A REVIEW ON THE STUDY OF ALTERATION OF STRENGTH PARAMETERS OF BITUMINOUS MIXES BY USING IRON WIRE FIBER AS ADDITIVE

[1]Insha Amin, [2]Nupur Subhashini

[1]M.Tech Scholar ,[2]Assistant Professor,
[1]Department of Civil Engineering,
[1]CBS Group of Institutions, Haryana, India.

Abstract: The distinctive characteristics of bitumen which ascribe worth to it as a reliable construction material are its amazing adhesion and excellent water-proofing capabilities. The suited requirements of the bituminous binders are evaluated as per various standards laid down by the enforcing authorities. The final properties of the bituminous mix depend on the colloidal structure, which in turn is dependent on the processing of the crude source. Of late, methods to modify the inferior characteristics of bitumen have been devised. These methods loosely have a thing in common- modification of rheological properties of bitumen. The concept of utilizing fibers as reinforcing agents is not exactly new. It has been undertaken since ancient times and the research continues unabated to this day. Desirable results such as increase in elasticity, augmentation of adhesion to the aggregate particles, decrease in viscosity etc. have successfully been achieved by the application of different additives. Nonetheless, in the recent years, a new trend has emerged in that fibers are now incorporated into the mix as an additional component or additive. Many fibers have also been observed to have superior tensile strength in comparison with bituminous mixes; with the result they exhibit promising results in the improvement of tensile strength of the mixes. In this review paper, we delve into the associated literature to find the studies carried out on this topic.

***Index Terms* – Bituminous mix, Iron wire fiber, Additives, Marshall stability, Metal tensile tests, Moisture sensitivity.**

I. INTRODUCTION

A typical highway pavement is composed of more than one layer of varying materials, which are in turn supported by a layer of soil known as subgrade. The asphalt concrete is an amalgamated material which is commonly employed in a variety of construction projects, viz. road surfaces, airport pavements, parking lot surfaces etc. It is obtained when asphalt and mineral aggregates are mixed together and laid down in layers and finally subjected to compaction.

The bituminous binder is a thermoplastic material whose stiffness depends upon the temperature. The relationship of temperature against stiffness of the bitumen leans on the source where from the crude oil is derived and also on the method which is employed in refining. As highway construction is an activity which in itself involves an enormous sum of money, therefore pertinent engineering design strategies and usage of waste material in the construction process of highways may prove to be an act of immense importance resulting in considerable saving of cost. Relevant to mention here is the fact that the major portion of highway system in India is made of flexible pavements. It has been established by several studies that the permanent deformation within the flexible pavement is usually confined to the top 100 to 150 mm of the pavement, which is also known as the surface course. In flexible pavements, bitumen assumes the character of a binding agent which is entrusted with the act of binding together the aggregates by forming a coating over the aggregates. In subtle terms, it aids in the improvement of the pavement strength characteristics.

An astonishing variety of fiber types have been merged into the asphalt mixtures. Some examples are that of synthetic polymers (polypropylene fibers, polyester fibers etc), cellulose fibers, coir fibers, basalt fibers, steel fibers, glass fibers et al. In addition, various non-conventional fibers have also been used e.g. carpet fibers, recycled tyre fibers etc. Innumerable researches have been published concerning the outcome of such inclusions in the asphalt. Presently, much work has been done on the use of synthetic fibers or polymers as stabilizing additives in stone mastic asphalt. Substituting expensive fibers and polymer additives with low-cost materials (fibers) is the need of the hour. In this experimental study, the most fitting use of iron wire fiber as reinforcement, while ensuring the above conditions, in addition to acceptable functioning in such factors as fatigue, moisture susceptibility etc., is deliberated upon. The ultimate aim is to produce a good quality and even road surface that may be commercially approved for use in any environmental condition.

The asphalt mixtures should be strengthened, notably more so when the pavement has to face heavy traffic conditions. Usage of low-priced iron wire fiber as reinforcement in place of other steeply-priced reinforcing additives in the bituminous mixture is very advantageous to the community as a whole, as it is a financially viable option. The aim of the undertaken study is to establish the properties of the reinforced bituminous mixtures with iron wire fiber as reinforcement.

