Study of the Literature on Using Natural Rubber and Crumb Rubber as Modified Materials in Hot Asphalt Mixtures

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Abstract. Waste is widely used in road construction, including the use of waste materials or natural materials. Crumb rubber is a waste product that comes from unused car tires and can pollute the environment if not treated properly. Using scrap tires (crumb rubber) in combination with asphalt is one technique to get around this problem. There is still a lack of information about crumb rubber and solid natural rubber in paving roads. This paper will follow the rubber asphalt research conducted and produce a map to identify research areas that have not been further investigated. According to the search results, much research has been done on the usage of crumb rubber, but little has been done on solid natural rubber. The utilization of a blend of natural rubber and crumb rubber is the suggested study topic that more researchers could pursue.

Keyword: Natural Rubber, Crumb Rubber, Hot Asphalt Mixtures

1. Introduction

About 70% of the rubber produced worldwide is used for tires. About 800 million used tires are disposed of each year around the world. Even though there are numerous approaches to treating used tires, the most popular one results in a stock of scraps: disposal in a landfill. These stockpiles pose a fire hazard and create an atmosphere that provides a breeding ground for mice, insects and other pests, posing health and environmental risks. Numerous nations restrict the disposal of used tires in landfills. As a result, numerous nations are conducting extensive research on tire recycling and repurposing [1]. However, recycling—which encompasses all processes where rubber waste is transformed into new goods like pavement technology—is the best way to dispose of rubber waste.

Hot mix asphalt is a type of road infrastructure commonly used in many countries because it provides long-term performance and good ride quality [2]. Flexible hot mix asphalt (HMA) pavements use an asphalt cement composed of saturated aromatics, resins, and asphaltenes (SARA) that either occur in naturally occurring oil sands or are vacuum distilled from crude oil [3]. Hot mix asphalt produced with asphalt concrete is believed to be able to support weight and reduce the damage that occurs. Numerous factors can damage asphalt pavements, including traffic volume, the way the material is used, and the environment. These factors

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affect the age and condition of the pavement. Traffic volume is one characteristic that significantly affects pavement performance and makes it more difficult to maintain the pavement's service life [4].

It is possible to modify the asphalt in the form of polymer asphalt to ensure the pavement properties of the asphalt mixture under this influence. Some other forms of polymers such as styrene-isoprene-styrene (SIS), styrene-ethylene-butadiene-styrene (SEBS), crumb rubber and natural rubber have also been used as modifiers. The benefits of polymer-modified bitumen have been extensively studied and grown over the years. The use of polymer-modified bitumen can significantly extend the life of pavements. The addition of various polymers can improve the stiffness, cohesion and elasticity of the bitumen. For example, it becomes stiffer at higher temperatures while exhibiting flexible properties at lower temperatures. A polymer can improve the elasticity and flexibility of the asphalt mixture, which ultimately increases its resistance to heat cracking and fatigue.

2. Literature review method

The sample was selected in four steps: Database selection, preliminary search, sample selection, and sample refinement after identifying the most linked articles. The initial search of the database using the keywords asphalt, rubber, and pavement found related results. By reading the title and abstract, all non-relevant studies were removed from the initial search for the sample [5].

3. Characteristics of crumb rubber

To limit the amount of scrap tire waste, scrap tire material is processed into pieces or powder and mixed with asphalt to make a type of rubber called "crumb rubber" [6]. Scrap tires are used to produce crumb rubber particles ranging in size from 4.75 mm to 0.075 mm for road pavement construction. The crushed tire particles are mechanically ground to different diameters in the surrounding area. To achieve good resistance, crumb rubber is mainly composed of 48% vulcanized natural rubber, 22% carbon black and silica, 15% metal reinforcements, and 5% fibers [7]. Crumb rubber, a recycled material made from End-of-Life Tires (ELTs), has recently gained popularity. As a result, several studies have been conducted in an effort to improve the material cycle where rubber, produced as a byproduct of the crushing and sieving of scrap tires, becomes the resource required in another production process for building the layers of road pavement. Applications for crumb rubber in creating asphalt mixtures are varied [8]. Physically, crumb rubber particles are porous, have an uneven form, and have a rough surface. Crumb rubber can absorb oil and resin from the asphalt through the pores of the particles, forming a strong bond [9]. Crumb rubber, made from used tire rubber in the asphalt matrix, has been crucial in improving the flexibility and heat resistance of the material. The microstructure of crumb rubber particles, namely their swelling in the asphalt, might influence how effectively modified asphalt performs. Some crumb rubber particles operate as flexible fillers while others absorb light components of asphalt or dissolve the primary components into the asphalt. It can have outstanding aging resistance performance because of the interaction between crumb rubber particles and the asphalt matrix, and crumb rubber has been chosen as a modifier to increase its anti-aging capabilities. Asphalt treated with crumb rubber may therefore be utilized in hot recycling [12].

