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Effect of addition of Medium Steel Fibers on Dense Bituminous Macadam

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ABSTRACT

In this research paper the use of fibres emerged as a need for improving the flexibility and tensile strength of the bituminous mixes due to increase in heavy traffic density in terms of number of axles, wheel loads and high tyre pressures resulting from vehicles. Fibre-modified bituminous mixtures are generally comprised of matrix and fibres. The adhesion between fibres and matrix along with shape and size of fibres affects the performance of these mixtures. Bituminous Mixes are most commonly used all over the world in pavement construction. India has a network of over 5,897,671 kilometres (3,664,643 mi) of roads as of 31 March 2017, the second largest road network in the world. About 98 % of the paved roads in India have flexible pavements, within which are included surfacing of various types and thickness. The bituminous mix design aims to determine the proportion of bitumen, filler, fine aggregates, and coarse aggregates to produce a mix which is workable, strong, durable and economical. The horizontal stresses induced between the layers may result in easily crack formation when loads are heavy and any local settlements also lead to cracking of the asphalt layers. Pavement distresses, such as: cracking, pot-holes, permanent deformation and surface wear are constantly reported by highway agencies. Some undesirable effects can occur mainly due to high number of vehicles imposing repetitive higher axle loads on roads, environmental condition and construction errors. These usually cause permanent deformation (rutting), fatigue and low temperature cracking, service life of the road pavement is going to be decreased. Fatigue and rutting are the most common distresses in road pavement which result in the shortening of pavement life and increase maintenance cost as well as road user cost. So, it is vital to find out ways to delay the asphalt pavement deterioration and increase its service life. Many studies have been conducted to improve road pavement characteristics which can provide comfortable ride and ensure greater durability and longer service life against climate changes and traffic loading.

Keywords : X12M steel, surface milling, face milling cutter, surface roughness

INTRODUCTION

Roads: Bridging the gap for progressive future

In order to understand the benefits and results of the steel fibers as additive in bituminous mixes, first we have to study about the history of roads with the present condition of road for understanding the economical use of steel fiber in composite pavement of roads construction. In the ancient times, it was nothing more than a scanty network of roads (tracks) for humans to use in order to reach out for its basic requirement. These tracks are used not only by humans but also by animals. More roads communication than these simple tracks did not appear until the increasing number of people in that specific areas and the social structure and organization of communities demanded more permanent contact between communities.

Roads are an integral part of the transport system. A country's road network should be efficient in order to maximize economic and social benefits. They play a significant role in achieving national development and contributing to the overall performance and social functioning of the community. It is acknowledged that roads enhance mobility, taking people out of isolation and therefore poverty. Roads play a very important role in the socio-economic development of the country but meanwhile this expansion also pose great challenges to the safety and security of the travelling public. The road transport industry is the backbone of strong economies and dynamic societies.

Roads exist in India for the last 5000 years. In developing country like India, the type and condition of highway facility will affect the economic, social, cultural, and industrial development of the country. Hence it is very important that the roads are planned, designed, constructed, operated, and maintained in such a way that it will be able to fulfill its requirements. Since road networks are largest and most important connecting way, it should be economical as well long lasting. Basically, there are three types of road pavements such as flexible pavement, rigid pavement, and semi rigid pavement. Rigid pavement is constructed from cement concrete while flexible pavement is made up of bituminous mixes. Since India is a developing country, the road transportation is vital to India's economy. Roads enable the country's transportation sector to contribute 4.7 percent towards India's gross domestic product (GDP). India has a road network of over 5,605,293 kilometers (km), the second largest road networking the world. At 1.66 km of roads per square kilometer of land, the quantitative density of India's road network is higher than that of Japan (0.91), United States (0.67), China (0.46), Brazil (0.18), and Russia (0.08). To address its large population India has less than 3.8 km of roads per 1000 people, including all its paved and unpaved roads. It is some of the lowest road and highway densities in the world. For example, United States has 21 kilometers of roads per 1000 people, while France about 15 kilometers per 1000 people. In terms of all season, 4 or more lane highways, developed countries like United States and France have a highway density per 1000 people is 15 times higher than that of India. India in its recent past did not allocate enough resources to build or maintain its road network. This has changed since 1995, with major efforts currently underway to modernize the country's road infrastructure. Indian road network is administrated by various government authorities. The following table shows the total length of India's road network by type of road as on 31 March 2017.

Table 1.1: Total length of India's road network

Road Classification	Length (km)
Expressway	2000 km
National Highways	1,01,011 km
State Highways	1,76,166 km
District Roads	5,61,940 km
Rural and urban Roads	4,445,067 km
Projected Roads	3,19,109 km
Total (approx.)	**5,605,293 km**

Evolution of mix design

During 1900's, the bituminous paving technique was used on rural roads, so as to handle rapid removal of fine particles in the form of dust from water bound Macadam, which was caused due to rapid growth of automobiles. At initial stage, heavy oils were used as dust palliative. An eye estimation process, called pat test was used to estimate requisite quantity of the heavy oil in the mix. By this process, the mixture was patted like a pancake shape and pressed against a brown paper. Depending on the extent of stain it made on the paper, the appropriateness of the quantity was adjudged. In the mid-1920s, Charles Hubbard and Frederick Field, with the newly created Asphalt Association (later the Asphalt Institute), developed a method of mix design called the Hubbard Field Method of Design, which was originally developed on sand-asphalt mixture. Mixes with large aggregates could not be handled in Hubbard field method. This was one of the limitations of this procedure. Francis Hveem, a project engineer of California Department of Highways, developed the Hveem Stabilometer. Hveem did not have any prior experience on judging the just right mix from its color, and therefore decided to measure various mix parameters to find out optimum quantity of bitumen. Hveem used the surface area calculation concept, to estimate the quantity of bitumen required. Moisture susceptibility and sand equivalent tests were added to the hveem test in 1946 and 1954 respectively. Bruce Marshall developed the Marshall testing machine just before the World War-II. It was adopted in the US Army Corps of Engineers in 1930's and subsequently modified in 1940's and 1950's. Superpave mix design was developed as part of the Strategic Highway Research Program (SHRP) from 1987 to 1993. The objective of the Asphalt Research Program was to develop a performance-based asphalt binder specification, a performance-based asphalt mixture specification, and a mix design system. The Performance-Grade (PG) asphalt binder specification is the result of the research. PG is not used in India due to complexity and expensive equipment's.

In India Marshall Method is adopted ASTM D 1559 and a standard practice for Bituminous Mixes is adopted.

Typical composition and structure of flexible pavement

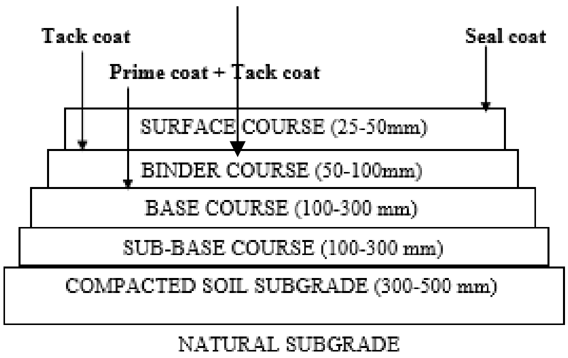


Fig. 1.1 Structure of Flexible Pavement

Surface course (25-50 mm): It is a layer directly in contact with traffic load and hence generally made up of superior quality materials. There are number of choices are available for surface course like dense graded bituminous concrete, semi dense bituminous concrete, mix seal surfacing, premix carpet, bituminous penetration macadam and surface dressing.

Binder course (50-100 mm): This layer is provided between the base course and surface course to transmit the load to the base course. The binder course generally consists of aggregates having less asphalt and does not require quality as high as surface course.

Base course (100-300 mm): The base course is the layer of material immediately beneath the surface of binder course. It provides additional load distribution and contributes to sub surface drainage. It usually composed of crushed stone, crushed slag and untreated stabilized materials.

Sub base course (100-300 mm): The sub base course is the layer of material provided immediately below the base course and primary functions are to provide structural, improve drainage, and reduce the intrusion of fines from the sub-grade in the pavement structure.

Sub-grade (300-500 mm): Sub-grade is the layer of natural soil prepared to receive the layers of pavement materials placed over it. The loads on the pavement are ultimately received by the soil sub-grade for dispersion to the earth mass. It is essential that at no time the sub-grade is overstressed. Therefore, it is desirable that at least top 50 cm layer of the sub-grade is well compacted under controlled conditions of optimum moisture content and maximum dry density.

Types of bituminous layers

There are several types of road construction that are currently in practice in India. These can be broadly categorized in following manner:

Surface Course

- **Bituminous Concrete -** Bituminous concrete is well graded material premixed with binder of optimum quantity, laid, and compacted to serve as a wearing course. It is either laid in single course or multiple layers. A single layer can be 30mm to 50mm thick. It is generally used for Expressways or NH or roads carrying heavy traffic.
- **Semi-Dense Bituminous Concrete** - Semi-Dense Bituminous Concrete consists of a single coarse of aggregates of varied sizes thoroughly mixed with the binder, laid on a previously prepared bituminous base to a thickness of 25 mm or 40 mm to serve as a wearing coarse. It can also be laid in multiple layers.
- **Premix Carpet with Seal Coat -** Premix carpet consists of small sized aggregates premixed with bituminous binder laid and compacted in single coarse of 20 mm thickness. It serves as a surface course. It is usually followed by application of seal coat to seal the voids and enhance the riding quality and as well as life of surface.
- **Bituminous Penetration Macadam -** It may be used as a base course for flexible pavements in short road stretches or in small projects where hot mix plant facility is not available. The coarse aggregates of specified size are spread and compacted well in dry state; the compacted thickness of an individual layer of penetration macadam is either 50 mm or 75 mm.

Bituminous Surface Dressing - Bituminous surface dressing is provided over a specified base course or existing pavement to serve as a thin wearing coat. Surface dressing work consists of application of suitable grade of bitumen or emulsion by spraying over a prepared base course or existing pavement surface followed by spreading specified size of hard aggregates at the recommended rate and rolling.

Bituminous Base Course

- **Dense Bituminous Macadam** - DBM is well graded material premixed with binder and laid to serve as base course in thickness 50 mm to 100 mm. It is also known as dense graded Bituminous Macadam.
- **Bituminous Macadam** -In this aggregate premixed with bituminous binder laid immediately after mixing in single course to a thickness of 50 mm to 100 mm or in multiple courses. It is usually used as a base course

under semi dense bituminous concrete, also used in low cost construction or village roads.

