Fiber Reinforced Asphalt Pavement: A Case Study

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Abstract- *In India recently large amount of construction of roads are going on. The construction may be a rigid pavement or a flexible pavement .In the case of flexible pavement, maintenance cost is a greater factor in comparison of construction cost due to continuous deterioration of pavement. The performance of bituminous surfacing depends to a great extent on the correct choice of quality and quantity of materials. So in order to improve the stability and life of this flexible pavement any additives like polymers , industrial waste, fibers can be used to improve the strength and durability of the pavement. . In this paper the use of different fibers is mentioned along with a case study The idea of utilizing different fibers to enhance the conduct of pavement is not new in nowadays. The modern developments of fiber fortification began in the mid-1960s. The fiber materials were presented and are ceaselessly being presented in the market as new applications for the pavement for example polyester fiber, asbestos fiber, glass fiber, polypropylene fiber, Carbon fiber, Cellulose fiber, etc. The present study investigates the benefits of reinforcing the fibers in the flexible pavements.*

Keywords- fibers, asplalt, fiber reinforced, marshal stability, flexible pavement

I. INTRODUCTION

Several waste materials can be used effectively in highway construction due to their numerous desirable engineering properties. By substituting waste materials for fine or coarse aggregates, natural stone reserves can be preserved. Utilization of industrial wastes for highway pavement construction could alleviate environmental pollution and pave the way for bulk waste disposal. Each construction material has some properties that it lacks and some that it excels at. For instance, a critical property of concrete is its high compressive strength. On the other hand, it has a low tensile strength. Similarly, soils are typically deficient in tensile and shear strength. Fibres are an important component of construction materials. Specific fibres can be selected and incorporated into these construction materials to enhance the properties of the parent material, resulting in a more balanced material. For synthetic fibres, different manufacturing processes and raw material compositions result in a range of mechanical properties. Fibers have a variety of properties and come in a variety of shapes and sizes. If implemented, the fibre type must be carefully selected, as some fibres, such as glass, basalt, and recycled polyethylene terephthalate, degrade in alkaline environments. Fibers can help reduce the overall cost of construction by serving as reinforcement, displacing the more traditional and energy-intensive wired mesh and steel reinforcement bars. As a result, labour costs will be reduced, maintenance costs will be reduced, construction time will be saved, and overall construction costs will be reduced. Additionally, energy will be conserved, as the volume of fibre used is typically significantly less than the volume of raw material required to manufacture the conventional reinforcement. By and large, there are numerous advantages to incorporating fibres into construction materials. Additionally, there is the possibility of incorporating waste fibres into construction materials, which repurposes waste materials, reduces landfill volume, conserves energy, is environmentally friendly, and promotes sustainable work practises in the industry.

Asphalt Concrete: The term Asphalt Concrete is referring to the liquid asphalt portion of the composite material. It is commonly called as Asphalt, blacktop or pavement in North America and Tarmac or Bitumen in Great Britain. A composite material used to surface roads, consists of mineral aggregate bound together with asphalt laid in layers and compacted.

The process of road construction can be summarized as follows:

• **Clearing:** The first step in road construction is to remove obstructions that obstruct the pathway, such as trees, rocks, and loose sand, using off-road/heavy vehicles.

• **Leveling the ground:** The next critical step is levelling the ground. Elimination of large chunks of rock and replacement with sand or gravel. The base layer of fine levelled soil is layered to a height of approximately 9 inches.

• **Materials added:** The gravel and molten asphalt mixture is now layered on top of the levelled ground/pathway. Coarse gravel is layered approximately six inches high, and another mixture of crushed gravel and molten asphalt is layered approximately four inches high on top. It is then pressed down with a road roller to improve adhesive strength and levelling for smooth operation of the vehicles.

There are several different types of conventional asphalt and aggregate mixing methods.

1. **Hot Mix Asphalt concrete (HMA)** is made by reducing the viscosity of the asphalt binder and drying the aggregate prior to mixing. Mixing is generally carried out at 300 degrees Fahrenheit for virgin asphalt and at 330 degrees Fahrenheit for recycled asphalt. Paving and compacting must be performed while the asphalt is sufficiently hot; otherwise, the asphalt will solidify, making it difficult to compact/smooth.

2. **Warm mix asphalt concrete (WMA):** This is made by adding zeolites or waxes to the mix, which results in significantly lower mixing and laying temperatures and thus lower fossil fuel consumption, resulting in low CO2 aerosols and vapours.

