A REVIEW PAPER ON IMPROVEMENT IN BITUMINOUS MIXES BY USING FINE STEEL FIBRES

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Abstract: The growing need for high quality bituminous mixtures in road construction and to cater to heavy traffic loads in terms of number of axles, modification of bituminous mixes emerges as a need to improve pavement performance and to extend the service life. In recent times, scientist and engineers have shown immense interest on utilizing various fibres because it acts as a very promising additive for the improvement of engineering characteristics of the bituminous mixes. The objective of this study is to have better understanding of utilizing fine steel fibres in dense bituminous macadam and bituminous concrete pavement layers. Generally, the review demonstrated an improvement in fatigue life of the pavement together with developing improved resistance to reflective crack when modified using steel fibres**.**

***Index Terms*- Bituminous mixes, Steel fibres, Fatigue cracking, Rutting, Distresses, Dense Bituminous Macadam, Bituminous Concrete**.

I. INTRODUCTION

Fibre-modified bituminous mixtures are generally composed by the matrix and fibres. The performance of these mixtures is mainly based on the shape, size and on the adhesion between fibres and matrix. The use of fibres emerges as a need for improving the flexibility and tensile strength of the bituminous mixes due to increase in traffic density in terms of numbers of axle wheel loads and high tyre pressures resulting from heavy vehicles. The horizontal stresses induced between the pavement layers soon result in crack formation and any local settlements also lead to cracking of the bituminous layers. Reflection cracking is one of the major distresses that occur frequently in bituminous concrete overlays in which the existing cracking pattern from the old pavement propagates into and through the new overlay. Bitumen binder with additives like crumb rubber, natural rubber and polymers have been used to overcome rutting and raveling in flexible pavements. However, the problem of fatigue cracking still persists. Fatigue cracking occurs because bituminous layers are weak in tension, hence utilization of fibres may improve fatigue life by increasing the resistance to cracking and permanent deformation.

The concept of modifying asphalt binders and mixtures is not new. In its earliest stages, asphalt modification consisted of mixing two or more asphalt binders of different paving grades from different sources.

Currently, synthetic fibres, such as: glass, carbon, polymer and aramid fibres are used as modifiers because of their high stiffness and strength properties. **Steel fibres** are a new class of materials which have shown good potential in bituminous mixes. Therefore, reinforcement of the bituminous mixes is one approach to improve the tensile strength and fibres are the most suitable reinforcing material. The objective of this study is to review research works on improvement in bituminous mixes by using fine steel fibres.

II. NEED OF STUDY

If a bituminous mix is properly designed with adequate quantity of bitumen and mineral aggregate and laid properly as a surfacing layer, the pavement should give a durable and reliable road structure. But rapid urbanization and industrial development has caused tremendous increase in traffic intensity and axle loads, resulting in premature failure of bituminous pavement. The performance of bituminous pavement can be enhanced considerably by reinforcing the bituminous mix with fibres. Though there has been a lot of research on bituminous mixes as well as fibres in lower layers of pavement, there is a very limited work reported in the literature regarding use of steel fibre in bituminous mixes so, there is a need for an extensive study on this aspect.

III. TYPES OF FIBRES

Many types and forms of fibres have been used in bituminous mixtures, either experimentally or routinely in order to improve engineering characteristics of the bituminous mixes. Cellulose, mineral, and polymer fibres are the most common. The most commonly used types of fibres;-

a) Cellulose fibres
b) Mineral fibres
c) Synthetic Polymer fibres
d) Glass fibres
e) Waste or recycled fibres
f) Other plant based fibres

These are explained briefly below:

a) Cellulose fibres

Cellulose fibres are plant-based fibres obtained most commonly from woody plants, although some are obtained from recycled newspaper. These fibres tend to be branching with fairly high absorption; it is this nature that helps cellulose fibres hold on to high binder contents in mixtures. Cellulose fibres can be provided in loose form or in pellets.

b) Mineral fibres

Either naturally occurring fibres, such as asbestos (chrystolite), or manufactured mineral fibres can be used. Mineral fibres (also called mineral wool or rock wool). Minerals used to create mineral fibres include slag or a mixture of slag and rock, basalt, brucite, and carbon. Carbon fibres and steel fibres (or steel wool) have been used in some fairly exotic ways to produce electrically conductive asphalt that can be used for deicing or to heal micro-cracks. Asbestos fibres were the first type of fibre used in hot mix asphalt; they were used from the 1920s until the 1960s when environmental and health issues curtailed the use of asbestos.

c) Synthetic Polymer fibres

The most commonly used polymer fibres are polyester, polypropylene, aramid, and combinations of polymers. Other fibres include nylon, poly para-phenyleneterephthalamide, and other less commonly used materials. Different polymers have different melt points, which need to be considered when adding to hot mix asphalt. Production of synthetic fibres typically involves drawing a polymer melt through small holes.

