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Artículo de Investigación

Polymeter fibers and natural fibers for vehicular pavement structures in Perú

Fibras polimétricas y fibras naturales para estructuras de pavimento vehicular en el Perú

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Abstract:
Introduction: Polymeter fibers and natural fibers for vehicular pavement structures in Peru. The objective of this systematic review was to analyze technical information on polymer fibers and natural fibers for vehicular pavement structures in Peru. The applied methodology had a qualitative bibliographic approach, whose design was framed in the literature review and documentary analysis of fifty scientific productions, published in journals indexed to the databases: Scopus, and scielo. The main results indicate that natural fibers and polymer are a good option for reinforcing flexible pavements, since good results were obtained in the tests carried out.

Keywords: fibers; polymer; natural; vehicle; Perú; biodegradability, low cost, lower density.

Resumen:
Introducción: Fibras polimétricas y fibras naturales para estructuras de pavimentos vehiculares en el Perú. El objetivo de esta revisión sistemática fue analizar información técnica sobre fibras poliméricas y fibras naturales para estructuras de pavimentos vehiculares en el

Perú. La metodología aplicada tuvo un enfoque bibliográfico cualitativo, cuyo diseño se enmarcó en la revisión bibliográfica y análisis documental de cincuenta producciones científicas, publicadas en revistas indexadas a las bases de datos: Scopus y scielo. Los principales resultados indican que las fibras naturales y el polímero son una buena opción para reforzar pavimentos flexibles, ya que se obtuvieron buenos resultados en los ensayos realizados.

Palabras clave: fibras; polímero; natural; vehículo; Perú; biodegradabilidad, bajo costo, menor densidad.

1. Introduction

La Worldwide, in the case of Canada, the practice of using polymer fiber materials for external reinforcement of concrete elements has not been sufficiently developed. These composite materials have been used to reinforce concrete elements in buildings, however, they have never been used to reinforce concrete elements in bridges.

The reason for such a delay appears to be linked to the lack of knowledge on the part of bridge engineers about the properties and behavior of the material, because it is not clear what its advantages and disadvantages are and because there is a perception that its high cost detracts from competitiveness (Vogele *et al*., 2020). Among the cutting-edge technologies for the structural reinforcement of concrete elements of bridges for cars, is the use of Fiber Reinforced Polymers, as it is known in the Anglo-Saxon world. The use of these composite materials is an alternative commonly used in developed countries such as the USA, Japan, Canada and Europe where they have been used not only as external reinforcement. On the other hand, the growing sensitivity towards environmental pollution and recent environmental protection laws have led to increasing attention to the so-called biocomposites, that is, ecological or renewable composite materials, obtained from biopolymers reinforced with natural fibers (Zuccarello & Zingales, 2017) . In recent decades, researchers encountered many difficulties in providing environmental supporting materials for product manufacturing. Natural fibers possess many advantages over synthetic fibers such as ease of availability, biodegradability, low cost, lower density, minimal health risks and eco-friendly in nature. Natural fiber reinforced polymeric composites are the new innovative class of sustainable materials that have good mechanical properties for practical applications (Kicińska *et al*., 2012). Furthermore, today's aerospace and automotive industries are seeking to change conventional materials, which are high-density materials, to composite materials to reduce the overall weight of the vehicle and increase its performance (Verma & Senal, 2019; Karthi *et al*., 2019). Typically, other factors, such as the age, maturity, location and processing methods of the fiber, along with the source of the fiber, also influence the tensile strength of the fiber.

In Peru, the deterioration observed in slabs, beams, columns, beam-column joints, piers, bastions of many bridges in our country is attributed to aging, degradation due to environmental factors, lack of maintenance and/or effect of natural events such as earthquakes. This deterioration combined with an increase in vehicular traffic; that exceeds the design load of the bridge, has accelerated the damage to these structures to such an extent that the useful life of many bridges in the country has been reduced. This panorama makes us meditate on the need to look for reinforcement solutions that are easy and quick to apply. On the other hand, natural fibers make it a vital component in national engineering applications in Peru. Natural fibers meet the needs of humans and the manufacturing industry with their positive environmental effect and economic prospects (SathishKumar *et al*., 2019; Bajwa & Bhattacharjee, 2016). Natural fibers, which are an important part of the human environment, are also valuable raw materials used for textile and non-textile production. The diversity of shapes and forms of natural fibers is due to their presence in different climatic zones. The abundance of fiber sources arouses interest and provides the opportunity to conduct more comprehensive studies and then find new applications for fibers in industry (Kicińska *et al*., 2012). The addition of materials made from natural fibers promises to be profitable in the recent past, particularly where agricultural waste was considered. Natural fibers from agricultural waste residues, such as rice husk, banana, and coconut fiber, are dominant in the literature for industrial applications in the polymeric composites community (Motaung *et al*., 2017). Also natural fibers such as jute and sisal have been used for years in various applications, such as ropes, building materials, particle boards, etc. The absence of essential information in the preparation of materials reinforced with natural fibers remains a challenge for future applications. Chemical treatments and surface modifications can improve the quality of natural fibers (Khalid *et al*., 2021).

