As per UGC guidelines an electronic bar code is provided to seure your paper

International Journal for Modern Trends in Science and Technology, 8(07): 164-169, 2022

ISSN: 2455-3778 online
DOI: https://doi.org/10.46501/IJMTST0807024
Available online at: http://www.ijmtst.com/vol8issue07.html

Improvement in Performances of Pavement by the Reinforcement of Glass Fibers in Bitumen

Lokesh Kumar

Department of chemistry, J. V. Jain College, Saharanpur-247001, India.
Email: lokesh.k.as@gmail.com

To Cite this Article
Lokesh Kumar. Improvement in Performances of Pavement by the Reinforcement of Glass Fibers in Bitumen. International Journal for Modern Trends in Science and Technology 2022, 8(07), pp. 164-169. https://doi.org/10.46501/IJMTST0807024

Article Info
Received: 05 June 2022; Accepted: 01 July 2022; Published: 09 July 2022.

ABSTRACT

Blends are made by using glass fiber of 3 mm and 7 mm in different dosages 2, 4, 8, 12, 16 weight percentage of bitumen binder in this study and they are evaluated for the performance characteristics of modified bituminous binders as the standard specifications. Conventional test such as penetration, softening point and Marshall Stability test were performed for the produced glass fiber modified bituminous binders. The stability of binders increases, when the size of fibers is reduced and their dosages are increased. It means fibers have increased the mechanical performances of bituminous binders and it can be for enhancement of service life and quality of roadways. The penetration and softening point data of glass fiber modified bituminous binder shows that their stiffness and hardness have increased as size of fibers is reduced and amount have increased. This will make pavement resistant to rutting and cracking.

KEYWORDS: bitumen, glass fiber, fatigue, reinforcement, Marshall Stability

1. INTRODUCTION

Over few decades, due to rapid urbanization and globalization, the number of vehicles has increased enormously which imposed axle load directly on road. The exceed axle load and adverse condition of environment causes permanent deformation, cracking, rutting, fatigue and lesser service life period of roads. The main distress of pavement is due to rutting and fatigueness, influencing the pavement life and maintenance cost of highways. Therefore, to make highways cost effective and durable, two approaches may be useful in designing of flexible pavement; pavement design and asphalt mix design (mixture of bitumen, aggregate and other additives). A good design of bituminous binder delivers strength, resistance to fatigue and permanent deformation, durability, better workability on site, economical and sustainability to the asphalt mix used in paving applications. Many researchers have worked to reduce distresses in pavements caused by heavy axle load and adverse weather conditions.

Amongst the several mix designs, the polymer modification of bitumen binder is most tested approach to enhance the performances of pavement, bitumen used as such, is characterized poor adhesion to the aggregate, inadequate temperature susceptibility leading to poor performance of roadways. It is found that modified bitumen gives enhanced flexibility, durability adequate temperature susceptibility[1-4]. The bitumen modifiers can be divided into four groups according to their action; adhesion, plasticizer, structure and comlex[5]. Adhesive provides better adhesion of bitumen to the aggregate and prevent water damages of asphalt mix and also reduces ageing of bituminous binder[6, 7]. Plastcizers are used to maintain the rheological properties of bitumen and polymer both[8, 9]. Moreover, plasticizers are essential to maintain the consistency of modified bitumen at required temperature[10]. Structuring additives are those additives which provide strength to the bitumen binder by reinforcing it. Complex additives are used to improve the physico-chemical, mechanical and rheological properties of the bitumen binder by chemical reaction with bitumen constituents and also forming interpenetrating network within bitumen matrix, which enhances the overall performances of pavement[11-14].

The researchers have focused over the last few decades on development of modified bitumen of industrial applications either by altering the source and composition of bitumen or by adding fibers, minerals, fillers and rubbers. Keeping in view of both practicability and economics, the modifier must have easy availability, resistance to degradation at mixing temperature, improved resistance to flow at high road temperature without making bitumen too viscous or too stiff. After blending with bitumen, the premium characteristics of an ideal modifier should be unaltered during storage, application and in-service life. It should be capable of being mixed with bitumen by conventional equipments. The blends of modifier and bitumen should stable over the period of storage and application[17].

