INTERNATIONAL JOURNAL OF ADVANCE RESEARCH, IDEAS AND INNOVATIONS IN TECHNOLOGY

ISSN: 2454-132X
Impact factor: 4.295
(Volume 4, Issue 4)
Available online at: www.ijariit.com

A review on quality improvised of bituminous mix by natural fiber

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ABSTRACT

Increase in traffic load in terms of numbers of axles and high pressure from heavy vehicles resulted into traffic related pavement distresses. Modified asphalt binder is one of the approaches to improve pavement performance. Natural fibers have become a research focus for scientist & engineering. Type of natural fibers, their surface treatment & reinforcement of asphalt concrete with natural fibers are presented. Generally the review demonstrated an improvement in the fatigue life & structural resistance to distress occurring in pavement when modified. Generally a bituminous mixture is a mixture of course aggregate, fine aggregate, filler & binder. A hot Mix Asphalt is a bituminous mixture where all constituents are mixed, placed & compacted at high temperature. HMA can be Dense Grade Bitumen (DGM) known as Bituminous Concrete (BC) or gap graded known as Stone Matrix Asphalt (SMA). SMA requires stabilizing additives composed of cellulose fiber to prevent drain down of the mix. In the present study an attempt has been made to study the effects of use of a natural fiber (SISAL FIBRE as stabilizer in SMA) & as an additive in BC.For preparation of the mixes aggregate gradation has been taken as per Morth Specification, binder content, has been varied regularly from 4% to 7% & fire content varied from 0% to maximum 0.5% of total mix. Then the BC [&SMA] mixes prepared are subjected different performance test like Drain down Test, Static Indirect Tensile strength & Static creep test to evaluate the effects of fiber additions on mix performance.

***Keywords**: SMA, DGM, Bituminous mix, Natural fiber*

1. INTRODUCTION

Construction of highway involves huge outlay of investment. A precise engineering design may save considerable investment as well as reliable performance of the in – service highway can be achieved. Two things are of major considerations in flexible pavement engineering-pavement design & mix design.

A good design of bituminous mix is expected to result in a mix which is adequately 1) Strong 2) Durable 3) resistive to fatigue 4) environment 5) economical and so on. The present research work tries to identify some of the issues involved in this art of bituminous mix design and the direction of current research.

1.1 Need for research

Increase in traffic loading density in terms of numbers of axles and density in terms of numbers of axles and high tyre pressure resulting fang heavy vehicles, places great demand on the existing great demand on the existing rood network. The horizontal stresses induced between the layers soon result in crack formation and any local settlement also leads to cracking of asphalt layers. Pavement distresses, such as: cracking, pot-holes, are constantly reported by highway agencies.

Reflection cracking is one of the major distresses that occur frequently in asphalt concert overlap in which the existing cracking pattern from the old pavement propagates into and through the new overlay. Asphalt 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. Fiber reinforcement improves fatigue life by increasing the resistance to cracking and permanent deformation.

Modification of bitumen is one of the approaches to improve the pavement performance when the asphalt produces does not meet the climatic, traffic and pavement structure requirement as reported by Fitzgerald and Kim. 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. The problem with this technique, however, lies in the possibility that the asphalt cement will be chemically incompatibility cannot always be effectively predicated and it can bad to premature asphalt pavement distresses.

Currently, Natural fibers such as hemp coir, jute, sisal fiber & flex are a new class of material which has good potential in bituminous mixes. Depending on their origin, Natural fibers can be grouped into bast (just, banana, flax, hemp, kemaf, Mesta), leaf (pineapple, sisal), seed or fruits fibers (coir, cotton, palm). Therefore, reinforcement of the bitumen mazes is one approach to improve the tensile strength and fibers are the most suitable reinforcing material.

1.2 History of Mix Design

1.2.1 Evolution of Mix Design

During 1900’s, the bituminous paving technique was the first used on rural roads -so as to hand rapid removal of fine particles in the form of dust, from water bound macadam, which was caused due to rapid growth of automobiles. At initial stage, heavy oils were used as dust palliative. An eye estimation process, called pat test was used to estimate the requisite quantity of the heavy oil in the mix. By this process, the mixture was patted like a pancake shape and pressed against a brown paper. Depending on the extent of stain it made on the paper, the appropriateness of the quantity was adjudged .The thirst formal mix design method was Hubbard field method, which was originally developed on sand-asphalt mixture. Mixes with large aggregate could not be handled in Hubbard field method.