3. **Cold mix Asphalt:** This type of asphalt is created by emulsifying the asphalt with water prior to mixing it with the aggregate. When emulsified, it becomes less viscous, making the mixture easier to work with. It is frequently used in path construction.

4. **Mastic asphalt concrete:** This is made by heating blown bitumen/asphalt in a mixer until it becomes a viscous liquid, and then adding aggregates. The bitumen aggregate mixture is cooked for 6–8 hours and then transported to the work site for layering.

5. **High modulus asphalt concrete:** This type of asphalt concrete contains a very hard bituminous asphalt in concentrations close to 6% of its aggregates, resulting in an asphalt concrete layer with a high modulus of elasticity of 13000 Mpa and high fatigue strength. They typically have a greater capacity for tension absorption and a higher resistance to fatigue.

How do roads degrade?

Different types of asphalt exhibit varying levels of performance in terms of surface durability, tyre wear, braking efficiency, traffic volume, and roadway noise.

Terminologies frequently used:

Alligator cracking is a result of the road's thin/weak surface and poor drainage.

Block Cracking: Using an old, dried-out asphalt and gravel mixture. Occasionally, cracks develop in areas of low traffic.

Cracks along the edge: frost heave, vegetation along the edge.

Linear/longitudinal cracks: Asphalt layer shrinkage.

Reflection cracking: Deterioration caused by heavy traffic.

Slippage cracks: Vehicles turning or stopping in low-surface-mix pavements. Inadequate bonding between the surface and base layers as a result of dust, oil, dirt, rubber, and other non-adhesive materials.

Corrugations & Shoving: An abnormally high level of moisture in the base layer. Air voids with a low volume. Asphalt with an excessive amount of fine aggregate

Pot hole: Inadequate surface preparation, thawing of a frozen subgrade, cracking, and a failed patch following the removal of sections of the original pavement.

These various types of pavement deterioration can be controlled with the use of various fibres and additives**.**

II. LITERATURE REVIEW

[1]Amazing Types, Properties, and Applications of Fibres in Construction Materials[Abbas Mohajerani , Siu-Qun Hui , Mehdi Mirzababaei , Arul Arulrajah,SuksunHorpibulsuk , Aeslina Abdul Kadir , Md Tareq Rahman and FarshidMaghool]: Fibres have been used in construction materials for a very long time. Through previous research and investigations, the use of natural and synthetic fibres have shown promising results, as their presence has demonstrated significant benefits in terms of the overall physical and mechanical properties of the composite material. When comparing fibre reinforcement to traditional reinforcement, the ratio of fibre required is significantly less, making fibre reinforcement both energy and economically e_cient. More recently, waste fibres have been studied for their potential as reinforcement in construction materials. The build-up of waste materials all around the world is a known issue, as landfill space is limited, and the incineration process requires considerable energy and produces unwanted emissions. The utilisation of waste fibres in construction materials can alleviate these issues and promote environmentally friendly and sustainable solutions that work in the industry.This study reviews the types, properties, and applications of di_erent fibres used in a wide range of materials in the construction industry, including concrete, asphalt concrete, soil, earth materials,blocks and bricks, composites, and other applications.

[2] An overview on using the waste denim fiber as a bitumen modifier for sustainable road construction [Abdulnaser Al-Sabaeei, MadzlanNapiah]: This paper introduces the waste denim fiber as a modifier for bitumen used in the flexible road construction. The sources, chemical components, and properties of denim fiber are discussed. Methods of adding different types of fibers into bitumen and asphalt mixtures are also presented. In addition to that, a review of the effects of cellulose fiber as the main component part of denim fiber in bitumen and asphalt mixture is summarized. The motivations of using denim fiber as a modifier for base bitumen are also highlighted, such as the mechanical properties, lower water content compared to other natural fibers and the sustainability in terms of low cost and mitigate the environmental problem in the same time. Furthermore, Challenges of using denim fiber for bitumen modification are reported. It is expected that a long lasting, cost effective and environmentally friendly denim fiber modified asphalt and asphalt mixtures, which are rut and fatigue resistant will be developed in near future. This will decrease the annual expenses of flexible pavements maintenance required around the world.

[3] Emerging road materials and innovative applications [Amit Goel and **Animesh Das]:** India is currently undergoing through a large number of road infrastructure development projects. Due to this initiative, fresh attention has been drawn to the issues related to latest road technology. This paper presents some emerging road materials and innovative application concepts, which appear to be promising for future developments. As the title of this article suggests, the discussion has been divided into two major parts. The first part discusses about the new and emerging materials in road construction technology and the second part discusses about the recent application concepts of various road materials. Emerging road materials can evolve in two ways (a) as modification of existing road materials and (b) as development of alternative road materials. They have been discussed in the subsequent sections.