Due to wide use of BC as a surface course and DBM as bituminous base course in India, these two bituminous mixes will be taken for study in this research to improve their performance and serviceability by using steel fibers. **Bituminous mix design**

Objective of Bituminous Mix Design:

Asphaltic Bituminous concrete consists of a mixture of aggregates continuously graded from maximum size, generally less than 25 mm, through the fine filler that is smaller than 0.075 mm. Sufficient bitumen is added to the mix so that the compacted mix is effectively impervious and will have acceptable dissipative and elastic properties. The bituminous mix design aims to determine the proportion of bitumen, filler, fine aggregates, and coarse aggregate to produce a mix, which is workable, strong, durable, and economical. The objective of the mix design is to produce a bituminous mix by proportioning various components to have:

1. Sufficient bitumen to ensure a durable pavement.
2. Sufficient strength to resist shear deformation under traffic at higher temperature.
3. Sufficient air void in the compacted bitumen to allow for additional compaction by traffic.
4. Sufficient workability to permit easy placement without segregation.
5. Sufficient resistance to avoid premature cracking due to repeated bending by traffic.
6. Sufficient resistance at low temperature to prevent shrinkage cracks.

Dense Bituminous Macadam

Dense Bituminous Macadam is commonly used as a bituminous base course for heavy traffic loads. It consists of bitumen as a binder and well graded aggregates premixed and laid down in a layer of 50 to 100 mm thickness. It is also known as Dense graded bituminous macadam.

The combined grading of aggregate mix should confirm the following as shown below.

Table -1.2: Combined Grading of Aggregates for DBM

Sieve Size (mm)	% Finer	
	Grading - 1 (75 to 100 mm)	Grading - 2 (50-75 mm)
37.5	95- 100	100
26.5	63 - 93	90 - 100
19.0	_	71 - 95
13.2	55 - 75	56 - 80
4.75	38 - 54	38 - 54
2.36	28 - 42	28 - 42
300µ	7 - 21	7 - 21
75µ	2 - 8	2 - 8
Bitumen* Content, %	Min. 4 %	Min. 4.5%

*Actual binder content as per Marshall Method of Design

Marshall Stability Test

Procedural overview

This test is done to determine the Marshall stability of bituminous mixture. The principle of this test is that Marshall Stability is the resistance to plastic flow of cylindrical specimens of a bituminous mixture loaded on the lateral surface. It is the load carrying capacity of the mix at 60°C and is measured in kN. The apparatus needed to determine Marshall Stability of bituminous mixture is (As per ASTM D6927):

i) Marshall Stability apparatus including mould, compaction hammer, and compaction pedestal etc.
ii) Balance and water bath,
iii) Loading Machine.

Marshall Stability Test Apparatus

From Marshall Stability graph, select proportions of coarse aggregates, fine aggregates, and filler in such a way, so as to fulfill the required specification. The total weight of the mix should be 1200 g.

Procedure to determine Marshall Stability of bituminous mixture

1. Heat the weighed aggregates and the bitumen separately up to 170°C and 163°C respectively.
2. Mix them thoroughly, transfer the mixed material to the compaction mould arranged on the compaction pedestal.
3. Give 75 blows on the top side of the specimen mix with a standard hammer (45 cm, 4.86 kg) with heated face. Reverse the specimen and give 75 blows again. Take the mould with the specimen and cool it for a few minutes.
4. Remove the specimen from the mould by gentle pushing. Mark the specimen and cure it at room temperature, overnight.
5. A series of specimens are prepared by a similar method with varying quantities of bitumen content, with an increment of 0.5 % (3 specimens) or 1 % bitumen content. Measure the quantity and height of the specimen.
6. Before testing of the mould, keeps the mould in the water bath having a temperature of 60°C for 45 minutes.
7. Check the stability and flow of the mould on the Marshall Stability apparatus.

Reporting of results

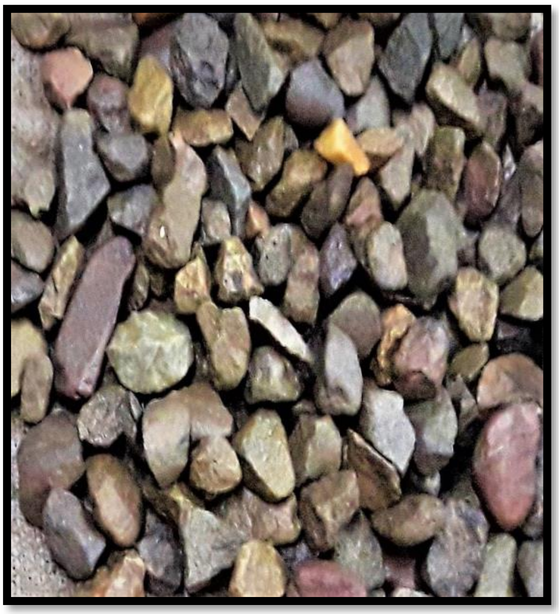
Plot % of bitumen content on the X-axis and stability in kg on the Y-axis to get maximum Marshall Stability of the bitumen mix. Also plot the values of VFB, Air Voids, Flow Value, and Density vs. Bitumen Content to Ascertain O.B.C. w.r.t. specified values.

Characteristics of material used in bituminous mixMineral Aggregates

There are various types of mineral aggregates that can be used in bituminous mixes. The aggregates used to manufacture bituminous mixes can be obtained from different natural sources such as glacial deposits or mines. These are termed as natural aggregates and can be used with or without further processing. The aggregates can be further processed and finished to achieve good performance characteristics. Industrial by products such as steel slag, blast furnace slag etc., sometimes are also used as a component along with other aggregates to enhance the performance characteristics of the mix. Reclaimed bituminous pavement is also an important source for bituminous mixes.

Aggregates play a very important role in providing strength to asphalt mixture as they contribute a greater part in the matrix. The higher proportion of coarse aggregate in the mixture forms a skeleton-type structure providing a better stone-on-stone contact between the coarse aggregate particles resulting in good shear strength and high resistance to rutting as compare to BC. According to MORTH & 5th Revision, has suggested the following characteristics for aggregate used in bituminous mixture. The aggregate must possess:

1. A Highly cubic shape and rough texture to resist rutting and movement.
2. A hardness which can resist fracturing under heavy traffic loads.
3. A high resistance to polishing, and high resistance to abrasion.



Mineral Aggregates

Mineral Filler

Mineral fillers have significant impact on the properties of HMA mixtures. Mineral fillers increase the stiffness of the asphalt mortar matrix. Mineral fillers also affect workability, moisture resistance, and aging characteristics of HMA mixtures. Generally, filler plays an important role in properties of bituminous mixture particularly in terms of air voids, voids in mineral aggregate. Different types of mineral aggregates are used in the HMA mixes such as stone dust, Ordinary Portland cement (OPC), slag cement, fly ash, hydrated lime, etc.

1.9.3 Binder

Bitumen acts as a binding agent to the aggregates, fines, and stabilizers in bituminous mixtures. Binder provides durability to the mix. The characteristics of bitumen which affects the bituminous mixture behavior are temperature susceptibility, visco-elasticity, and aging. The behavior of bitumen depends on temperature as well as on the time of loading. It is stiffer at low temperature and under shorter loading period. Bitumen must be treated as a visco-elastic material as it exhibits both viscous as well as elastic properties at the normal paving temperature. Though, at normal temperature it behaves like an elastic material and at high temperature its behavior is like a viscous fluid.

Bitumen along with different additives (fibers, polymers etc.) is acts as stabilizers for bituminous mix. Polymer modified bitumen can also be used as a stabilizer with or without additives in the mixture. Different types of bitumen have been used by various researchers to prepare the mixture. Penetration grade bitumen such as VG-30, modified bitumen such as CRMB, PMB, and Super pave performance grade bitumen are used to evaluate HMA mixture.

Selection of binder

Different researcher for their research work has used different types of binder like conventional VG-10 and VG-30 viscosity grade bitumen and many modified binder like Polymer Modified Bitumen (PMB), Crumb Rubber Modified Bitumen (CRMB), Natural Rubber Modified Bitumen (NRMB). Some researcher also used Superpave performance grade binder like PG 76-22 with bituminous mixture like Bituminous Concrete (BC) and Stone Matrix Asphalt (SMA) however these type of mixes have not become practicable so far in India.

The commonly used binder in hot weather condition is VG-30. However now a days VG-40 is getting more popular. It is also available easily commercially. VG-10 is suitable in cold climatic condition so here in this research a comparative study will be done between different bituminous mixes using VG-30 grade bitumen as binder.

Types of Bituminous Viscosity Grade

Grades	Minimum Absolute	Approximate

	Viscosity, poise @60°c	Penetration Grade
VG 10	800	80-100
VG 20	1600	---
VG 30	2400	60-70
VG 40	3200	30-40/40-50

VG 10: Mostly used in spraying applications such as surface dressing and paving in very cold climate conditions. It is also used to produce emulsion and modified bitumen products.

VG 20: Used for paving in cold climate and high altitude regions.

VG 30: Is especially used to construct extra heavy duty bitumen pavement that need to tolerate significant traffic roads. It can be used instead of 60/70 penetration bitumen grade.

VG 40: Used in highly stressed areas such as intersections, near toll booths and truck parking lots instead of 30/40 penetration grade. Because of higher viscosity, stiffer bitumen mixes can be produce to amend resistance to shoving and other problems related to higher temperature and heavy traffic loads.

Tests for VG bitumen

Softening Point Test of Bitumen

This test is done to determine the softening point of asphaltic bitumen and fluxed native asphalt, road tar, coal tar pitch and blown type bitumen as per IS: 1205 – 1978. The principle behind this test is that softening point is the temperature at which the substance attains a particular degree of softening under specified condition of the test.

The apparatus required for this test:

i) Ring and ball apparatus

ii) Thermometer– Low Range: -2 to 80° C, Graduation 0.2° C – High Range: 30 to 200° C, Graduation 0.5° C.

Softening point test apparatus

Preparation of sample

1. The sample should be just sufficient to fill the ring. The excess sample should be cut off by a knife.
2. Heat the material between 75 and 100° C. Stir it to remove air bubbles and water, and filter it through IS Sieve 30, if necessary.
3. Heat the rings and apply glycerin. Fill the material in it and cool it for 30 minutes.
4. Remove excess material with the help of a warmed, sharp knife.

Procedure to determine Softening Point of Bitumen

A) Materials of softening point below 80° C:

1. Assemble the apparatus with the rings, thermometer and ball guides in position.
2. Fill the beaker with boiled distilled water at a temperature 5.0 ± 0.5° C per minute.
3. With the help of a stirrer, stir the liquid and apply heat to the beaker at a temperature of 5.0 ± 0.5° C per minute.

4. Apply heat until the material softens and allow the ball to pass through the ring.
5. Record the temperature at which the ball touches the bottom, which is nothing but the softening point of that material.

B) Materials of softening point above 80° C:

The procedure is the same as described above. The only difference is that instead of water, glycerin is used and the starting temperature of the test is 35° C.

Reporting of results

Record the temperature at which the ball touches the bottom.

1.11.2 Ductility Test

The Ductility test is again an empirical test which measures the cohesive strength of bitumen. In this test a standard size bitumen sample is maintained at a constant temperature. The sample is pulled at a constant rate at constant temperature. The length at which the sample breaks is called the ductility of the sample. One unique feature of ductility test is that the test temperature at times varies from country to country and also from grade to grade.

