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Experimental Investigation on Effect of Natural Fibre on the Properties of Fibre Reinforced Bituminous Concrete : A Review

Nikhil Chourasiya[1], Nadish Pandey[2], Rajesh Joshi[3]

[1]P. G. Scholar, Department of Civil Engineering, RGPM, Bhopal, Madhya Pradesh, India

[2]Assistant Professor, Technocrats Institute of Technology, Excellence, Madhya Pradesh, India

[3]Head of Department, Rajiv Gandhi Proudyogiki Mahavidyalaya Bhopal, Madhya Pradesh, India

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ABSTRACT

Transport is a key infrastructure of a country. Further, the country's economic status depends on how well the country is served by its road, railways, airports and ports. The growth rate of the country is closely connected to its development in the transport sector. Among the four major modes of transportation (viz. roadways, railways, waterways and airways), road provides maximum service. Road transportation has the maximum flexibility for travel with reference to route, direction, time, speed and mode of the vehicle. The road transport has become a wider choice among all the transport systems in India, keeping in view of its level of penetration in to the populated area and its cost effectiveness. Road transport is a critical infrastructure for the economic development of a country. It influences the pace, structure and pattern of development. Road transport also acts as a feeder service to railways, shipping and air traffic; hence a better and planned network of roads is necessary throughout the country.

In this study we are reviewing the literatures related to utilization of natural fibers in bitumen.

Keywords : Bitumen, Road, Review, Technology, Fibers, Pvements

I. INTRODUCTION

The use of modified bitumen with modifiers such as polymers (elastomers and plastomers), crumb rubber, natural rubber latex and chemical modifiers improves the performance of the pavement against rutting and moisture resistance damage. Further, the use of modified bitumen has extended the life of the pavements. Modified bitumen delays the fatigue cracking also.

The modern development of fibre reinforcement started in the early 1950s. Initially, studies were carried out using wire mesh as reinforcement for arresting reflective cracks in the bituminous overlay. Asbestos fibres were used until they were found hazardous to health. As a reinforcement material, the principal function of the fibre is to provide additional tensile strength in the resulting composite. This could increase the amount of strain energy that can be absorbed during the fatigue and fracture process of the mix.

Recently studies have been carried out on the use of fibres to improve the behaviour of bituminous mixes in many countries. The use of synthetic fibres such as polypropylene, polyester, cellulose, mineral fibres etc. have been widely studied and are practised presently throughout the world. Additions of fibre in Stone Matrix Asphalt (SMA) and open graded mixes are widely practiced to prevent drain down of bitumen from aggregates. However, the addition of fibres in dense graded bituminous mix to improve its properties is not generally practiced. The addition of fibres in small quantities in the bituminous mix improves tensile strength, rutting potential, crack resisting capacity, abrasion resistance, the life of the pavement and anti-slide performance. The effect of using fibre in bitumen and bituminous mixes vary widely depending on the dosage, process, combinations, the properties of fibre and their compatibility.

II. Literature Review

Salim Khoso et al (2019) the research paper presented an experimental investigation on the use of GFRP, CFRP and SSF fibres alone or as a combination to improve the mechanical properties of concrete. Furthermore, concrete cylinders were cast and tested for compression and tension using 10% fly ash as cement replacement in all specimens. Besides fibre material types, fibre reinforcement ratios of 1% and 1.5% were tested to investigate the mechanical properties of concrete.

In all concrete cylinder tests, the fibre reinforcement ratio of 1% had a significant contribution in increasing the tensile strength as opposed to compressive strength. As a result, the tensile and compressive strengths were increased by 26% and 11%, respectively as compared to the control specimen. Increasing the fibre reinforcement ratio from 1% to 1.5%, resulting in diminishing the mechanical properties of concrete. However, reduction in concrete compressive strength was more prominent than the tensile strength. Fibres helped in enhancing the post crack ductile behaviour which is almost absent in plain cement concrete. While testing the concrete specimens, it was observed that the fibres hold the concrete matrix up to a considerable limit after being cracked not allowing the aggregates to disperse when tested.