[4] Effects of Fiber Finish on the Performance of Asphalt Binders andMastics[Bradley J. Putman]: The objective of this study was to determine the effects of finishes applied to polyester fibers on the properties of asphalt binders and mastics. Asphalt binders were mixed with finishes that were extracted from the fibers, and mastics were also made with binder and fibers (with and without finish) to isolate the effects of the finish. The results indicated that crude source plays a significant role in how the fiber finish affects the binders and mastics. Additionally different finishes had different effects on binder properties. The major finding of this study is that different polyester fibers, even from the same manufacturer, may not necessarily perform the same in an asphalt mixture. It is important to use fibers that are compatible with the particular asphalt binder that is being used because of the significance of the binder source on the interaction between the finish and the binder.

[5] Study on Stone Matrix Asphalt Using Banana Fibre [ChikkanagoudaChoudhari, Pratiksha Malviya]: Matrix Asphalt having good stability, strength and maintenance of smooth surface of roads & other structure is required. Stone Matrix Asphalt mix is prepared by blending of course and fine aggregates. Banana fibers improve service properties of SMA Mix by forming micromesh in the mix to prevent drain down flow of asphalt so as to increase its stability and durability of mix. Aggregate gradation was taken as per MoRTH specification for SMA mix. Binder content was 4, 4.5, 5, 5.5, 6, 6.5, & 7 percentages by weight of aggregate. Fiber was 0.35% by weight of aggregate. Cement was used as a filler material and 60/70 grade of bitumen is used as a binder. Study resulted that optimum bitumen content for samples prepared by mix of banana fiber is found to be 5.3%. Mixing of banana fiber in SMA was observed cost effective & economical. Study resulted higher stability, strength & durability of roads.

[6] The effects of fibers on the performance of bituminous mastics for road pavements [Cristina Bonica, Emanuele Toraldo, Luca Andena, Claudia Marano, EdoardoMariani]: Hot Mix Asphalts (HMAs) are the materials most used for road pavements through the world. They are composed of aggregates, bitumen and filler [1]; different types of additives are also frequently used for both processing and performance purposes. Aggregates, generally deriving from rock quarries, are the skeleton of a HMA. Bitumen and filler together form the so-called mastic which, when mixed with the aggregates, acts as an effective binder for the lithic skeleton. Thus mastics have a crucial role in the HMAs' performance during a pavement service life [2-5] because they have to bear both traffic loads and climatic changes.Polymers and natural or synthetic fibers are often used as HMAs' additive to improve their performance in the field. They can be added either to the bitumen (modified bitumen) or directly to the final HMAs; the latter option is of particular interest in areas of the world in which bitumen modification plants are not available or too far from the construction site.The main effects of an additive on the HMA's behavior are related to its interaction with the mastic: this is true for both a polymer-based additive, due to its affinity to the bitumen, and an additive based on fibers, whose specific area is significantly higher than that of typical aggregates.

[7] A laboratory study of bituminous Mixes using a natural[Debashish Kar]: Generally a bituminous mixture is a mixture of coarse aggregate, fine aggregate, filler and binder. A Hot Mix Asphalt is a bituminous mixture where all constituents are mixed, placed and compacted at high temperature. HMA can be Dense Graded mixes (DGM) known asBituminous Concrete (BC) or gap graded known as Stone Matrix Asphalt (SMA). SMA requires stabilizing additives composed of cellulose fibbers, mineral fibres or polymers to prevent drain down of the mix. In the present study, an attempt has been made to study the effects of use of a naturally and locally available fibre called SISAL fibre is used as stabilizer in SMA and as an additive in BC. For preparation of the mixes aggregate gradation has been taken as per MORTH specification, binder content has been varied regularly from 4% to 7% and fibre content varied from 0% to maximum 0.5% of total mix. As a part of preliminary study, fly ash has been found to result satisfactory Marshall Properties and hence has been used for mixes in subsequent works. Using Marshall Procedure Optimum Fibre Content (OFC) for both BC and SMA mixes was found to be 0.3%. Similarly Optimum Binder Content (OBC) for BC and SMA were found to be 5% and 5.2% respectively. Then the BC and SMA mixes prepared at OBC and OFC are subjected to different performance tests like Drain down test, Static Indirect Tensile Strength Test and Static Creep Test to evaluate the effects of fibre addition on mix performance. It is concluded that addition of sisal fibre improve the mix properties like Marshall Stability, Drain down characteristics and indirect tensile strength in case of both BC and SMA mixes. Ii is observed that SMA is better than BC in respect of indirect tensile strength and creep characteristics.

