STM JOURNALS

Trends in Transport Engineering and Applications

Volume 1, Issue 3
www.stmjournals.com

Studies on Polymer Modified Bitumen with various Fiber Impregnation

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Abstract
Transportation sector is showing immense growth in the recent decades, modern vehicles introduced require a more stable platform to run better. In terms of road construction, we are not yet reaching the modernized standards adopted by other countries and usage of modern and innovative road construction materials are yet to be used in transportation infrastructure sector. The available roads are also getting damaged due to improper maintenance of top layer of the road and no bond strength between the bitumen and coarse aggregate. To avoid this kind of cracks and failure of surface bitumen, this is the main binder in the road construction need modification. In this study, an attempt is made to include mixture of glass and sisal fibre to increase the strength parameter of the bitumen. The bitumen used in the study has a penetration grade of 30/40. In the present study, an attempt has been made to study the effects of use of a naturally and locally available fibres namely sisal and glass fibre which are used as stabilizer in Smart Mix Asphalt (SMA) and as an additive in Bituminous Concrete (BC). Binder content has been varied sequentially from 4 to 7% and fibre content is varied from 0 to 10% of total mix. As a part of preliminary study, Sisal fibre has been found to result satisfactory in 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 10%. Similarly, Optimum Binder Content (OBC) for BC and SMA were found to be 5 and 5.2 % respectively. The testes are done based on IS 1201-1220(1978) and other relevant ASTM standards.

Keywords: *Bitumen Binder, Polymer Modified Bitumen, Glass Fiber*

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INTRODUCTION

Fibres have been extensively used to increase rheological properties of engineering materials for a long time. It is well known that modified bitumen considerably increases rheological properties of bitumen used within bituminous pavements suffering from different kinds of distresses like low temperature cracking, rutting, fatigue, etc. Cellulose fibre, which forms three dimensional reinforcements within the bitumen, is also alternative modifier for bitumen and highway materials. The prime role of the bitumen modifier is to increase resistance of asphalt to permanent deformation at high road temperatures without adversely affecting the properties of bitumen or bituminous materials [1]. The waste plastic partially replaced the conventional material to improve desired mechanical characteristics for particular road mix. They said present paper developed techniques to use plastic waste for construction purpose of roads and flexible pavements have reviewed. In conventional road making process, bitumen is used as binder. Such bitumen can be modified with waste plastic pieces and bitumen mix is made, which can be used as a top layer coat of flexible pavement. This waste plastic modified bitumen mix show better binding property, stability, density and more resistant to water [2].

This research has accomplished a comparative rheological test on the unmodified and nanoclay modified bitumen. The results show that compared to unmodified bitumen, the nanoclay modification leads to changes in rheological parameter by increasing stiffness and decreasing the phase angle hence; it can also reduce aging effect on bitumen. Further, the comparison of the rutting parameter shows that the nanoclay modification could increase the rutting resistance of bitumen where the improvement is dependent upon the type and amount of nanoclay. The said tests performed on bitumen samples proved that the nanoclay modifications help increase the stiffness and aging resistances [3]. They studied the effect of mineral fillers on properties of SMA mixtures. They chose eight mineral fillers on the basis of their performance, gradation etc. They evaluated the properties of SMA mixtures in terms of drain down of the mastic, rutting, low temperature cracking, workability and moisture susceptibility [4]. They used waste marble dust obtained from shaping process of marble blocks and lime stone as filler and optimum binder content was determined by Marshall Test and showed good result [5]. They utilized municipal solid waste incinerator (MSWI) fly ash as a partial replacement of fine aggregate or mineral filler in stone matrix asphalt mixtures. They made a comparative study of the performance of the design mixes using Super pave and Marshall Mix design procedures [6]. They studied effect of using waste glass power as mineral filler on Marshall property of SMA by comparing with SMA where lime stone, ordinary Portland cement was taken as filler with varying content (4–7%) [7]. They studied on SMA using different type of filler, stabilizer and concluded that Drain down in SMA is effected by type of filler, type of stabilizer, amount of stabilizer (higher the amount of stabilizer lower the drain down).Optimum binder content of SMA mixes is greater than DGM [8]. They studied utilization of waste fibres in stone matrix asphalt mixtures. They used carpet fibre and polyester fibres and waste tires to improve the strength and stability of mixture compared to cellulose fibre. They found waste tire and carpet fibre are effective in preventing excessive drain down of SMA mixture also found that tensile strength ratio of mixes more than 100%, it means fibre don't weaken the mixture when exposed to moisture. Addition of tire and carpet fibre increases toughness of SMA. They found no difference in permanent deformation in SMA mix containing waste fibres as compared to SMA mix containing cellulose or mineral fibre [9].

