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Review

Utilisation of natural fibre as modifier in bituminous mixes: A review

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HIGHLIGHTS

- Papers on natural fibres in asphalt concrete was reviewed.
- Natural fibres can replace synthetic fibres.
- Reinforcement with natural fibres improves the asphalt properties.
- Natural fibres can improve resistance to pavement distress.
- Research focus is on fibre content, length and effect of binder content on fibre parameter.

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ABSTRACT

This paper provides a review on the utilisation of natural fibre 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 fibres have become a research focus for scientist and engineers. Types of natural fibres, their surface treatment and reinforcement of asphalt concrete with natural fibres are presented. Generally, the review demonstrated an improvement in fatigue life and structural resistance to distresses occurring in pavement when modified.

Contents

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1. Introduction

Increase in traffic loading density in terms of numbers of axles and high tyre pressures resulting from heavy vehicles, places great demand on the existing road network. The horizontal stresses induced between the layers soon result in crack formation 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 [1–5]. Reflection cracking is one of the major distresses that occur frequently in asphalt concrete overlay 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 ravelling in flexible pavements. However, the problem of fatigue cracking still persists. Fatigue cracking occurs because bituminous layers are weak in tension. Fibre reinforcement improves fatigue life by increasing the resistance to cracking and permanent deformation [6,7].

Modification of bitumen is one of the approaches to improve the pavement performance when the asphalt produced does not meet the climatic, traffic and pavement structure requirement, as reported by Fitzegarald [8] and Kim [9]. 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 incompatible [10]. This incompatibility cannot always be effectively predicted, and it can lead to premature asphalt pavement distresses. Today, all forms of paving asphalts: asphalt cements, emulsions, and cut-backs are usually modified. The modified binders are used for fog seals, slurry seals, chip seals, patching mixtures, cold-mixed and hot-mixed mixtures, in dense and open-graded forms. Yugel [11] classify asphalt modifiers as fillers, extenders, polymers, fibres, oxidants and antioxidants, anti-stripping agents, waste materials and hydrocarbon.

Currently, synthetic fibres, such as: glass, carbon, polymer and aramid fibres are used as modifiers because of their high stiffness and strength properties. Natural fibres such as hemp, coir, jute, sisal and flax are a new class of materials which have good potential in bituminous mixes. Depending on their origin, natural fibres can be grouped into bast (jute, banana, flax, hemp, kenaf, mesta), leaf (pineapple, sisal, henequen, screw pine), seed or fruit fibres (coir, cotton, palm). Different fibre arrangements, such as: short-randomly oriented, long-unidirectional and woven fabrics have been fabricated for natural fibre composites. 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 the utilisation of natural fibres as reinforcement in bituminous mixes.

2. Utilisation of fibres in bituminous mixes

Zube [12] reported the earliest known study on the reinforcement of asphalt mixtures. The study evaluated various types of wire mesh placed under an asphalt overlay in an attempt to prevent reflection cracking. It was concluded that all types of wire reinforcement prevent or greatly delay the formation of longitudinal cracks. He suggested that the use of wire mesh would allow the thickness of overlays to decrease while they still achieve the same level of performance. The principal functions of fibre reinforcement in bituminous mixes are to provide additional tensile strength in the resulting composite and increasing strain energy absorption of the bituminous mix in order to inhibit the formation and propagation of cracks that can reduce the structural integrity of the road pavement [13]. The idea was based on the general concept that if hot mix asphalt (HMA) is strong in compression and weak in tension, then reinforcement could be used to provide needed resistance to tensile stresses [7,14,15].

Fibres have been reported to improve the performance of asphalt mixtures against permanent deformation and fatigue cracking [16]. There are some fibres that have high tensile strength relative to asphalt mixtures, thus it was found that such fibres have the potential to improve the cohesive and tensile strength of bituminous mixes. Principally, fibre changes the viscoelasticity of the modified asphalt [17], increases the dynamic modulus [18], moisture susceptibility [19], creep compliance, rutting resistance [20] and freeze–thaw resistance [21], while reducing the reflective cracking of asphalt mixtures and pavements [21–23]. Studies on stability, flow and volumetric properties of fibre reinforced bituminous concrete (FRBC) showed varied result. 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 [4,24–26]. In some cases the stability decreases and flow increases because large fibres reduce the contact point between the aggregates [27]. The fibre content and fibre length are important parameters with respect to the stability and volumetric properties. Studies on fibre content and length variations are limited moreover studies on the effect of binder content on fibre parameters are not common.

