A review on the effect of crumb rubber in civil engineering applications

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Abstract. The increasing amount of tyre waste seen each year, which corresponds to growth in vehicle demand and usage around the world. The subject of tire waste disposal has been a hot topic among researchers due to the growing amount of waste production each year, the negative influence on the environment, and the potential solutions to these issues. Because of the complexity of the structure, content, and quality of the rubber, disposing of discarded tyres is difficult. Researchers have recently become interested in crumb rubber, which is a product regenerated from tire waste after undergoing a separation process, because of its potential as a raw material in the development of construction materials that may be used to replace natural resources. Crumb rubber, depending on its quality and category, can be utilised in a variety of civil engineering projects to help make them more cost-effective and long-lasting. Further study and development of crumb rubber processing and application methods may enhance tyre waste recycling rates and, as a result, reduce environmental difficulties associated with tire waste landfilling. The primary goal of this research is to review existing crumb rubber research, particularly in terms of characteristics, processing methods, and rates of application in the construction industry. This study could serve to encourage and promote the widespread usage of crumb rubber in civil engineering projects.

1. Introduction

Annually, the world's population grows, resulting in a dramatic increase in demand for rubber-based products, resulting in massive rubber waste creation. As a result, early intervention and effective solutions were necessary to mitigate the negative consequences on the ecosystem. The transportation industry is the largest producer of rubber used to make tires. According to prior studies, over 1000 million tires are disposed of annually, with projections of 1200 million tires by 2030 [1]. As seen in 2007-2010, the annual tonnage of scrap tire continues to rise in Peninsular Malaysia. In 2007, 208911 waste tires were produced, rising to 245087 in 2010. Between 2007 and 2010, the volume of scrap tire increased by 17% [2]. Because natural resources are depleting and there is a growing awareness of sustainable waste management, a practical method to recycle and re-use tire waste into something useful, particularly in the construction industry, is a constructive approach to reducing the negative impact of mass tyre waste on the environment.

2. Methodology

The literature review and data collection focused on the source or generation, processing stage, recovery rate, and recovery process drawbacks in various nations throughout the world, which were divided into five continents: Oceania, Asia, Europe, Africa, and America. Each country's strategy was thoroughly examined based on the numerous aspects taken into account. Comparison of tabulated data to aid in the analysis process by classifying the parameters appropriately.

3. Source and recovery of rubber waste

Due to its various components, recovering waste rubber is more difficult than recovering other wastes. Car and truck tire are the primary source of waste rubber. Tires come in a variety of compositions to assure their strength and endurance. These compositions present significant hurdles in the effort to prevent waste rubber from ending up in landfills. Rubber, carbon black, metal, cloth, zinc oxide, sulphur, and additives are common components of vehicle, truck, and off-the-road (OTR) tire. The presence of a three-dimensional network generated after vulcanization, the variety of compositions, and other variables make recycling leftover rubber difficult.

The percentages of recovered waste rubber are still quite low over the world, necessitating extensive solutions. The percentage of waste rubber generated and recovered varies by country. According to the data, Canada is the most efficient country in terms of recovering end-of-life tires, with over 100% recovery rates in 2015 by recovering waste tires from the previous year. Strong public engagement, well-developed regulations, and supportive government are factors that help Canada achieve maximum efficiency in waste tire recovery, according to data from the Canadian Association of Tire Recycling Agencies (CATRA) Annual Report 2016, as cited by the World Business Council for Sustainable Development [4]. ELTs are primarily regulated at the provincial level in Canada through used tire recycling programmes run by non-profit groups [4]. The lack of a legal framework for ELT management in Argentina, as well as the requirement for financial assistance in the treatment process, contributed to the low recovery rate. Saudi Arabia is unable to recover a large volume of waste rubber due to an increase in the number of motorised vehicles, insufficient operations and investment in generating processing technology, and a lack of monitoring and frequent reporting.

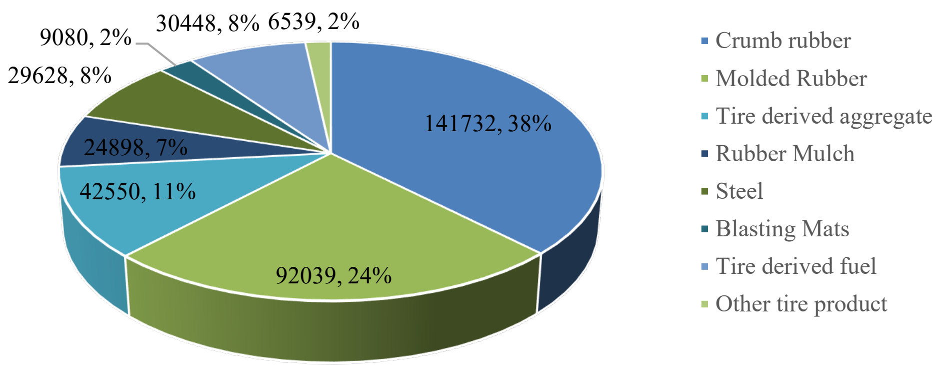

Figure 3.1: End uses of recycled tires in Canada [5]

4. Processing of rubber waste

Rubber waste that has been recycled is beneficial to the environment and the construction sector. Rubber waste recycling processes vary with the procedure chosen depending on the intended type of end product. According to Lapkovskis et al., research's rubber waste processing may be divided into two types: mechanical and mechano-chemical processes [3]. The methods chosen should take into account the equipment's availability as well as the total processing cost. This may be seen in the methods employed in different countries, as the methods are chosen based on the resources available in the country.

Because rubber is made up of different polymers that don't always mix well, it's critical to separate the rubber waste by type to guarantee that the process runs well. Chemical and mechanical procedures are the two basic types of rubber waste processing. The qualities of the rubber, such as the elastomeric structure and other features of the rubber component, should be considered while choosing processing procedures. The irreversible changes in rubber properties are known as a result of chemical processing. Mechanical methods are more prevalent than chemical methods because they need high temperatures and involve the thermal degradation of polymers that occur only in certain environments [3].

5. Civil engineering applications of crumb rubber

According to the few research conducted before, the application of crumb rubber in civil engineering can be categorized into three types such as crumb rubber in concrete, masonry bricks and engineered cementitious composites (ECC) [14].

Most of the previous research study about the applications of the crumb rubber in concrete and asphalt as shown in table below.

Table 5.1: Applications of crumb rubber in civil engineering

Crumb Rubber size	Replacement or addition of Crumb Rubber	Civil engineering applications	Reference
1.18 – 2.36 mm	Replacement of18% of sand by volume	Concrete	[6]
0.15 – 2.36 mm	Addition of 14%	Asphalt	[7]
400 µm – 600 µm (fine) 10 – 15 mm (coarse)	1 – 2% addition by weight percentages of aggregate	Pavement	[8]
0.075 – 4.75 mm	Replacement of sand with 5%, 10%, 15% and 20% by volume with untreated and treated crumb rubber.	Concrete	[9]
Passing 250 µm	5% and 10% by weight of the binder	Asphalt	[10]
-	15% crumb rubber	Asphalt	[11]
0.075 – 4.75 mm	5%, 10% and 15% crumb rubber used to replace natural aggregate	Concrete	[12]
-	10% crumb rubber	Asphalt	[13]

6. Conclusion

Along with its good qualities, which can improve certain properties of civil engineering materials, the potential for crumb rubber applications in the manufacturing of civil engineering materials is very high. As a result, greater research into its applications in the production of compressed earth bricks could be more beneficial to the environment and construction materials affordability.

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