They carried laboratory study using natural rubber powder with 80/100 bitumen in SMA by wet process as well as dense graded bituminous mix with cellulose fibre and stone dust and lime stone as filler and found its suitability as SMA mix through various tests Punith *et al.* (2004) did a comparative study of SMA with asphalt concrete mix utilizing reclaimed polythene in the form of LDPE carry bags as stabilizing agent (3 mm size and 0.4%) [10]. The test results indicated that the mix properties of both SMA and AC mixture are getting enhanced by the addition of reclaimed polythene as stabilizer showing better rut resistance, resistance to moisture damage, rutting, creep and aging [11]. They used Crumb Rubber (CR) OBTAINED from discarded tire with 80/100 penetration grade bitumen in SMA and concluded that it improves fatigue and permanent deformation characteristics, greater resistance to moisture damage than normal mixes [12]. They performed different test like Marshall stability test, loss of Marshall stability, tensile strength, loss tensile strength, resilient modulus, fatigue life, rutting resistance were conducted on both SMA and DGM. He concluded that though DGM have high compressive strength and tensile strength; SMA has higher durability, high resilience property, high rutting resistance as compare to DGM. Hence SMA is preferable in hot climate weather [13]. They used Cellulose oil palm fibre (COPF) and found fibre-modified binder showed improved rheological properties when cellulose fibres were pre blended in PG64-22 binder with fibre proportions of 0.2, 0.4, 0.6, 0.8 and 1.0% by weight of aggregates. It showed that the PG64-22 binder can be modified and raised to PG70-22 grade. The Cellulose oil palm fibre (COPF) was found to improve the fatigue performance of SMA deign mix. The fatigue life increased to a maximum at a fibre content of about 0.6%, while the tensile stress and stiffness also showed a similar trend in performance. The initial strains of the mix were lowest at a fibre content of 0.6 % [14]. They studied on two types of fibre. Tried to use a fibre in SMA by taking jute fibre which is coated with low viscosity binder and compare the result with aim ported cellulose fibre (a cellulose fibre imported from Germany) using 60/70 grade bitumen. And found optimum fibre percentage as 0.3% of the mixture. Jute fibre showed equivalent results to imported patented fibres as indicated by Marshall Stability Test, permanent deformation test and fatigue life test. Aging index of the mix prepared with jute fibre showed better result than patented fibre. They used waste marble dust obtained from shaping process of marble blocks and lime stone as filler and optimum binder content was determined by Marshall test and showed good result [15].

