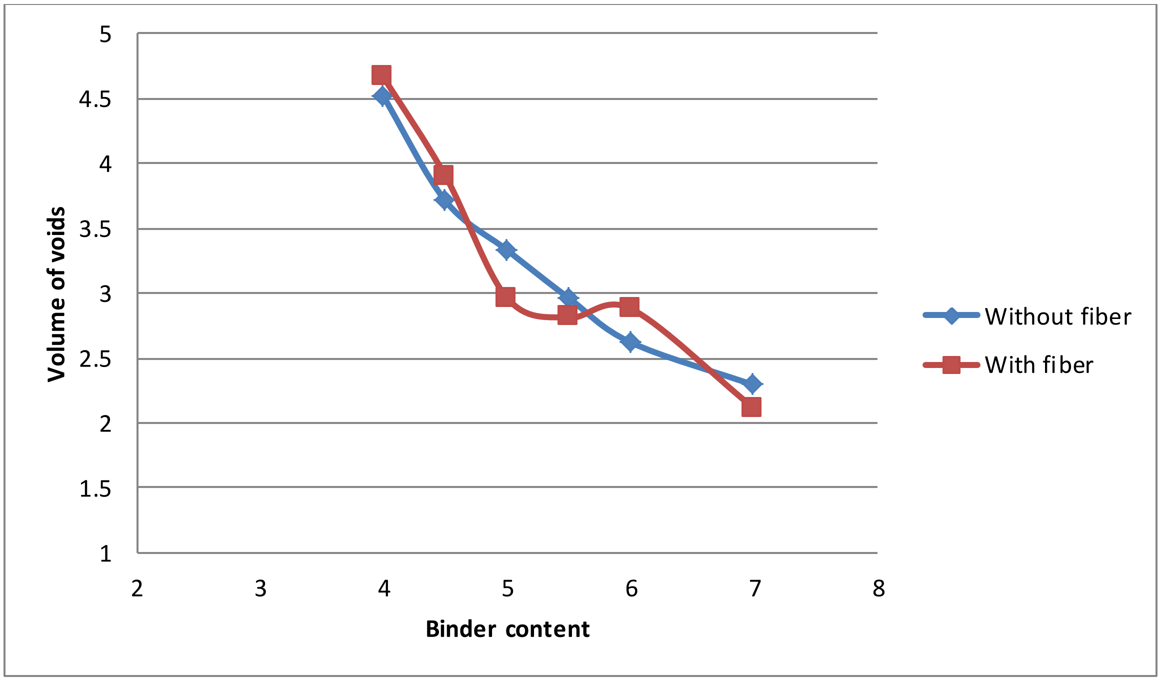


**Fig 4.6** Graph between Volumes of voids vs. binder content

### 4.3.6 Unit weight vs. Binder content:

Graph for unit weight vs. binder content is plotted in which the binder content is in horizontal x-axis and unit weight is in vertical y-axis.

**Table 4.19** Unit weight vs. binder content

| Binder (%) | 4 | 4.5 | 5 | 5.5 | 6 | 7 |
|---|---|---|---|---|---|---|
| Without fibers | 2.45 | 2.48 | 2.49 | 2.52 | 2.51 | 2.48 |
| With fibers | 2.45 | 2.50 | 2.53 | 2.59 | 2.60 | 2.58 |

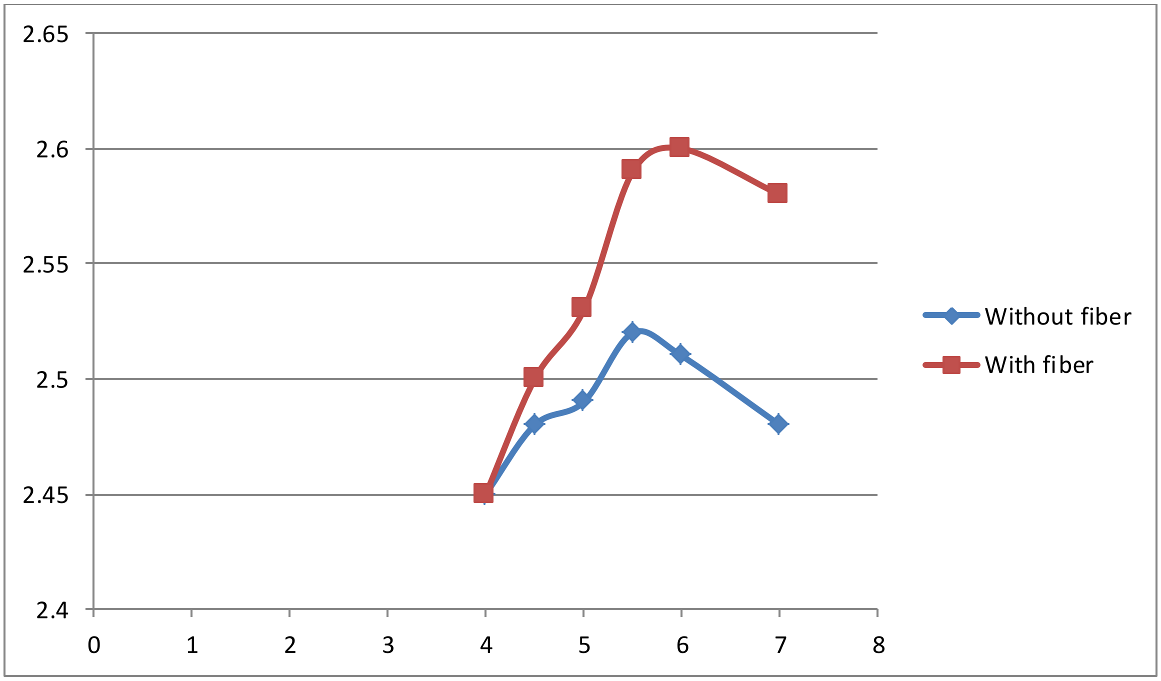


**Fig 4.7** Unit weight vs. binder content

## 4.4 Determining the mix design's parameters:

From the above curves the mix properties at 4% air voids the OBC obtained was 5.15% for samples when 0.3% of fiber was added to Marshall Samples. Now by comparing the binder content for both samples made without fiber and with fiber at 5.15% the results obtained of Marshall Properties is as follows:

**Table 4.20** Various mixture parameters at 4% air voids

| | Without fiber | With Fiber |
|---|---|---|
| Binder Content (%) | 5.15 | 5.15 |
| Stability (KN) | 8.78 | 9.48 |
| Flow (mm) | 3.72 | 3.55 |
| VMA (%) | 14.42 | 14.15 |
| VFB (%) | 82.73 | 85.15 |

## 4.5 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 decrease in stability value it was because with increase of binder content the bond between aggregates and bitumen gets stronger and with further addition it decreases and the bond gets 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 and also at OBC. 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 values at initial falls because of the re-orientation of the aggregates with 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 in increased VMA value.

4. 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 theoretically decreases when binder addition is increased it is due to the fact that it fills up the voids present in mix. The $V_a$ was less near OBC of samples with fiber because of the 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 Concluding remarks:

The literature review provides a general idea about the previous researches made which were done on bituminous mixes such as SMA, dense grade mixture. Observing the chief points from these researches in mind, the selection for SMA composition based on current study is used. In this research an effort is made to evaluate different properties of SMA by performing various tests like Marshall Test. The binder's grade used in this research is VG-30 grade bitumen. Fly ash is added as filler in the research. MORT&H gradation is adopted. In this research fiber which was used is Hemp fiber and other materials are added to mix. Fiber is added to avert the drain down of bitumen and it is found in previous researches that by adding fiber the drain down of binder gets decreased from asphalt film. At OBC of samples it was showing increased stability when compared to the samples made without fibers at same binder content. The fiber added was taken 0.3% which is a standard value for SMA mix samples. This fiber is abundantly available across the world as also in India and is considered as a waste because it is illegal in India. This fiber has not been used yet in SMA Mix or in past literature review.

## 5.2 Future Scope:

- Hemp fiber can also be tested /checked with other type of bitumen of different grades.
- Other type of test with other HMA type and super paves.
- Other natural and synthetic fibers with different content of fiber can also be tried.
- Future investigation of hemp fiber used in rigid pavements.
- Use of other type of fillers can also be tested with hemp fiber to check the performance.
- Legalization of cannabis plant in India, so with the help of this fiber we can utilize it in other useful purposes.

# REFERENCES


**1.** Brown, E. R., & Manglorkar, H. (1993). Evaluation of laboratory properties of SMA mixtures. *National Center for Asphalt Technology, Report*, (93-5), 159.

**2.** Bradley J. Putman and Serji N. Amirkhanian (2004), "Utilization of Waste Fibre in Stone Matrix Asphalt Mixtures", *Resources, Conservation and Recycling, Volume 42, Issue 3, pp 265-27.*

**3**. Kamraj C., Kumar G., Sharma G., Jain P.K. and Venkanna Babu P. (2004), "Laboratory Studies on the Behaviour of Stone Matrix Asphalt vis-à-vis Dense Graded Bituminous Mixes using Natural Rubber Powder (Wet Process)", *Highway Research Bulletin, No 71, IRC, New Delhi.*

**4.** Reddy K.S., Palit S.K. and Pandey B.B. (2004), "Laboratory Evaluation of Crumb Rubber Modified Asphalt Mixes", *Journal of Materials in Civil Engineering, ASCE, pp 45-53*

**5.** Huaxin Chen and Qinwu Xu (2010), Experimental study of fibers in stabilizing and reinforcing asphalt binder, Fuel 89 (2010) 1616–1622

**6.** Muniandy, R., & Huat, B. B. (2006). Laboratory diameteral fatigue performance of stone matrix asphalt with cellulose oil palm fiber. *American Journal of Applied Sciences*, *3*(9), 2005-2010.

**7.** Bindu, C. S., & Beena, K. S. (2013). COMPARISON OF SHEAR STRENGTH CHARACTERISTICS OF STONE MATRIX ASPHALT MIXTURE WITH WASTE PLASTICS AND POLYPROPYLENE

**8.** Ahmadinia, E., Zargar, M., Karim, M. R., Abdelaziz, M., & Shafigh, P. (2011). Using waste plastic bottles as additive for stone mastic asphalt.*Materials & Design*, *32*(10), 4844-4849.

**9.** Punith, V. S., Suresha, S. N., Raju, S., Bose, S., & Veeraragavan, A. (2011). Laboratory investigation of open-graded friction-course mixtures containing polymers and cellulose fibers. *Journal of Transportation Engineering*, *138*(1), 67-74.

**10.** Kumar, P., Chandra, S., & Bose, S. (2007). Laboratory investigations on SMA mixes with different additives. *International Journal of Pavement Engineering*, *8*(1), 11-18.

**11.** Xue, Y., Hou, H., Zhu, S., & Zha, J. (2009). Utilization of municipal solid waste incineration ash in stone mastic asphalt mixture: pavement performance and environmental impact. *Construction and Building Materials*, *23*(2), 989-996.

**12.** H. Jony Hassan, Y. Jahad Israa (2010), "The Effect of Using Glass Power filler on Hot Asphalt Concrete Mixture Properties*", Engg and Technology journal, vol.29, Issue1*