This was one of the limitations of this procedure. Francis Hveem, a project engineer of California department of highways developed the Hveem stabilometer. Heveem did not have any prior experience on judging the just right mix from its color, and therefore decided to measure various mix parameters to find the optimum quantity of bitumen. Hveem used the surface area calculation concept, to estimate the quantity of bitumen required. Bruce Marshall developed the Marshall testing machine just before the World War-2.It was adopted in the US Army Corps of Engineers in 1930’s and subsequently modified in 1940’s & 1950’s

1.2.2 Hubbard Field Mix Design

In the mid-1920’s, Charles Hubbard & Frederick Field, with the newly created asphalt Association, developed a method of mix design called the Hubbard Field Method of design. The Hubbard Field Method was commonly used among state highway departments in 1920’s&1930’s although use continued on into 1960’s in some states.

Initially, the Hubbard Field Method focused on the surfacing mixture, the sand asphalt-wearing course specimens were 2 inches in diameter & were compacted with a hand rammer.

The Hubbard Field Method built upon Richardson’s Process. Specimens were made in laboratory but instead of using a paper stain test, they developed an elevation method to determine design asphalt content. Bulk specific gravity was computed using aggregate bulk specific gravity. So, the volumetric analysis was similarly to the properties used today.

In addition to the volumetric analysis, the Hubbard Field Method used stability test where the compacted mix is squeezed through a ring slightly smaller than the specimen diameter.

1.2.3 Hveem Field Mix Design

An early pavement in California was made using natural bitumen from the La Brea Tar pits located in Los Angles & Santa Barbara area. Although referred to as far, these were actually natural asphalt seeps.
In the 1920’s oil mix made with cutback asphalt sprayed on top of a knocked-down window & mixed back & forth with a motor grader. Oil content was determined by eye, so an experienced person was needed to ensure that the mix had the proper brown color.

In 1927’s, Francis Hveem became a resident engineer in California, having no experience with oil mixes, used the information about gradation with the paper strain test to evaluate asphalt content. He recognized this process was controlled by aggregate surface area and found a method to calculate surface area. He used surface area factors published in 1918 by a Canadian Engineer, Captain L.N. Edwards, which were proposed for use in Portland Cement Concrete Design.

Hveem started developing a stability test. He recognized that mechanical strength of the mix was important and developed the Hveem stabilometer, which is pseudo-triaxial test. A vertical load is applied to a confined specimen and the resulting horizontal pressure increase, and Hveem used this property to discern stable and unstable pavements. Based on oil mixes, he developed threshold values for stability and applied them to HMA.

Hveem’s mix design philosophy is that sufficient asphalt binder is needed to satisfy aggregate absorption and to have a minimum film thickness on the surface of the aggregate. In order to carry load, the aggregate had to have a sliding resistance and minimum tensile strength to resist turning movement. Stability and cohesion were influenced by aggregate properties and the amount of asphalt binder. For durability, Hveem the swell test used liquid water, and the vapor sensitivity test used moisture vapor. The effect on Hveem stability after conditioning was measured. Hveem found that thicker asphalt films had more resistance to moisture.

1.2.4 Marshall Mix Design

Bruce Marshall of the Mississippi Department of Highways developed Marshall mix design in the late 1930s to early 1940s. In 1943 Marshall approached the Corps of Engineers in Vicksburg, MS about using the Marshall method of design and was hired. The corps adopted Marshall’s system in World War II for use on air fields. Post World War II, it was “civilianized” for use by state highway departments.

Marshall Mix design is essentially an outgrowth of the Hubbard Field method. The approach is similar although the practice was different. Hubbard Field used two different sized rammers to compact samples. Marshall used one hammers and matched the compact diameter to the mold diameter. Hubbard Field has used the hand-tamp rammer. Marshall standardized the compaction energy applied by using a drop hammer.