They used asphalt rubber (AR) produced by blending ground tire rubber (GTR) (i) 30% of a coarse GTR with a maximum size of #20 sieve and (ii) 20% of a fine with a maximum size of #30 sieve with an asphalt, as a binder for SMA and found AR-SMA mixtures were not significantly different from conventional SMA in terms of moisture susceptibility and showed better rutting resistance than that of conventional dense graded mixture [16]. They used basic oxygen slag as aggregate with PG76-22 modified binder and lime stone as filler and chopped polyester fibre in SMA and concluded that experimental SMA is superior than convectional S MA. They used municipal solid waste incinerator (MSWI) fly ash as a partial replacement of fine aggregate or mineral filler and Basic Oxygen Furnace (BOF) Slag as part of coarse aggregate with polyester fibre of 6.35 mm in length obtained from recycled raw materials, PG76-22 binder in the SMA mix and performed Marshall and super pave method of design and found it's suitability for use in the SMA mix [6]. They used shredded waste plastic as stabilizing agent in stone matrix asphalt mixture and compare its property with SMA without stabilizing agent. Marshall Test, compressive strength test, tensile strength test, tri axial test were performed with varying percentage of bitumen (6–8%) and different percentage of plastic (6–12%) by weight of mix [17]. They studied effect of using waste glass power as mineral filler on Marshall property of SMA by comparing with SMA where lime stone, ordinary Portland cement was taken as filler with varying content (4–7%). Optimum glass power content was found 7%. By using glass power as filler in SMA its stability increases up to 13%, flow value decreases up to 39%, density also decreases as compare to SMA contains lime stone and cement filler [7].

METHODOLOGY

Materials Used

Materials used in this study include 30/40 penetration grade base bitumen. The polymer used for modification is obtained from Merck Inc and its commercial grade. Solution of polymer is prepared by mixing the polymer in hot water boiled at 80 ^{0}C and mixing is done with hand blender. Glass fibers are obtained from MN polyster Pvt. limited, India and the properties of the glass fibers used is given in Table 1.

Table 1: *Properties of Glass Fibers Used.*

Property	Value
Specific weight	11.008 kN/m^3
Tensile strength	43–50 N/mm^2
Tensile modulus	2741 N/mm^2
Elongation at bread	2.03– 2.049 %
Flexural strength	77–80 N/mm^2
Flexural modulus	4016 N/mm^2
The results were supplied by the manufacturer	

Sisal fibers were obtained from local field and they are prepared using standard methods of fiber extraction from sisal plant. They are sun dried for a month of time until the inner sheath dries up, the yarn is obtained via hand extraction using scissors.

The obtained fibers are prepared in various thickness and diameters. The glass fibre has length of 3 mm and sisal fibre length of 12 mm and diameter of 0.86 mm.

Sample Preparation

Samples were prepared using melt blending technique. The bitumen about 400 gm was heated in oven till fluid condition and polymer was slowly added, while the speed of the mixer was maintained at 140 rpm and temperature was kept between 180 °C and 200 °C. The concentration of sisal fiber used, were 2, 4, 8, 12 and 16% by weight of blend. Mixing was continued for 1 h to produce homogenous mixtures.

The modified bitumen was then sealed in containers covered with aluminum foil and stored for further testing. Empirical test such as penetration, softening point and viscosity were then conducted on the prepared samples.

Laboratory Testing

Test on the prepared samples were conducted according to ASTM method to characterize the Properties of PMBs. The different percentage of sisal fiber concentration provides a wider range of results which helps in analyzing each type of the sisal fiber blend at particular concentration. The rheological test includes penetration at 25 ºC, softening point and Marshall Stability. The test results of base bitumen are presented in Table 2.

Penetration (ASTM D-5)

The standard 100 g, 25 °C and 5 s penetration test was performed both on base bitumen and PMB with the concentration of polymer varying between 2, 4, 8, 12, 16% by weight of the bitumen. The results of the test are shown in Table 2.

Table 2: *Properties of Base Bitumen Used in the Study.*

Grade	30/40 pen
Specific gravity	1.16
Penetration	34 mm
Softening point	83 °C
Flash point	242 °C
Fire point	163 °C
Stability of the bitumen	8.5 kN

Softening Point (ASTM D-36)

Ring and ball is the standard test to determine the consistency of the bitumen, which represent the temperature at which a change of phase from solid to liquid occurs. It is the temperature at which standard 3/8 inch steel ball weighing 3.55 gm fall and touches the base plate which is 2.5 mm away.

Marshall Stability Test

Stability is an important property of the bitumen mixture in the wearing course design. It shows the ability to resist shoving and rutting under traffic. Marshall Stability test of PMB was performed in a Marshall testing machine at a constant rate of 51 mm/min.