Ductility test is an indicator of the cohesive strength of bitumen which in turn is a very loose indicator of the fatigue strength of the material. Material with higher ductility is more likely to withstand repeated cycles of loading and unloading in a better way. However some of the countries have completely discarded this test as the relationship between the fatigue strength and ductility appears to be very hazy. Moreover, testing of Thin Film Oven Test residue for change in penetration, softening point, viscosity, etc. is considered to be a much better indicator of the fatigue resistant properties.

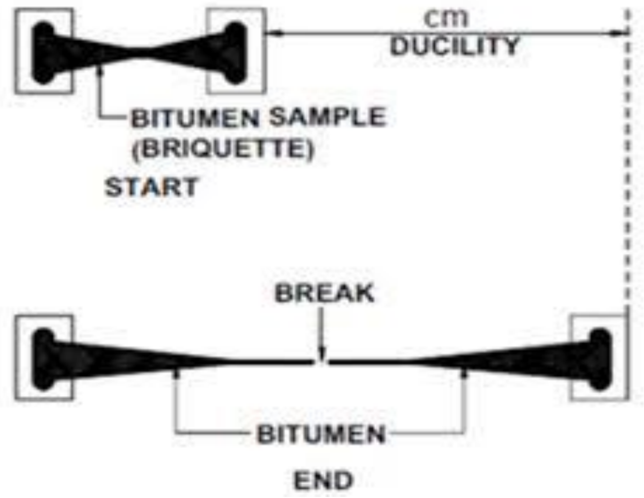


Figure 1.5: Ductility Test

1.12 Use of stabilizers/additives

It is generally understood that bituminous mixes is strong in compression and weak in tension. Adding fibers with high tensile strength can help increase the tensile strength of a mixture. In theory, stresses can be transferred to the strong fibers, reducing the stresses on the relatively weak asphalt mix. To effectively transfer stresses, there must be good adhesion between the fiber and the asphalt binder; a greater surface area on the fibers can aid this adhesion. In addition, the fiber needs to be uniformly dispersed in the mixture to avoid stress concentrations. If the primary reason for adding fibers is to reduce binder drain down, high strength is not required; fibers that will absorb or retain binder are used in these applications. The properties that affect fiber performance, how those properties are measured, and the types of fibers used are described in this section.

Types of fibers

Many types and forms of fibers have been used in asphalt mixtures, either experimentally or routinely. Cellulose, mineral, and polymer fibers are the most common. The most commonly used types of fibers;-

Cellulose

Cellulose fibers are plant-based fibers obtained most commonly from woody plants, although some are obtained from recycled newspaper. These fibers tend to be branching with fairly high absorption; it is the nature that helps cellulose fibers hold on to high binder contents in mixtures. Cellulose fibers can be provided in loose form or in pellets.

Mineral

Either naturally occurring fibers, such as asbestos (chrystolite), or manufactured mineral fibers can be used. Mineral fibers (also called mineral wool or rock wool) are manufactured by melting minerals then physically forming fibers by spinning [similar to making cotton candy or extruding. Minerals used to create mineral fibers include slag or a mixture of slag and rock, basalt, brucite, and carbon. Carbon fibers and steel fibers (or steel wool) have been used in some fairly exotic ways to produce electrically conductive asphalt that can be used for deicing or to heal micro-cracks. Asbestos fibers were the first type of fiber used in hot mix asphalt; they were used from the 1920s until the 1960s when environmental and health issues curtailed the use of asbestos.

Synthetic polymer fibers

The most commonly used polymer fibers are polyester, polypropylene, aramid, and combinations of polymers. Other fibers include nylon, poly para-Phenyleneterephthalamide, and other less commonly used materials. Different polymers have different melt points, which need to be considered when adding to hot mix asphalt. Production of synthetic fibers typically involves drawing a polymer melt through small holes.

Other plant-based fibers

These have been used in more limited areas. They may be derived from woody fibers (such as jute, flax, straw, and hemp), leaves (such as sisal), and seeds; or they may be fruit fibers, such as coir, cotton, coconut, or palm. Though these may have some strengthening effect, their performance on long term basis and also the effect of high temperature during mixing makes them susceptible and need careful evaluation.

Glass fibers

These have not been reported often in the literature but appear to have desirable properties, including high tensile modulus (˜60 GPa), low elongation (3 % – 4 %), high elastic recovery (100 %), and high softening point (815°C). They are, however, brittle and must be handled carefully during construction. Glass fibers have successfully been used as a stress absorbing membrane to provide effective solution to problem of cracking in flexible pavements.

Waste or recycled fibers

The increasing importance of sustainability in construction has led to increased interest in reusing materials that would otherwise be disposed of, including waste fibers from a variety of sources for example, steel industrial waste, steel fibers etc.

Using steel fibers shall have strengthening effect, particularly for tensile strength. However, since bituminous mixes preparation requires high temperature up to 160°C, therefore the effect of temperature on fibers need to ascertained and evaluated.

Need to strengthen Pavement

- Multiaxial loads, Channelized areas, Warehouses

Methods of mixing

Mixing of bituminous binder and aggregate is accomplished in one of the several ways: -

Hot Mix Asphalt (Commonly abbreviated as HMAC or HMA)

It is produced by heating the asphalt binder to decrease its viscosity, and drying the aggregates to remove moisture from it prior to mixing. Mixing is generally performed with the aggregate at about 300°F (roughly 150°C) for virgin asphalt and 330°F (roughly 166°C) for polymer modified asphalt, and the asphalt cement at 200°F (roughly 95°C). Paving and compaction must be performed while the asphalt is sufficiently hot. In many countries paving is restricted to summer months because in winter the compacted base will cool the asphalt too much before it is packed to the optimal air content. HMAC is the form of asphalt concrete most commonly used on highly trafficked pavements such as those on major highways, racetracks, and airfields.

Warm Mix Asphalt (Commonly abbreviated as WMA)

It is produced by adding either Zeolites waxes, asphalt emulsions, or sometimes even water to the asphalt binder prior to mixing. This allows significantly lower mixing and laying temperatures and results in lower consumption of fossil fuels, thus releasing less carbon dioxide, aerosols, and vapors. Lower laying temperature also leads to more rapid availability of the surface for use, which is important for construction sites with critical time schedules. The usage of these additives in hot mix asphalt (above) may afford easier compaction and allow cold weather paving or longer hauls.

Cut-back Asphalt Concrete

It is produced by dissolving the binder in kerosene or another lighter fraction of petroleum prior to mixing with the aggregate. While in its dissolved state the asphalt is less viscous and the mix is easy to work and compact. After the mix is laid down the lighter fraction evaporates. Because of the lighter fraction of volatile organic compounds in cut-back asphalt, cut-back asphalt has been largely replaced by asphalt emulsion.

Mastic Asphalt or Sheet Asphalt

It is produced by heating hard grade blown bitumen (oxidation) in a green cooker (mixer) until it has become a viscous liquid after which the aggregates mix is then added. Then bitumen aggregates mixture is cooked for around 6-8 hours and once it is ready the mastic asphalt mixer is transported to the work site where experienced layers empty the mixer and either the machine or hand laid the mastic asphalt content on the road. Mastic asphalt concrete is generally laid to a thickness of around ¾ - 1 3/16" (20-30 mm) for footpath and road applications and around 3/8" (10 mm) for flooring or roof applications.

Natural Asphalt Concrete

It can be produced from bituminous rock, found in some parts of the world, where porous sedimentary rocks near the surface have been impregnated with upwelling bitumen.

Improvement in bituminous mixes

In past, various researches on bituminous mixes have shown that we can improve the properties of bituminous mixes over conventional mixes using variant type of fibers in various proportions. Various improvements in bituminous mixes using fibers are as follows:

1. Improvement in Bituminous mix properties like marshal stability value, Flow value etc.
2. Improvement in resistance against Rutting
3. Improvement in the overall thickness of pavement using suitable fibers.
4. Improvement in the dynamic modulus of the mix.
5. Improvement in the amount of reflective cracks in asphalt mixtures and pavement.
6. Improvement in the visco-elastic characteristics of the mixture.
7. It improves the performance and expected life period of flexible pavement.

LITERATURE REVIEW

Introduction

Few Researches has already undertaken by research scholars throughout the globe. Few articles have been published in various journals in this area. Hence an attempt is made by the author to review the literature to know the latest development in the study area.

Researches related to fiber reinforced bituminous mixes

Halim-A Mahmoud; et al. (2006) [1] polyvinyl chloride (PVC) pipe waste have been employed as a soft filler up to a level of 11 weight % in making bitumen products for paving applications. The PVC wastes were homogenously mixed with bitumen in the molten state. The viscoelastic properties of the bitumen blends such as storage modulus, loss modulus, and dynamic viscosity were studied and compared with those of neat bitumen. These properties were studied using an ARES-Rheometer (Rheometric Scientific, Co.) under nitrogen atmosphere. The results indicate that the incorporation of the waste PVC into bitumen enhances the dynamic mechanical moduli and viscosity of the bitumen.

Xu Qinwu; et al. (2010) [2] this paper studies the reinforcing effects and mechanisms of fibers for asphalt concrete (AC) mixtures under the environment temperature and water effects. Four typical fiber types – polyester, polyacrylonitrile, lignin, and asbestos – are studied. Laboratory tests were conduct on the fiber reinforced AC (FRAC) to measure its strength, strain and fatigue behaviour. Results show that fibers have significantly improved AC's rutting resistance, fatigue life, and toughness. The flexural strength and ultimate flexural strain, and the split indirect tensile strength (SITS) at low temperature have also improved. The polymer fibers(polyester and polyacrylonitrile) have improved rutting resistance, fatigue life, and SITS more significantly than lignin and asbestos fibers, which may be primarily due to their greater networking function; while lignin and asbestos fibers result in greater flexural strength and ultimate flexural strain, which maybe primarily due to their greater asphalt stabilization effect. However, fibers effect under the water freezing–thaw effect does not seem promising, and the SITS of FRAC with lignin and asbestos fibers even reduces to some extent under this effect. It is also found that a fiber content of 0.35% by mass of mixture achieves the optimum performance outputs of rutting resistance and SITS for polyester fiber.

Vuong T Binh; et al. (2010) [3] investigated several reinforced asphalt products for use in road applications, particularly for rehabilitation of existing cracked reinforced-concrete pavements required for heavy-duty pavements. The products are assessed based on their structural capacity for the specific designs, especially with regard to joints or cracks in the underlying layers using new 3D nonlinear finite element (FE) analysis procedures. This allows comparison of relative performance of various reinforced products and, hence, selection of the most effective solution for the design concerned. Others factors influencing their use such as availability, costs and long-term environmental sustainability also considered to examine the suitability of reinforced asphalt products for the long-term cost-effective solutions over the traditional asphalt materials. This helped the issues of sustainability in material selection for pavement works.