[8] Investigation of Fiber Concrete for Road and Bridge Building[Katerina Krayushkina, TetianaKhymerik, OleksandraSkrypchenko,IuriiMoshkovskyi, ValeriiPershakov]: As is well known, fibrous concrete has an increased fracture toughness, impact strength, toughness, and abrasion resistance.Products made of this type of concrete can be manufactured without special reinforcement grids and frames. This simplifies the production technology and reduces its complexity. For reinforcement of concrete are using various metallic and non-metallic fibers.In the last thirty years, it began widespread use of steel fiber-reinforced concrete. Its best qualities are to increase the tensile strength and high fracture toughness, because the fibers provide effective resistance to the cracks (in the axial direction of the resistance to the fibers). The fibers used as a thin wire diameter of 0.1 plus or minus 0.5 mm.The wire is divided into segments of 10−50 mm. According to Y. M. Bazhenovfiber diameter of 0.3 m and a length of 25 mm provides better results [1]. In [2] we can see the results of research of steel fiber reinforced concrete with a fiber amorphous with high corrosion resistance. It is important that the reduction of fiber diameter to 0.1 mm leads to increase of separation stops. Deformation occurs through a mechanism of accumulation of damage .

[9] The properties and performance of polymer fibre reinforced bituminous mixtures[Kamaruddin& M. Napiah]: The low tensile strength of bituminous mixtures has been recognized as a source of its poor performance, particularly that which relates to cracking. Laboratory investigations into improving their tensile properties have been performed utilizing polypropylene and polyester fibres which were added to Hot Rolled Asphalt (HRA) bituminous mixtures as partial replacement of Ordinary Portland Cement (OPC) used as the filler material.Theincorporation of the polymer fibres into the bituminous mixtures altered the rheological properties and behaviour of the resulting binder whilst resulting in a higher optimum bitumen content for the mixture. Laboratory tests showed that the fibres reduced the density, stability and stiffness of the resulting mixture while increasing its porosity and permeability.Bituminous mixtures containing the fibres displayed lower susceptibility to moisture induced damage. Even though these mixtures have a higher void content than the base mixture, the additional bitumen in the fibre mixtures increased the film thickness on the aggregate particles thus affording greater protection from moisture. The addition of the fibres into the bituminous mixtures caused a slight decrease in the tensile strength and a slight increase in the tensile strain (elongation) at failure, indicating that the additional bitumen added flexibility or extensibility to the mixtures. This was manifested in the higher toughness and energy that was obtained in the mixtures, thus improving its resistance to cracking. This was supported by the fatigue tests which showed improved fatigue performance of the mixtures. The fatigue properties of the fibre mixtures were not enhanced at low strain levels; but at high strain levels, the fibre mixtures provided a far superior performance than the base mixture, making it appealing for use as a base-course in highway construction.

[10] Review Paper on Effect of Various Fillers on Bituminous[Mohammad Altaf Bhat, O.P Mittal]: This paper summarises the ongoing researches about the effect of various fillers on bituminous mixes. Many studies regarding bitumen fillers that have been carried out earlier were studied, and their effects on the bituminous paving mixes were also analyzed. Bitumen in combination with filler forms mastic. This mastic can be seen as a constituent of mixture of asphalt that holds the aggregates together. An important role is played by the fillers that pass through 0.075mm sieve. With the increase in the amount of filler, Marshal Stability of the bitumen mix increases directly. Use of 4-8% filler in asphalt concrete is recommended by the Asphalt Institute. It was concluded that various fillers such as carbon black, fibres, rubbers, polymers, fly ash, silica or their combination not only hardens the mastic at high temperature during its production an placement but also obtained high binder content for increase in durability. By addition of fillers to bituminous mixes a considerable amount of increase in Marshall Properties can also be observed.