A good number of researches are found in the recent history on bituminous mixes reinforced with various kinds of fibers. A methodical assessment of these studies will give us a pretty good insight about the general consequences of incorporating various kinds of fibers into the bituminous mixes. However, little to no literature is available on the use of iron wire as fiber in asphaltic concrete. Therefore, prior researches on other fibers as additives in the bituminous mix would serve as the necessary guideline for the present research.

II. LITERATURE REVIEW

Al-Ridha et al piloted a study about the effect of steel fibers on the proficiency of hot-mix asphalt. They studied the results at varying temperatures and compaction levels. The study recommended the use of steel fibers in the binder course in minimal amounts, not exceeding 0.2%. Guo (2014) also used steel fibers for the purpose of improving of the mechanical properties of asphalt concrete. His test results showed that addition of steel fibers into the asphalt concrete caused significant improvement in theaoverall performance of the pavement.

Garcia et al (2013) explored how steel wool fibers impacted the properties of dense asphalt concrete. Meticulous experimentation suggested that the optimum fiber content in the asphalt mixture should approach 6% or even higher so as to obtain satiating results. Also, the shorter length fibers were found to disperse very well in the mixtures.

Serin et al also studied the effect of fibers in asphalt concrete mixtures. The final conclusion of their experimentation allowed the use of fiber as additive in the binder course of the flexible pavements because of the enhanced stability. As per the recommendation of this study, fiber in the ratio of 0.75% by weight was found to yield the best results. Cristina Bonica et al conducted experimentation to determine the effect of fibers on the performance of bituminous mastics for the purpose of road pavements. They applied cellulose-based fibers in bituminous mastics and analysed the consequences on the mechanical properties thereof. The results indicated that fibers agreeably improved the behaviour of hot mix asphalts, most importantly with reference to the occurrence of rutting at high service temperatures.

In an almost similar study performed by Apostolidis, Liu and others, experimental analysis of the fracture performance of synthetically reinforced asphalt mixes was done. Samples with different fiber contents and fiber lengths were evaluated. The longer fibers in lower dosages were found to yield results comparable to those with higher dosages of smaller length fibers.

Kar, Nagabhushana & Jain researched the functioning of hot bituminous mixes which were admixed with the blended synthetic fibers. In the aforementioned study, implications of the addition of the fiber on the thickness and diminution of cost of the bituminous layers were studied carefully. A mixture of polypropylene and aramid fibers was used. The final conclusion recommended the optimum fiber content as 0.05% by weight of mix. Overall, the fiber addition resulted in 2% higher costs. But at the same time, a marginal increase in efficiency of the pavement surface coupled with 13% reduction in the pavement thickness justifies the act.

Kar, Debashish studied the effect of indigenously available sisal fiber on stone mastic asphalt and bituminous concrete mixtures. Fiber content, in this study, varied from 0% to 0.5% by weight of the total mix whereas the binder content varied from 4% to 7%. The addition of said fiber was seen to improve the Marshall Stability and Indirect Tensile Strength of the mixture. The optimum binder content for BC and SMA were designated at 5 & and 5.2%, respectively. One more study in this regard by Bakiya et al deduced that coir fiber when used as an additive in the bituminous pavement gives good results and the pavement can sustain in varying Indian climatic conditions. The maximum stability of the modified coir mix was 22.6% more than the conventional hot mix. The optimum binder content was found to be around 5.3% by weight of the mix.

Monika, Prakash and Ravinder in a research, carried out recently, also investigated the role of naturally-available sisal fiber as a potential stabiliser in the stone mastic asphalt mixtures and as an additive in bituminous concrete mixtures. The binder content was fluctuated from 4% to 7% and the fiber content upto 0.5 % of the mix. The most optimal fiber content in both the cases came out to be 0.3%. The incorporation of sisal fiber into the mix substantially ameliorated the mix properties like Marshall Stability, Indirect tensile strength and drain-down operation of the mixes.

Muniandy and Huat (2006) employed the cellulose oil palm fibre (COPF) and established that the binder modified with the said fiber exhibited superior rheological characteristics when the cellulose fibres were pre-blended in the binder. The fibre proportions varied from 0.2% to 1.0% by weight of aggregates, with an increment of 0.2% being made at each step. It was also seen that the fatigue performance of the design mix also showed clear signs of enhancement on the addition of cellulose oil palm fiber. The dosage of the fiber at which fatigue life of the mastic asphalt mix reached its maximum was 0.6% by weight of aggregates. A parallel tendency was also seen in the performance of tensile stress and stiffness of the mix.