Maharez Abdelaziz; et al. (2010) [4] revealed that polymer modified asphalt mixture is a relatively costly mixture for paving roads. One way to reduce the cost of such constructions and rendering them more convenient is by using inexpensive polymers, i.e. waste polymers. The main purpose of this research is to determine the effect of incorporating waste plastic bottles (polyethylene Terephthalate (PET)) on the engineering properties of the stone mastic asphalt (SMA) mixture. The volumetric and mechanical properties of asphalt mixes that include various percentages of PET (0 %, 2 %, 4 %, 6 %, 8 %, and 10 %) were calculated and assessed with laboratory tests. The appropriate amount of PET was found to be 6 % by weight of bitumen. The outcomes were statistically analysed and the determination of the significance at certain confidence limits was performed with the two factor variance analysis (ANOVA). Moreover, some studies conducted on the polyethylene modified asphalt mixture also considered. The results showed the addition of PET significance positive effect on the properties of SMA and it can promote the re-use of waste material in industry in an environmental friendly and economical way.

Ahmadinia Esmaeil; et al. (2011) [5] studied that asphalt modification/reinforcement is a viable solutions to enhance flexible pavement performance. This was mainly promoted by the unsatisfactory performance of traditional road materials exposed to dramatic increase and changes in traffic patterns. They presented the characteristics and the properties of glass fiber reinforced stone mastic asphalt. Laboratory tests were conducted to evaluate such related properties of asphalt mixture with different fiber contents. The tests undertaken comprise the Marshall test, indirect tensile test, creep test and fatigue test using repeated load indirect tensile test. The results showed that the addition of fiber does affect the properties of bituminous mixes, by decreasing its stability and increasing the voids in the mix. Stiffness properties of reinforced SMA Mix were enhanced by about 12 % as compared to control mix. Mix with more than 0.2 % fiber content exhibited lower resistance to permanent deformation. The results indicated that the fiber has the potential to resist structural distress that occur in road pavement as result of increased traffic loading, thus improving fatigue life by increasing the resistance to cracking and permanent deformation especially at higher level stress.

Rahman Afifa; et al. (2012) [6] presented that fillers play an important role in engineering properties of the bituminous paving mixes. Conventionally, cement, lime and stone dust have used as fillers. They attempt to assess the effects of different types of fillers (e.g. non-conventional and conventional) on the Marshall properties of bituminous paving mixes. For this purpose, non-conventional filler such as brick dust and conventional fillers such as cement and stone dust have used. All of these materials have tested according to the standard test procedure of AASHTO. Total 15 sets specimens were prepared by using different types of filler having different amount in the mix. The Marshall properties obtained for both types of fillers reveal that, brick dust filler specimen have found to exhibit higher stability value compared to cement and stone dust filler specimens. In addition, mixers containing brick dust filler showed maximum stability at 6.2 % bitumen content and the percentage of air voids were found to be decreased with the increase of bitumen content.

Joshi B Darshan; et al. (2013) [7] explained that as the knowledge regarding paving material expanded, need for economical, functional and safer design criteria required to find out optimum bitumen content in semi dense bitumen macadam. To satisfy the mix design specification, number of methods has been developed. They presented that the variability involved in the asphalt mix design process and developed a procedure to find out the optimum bitumen content by Marshall Mix design method which attains maximum stability. Their study was according to Indian specifications, where mix design, like in many other countries, performed in accordance with Marshall Method.

Terzi Serdal; et al. (2013) [8] presented the potential of Genetic Expression Programming (GEP) computing paradigm to forecast the Marshall stability of steel fiber reinforced asphalt concrete and has various mix proportions has been developed. Experimental details were used to construct the model. The steel fiber content (0 %, 0.25 %, 0.50 %, 0.75 %, 1.0 %, 1.5 %, 2.0 %, and 2.5 %), percentage of bitumen (5 %, 5.5 %, and 6.0 %), and unit weights (2,465–2,515 g/cm^3) were used as output variables. The performance of models was comprehensively judged using several statistical verification tools. Results have shown that developed GEP model has a strong potential for predicting the Marshall stability of asphalt concrete without performing any experimental studies.

Lin Youngui; et al. (2013) [9] explained that for roller compacted concrete used in pavements, optimal water content is one of main concerns for mix design. However, the mix design method aiming at achieving both high bond strength and roller compactability is not available so far. The modified proctor compaction method and modified Vee-bee method were investigated and found to be inappropriate to the type of mixes in terms of durability. A method for determining optimal water content also proposed for steel fiber-reinforced, roller compacted and polymer modified bonded concrete overlays. Two types of mixes suitable for asphalt paver placement and roller compaction were developed. They were the SBR and the SBR-PVA hybrid polymer modified concrete mixes with the optimal water content determined by the proposed method. Both mixes achieved good bond with the old concrete substrate.

Parsad Nitin; et al. (2013) [10] revealed that secondary compaction is a state; where the pavement which is compacted with the conventional compaction has been further compacted due to the movement of traffic and which corresponds to the ultimate density which can be attained on the bituminous pavement called as "Refusal density" of the pavement. Secondary compaction has to be studied in detail and it is understood that the 75 blows of the Marshall text does not determine the actual field circumstances. The Marshall design actually in the field will not simulate the field conditions hence there will be a reduction on the air voids to the refusal density. Then due to fineness of the mix, this causes the plastic deformation on the pavement surfaces. They attempt to study the air void content at refusal density along with Bulk density, Air voids (V_a), Voids in mineral aggregate (VMA), voids filled with bitumen (VFB) of the mix. For the simulation of field density in the laboratory a huge hammer is used. The usage of the polymer modified bitumen reduces the plastic deformation and other distresses of the pavements.

Abiola O; et al. (2014) [11] provided a review on the utilization of natural fibers as modifier in bituminous mixes. Increase in traffic loads in terms of number of axles and high tyre pressure from heavy vehicles resulted into traffic related pavement distresses. Modification of asphalt binder is one of the approaches to improve pavement performance. Natural fibers have become a research focus for scientist and engineers. Types of natural fibers, their surface treatment, and reinforcement of asphalt concrete with natural fibers have presented. Generally, the review demonstrated an improvement in fatigue life and structural resistance to distresses occurring in pavement when modified.

Teppala Bela; et al. (2014) [12] pointed out that the burgeoning urban population of India with rapid rise in industrialization coupled with high increase of road vehicles engaging in rapidly expanding cities to fit the developmental needs of the economy demands good quality of roads to cope up the increasing pressure of road traffic. It becomes the responsibility of researchers, scientists, contractors to improve the riding quality while maintaining the economy for the country like ours. They initially investigated the engineering properties of locally available crushed stones, fillers and 60/70 grade bitumen for mix design. Marshall Method of mix design for DBM (grade1) has adopted to find out the optimum bitumen content. In order to arrive at homogenous mix with compared standards, VG 30 bituminous mix with obtained 4.25 % optimum bitumen content was taken into consideration for modified Marshall mix design by addition of 0.03 %, 0.04 % and 0.06 % dosage of zycosoil chemical was prepared and tested to determine the key properties as per the codal provision. The test indicated the desire to opt for chemically modified DBM mix it shows better results as compared to conventional mix.

Ahad Abdul; et al. (2015) [13] recently, the use of steel fiber at high rates has been introduced as the sole method of reinforcement for fully elevated-suspended slabs having long span such as 5 m to 8 m each way, with a span to depth ratio of up to 33 [1]. As a result of long practical experience the total replacement of traditional rebar is a new routine. Now it is also used in the designing of SFRC pavements over conventional concrete pavements. Within the project framework a demonstration of a steel-fiber reinforced roller-compacted concrete (SFR-RCC) pavement was constructed in a rural as well as urban area. In order to assess the economic condition of the demonstration pavement, life cycle assessment (LCA) and life cycle cost analysis (LCCA) studies were undertaken. This is the advancement study of the various papers which is already published in many publications which serve as the main and important source of study for the research. Many applications of steel fiber are listed in the paper but the main output of this paper is that SFR-RCC is more economically sustainable than others and also helps in reducing the thickness of the pavement up to 20 to 25 percent, due to the excessive strength of steel fiber. The roads of the present system required high cost investment. And the life period is almost 20 years theoretically but the actual life of the road is depending on the maintenance and the applied load. The constructions of road have been done since the 3500 BC but the method does not change fully. Also the cost of the construction is increased continuously; as a result, the construction of roads is more and more complicated and time taken. For the better and economical construction of the roads, we use steel fibers in the composite pavement. The theoretical plan of the construction of composite pavement is given in the methodology, which gives the appropriate idea about the construction of road using steel fiber. Here we use the composite pavement in which the steel fiber is mixed in the concrete layer, after which the bitumen layer is laid for the smooth and suitable riding of the vehicles.

Aniruddh; et al. (2016) [14] one of the innovative technique of improvement in bitumen concrete surface practiced all over the world is addition of steel fibres in it. The performance of Bituminous concrete Mixes with steel fibre in varied proportions (2 %, 2.5 %, 3 %, 3.5 %, 4 %, 4.5 %,5 %, 5.5 % & 6 % with 18 mm and 11 mm length was studied by conducting Marshall Stability Test for Stability of Bituminous Mixes .The results have been noticed that the considerable improvement in stability of bitumen concrete was at an optimum percentage of added steel fibre for bitumen concrete at 3.5 % of 11 mm long steel fibre. Therefore these fibre content has been recommended for making improvements in parameter of Bituminous Mixes.

Mendapara Kaushik; et al.(2017) [15] bituminous for mix can be prepared and used in a pavement section for a bituminous binder course use different types of additives likes as Polymers, Rubber and waste materials like discard rubber fibre (tube Tyres), plastic west and jute fiber. Modifying bituminous mix is expect to gives higher life. The present study objective are developing bituminous mixes for the Dense Bituminous Macadam (DBM) incorporating the plastic wastes, waste tyre tubes and rice husk ash as partial replace of the different bitumen content. In this study, the Stability, and Flow value analysis for the various DBM Grade 1 mixtures with binders and with different percentage replacement of bitumen with plastic wastes, waste tyre tubes and jute fibre are reported.

Polagani Sateesh; et al. (2017) [16] exponential increase in traffic, overloading of commercial vehicles and significant variations in daily and seasonal temperatures have shown some limitations of conventional bitumen performance. It is thought that with the help of additives is one of the approaches to improve performance of flexible pavements. Here fibres have been used to improve the performance of asphalt mixtures against permanent deformation and fatigue cracking, Because of their inherent compatibility with asphalt cement and excellent mechanical properties. In the present study, an attempt has been made to study the effects of use of a mineral fibre called Glass fibre is used as an additive in Dense Bituminous Macadam (DBM). An experimental study is carried out on conventional bitumen and fibre modified binder. Using Marshall Procedure, Optimum Fibre Content (OFC) and Optimum Binder Content (OBC) for DBM are found respectively. The modified bitumen at Different percentages are subjected to different performance tests like Dynamic Shear Rheometer (DSR) and Creep Properties to evaluate the effects of fibre addition on mix performance.

