A Review on Effect on Addition of Medium Steel Fibers on Dense Bituminous Macadam

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Abstract: Need for higher quality bituminous mix in road construction is increasing rapidly, as exponential increase in traffic, overloading of commercial vehicles, rapid rise in industrialization is taking place. To serve heavy traffic load in terms of no. of axles, modification of bituminous mixes is a prominent need for development of pavement performance and to enhance the quality of pavement as well as increase in service life. Various fibers has been utilized by scientist and engineers in recent times, as use of fibre additives is quite encouraging for improvement of engineering characteristics of bituminous mixes. The objective of this study is to analyse various properties such as stability value, flow value , optimum binder content,% air voids VFA, VMA, at varying percentages(2%, 4%, 6%, 7%) of medium steel fibre. The review exhibited furtherance in fatigue life of the pavement and improved resistance towards reflective crack when modified using medium steel fibres.

Keywords: Marshall Stability, DBM, Medium Steel Fibres, Optimum Binder Content (OBC)

I. INTRODUCTION

The use of fibres emerged as a need for improving the flexibility and tensile strength of the bituminous mixes due to increase in traffic density in terms of no. of axles, wheel loads and high tyre pressures resulting from heavy vehicles. Fibre-modified bituminous mixtures are generally comprised of matrix and fibres. The adhesion between fibres and matrix along with shape and size of fibres affects the performance of these mixtures.

Bituminous Mixes are most commonly used all over the world in pavement construction. India has a road network of over 5,605,293 kilometres in 2016, the second largest road network in the world. About 98 % of the paved roads in India have flexible pavements, within which are included surfacing of various types and thickness.

The bituminous mix design aims to determine the proportion of bitumen, filler, fine aggregates, and coarse aggregates to produce a mix which is workable, strong, durable and economical.

The horizontal stresses induced between the layers may result in easly crack formation when loads are heavy and any local settlements also lead to cracking of the asphalt layers. Pavement distresses, such as: cracking, pot-holes, permanent deformation and surface wear are constantly reported by highway agencies.

Some undesirable effects can occur mainly due to high number of vehicles imposing repetitive higher axle loads on roads, environmental condition and construction errors. These usually cause permanent deformation (rutting), fatigue and low temperature cracking, service life of the road pavement is going to be decreased. Fatigue and rutting are the most common distresses in road pavement which result in the shortening of pavement life and increase maintenance cost as well as road user cost. So, it is vital to find out ways to delay the asphalt pavement deterioration and increase its service life. Many studies have been conducted to improve road pavement characteristics which can provide comfortable ride and ensure greater durability and longer service life against climate changes and traffic loading

II. RESEARCH AND STUDIES ON USE OF STEEL FIBERS

Relevant research work and studies are reviewed here:

[1] Halim-A Mahmoud; *et al.* (2006) polyvinyl chloride (PVC) pipe waste have been employed as a soft filler up to a level of 11 wt % in making bitumen products for paving applications. The PVC wastes were homogenously mixed with bitumen in the molten state. The viscoelastic properties of the bitumen blends such as storage modulus, loss modulus, and dynamic viscosity were studied and compared with those of neat bitumen. These properties were studied using an ARES-Rheometer (Rheometric Scientific, Co.) under nitrogen atmosphere. The results indicate that the incorporation of the waste PVC into bitumen enhances the dynamic mechanical moduli and viscosity of the bitumen.

[2] Xu Qinwu; *et al.* (2010) This paper studies the reinforcing effects and mechanisms of fibers for asphalt concrete (AC) mixtures under the environment temperature and water effects. Four typical fiber types – polyester, polyacrylonitrile, lignin and asbestos – are studied. Laboratory tests were conduct on the fiber reinforced AC (FRAC) to measure its strength, strain and fatigue behaviour. Results show that fibers have significantly improved AC's rutting resistance, fatigue life, and toughness. The flexural strength and ultimate flexural strain, and the split indirect tensile strength (SITS) at low temperature have also improved. The polymer fibers(polyester and polyacrylonitrile) have improved rutting resistance, fatigue life, and SITS more significantly than lignin and asbestos fibers, which may be primarily due to their greater networking function; while lignin and asbestos fibers result in greater flexural strength and ultimate flexural strain, which maybe primarily due to their greater asphalt stabilization effect. However, fiber's effect under the water freezing–thaw effect does not seem promising, and the SITS of FRAC with lignin and asbestos fibers even

reduces to some extent under this effect. It is also found that a fiber content of 0.35% by mass of mixture achieves the optimum performance outputs of rutting resistance and SITS for polyester fiber.

