International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES)
Impact Factor: 3.45 (SJIF-2015), e-ISSN: 2455-2585
Volume 4, Issue 5, May-2018

A REVIEW PAPER ON USE FIBRES IN STONE MATRIX ASPHALT

[1]Reyaz Hussain Akhoon, [2]Dr. V.S. Batra, [3]Er. Sandeep Singla
[1]M. tech (Scholar), Civil Department, RIMT University, Mandi Gobindgarh, Punjab, India
[2]Sr. Professor, Civil Department, RIMT University, Mandi Gobindgarh, Punjab, India
[3]HOD, Civil Department, RIMT University, Mandi Gobindgarh, Punjab, India
[1]er.reyazhussain@gmail.com, [2]vidyabatra6@gmail.com, [3]prof.sandeepsingla@gmail.com

Abstract: This paper provides a review of use of fibre in the SMA mixes design for road construction. Some Research has use fibres in fresh form or in waste form in highway industry. Some studies showed that fibre can increase the stability, tensile strength and can improve the indirect tensile strength and static creep behaviour of the asphalt pavement. In contrast, fibres improve the fatigue life of the modified bituminous mixes. In general, the previous research illustrates that fibre significantly improves the engineering properties of asphalt mixtures when mixed with SMA bitumen mix. SMA requires stabilizing additives composed of cellulose fibbers, mineral fibres or polymers to prevent drain down of the mix. In this Paper various applications and properties of SMA mixes are studied. Also the studies done by various authors are reviewed in this study.

1. INTRODUCTION:

For the past few years, polyester fibres have been promoted for use in bituminous concrete mixes as a substitute for asbestos fibres which are no longer available due to health hazards. The polyester fibres reportedly reduce air voids, increase mix stability and reduce reflective cracking of new bituminous overlays. Suppliers propose t hat the use of fibres allows the placement of thinner overlays resulting in cost savings to the user [1].

Aggregates bound with bitumen are conventionally used all over the world in construction and maintenance of flexible pavements. The close, well, uniform, or dense graded aggregates bound with normal bitumen normally perform well in heavily trafficked roads if designed and executed properly and hence very common in paving industry. However, it is not always possible to arrange dense graded aggregates available at the site in view of higher cost and fast depleting aggregate resources because of increased infrastructure activities. In a normal stone crushers, aggregates normally formed do not have a well grading, rather has particularly the most of middle size fractions missing. In such situations a bituminous mix called stone matrix asphalt (SMA) which basically consists of higher proportion of coarse aggregate, lower proportion of middle size aggregate and higher proportion of mineral filler compared to normal mixes is used. The large amount of coarse aggregates in the mixture forms a skeleton-type structure providing a better stone-on-stone contact between the coarse aggregate particles, which offers high resistance to rutting. The SMA mixtures have a rough macro texture, forming small path between the coarse aggregate, which useful for an efficient surface drainage [2]. Stone matrix asphalt has higher proportion of coarse aggregates and binder mortar compared to conventional mixtures. Good stone-to-stone contact exists between the aggregates forming coarse aggregate skeleton, which provides better strength and rut resistance to the mixture. The coarse aggregate skeleton contributes to the shear strength and effective loading distribution pattern of vehicles to endure heavier traffic loads compared to the dense-graded mixtures [3–5]. Addition of a small quantity of cellulose or mineral fibre prevents drainage of bitumen during transport and placement. There are no precise design guidelines for SMA mixes. The essential features, which are the coarse aggregate skeleton and mastic composition, and the consequent surface texture and mixture stability, are largely determined by the selection of aggregate grading and the type and proportion of filler and binder. SMA improved rut resistance and durability. It has good fatigue and tensile strength.SMA is almost exclusively used for surface courses on high volume roads. Materials used for SMA are Gap graded aggregate, modified asphalt binder, fibre filler. Other SMA benefits include wet weather friction (due to a coarser surface texture), lower tire noise (due to a coarser surface texture) and less severe reflective cracking. Mineral fillers and additives are used to minimize asphalt binder drain-down during construction, increase the amount of asphalt binder used in the mix and to improve mix durability [6-10].