Sood Parvinder and Duggal K Ajay; (2018) [17] the growing need for high quality bituminous mixtures in road construction and to cater to heavy traffic loads in terms of number of axles, modification of bituminous mixes emerges as a need to improve pavement performance and to extend the service life. In recent times, scientist and engineers has shown immense interest on utilizing various fibres because it acts as a very promising additive for the improvement of engineering characteristics of the bituminous mixes. The objective of this study is to have better understanding of utilizing fine steel fibres induce bituminous macadam and bituminous concrete pavement layers. Generally, the review demonstrated an improvement in fatigue life of the pavement together with developing improved resistance to reflective crack when modified using steel fibres.

Identification of gaps

1. The evaluation is new most of the studies have done abroad and need to made more in our country.
2. No specific considerations have given to reinforce the Bituminous Mixes for Flexible Pavement.
3. There are limited studies which are based on use of steel fiber in bituminous Mixes.
4. More studies specific to the type of fibers is the need of today to evaluate their effect on properties of bituminous mixes used for surface and binder course.
5. Effect of size, shape and a few other properties of steel fibers need to be studied.
6. There is need to establish some correlation between Mix properties and their field performance.

Conclusions

After going through the variant studies carried out by different researchers, it may be concluded that:

1. These studies essentially provide a better understanding of the good performance capabilities of bituminous mixes.
2. The resilient modulus and modulus of elasticity is effectively improved by using fiber polymers as additive in asphaltic concrete pavement in high temperature environment.
3. The output data of genetic expression programming shows that there is a strong potential for predicting the Marshall stability of Asphaltic Concrete and with certain modification it can be utilized for the prediction of Marshall Stability of Flexible Asphaltic Concrete.
4. The reinforced asphaltic concrete will sustain in performance of the pavement over the traditional asphalt material.
5. At higher stress level, the fatigue life is increased due to increase in the resistance to cracking and permanent deformation by using glass fiber.
6. Due to heavy traffic load and increased volume, we need to prepare mixes other than the conventional types that can survive the heavy traffic load for a longer period of span.

7. The reinforced asphaltic concrete provides an improvement in the fatigue life, increases the stability and that it has the potential to improve structural resistance to distress occurring in flexible pavement, due to traffic loads.

PROPOSED WORK

Problem statement:

The problem **"Effect of addition of Medium Steel Fibers on Dense Bituminous Macadam"** is selected for the purpose of the study. The Bituminous Mixes used is Dense Bituminous Macadam and the additive will be Medium Steel Fibers.

Objectives of the study

The main objectives of this study are listed below:

1. To determine the effect of addition of Steel fibers on Stability and Flow of Bituminous mixes namely Dense Bituminous Macadam grade-1 and Dense Bituminous Macadam grade-2.
2. To determine the effect of addition of Steel fibers on Density and other characteristics of the mixes e.g., VFB, VMA etc. for DBM grade-1 and DBM grade-2.
3. To ascertain the optimum percentage of steel fibers in DBM grade-1 and grade-2.
4. To determine the effect on optimum binder content on account of addition of Steel Fibers.

Scope of work

Research has been carried out to find out the optimum percentage of Steel Fibers for bituminous mixes and other engineering characteristics of bituminous mixes. In this study an attempt has done to improve the properties of bituminous mixes prepared by using steel fibers.

Methodology

In order to accomplish this research work the methodology adopted is explained below.

1. Material used in the study was collected from nearby hot mix plant like as-Aggregates, Fillers, and Bitumen.
2. Steel fiber used for this study has been procured from the steel fiber supplier of Mohali.
3. Fibers procured has the fragments of steel i.e., steel scrap which is left over after cutting at Hexa Machine (Steel Industrial Waste). Fibers are varied in size and shape and its length is in between 8-10 mm. The amount of fibers added has been in varied proportions of 2 %, 4 %, 6 %, and 7 % by weight of total mix.
4. Samples of Bituminous mix has been prepared without using steel fibers (Control Mix) to find out the optimum binder content for Dense Bituminous Macadam Grade 1,2 (DBM) as well.
5. Samples of Bituminous mix for Dense Bituminous Macadam Grade 1, 2 (DBM) has been prepared at optimum binder content with varied percentages of fibers.
6. Samples of Bituminous mix are prepared by Marshall Method of mix design.
7. Various properties e.g. Marshall Stability, Flow Value, Density, VMA, VFB, Air Voids etc., has been determined for samples on different proportions of fibers.

Laboratory Tests

Following tests are going to be performed in this thesis work:

1. Particle size distribution test on various aggregates and filler for determining the grain size distribution by sieve analysis (As per IS 2720: Part 4).
2. Specific gravity test for determining the specific gravity of 20mm, 10mm, 6.7mm size aggregate and stone dust (As per IS 2720: Part 3).

3. Aggregate Impact Value, Aggregate Crushing Value, Elongation Index, and Flakiness Index tests are conducted for determining the properties of aggregates to evaluate their fitness of use (As per MORTH 5th Revision Specification).
4. Specific gravity and Softening point test for determining the specific gravity of VG-30 and VG-10 (As per IS 73: 2006).
5. Penetration test for determining the penetration of VG-30 and VG-10 (As per IS 73: 2006).
6. Marshall Stability test: Samples shall be prepared by adding different percentage of Fibers, a detailed analysis is then carried out to determine the variations in stability, flow and other parameters as per MS-2 and ASTM D2041.
7. An attempt will be made to prepare a mix with optimum bitumen content with fibers that will be able to fulfill the requirement or specifications for bituminous mixes.

Expected outcomes

After completion of this thesis work the following outcomes were expected:

1. Effect on performance of mix at different percentages of fibers.
2. Optimum percentage of fibers that can be used in Dense Bituminous Macadam Grade 1 and 2.
3. Effect of steel fibers on different parameters of bituminous mixes viz Stability, Flow value, Voids in mineral aggregates, Density and Air Voids.
4. Addition of fibers in bituminous mixes will improve fatigue life by increasing the resistance to cracking and permanent deformation.
5. Thickness of the surface could be reduced to cater the same traffic load by addition of Steel fibers in bituminous mixes and that too could reduce the overall cost of the construction of road.

RESULT AND ANALYSIS

General

In this study the effect of use of medium steel fibers in bituminous mixes to improve its performance and serviceability of the road surface has been evaluated. The fiber used is an industrial waste material and is not much popular among researchers. In this study, result obtained from virgin mix and with varying percentage of **Medium Steel Fibers** i.e. (2 %, 4 %, 6 %, and 7 %) are discussed. DBM sample were prepared at optimum bitumen content of [4.50 % (VG-10) & 4.50 % (VG-30)] grading-1 and [4.68 % (VG-10) & 4.66 % (VG-30)] of grading-2.

Flow Value, Stability and Density and other properties of bituminous mixes using varying percentage of medium steel fiber content at 2 %, 4 %, 6 %, and 7 % were compared to that of virgin mix to find out the optimum percentage of steel fiber content for grading of DBM mix.

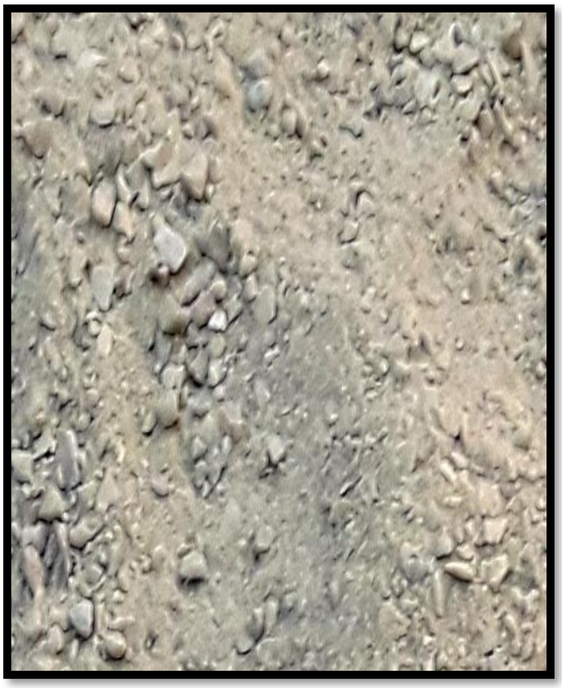
Material used

In this study following materials are used:

- **Fiber:** Medium steel fibers are collected from local supplier of Aurangabad, Bihar. Fibers used are industrial waste material and it is basically the residue left from hexa machine. The length of fiber is in between 8 mm to 10 mm. Thickness of medium steel fiber is approx 0.371 mm.

Medium Steel Fibers

- **Stone Dust:** Stone dust is used as filler and collected from NH2 highway. The specific gravity of stone dust was found to be 2.61.



Stone Dust

- **Aggregates:** The sizes of aggregates used were 37.5 mm, 26.5 mm, 20 mm, and 10 mm.

Aggregates

Some of the test were performed on the material used to satisfy the requirements set by MORTH 5th revision and results are shown in the table below.

Physical Properties of Aggregates

Physical Properties	26.5 mm	20 mm	13.2 mm	Required values as per MORTH 5th revision
Specific Gravity	2.61	2.67	2.60	2.60-2.80
Impact Value (%)	9.72	11.50	8.69	Max. 24 %
Water Absorption (%)	0.91	1.10	1.00	Max. 2 %
Stripping Value (%)	<3.00	<3.00	<3.00	<5 %
Flakiness Index (%)	13.50	14.50	12.50	Max. 30 % Combined value
Elongation Index (%)	14.00	13.67	13.65	

Combined Value (Flakiness index and Elongation index) (%)	27.50	28.17	26.15	

- **Binder VG-10:** Bitumen of VG-10 grade was used with specific gravity 1.05. Some other properties are also determined whose results are given in table below:

Properties of Bitumen (VG-10) used

Properties	VG-10 Grade		Test Method
	Determined	Required (min)	
Softening Point, (⁰C)	56.5	47	IS: 1205:1978
Ductility (mm)	87.5	45	IS: 1208:1978
Penetration (mm)	35	45	IS: 1203:1978
Specific Gravity	1.05	0.99	IS: 1202:1978

- **Binder VG-30:** Bitumen of VG-30 grade was used with specific gravity 1.03. Some other properties are also determined whose result are given in table below:

Properties of Bitumen (VG-30) used

Properties	VG-30 Grade		Test Method
	Determined	Required (min)	
Softening Point (°C)	60° C	47° C	IS: 1205:1978
Ductility (mm)	85.50	45	IS: 1208:1978
Penetration (mm)	45.20	45	IS: 1203:1978
Specific Gravity	1.03	0.99	IS: 1202:1978

Requirements for mix design for Dense Bituminous Macadam

Apart from conformity with the grading and quality requirement for individual ingredients, the mixture shall meet the requirements set out in table 500-11 in "Specifications for Road and Bridge Works," MORTH 5th revision. Some important guidelines are as given below:

Guidelines for Dense Bituminous Macadam Mix as per MORTH 5th revision

Properties	Required Values
Marshall Stability Value, kN	9.0
Flow Value, mm	2 – 4
Air Voids (%)	2 – 5
Marshall Quotient (Stability/Flow)	3 – 5
Minimum Voids in Mineral Aggregate (VMA), (%)	11 – 13*
Voids Filled with Bitumen (VFB), (%)	65 – 75

* For nominal aggregate size for grading –2

Job mix formula for DBM using fresh bituminous mix

The Design mix was prepared using job mix formula according to Table 500-17 as given in **"Specifications for Road and Bridge works"** by MORTH 5th Revision. Sieve analysis of different aggregates of sizes 37.5 mm, 26.5 mm, 20 mm, 10 mm, and stone dust was done to obtain individual gradation of these aggregates. In this study Grading-1 and Grading-2 were selected. After finding the individual grading of aggregates, the desired gradation was then calculated by trial-and-error method using Microsoft excel.