There are two methods cited in literature for the introduction of fibres: the wet and dry processes. The wet process blends the fibres with asphalt cement prior to incorporating the binder into the mixture. The dry process mixes the fibre with the aggregate before adding asphalt. Experimentally, the dry process is easier to perform and allows even distribution of fibre in the mixture. Abtahi et al. [28] reported that there is no difference in the Marshall properties between the dry and wet processes, when nylon fibres were used in fibre- reinforced asphalt mixture. Meanwhile, fibres used do not melt in the asphalt which means that there are no apparent special benefits to the wet process. Moreover, the field work done on fibre reinforced asphalt mixtures used the dry process [21,29,30].

3. Natural fibres

The introduction of natural fibres, from annual renewable resources, is now a popular occurrence or phenomenon in the reinforcement of polymer matrix. These provide benefits to the environment with respect to the degradability and utilisation of natural materials [31]. Plant-based natural fibres are lignocellulosic in nature and hence they are composed of cellulose, hemicelluloses, lignin, pectin and waxy substances. The structural composition and chemical structure of fibres are presented in Table 1 and Fig. 1 [32]. Fig. 2 shows a schematic structure of a natural fibre and Fig. 3 presents the model of the structural organisation of the three major structural constituents of the of the fibre cell wall [33]. Cellulose is considered the major framework component of the fibre structure. The advantages of natural lignocellulosic fibres over traditional reinforcing materials, such as: glass fibres, talc and mica are the acceptable specific strength and other mechanical properties, low cost, low density, non-abrasivity, good thermal properties, enhanced energy recovery and biodegradability. The main bottle necks in the broad use of these natural fibres in various polymer matrixes are the poor compatibility between the fibres and the matrix and the inherent high moisture absorption, which brings about dimensional changes in the lignocellulosic based

Table 1
Structural composition of natural fibres [34,35].

Name of the fibres	Cellulose (wt.%)	Lignin (wt.%)	Hemicellulose (wt.%)	Pectin (wt.%)	Wax (wt.%)	Micro-fibrillar/spiral angle (°)	Moisture content (wt.%)
Bast fibres							
Jute	61–71.5	12–13	13.6–20.4	0.2	0.5	8.0	12.6
Flax	71	2.2	18.6–20.6	2.3	1.7	10.0	10.0
Hemp	70.2–74.4	3.7–5.7	17.9–22.4	0.9	0.8	6.2	10.8
Ramie	68.6–76.2	0.6–0.7	13.1–16.7	1.9	0.3	7.5	8.0
Leaf fibres							
Sisal	67–78	8.0–11.0	10.0–14.2	10.0	2.0	20.0	11.0
Pineapple leaf fibre	70–82	5–12	–	–	–	14.0	11.8
Seed fibres							
Cotton	82.7	0.7–1.6	5.7	–	0.6	–	33–34

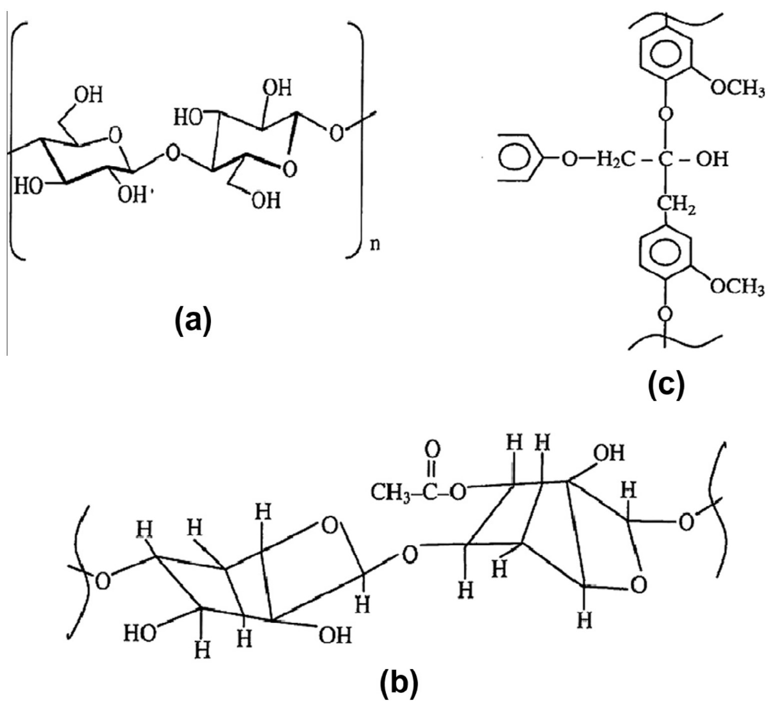

Fig. 1. Chemical structure of (a) cellulose (b) hemicelluloses and (c) lignin [37].