The properties of polymer modified bitumen depend on nature of polymer, characteristic of bitumen, processing conditions and compatibility between polymer and bitumen[15]. The polymers that have been used to improve the engineering properties of bitumen binders are classified mainly into two groups; thermoplasts and thermosets. They again subdivided into four groups; elastomers (natural and synthetic rubber), thermoplastic elastomers SBS, SBR, etc), thermosetting plastics (epoxy, furfurol- and phenol-formaldehyde, carbamide, silicone, etc,) and thermoplastic polymers (polyvinyl acetate, polystyrene, polyisobutylene, polyethylene, polypropylene, APP, polyvinyl chloride, GMA, latexes of Butonal, EVA, petroleum resins)[1, 2, 13, 14]. Globally, 75% elastomeric modified binder, 15% plastomeric and remaining 10% include rubber or other modifiers are commonly used to modify the bitumen[16].

However, most acceptable technique for modification of bitumen is the polymer modification either by virgin or recycled polymer, but many researchers have shown their interest in fiber modified bitumen[18, 19]. Incorporation of fiber in the bitumen gives strength as they performed as reinforcement, ductility and also tensile strength interlocking action with aggregate which enables durable and safer roadways[40,41]. **Table 1** shows a brief description of the different types of fibers used in hot mix asphalt[42].

The idea of using fibers to enhance the behaviour of materials was thought of as an old suggestion by Hongou and Philips. Among the first use of fibers is an arch made with a mixture of clay and fibers about 4000 year ago[21]. However, the commencement of modern fiber reinforcement[20] dates back to 1960s. The earliest studies of reinforcement of asphalt mixture were first released by Zube. The studies comprise of numerous types of wire mesh stationed under an asphalt overlay in order to prevent reflection cracking. The studies depicted that the formation of longitudinal cracks were prevented or tremendously delayed by all forms of wire reinforcement. It was suggested that wire reinforcements allows decreasing the thickness of overlays without hampering the performance. Around 60 years ago, coarsely woven cotton layers were laid between coats of asphalt to enhance the durability of the road surface in South Carolina. The cotton acted as binder for the road surface with inturn prevented water from seeping down and eroding the base. Serfass and Samanos studied the effects of fiber-modified asphalt on asphalt using rock wool, glass wool, cellulose and asbestos. The test comprised of resilient modulus, rutting resistance, low-temperature direct tension and fatigue resistance. The test comprised of resilient modulus, rutting resistance, low-temperature direct tension and fatigue resistance. Three studies were conducted in Nantes on a test track.

Table 1 Description of raw material in the manufacturing process of fibers used in HMA[42]

Fiber type	Remarks
Mineral	Mineral fibers mainly include asbestos, basalt and brucite. They are recoverd from deep in the Earth's crust and cracks in solid rock. The most commonly used raw materials are silicates[23], which can be manufactured by electro thermal methods[24, 25].
Polyester	Polyester fibers are one of the most widely used synthetic fibers in the textile sector[26]. Polyester is a recycled fiber which can be remelted and remoulded. Its structure is a combination of crystalline and acrystalline regions[27].
Polyacrylonitrile (PAN)	Polyacrylonitrile (PAN) fibers are produced by the acrylonitrile polymerization process in the presence of peroxide[28, 29]. It is used for the manufacturing of composite structures for military and commercial aircraft[30].
Carbon	PAN fibers are considered the first precursor of the carbon fibers[31]. Carbon fibers give higher specific strength, resistance to fatigue and stiffness. They also exhibit good electrical and thermal conductivity[32-34].
Glass	Glass fiber is considered a mineral fiber as its manufacturing process involves limestone, dolomite, fluorspar, kaolin clay, and other minerals[35].
Steal	Steel fibers are short discontinuous strips of manufactured steel. Their manufacturing process includes different type of materials such as carbon and phosphorous[36].
Aramid	Aramid fibers are considered man made high performance fibers and it is mainly used as reinforcement of composites. Continuous fiber reinforcement polymers (CFRP) or aramid fiber reinforcement polymers (ARFP) are used in aircraft, sports goods, ballistic protection or structural applications, etc[38, 39].
Coconut	Coconut fiber is 100% natural fiber is obtained from the outer shell of the coconut fruit. Their walls are composed by lignin[39].