Job Mix Formula for DBM using Fresh Bituminous Mix

The gradation of various aggregates and fillers used namely 37.5 mm, 26.5 mm, 10 mm, and stone dust are shown in table below:

Grading of various Aggregates for Control Mix for DBM Grading-1

I.S Sieve Size	% Passing Required	% Passing 37.5 mm	% Passing 26.5 mm	% Passing 10 mm	% Passing Stone Dust	Grading of Mix
37.5	95-100	100	100	100	100	100.0
26.5	63-93	22.9	100	100	100	87.70
20	-	0.5	51.5	97.80	100	75.00
13.2	55-75	0.5	0.6	96.50	100	65.60
4.75	38-54	0.5	0.6	0.5	98.8	47.20
2.36	28-42	0.5	0.6	0.4	83.4	30.60
300 µ	7-21	0.5	0.6	0.0	42.8	11.30
75 µ	2-8	0.5	0.6	0.0	16.5	4.00
Blending Ratio		0.16	0.18	0.33	0.33	

weighing of testing sample

Grading of various Aggregates for Control Mix for DBM Grading-2

I.S Sieve Size	% Passing Required	% Passing 26.5 mm	% Passing 20 mm	% Passing 10 mm	% Passing Stone Dust	Grading of Mix
37.5	100	100	100	100	100	100.0
26.5	90-100	22.9	100	100	100	92.29
19	71-95	0.6	51.3	100	100	80.81
13.2	56-80	0.6	3.60	99.2	100	71.46
4.75	38-54	0.6	0.3	11	98	38.38
2.36	28-42	0.6	0.3	0.8	83	29.46
300 µ	7-21	0.6	0.3	0.5	42.2	15.07
75 µ	2-8	0.6	0.3	0.5	16	5.90
Blending Ratio		0.10	0.19	0.36	0.35	

Quantity of Aggregates

According to grading in table 4.5 quantity of aggregates required for preparation of sample by Marshall Method are as follows:

Percentages and Quantities of Aggregates for DBM

Size of Aggregate	Percentage (%)	Weight of Aggregate in (g)
37.5 mm	16	192
26.5 mm	18	216
10.0 mm	33	396
Stone Dust	33	396

According to grading in quantity of aggregates required for preparation of sample by Marshall Method are as follows: -

Percentages and Quantities of Aggregates for DBM

Size of Aggregate	Percentage (%)	Weight of Aggregate in (g)
26.5 mm	10	120
20.0 mm	19	228
13.2 mm	36	432
Stone Dust	35	420

Percentages and Quantity of Bitumen (VG-10 & VG-30) Used

Following percentages and quantities of bitumen are used for **grading-1:**

Bitumen percentages, Steel Fiber percentages, and quantities for DBM

Percentage of Bitumen (%)	Weight of Bitumen (g)	Percentage of Fiber (%)	Weight of Fiber (g)
4.00	50	2	24
4.15	52	4	48
4.30	54	6	72
4.45	56	7	84
4.60	58	-	-

Following percentages and quantities of bitumen are used for **grading-2:**

Bitumen percentages and quantities for DBM

Percentage of Bitumen (%)	Weight of Bitumen in (g)
4.53	57
4.68	59
4.83	61
4.98	63
5.13	65

Results of Marshall Stability Test for Control Mix For DBM

The results of different parameters of Marshall Stability test for control mix are shown in table below:

Results of Marshall Stability test for fresh mix for DBM grading-1 (VG-10)

Binder Content (%)	4.00	4.15	4.30	4.45	4.60
Specific Gravity of Bitumen	1.05	1.05	1.05	1.05	1.05
Density, g/cc	2.344	2.347	2.342	2.335	2.327
Volume of Aggregates, V_a (%)	85.80	85.86	85.45	85.15	84.73
Volume of Bitumen, V_b (%)	8.92	9.27	9.59	9.89	10.19
Voids in Mineral Aggregate, VMA (%)	14.12	14.14	14.55	14.85	15.27
Voids Filled with Bitumen, VFB (%)	64.68	67.12	67.86	68.11	68.16
Air Voids, (%)	4.87	4.54	4.54	4.63	4.76
Marshall Stability, Kn	12.38	13.56	14.61	17.99	15.30
Flow Value, mm	4.20	4.25	4.35	4.50	5.00
Marshall Quotient	2.94	3.19	3.35	3.99	3.00

Bitumen (VG-10)

Results of Marshall Stability test for fresh mix for DBM grading-1 (VG-30)

Binder Content (%)	**4.00**	**4.15**	**4.30**	**4.45**	**4.60**
Specific Gravity of Bitumen	1.03	1.03	1.03	1.03	1.03
Density, g/cc	2.346	2.349	2.345	2.336	2.329
Volume of Aggregates, V_a (%)	85.96	85.93	85.65	86.19	84.80
Volume of Bitumen, V_b (%)	9.11	9.46	9.78	10.09	10.40
Voids in Mineral Aggregate, VMA (%)	14.04	14.07	14.35	14.81	15.20
Voids Filled with Bitumen, VFB (%)	64.88	67.23	68.15	68.12	68.42
Air Voids, %	4.93	4.61	4.75	4.72	4.80
Marshall Stability, kN	15.86	19.50	21.22	22.50	22.15
Flow Value, mm	3.50	3.92	4.50	4.80	5.00
Marshall Quotient	4.53	4.97	4.57	4.93	4.72

Bitumen (VG-30)

Results of Marshall Stability test for fresh mix for DBM grading-2 (VG-10)

Binder Content (%)	**4.53**	**4.68**	**4.83**	**4.98**	**5.13**
Specific Gravity of Bitumen	1.05	1.05	1.05	1.05	1.05
Density, g/cc	2.343	2.348	2.340	2.334	2.330
Volume of Aggregates, V_a (%)	84.70	85.71	85.32	84.97	84.69
Volume of Bitumen, V_b (%)	10.10	10.46	10.76	11.06	11.38

Voids in Mineral Aggregate, VMA (%)	14.30	14.29	14.68	15.03	15.31
Voids Filled with Bitumen, VFB (%)	70.62	73.19	73.29	73.58	74.33
Air Voids, %	4.20	3.97	3.93	3.92	3.80
Marshall Stability, kN	19.02	21.99	21.55	21.00	19.88
Flow Value, mm	3.95	4.50	4.59	4.65	4.05
Marshall Quotient	4.81	4.88	4.69	4.51	4.05

Prepared Samples with Steel Fiber

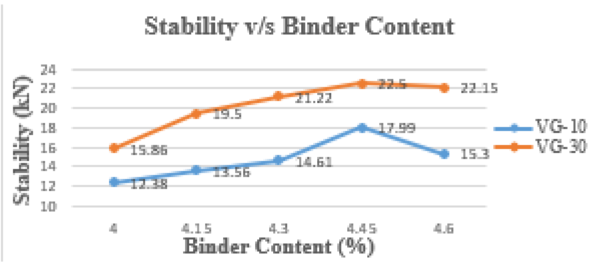
Results of Marshall Stability test for fresh mix for DBM grading-2 (VG-30)

Binder Content (%)	**4.53**	**4.68**	**4.83**	**4.98**	**5.13**
Specific Gravity of Bitumen	1.03	1.03	1.03	1.03	1.03
Density, g/cc	2.347	2.350	2.348	2.340	2.335
Volume of Aggregates,	85.84	85.82	85.61	85.19	84.87
V_a (%)					
`	10.32	10.67	11.01	11.31	11.62
Voids in Mineral Aggregate, VMA (%)	14.16	14.18	14.16	14.81	15.13
Voids Filled with Bitumen, VFB (%)	72.88	75.24	76.75	77.36	77.80
Air Voids, %	3.82	3.60	3.51	3.50	3.48
Marshall Stability, kN	20.00	22.77	22.10	21.22	20.54
Flow Value, mm	4.50	4.75	4.80	4.90	4.94
Marshall Quotient	4.44	4.79	4.60	4.33	4.15

Determination of Optimum Binder Content for DBM

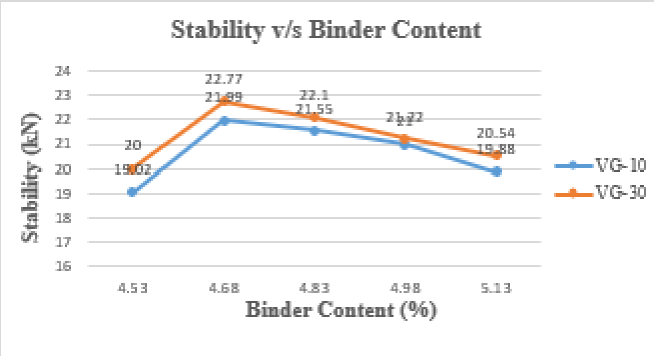
Maximum Marshall Stability and density are obtained at 4.55 % (VG-10) and 4.50 % (VG-30) for grading-1 bitumen content calculated from the graph below, i.e. 4.55 % and 4.50 % respectively.

Note: Stability is the governing parameter for finding the optimum binder content. Stability value first start increasing then start decreasing. Maximum Marshall Stability are obtained at 4.55 % for VG-10 i.e., 17.99 kN and for VG-30 at 4.50 % i.e., 22.50 kN .



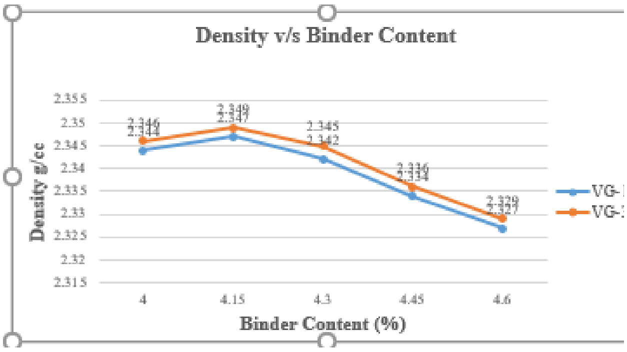
Relation between Stability and Binder Content for grading-1

Note: Stability is the governing parameter for finding the optimum binder content. Stability value first start increasing then start decreasing. Maximum Marshall Stability are obtained at 4.68 % for VG-10 i.e., 21.99 kN and for VG-30 at 4.66 % i.e., 22.77 kN shown in fig.4.9.