The objective of this article is to analyze technical information about polymer fibers and natural fibers for vehicular pavement structures in Perú.

1.1. Natural fibers reinforced with polymers

Originally, composite materials only used synthetic fibers due to their relative low cost and good mechanical properties, with glass fibers and carbon fibers being the most used by the automotive industry (Jariwala & Jain, 2019). On the contrary, there is a considerable amount of polymers used as matrix in composite materials intended for automotive applications (Chaudhary & Ahmad, 2020). Polymers such as polyester, phenolic, epoxy, vinyl ester resins, polyethylene, polyurethane, polylactic acid and polypropylene are some of the widely used polymers, with polypropylene being one of the most used in the automotive industry Vigneshwaran *et al*., 2020).

1.2. Properties of polymeters with natural fibers

A comparative study was recently reported on the mechanical and damping properties of thermoplastic (polypropylene), thermoset (epoxy) composites and biodegradable polylactic acid (PLA) composites reinforced with flax fiber at 40% fibers in all cases, compared to carbon and glass fiber reinforced epoxy compounds. In the study, a better relationship between stiffness and cushioning was reported with semicrystalline PLA reinforced with flax fiber. At room temperature, the damping properties are better in composites reinforced with flax fiber, compared to those reinforced with glass fiber and carbon fiber [13]. The improvement of the mechanical and thermal properties of polymeric composite materials reinforced with natural fiber depends on the following factors [5]: Type of fiber, Type of matrix, Type of fillers (if used), Percentage of fibers in composite materials, Aspect ratio and fiber orientation, Fiber shape (cylindrical, spherical, rectangular cross-section prisms or platelets), Manufacturing methods/techniques.

1.3. Comparison of natural fibers and the polymeter

Natural fibers have the disadvantage of absorbing moisture in considerable quantities. The increase in humidity on the surface of the fibers further leads to the decrease in mechanical properties which results in the loss of dimensional stability and leads to biodegradation. This significantly reduces the potential application of natural fibers for polymer-based composite materials, since the adhesion at the interface is not suitable for its development. Fortunately, there are various surface modification techniques applicable with the purpose of making them more suitable for their final application (Koronis & Silva, 2018). These techniques are divided into 2: Physical type surface modification, Chemical type surface modification.

The physical techniques or methods mainly involve the separation of natural fibers into individual filaments, as well as modifying the surface structure of the fibers in order to improve their final application. Some examples of physical methods for the functionalization of natural fibers are related to the use of plasma, ultrasound and ultraviolet light. Alternatively, natural fibers can also be modified with various chemical agents capable of significantly improving the mechanical properties of the fibers by modifying their crystalline structure and eliminating weak components such as hemicellulose and lignin from the fiber structure (Cruz & Fangueiro, 2016).

1.4. Process of obtaining the polymeter with natural fibers

There are various methods or techniques for obtaining or manufacturing composite materials based on polymers reinforced with natural fibers. Some methods such as extrusion, injection molding, compression molding and resin transfer molding are some of the most commonly used methods. Parameters such as residence time, molding temperature, pressure and compression time remain complex parameters to consider, but they have a significant impact on the final mechanical properties of the material. The method of obtaining it by extrusion, for example, is one where the polymer is melted, mixing the fibers into the polymer. Material extrusion techniques are usually relatively simple, which is why they are the most used (Zindani & Kumar, 2019). For extruding short fibers, almost no modifications are required, while only some modifications related to the extrusion head are required in case the fibers are long (Zindani & Kumar, 2019). Injection molding can be performed with thermoset or thermoplastic dies, although it is often used for thermoplastic dies. During the incorporation of the fibers by this method, the fibers usually align in the direction of the injection flow. The most notable limitation is usually the low processing temperature due to the low thermal stability of natural fibers, the processing temperature should not be higher than 150 °C for long processing time and 220 °C for short exposures. Exceeding these temperatures would produce thermal decomposition (Zhang *et al*., 2020) The compression molding method tends to be the most common option for bulky materials that are typically used for thermoplastic or thermoset matrices reinforced with long or short, oriented or even random fibers. Using this method, almost 70% by weight of fibers can be incorporated, capable of achieving thicknesses between 1 mm and 10 mm (Lotfi *et al*., 2019). Lastly, resin transfer molding is performed by injecting liquid resin into a mold containing a preform. The main variables of this method are usually injection pressure, temperature, resin viscosity and mold configuration (Salit *et al.,* 2015).