[11] A Review on Comparative Study on Bitumen Modification Using Synthetic and Natural Fiber[Midhila V S, Veena G Raj]: Fiber-modified mixtures are basically composed by the matrix and fibers. The performance of these mixtures is mainly based on the content and length of fibers and on the physical properties and adhesion of fibers and matrix. The use of fibers emerges as a need for improving the flexibility and tensile strength of the bituminous mixtures submitted to a higher volume of traffic and to the increase of loads by axis of heavy vehicles. These are some of the causes which cause the plastic and viscoelastic deformations in the mixture and, consequently, the rutting formation and the progressive propagation of cracks. Fibers are included in the bituminous mixtures to improve some of their properties such as adhesion and flexibility, in order to increase the resistance of the mixture and to prevent premature distress. Some of the main practical examples of the application of fibers in flexible road pavements are referred below, namely through the incorporation of nylon, carbon, synthetic, natural, polymer, glass, acrylic fibers etc. Currently, synthetic fibers, such as: glass, carbon, polymer and aramid fibers are used as modifiers because of their high stiffness and strength properties. Natural fibers such as hemp, coir, jute, sisal and flax are a new class of materials which have good potential in bituminous mixes. Depending on their origin, natural fibers can be grouped into bast (jute, banana, flax, hemp, kenaf, Mesta), leaf (pineapple, sisal, henequen, screw pine), seed or fruit fibers (coir, cotton, palm). Different fiber arrangements, such as: short-randomly oriented, long-unidirectional and woven fabrics have been fabricated for natural fiber composites. Therefore, reinforcement of the bituminous mixes is one approach to improve the tensile strength and fibers are the most suitable reinforcing material.

[12] Effect of polymer fibres reinforcement on selected properties of asphalt mixtures[Piotr Jaskuła, Marcin Stienss, Cezary Szydłowski]: The paper presents selected results of the research program concerning fibre reinforced asphalt concrete. Aramid-polyalphaolefin fibres was used in this study. Selected properties responsible for low temperature cracking and resistance to permanent deformation are presented in this paper. Low temperature cracking susceptibility was evaluated with the results obtained from bending test of rectangular beams with constant rate of deformation and semi-circular bending test based on fracture mechanics theory. Performance in high temperatures was assessed by master curves of dynamic modulus. Obtained results indicated that evaluated fibres can improve low temperature pavement performance.

[13] Different types of Fibres used in FRC[Parveen Kaur, Mohit Talwar]: the world like a stone with desirable durability and high compressive strength. Concrete is used as a construction material but it has a disadvantage that is brittleness means concrete has the relatively low tensile strength and poor resistance to crack opening and propagation and weak in tension. With some assumptions, deformed steel bars or pre-stressing tendons are provided on concrete to improve its limitations (RCC). It can usually be reinforced with materials that are strong in tension. Fibre is such a reinforcing material. Fibres are small pieces of reinforcing material possessing certain characteristics and properties. Fibres are considered as a construction material to enhance the flexural and tensile strength and as a binder that could combine Portland cement in bonding with cement matrices. Fibres increase the structural integrity of the concrete. Fibres are usually used in concrete to control cracking due to plastic shrinkage and drying shrinkage. It produces greater impact and abrasion resistance. Use of micro fibres offers better impact resistance. Fibre reinforced concrete (FRC) is a new structural material which is gaining increasing importance. FRC is relatively a new composite material made of hydraulic cement, aggregates and discrete fibres. FRC system has been used for various purposes.

[14] Rheology of waste plastic fibre-modified bitumen [Praveen Kumar &Rashi Garg]: Development of modified asphalt materials to improve the overall performance of pavements has been the focus of several research efforts made over the past few decades. Use of discarded waste plastic construction was one of the steps taken in this direction. Using the waste materials in road construction will not only bring out significant saving in road material costs but also help towards tackling the problems of disposal of such waste materials, which tend to be hazardous in as much as they can cause pollution of both air and water. The dynamic shear rheometer is used for the determination of the rheological properties of bitumen in a wide range of temperatures. The rheological properties of road bitumen are improved by means of polymer modification as identified by both conventional and more fundamental rheological parameters. The present study aimed

at preparing bitumen modified with waste plastic fibres and finding the variation of conventional and rheological
properties (before and after ageing) at different temperatures. Both short- and long-term ageing is considered. The complex modulus is determined at 10 rad/s and at temperatures varying from 46 to 588C. Using the test results, the optimum fibre content was found out and properties of unmodified and modified bituminous mixes were compared using the Marshall test.