Dr.R.Kumutha et al (2017) in the research paper, fly ash and GGBS were utilized in making Geopolymer concrete. The alkaline solution is used that comprises sodium silicate (114.206 kg/m3) and Sodium hydroxide (57.10 kg/m3) in the ratio of 2.0. Sodium hydroxide of 8 Molarity is used. In this research, various percentages of basalt fibres are added to the geopolymer concrete and the compressive, flexural and split tensile strength of the different mixes were compared with the geopolymer concrete without basalt fibres. fibres are added to the geopolymer concrete in the range of 0.5% to 2.5% at 0.5% increments.

The results stated that the addition of basalt fibres to geopolymer concrete improves the mechanical properties of geopolymer concrete. The increase in compressive strength was about 8.5% for the addition of 0.5% basalt fibres. For 1%, 1.5% and 2% of basalt fibres, there was an increase in compressive strength of 14%, 27% and 38% respectively. From the test results, it was seen that as the percentage of fibre increases, the compressive strength also increases. The increase in split tensile strength is about 12%, 22%, 36% and 50% for 0.5%,1%, 1.5% and 2% of basalt fibres respectively. From the test results, it was further seen that as the percentage of fibre increases, the split tensile strength also increases. As the basalt fibre content increases flexural strength of GPC also increases. There has been an increase in flexural strength of about 35%, 87%, 117% and139% respectively when the basalt fibre content is increased from 0.5% to 3%. The formation of cracks was more in the case of concrete without fibre than the basalt fibre reinforced geopolymer concrete. Hence it was concluded that basalt fibre acts as crack arrestors and can prevent sudden failure of the structure.

Palkannan. S et al (2015) in the research paper, the combination of fibres termed as hybridization was investigated for M25 grade concrete. Control and two-fibre hybrid composites were cast using different fibre proportions of steel and coconut coir. Compressive test, split tensile strength and flexural strength were performed and results were extensively analyzed to associate with different fibre combinations.

The best results were seen in the sample in combination with 0.8% steel fibre and 0.2% gave High Strength as compressive strength, flexural strength and split tensile strength in comparison to other combinations.

Balasubramanian et al (2015) the research paper investigated the use of sisal fibres in structural concrete to enhance the mechanical characteristics of concrete and compare the differences in properties of concrete containing no fibres and special concrete with fibres, as well as the correlation on the effects of different type and geometry of fibres to the concrete is the aim of the study. This scrutiny was carried out using several tests, which contained workability test, compressive test, split tensile test, flexural test. A total of ten mix batches of concrete containing 0%, 0.5%, 1%, 2% dosage of fibre were cast.

Results stated that the Addition of fibres of aspect ratio 300 by a dosage of 1.5% shows an increase in compressive strength as compared to conventional concrete. The addition of fibres of aspect ratio 300 by a dosage of 0.5% shows an increase in split tensile strength as compared to conventional concrete. Addition of fibres of aspect ratio 300 by a dosage of 1% shows an increase in flexural strength as compared to conventional concrete.

Dayanand Kumar R et al (2017) the research paper conducted an experimental investigation on Tin Fiber Reinforced Concrete for pavement application. The investigation was done on the influence of the addition of soft drink can waste material as fibres with various aspect ratios keeping the dosage of fibre constant as 1% by volume of concrete. The sizes of the fibre vary from 10mm to 40mm respectively. The properties investigation include compressive strength, flexural strengths and fatigue test. The research was conducted on an M40 grade concrete mix for pavement application. The test results were compared for compressive and flexural concrete strengths, with and without the use of fibres of different sizes and fatigue characteristics of fibre reinforced concrete are studied and pavement design and cost analysis was done.