The first one depicted that fiber-modified mixtures achieved the highest percent of voids. It was concluded that this results in efficient drainage. The second study consist of applying two million load application to a fiber modified asphalt that was used as overlay mixture on hampered pavements. After laying the fiber modified asphalt the pavement surface had well maintained macrostructure and no cracking was noticed even on the flexible structural pavement and it was concluded by the researchers that this study verified the performance of fiber-modified asphalt mixture to be used as overlay mixture on pavement[22]. The same was practiced in the third study By Serfass and Samanos. After 1.2 million load applications were laid as overlays and fatigue related depressions or rutting were not observed as compared to unmodified samples where distresses were recorded[22]. Less aging and improved binder properties can be achieved by increasing the film thickness through fiber modification. Adequate temperature susceptibity and resistance to moisture, aging, fatigue and cracking of asphalt mix can be obtained by the addition of fibers in bitumen[43].

Stiffness and tensile strength of HMA can be increased by blending glass fiber with bitumen, but care must be taken in handling of glass fiber during the processing. Propylene fibers act as three-dimensional network reinforcement in concrete, giving strength and adhesion with the concrete[44]. PP fibers can delay the reflective cracking, which is caused by vertical and horizontal movements of underlying concrete slabs[45].

In the present study, glass fibers were used as reinforcement to asphalt mix. Glass fiber possesses high strength and its elongation is about 3-4%, but its elastic recovery is 100%. Industrially it is well known material today, comparable mechanical properties to other fibers such as carbon fibers and polymeric synthetic fibers. It has greater tensile strength even more then steals of same diameter. It is not sensitive to variation in temperatures and moisture, because of its low linear coefficient of expansion. Due to high ratio of surface to area, the glass fiber is good thermal insulator; this property makes it of great industrial utility. Being a mineral, glass fiber is naturally incombustible. It has resistance against most of chemicals. The prepared blend was tested in laboratory for conventional and mechanical properties. It is believed that the blend of glass fiber and bitumen enhances strength and ductility which results resistance to fatigue. The resulted asphalt mix meets requirement of specification for performances of pavements.

2. MATERIALS AND METHODS

The 30/40 grade bitumen (specific gravity 1.13, penetration 34 dmm, softening point 81⁰C, Flash point 241⁰C, and Fire point 164⁰C) was procured from market. The glass fiber of length 4 mm and 7 mm was collected from an industry. The physical properties of glass fiber are given in table 2.

Table 2. Properties of glass fiber

Property	Description
Color	White
Shape	Rectangular
Length (mm)	4 and 7
Width (mm)	1
Density (g/cm³)	2.52
Melting point (ºC) > 300	More than 300
Moisture (%)	Less than 0.2
Loss on ignition (%)	Less than 0.25
Non-Fibrous materials (%)	Less than 1.0

Course aggregate having stone chips was collected from local stone crusher up to 4.70 mm size and its specific gravity was 2.71. The fine aggregate was also collected from local stone crusher of size 0.75mm and specific gravity 2.60. Gradation is given in table 3.

Table 3. Gradation of aggregate

Sieve size (mm)	% passing
26.4	100
18	95
9.4	70
4.70	50
2.32	35
0.31	12
0.075	5

Methods

500 gm of bitumen was heated in steel vessel fitted with peddle type high speed shear mixer for about 30 minutes at 160⁰C temperature at the speed of 150 rpm. The glass fiber was added in different percentage by weight. Then stir the composition for 1.5 hour continuously. The modified bituminous binder stored in sealed container and conventional test, such as penetration, softening point and Marshall Stability test was performed as per their standard specification. The details of these tests were given in previous articles of author.

3. RESULTS AND DISCUSSION

The results of the Marshall Stability tests are given in table 4. In this table the average stability of five specimens and corresponding standard deviation of them are reported. From these data it is evidenced that the stability of bituminous mix is increased with decrease in the length of fiber. It is also found that the stability of bituminous mix is increased with the increased dosages of glass fiber (figure 1).