d) Glass Fibres

These have not been reported often in the literature but appear to have desirable properties, including high tensile modulus (~60 GPa), low elongation (3%–4%), high elastic recovery (100%), and high softening point (815°C). They are, however, brittle and must be handled carefully during construction

e) Waste or Recycled fibres

The increasing importance of sustainability in construction has led to increased interest in reusing materials that would otherwise be disposed of, including waste fibres from a variety of sources for example, steel industrial waste, steel fibres etc.

f) Other plant based fibres

These have been used in more limited areas. They may be derived from woody fibres (such as jute, flax, straw, and hemp), leaves (such as sisal), and seeds; or they may be fruit fibres, such as coir, cotton, coconut, or palm

IV. ADVANTAGES OF USING FINE STEEL FIBRES

Bituminous mixes exhibits an ultimate tensile strength which is usually less than the ultimate compressive strength by an order of magnitude and therefore, reinforcing bituminous mixes is expected to yield several important advantages, such as:

a) Improvement in the tensile strength of bituminous mixes.
b) Provides greater resistance to cracking.
c) Improved shearing resistance due to lateral restrain.
d) Reduction in the overall thickness of pavement.
e) Increase the overall performance and expected life period of flexible pavement.
f) Improved resistance against rutting and fatigue cracking.
g) Higher Marshall Stability and lower maintenance cost.

V. UTILIZATION OF FIBRES IN BITUMINOUS MIXES

The concept of utilizing fibres in bituminous mixtures is not new. In its earliest stages, asbestos fibres were used in concrete and asphalt to stabilize the mixture. Asbestos fibres were found to increase tensile strength, compressive strength, stability, ability to sustain load after reaching maximum stability, and resistance to weathering. Because of health and environmental concerns swarming around asbestos, the fibres were replaced with polyester and polypropylene fibres, as well as variant types of other forms of fibres too. Today, all forms of fibres are used in dense and open-graded forms in bituminous mixtures. The process of utilizing fibres in bituminous mixes starts with the collection of fibre materials. The collected materials are then subjected to various tests like sieve analysis. The suitability of fibres is ascertained by blending it with virgin materials and then evaluating the performance characteristics of the mix by suitable test procedure e.g. Marshall Stability test. All the results of the tests, fibres along with virgin aggregates that have to be added are then analyzed and an optimal percentage of fibres are defined. The process of construction of bituminous mixes with fibres is carried out as the same conventional method of construction of bituminous pavement.

Many researches performed on this topic revealed that:

a) Fibre reinforcement is used as a crack barrier rather than as a reinforcing element whose function is to carry the tensile loads as well as to prevent the formation and propagation of cracks.
b) Fibre improves the different properties of the resulting mix. It changes the viscoelasticity of the modified bitumen, increases dynamic modulus, moisture susceptibility, creep compliance, rutting resistance and reduction in amount of reflective cracks.
c) The percentage increase in retained stability of the mixture as compared to the conventional mix was about 14% at the optimum fibre content of 0.3% and the reduction in bitumen content is 5% giving an appreciable saving in binder.
d) Optimum bitumen content, air voids, volume of mineral aggregate and Marshall Stability value increased, while unit weight decreased with the addition of fibre.
e) Fibre-reinforcement bituminous mixes increased the viscosity of asphalt binder until 0.5% by mass.
f) Bituminous mixtures strengthened with fibres increase the fatigue life of a pavement, approximately 20 to 25 times when compared with mixtures without fibres.
g) Optimum fibre content depended on fibre type, length and diameter. Typically in a study using a fibre length of 15mm with fibre content of 0.52% and binder content of 5.72% provided good stability and volumetric properties. However there may be variation on case to case basis.
h) Stability increases due to the additional resistance provided by the fibres, while flow decreases because deformation was resisted by the fibres. Air voids increase because fibres absorb the binder needed to coat the aggregate, there by introducing an air gap between the aggregates.
i) The induction heating of steel fibre modified bituminous mixtures could significantly improve their ice melting efficiency compared with the natural condition.

VI. SUMMARY AND CONCLUSION

Research will be carried out to find out the optimum percentage of fine steel fibres that can be used in bituminous concrete and dense bituminous macadam and to evaluate the performance of mix at different percentages of fine steel fibres. Also, studies will be carried out on the usability of steel fibres in flexible pavements in order to determine the effect of fine steel fibres on different parameters of bituminous mixes. For this aim, Marshall Mixtures will be prepared and evaluated with different steel fibre rates and bitumen contents. This study is important too because variant types of fibres have been used in bituminous mixes, but there is no enough literature review related to the utilization of steel fibres in flexible pavement.

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