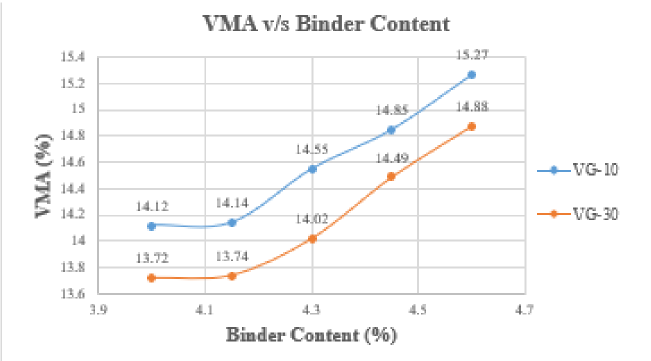
Relation between Stability and Binder Content for grading-2

Note: It is observed that the density increase with increase in bitumen content up to 4.15 % (VG-10) and (VG-30) further increase the binder content but density decreases.



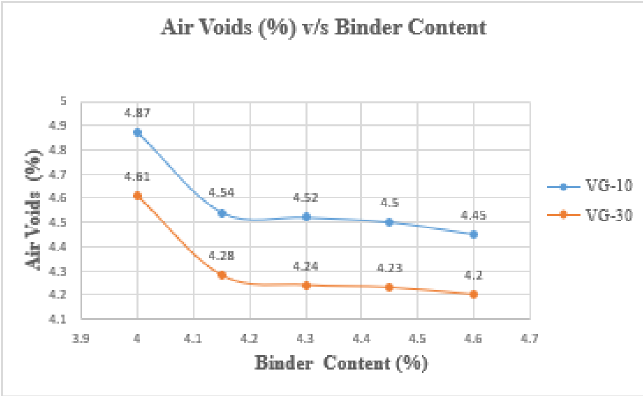
Relation between Density and Binder content for grading-1

Note: It is observed that value of VMA increases with respect to binder content



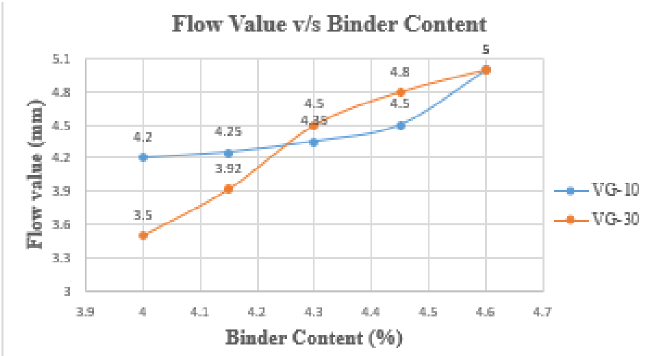
Relation between VMA and Binder content for grading-1

Note: It is observed that initially air voids is showing maximum value further increase the binder content but value of air voids is decreases



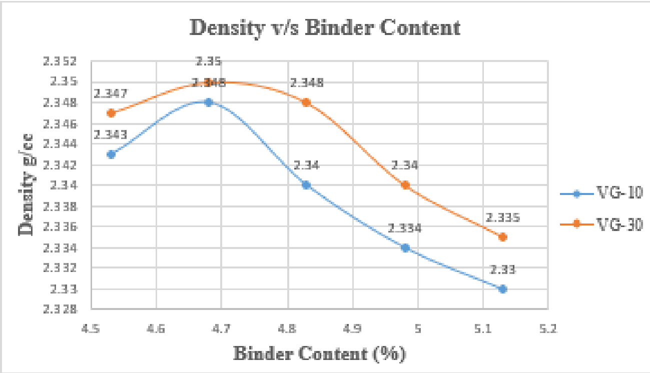
Relation between Air Voids and Binder content for grading-1

Note: It is observed that flow value increases with the binder content. Variation of flow value with different percentage of binder content and different grade of bitumen



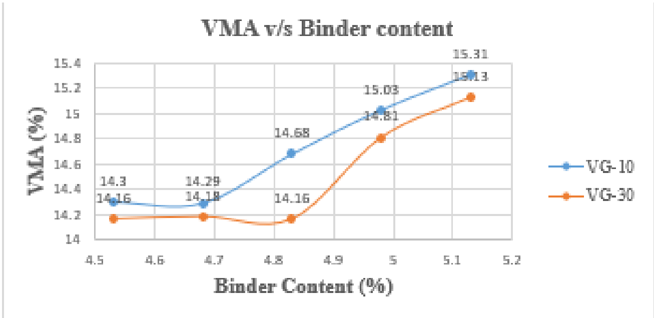
Relation between Flow Value and Binder content for grading-1

Note: It is observed that density first increase after decrease when binder content is increases. Variation



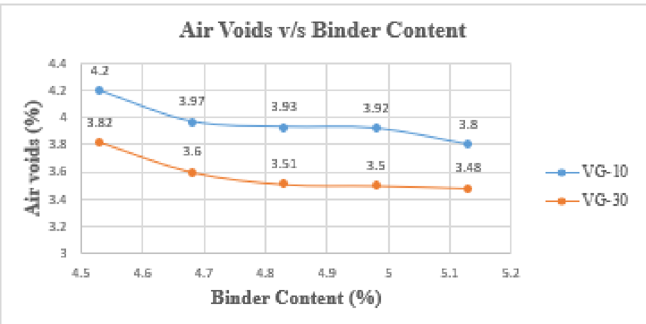
Relation between Density and Binder content for grading-2

Note: It is observed that VMA value increases with binder content respectively. Variation shown



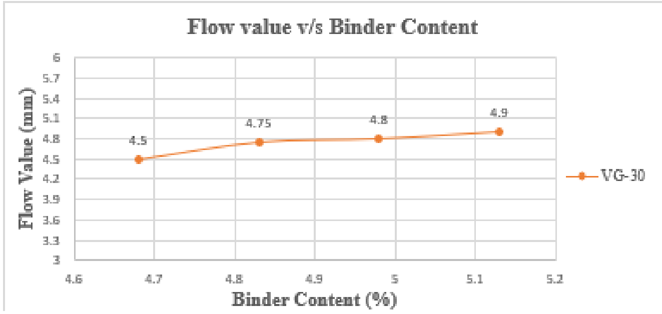
Variation of VMA value with different binder content for grading-2

Note: It is observed that air voids decreases with increases in binder content up to replacement 5.13 % binder. Variation shown



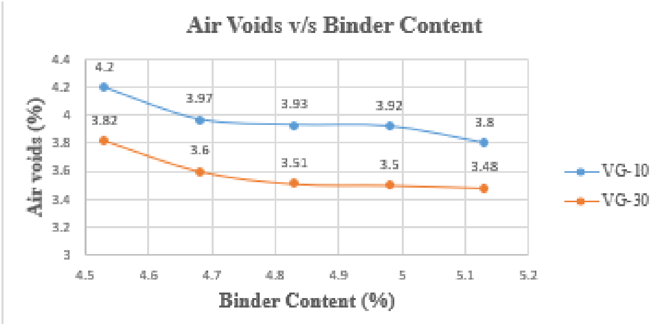
Variation of Air voids with different binder content for grading-2

Note: It is observed that flow value increases with increase binder content. Variation shown



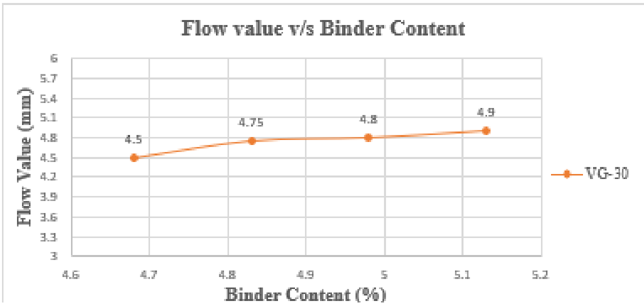
Variation of Flow value with different binder content for grading-2

Note: It is observed that air voids decreases with increases in binder content up to replacement 5.13 % binder. Variation shown



Variation of Air voids with different binder content for grading-2

Note: It is observed that flow value increases with increase binder content. Variation shown



Variation of Flow value with different binder content for grading-2

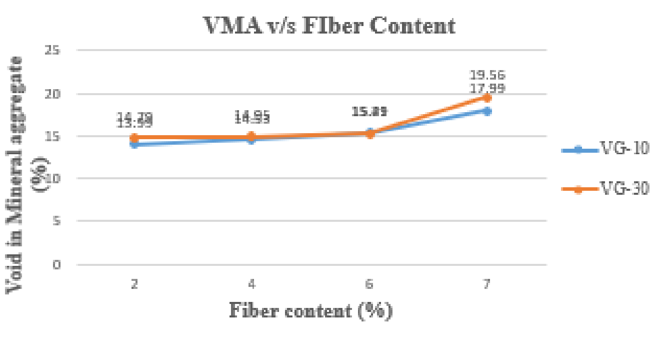
Effect of Medium Steel Fiber on DBM

To analyze the results, some graphs are plotted between Voids in mineral Aggregate V/s Fiber content, Stability V/s Fiber content, Flow V/s Fiber content, Air voids V/s Fiber content, Density V/s Fiber content

Void in Mineral Aggregate v/s Fiber content

It is observed that VMA increases with increase in fiber content up to 7 %. VG-30 binder shows higher value of VMA in comparison to VG-10. These values are higher than the control mix. Variation of Voids in mineral aggregates with different fiber content and different binder content shown

Voids in Mineral Aggregates and their corresponding Fiber content for grading-1



Variation of VMA with different fiber content for grading-1

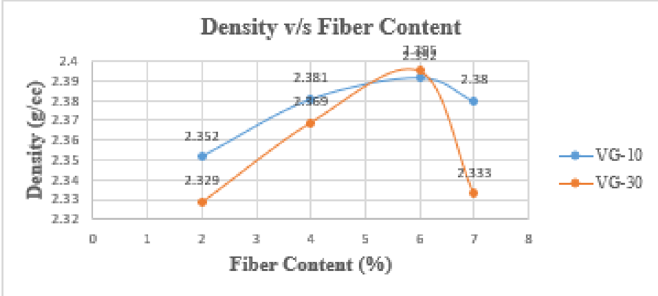
Density v/s Fiber Content

It is observed that the density increases with increase in fiber content up to replacement of 6 % of steel fibers in both binders then decreased with the further increment of the steel fiber. Variation of density with different steel fiber content and with different binders.

