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Using Plastic Wastes in Construction: Opportunities and Challenges

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Urbanization and the evolution of people's lifestyles have a significant impact on the quantity of waste that is generated and dumped each year. In addition, due to the emergence of the COVID-19 pandemic, the use of masks has increased significantly, and the amount of plastic waste generation worldwide has doubled. These wastes have had a negative impact on the environment and have attracted the attention of many departments. Faced with both increasing amounts of generated plastic wastes and the growing interest of sustainability, the construction sectors must take an advantage using recycled plastic wastes in construction applications to reduce the negative impacts of the generated plastic wastes, while meeting future infrastructure demand. This study conducts a comprehensive analysis of the opportunities and challenges of plastic waste application in the construction industry. In this context the objective of the study is to 1) explore the most used plastic wastes in construction industry, 2) identify potential application of plastic waste in construction industry, 3) identify potential application of COVID-19 plastic waste in construction industry, 4) outline challenges and opportunities involving the applications, and 5) Provide recommendations for advanced research required for plastic waste application in construction industry. It is concluded that the use of plastic waste in construction will significantly improve environmental sustainability, reduce the construction cost, improve the performance of construction, and serve as a reliable supply of construction materials. Finally, to overcome challenges areas for further research are also suggested.

Key Words: Plastic Waste, Construction, Construction Material, Recycling, Safety, Sustainability, Environment

Introduction

Urbanization and the evolution of people's lifestyles have a significant impact on the quantity of waste that is generated and dumped each year. Products are made and then discarded, resulting in waste. Most of these wastes are disposed at landfills. The high cost of landfilling, the inefficiency of non-specific locations, and the use of land space may hinder waste management. Although the output of solid waste is increasing year by year, only a small part of it is recycled or landfilled, and a large part of it is deposited directly or indirectly in the marine environment. Moreover, during COVID-19 pandemic, a large amount of face masks has been generated and littered in the parking lots, parks, and ocean, which result in an increased number of wastes (Saberian et al., 2021).

Plastic wastes are one of the big solid wastes that threaten our world's sustainability. Annually, almost 300 million tons of plastic waste are generated (Singh & Sharma, 2016). Plastic waste is produced globally due to its widespread use in industries including automotive, manufacturing, packaging, and healthcare (Rokdey et al., 2015). Due to the significant expense and energy involved with landfilling, these wastes have been dumped in aquatic bodies. When plastic waste enters in the oceans, it causes ecological, economic, and aesthetic harm (Jambeck et al., 2018). Plastic's limited biodegradability further limits its recyclability and environmental disposal. Finding uses for plastic wastes will help to manage it in a sustainable manner. Moreover, reuse and recycling of plastic waste outperform landfilling and incineration (Lazarevic et al., 2010).

Source reduction, reuse, and landfilling have all been used to limit the quantity of plastic waste that is produced each year to a manageable level. Plastic waste generation has steadily increased because of significant technological advancements. To preserve a sustainable ecosystem, it is important to develop new methods to recycle this plastic waste. In addition to protecting the environment, recycling plastic waste provides a way to absorb these materials into various industries, such as construction, where they may be used. Utilizing plastic waste in construction not only protects the environment, but it also lessens the environmental hazard that this plastic's manufacturer offers to the environment. Using plastic in the construction industry might also aid in the industry's environmental goals, as well. By reducing the quantity of new plastic processed and generated, reusing plastic waste results in significant reductions in energy use and carbon emissions. From an engineering perspective, plastics are very durable, cost-effective, long-lasting, easy to mold, and easy to maintain (Hopewell et al., 2009). As a result of these characteristics, as well as the growing awareness of the environmental impact of plastic waste, plastic has become an increasingly popular material for engineering and construction applications.

The most common plastic waste in the waste stream is polyethylene and polyethylene terephthalate (PET) have been used in concrete, building plaster, pavements, bock, mortar, to reinforce asphalt in road surfaces and create a stronger, more crack-resistant structures (Almeshal et al., 2020; Okunola A et al., 2019; Proshad et al., 2017; Siddique et al., 2008; da Silva et al., 2021). Although the potential of plastic waste in the construction industry is huge, its application and development are now severely limited. As plastic waste may be used in the construction industry, this study provides a comprehensive analysis of its opportunities and challenges. In this context, the objective of this study is to 1) explore the most used plastic wastes in construction industry, 2) identify potential application of plastic waste in construction industry, 3) identify potential application of COVID-19 plastic waste in construction industry, 4) outline challenges and opportunities involving the applications, and 5) provide recommendations for advanced research required for plastic waste application in construction industry.