1.2 FIBRES:

Fibres have been used to reinforce paving materials for many decades in various parts of the world. Their use in stone matrix asphalt and porous or open-graded mixtures to prevent draindown of the binder from the aggregate particles is very common. Less common is the use of fibres in dense-graded mixtures to increase stability (reduce rutting) and improve resistance to cracking. Cracking of asphalt pavements appears to be an increasing concern in many states, so identification of a potential tool to reduce cracking could be very beneficial. This synthesis is intended to explore past and current use of fibres in asphalt mixtures. Many types of fibres are available for incorporation into asphalt paving mixtures[11-15]. Cellulose and mineral fibres are commonly used in gap-graded stone matrix asphalt (SMA) and open-graded or porous mixtures[16]. Polypropylene and polyester fibres were previously used in dense-graded mixtures and are used to some extent. Various polymers, steel wool, and other fibres are also sometimes added to asphalt mixtures. The relative benefits and issues with these various types of fibres are not well documented. The appropriate specifications and material characteristics to ensure the best performance in different climates, under different traffic loadings, and in different applications are also not widely recognized. This synthesis assembles and summarizes the available literature on asphalt mixtures with fibre additives.[17-18] Agencies were surveyed to determine their current and past use of fibres in asphalt, their testing and mix design procedures, performance history, and other information. In particular, the synthesis panel examined the following:

• Types of fibres (e.g., materials, dimensions, applications, sources).

• Specifications, test methods, and acceptance criteria.

• Fibre quality, interactions, and supply issues.

• Health, safety, and environmental issues.

• Use of fibres in both experimental and routine construction.

• Mix design, production, placement, and acceptance issues/resolutions.

• Factors that affect performance (e.g., climate, traffic, application, fibre type).

• Performance mechanisms/material characteristics.

• Costs/benefits, and

• Impact on recycled materials.

The use of fibres in specialty mixes (such as cold mix or curb mixes) and in spray-applied pavement preservation treatments is not considered; however, if an agency mentioned such applications in its comments, the comments have been included in the summary response tables.

1.2.1 BACKGROUND:

The use of fibres in asphalt mixes dates back many decades. Or longer: Button and Epps (1981) maintain that the earliest use of fibres in asphalt was the use of straw in ancient Egyptian building specifications. In the United States, asbestos fibres were used as early as the 1920s (Serfass and Samanos 1996), and this usage continued until the 1960s, when health and environmental concerns put an end to it (Busching et al. 1970). Cotton fibres were used in the 1930s (Busching et al. 1970), but they tended to degrade over time (Freeman et al. 1989). Since then many types of fibres have been used in various applications and different parts of the world. Fibres were reportedly used to provide the following benefits (Busching et al. 1970; Peltonen 1991):

• Increased tensile strength resulting in increased Resistance to cracking,

• Reduced severity of cracking when it did occur,

• Increased fatigue resistance,

• Increased rutting resistance as a result of lateral Restraint within the mixture,

• Increased abrasion resistance,

• Higher asphalt contents leading to increased durability, and

• Potential lower life cycle costs arising from longer Service life.

Early applications were in dense-graded mixtures. Beginning in 1991, the first SMA mixtures were placed in the United States after more than 30 years of successful use in Europe (Cooley and Brown 2001). These mixes were designed in Europe mainly to resist studded tire wear but were found to be highly resistant to permanent deformation as well. Usage in the United States increased rapidly: by 1997 more than 140 SMA projects across the country were evaluated by the National Center for Asphalt Technology (NCAT) (Cooley and Brown 2001).

These mixes generally used cellulose or mineral fibre to help hold the asphalt binder in the gap-graded aggregate structure; that is, to prevent draindown of the binder. Fibres are also used in open-graded friction courses (OGFCs) or porous asphalt mixes to prevent draindown.

These mixes have open-graded aggregate structures and high air voids to create stone-on stone contact to resist rutting, reduce noise (McGhee et al. 2013), reduce splash and spray, and improve friction (Watson et al. 1998).In summary, there are two main uses for fibres: (1) to prevent draindown in gap- and open-graded mixes, and (2) to strengthen dense-graded asphalt mixes to resist rutting and cracking. These uses plus other potential benefits and applications of the use of fibres are explored in this synthesis.

1.2.2 TYPES OF FIBRES:

Many types and forms of fibres have been used in asphalt mixtures, either experimentally or routinely. Cellulose, mineral, and polymer fibres are the most common. The most commonly used types of fibres and their reported benefits and disadvantages are summarized in Table 1.

Cellulose: 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.

Mineral: Either naturally occurring fibres, such as asbestos (crystallite), or manufactured mineral fibres can be used. Mineral fibres (also called mineral wool or rock wool) are manufactured by melting minerals then physically forming fibres by spinning [similar to making cotton candy (Science Channel n.d.)] or extruding. Minerals used to create mineral fibres include slag or a mixture of slag and rock (U.S. EPA 1995; Brown et al. 1996), basalt (Morova 2013), brucite (Guan et al. 2014), steel (Garcia et al. 2009, 2012 a and b, 2013 a and b; Serin et al. 2012), and carbon (Clevin 2000; Liu and Shaopeng 2011; Khattak et al. 2012, 2013; Yao et al. 2013). 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 de-icing (Garcia et al. 2009, 2012 at and b, 2013 at and b) or to heal micro cracks (Gallego et al. 2012; Liu et al. 2012; Garcia et al. 2012a, 2013a; Dai et al. 2013). Steel fibres have been used for research purposes, but because they corroded upon exposure to water, they were not effective in the long term (Freeman et al. 1989; Putnam 2011). Asbestos fibres were the first type of fibre used in hot mix asphalt; they were use from the 1920s (Serfass and Samanos 1996) until the 1960s when environmental and health issues curtailed the use of asbestos (Busching et al. 1970).