Putman, Bradley J., and Serji N. Amirkhanian (2004**)** studied the use of waste fiber in stone mastic asphalt mixtures. The trio utilised waste tire and carpet fibers as a feasible additive in order to alleviate the disproportionate drain-down occurring due to comparatively higher content of air voids in SMA. The functioning of the characteristics of stone matrix asphalt mixtures prepared with waste tire and carpet fibers was carefully scrutinised. Consequently, comparison with other mixes that were prepared with cellulose and polyester was also made. It was safely concluded that the samples containing carpet and tire fibers were effectual in hindering the unwarranted drain-down of the SMA mix. The resistance to moisture-induced damage of the bituminous mixes, which contained tire and carpet fibers was measured at 100.9 and 101.8%, respectively.

Kamaraj et al carried out laboratory study by using natural rubber powder with 80/100 penetration grade bitumen as well as dense graded bituminous mix with cellulose fibre and stone dust and limestone as filler and ascertained the suitability by means of various tests. Muniandy and Huatt used cellulose oil palm fiber (COPF) and came to the conclusion that fiber-modified binder exhibited improved rheological properties, having taken fiber proportions in the range of 0.2% through 1%.

Arabani et al proposed the application of rice husk ash in the bituminous roadways. Rice husk ash is a by-product of the milling process that rice is subjected to. As such, its use offers numerous benefits that concern the degradation of environment. They inspected the impacts of rice husk ash on hot mix asphalt and performed a multitude of tests to achieve this end. The modifier contents were kept at 5 %, 10 %, 15 & and 20 %. The results visibly showed an improvement in the rheological properties of bitumen. An affirmative bearing was also reported on such factors as Marshall stability, stiffness modulus and fatigue behaviour of the mixes.

Hardiwordoyo used short coconut fibers in his mix. He took coconut fibers starting from 0.5% by weight of the mix, supplying regular increments of 0.25% at each step and finally reached till 1.5%. In this study, the fiber size was also varied, starting from 5 mm and going upto 12.5 mm. The results showed that Marshall stability improved by almost 15% at the optimum fiber content of 0.75% and the limited optimum length of 5 mm.

In another study, two types of fibers were used and the results were subsequently weighed against each other. This study was taken in hand by Kumar et al (2007). He used a jute fiber encrusted with a low-viscosity binder and contrasted the outcome with a cellulose fibre that been imported from Germany. The penetration grade of the bitumen that was used was 60/70. After laboratory testing, he arrived at 0.3% as the optimal fiber content percentage. The jute fiber showed comparable results to that of the imported fibers. However, one parameter where the jute fiber fared better than the imported fibers was the aging index of the mix.

Partl, Manfred et al carried out laboratory studies on a distinctive kind of carbon fiber grid, which was positioned at different depths in the asphalt pavements. The target behind the study was to collect the design information about the position of the grid that would furnish the most favourable results. They inspected two different types of asphalt pavements; asphalt concrete and mastic asphalt. This study brought to light the fact that with the application of carbon grid, parameters like stiffness, failure strain and stress, and resistance against low temperature cracking increased.

Ali, N., and others performed experiments to detect the outcome of fly ash on the mechanical properties of the bituminous mixtures. They aimed at assessing the role of fly ash in improving the performance characteristics of road pavements. In this study, four types of specimens having varying percentage contents of fly ash fractions were evaluated. Various properties such as permanent deformation, creep, fatigue etc. were determined at three different temperatures. The end results hinted at the efficiency of fly ash as a mineral filler and its ability in increasing resilient modulus characteristics and stripping resistance of the concerned mixtures.

The scrutiny of the effects of infusing basalt fibers in hot mix asphalt concrete was researched upon by Nihat Mirova (2013). Depending upon the optimum bitumen content of 5% that was obtained and deatailed experimentation carried out later, the optimal basalt fiber addition of 0.5% was reached at. Another study that was carried out in this regard was by Davar, Tanzadeh and Fadaee. They infused basalt fibers and diatomite powder compound into hotemix asphalt (HMA) at high temperatures. After thorough analysis, it was found that the usage of fibers in diatomite reinforced mixes ended up increasing their fatigue life by almost double. The indirect tensile tests at very low temperatures (-5⁰C) demonstrated the propensity of the said fibers in improving HMA properties at minimal temperatures. The concurrent addition of basalt fibers and diatomite compound recompensed the limitation of low temperature mixes.