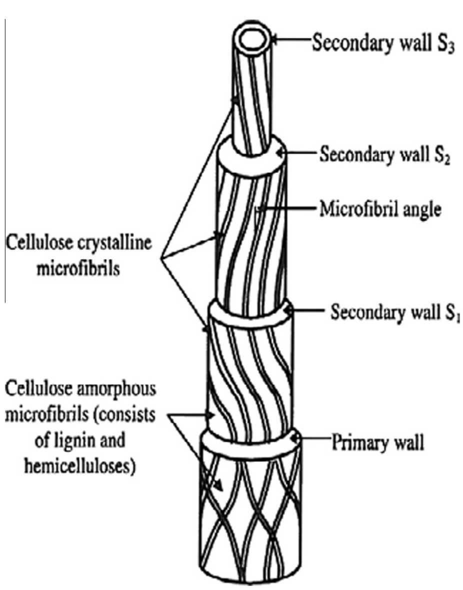

Fig. 2. Structure of natural fibre [50].

Fig. 3. Structural organisation of the three major constituents in the fibre cell wall [50].

fibres [36]. The efficiency of a fibre reinforced composite depends on the fibre/matrix interface and the ability to transfer stress from the matrix to the fibre. This stress transfer efficiency plays a dominant role in determining the mechanical properties of the composite.

The hydrophilicity of natural fibres results in high moisture absorption and weak adhesion to hydrophobic matrices. Natural fibres can be treated in order to improve their adhesion to matrix materials. Additionally, most natural fibres have low degradation temperatures (~200 °C), which make them incompatible with thermosets that have high curing temperatures. This also restricts natural fibre composites to relatively low temperature applications. There are several other challenges, such as: large variability

Table 2
Natural fibre properties [59].

Plant fibre	Tensile strength (MPa)	Young's modulus (GPa)	Specific modulus (GPa)	Failure strain (%)	Length of ultimate l (mm)	Diameter of ultimate (μm)	Aspect ratio, l/d	Microfilb, θ (°)	Density (kg m^{-3})	Moisture content (eq.) (%)
Cotton	300–700	6–10	4–6.5	6–8	20–64	11.5–17	2752	20–30	1550	8.5
Kapok	93.3	4	12.9	1.2	8–32	15–35	724	–	311–384	10.9
Bamboo	575	27	18	–	2.7	10–40	9259	–	1500	–
Flax	500–900	50–70	34–48	1.3–3.3	27–36	17.8–21.6	1258	5	1400–1500	12
Hemp	310–750	30–60	20–41	2–4	8.3–14	17–23	549	6.2	1400–1500	12
Jute	200–450	20–55	14–39	2–3	1.9–3.2	15.9–20.7	157	8.1	1300–1500	12
Kenaf	295–1191	22–60	–	–	2–61	17.7–21.9	119	–	1220–1400	17
Ramie	915	23	15	3.7	60–250	28.1–35	4639	–	1550	8.5
Abaca	12	41	–	3.4	4.6–5.2	17–21.4	257	–	1500	14
Banana	529–914	27–32	20–24	1–3	2–3.8	–	–	11–12	1300–1350	–
Pineapple	413–1627	60–82	42–57	0–1.6	–	20–80	–	6–14	1440–1560	–
Sisal	80–840	9–22	6–15	2–14	1.8–3.1	18.3–23.7	115	10–22	1300–1500	11
Coir	106–175	6	5.2	15–40	0.9–1.2	16.2–19.5	64	39–49	1150–1250	13

Table 3
Creep modulus of synthetic and natural fibres (51).

	Synthetic fibre (MPa)	Natural fibre (MPa)
Creep modulus at 3600 point at 40 °C	7.1	6.8
Creep modulus at 3600 point at 50 °C	6.7	6.2

of mechanical properties [38,39], lower ultimate strength [40], lower elongation [40], problems with nozzle flow in injection moulding machines [40], bubbles in the product [40] and poor resistance to weathering presented by natural fibres.