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. Fibres can be bundled together into yarn (although yarn is not typically used today in asphalt concrete) (Busching et al. 1970). Reportedly, agamid fibres contract at high temperatures, which helps resist pavement deformation (Kaloush et al. 2010).

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 (Cleven 2000; Oda et al. 2012; Das and Banerjee 2013; Qiang et al. 2013; Abiola et al. 2014; Do Vale et al. 2014; Muniandy et al. 2014).

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 (Abtahi et al. 2013).

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. Putnam, for example, has explored the possibility of reusing waste carpet fibres and tire fibres from the auto manufacturing industry, with favourable results in terms of increased mixture toughness, permanent deformation, and moisture resistance (Putnam and Amirkhanian 2004). Chowdhury et al. (2005) investigated the use of fibres from recycled tires and found that they performed well, especially in reducing draindown.

The advantages of natural fibres include low cost, acceptable strength and mechanical properties, and sustainability. One disadvantage is their tendency to absorb moisture, which can cause them to swell (Table 1) and can interfere with bonding of hydrophobic asphalt with the moisture-laden fibre. Natural fibres can also degrade at high temperatures or moisture conditions. Compatibility of the fibre and the asphalt can be improved with various surfaces

Treatments. Overall, however, it appears that some natural fibres, such as jute and sisal, can be used to replace synthetic fibres in asphalt mixes (Abiola et al. 2014).

Table 1: REPORTED BENEFITS AND DISADVANTAGES OF COMMON FIBER TYPES:

Fibre Type	Reported Advantages	Reported Disadvantages
Cellulose	• Stabilizes binder in open- and gap-graded stone matrix Asphalt (SMA) mixtures. • Absorbs binder, allowing high binder content for more durable Mixture. • Relatively inexpensive. • May be made from a variety of plant materials. • Widely available. • May be from recycled materials such as newsprint.	• High binder absorption increases binder cost. • Not strong in tensile mode.
Mineral	• Stabilizes binder in open- and gap-graded SMA mixtures. • Not as absorptive as cellulose. • Electrically conductive fibres have been used for inductive Heating for de-icing purposes or to promote healing of cracks.	• Some may corrode or degrade because of moisture Conditions. • May create harsh mixes that are hard to compact and may be Aggressive, causing tire damage if used in surfaces.
Polyester	• Resists cracking, rutting, and potholes. • Increases mix strength and stability. • Higher melting point than polypropylene. • High tensile strength.	• Higher specific gravity means fewer fibres per unit weight Added. • Cost-effectiveness not proven/varies.
Polypropylene	• Reduces rutting, cracking, and shoving. • Derived from petroleum, so compatible with asphalt. • Strongly bonds with asphalt. • Disperses easily in asphalt. • Resistant to acids and salts. • Low specific gravity means more fibres per unit Weight added.	• Lower melting point than some other fibre materials requires Control of production temperatures. • Begins to shorten at 300°F. • Cost-effectiveness not proven/varies.
Aramid	• Resists cracking, rutting, and potholes. • Increases mix strength and stability. • High tensile strength. • May contract at higher temperature, which can help resist rutting.	• Cost-effectiveness not proven/varies.
Aramid and polyolefin	• Controls rutting, cracking, and shoving. • Combines benefits of aramid and polyolefin (polypropylene) Fibre types.	• Cost-effectiveness not proven/varies.
Fibreglass	• High tensile strength. • Low elongation. • High elastic recovery. • High softening point.	• Brittle. • Fibres may break where they cross each other. • May break during mixing and compaction. • Cost-effectiveness not proven/varies.

1.3 BINDERS:

Bitumen acts as a binding agent to the aggregates, fines and stabilizers in bituminous mixtures. Binder provides durability to the mix. The characteristics of bitumen which affects the mixture behaviour are temperature susceptibility, visco-elasticity and aging. The behaviour of bitumen depends on temperature as well as on the time of loading. It is stiffer at lower temperature and under shorter loading period. Bitumen must be treated as a visco-elastic material as it exhibits both viscous as well as elastic properties at the normal pavement

temperature. Though at low temperature it behaves like an elastic material and at high temperatures its behaviour is like a viscous fluid. Bitumen along with different additives (fifers, polymers etc.) are act as a stabilizer for bituminous Mix. Polymer modified bitumen can also be used as a stabilizer with or without additives in the mixture. Different types of bitumen have been used by various researchers to the mixture properties. Penetration grade bitumen such as 60/70, 80/100 grade of bitumen are used to evaluate SMA mixtures.