Methodology

The methodology used was to search for the information present in this review through literature and articles in the academic databases: google scholar, science direct, springer, Elsevier, research gate, and academia, using a selection criterion based on the following keyword: Plastic Waste, Construction, Construction material, Recycling, Safety, Sustainability, Environment.

Literature Review

Major component of plastic waste and level of recyclability

Polyethylene terephthalates (PET), High density polyethylene (HDPE), Polyvinyl Chloride (PVC), Low density polyethylene (LDPE), Polypropylene (PP), and Polystyrene (PS) were the most used in Concrete, building plaster, Block, Mortar, Pavements, Base/Subbase of Pavement, hot mix asphalt (HMA) (Almeshal et al., 2020; Okunola A et al., 2019; Proshad et al., 2017; Siddique et al., 2008; da Silva et al., 2021).

Figure 1. shows construction applications of different plastics in different sectors (i.e., Concrete, building plaster, Block, Mortar, Pavements, Base/Subbase of Pavement, hot mix asphalt (HMA)). From Figure 1 it can be said that PET is the most popular plastic in construction application (i.e., concrete, mortar, building plaster, block, pavements). Where PVC is the least applied plastic in construction (i.e., concrete, mortar). Moreover, HDPE, LDPE, PS, PP are also used frequently in the construction industry. By comparing Figure 1 and Figure 2 it can be said that recyclability is one of the main factors which influences the application of plastic in construction industry. Since the recyclability level PVC in is difficult they are being least applied in the construction industry where other plastics with easier recyclability is the most applied in construction industry.

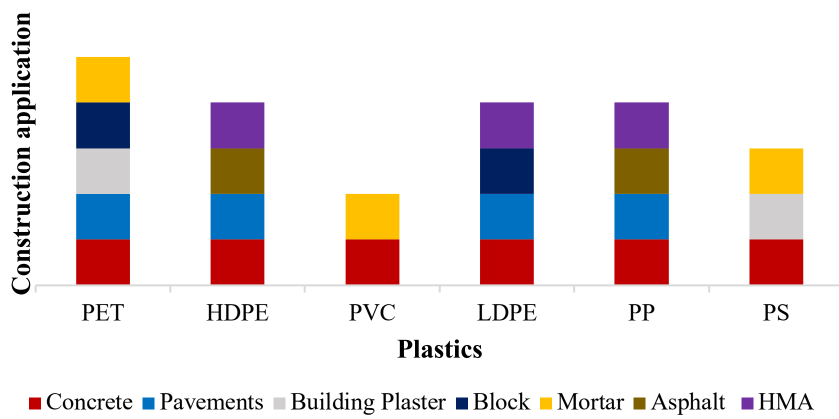

Figure 1. Construction application of different plastics

Figure 2 represents the recyclability levels of different plastics for construction application. Basically, recyclability depends on different factors (i.e., cost of processing, availability, collection procedure). In most cases, the plastic which recyclability level is easier have high levels of application and the plastic which recyclability is difficult have low levels of application as shown in the Figure 2. From Figure 2 it can be said that PET, HDPE, PP and LDPE could be recycled easily but recyclability of PVC and PS is difficult. Polystyrene (PS)) has a high level of application despite their recyclability is very difficult. The reason for that may be related to the wide availability, low cost of production, and PS is mostly used plastics in terms of packaging of different products.

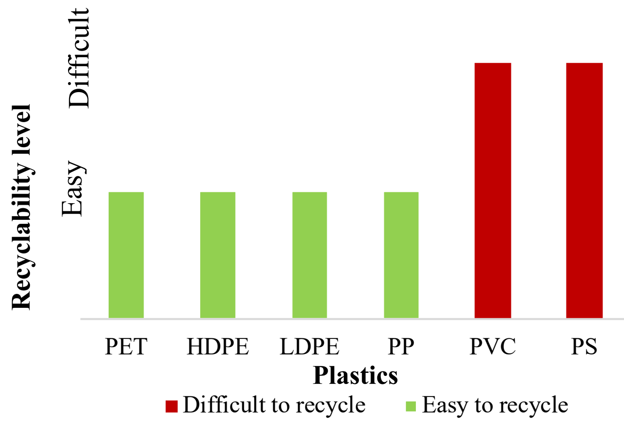

Figure 2. Recyclability level of different plastics.