The Marshall and Hveem mix design procedures served as the primary means of designing dense mixture until the mid-90's when the super pave procedures was introduced.

One of the limitations of current mix design systems (Marshall & Hveem) is the inability to measure expected performance-specially, the ability to measure rust resistance, fatigue cracking, low temperature cracking, asphalt binder aging or mixture resistance to measure damage. Prediction of these properties for a given application was the goal of SHRP. But SHRP products could not be implemented. In all these three mix designs methods surrogate properties are used to control the performance properties of the asphalt mixture.

1.3 Bituminious mix design

1.3.1 Requirements of Bituminous Mixes

a) Stability: Stability is defined as the resistance of the paving mix to deformation under traffic load. Stability depends on the inter-particle friction primarily of the aggregates and the cohesion offered by the bitumen. However the stability decreases when the binder content is high and when the particles are rapt apart.

b) Durability: Durability is defined as the resist trance of the mix against weathering and abrasive actions .Weathering causes hardening actions. Weathering causes hardening due to loss of volatiles in the bitumen, Abrasion is due to wheels loads which causes tens isle strains.

Disintegration is minimized by high binder content they cause the mix to be air and waterproof and the bitumen film is more resistant to hardening.

c) Flexibility: Flexibility is a measure of the level of bending strength needed to counteract of surface. Fracture is the cracks formed on the surface, main reasons are shrinkage brittleness of the binder. Higher bitumen content will give better edibility and less fracture.

d) Skid Resistance: It is the resistance of the finished pavement against skidding which depends on the surface texture and bitumen contents. It is an important factor in high speed traffic. It is an important factor in high speed traffic. Normally, an open graded courses surface texture is desirable.

e) Workability: Workability is the ease with which can be laid and compacted and formed to the required condition and shake. This depends on the gradation of aggregates, their shakes and textural bitumen content and its type .Angular, bitumen content and its type. Angular, Flaky and elongated aggregates workability. On other hand, rounded aggregates improve workability.

f) Desirable properties: + Stability to meet traffic demand.

- Bitumen content to ensure proper binding and water pronging
- Voids to accommodate compaction due to traffic.
- Flexibility to meet traffic loads esp. in cold season.
- Sufficient workability for construction
- Economical mix.

1.3.2 Selection of Binder: Different type of binder like conventional 60/70or 80/100 penetration grade bitumen and many modified binder like polymer. Modified bitumen (CRMB), Natural rubber modified bitumen (NRMB)is used by different researcher for their research work.

Here in this research a comparative study is done between BC (and soma) with and without using fiber where 60/70 penetration grade bitumen id used as binder and sisal fiber as stabilizer.

2. LITERATURE REVIEW

The history of the use of fibres can be traced back to a 4000 year old arch in China constructed with a clay earth mixed with fibres or the Great Wall built 2000 years ago (Hongu and Philips,1990). However, the modern developments of fibre reinforcement started in the early 1960s (Mahrez, 2003). Zube (1956) published the earliest known study on the reinforcement of bituminous mixtures. This study evaluated various types of wire mesh placed under an overlay in an attempt to prevent reflection cracking. The study concluded that all types of wire reinforcement prevented or greatly delayed the formation of longitudinal cracks.

Fibres are added as reinforcement in bituminous mixtures. Reinforcement consists of incorporating certain materials with some desired properties within other material which lack those properties (Maurer and Gerald, 1989). Fundamentally, the principal functions of fibres as reinforcing materials are to provide additional tensile strength in the resulting composite and to increase strain energy absorption of the bituminous mixtures (Mahrez et al., 2005).

Some fibres have high tensile strength relative to bituminous mixtures, thus it was found that fibres have the potential to improve the cohesive and tensile strength of mixes. They are believed to impart physical changes to bituminous mixtures (Brown et al., 1990). Research and experience have shown that fibres tend to perform better than polymers in reducing the drain down of bituminous concrete mixtures 14 fibres are mostly recommended (Hassan et al., 2005). Because of the inherent compatibility of fibres with bitumen and its excellent mechanical properties, adding fibres to bitumen enhances material strength and fatigue characteristics while at the same time increasing ductility (Fitzgerald, 2000). According to Maurer and Gerald (1989), 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,mixtures with fibre showed a slight increase in the optimum binder content compared to the control mix. In this way, adding fibres to bitumen is very similar to the addition of very fine aggregates to it. Thus, fibre can stabilize bitumen to prevent leakage (Peltonen, 1991).