1.3.1 GRADES OF BITUMEN:

Bitumen shall be classified into four grades based on the viscosity, and suitability recommended for maximum air temperature as per IS-73 (2013) specification given below:

Table 2: Different Grades Bitumen:

Grade	Suitable for 7 day Average Maximum Air Temperature °C
VG10	< 30
VG20	30-38
VG30	38-45
VG40	> 45

NOTE — This is the 7 day average maximum air temperature for a period not less than 5 years from the start of the design period.

Table 3: Requirements for Paving Bitumen

		Paving Grades				
S l No.	Characteristics	VG10	VG20	VG30	VG40	Method of Test, Ref to
i)	Penetration at 25°C, 100 g, 5 s, 0.1 mm, *Min*	80	60	45	35	IS 1203
ii)	Absolute viscosity at 60°C, Poises	800-1200	1600-2400	2400-3600	3200-4800	IS 1206 (Part 2)
iii)	Kinematic viscosity at 135°C, cSt, *Min*	250	300	350	400	IS 1206 (Part 3)
iv)	Flash point (Cleveland open cup), °C, *Min*	220	220	220	220	IS 1448 [P : 69]
v)	Solubility in trichloroethylene, percent, *Min*	99.0	99.0	99.0	99.0	IS 1216
vi)	Softening point (R&B), °C, *Min*	40	45	47	50	IS 1205
vii)	Tests on residue from rolling thin film oven test: a) Viscosity ratio at 60°C, *Max* b) Ductility at 25°C, cm, *Min*	 4.0 75	 4.0 50	 4.0 40	 4.0 25	 IS 1206 (Part 2) IS 1208

1.4 DIFFERENCE BETWEEN SMA & CONVENTIONAL MIXES:

SMA is successfully used by many countries in the world as highly rut resistant bituminous course, both for binder (intermediate) and wearing course. The major difference between conventional mixes and SMA is in its structural skeleton .The SMA has high percent about 70-80 percent of coarse aggregate in the mix .This increases the interlocking of the aggregates and provides better stone to stone contact which serves as load carrying mechanism in SMA and hence provides better rut resistance and durability. On the other hand, conventional mixes contain about 40-60 percent coarse aggregate. They does have stone to stone contact, but it often means the larger grains essentially float in a matrix composed of smaller particles, filler and asphalt content .The stability of the mix is primarily controlled by the cohesion and internal friction of the matrix which supports the coarse aggregates .It can be followed from diagram of the grain size distribution of the mixes given below. The second difference lies in the binder content which lies between 5-6 percent for conventional mixes. Below this the mix becomes highly unstable. Above this percent will lead to abrupt drop of stability because the binder fills all the available voids and the extra binder makes the aggregates to float in binder matrix. The SMA uses very high percent of binder > 6.5 percent which is attributed to filling of more amount of voids present in it, due to high coarse aggregate skeleton. The high bitumen content contributes to the longevity of the pavements. The third difference is the use of stabilizing additives in SMA which is attributed to the filling up of large no of voids in SMA so as to reduce the drain down due to presence of high bitumen content. On the contrary, there is no stabilizing agent in conventional mixes since the bitumen content is moderate, which only serves the purpose of filling the moderate amount of voids and binding the aggregates.

1.4.1 SMA With different Fibre content:

Requirements of SMA according to IRC SP-79-2008 IS given in table 4:

Table 4: IRCSP79-2008 Specification mix design requirements of SMA:

Property	Value
Void (%)	4
Binder Requirement (%)	5.8 min
VMA (%)	17
OFC (%)	SHOULD NOT EXCEED 0.3%

2.0 Fibers in Stone Matrix Asphalt and Open-Graded Asphalt Mixes:

Stone matrix asphalt mixtures are gap-graded mixtures in which the voids in the mineral aggregate are mostly filled with asphalt mastic (binder, filler, and sometimes fibres). Open-graded mixtures, as their name implies, have open void space, which allows water to flow into and out of the mixture; therefore, these mixes are also called porous asphalt or permeable asphalt mixes. The main purpose of using fibres in these mixes is to control binder draindown; both will be discussed in this section.

Stuart and Malmquist (1994), summarized the properties and purported benefits of using SMAs fairly early in the U.S. usage of this type of mix, after about 20 had been placed in the United States. On the basis of previous European experience with this type of mix in surface courses, it was expected that SMAs would perform better in terms of rutting under heavy traffic. These mixes are gap-graded with high coarse aggregate, binder, and mineral filler contents. Because of the lack of intermediate aggregates in the mixture, stabilizers are typically added to help retain the binder in the mixture; that is, to prevent draindown during production, transport, and laydown.