Results stated that the addition of fibres in concrete mix affects the properties of fresh concrete such as slump value, hardened concrete such as compressive strength & flexural strength. compression and flexural strength of specimen of aspect ratio 150 are more than another specimen, compression strength and flexural strength of specimen of aspect ratio 150 are 7.67 % and 11 % more than the conventional concrete specimen. Fatigue results show adding fibres increases the number of cycles to failure by 15% between plain and fibre reinforced concrete hence tin fibres can be used in pavement. Adding 1% of the fibre reduces pavement thickness i.e.24 cm than normal concrete which is 28 cm and it also gives 11.05 % of cost-savings in construction. Hence results concluded that tin fibre reinforced concrete is an excellent new type of composite material compared with ordinary concrete as the thickness of the road is reduced without affecting the load-carrying capacity and is a cost-effective technology.

Amit Kundal and Dr Amit Goel (2019) the objective of the research paper was to determine the benefits of the use of naturally available fibre called SISAL fibre used as an additive in Bituminous concrete. SISAL fibre was used in bituminous mixes to study the benefits of the use of natural fibre and environmentally sustainable design. Standard Marshall Mix design test and Drain Down test were performed. The process of mixing and preparation of aggregate, gradation had been taken as per the specification of (IS- MORTH). The various percentages of binder varied (4%-6%) and additive fibre varied (0%-0.8%) of total aggregates and Stone dust as a filler. Using Marshall Procedure, the optimum value of bitumen content was found to be (5%). Similarly, Fibre content for Bituminous Concrete (BC) was found to be (0.4%). Bituminous Concrete (BC) mix samples were made to identify their OBC and OFC, then performed with tests like Marshall Stability and Drain down test to assess the result of the addition of fibre in the bituminous mix.
It was observed that after adding Sisal fibre to 0.4% and fibre length 10mm and bitumen content-5% the stability of the mix increases, but when adding more than 0.4% fibre content stability start to decrease. It was identified that with an increase in fibre content and fibre length up to a certain level, Air void and flow value decreases Thus the consistency of asphalt changes and becomes harder. The use of emulsion coated fibre increases resistance to moisture-induced damages. The drain down of the binder decreases which show good characteristics of bitumen.

T.Subramani and J.Karthick Rajan (2019) in the research paper, the compressive strength, water absorption and flexural of paver squares were controlled by including coconut fibre in the best 20mm thickness. Coconut filaments were included extent of 0.5% in the volume of cement. The compressive strength, flexural strength and water absorption were resolved toward the finish of 7, 14 and 28 days.

Results stated that Compressive Strength enhancement ranges from 0.5% when % of fibre increases the compressive strength value at 41.32 N/mm2 at 28 days compared to conventional mix. By changing the layer thickness and utilizing coconut filaments the properties of the paver block are enhancing altogether and it was observed to be economical. Flexural strength is significantly improving from the increasing 0.5% of coconut fibre 5.08 N/mm2 at 28 days when compared to conventional concrete paver block.

T.Naveen Kumar et al (2015) the research paper presented the effect of human hair on plain cement concrete of M-40 grade based on its mechanical properties which include compressive, flexural and split tensile strength and also to reduce environmental problems. Experiments were conducted on Concrete cubes, beams and cylinders of standard sizes with the addition of various percentages of Human Hair fibre i.e., 1%, 1.5%, 2%, 2.5% and 3% by weight of cement and results were compared with those of plain cement concrete of M-40 grade. For each percentage of human hair added in concrete, six cubes, three beams and three cylinders were tested for their respective mechanical properties at curing periods of 7 days, 14 days and 28days. The change in mechanical properties of concrete was determined and analyzed.