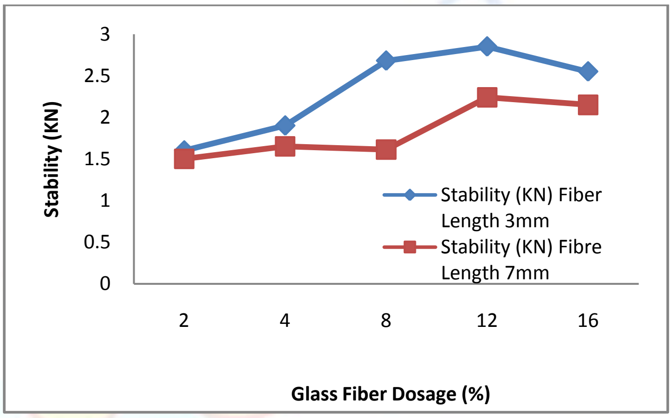

Figure 1. Marshall stability test of glass fiber modified bituminous binder

The penetration of fiber modified bituminous mix is given in table 5. The penetration of the blend is decreases with increased amount of glass fiber and the increased in penetration value is more pronounced with the short length of glass fiber also shown in figure 2.

Table 4. Marshall Stability test results of Bituminous binder

Glass fiber dosage (%)	Stability (KN) Fiber length 3 mm	Stability (KN) Fiber length 7mm
2	1.6	1.50
4	1.90	1.65
8	2.68	2.61
12	2.85	2.24
16	2.55	2.15

This increment in penetration may be due large surface area of glass fiber, which makes better mix with bitumen, resulting hardens bituminous mix.

Table 5. Penetration test results of Bituminous binder

Glass fiber dosage (%)	Penetration (dmm) Fiber length 3 mm	Penetration (dmm) Fiber length 7 mm
2	36	41
4	39	47
8	56	59
12	47	51
16	63	68

The penetration value of fiber modified bituminous mix also increased with increased dosages of glass fiber, but a sudden decrease in penetration was observed, which may be due to separation of maltene fraction from bituminous mix.

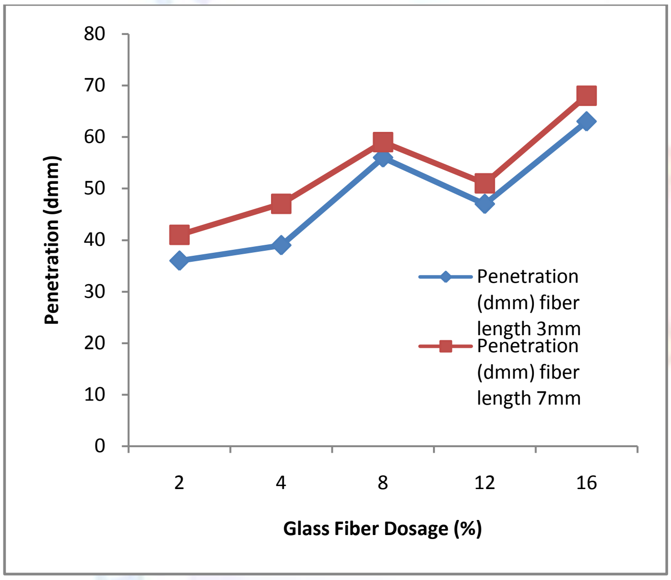

Figure 2. Penetration test of glass fiber modified bituminous binder

The softening point results are given in table 6, and it is evidenced that softening point increases with increased dosages and decreased length of fiber.

Table 6. Results of softening point test of Bituminous binder

Glass fiber dosage (%)	Softening point (^{0}C) Fiber length 3 mm	Softening point (^{0}C) Fiber length 7 mm
2	86	83.4
4	90.2	88.3
8	93.5	92.1
12	95.6	94.8
16	98	97.3

4. CONCLUSIONS

The results performed on the blends prepared using glass fiber and bitumen shows an improvement in the performance of bituminous mixes, which in turn will enhance the resistance against rutting, cracking and permanent deformation of pavement. The modified binder also shows an increase in Marshall Stability test those results in durability in pavement. From different test results it is concluded that small size fibers deliver better performance of pavements as compared to larger size fibers, which could lead better mechanical properties, resistance to moisture, rutting to the asphalt pavement.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