Reported on a study to evaluate the effects of different types of stabilizers in SMA, including loose cellulose fibres, pelletized cellulose fibres, loose rock wool fibres, and two polymers with AC-20 binder. Six stabilizers were evaluated in terms of their effects on mixture resistance to rutting, low temperature cracking, aging, and moisture damage, as well as Draindown. The four fibre mixes evaluated in this study exhibited similar low amounts of draindown, but the polymer-modified mix had relatively high amounts of draindown and did not pass the German and open-graded friction course Draindown tests. On the basis of the initial results, one loose cellulose and one loose rock wool fibre were dropped from further testing because they were expected to perform similarly to the remaining loose cellulose and pelletized cellulose fibres in the study.

There were no significant differences in the resistance to rutting of the remaining two fibre and two polymer-modified mixes as measured by the Georgia loaded wheel test, the French pavement rutting test, and the gyratory testing machine. Similarly, there were no significant differences in the low temperature cracking resistance. The two polymer modified mixes demonstrated less age hardening than the fibre mixes but were not effective at controlling draindown. It was noted that none of the actual mixes placed on US-15 exhibited any draindown during construction, despite the fact that the two polymers did drain down in the lab; the discrepancies between testing and performance were reported to be "difficult to explain." After 18 months in the field, all the SMA sections were performing without noticeable distress.

Brown et al. (1996), conducted a laboratory study of mortars for SMA mixtures using different fine aggregate types, two mineral fillers, modified and unmodified asphalts, and three types of fibers—cellulose, rock wool, and slag wool. The goals were to determine whether Superpave PG binder tests could be used to characterize SMA mortars and to determine how the components of the mortar affect performance. Fine mortar was defined as the binder plus stabilizer, mineral filler, and aggregate that passed through the 75-µm (#200) sieve and was considered for testing as a binder under the performance grade system. The total mortar was also tested in some cases; it included the fine mortar plus aggregates that passed through the 2.36-mm (#8) sieve. The fibers were added at 1.9% to 3.0% by weight of the mortar, which would be typical of the fiber content in the mortar fraction of SMAs.

The results of testing both the total mortar and the fine mortar indicated that most of the stiffening came from the mineral filler; the fibres did little to stiffen the mortar at most temperatures. However, at high temperatures, such as those encountered during production and placement, the fibres did stiffen the mortar appreciably. This high temperature effect is credited with reducing the draindown during construction and may be the main reason to use fibres in SMA.

Watson et al. (1998) summarized the Georgia DOT's (GDOT's) history of using open-graded friction courses. GDOT had used OGFCs for decades before banning them in 1982 after numerous problems with draindown, oxidation, ravelling, and stripping of the pavement layer under the OGFC. Beginning in 1993, GDOT began using a modified 12.5-mm OGFC that included polymer-modified binder, fibres, and hydrated lime placed at 41 to 50 kg/m2 (75 to 90 lb/yd2). The use of polymer-modified binder and fibres reportedly allowed the buildup of thicker films coating the aggregates, which reduced weathering and early oxidation. Hydrated lime was added to both the OGFC and the underlying layers to prevent stripping.

Mineral fibres were used at about 0.4% by weight of the mix to prevent binder Draindown and increase mix strength. They also reportedly worked with the modified binder to increase film thickness; calculated film thicknesses in OGFCs with fibers were about 400% greater than those in conventional dense-graded mixes and about 30% to 40% greater than in previous OGFCs. Similar mixes are still routinely used in Georgia.

Cooley et al. (2000) compared the performance of cellulose with mineral fibers in OGFC. Cooley et al. credited a 1998 survey by Kandhal and Mallick as one impetus for their study; that survey reportedly revealed that many states specified mineral instead of cellulose fibres in OGFCs because of concerns that the cellulose would absorb water and cause moisture-related damage to the pavement. Cooley et al. conducted a field inspection of a 6-yearold Georgia DOT trial project that showed no significant performance differences between sections with cellulose and those with mineral fibres in terms of surface texture, rutting, cracking, and raveling.

Cores from the field sections were tested for permeability; the cores with cellulose and cellulose with polymer-modified binder had the highest permeabilities, but the differences were not statistically significant. Differences in water absorption into Marshall compacted specimens did not appear to be significantly different for the cellulose and mineral fibre specimens, though the loose cellulose mixes did have the highest absorption. Mixes with loose cellulose, two cellulose pellets (pelletized with 34% and 20% asphalt), and mineral fibres did not perform differently in terms of tensile strength ratio (TSR). No visual stripping was observed in any of the mixes. Submerged asphalt pavement analyzer (APA) rut depths were low, but the loose cellulose mix did have lower rutting (5.2 mm at 8,000 cycles compared with 7.6 mm for the mineral fibre). The authors concluded that cellulose was as effective as mineral fibres and no moisture problems should be expected because of the use of cellulose.