4. Characteristics of natural rubber

Due to its excellent elasticity, flexibility, and temperature tolerance, rubber is a natural polymer that can be employed in combinations with asphalt [10]. Hevea brasiliensis trees account for almost 99% of all global natural rubber (NR). To prevent it from leaking to other areas of the tree. There are primarily two different approaches to gathering NR. The first involves keeping latex liquid by adding some ammonia and then forming the rubber into soft slabs. The second consists of gathering latex in a hard shape by allowing it to coagulate on its own or adding formic acid to accelerate latex conversion to cup lump natural rubber. Hevea brasiliensis, on the other hand, has the chemical formula C5H8 and is practically pure poly-cis-1,4 isoprene, consisting of 99.9% cis-1,4 structural units. Its particles range in size from 0.15 to 3 mm [5]. Additionally, natural rubber has a long chain molecule and double bonds that are difficult to break, so its physical qualities can be elastic. The natural rubber has the shape of a chain of bonds in the form of a spiral that has the same nature as a spring, giving it a flexible nature. The modified binder's properties, particularly those related to stability during storage and transportation, are significantly impacted by the interaction between asphalt and natural rubber. The physical and chemical properties of the material, which affect the properties of the asphalt, determine the stability or phase properties of polymer-modified bitumen. Asphalt acts as a swelling agent on natural rubber. Degradation and rubber evolution (physical diffusion process) are the two basic phases of contact (a chemical process in which new substances are formed) [11].

5. Tracking hot mix asphalt study using natural rubber and crumb rubber

In 2019 to 2021, many studies were conducted on rubber asphalt. The types of rubber that past researchers employed to enhance the qualities of asphalt mixtures include:

- To preserve the rubber's qualities in a liquid form, liquid rubber latex is mixed with stabilizing chemicals to create natural latex-type rubber. Integrating this kind of rubber with asphalt is simpler.
- Liquid rubber that has been clumped together and then moulded into a solid compound, thin sheet, or chopped shape produces solid type natural rubber.
- Crumb rubber is a term for rubber obtained in the form of shreds with a specific grain size from scrap tires.

Tables 1 and 2 present the results of international studies on the admixture of rubber in asphalt mixtures. Table 1 presents the conclusions showing the stability of the mixture, higher asphalt absorption, and rheological performance are all improved by using crumb rubber in asphalt mixes. increased stiffness and resistance, improved quality, and increased service life. Table 2 lists the rubber types frequently used to modify asphalt. These rubber forms include latex, crumb rubber, and cup lump rubber (dry solid rubber). Each of the earlier researchers found that using different rubber mixing formulations as an alternative to asphalt allowed them to improve the material's Marshall stability, stiffness, softening point, resistance to high temperatures, and rutting resistance.

Table 1. Asphalt and crumb rubber research track results

Previous Researchers	Replacement of Asphalt	Findings
Peilong Li, et al (2017) [13]	crumb rubber 5%, 10%, 15%, 20%, 25%, 35%	Increased absorption of asphalt
Venudharan, et al (2018) [14]	crumb rubber 10%, 20%, and 30%	Changes in the asphalt binders' chemical and thermal properties
Ragab, et al (2018) [15]	crumb rubber 10%	Improved storage stability
Chen, et al (2019) [16]	crumb rubber 12%	Improves high-temperature rheological performance
Bakheit, et al (2019) [6]	crumb rubber 6%, 12%, 18% and 24%	Extend the life of the pavement under heavy traffic situations
Tahami, et al (2019) [2]	crumb rubber 1.4%, 2.8% and 4.2% to the weight of the aggregate	Asphalt mixture's resistance to failure
Poovaneshvaran, et al (2020) [17]	crumb rubber 5%, 10% and 15%	Improves stiffness, softening point and torsional recovery
Al-Sabaeei, et al (2020) [18]	crumb rubber 0%,4%,6% and 8%	Increase complex modulus and rutting resistance
Fernández, et al (2020) [19]	crumb rubber 10%, and 15%	Distributed in the asphalt mixture