Five specimens were immersed into a water bath at 60 ºC and were tested after 1 h and the average compressive load required to break the sample was determined and corrected by multiplying with a stability correction factor to get the initial stability to get the final stability.

RESULT AND DISCUSSION

Marshall Stability Test

The results of Marshall Stability are presented in Table 3. Five samples were used to obtain the average stability and the corresponding standard deviations were reported. It is observed that the stability value increases with the increase in fiber length. When the length goes on decreasing the stability value goes on decreasing gradually but the penetration values goes increasing (Figure 1).

Table 3: *Marshall Stability Test Result.*

Percentage of Glass and Sisal Fibre	Marshall Stability Value (kN)
2	9.43
4	9.94
6	8.36
8	5.43
10	4.32

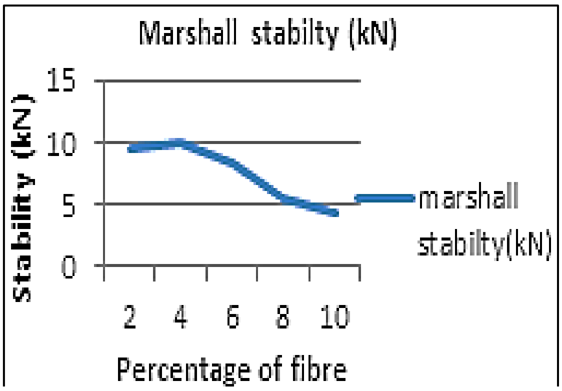

Fig. 1: *Stability Result for Glass and Sisal Fibre.*

Penetration Results

The sharp decrease in the penetration value of 34 mm for base bitumen to 25 dmm for PMB of 0.65 mm and 29 mm for 0.33 mm length shows that increase in hardness is due to high molecular weight PMB added in the bitumen. It is obvious from the observation that thermoplastics influence is more on the penetration with the increase in the viscosity of the bitumen as can be observed by the decrease in the value of penetration with the increase in concentration of polymer. Thus it increases the viscosity by the end of mixing process, and by the time it cools harden mixture was formed. The hardening of the bitumen can be beneficial as it increases the stiffness of the material, thus the load spreading capabilities of the structure but also can lead to fretting or cracking. This can be evaluated at later stage of this study by performance tests. The results obtained by the penetration are highly controversial although being widely used by paving industry as penetration needle displaces a relatively small volume of fluid (Table 4, Figure 2).

Table 4: *Penetration Result.*

Percentage of Glass and Sisal Fibre	Penetration (mm)
2	38
4	32
6	30
8	30
10	31

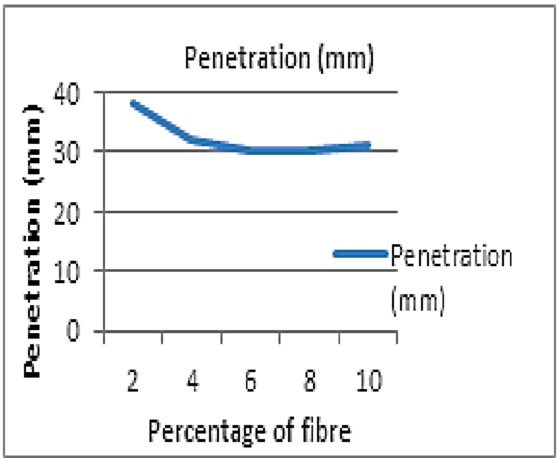

Fig. 2: *Penetration Result for Glass and Sisal Fibre.*

CONCLUSION

In this study fibers of different sizes were used in polymer modified bitumen to compare the strength of variations in bitumen. The following observations were derived with various results obtained from various tests:

1. PMB showed increase in stability when compared to the base bitumen.
2. Penetration result generally decreases when polymers are added.
3. This can be used to avoid rutting and pot hole failure that occur frequently in roads constructed across water logged areas.

The study indicated physical hardness of the binder after adding sisal fibers of different size reduces binder penetration and increases softening points. This indicates that aging depends on time and binder source.

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