The results stated that the optimum content of human hair fibre to be added to the M-40 grade of concrete was 1.5% by weight of cement and consequently there has been a significant increase in mechanical properties of concrete. Also, the addition of human hair fibres enhances the binding properties, microcracking control, imparts ductility and also increases spalling resistance. As the percentage of human hair increases, the strength increased up to 1.5% itself and then decreased. It's the tendency of human hair that has a water absorption capacity of about 30% of its weight. And, it was in impure nature, the percentage may increase to 45-50% of its weight. Thus, one needs to add to concrete that centre fibrei s not sufficiently utilized by the cement, thereby percentage of un hydrated cement increases much more. Hence it weakens the structure and strength get reduced.

Peter Gallo (2017) research paper presented the potential of the use of materials from renewable energy sources in asphalt pavement. Except for cellulose fibres, these materials are not common in road construction. Perhaps this is due to prejudice, distrust or underestimation of natural materials. It is understandable, that using vegetable fibres in an environment of relatively high temperatures, which undoubtedly hot asphalt mixtures are, may create some concerns. Only empirical concerns are not sufficient justification for ignoring any attempt to research this field.

Results stated that Asphalt mixtures with vegetable fibres achieved better results than the reference mixture; showing better tensile strength, stiffness and resistance to permanent deformation.

Abass Abayomi Okeola et al (2018) research paper presented the physical and mechanical properties of sisal fibre-reinforced concrete were reported. Sisal fibres were added in the mix at percentages of 0.5%, 1.0%, 1.5%, and 2.0% by weight of cement. Physical properties measured are workability, water absorption, and density while mechanical properties reported are compression strength, split tensile strength and static modulus of elasticity. The computed modulus of elasticity of sisal fibre-reinforced concrete was compared with predicted values in some common design codes.

The compressive strength of concrete was observed to reduce due to the presence of sisal fibre in the mix, hence sisal fibre cannot improve the compressive strength of concrete, although it significantly improves the split tensile strength of concrete and makes it lighter by reducing its density. However, computing the modulus of elasticity of SFRC is somewhat difficult and cannot be predicted accurately with empirical relations, as its static modulus of elasticity is not linearly related to its compressive strength and density as stated in most design codes. The recommended optimum mix based on the physical and mechanical parameters in this study is 1.0% sisal fibre addition, which gave 33.55 MPa compressive strength and 3.463 MPa split tensile strength at 28 days of curing, therefore 1.0% sisal fibres can be used in the production of SFRC. Therefore, the utilization of sisal fibres up to 1.0% can potentially enhance concrete ductility properties. Hence, results concluded that sisal fibre can enhance the split tensile strength and Young's modulus of concrete but cannot improve its workability, water absorption, and compressive strength.

E. Arunakanthi and J. D. Chaitanya Kumar (2016) the primary aim of the research was to investigate the effect of glass fibre and steel fibres in the concrete. FRC has the high tensile strength and fire resistant properties thus reducing the loss of damage during fire accidents. In the present work the strength studies are carried out to compare the glass and steel fiber concrete. The FRC is added 0.5, 1, 2 and 3% are added for M20 grade concrete.

Results stated that In compressive strength, flexural strength and split tensile strength, the addition of Steel fibre strength increases linearly, but in glass fibre, up to 1% it is increasing and from 2% it is decreasing. It was concluded that the strength is increasing while increasing the percentage of steel fibre. But in the case of glass fibres, the strength is increasing up to 1%.

Ali Raza and Qaiser uz Zaman Khan (2020) in the research paper, twenty hybrid-fibre-reinforced concrete (HFRC) columns and one plain concrete column were cast to examine the effect of hybrid fibres on the axial capacity, load-defection response and cracking patterns of columns under axial concentric loading. All specimens were square in cross-section having a side length of 150 mm and a height of 1200 mm. Two different types of fibres were used; one is steel fibres (SF) and the second is polypropylene fibres (PPF). Four different volumetric ratios of SF (0.7%, 0.8%, 0.9%, 1.0%) and five different ratios of PPF (0.1%, 0.3%, 0.5%, 0.7%, 0.9%) were used in the investigation.