Bradeley et al. carried out studies regarding the application of waste fibres in the stone matrix asphalt mixtures. In this study, carpet fiber, polyester fiber and waste tires were added to the bituminous mix. It was found that the addition of tire and carpet fibre enhanced the toughness of stone mastic asphalt. Similarly, Mustafa and Serdal used waste marble dust as an additive and obtained promising results. The marble dust was obtained as a residue from the shaping process of marble blocks.

In an identical research, Jony Hassanet et al studied the effects of waste glass powder on the properties of stone mastic asphalt as opposed to SMA with limestone in varying contents (as filler). The optimum content of the glass powder settled somewhere around 7%. The stability of the mix shot up 13% by using glass powder as filler.

The likelihood of using glass fiber reinforced mixes was brought into light by a study undertaken by Mahrez, Karim and Katman H. They directed their focus particularly on the fatigue performance and deformation characteristics of the reinforced mix. Glass fiber is a relatively new addition to the family of fibers that have been experimentally incorporated into the asphalt mixes. Hence, its true potential is yet to be unravelled fully. Addition of glass fibers to bituminous mixes displayed varying results, with some parameters improving and the others remaining unchanged. The addition of glass fibers however, reduced the stability of the mix. Flow value of the mix was seen to increase, on the other hand.

Jahromi, S.G., and Ali Khodaii undertook a study to examine the viability of asphalt concrete reinforced with Carbon fiber. They ran wide-ranging tests from Marshall test, indirect tensile test to creep test. The Carbon fiber showed promising reliability in terms of increasing the stability of the mix. The results also pointed out the contribution of fibers in withstanding the structural distress in the pavement layers. This ultimately could prove as a breakthrough in increasing the endurance of pavements to the cracks caused by ever-increasing traffic loads.

III. CONCLUSIONS

An extensive literature review on the bituminous mixtures is carried out. The literature review gives a basic overview of various meticulous researches performed on bituminous mixtures. Taking the crux of these researches into consideration, the composition of various materials to be used has been chosen. These studies provide a fair bit of idea about the way application of additives in various bituminous and asphalt mixtures operates. Also, it helps in choosing the corresponding test methods for the present investigation. In this research work the MORTH gradation has been adopted.

From the review of available literature, it is evident that the usage of various kinds of fibers as additives in the asphalt concrete delivers comparatively agreeable results in terms of operative characteristics. However, in most of the cases, higher additive content of fibers shows detrimental results. The main impetus behind this research is to arrive at a cost-effective and environmental friendly addition to the bituminous mix, which would enhance its behaviour.

In our research, iron wire fiber is studied as a potential modifier for improving the engineering properties of conventional DBM mixtures. The performance of natural fibers, as also of steel fiber to augment the mechanical properties of bituminous mixes has already been recognized from time to time. The iron wire fiber can prove to be a feasible low-cost replacement for steel fibers. These iron fibers are comparatively very cheap and can also be procured from any construction site with relative ease.

There is always a scope for expanding the perspective of research so as to draw some more information and consequently to attain better results. In this case too, prospects of future researches are many. Further research can be performed to determine the feasibility of the iron wire fiber or powdered form of iron wire on stone mastic asphalt and dense graded asphalt mixture. The stone mastic asphalt possesses gap-graded gradation and therefore the high air void content (caused by the higher additive content) might not lead to compressive strength problems in the mixture.

Compared to carbon, glass or natural fibers, iron (metal) fibers have a low electrical resistance. This attribute makes them well-suited for all those applications that involve the aspect of electrical conductivity. Another favourable property is their remarkable thermal resistance which aids them in withstanding extreme temperatures. The other advantageous mechanical properties of the iron wire fiber include; high failure strain, ductility, fire resistance etc. However, the way these properties might affect our investigations remains to be seen and does not entirely lie under the scope of our research. Our sole focus will be directed at how the addition of this fiber into the mix influences its strength parameters.