Various fibres such as oil palm fruit bunch fibre [41], jute [42], betelnut [43], coir [44] and hemp [45] have been tested as reinforcement in composites, for their many desirable properties when used as reinforcement in polymer composites [46].

3.1. Surface modification of natural fibre

The fibre–matrix interface is the diffusion or reaction zone, in which the fibre and matrix phases are, chemically and/or physically bonded. If there is a poor adhesion across the phase boundary, then relatively weak dispersion of force occurs, resulting in poor mechanical properties of the composites [47]. Reinforcement of natural fibres in composites poses challenges along the interface due to the presence of hydrophilic hydroxyl groups on the fibre surface. To affect the interfacial bonding between the fibre and matrix, the fibre needs to be modified with different chemical treatment, reactive additives and coupling agents. As a consequence of such treatment significant improvements in the mechanical properties of the composites are reported [48–50]. Table 2 summarises the mechanical properties of natural and man-made fibres.

4. Utilisation of natural fibres in bituminous mixes

4.1. Jute fibre

Jute plant has an erect stalk with leaves that thrives in hot and humid climate, especially in areas where there is a lot of rainfall. It can grow up to three metres in height and matures within four to six months. The fibre contains lignin and cellulose, including hemicellulose besides waxes, sugar, minerals etc. The advantage of jute material is its strength, excellent absorbency, environmental compatibility, biodegradability and annual renewability.

Kumar et al. [51] conducted a research on coated jute fibres as an alternative to synthetic fibres that used conventionally in the construction of stone matrix asphalt (SMA) in bituminous pavements. The results indicated that the natural jute fibre can replace synthetic fibres in SMA mixture. However, the permanent deformation is same for the fibres and the tensile strength ratio (97%) is more than the prescribed limits (70%). This indicates that both the mixtures have good adhesion. The creep modulus values estimated at 40 °C and 50 °C temperatures are shown in Table 3. The maximum creep modulus is obtained for SMA-synthetic fibre at both test temperatures. The creep modulus of SMA-natural fibre is 4% and 8% lower at 40 °C and 50 °C temperatures respectively. The low value of creep modulus indicates high permanent deformation and therefore, SMA with natural fibre has slightly lower resistance to permanent deformation. There is a reduction of 18% in construction cost per metric ton of the mix of the SMA with natural fibre than the mixes prepared with synthetic fibre (Table 4). Jute is also known to have good adhesion with asphalt as evident from the widespread application of asphalt-impregnated jute fabric. Hence, it appears reasonable to propose that asphalt overlay fabrics can also be manufactured from jute. A jute-based product may not last long enough when subjected to elements of nature, due its bio-degradability. To this end, investigations carried out by Banerjee and Ghosh [52] on the mechanical behaviour of jute in asphaltic medium, following hygral and enzyme treatments that simulate microbial attack, reveals that hygral treatment of a 6-month period is ineffective in damaging the jute–asphalt interface and the encased jute therefore, asphalt acts as protector for jute against microbial attack. Consequently, a 100% jute-based asphalt overlay fabric of moderate capability suitable for low traffic roads was developed and it is in situ performance within pavement in preventing reflective crack propagation under accelerated cyclic mechanical loading simulating traffic load was investigated. Additionally, its efficacy to retard crack propagation after hygral loading, was also evaluated by employing similar accelerated cyclic mechanical loading tests.

Table 4
Cost comparison (51).

	Synthetic fibre	Natural fibre
Total cost of asphalt @Rs. 11/kg in 1 mT of mix	666.5	605
Cost of 4.5 kg synthetic fibre in 1 mT of the mix including the preparation of fibre @ Rs. 90/kg	405	–
Cost of 9.0 kg natural fibre in 1 mT of the mix including the preparation of fibre @ Rs. 30/kg	–	270
Total cost per mT of mix	1070.5	875

1 USD = 45 Indian Rupees (Rs.).

Table 5
Result of drain down test (53, 58).