1.5. Mechanical vehicular tests

Vehicle tests are destructive tests in which materials are subjected to different types of stress by applying external force to the material until its breaking or deformation point. Based on this, different properties can be determined due to its mechanical behavior. One of the most used tests is the tensile test, in which the material's ability to resist rupture is measured (Navaneethakrishnan, 2020). There are also bending tests or tests whose goal is the same as that of the tension test, only in this case an external force is applied directly to the material until it deforms (Lee *et al*., 23017). On the other hand, there are impact tests, in which the amount of energy that the material is capable of absorbing in the face of a shock load is determined (Cavalcanti *et al*., 2019). While compression tests measure the resistance and ability of a material to withstand loads that usually reduce its size (Tadasse *et al*., 2018).

There are even more techniques for mechanical testing such as those dedicated to measuring penetration and hardness, as well as cutting and shear tests, most of which are subject to following the procedures set by the ASTM standards established by the American Society for

Testing and Materials for its acronym in English (American Society for Testing and Materials or ASTM International).

1.6. Materials and methods

The study was in a methodology applied in a narrative approach adopted in a literature review on job satisfaction from the perspective of the public sector. A literature review is an organized summary that presents the findings of various main studies, focused on addressing the research questions after collecting, selecting and critically analyzing sources of information (Moreno *et al*., 2018). In this context, the study adopted a qualitative approach based on systematic literature review and document analysis, focusing on theses and scientific articles that address job satisfaction in the public sector.

In documentary research I use a variety of methods and tools as means to collect information, which facilitates the ability to deduce, understand, and thoroughly describe a research phenomenon (Sánchez *et al*., 2021).

Furthermore, in the selection of sources and databases: it focused on scientific publications covering the period between 2020-2024, found in journals indexed in databases such as Scielo, Scopus and bibliographic materials. The review used 50 indexed articles.

In addition, it consisted of 3 selection criteria for the inclusion of the research study: a) that the scientific articles have been published in the last 5 years b) that they are indexed in the aforementioned databases c) that they are written in English or Spanish. In addition, one hundred articles were examined, finally selecting ten articles that were the central focus of this literature review.

In the volume of publications made, articles and bibliographic materials have been consulted, addressing the specific objectives. However, for the purpose of showing the different scientific articles in the database, the objective is presented: to analyze technical information about polymer fibers and natural fibers for vehicular pavement structures in Perú.

Table 1.
Year of publication of scientific articles

Database	Year of publication					Total
	2020	2021	2022	2023	2024	
Scopus	25	2	1	1	1	30
Scielo	6	0	4	5	5	20
Total	31	2	5	6	6	50

Source: Own elaboration (2024).

Table 2.
Selection of scientific articles

Database	Year	Search	Number of documents	Search area	Filter result	Chosen articles
		Asphalt pavement with fibers	679	Engineering	565	10
		Fiber performance with asphalt	684	Engineering	628	3
Scopus	2020-	Flexible	137	Engineering	116	13

	2024	pavement fiber				
		Asphalt with natural fiber	115	Engineering	101	2
		Asphalt mix with natural fibers	50	Engineering	44	2
Scielo	2020-2024	Asphalt with fibers	416	Engineering	153	10
		Natural asphalt with fibers	20	Engineering	10	10
Total						50

Source: Own elaboration (2024).

2. Results and Discussion

This article gathered information from different studies comparing results and criteria of the various authors, with the aim of classifying them, producing an exchange of criteria on the use of different types of polymer and natural fibers that improve the mechanical characteristics of asphalt mixtures.

2.1. Polymeter fibers

Kassem and collaborators stated that there are many synthetic fibers used in asphalt mixtures, within the different types used, polymeter fibers have a positive effect on the performance of the asphalt mixture when used in mixtures with a maximum aggregate size large nominal (Kassem *et al.*, 2018). Furthermore, Bueno and Poulikakos (2020) studied not only the use of polymer (type A), but also polymer fibers (type B), demonstrating the suitability of their use in asphalt mixtures, by showing positive effects greater than that of a ordinary mix.