REFERENCES

[1] Galdina V.:Modifitsirovanye Bitumy. SibADI, Omsk 2009.
[2] Kishchynskiy S.:Vestnik HNFDU, 2008, 40, 28.
[3] Zhu J., Birgisson B. and Kringos N.: Eur. Polym. J., 2014, 54, 18.
[4] Tarasov R., Makarova L. and Kadomtseva A.: Mod. Sci. Res. Innovat., 2014, 5, 56.
[5] Serhiy Pyshyev, Volodymyr Gunka, Yuriy Grytsenko and Michael Bratychak, Polymer modified Bitumen: A review, chemistry and chemical technology, Vol. 10, No. 4(s), 2016.
[6] Valentova T., Altman J. and Valentin J.: Transp. Res. Procedia, 2016, 14, 768.
[7] Aziz H., HamzahM, Ahmad F. et al.: Appl. Mechan. Mat., 2015, 802, 309.
[8] D. Lesueur, Advances in Colloid and Interface Science, 145(1–2), 42-82 (2009) DOI: 10.1016/j.cis.2008.08.011
[9] R. Tauste, F. Moreno-Navarro, M. Sol-Sánchez, M.C. Rubio-Gámez, Construction and Building Materials, 192, 593-609 (2018) DOI: 10.1016/j.conbuildmat.2018.10.169
[10] Kinzyagulova G., Alyabev A., Evdokimova N. and Sultanbekova I.: Oil Gas Bus., 2009, 1, 1.
[11] Mousavi S., Farsi M. and Azizi M.: J. Appl. Polym. Sci., 2015, 132, 41875.
[12] Belyaev P., Polushkin D., Makeev P. and Frolov V.: Transactions TSTU, 2016, 22, 264.
[13] Muneraa J. and Ossa E.:Mater. Design, 2016, 62, 91.
[14] http://www.econf.rae.ru/article/4548
[15] Yvonne Becker, Maryro P. Mendez and yajaira Rodrguez, Polymer Modified Asphalt, vision Technologic, Vol. 9 N°1, 2001.
[16] Bardesi A, et al. "Use of modified bituminous binders, special bitumens with bitumen additives in pavement applications". Technical Committee Flexible Roads (C8) World Road Association (PIARC),1999.
[17] Denning J H and J Carswell, improvement in rolled asphalt surfacing by the addition of organic polymer, Laboratory Report, 989, 1981, Transport and Road Research Laboratory, Crowthorne.

[18] Wu S, Ye Q, Li N. Investigation of rheological and fatigue properties of asphalt mixtures containing polyester fibers. Constr Build Mater 2008; 22(10):2111–5.

[19] L.M.G. Klinsky, K.E. kaloush, V.C. Faria and V.S.S. Bardini, performance characteristics fibre modified hot mix asphalt, Constr Build Mater, 176, 747-752, 2018.

[20] Mahrez A, Karim M, Katman H. Prospect of using glass fiber reinforced bituminous mixes. J East Asia Soc Trans Studies, 2003; 5: 794–807.

[21] Hongu T, Philips G. New fibers ellis horwood series in polymer science and technology. New York: Springer; 1990.

[22] Serfass J, Samanos J. Fiber-modified asphalt concrete characteristics, applications and behavior. J Assoc Asph Pav Tech 1996;65:193–230

[23] R. Costa, R. Orriols, Man-Made Mineral Fibers and the Respiratory Tract, Arch. 747 Bronconeumol. 48 (2012) 460–468.

[24] U. Larisaa, L. Solbona, B. Sergeib, Fiber-reinforced concrete with mineral fibers and nanosilica, Procedia Eng. 195 (2017) 147–154.

[25] [38] B. SL, M. DM, B. BB, The mini plant producing thermal insulation materials from basalt on the basis of electromagnetic melting units with low energy consumption, Bull. East Sib. State Univ. Technol. Manag. 1 (2012) 16–20.

[26] J. Militký, Tensile failure of polyester fibers, in: Handb. Prop. Text. Tech. Fibres, Elsevier, 2018: pp. 421–514. doi:10.1016/B978-0-08-101272-7.00013-4.

[27] S. Grishanov, Structure and properties of textile materials., in: Hnadb. Text. Ind. Dye., 2011.

[28] [41] P. Morgan, Carbon Fibers and Their Composites, CRC Press, 2005 doi:10.1201/9781420028744.