In another study, Watson (2003) inspected 13 SMA projects in five states after 5 to 10 years in service. On the basis of visual examination, he concluded that SMAs with fibre and unmodified binder performed as well as SMAs with polymer-modified binder. The types of fibres were not identified, but they probably included cellulose and possibly mineral fibres.

Putnam and Amirkhanian (2004), compared the laboratory performance of cellulose, polyester (recycled raw materials), scrap tire, and waste carpet fibres (nylon) in an SMA with a PG 76-22 binder and granite aggregate. The waste carpet fibres were in the form of tufts of fibres and were added at 0.3% for each fibre type. An optimum asphalt content was determined for each mix. The synthetic fibres had lower optimum asphalt content than the cellulose because they were less absorptive. The mixes were evaluated in terms of draindown (AASHTO T 305), moisture sensitivity (ASTMD4867 modified), and rut testing (APA). Draindown was determined at the optimum asphalt content and at higher contents to see how well the fibres could stabilize an excess amount of binder.

Hassan et al. (2005), in a study for Oman, explored the effects of 6-mm-long cellulose fibres (0.4% by weight of mix), SBR-modified binder (4% SBR), and a combination of fibres and SBR compared with a control with no additives. The study found that the polymer was more effective at resistance to ravelling in the short term, while both polymer and fibres improved the long-term resistance (resistance in an aged condition). Fibres reduced draindown more than polymer alone.

Tayfur et al. (2007) compared the performance of unmodified and modified SMAs for their resistance to permanent deformation using indirect tensile strength, static and repeated creep, and wheel-tracking tests. The modifiers included granular amorphous polyalphaolefin, cellulose fibres, polyolefin, bituminous cellulose fibre, and styrene butadiene styrene. The researchers found that all the modified mixes had higher tensile strengths than the unmodified control, with the polyolefin and SBS having the highest tensile strengths. The SBS mixes had the greatest resistance to permanent deformation in the wheel-tracking test; the fibre mixes had some of the highest deformations in this test. The SBS mixes also had the highest resilient modulus among the modified mixes; the control had the highest resilient modulus at 5°C but not at 25°C or 40°C. Overall, the SBS mix performed most effectively; the fibre mixes did not perform particularly well.

Stempihar et al. (2012) conducted a lab and field study to explore the feasibility of using fibre-reinforced porous asphalt mixtures for airfield pavements. The addition of fibres was considered a potentially sustainable paving practice because they might improve the performance of the pavement. Airfield pavements in cool climates need to be able to withstand heavy loads from aircraft, extreme variations in temperatures, and snow plowing in winter; fibres could potentially help with all these issues. An increase in service life would also increase sustainability by reducing carbon emissions from maintenance and reconstruction, and from production of new paving materials. Use of recycled or waste fibres would also increase sustainability.

This study compared the laboratory performance of fiber reinforced asphalt concrete (FRAC) mixture samples from a paving project at the Jackson Hole Airport (JAC) in Jackson, Wyoming, with a control mixture without fibres. The control mix was reproduced in the laboratory using the same materials from a mix that was placed at the Sheridan County Airport (SHR) in Sheridan, Wyoming. The mixtures were evaluated in terms of dynamic modulus, fatigue, indirect tension, and Cantabro mass loss. A blend of polypropylene and aramid fibres was added to the batch plant at a rate of 1 lb/ton (0.5 kg/MT). The fibres were added to the hopper after the bag house so they would not be pulled into the bag house. Both mixtures used a PG 64-34 binder and similar binder contents (5.70% at JAC and 5.6% at SHR) and were open-graded mixes with a maximum aggregate size of 19 mm, conforming to the FAA P-402 porous friction course specification control points. The JAC mixture also included 0.75% hydrated lime.

Confined dynamic modulus testing according to AASHTO TP 62-03 showed that the FRAC was significantly stiffer than the SHR mixture at higher temperatures, which should represent increased rutting resistance. There were no substantial differences in the dynamic moduli at lower temperatures.

Beam fatigue testing (AASHTO T 321-03) showed that the fibre mix performed better in fatigue than the control mix at strain levels of 400 μm and 600 μm, but the performance was similar at 800 μm.

Tensile strength testing was conducted on the mixtures at 0°C, 10°C, and 21.1°C according to AASHTO TP 9-02. The FRAC outperformed the control in terms of tensile strength, energy at fracture, and total energy. The authors noted that “although the specimen cracks, the fibres hold the specimen together, which requires more energy for the asphalt sample to fail”.