FIBER (%)		2	4	6	7
Bitumen Content (%)	VG-10	4.55	4.55	4.55	4.55
	VG-30	4.50	4.50	4.50	4.50
Density (g/cc)	VG-10	2.352	2.381	2.393	2.380
	VG-30	2.329	2.369	2.395	2.333

FIBER (%)		2	4	6	7
Bitumen Content (%)	VG-10	4.55	4.55	4.55	4.55
	VG-30	4.50	4.50	4.50	4.50
Marshall Stability (kN)	VG-10	19.50	22.48	25.15	18.40
	VG-30	16.38	22.10	27.56	20.02

Density and their corresponding Fiber content for grading-1



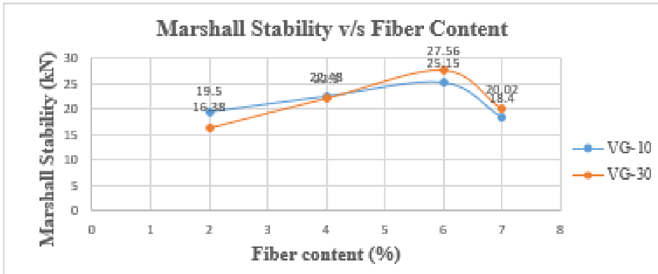
Variation of Density with different fiber content for grading-1

FIBER (%)		2	4	6	7
Bitumen Content (%)	VG-10	4.55	4.55	4.55	4.55
	VG-30	4.50	4.50	4.50	4.50
Voids in Mineral Aggregates (%)	VG-10	13.99	14.53	15.41	17.99
	VG-30	14.79	14.95	15.29	19.56

Marshall Stability v/s Fiber Content

It is observed that Marshall Stability increases with increase in fiber content up to replacement of 6 % and further increment 1 % of steel fiber content Marshall Stability decreased. VG-30 binder has higher value than the VG-10 binder at 6 % fiber content. Variation of Marshall Stability with different fiber content and different binder content.

Stability and their corresponding Fiber content for grading-1



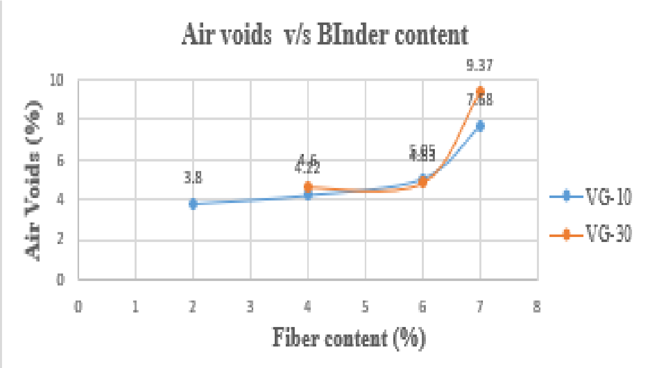
Variation of Marshall Stability with different fiber content for grading-1

Air Voids v/s Fiber Content

It is observed that Air voids increases with increase in fiber content. Variation of air voids with different fiber content and binder content in shown

FIBER (%)		2	4	6	7
Bitumen Content (%)	VG-10	4.55	4.55	4.55	4.55
	VG-30	4.50	4.50	4.50	4.50
Air Voids (%)	VG-10	3.80	4.22	5.05	7.68
	VG-30	4.62	4.60	4.83	9.37

Air Voids and their corresponding Fiber content for grading-1



Variation of Air Voids with different fiber content for grading-1

Flow Value v/s Fiber Content

It is observed that the flow value increases with increase in fiber content in both binder content. Variation of Flow value with different fiber content and binder content is shown

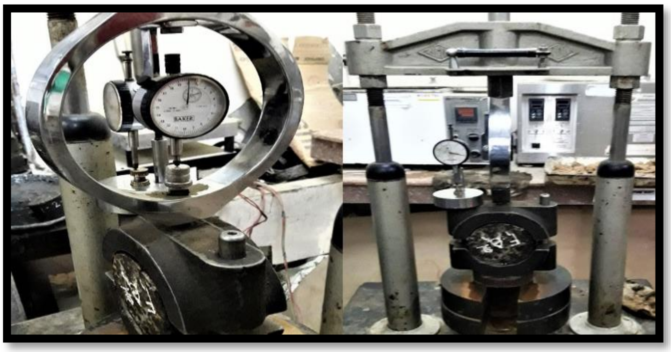
Analysis of results of DBM mix with medium steel fiber and control mix

1. It is observed that the Flow value of both the mixes with Grading-1 and Grading-2 increases with increase in fiber content. This happens mainly because of increment of fine material in the mix.
2. The Stability value of mix obtained with Grading-1 is more than Grading -2, i.e., 22.48 kN and 20.02 kN respectively in VG-10 binder grade. The Stability value of mix obtained with Grading-1 is less than Grading-2, i.e., 22.10 kN and 23.50 kN respectively in VG-30 binder grade. The percentage increase in Stability value with Grading-1 (VG-10, VG-30) and Grading-2 (VG-10, VG-30) has been found to be 7.1 %, 4.2. % and 4.68 %, 3.20 % respectively as compared to conventional mix. The increment in Stability value at different percentage of steel fiber is not much significant.
3. Density of mix obtained with Grading-1 (VG-10, VG-30) and Grading-2 (VG-10, VG-30) is 2.338 g/cc, 2.325 g/cc. and 2.348 g/cc, 2.347 g/cc. respectively, but there is marginal increase in density as compared to conventional mix.
4. All the parameters of dense bituminous macadam obtained by Marshall Test like Stability, Flow, % Air Voids, VMA, of mix with Grading-1 (VG-10, VG-30) and Grading-2 (VG-10, VG-30) at (4.50 %,4.55 %) and (4.66 %, 4.68 %) bitumen content and 4 % steel fiber are within the permissible limits as per MORTH 5th revision.
5. It is observed that the flow value of Grading-1 and Grading-2 with binder grade (VG-10, VG-30) and steel fiber content increases as compare to the control mix.
6. It is observed that the Stability value of Grading-1 with binder grade (VG-10, VG-30) and steel fiber content increases as compare to the control mix. But in Grading-2 value of Stability decreases with binder grade (VG-10) and increases with binder grade (VG-30) and with steel fiber content as compared to the control mix.
7. It is observed that the Density of Grading-1 with binder grade (VG-10, VG-30) and steel fiber content increases as compared to the control mix. But in Grading-2 value of Density is negligible decreases with binder grade (VG-10, VG-30) and with steel fiber content as compared to the control mix.
8. It is observed that the VMA of Grading-2 with binder grade (VG-10, VG-30) and steel fiber content increases as compare to the

control mix. But in Grading-1 value of VMA decreases with binder grade (VG-10) and increases with binder grade (VG-30) and with steel fiber content as compared to the control mix.

9. It is observed that the VFB of Grading-1 with binder grade (VG-10, VG-30) and steel fiber content increases as compare to the control mix. But in Grading-2 value of VFB decreases with binder grade (VG-10, VG-30) and with steel fiber content as compared to the control mix.

Samples in water bath at 60⁰ C temperature



Sample testing on Marshall Stability machine

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The percentage fiber content in DBM is varied from 2 to 7 % with increments of 2 % initially and then 1 % for different series of tests. Based on the result and discussions of experimental investigation carried out on mixes i.e. Dense Bituminous Macadam following conclusions are drawn.

1. Effect of Steel fiber content and binder grade the optimum results for DBM in terms of Stability, Flow, Density, VMA and Marshall Quotient were observed at mix with 4% Steel fiber content for both the binders.

2. The Stability value of DBM with optimum steel fiber content and with Grading-1 (VG-10, VG-30) was found out to be (22.48 kN, 22.10 kN) which is higher than the value of (17.99 kN, 22.53 kN) obtained at control mix. The Stability value of DBM with optimum steel fiber content and binder grade (VG-10) with Grading-2 was found out to be (20.02 kN) which is lesser than the value of (21.99 kN) obtained at control mix. The Stability value of DBM with optimum steel fiber content and binder grade (VG-30) with Grading-2 was found out to be (22.77 kN) which is more than the value of (23.50 kN) obtained at control mix.

3. The percentage increase in Stability value of DBM with optimum fiber content and Grading-1 (VG-10) and Gading-2 (VG-30) has been found to be (12.4 %, 3.20 %) respectively as compared to conventional mix. The percentage decrease in Stability value of DBM with optimum fiber content and Grading-1 (VG-30) and Gading-2 (VG-10) has been found to be (1.90 %, 8.95 %) respectively as compared to conventional mix.

4. It was observed that used steel fiber as replacement of aggregates in Grading-1 (VG-10, VG-30) shows considerable good results as compared to utilizing steel fiber by replacement of Grading-2 (VG-10, VG-30) in terms of Stability, Flow value, Density, VMA, VFB and Marshall Quotient.

5. It was observed that all the properties of the DBM have been improved with the addition of steel fiber but with the limiting value 4 % and less; it is mainly due to larger aggregates size in DBM mix.

6. The percentage increase in VMA value with Grading-2 (VG-10, VG-30) has been found to be

(22.39 %, 22.70 %) as compared to conventional mix. The percentage increase is almost equal in both binder grades.

7. The percentage increase in Density value of DBM with only Grading-1 (VG-10, VG-30) has been found to be (1.92 %, 1.71 %) as compared to conventional mix. The percentage increase is almost equal in both binder grades.

8. The percentage increase in VFB value of DBM with Steel fiber and binder grade (VG-10, VG-30) in Grading-1 has been found to be (4.06 %, 1.18 %) as compared to conventional mix. The percentage increase is more in VG-10 as compare to VG-30 binder grade. The percentage decrease on VFB value of DBM with steel fiber and binder grade (VG-10, VG-30) in Grading-2 has been found to be (18.37 %, 18.88 %).

With the help of these observations and conclusion it is concluded that all the properties of the Dense Bituminous Macadam have been improved with the replacement of the steel fibers. Here it is also important to state that the results of the specimens with Grading-2 are much better than the Grading-1 for the mixes because Grading-1 has larger size of aggregate. The best values of DBM in terms of stability and flow value are with 4% and of steel fiber content gives better result than control mix and will improve the performance of DBM mixes.

Recommendations

From the compilation of research work conducted and the conclusion drawn following are the recommendations.

1. It is suggested in order to utilize medium steel fibers by weight of mix it is recommended to find optimum binder content at different % of medium steel fibers and evaluate the result.
2. It is suggested size, shape and texture of fiber plays a very important role in the mix.
3. It is suggested that the size of the fiber to be used should be correlated to the size of the aggregates used in the mix within the specified requirements. While dealing with the larger aggregates, the size of fiber should be adequately big and vice-versa.

Future Research Area

1. The effect of same type of fiber in case of other Bituminous mixes.
2. Utilization of other proportions and lengths of steel fiber in different percentages.
3. The comparative study can be made using other size and shape of steel fiber.
4. Studies related to economic viability of the use of steel fiber in bituminous mixes can be done.
5. Performance evaluation study of the use of steel fiber in bituminous mixes can be done.
6. Various composition of steel fiber can be chosen for the comparative strength analysis.

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1. **ASTM D 6927 (American Society for Testing and Materials),** Test method for Marshall Stability and Flow of Bituminous Mixtures.

2. IS: 1205 –1978, Determination of Softening Point of Bitumen.

3. IS: 1203 –1978, Determination of Penetration value of Bitumen.

4. IS: 1202 -1978, Determination of Specific gravity of Bitumen.

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