Fundamentally, fibre improves the different properties of the resulting mix. It changes the viscoelasticity of the modified bitumen (Huang and White 1996), increases dynamic modulus (Wu, Ye and Li,2007), moisture susceptibility (Putman and Amirkhanian, 2004), creep compliance, rutting resistance (Chen et al., 2004) and freeze– thaw resistance (Echols, 1989), while reducing the reflective cracking of bituminous mixtures and pavements (Echols, 1989; Tapkın et al., 2009, Maurer and Malasheskie,1989). Goel and Das (2004) reported that fibre-reinforced materials develop good resistance to ageing, fatigue cracking, moisture damage, bleeding and reflection cracking.

Bushing and Antrim (1968) used cotton fibres in bituminous mixtures. These were degradable and were not suitable as long term reinforcement. Metal wires has been proposed by Tons and Krokosky (1960), but they were susceptible to rusting with the penetration of water. Asbestos fibres were also used in pavement mixes until it was determined as a health hazard (Kietzman, 1960; Marais, 1979). With the new developments in the technology of production, natural fibre reinforced bituminous mixtures can be cost competitive when compared with modified binders. The natural coir fibre which is a cheaper and an ecofriendly alternative to synthetic fibre, can be effectively used as a stabilizing additive in bituminous concrete (Bindu and Beena, 2009). 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.

Brown (1994) studied on SMB and DGM by using two type of aggregate (granite and local siliceous gravel) and also used cellulose and mineral fiber in SMB and tested the Marshall test, drain down test, indirect tensile strength test, resilient modulus. He found that SMB mixture offer high resistance to rutting. SMB has shown good resistance to plastic deformation under heavy traffic loads with high tyre pressure. It has a rough texture which provides good friction properties after surface film of the binder is removed by the traffic.

Bradely etal (2004) studied utilization of waste fibers in SMB mixtures. They used carpet, tyre and polyester fibres to improve the strength and stability of mixture compared to cellulose fibre. They found no difference in moisture susceptibility and permanent deformation in SMB mix containing waste fibres and cellulose fibres

3. CONCLUSION

General

Based on the results and discussion of experimental investigation carried out on mixes i.e. SMA and BC following conclusion are drawn.

1) BC with different type of filler

1) As per MORTH Specification mix design requirements of bituminous mix is given in table 5.1
2) As BC made of from all the three type filler satisfy above requirements we can use them as filler.
3) Use of fly ash is helpful in minimize industrial waste.

2) BC With different Fibre content

1) Here OBC is 5%, OFC is found as 0.3%
2) By addition of fibre up to 0.3% Marshall Stability value increases and further addition of fibre it decreases. But addition of fibre stability value not increased as high as SMA.
3) By addition of fibre flow value also decreases as compare to mix without fibre, but addition of 0.5% fibre again flow value increases.

3) SMA With different Fibre content

1) Requirements of SMA according to IRC SP-79-2008 IS given in table 5.2 here OBC is 5.2% and OFC is 0.3%.
2) By addition of 0.3%fibre to SMA Stability value increases significantly and further addition to it, stability decreases.
3) By addition of 0.3%fibre to SMA flow value decreases and further addition of fibre flow value increases.

4) MIX at their OBC and OFC

1) Drain down of SMA is more than BC without fibre. At their OFC drain down of Binder is decreases.
2) From Indirect Tensile Strength it is concluded that Tensile Strength of SMA is more than BC.

5) Concluding Remarks

Here two type of mix i.e. SMA and BC is prepared where 60/70 penetration grade bitumen is used as binder. Also a naturally available fibre called sisal fibre is used with varying concentration (0 to 0.5%). OBC and OFC is found out by Marshall Method of mix design. Generally by adding 0.3% of fibre properties of Mix is improved. From different test like Drain down test, Indirect Tensile Strength and static creep test it is concluded that SMA with using sisal fibre gives very good result and can be used in flexible pavement.

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