[3] Vuong T Binh; *et al.* (2010) Investigated several reinforced asphalt products for use in road applications, particularly for rehabilitation of existing cracked reinforced-concrete pavements required for heavy-duty pavements. The products are assessed based on their structural capacity for the specific designs, especially with regard to joints or cracks in the underlying layers using new 3D nonlinear finite element (FE) analysis procedures. This allows comparison of relative performance of various reinforced products and, hence, selection of the most effective solution for the design concerned. Others factors influencing their use such as availability, costs and long-term environmental sustainability also considered to examine the suitability of reinforced asphalt products for the long-term cost-effective solutions over the traditional asphalt materials. This helped the issues of sustainability in material selection for pavement works.

[4] Mahrez Abdelaziz; *et al.*(2010) revealed that polymer modified asphalt mixture is a relatively costly mixture for paving roads. One way to reduce the cost of such constructions and rendering them more convenient is by using inexpensive polymers, i.e. waste polymers. The main purpose of this research is to determine the effect of incorporating waste plastic bottles (polyethylene Terephthalate (PET)) on the engineering properties of the stone mastic asphalt (SMA) mixture. The volumetric and mechanical properties of asphalt mixes that include various percentages of PET (0%, 2%, 4%, 6%, 8% and 10%) were calculated and assessed with laboratory tests. The appropriate amount of PET was found to be 6% by weight of bitumen. The outcomes were statistically analyzed and the determination of the significance at certain confidence limits was performed with the two factor variance analysis (ANOVA). Moreover, some studies conducted on the polyethylene modified asphalt mixture also considered. The results showed the addition of PET significance positive effect on the properties of SMA and it can promote the re-use of waste material in industry in an environmental friendly and economical way.

[5] Ahmadinia Esmaeil; *et al*. (2011) Studied that asphalt modification/reinforcement is a viable solutions to enhance flexible pavement performance. This was mainly promoted by the unsatisfactory performance of traditional road materials exposed to dramatic increase and changes in traffic patterns. They presented the characteristics and the properties of glass fiber reinforced stone mastic asphalt. Laboratory tests were conducted to evaluate such related properties of asphalt mixture with different fiber contents. The tests undertaken comprise the Marshall test, indirect tensile test, creep test and fatigue test using repeated load indirect tensile test. The results showed that the addition of fiber does affect the properties of bituminous mixes, by decreasing its stability and increasing the voids in the mix. Stiffness properties of reinforced SMA Mix were enhanced by about 12% as compared to control mix. Mix with more than 0.2% fiber content exhibited lower resistance to permanent deformation. The results indicated that the fiber has the potential to resist structural distress that occur in road pavement as result of increased traffic loading, thus improving fatigue life by increasing the resistance to cracking and permanent deformation especially at higher level stress.

[6] Rahman Afifa; *et al.* (2012) Presented that fillers play an important role in engineering properties of the bituminous paving mixes. Conventionally, cement, lime and stone dust have used as fillers. They attempt to assess the effects of different types of fillers (e.g. non-conventional and conventional) on the Marshall properties of bituminous paving mixes. For this purpose, non-conventional filler such as brick dust and conventional fillers such as cement and stone dust have used. All of these materials have tested according to the standard test procedure of AASHTO. Total 15 sets specimens were prepared by using different types of filler having different amount in the mix. The Marshall properties obtained for both types of fillers reveal that, brick dust filler specimen have found to exhibit higher stability value compared to cement and stone dust filler specimens. In addition, mixers containing brick dust filler showed maximum stability at 6.2% bitumen content and the percentage of air voids were found to be decreased with the increase of bitumen content.

[7] Joshi B Darshan; *et al.* (2013) Explained that as the knowledge regarding paving material expanded, need for economical, functional and safer design criteria required to find out optimum bitumen content in semi dense bitumen macadam. To satisfy the mix design specification, number of methods has been developed. They presented that the variability involved in the asphalt mix design process and developed a procedure to find out the optimum bitumen content by Marshall Mix design method which attains maximum stability. Their study was according to Indian specifications, where mix design, like in many other countries, performed in accordance with Marshall Method.