REFERENCES

[1] Abtahi, S.M., Sheikhzadeh, M., Hejazi, S.M., Fiber-reinforced asphalt concrete – A review, Construction and Building Materials 24 (2010), 871-877.
[2] Al-Ridha A.S.D., Hameed A., Ibrahim S.K., Effect of steel fiber on the performance of hot mix asphalt with different temperatures and compaction, Australian Journal of Basic and Applied Sciences, 8 (6), 2014: 123-132.
[3] Benedito de S. Bueno, Wander R. Da Silva, Dario C. De Lima and Enivaldo Minnete; Engineering properties of fiber reinforced cold asphalt mixes, Journal of Environmental Engineering (2003), Vol. 129 (10), 952-955.
[4] Bradley J. Putman and Serji N. Amirkhanian, Utilization of waste fibers in stone matrix asphalt mixtures, Resources, Conservation and Recycling (2004), Volume 42, Issue 3, 265-274.
[5] Chui-Te Chiu and Li-Cheng Lu, A laboratory study on stone matrix asphalt using ground tire rubber, Construction and Building Materials, Volume 21, Issue 5, 1027-1033.
[6] Emon, M.A.B., Manzur, T., Yazdani, N., Improving performance of light weight concrete with brick chips using low-cost steel wire fiber, Construction and Building Materials 106 (2016), 575-583.
[7] Fazaelli, H., Samin,Y., Pirnoun, A., Dabiri, A.S., Laboratory and field evaluation of the warm fiber reinforced high performance asphalt mixtures (Case study Karaj-Chaloos road), Construction and Building Materials 122 (2016), 273-283.
[8] G. Ferrotti, E. Pasquini, F.Canestrari, Experimental characterization of high performance fiber reinforced cold mix asphalt mixtures, Construction and Building Materials 57 (2014), 117-125.
[9] Guo, J.F., The effect of steel fiber on the road performance of asphalt concrete, Applied Mechanics and Materials, 584-586 (2014), 1342-1345.
[10] Hayder Kamil Shanbara, Felicite Ruddock, William Atherton, A laboratory study of high performance cold mix asphalt mixtures reinforced with natural and synthetic fibers, Construction and Building Materials 172 (2018), 166-175.
[11] Kaushal, Deulkar; Influence of mineral fibers on asphalt concrete, International Journal for Research in Applied science and Engineering technology (2018), 2321-9653.
[12] Kinthali Sai Nanda Kishore, Anirudh Gottala; A study on the effect of addition of natural rubber on the properties of bitumen and bituminous mixes, International Journal of Science Technology and Engineering (2015), 2349-784X.
[13] Muniandy Ratnasamy and Huat Bujang B.K., Laboratory diameteral fatigue performance of stone matrix asphalt with cellulose oil palm fibre, American Journal of Applied Sciences (2006), 3 (9): 2005-2010.
[14] Ravi Shankar A.U., Vishwanath N. and Koushik K., Performance studies of stone matrix asphalt using waste plastics as modifier (Dry process), Highway Research Board, IRC,Vol 2 (2009).
[15] Sevil Kofteci, Experimental study concerning iron wire fiber reinforced asphalt concrete, Teknik Dergi (2018), Paper 510.
[16] Tapkin, S., The effect of polypropylene fibers on asphalt performance, Building and Environment,43 (2008) 1065 – 1071.
[17] Thanaya I.N.A., Forth J.P. and Zoorob S.E., Utilisation of coal ashes in hot and cold bituminous mixtures, AshTech (2006), International Coal Ash Technology Conference, Paper ref. A9.
[18] Wu, S., Liu, G., Mo, L., Chen, Z., Ye, Q., Effect of fiber types on relevant properties of porous asphalt, Transactions of Non ferrous Metals Society of China, 16 (2006): 791-795.
[19] Zeng, M. And Ksaibati, K., Evaluation of moisture susceptibility of asphalt mixtures containing bottom ash, Transportation Research Record:Journal of the Transportation Research Board 1832.1 (2003), 25-33.
[20] Zoorob, S.E., Suparma, L.B., Laboratory design and investigation of the properties of continuously graded asphaltic concrete containing recycled plastics aggregate replacement (Plastiphalt), Cement & Concrete Composites 22 (2000), 233-242.