The results indicate that the combination of 0.8% SF and 0.5% PPF performed well for load-carrying capacity and a combination of 0.9% SF and 0.3% PPF presented the best performance for the ductility of HFRC columns. Moreover, a constitutive finite element model (FEM) was proposed using the concrete damaged plastic (CDP) model in ABAQUS for predicting the axial behaviour and crack patterns of HFRC columns under concentric loading. A close agreement was observed between the experimental measurements and FE predictions.

Debasis Panda and Shubham Dutta (2019) research paper investigated the effects of the addition of binding wires on the compressive strength, flexural strength and split tensile strength of concrete. Different quantities of binding wires are added to the concrete to find out the optimum quantities of binding wires in which the FRC with binding wires is more effective in terms of strength and crack resistance capacity.

The result stated that the addition of binding wires improves the strength characteristics of concrete. It is also seen that with an increase in the quantities of fibre, the compression, split tensile and flexural strength of concrete is increasing. But with an increase in the quantities of fibres in concrete, impart extra load on the structure and also increase the cost. Apart from the strength characteristics, it is also clear from the results and the crack pattern of the tested specimens that the addition of binding wires as fibre improves the ductility of the concrete along with its post cracking load-carrying capacities.

Ying Gao et al (2017) in the research paper, the numerical method was used to investigate the reinforced mechanism of FRAC from a micro perspective. The 2D micromechanical model of FRAC was established based on Monte Carlo theory. Effects of fibre length and content on the stress state of asphalt mortar, effective modulus, and viscoelastic deformation of asphalt concrete were investigated. Indirect tensile stiffness modulus (ITSM) test and uniaxial creep test were carried out to verify the numerical results.

Results stated that the maximum stress of asphalt mortar was lower compared to the control concrete when the fibre length is longer than 12 mm. Fiber reduces the stress level of asphalt mortar significantly. Fibre length has no significant influence on the effective modulus of asphalt concrete. Fibre length and content both have notable impacts on the viscoelastic performance of FRAC.

Huan Gao et al (2021) Based on the simulation model of the asphalt concrete matrix center point stress and the average value of the fiber stress at the center point, fiber with a 6 mm length or with a diameter over 60 μm had the best reinforcement effect on the matrix.

The fibres with lengths 3 and 9 mm or with a diameter below 40 μm had more obvious toughening effects. It could also be seen that fiber reinforcement provided a balance between the effects of strengthening and toughening when the fiber volume was 0.1%. When the fiber volume was 0.3% or the fiber modulus was 20–30 GPa, the fiber reinforcement effect on the specimen was the best. This effect was mainly toughening when the fiber volume was over 0.3% or the fiber modulus was over 30 GPa in the asphalt concrete specimen. Furthermore, the influence of fiber length, volume ratio, diameter, and modulus on the mechanical properties of FRAC was studied through the indirect tensile test. The splitting tensile strength of the specimen after adding fibre was higher than that of the original asphalt concrete. PAN specimens have a better elevation than PVA specimens. These results prove that adding fibre has a reinforcing effect on the asphalt mixture. Considering the von Mises stress distribution diagram simulation, it was found that the distribution of tensile and compressive stresses was consistent with the theoretical situation. The error of the experimental and simulated data was within an acceptable range. The elastic-plastic model used in this work is thus reasonable and effective.

III. CONCLUSION

The uses of fibres in bituminous mixes have been widely studied using open graded and gap graded mixes. The studies on the usage fibre in dense graded bituminous mixes are less common. Further studies with use of synthetic fibres are more prevalent. Studies on the use of locally available natural fibres in dense graded bituminous mixes are very limited. Among the natural fibres, sisal fibre was found to have excellent characteristics in terms of tensile strength, impact resistance, anti-friction, marine corrosion resistance. Though the research studies show that the use of fibres can enhance the pavement life and the serviceability, further studies are to be carried out to assess the potential benefit.

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