Plastic waste application in construction industry

Mixing plastic waste into concrete, mortar, building plaster, asphalt, Hot mix asphalt (HMA) and pavement base/subbase modification is a better choice for plastic waste disposal. Table 1 describes the application of plastic waste in the construction industry. The review focuses on the challenges and opportunities of plastic waste as construction material. It can be said from Table 1, opportunities (improve performance, environment quality, reduce cost) and challenges (i.e., Functionality, recycling plan, collection, separation, processing, field performance) are quite similar for all plastic application in construction. Improvement of concrete overall quality, concrete cracking resistance, plaster tensile resistance and compressive strength of earth block is possible by using PET, PS and PVC (Ismail & AL-Hashmi, 2008; Batayneh et al., 2007; Hama & Hilal, 2017; Puri et al., 2013; Aciu et al., 2018). Besides, using HDPE, LDPE, PP, PET and PS it is possible to improve asphalt's mechanical properties, asphalt binder's viscosity, CBR and subgrade modulus (k_s) (Abu Abdo & Khater, 2018; Gibreil & Feng, 2017; Jha et al., 2014; Wang et al., 2022; Angelone et al., 2015; Arabani & Pedram, 2016). However, after all these opportunities researchers have found that the challenges have narrowed the scope of applications. The main challenges of using plastic waste are collection, separation and processing of the plastic waste. Though there are separate bins are provided for recycled plastic waste disposal, most often the bins are contaminated by other wastes. Moreover, people are not using the bins for the disposal of plastic waste. For this reason, collection & separation procedure get complex, operation cost of this process increases. Moreover, for using plastic waste in the construction it is required to process the material in smaller size by advanced process (i.e., grinding, pelleting, shredding), so expensive machines are required for this. Above all, researchers addressed environmental benefits and reduction of construction cost are the prime benefits of using plastic waste in the construction industry.

Table 1

Summary associated opportunities and challenges of plastic waste application in construction industry

Material	Application	Challenge	Opportunity	Author
PET	Concert, Building plaster Asphalt Block	Functionality, Recycling plan, collection, separation, processing	Improve performance, environment quality, reduce cost	Ismail & AL-Hashmi, (2008); Batayneh et al., (2007); Hama & Hilal, (2017); Khalid et al., (2018); Salim et al., (2019); Abu Abdo & Khater, (2018)
HDPE	HMA Asphalt Pavement	Processing, functionality	Improve performance, environment quality, reduce cost	Gibreil & Feng, (2017); Jha et al., (2014); Angelone et al., (2015); Arabani & Pedram (2016)
LDPE	Asphalt HMA Block	Processing Functionality	Improve performance, environment quality, reduce cost	Angelone et al., (2015); Suaryana et al., (2018); Kumi-Larbi et al., (2018)
PP	HMA Asphalt	Processing, functionality	Improve performance, environment quality, reduce cost	Wang et al., (2022); Angelone et al., (2015)
PVC	Concrete Mortar	Processing, recyclability, functionality	Improve performance, environment quality, reduce cost	Puri et al., (2013); Aciu et al., (2018);
PS	Concert Building plaster Pavement	Processing, Functionality, Field performance	Improve performance, environment quality, reduce cost	Ismail & AL-Hashmi, (2008); Hama & Hilal, (2017); Salim et al., (2019); Mohajerani et al., (2017

Applications of Plastic Wastes in Construction Industry During Covid-19

During the pandemic, masks have always been the most popular protective equipment. As a result, more people are using face masks for different purposes. It can protect people against COVID-19, but it is not good for the environment since the most often used single-use mask is not biodegradable (i.e., Plastic). The most common surgical mask is a disposable one. Most of the masks are made of polypropylene (Henneberry, 2020).

Saberian et al., (2021) performed a series of tests on shredded face mask blends at different percentages for highway base and subbase applications, including modified compaction and resilient modulus testing. The combination of recycled concrete aggregate (RCA) base with three different concentrations of shredded face mask (1%, 2%, and 3%) gave the necessary stiffness and strength for paving/foundation. The inclusion of shredded face mask increased the strength and pliability of the fibrous recycled concrete aggregate mixes. When 1% SFM and RCA were added, the strength remained totally unconfined at 216 kPa, but the modulus substantially increased (314.35 MP). Even when SFM was increased by more than 2%, stiffness and strength were decreased.