Fibre	Fibre content (%)	Drain value (%) (53)		Drain value (%) (58) $T = 180$ °C
		$T = 165$ °C	$T = 180$ °C	
Without fibre	0.0	1.06	0.70	0.42
Coconut fibre	0.3	–	–	
0.08	0.25	0.18		
	0.5		0.03	
	0.7	0.04	0.09	
Cellulose	0.3	0.01	0.03	0.11
	0.5	0.01	0.02	0.07
Polyester	0.3		0.21	
	0.5		0.03	
Sisal	0.3		0.21	
	0.5		0.05	

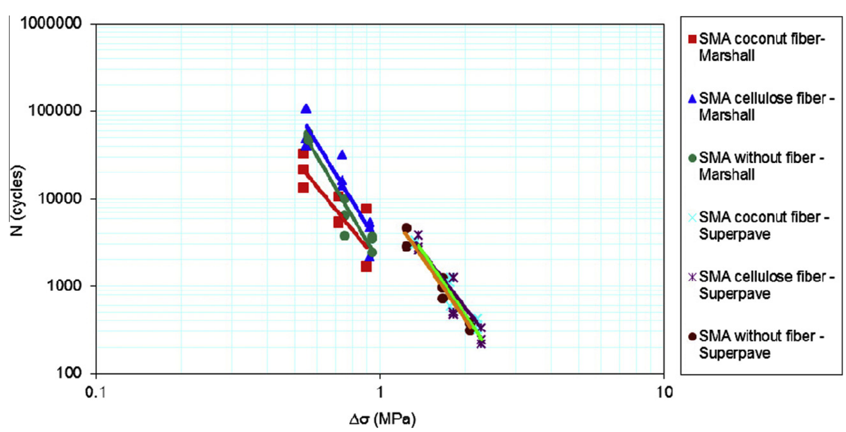

Fig. 4. Fatigue life the SMA mixtures at 25 °C (53).

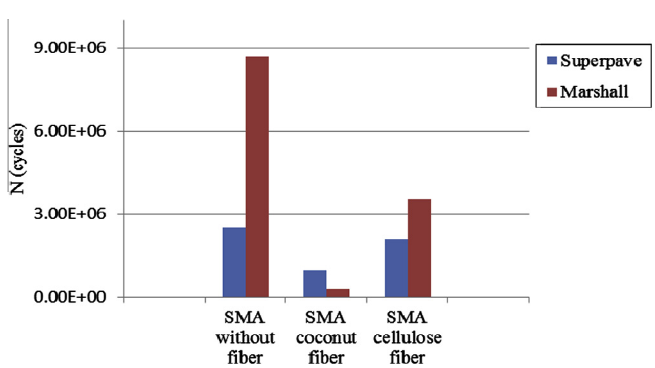

Fig. 5. Results of analysis of fatigue test (53).

4.2. Coconut or coir fibres

Coconut fibre or coir is a product which is extracted from the outer shell of the coconut fruit. Coir fibre is 100% natural and originates in the husk of coconuts; it comes from part of the seedpod of the coconut palm. There are two different types of coconut fibre: white coir and brown coir. White coconut fibre comes from young coconuts, while brown coconut fibre comes from more matured specimens. In matured coconuts, a layer of lignin is deposited in the cellulose walls of the fibre, causing it to darken in appearance. Matured coir fibres contain more lignin, a complex woody chemical and less cellulose than fibres such as flax or cotton. This makes coir stronger and less flexible. Coir fibre is relatively water-proof and is the only natural fibre resistant to damage by salt water.

Do Vale et al. [53] investigated the behaviour of natural fibres (coconut fibres) on SMA mixtures using two different methods (Marshall and super pave). The specimens were tested using several common laboratory test procedures: drain down test, indirect tensile strength, resilient modulus, fatigue life and moisture susceptibility. The drain-down test results clearly suggested that coconut fibre can be used in SMA mixtures as a replacement for cellulose staple fibre in order to prevent drain-down during production (Table 5). Figs. 4 and 5 show SMA mixtures with coconut fibres presented a lower fatigue life than other SMA mixtures. Apparently, the addition of coconut fibre did not improve the cracking resistance of the SMA mixtures; in fact, for coconut fibre

Table 6
Mechanical analysis of mixtures evaluated (58).

Mixtures SMA	Modulus resilient (MPa)	Tensile strength (MPa)
CAPFLEX B without fibre	3.077	1.1
AC 50-70 without fibre	7.306	0.9
AC 50-70 with cellulose fibre	6.417	1.1
AC 50-70 with coconut fibre	7.948	1.1
AC 50-70 with sisal fibre	7.193	1.0
AC 50-70 with polyester	5.629	0.8

Table 7
Fatigue models of SMA mixtures with different types of fibres (58).