[8] Terzi Serdal; *et al*. (2013) Presented the potential of Genetic Expression Programming (GEP) computing paradigm to forecast the Marshall stability of steel fiber reinforced asphalt concrete and has various mix proportions has been developed. Experimental details were used to construct the model. The steel fiber content (0%, 0.25%, 0.50%, 0.75%, 1.0%, 1.5%, 2.0%, and 2.5%), percentage of bitumen (5%, 5.5% and 6.0%) and unit weights (2,465–2,515 gm/cm^3) were used as output variables. The performance of models was comprehensively judged using several statistical verification tools. Results have shown that developed GEP model has a strong potential for predicting the Marshall stability of asphalt concrete without performing any experimental studies.

[9] Lin Youngui; *et al.* (2013) Explained that for roller compacted concrete used in pavements, optimal water content is one of main concerns for mix design. However, the mix design method aiming at achieving both high bond strength and roller compactability is not available so far. The modified proctor compaction method and modified Vee-bee method were investigated and found to be inappropriate to the type of mixes in terms of durability. A method for determining optimal water content also proposed for steel fiber-reinforced, roller compacted and polymer modified bonded concrete overlays. Two types of mixes suitable for asphalt paver placement and roller compaction were developed. They were the SBR and the SBR-PVA hybrid polymer modified concrete mixes with the optimal water content determined by the proposed method. Both mixes achieved good bond with the old concrete substrate.

[10] Parsad Nitin; *et al.* (2013) Revealed that secondary compaction is a state; where the pavement which is compacted with the conventional compaction has been further compacted due to the movement of traffic and which corresponds to the ultimate density which can be attained on the bituminous pavement called as "Refusal density" of the pavement. Secondary compaction has to be studied in detail and it is understood that the 75 blows of the Marshall text does not determine the actual field circumstances. The Marshall design actually in the field will not simulate the field conditions hence there will be a reduction on the air voids to the refusal density. Then due to fineness of the mix, this causes the plastic deformation on the pavement surfaces. They attempt to study the air void content at refusal density along with Bulk density, Air voids (Va), Voids in mineral aggregate (VMA), voids filled with bitumen (VFB) of the mix. For the simulation of field density in the laboratory a huge hammer is used. The usage of the polymer modified bitumen reduces the plastic deformation and other distresses of the pavements.

[11] Abiola O; *et al.* (2014) Provided a review on the utilization of natural fibers as modifier in bituminous mixes. Increase in traffic loads in terms of number of axles and high tyre pressure from heavy vehicles resulted into traffic related pavement distresses. Modification of asphalt binder is one of the approaches to improve pavement performance. Natural fibers have become a research focus for scientist and engineers. Types of natural fibers, their surface treatment and reinforcement of asphalt concrete with natural fibers have presented. Generally, the review demonstrated an improvement in fatigue life and structural resistance to distresses occurring in pavement when modified.

[12] Teppala Bela; *et al.* (2014) Pointed out that the burgeoning urban population of india with rapid rise in industrialization coupled with high increase of road vehicles engaging in rapidly expanding cities to fit the developmental needs of the economy demands good quality of roads to cope up the increasing pressure of road traffic. It becomes the responsibility of researchers, scientists, contractors to improve the riding quality while maintaining the economy for the country like ours. They initially investigated the engineering properties of locally available crushed stones, fillers and 60/70 grade bitumen for mix design. Marshall Method of mix design for DBM (grade1) has adopted to find out the optimum bitumen content. In order to arrive at homogenous mix with compared standards, VG 30 bituminous mix with obtained 4.25% optimum bitumen content was taken into consideration for modified Marshall mix design by addition of 0.03%, 0.04% and 0.06% dosage of zycosoil chemical was prepared and tested to determine the key properties as per the codel provision. The test indicated the desire to opt for chemically modified DBM mix it shows better results as compared to conventional mix.