Lyons and Putnam (2013) compared the laboratory performance of cellulose fibres, CR-modified asphalt, and SBS-modified asphalt in porous asphalt mixtures. They found that the addition of fibres and polymers led to reductions in the porosity and permeability of the porous mixtures. However, it also led to improvements in draindown, abrasion resistance (Cantabro), and indirect tensile strength. Cellulose and crumb rubber were most effective at reducing Draindown compared with the unmodified control. Crumb rubber and a combination of cellulose fibres with SBS-modified binder were most effective at improving the abrasion resistance of the mixtures. Finally, cellulose did not have a significant effect on tensile strength, but SBS and crumb rubber did lead to increased strength.

Do Vale et al. (2014) studied the effects of using coconut fibres in SMA. The northeastern part of Brazil is a leading producer of coconuts. They found that the addition of cellulose and coconut fibres increased the TSR. But SMA mixes with coconut fibres did not perform as well in fatigue as mixes with cellulose or no fibre. This was possibly because the high absorption of the coconut fibre increased the stiffness of the mix. The researchers also noted that long coconut fibres were difficult to mix with the aggregate and could have lowered the strength of the mix by interfering with aggregate interlock. Work using shorter coconut fibres was planned.

2.1 Discussion of Performance of Fibres Reinforced Mixtures:

The literature survey on the performance of fibre-reinforced mixtures shows that the results are mixed. The use of fibres is not reported to cause any performance problems, provided the mix design, fibre dosage, and mix production are adequate. In some cases, fibres are reported to improve cracking or rutting resistance; in others they appear to have no effect. There are many possible explanations for these apparent discrepancies, including differences in the materials used in different studies, construction or laboratory mix preparation issues, and natural variability. Work by Cloven (2000) suggests an additional explanation.

Cleven reported that the use of fibres may have a greater impact on the performance of marginal or low-quality mixtures. His findings showed that fibres did not affect low temperature cracking resistance until the binder began to fail. When cracking began to develop in the binder, the fibres were mobilized and helped reduce the cracking (Cloven 2000). This conclusion is supported by Kutay et al. (2009), who observed that when cracking initiated in the ALF fibre section, the fibres helped reduce the severity of the cracking. A paper by Gibson and Li (2015), also using the FHWA ALF, showed that fibre-reinforced mix performs better in fatigue than polymer-modified mix at high strain levels, but not at lower strain levels.

These observations might also explain some of the seemingly disparate results reported in the literature. For example, the Indiana test section placed in 1980 exhibited much better rutting and cracking resistance than the control section without fibres (Galinsky 1984; McDaniel 1985). The severe rutting and cracking in the control section, however, showed that the control mixture was not of sufficient quality to withstand the interstate traffic loadings applied. Later, when fibres were added to a much more visible and closely controlled study in Indiana (McDaniel 2001; McDaniel and Shah 2003), all the mixes, including the unmodified control, performed very well for more than 10 years under interstate traffic loadings. Adding fibres or a variety of polymer binders to a high-performing mixture did not have as great an impact on performance.

3. CONCLUSION:

Detailed investigated should be done on the Firers used in SMA like reinforcing mechanisms as well as optimum fibre and Binder content. The various properties of Fibre like fibre content, fibre length, fibre’s size, fibre’s shape and colour of fibre should be focus in the asphalt pavement in the future research. In addition, field performance of fibre modified asphalt pavement should be determining the boundary effects on the test results. New research field can be conducting such as investigate modelling of mechanical properties of fibres modified asphalt pavement by using composite science principles. Both SMA mixtures satisfied drain down requirements without any stabilising additive.

4. FUTURE USAGE OF FIBRES:

With the implementation of the SHRP (Strategic Highway Research Program) for asphalt binders and mix designs coming on stream in the next few years there is potential growth in the use of all fibre types. Data obtained from SHRP and other research programs indicates that mixes such as SMA, OFC and porous asphalt will be required to combat permanent deformation (rutting), skid resistance and traffic noise. Because of increased traffic volumes and the types of vehicles (bigger loads) now on the major highways and city streets these mixes will become the way of the future. Since fibres are one of the basic components of these mix types the projection is for a definite increase in fibre demand over the next ten to twenty years.

REFERENCES:

1. R.I. Frascoia Research & Development Supervisor "EXPERIMENTAL USE OF POLYESTER FIBER MODIFIED BITUMINOUS PAVEMENT ON VERMONT ROUTE 12A" Initial Report 82-7 August 1982.

2. Motta, L. M .G., Leite, L. F. M., Bernucci, L. B. and Ceratti, J. A. P., Síntese de Estudos Sobre Misturas Asfálticas Tipo SMA. In: Anais do 17° Encontro de Asfalto, artigo IBP901_04. Rio deJaneiro, Brazil. 2004.