Kamaruddin and collaborators mentioned that synthetic fibers are used in order to act as modifiers of asphalt mixtures, presenting as possible modifiers they used two types of polymeric fibers (polypropylene fiber), which demonstrated a positive effect when added to the mixtures, favoring the reduction of moisture damage (Kamaruddin *et al.*, 2016). Likewise, Morova and collaborators improved the same characteristic using polyparaphenylene terephthalamide polymeric fiber under an optimal content of 0.25% (Morova *et al.*, 2016). Furthermore, Wang and collaborators showed that another possible synthetic modifier to use is polymer fiber, because it substantially improved the mechanical properties, compared to ordinary mixtures (Wang *et al.*, 2021).

2.2. Natural fibers

[31] investigated the use of fibers collected from banana stem and the waste part of mature coconut, showing that their use provides better ability to resist rutting and cracking. In a complementary manner, in their research Colares and collaborators investigated the incorporation of coconut fibers in discontinuous asphalt mixtures, generating satisfactory characteristics in susceptibility to humidity and tensile strength (Colares do Vale *et al.*, 2014).
On the other hand, Aljubory and collaborators investigated the use of palm fibers in asphalt mixtures, which improve indirect tensile strength by increasing the fiber content from 0% to 1% (Aljubory *et al.*, 2020). Property that Kar and collaborators also investigated, and concluded

that it is improved by adding 0.3% sisal fiber, but in a mixture with fly ash as filler (Kar *et al*., 2019). Pirmohammad and collaborators demonstrated that the improvement of fracture resistance is also present, studying the addition of kenaf fibers and goat wool, they showed that fracture resistance is improved depending on the length and content of fiber used (Pirmohammad *et al*., 2020). Additionally, Kara De Maeijer and collaborators in their research showed that another characteristic to optimize with the use of natural fibers is the drainage of asphalt cement, which is reduced by adding natural peat fiber in a controlled manner in order to avoid difficulties in the compaction of these mixtures (Kara De Maeijer *et al*., 2019).

2.3. Percentages of polymer and natural fibers

Ziari and collaborators used polymer-aramid fibers as additives in percentages of 0.025%, 0.05% and 0.075% in relation to the weight of the mixture, recommending the use of 0.075% fibers when problems with grooves or cracks occur and 0.05% fibers to improve fatigue resistance (Ziari *et al*., 2020). While Alnadish *et al.* (2019) analyzed only aramid fibers in proportions of 0.05; 0.1; 0.2 and 0.3% in relation to the total weight of aggregate, with the first evaluated percentage of 0.05% standing out, because the useful life increased under this proportion.

On the other hand, Chen and collaborators investigated the use of corn stalk fibers within the use of natural fibers, which were used in percentages of 0%, 2%, 4%, 6%, 8% and 10% in relation to the weight of the asphalt cement, positively influencing the low temperature behavior of the asphalt cement under the addition of 2% fibers (Chen *et al*., 2019).Likewise, Li and collaborators investigated sugarcane bagasse fibers which, used at a percentage of 0.2% in relation to the total weight of the mixture, showed that high temperature stability and resistance to cracking were greatly improved at low temperature of asphalt mixtures (Li *et al*., 2020).

3. Conclussions

Finalmente Through the literary review of the research found by different authors on the improvement of the mechanical properties of asphalt mixtures with the addition of fibers, the following conclusions have been reached:

It was concluded that within the different types of natural fibers and polymer used in asphalt mixtures, the use of different types of natural fibers was presented in an effort to improve the different characteristics of the mixtures.

Fibers are a good option for reinforcing flexible pavements, since in tests carried out such as: Marshall, indirect traction, cone penetration, wheel tracking test, good results were obtained. Regarding the optimal percentage of fibers that was needed to improve the properties of the asphalt mixtures, these vary depending on the type of fiber, shape, size and how they are added to the mixtures, since depending on the research it can be added by replacing it in percentage or weight, of the fine aggregate, coarse aggregate, of the asphalt cement, components of the asphalt mixture.

By adding different types of fibers to asphalt mixtures, different properties were improved such as: susceptibility to humidity, fatigue resistance, resistance to deformation, tensile strength, high temperature stability, resistance to cracking. Being the resistance to the formation of ruts the property that stood out the most in the different investigations. But not all the fibers used achieved the objective of positively modifying the properties of the pavement; some affected the bond between the aggregates and the asphalt cement, reducing the useful life of the pavement.

Based on the bibliographic review carried out, it is recommended to continue with studies aimed at using fibers in the manufacture of asphalt mixtures due to the improvements it provides.

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