[13] Ahad Abdul; *et al.* (2015) Recently, the use of steel fiber at high rates has been introduced as the sole method of reinforcement for fully elevated-suspended slabs having long span such as 5 m to 8 m each way, with a span to depth ratio of up to 33 [1]. As a result of long practical experience the total replacement of traditional rebar is a new routine. Now it is also used in the designing of SFRC pavements over conventional concrete pavements. Within the project framework a demonstration of a steel-fiber reinforced roller-compacted concrete (SFR-RCC) pavement was constructed in a rural as well as urban area. In order to assess the economical condition of the demonstration pavement, life cycle assessment (LCA) and life cycle cost analysis (LCCA) studies were undertaken. This is the advancement study of the various papers which is already published in many publications which serve as the main and important source of study for the research. Many applications of steel fiber are listed in the paper but the main output of this paper is that SFR-RCC is more economically sustainable than others and also helps in reducing the thickness of the pavement up to 20 to 25 percent, due to the excessive strength of steel fiber. The roads of the present system required high cost investment. And the life period is almost 20 years theoretically but the actual life of the road is depending on the maintenance and the applied load. The constructions of road have been done since the 3500 BC but the method does not change fully. Also the cost of the construction is increased continuously; as a result, the construction of roads is more and more complicated and time taken. For the better and economical construction of the roads, we use steel fibers in the composite pavement. The theoretical plan of the construction of composite pavement is given in the methodology, which gives the appropriate idea about the construction of road using steel fiber. Here we use the composite pavement in which the steel fiber is mixed in the concrete layer, after which the bitumen layer is laid for the smooth and suitable riding of the vehicles.

[14] Aniruddh; *et al.* (2016) One of the innovative technique of improvement in bitumen concrete surface practiced all over the world is addition of steel fibres in it. The performance of Bituminous concrete Mixes with steel fibre in varied proportions (2%,2.5%,3%,3.5%,4%,4.5%,5%,5.5% & 6% with 18 mm and 11 mm length was studied by conducting Marshall Stability Test for Stability of Bituminous Mixes .The results have been noticed that the considerable improvement in stability of bitumen concrete was at an optimum percentage of added steel fibre for bitumen concrete at 3.5 % of 11 mm long steel fibre. Therefore these fibre content has been recommended for making improvements in parameter of Bituminous Mixes.

[15] Mendapara Kaushik; *et al.*(2017) Bituminous for mix can be prepared and used in a pavement section for a bituminous binder course use different types of additives likes as Polymers, Rubber and waste materials like discard rubber fibre (tube Tyres), plastic west and jute fiber. Modifying bituminous mix is expect to gives higher life. The present study objective are developing bituminous mixes for the Dense Bituminous Macadam (DBM) incorporating the plastic wastes, waste tyre tubes and rice husk ash as partial replace of the different bitumen content. In this study, the Stability and Flow value analysis for the various DBM Grade 1 mixtures with binders and with different percentage replacement of bitumen with plastic wastes, waste tyre tubes and jute fibre are reported.

[16] Polagani Sateesh; *et al.* (2017) Exponential increase in traffic, overloading of commercial vehicles and significant variations in daily and seasonal temperatures have shown some limitations of conventional bitumen performance. It is thought that with the help of additives is one of the approaches to improve performance of flexible pavements. Here fibres have been used to improve the performance of asphalt mixtures against permanent deformation and fatigue cracking, Because of their inherent compatibility with

asphalt cement and excellent mechanical properties. In the present study, an attempt has been made to study the effects of use of a mineral fibre called Glass fibre is used as an additive in Dense Bituminous Macadam (DBM). An experimental study is carried out on conventional bitumen and fibre modified binder. Using Marshall Procedure, Optimum Fibre Content (OFC) and Optimum Binder Content(OBC) for DBM are found respectively. The modified bitumen at Different percentages are subjected to different performance tests like Dynamic Shear Rheometer (DSR) and Creep Properties to evaluate the effects of fibre addition on mix performance.

III. Conclusions

This paper reviewed the concept of utilization of medium steel fibers in dense bituminous macadam. Most of the literature cited above showed that medium steel fiber can replace mineral aggregate as there is good adhesion of the fiber and bitumen. The size and texture of the fibers however matter in development of the bond and strengthening of the mix .This aspect need to evaluation to greater details in order to develop some guidelines in their usage . Therefore an experimental study is being undertaken with Steel Fibers of particular size. To achieve this, Marshall mixtures will be prepared and evaluated with different steel fiber rates and bitumen content. This study is important because various types of fibers have been used in bituminous mixes, but there is no enough literature review related to the utilization of steel fiber in flexible pavement.

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