[15]A Study on Use of Natural Fiber for Improvement in Engineering Properties of Dense Graded Bituminous Mixes with Coal Ash[SaswatBiswapriya Dash, Mahabir Panda]: Coal-based thermal power plants have been a major source of power generation in India. The prime waste products of a coal based thermal power plant are fly ash and bottom ash. Heavy dumping of these waste products causes fatal environment pollution to air, water, and land, besides impairing human health. This research work is done to explore the optimum use of ash, namely bottom ash (as part of fine aggregate) and fly ash (as mineral filler) along with natural fiber (such as sisal fiber) used to improvise the engineering properties of bituminous pavingmixes. In the present laboratory study, dense graded bituminous mix specimens were prepared using natural aggregates as coarse aggregates, bottom ash as fine aggregates, fly ash as filler and sisal fiber as additive. To strengthen the mix, slow setting emulsion (SS1) coated sisal fiber was added in varying percentages such as 0,0.25, 0.5, 0.75, and 1 % by weight of the mix, with variations of sisal fiber length such as 0, 5, 10, 15 and 20 mm. The most suitable composition (such as optimum bitumen content and optimum fiber content including the optimum length of fiber in the bituminous mix) was selected based on the results of Marshall tests. Further, for justifying the performances of the bituminous paving mix thus developed, tests for indirect tensile strength and moisture susceptibility in the form of tensile strength ratio and retained stability of bituminous mixes were conducted.

[16]UTILIZATION OF POLYMER WASTE FOR MODIFICATION OF BITUMEN IN ROAD CONSTRUCTION[SHIRISH N. NEMADE and PRASHANT V. THORAT]: Generation of polymer waste is increasing day by day and necessity to dispose this waste in proper way is arising.This waste is disposed by using different methods such as incineration, land-filling which affects the environment; but by adding polymer into roads is the eco-friendly process. The addition of polymer into dry bitumen improves the service properties of bitumen. If we use the polyolefins waste with or without crumb rubber upto certain percentage of bitumen then the properties of modified bitumen will be increased. The use of this innovative technology (polymer loading into bitumen) not only strengthen the road construction but also increases the road life as well as will help to improve the environment and also creating a source of income. By utilization of such polymer waste would be a boon for India’s hot and extremely humid climate, where temperature frequently crosses 500C and torrential rains create havoc, leaving most of roads with big potholes.There are two types of techniques can be used for disposal of polymer waste in road construction. Dry process is suitable because by this process 15-20 % of plastic waste addition by weight % with respective to aggregate. But considering the limitations of this process that it is applicable to plastic waste only and hence our aim of disposing the total polymer waste for eco-friendly environment cannot be completely achieved. Wet process though it requires strong mechanical stirrer and continuous rotation, batch type production and separate chamber. If processing parameters such as heat losses, temperatures etc. are properly controlled there is reduction in the residence time which minimizes production time and thus improves productivity, hence this process is economically feasible and limitations of dry process can be overcome. As far as type of polymer waste is concerned, wet process is suitable for any type of polymeric waste (rubbery or plastic) or any size and form (either strand or powder). By the actual experimentation, we obtained optimum results for polymer waste at different composition. Hence, from the results, polyolefin waste can be loaded upto 6%HDPE, LDPE upto 6%, PP upto 4% crumb rubber upto 4% and mixture of crumb rubber and HDPE waste upto 8% (4% + 4%) in road construction. Under the similar conditions most of the bitumen roads are performing well at all.

[17]The effect of polypropylene fibers on asphalt performance [Serkan Tapkın]: Polypropylene fibers are extensively used in civil engineering applications for many years. These fibers are used in concrete as a three dimensional secondary reinforcement. Due to adhesion between polypropylene fibers and bitumen, the strengthening mechanism in asphalt concrete is somehow different. In this study, asphalt concrete specimens with polypropylene fibers were manufactured at the optimum bitumen content. It was
observed for fiber-reinforced specimens that the Marshall stability values increased and flow values decreased in a noticeable manner. The fatigue life of these specimens was also increased. The improvement of the properties of asphalt concrete shows the positive effect of polypropylene fibers. The fiber-reinforced asphalt mixture exhibits good resistance to rutting, prolonged fatigue life and less reflection cracking. Therefore it is concluded that the application of polypropylene fibers alters the characteristics of asphalt mixture in a very beneficial way.

Fiber Reinforced Asphalt: Asphalt containing a mixture of discrete fiber improves and increases the structural integrity of the asphalt. The fibers are distributed uniformly and randomly oriented maintaining a pattern to strengthen the asphalt concrete overall. Only 3% percentage of fibers is introduced to the asphalt mixture to act effectively.

Effects of Fiber in Asphalt:

- Fibers control the cracking due to plastic shrinkage.
- Reduce the bleeding of water.
- Improves thaw resistance.
- Improves resistance to explosive spalling in case of a severe fire.
- Improves impact resistance and abrasion resistance.
- Reduces crack widths and control the crack widths tightly, thus improving durability.
- Increases the tensile strength.
- Reduces air voids; water voids the inherit porosity of gel.
- It has been recognized that the addition of small, closely, spaced and uniformly dispersed fibers to concrete would act as crack arrester and would substantially improve its static and dynamic properties.