3. Dr. R. Vasudevan, S.K. Nigam, R. Velkennedy, A. Ramalinga Chandra Sekar, B. Sundarakannan .Utilization of Waste Polymers coated Aggregate for Flexible Pavement And easy Disposal of Waste Polymers. Proceedings of the International Conference on Sustainable Solid waste Management, Chennai, India. pp. 105-111, 5-7 September (2007).

4. D S V Prasad, M.Anjan Kumar, G V R Prasad Raju, V. Kondayya .A Study on Flexible Pavement Performance with Reinforced Fly ash Sub base. International Journal of Earth Sciences and Engineering 4ISSN 0974-5904, Volume 04, No. 06 SPL, October, pp. 403- 408(2011).

5. Brown ER (1992) Evaluation of SMA used in Michigan (1991). Report No. 93-03, National Center for Asphalt Technology, Auburn University, Alabama, US.

6. Qiu YF, Lum KM (2006) Design and performance of stone mastic asphalt. J Transp Eng 132(12):956–963. doi:10.1061/ (ASCE)0733-947X(2006)132:12(956).

7. Tashman L, Pearson B (2012) Characterisation of stone matrix asphalt mixtures. Int J Pavement Eng 13(4):297–309. doi:10. 1080/10298436.2011.595793.

8. Meor O. Hamzah , and Teoh C. Yi . effects of Temperature on Resilient Modulus of Dense Asphalt Mixtures Incorporating Steel Slag Subjected to Short Term Oven Ageing. World Academy of Science, engineering and Technology 46, 008

9. P Sreejith .Use of plastic waste in Bitumen Roads. Powered by WordPress.com (2010) Pada Sabtu, Utilisation Of Waste Plastic In Bituminous Mixes For Road construction,(2010).

10. K.Karthik, .Carbon fibre modified bitumen in bituminous macadam., International Journal of Advance Engineering and Research Development Volume 2, Issue 12, December -2015.

11. Anderson, D.A., and Goetz, W.H. (1973), "Mechanical Behaviour and Reinforcement of Mineral Filler-Asphalt Mixtures", Proceedings of Association of Asphalt Paving Technologists, Volume 42, No. 1, pp. 37-66, USA.

12. Liu, X. and W. Shaopeng, "Study on the Graphite and Carbon Fibre Modified Asphalt Concrete," Construction and Building Materials, Vol. 25, 2011, pp. 1807–1811.

13. Dr. R. Vasudevan, S.K. Nigam, R. Velkennedy, A. Ramalinga Chandra Sekar, B. Sundarakannan .Utilization of Waste Polymers coated Aggregate for Flexible Pavement And easy Disposal of Waste Polymers. Proceedings of the International Conference on Sustainable Solid waste Management, Chennai, India. pp. 105-111, 5-7September (2007)

12. Maurer, D.A. and G.J. Malasheskie, "Field Performance of Fabrics and Fibres to Retard Reflective Cracking," Geotextiles and Geomembranes, Vol. 8, 1989, pp. 239–267.

13. McDaniel, R.S., Supplemental Report: *1985* Update on Performance of Bituminous Surface with Fibres, Indiana Department of Highways, Division of Research and Training, West Lafayette, Dec. 1985.

14. McDaniel, R.S., Asphalt Additives to Control Rutting and Cracking, PhD Dissertation, Purdue University, West Lafayette, Ind., 2001.

15. McDaniel, R.S. and A. Shah, Asphalt Additives to Control Rutting and Cracking, Final Report, FHWA/IN/JTRP- 2002/29, Joint Transportation Research Program, West Lafayette, Ind., Jan. 2003.

16. McGhee, K.K., E.D. de León Izeppi, G.W. Flintsch, and D.E. Mogrovejo, "Virginia Quieter Pavement Demonstration Projects: Initial Functional Assessment," Transportation Research Record: Journal of the Transportation Research Board, *No. 2362*, Transportation Research Board of the National Academies, Washington, D.C., 2013, pp. 16–24.

17. Morova, N., "Investigation of Usability of Basalt Fibres in Hot Mix Asphalt Concrete," Construction and Building Materials, Vol. 47, 2013 [Online]. Available: http://dx. doi.org/10.1016/j.conbuildmat.2013.04.048 [accessed June 15, 2014].

18. Muniandy, R., N.A.B.C.M. Akhir, S. Hassim, and D. Moazami, "Laboratory Fatigue Evaluation of Modified and Unmodified Asphalt Binders in Stone Mastic Asphalt Mixtures Using a Newly Developed Crack Meander Technique," International Journal of Fatigue, Vol. 59.