Types of fibres	Fatigue models
Without fibre	$N = 13{,}565.0(1/\Delta\delta)^{2.4406}$
	$N = 1.71 \times 10^{-7}(1/\varepsilon)^{2.4406}$
Cellulose	$N = 3448.3(1/\Delta\delta)^{2.0609}$
	$N = 2.82 \times 10^{-6}(1/\varepsilon)^{2.0609}$
Coconut	$N = 4424.5(1/\Delta\delta)^{3.029}$
	$N = 1.02 \times 10^{-8}(1/\varepsilon)^{3.0294}$
Sisal	$N = 3243.2(1/\Delta\delta)^{3.0603}$
	$N = 7.33 \times 10^{-11}(1/\varepsilon)^{3.0603}$
Polyester	$N = 5292.0(1/\Delta\delta)^{2.3773}$
	$N = 2.12 \times 10^{-7}(1/\varepsilon)^{2.3773}$

the numbers of cycles to failure were consistently lower than SMA mixtures with cellulose. They also recommended the use of natural fibres as good substitutes for synthetic fibres, due to their lower cost, ecological recycling and low specific gravity.

Coir fibre was reported to have improved fatigue life of bituminous mixes [54]. Thulasirajan and Narasimha [55] presented a study on stability, flow and volumetric properties of the coir fibre-reinforced bituminous concrete by varying the binder content, fibre content and fibre length. The results indicated that the addition of coir increased the stability and voids with decrease in the flow rate. Fibre length of 15 mm with a fibre content of 0.52% and a binder content of 5.72% provided good stability and volumetric properties. It can be said that coir fibre has the potential to improve the structural resistance to distress occurring in flexible pavement due to traffic loads.

4.3. Sisal fibres

Sisal fibre is one of the most widely used natural fibres and is very easily cultivated. Nearly 4.5 million tons of sisal fibres are produced every year throughout the world. Tanzania and Brazil are the two main producing countries [56]. Sisal fibre is a hard fibre extracted from leaves of the sisal plant. A sisal plant produces between 200 and 250 leaves and each leaf contains between 1000 and 1200 fibre bundles, which are composed of: 4% fibre, 0.75% cuticle, 8% dry matter and 87.25% water [57]. Therefore, a leaf which weighs about 600 g will yield about 3% by weight of fibre with each leaf containing ~1000 fibres. The advantages of sisal fibres are: they have good resistance against moist, heat and short fibres delay restrained plastic shrinkage thereby controlling crack development at early ages. In developing countries, sisal fibres are used as reinforcement in houses.

Oda et al. [58] evaluated the use of asphalt rubber binder and natural fibres (sisal and coconut) in discontinuous stone asphalt mixture (d-SMA). Comparison was done between the performances with: (i) mixture without fibres, (ii) polyester fibres and (iii) cellulose. The results of the mechanical tests (tensile strength and modulus of resilience, see Table 6) demonstrated that blends with natural fibres showed high resistance, while preventing the asphalt drain down (Table 5). The result of fatigue analysis showed that the mixture with an asphalt modified rubber (CAPFLEX B, without fibre) had the best behaviour and the results obtained with cellulose fibres, sisal and coconut shells were not significantly different (Table 7).

4.4. Hemp fibre

Hemp fibre is obtained from the bast of the plant *Cannabis sativa L.* It grows easily to a height of 4 m without agrochemicals and captures large quantities of carbon. Optimum yield of hemp fibre is more than 2 tonnes per hectares, while average yields are around 650 kg [59]. Long, strong and durable, hemp fibres are about 70% cellulose and contain low levels of lignin (around 8–10%). Hemp fibre conducts heat, dyes very well, resists mildew, blocks ultraviolet light and has natural anti-bacterial properties. Hemp fibres are also used to reinforce moulded thermoplastics in the automobile industry. The short core fibres go into insulation products, fibre board and erosion control mats, while the fibrous core can be blended with lime to make strong lightweight concrete.

Delgado and Arnaud [60] investigated the potential use of hemp fibres as reinforcement for asphalt paving materials. Four different lengths of fibre and three different proportions were investigated in order to assess the influence of fibre content and length on the fatigue behaviour of the composite. The results indicated that there is a reduction in the complex modulus and phase angle (damping) of the fibre-modified asphalt mixtures in comparison with the control. Fatigue life was improved for fibre-modified asphalt mixtures with fibres of 5 cm length and percentage of 0.4%.