Methods used for introducing the fibers in Asphalt mixture:

Dry Mix Process: The dry process mixes the fiber with the aggregate before adding asphalt. The dry process allows for the best fiber distribution in the mixture. It also reduces the clumping or balling of fibers in the mixture.

Wet Mix process: The wet process blends the fibers with the asphalt prior to incorporating the binder into the mixture

III. CASE STUDY

To find the Properties of Marshall Tests performed in Polypropylene Reinforced Asphalt Concrete as per ASTM standards.

1) Density of bituminous concrete samples

The density of the mix has a significant effect on the pavement's service life [15]. As shown in Figure 1, both dry and wet modified mixes had a lower density than the control mix. Mixtures with a higher internal resistance resist densification, as observed for both wet and dry PP modified samples, with the exception of a 3% PP wet mix that is nearly identical to the control mix. Except for the 3% PP wet mix, which is nearly identical to the control mix, PP modified samples for dry mix samples. The arrangement of aggregate and dry polymer rasin in the dry mix sample precludes further densification at the same energy level of compaction. This trend toward decreased density for wet modified samples may be due to an increase in binder viscosity, which impedes aggregate sliding against rearrangement during densification caused by the application of constant vertical pressure by the gyratory compactor. The polymer resin acts as an additional aggregate material that resists densification in dry mix modified samples. Another factor that contributes to densification is that bitumen, when added to a dry mix, does not always form multiple layers on the aggregate or polymer due to a lack of adhesion or absorption of the binder following the formation of the initial monolayer on the aggregate's surface. The decrease in flow values for dry mixed samples also confirms this. For a 1% PP dry mix sample, the results appear promising as long as the air void content does not exceed the 3-5% limit specified in the JKR standard specification. For the remainder of the dry sample, the increase in air voids also contributes to the decrease in density. In short, values of density less than or equal to the control mix density indicated that additional densification is possible and would benefit pavements subjected to unexpectedly high wheel loads if the criteria for air void content at 4% can be maintained.

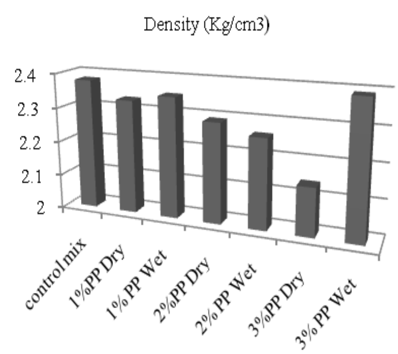

Fig. 1 Density Vs Binder content for Control, Wet and Dry PP Modified bitumen

2) Flow of Bituminous concrete samples

As illustrated in Figure 2, flow values for wet blend samples are greater than those for control mixes, whereas flow values for dry mixed samples remain constant up to a polymer content of 2%. These findings indicate that in wet blend samples, the binder acts as a lubricant, allowing aggregates to slide past one another, thereby improving the elastic and plastic properties of the bituminous concrete mixture. For samples containing 3% PP, a decrease in flow was observed, which could be due to polymer agglomeration resisting particle sliding past as per viscosity test results. For dry mixes containing 3% PP, a decrease in flow was observed. Thus, a stiffer initial mix with improved flow properties benefits by distributing load more evenly and causing less permanent deformation [16].

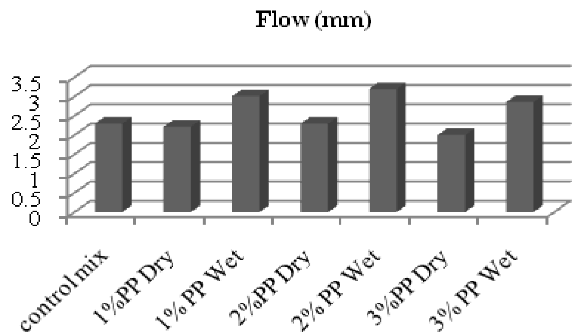

Fig. 2 Flow Vs Binder content for Control, Wet and Dry PP Modified bitumen

3)Stability of Bituminous concrete samples

As illustrated in Figure 3, the stability values for the control, wet, and dry mix samples all meet the requirements of the JKR standard (Table VI). Significant increases in stability values were observed for all wet mix samples when compared to control mix. The increased viscosity of the wet blend modified binder is one of the reasons for the mix's increased stability. For dry mix samples, the decrease in stability was more pronounced for samples modified with 2% and 3% PP. The decrease in density associated with increasing polymer content in dry mix is due to a decrease in adhesion, as evidenced by the increase in air voids and subsequent decrease in density for all dry mix samples.