Table 2. Asphalt and natural rubber research track results

Previous Researchers	Replacement of Asphalt	Findings
Siswanto (2019) [20]	Latex 0%, 2%, 4% and 6%	Reducing the use of ordinary asphalt content
Prastanto (2019) [11]	Prevulcanized latex 3%, 5% and 7% Solid rubber 3%,5%, 7% and 9%	5-7% prevulcanized latex improves Marshall stability
Poovaneshvaran, et al (2020) [17]	Latex 5% dan 10%	Improves stiffness, softening point and torsional recovery
Wititanapanit, et al (2020) [10]	Latex 0%, 3% and 7%	Resistant to moderate to high temperatures
Ramadhan, et al (2020) [23]	Latex 7%	In comparison to solid rubber, using natural rubber latex is more advantageous
Al-Sabaeei, et al (2020) [18]	Latex 4%, 6% and 8%	Asphalt and natural rubber mixtures are now at 4% levels
Abdulrahman, et al (2021) [21]	Cup lump rubber 2.5%, 5%, 7.5% and 10%	Rutting resistance and Tensile strength
Jitsangiam, et al (2021) [22]	Latex 3%, 7% and 12%	Cross-link and strengthen the binding between asphalt and rubber

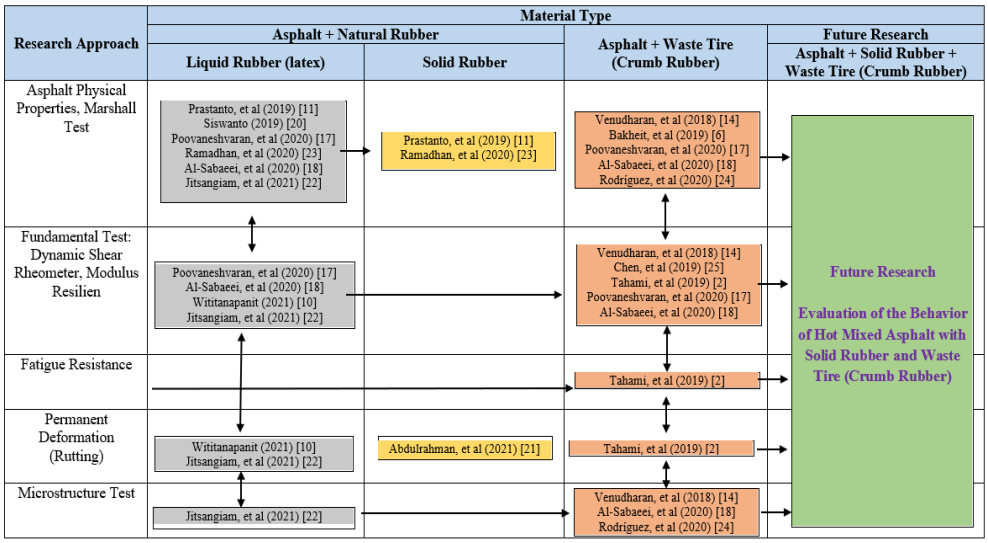

Figure 1. The results of tracking research on rubber asphalt and future research

6. Proposed Further Research

In the summary of the research position, further research is discussed, which is currently being carried out or has already been determined after the analysis of the rubber asphalt research track, as shown in Figure 1. The research item is divided according to the type of material, and the research methodology was compiled according to the previous year of the researcher. Figure 1 demonstrates that research on Asphalt + Natural Rubber in Liquid Rubber (Latex) has been conducted using methods other than fatigue resistance. In contrast, research on Solid Rubber has only been conducted using techniques related to the Marshall Test, Asphalt Physics Properties, and Permanent Deformation (Rutting). Previous studies on the use of natural rubber in asphalt mixtures have not been extensive, with only three researchers investigating the use of solid rubber in hot mix asphalt. There have also been a significant number of studies on waste materials such as crumb rubber in asphalt mixes, but not nearly as much on fatigue resistance and permanent deformation (rutting). According to the tracking data, no studies have been conducted on the combination of solid natural rubber and scrap tyres (crumb rubber) in asphalt mixtures. It is conceivable to have good potential for asphalt performance when examining the two types of material features, particularly when using waste-based materials that can reduce environmental pollution, regarding the topic of potential future study proposals that can supplement existing research on the usage of solid natural rubber and waste tire (crumb rubber) in asphalt mixtures utilizing the Fundamental Test method, fatigue resistance test, permanent deformation test, and microstructure test.

7. Conclusion

Many years ago, adding chemicals to road pavement was done to improve performance and safeguard the sources of asphalt. In light of this and due to a decline in oil sources, researchers are looking for an alternative pavement binder and modifier all over the world.

Additionally, crumb rubber and natural rubber have been testing a combination with bitumen while recently expanding their applications. According to the research on rubber asphalt, more study is needed to determine how well solid natural rubber performs as flexible pavement and whether it can be coupled with crumb rubber. By sharing this knowledge, it is hoped that professionals will be better equipped to provide flexible, sustainable road construction.

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