5. Discussion

The use of fibres provides a need for improving the tensile strength and flexibility of the bituminous mixtures as pavement experiences higher volume of traffic and increase in loads, especially coming from heavy vehicles. These cause plastic and visco-elastic deformations in the mixture, thus resulting in rutting formations and progressive propagation of cracks. Different researchers have reported the results emanating from the addition of a large variety of fibres to asphalt concrete. Reinforcement with natural fibres has been shown to possess certain advantages over, such as: their ease availability, low density, acceptable specific properties enhanced energy recovery and biodegradability other fibres. The main drawbacks in the use of natural fibres in various polymer matrixes are the poor compatibility between the fibres and the matrix and the inherent high moisture absorption, which brings about dimensional changes in the lignocellulosic-based fibres. Therefore, chemical treatments are considered in modifying the fibre surface. Some compounds such as: sodium hydroxide, silane, and acetic acid maleated coupling agents peroxide have shown to promote adhesion to the material. Most of the chemical treatments achieved various levels of success in improving fibre strength, fibre fitness and fibre adhesion in natural fibre reinforced asphalt composites.

Efforts at improving the properties of the fibres have made researchers to focus on the study of effect on mechanical properties due to hybridization of natural fibres with synthetic fibres. Owing to high initial cost, adverse effects on the environment and the requirement for a large quantum of energy to produce synthetic fibres, researchers started exploring natural fibre-based hybrid composites. There is little or no work reported on the possibility of two or more natural fibre based hybrid composites in asphalt reinforcement.

Modification of bituminous mixes is expected to enhance the material strength, fatigue characteristics and at the same time, exhibit excellent mechanical properties and increase the ductility of the composite. Various studies on the use of natural fibres have been on SMA, which is a gap-graded mixes, while little or no work has been reported on dense-graded mixes. Fibres are used in SMA mixes to act as a stabilizer thereby preventing the draining down of the asphalt binder [61]. Different researchers have reported the results of the addition of a large variety of fibres to bituminous mixes. The result shows that fibre improves the fatigue life by increasing the resistance to cracking and permanent deformation. The fibre reinforcement thus provided additional tensile integrity in the mixes and hence increasing the strain energy absorption thereby inhibiting the formation and propagation of cracks.

Researchers on natural fibres agreed that uniform distribution, fibre length, percentage and orientation are the keys to mixture performance. In order to understand the mechanical properties of fibre reinforced bituminous mixes, it is recommended that the orientation of fibres through the mixes should be examined with the aid of optical and/or scanning electron microscopy.

6. Research works for the future

Understanding the reinforcing mechanisms as well as ways of optimising fibre properties, performance enhancement of bituminous mixes reinforced by these fibres is still marginal, hence further studies on the fibre reinforced bituminous mixes needs to be fully investigated.

Modification of dense graded asphalt with natural fibres and the hybridization of two or more fibres need to be studied and the fracture mechanism associated with road/pavement failure. Hybridization should aim to optimally combine the natural fibres that are cost-effective and of high performance.

Based on the above discussion, it is apparent that the fibre content, length variations and effect of binder content on fibre parameter should be a major research focus in the use of fibres composites in asphalt concrete. In addition, further work is needed to optimise the size, length, shape and orientation of fibres. Field performance of fibre modified asphalt concrete is also needed to determine the boundary effects on test results. Modelling of the mechanical properties of fibre reinforced asphalt concrete mixtures, using composite science principles, can be considered as a new research field [62].

7. Conclusion

This paper reviewed the concept of utilisation of natural fibres and its composites in asphalt concrete modification. Natural (coir, sisal, hemp, jute, palm, flax) and synthetic (PP, PE, nylon, glass, and steel) fibres that have been used to modify asphalt concrete are reviewed. Emphasis was laid on the use of natural fibres, such as: jute, sisal, coir and hemp in improving the mechanical properties of bituminous mixture. Most of the literature cited above show that natural fibres can replace synthetic fibres in SMA mixtures as there is a good adhesion of the fibre with asphalt. It is also reported that reinforcement with natural fibres, provides an improvement in the fatigue life, increases the stability and that it has the potential to improve structural resistance to distress occurring in flexible pavement, due to traffic loads. Finally, it is recommended that future studies be carried out on the application of natural fibres in modifying dense graded asphalt.

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