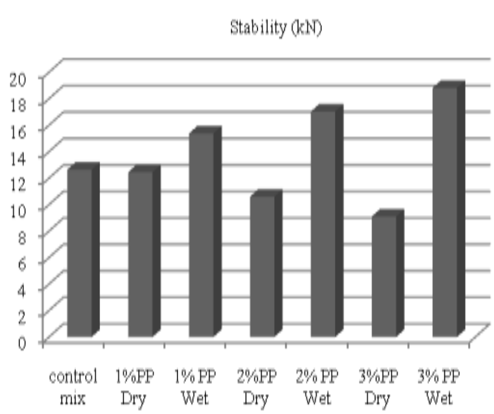

Fig. 3 Stability Vs Binder content for Control, Wet and Dry PP Modified bitumen

4) Stiffness of Bituminous concrete samples

The stiffness of a material, or its Marshall Quotient, is a measure of its resistance to shear stresses, permanent deformation, and thus rutting [1]. A mix with a high stiffness value has a greater ability to spread the applied load and is more resistant to creep deformation [17]. As shown in Figure 4, when compared to the control mix, the wet mix exhibits an increase in stiffness values as the polymer content increases. As observed for wet mix samples, the increased viscosity of blended binder improves the mechanical properties of the mix. This property would benefit the mix's creep modulus. Only a 1% PP dry mix sample exhibits a marginal increase in stiffness value, indicating that the strength is imparted by the binder, with some strength derived from dry polymer resin.

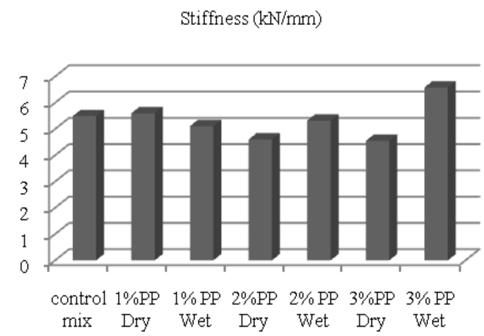

Fig. 4 Stiffness Vs Binder content for control, Wet and Dry PP Modified Bitumen

5) Workability Index of Bituminous concrete samples

The Workability Index is a measurement of how easily a bituminous mixture can be laid and compacted. Both the dry and wet mix workability indices decrease when compared to the control mix. For wet mix samples, the increased viscosity of the modified binder provides resistance to compaction, but all values for wet mix were significantly greater than 6.0, as mixtures with a workability index less than 6.0 experience difficulties during field compaction [18]. Only 1% PP dry blend samples have a workability index greater than 6.0, indicating that the small amount of dry polymer in the mix acts as a filler without impairing the mix's properties. For dry samples containing 2% and 3% PP, the added polymer was unable to form a compatible network, resulting in resistance to densification and a lower workability index for the mix.

IV. CONCLUSION

It can be seen from the graphs above that the addition of polypropylene (PP) fibres to wet mix asphalt concrete increases its viscosity and has an effect on the stiffness, flow, and density of the asphalt mixture. On the other hand, dry asphalt exhibits no significant increase in stiffness, as the polymer does not interact properly during the brief mixing time and thus fails to impart any desired properties. 3 percent PP in a wet asphalt mixture provides superior density, stability, and stiffness compared to 1 – 2 percent PP in a wet asphalt mixture. In terms of stiffness, stability, flow, density, and stiffness, 1% PP with dry asphalt mixture performs better than 2%–3% PP with dry asphalt mixture. All wet and dry asphalt mixtures have a lower density than the control mixture. It has been demonstrated that combining fibres with asphalt concrete has a significant effect on the engineering properties of the road. All fibres are effective in one or two properties but fall short in others. Polypropylene, on average, is the best material for reinforcing asphalt concrete. Carbon and glass fibres outperform all other fibres in terms of performance, but both are prohibitively expensive to manufacture on a large scale. Additionally, there are various grades of asphalt used in road paving. This allows for the incorporation of any percentage of fibres into the asphalt during the wet or dry mix process, ensuring effective engineering properties. While it is claimed that polyester performs better than polypropylene in dry mix processes, there is no evidence to support this claim.

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