[29] C.A.R. Brito, R.R. Fleming, L.C. Pardini, N.P. Alves, Empregados na Indústria, Polímeros Ciência e Tecnol. 23 (2013) 764–770. doi:10.4322/polimeros.2013.006.

[30] N. FASANELLA, MECHANICAL CHARACTERIZATION OF ADVANCED POLYACRYLONITRILE DERIVED CARBON FIBERS REINFORCED WITH CARBON NANOTUBES, University of Illinois at Urbana-Champaign, 2012.

[31] R.F. Ribeiro, L.C. Pardini, N.P. Alves, C.A.R. Brito Júnior, Thermal Stabilization study of polyacrylonitrile fiber obtained by extrusion, Polímeros. 25 (2015) 523–530. doi:10.1590/0104-1428.1938.

[32] P. Pan, S. Wu, F. Xiao, L. Pang, Y. Xiao, Conductive asphalt concrete: A review on structure design, performance, and practical applications, J. Intell. Mater. Syst. Struct. 26 (2015) 755–769. doi:10.1177/1045389X14530594.

[33] X. Liu, S. Wu, Study on the graphite and carbon fiber modified asphalt concrete, Constr. Build. Mater. 25 (2011) 1807–1811. doi:10.1016/j.conbuildmat.2010.11.082.

[34] Y. Agari, A. Ueda, S. Nagai, Thermal conductivity of a polyethylene filled with disoriented short-cut carbon fibers, J. Appl. Polym. Sci. 43 (1991) 1117–1124. doi:10.1002/app.1991.070430612.

[35] T. Tam, A. Bhatnagar, High-performance ballistic fibers and tapes, 2016. doi:10.1016/B978-0-08-100406-7.00001-5.

[36] H. Jamal, Manufacture, Properties and Design of Steel Fibers in Reinforced Concrete, n.d. https://www.aboutcivil.org/steel-fibers-reinforcing-concrete.html .

[37] Z. Cheng, L. Zhang, C. Jiang, Y. Dai, C. Meng, L. Luo, X. Liu® , Aramid fiber with excellent interfacial properties suitable for resin composite in a wide polarity range, Chem. Eng. J. 347 (2018) 483–492.

[38] B.A. Pattersona, M.H. Malakootib, J. Linc, A. Okoromd, H.A. Sodano, Aramid nanofibers for multiscale fiber reinforcement of polymer composites, Compos. Sci. Technol. 161 (2018) 92–99.

[39] O.S. Abiola, W.K. Kupolati, E.R. Sadiku, J.M. Ndambuki, Utilisation of natural fibre as modifier in bituminous mixes: A review, Constr. Build. Mater. 54 (2014) 305–312. doi:10.1016/j.conbuildmat.2013.12.037.

[40] A. Mahrez, M. Karim, H. Katman, Fatigue and Deformation Properties of Glass Reinforced Bituminous Mixtures., East. Asia Soc. Transp. Stud. 6 (2005) 997–1007.

[41] J. Stempihar, M. Souliman, K. Kaloush, Fiber-Reinforced Asphalt Concrete as Sustainable Paving Material for Airfields, Transp. Res. Rec. J. Transp. Res. Board. 2266 (2012) 60–68. doi:10.3141/2266-07.

[42] Carlos Slebi-Acevedo, Pablo Lastra-González, Pablo Pascual-Muñoz, Daniel Castro-Fresno. "Mechanical performance of fibers in hot mix asphalt: a review". Construction and Building Materials 200 (2019), 756–769. ISSN 0950- 0618. DOI: 10.1016/j.conbuildmat.2018.12.171.

[43] M.A. Cleven, Investigation of the Properties of Carbon Fiber Modified Asphalt Mixtures M.S. thesis, Department of Chemical Engineering, Michigan Technological University, Houghton, MI, 2000.

[44] S. Tapkin, The effect of polypropylene fibers on asphalt performance, Build. Environ. 43 (6) (2008) 1065–1074.

[45] T. Jiang, R.S. Mcdaniel, Application of Cracking and Seating and Use of Fibers to Control Reflective Cracking. In: Transportation Research Record: Journal of the Transportation Research Board, No. 1388, Transportation Research Board of the National Academies, Washington, D.C., 1993, pp. 150–159.