Kilmartin-Lynch et al., (2021) conducted some tests of concrete using face mask as a modifier. The masks have been inserted with volume at 0% (control), 0.10%, 0.15%, 0.20% and 0.25%, to test the overall quality of the concrete, with the test focus on pressure strength and indirect tensile strength, elasticity modulus and ultrasonic pulse velocity. With the addition of the single-use masks, the strength properties of the concrete settings were increased as well as the overall quality of the concrete increased. However, the trend of increasing force began to decline over 0.20 percent.

However, previous studies have shown that in terms of performance, there is an opportunity to use covid 19 masks in construction. The use of masks in the construction industry is environmentally beneficial and cost-effective, but the challenges of using covid 19 masks are huge. Due to safety issues, it is challenging to collect, separate and process of such masks during this pandemic. Throughout the process of using masks in construction, people may be affected by the covid-19 virus.

Challenges of Applying Plastic Wastes in Construction Industry

Although the use of plastic wastes for construction has several environmental and economic advantages, its widespread adoption still presents certain challenges. Based on the above reviewed studies, some of the main challenges and opportunities of using plastic wastes in construction industries. Challenges are categorized based on collection and processing, functionality, and field performance.

Collection & Processing:

1. One of the main challenges of plastic wastes is collecting and separating before recycling as these wastes are contaminated with other wastes as they are collected from different sources, as a result, these wastes are consisted hazardous and certain causation procedures are needed.
2. No separate collection and separation method is being used to collect the used facemasks during Covid-19 pandemic.
3. The complicated chemical composition of some plastics such as polystyrene makes traditional recycling techniques unsuitable, as a result, advanced technology is needed, which may result in added cost.
4. Plastic wastes need to be processed for using in construction in smaller size by grinding, pelleting, or shredding, as a result, advanced equipment is needed, which may require skilled manpower to operate and increase the cost of construction.

Functionality

1. Plastic has limited strength; therefore, it is not ideal for projects that need to withstand a lot of pressure. Moreover, the low surface energy of the plastic can lead to poor mechanical adhesion in composite material. Due to this insufficient combination, the overall mechanical properties of the composite material may be reduced.
2. Lack of standards for the use of plastic waste in the construction industry despite extensive research has been conducted on construction applications, these applications are still not well standardized commercially.

3. While there have been many field projects with recycled plastics constructed, a more thorough and comprehensive evaluation of how these are performing over the long-term is needed.

Field performance

1. Construction workers are not properly trained up in using plastic wastes in construction sectors as they are not familiar with this process. Moreover, proper safety measures and safety training is not available for the application of plastic waste in construction industry.
2. During Covid-19 pandemic using recycled face mask in construction is a threat for the construction workers, as there are no proper safety guidelines available regarding using covid 19 face mask in the construction.

Opportunities of Applying Plastic Wastes in Construction Industry

1. The use of plastic waste in construction applications will solve the problem of solid waste management and the consumption of raw materials of construction. For this reason, construction cost will be reduced because conventional construction materials are expensive. Moreover, Plastic waste in construction industry will be energy efficient because of replacing conventional raw materials which requires energy for production.
2. Using plastic wastes in construction application will bring a new horizon in the academic field of Construction Management and Engineering.
3. Using Covid-19 face mask in construction application will reduce the pandemic generated waste and construction cost. Moreover, facemask can improve the performance of construction.
4. Using plastic wastes in Construction Management will reduce the environmental pollution and make the world environment more sustainable.

Conclusions and Recommendations

Plastics are widespread in our modern world, and the waste they generate is unavoidable. Consequently, the use of plastic wastes in different construction applications is a viable option for managing these wastes and enhancing the sustainability of the environment, reducing the cost of construction, improving the performance of construction work, and serving as a reliable supply of construction materials. In this study, the opportunities, and challenges of the application of plastic waste in the construction industry have been thoroughly addressed. The conclusions and recommendations of the study are the following:

- The use of plastic wastes for construction applications is an efficient and sustainable waste management solution despite its applications is full of challenges, however, the advanced technology makes the application more possible.
- The use of Covid-19 pandemic plastic waste in transportation industry could improve the United states road network and reduce the future environmental threats from this plastic wastes.
- Proper safety guideline and separate collection procedure should be developed for the application of recycled Covid-19 face mask in construction industry.
- The use of recycled plastic waste should be included in academic curricula to familiarize future construction leaders with the use of plastics in construction.

- Appropriate training programs should be developed to train and understand construction workers on the application of plastic waste in construction.
- Further research work is required to determine the solutions for resisting chemical reaction occurs for using plastic waste in construction.

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