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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