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Waste Plastic to construction material: A review

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Abstract
Because of its versatility and great demand in a variety of uses, plastic trash has become a significant environmental concern. Recycling or reusing plastic trash as a constituent of construction materials has developed as an environmentally responsible approach, as traditional building materials frequently demand a large amount of energy during manufacture, which has serious environmental consequences. The use of plastic waste in construction materials such as bitumen modification, soil stabilization, Geo-synthetic materials, bricks, plastic reinforcement, and natural aggregates can reduce the need for natural aggregate extraction, reducing the construction industry's negative impact on the environment. This study gives an in-depth examination of the advancements concerning the utilization of plastic waste in construction materials. The study is divided according to whether it deals with the utilization of plastic waste in bricks, tiles, or concrete for road construction. The effect of adding plastic trash on strength, water absorption, durability, and other attributes has also been thoroughly examined. The report finds that using plastic trash as an innovative alternative in the building industry has the potential to stimulate economic growth while also assisting the government's efforts to accomplish sustainable development goals.
Keywords: *Plastic waste, Plastic bricks, waste management, solid waste management.*

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I. INTRODUCTION

In today's world, plastic has become an integral part of our daily lives due to its flexibility and durability. However, this has resulted in a significant increase in plastic waste production, with studies showing that around 300 million tons of plastic garbage are generated globally each year, with a considerable portion ending up in the ocean [1]. Recycling has been attempted but is inefficient due to its labor-intensive method and poor success rate [2]. As a result, there has been a growing interest in finding alternative uses for plastic waste, such as incorporating it into building materials [3]. Plastic waste integration in construction materials has shown potential benefits, including improved compressive strength, water absorption rate, and durability. However, limited studies have been on its use in the production of bricks and paving blocks [4] Therefore, the primary objective of this thesis paper is to evaluate recent developments in using recyclable plastic waste as raw material and aggregate in the manufacture of bricks and paving blocks, analyzing the advantages and disadvantages of using plastic waste in construction materials. Ultimately, the goal is to provide an analysis that contributes to finding sustainable solutions for plastic waste management while meeting the sustainability goals of the building industry.

II. PLASTIC

Plastics have become a ubiquitous and versatile material that is utilized in numerous daily applications, such as packaging, construction, apparel, transportation, and medical [5–8]. The material is derived from fossil fuels and gas and is classified into two types: thermoplastics and thermosets. While thermoplastics can be repeatedly melted and remolded, thermosets undergo irreversible chemical changes when heated [9–11]. Plastic packaging, which accounts for 40% of plastic demand [12], is widely used to protect food and goods from contamination, and plastic water distribution systems and storage containers provide clean water [13]. Plastics are also employed in protective clothing and safety equipment, such as fire-resistant textiles, helmets, and airbags, to avoid injuries. Furthermore, medical equipment, including tubing, blood bags, prostheses, and disposable syringes, is made from plastics that help improve health conditions. Low-density polymers are also used as metal and ceramic alternatives in airplanes and automobiles.

However, the wide use of plastics results in a variety of waste streams, with a substantial portion of plastic products having a lifespan of less than a month [13] According to research studies, plastic waste is a significant environmental management challenge. Plastic production has gradually increased over the previous 50 years, surpassing traditional materials such as glass, steel, and wood [14,15]. A large volume of plastic waste, almost 13 million metric tons, ends up in the ocean, posing a significant threat to marine life [16]. People throw away at least two pieces of plastic debris per day [17] resulting in more than 400 million metric tons of plastic items manufactured in 2018. The plastic production rate is expected to increase to 500 million metric tons by 2025, [16,18]. In Malaysia, polyethylene and polypropylene are the most used plastics, with polyethylene terephthalate (PET) widely used in packaging because of its strength, shatterproof qualities, and non-reactivity with water and food.

In conclusion, plastics are a versatile and widely used material that provides convenience and benefits in various sectors of the economy, including food, transportation, construction, and medical. However, the massive amounts of plastic waste generated due to the short lifespan of many plastic products have severe environmental consequences. To mitigate the negative impacts of plastic waste, it is crucial to develop more sustainable practices and alternatives to plastics.

2.1. Types and Classification of Plastic for Use in Construction

Plastic trash is a significant environmental concern, and finding ways to repurpose it is critical for long-term sustainability. One interesting idea is to use discarded plastics as a construction material. Nevertheless, not all plastics may be utilized for this purpose. Knowing the different types and classifications of plastic is critical in identifying which ones are suited for construction applications (Crawford RJ, 2013).

- **Thermoplastics and Thermosets**

Plastics are usually categorized into two types: thermoplastics and thermosets. Thermoplastics are polymers that can be melted and remolded several times, whereas thermosets are plastics that harden permanently once cooled and solidified [19]. Thermoplastics include polyvinyl chloride (PVC), polyethylene (PE), polypropylene (PP), and polystyrene (PS) [13]. Epoxy resins, polyurethanes, phenolic resins, and polyester resins are examples.

- **Recycling Plastics**

Only thermoplastics can be recycled among the various forms of plastic. This is because they may be melted and remolded numerous times without incurring any chemical changes[19]. Polyethylene terephthalate (PET), high-density polyethylene (HDPE), low-density polyethylene (LDPE), PVC, PP, and PS are examples of common recyclable thermoplastics [13]).

- **Polymers that are not recyclable**

Because of their chemical qualities, thermosets, synthetic fibers, and multi-layer and laminated plastics cannot be recycled. Teflon, PUF, Bakelite, polycarbonate, melamine, and nylon are examples of non-recyclable plastics [19]

- **Classification of Particle Size**

Polymers can also be classed by particle size. Nano plastics (particle size 0.0001 mm), tiny microplastics (particle size 0.00001-1 mm), large microplastics (particle size 1-4.75 mm), meso plastics (particle size 4.76-200 mm), and microplastics (particle size >200 mm) are examples of these materials.

Understanding the various types and classifications of plastic is critical in understanding which types can be reused as building materials. Recyclable thermoplastics such as PET, HDPE, LDPE, PVC, PP, and PS can be used in construction, however non-recyclable plastics and thermosets cannot.

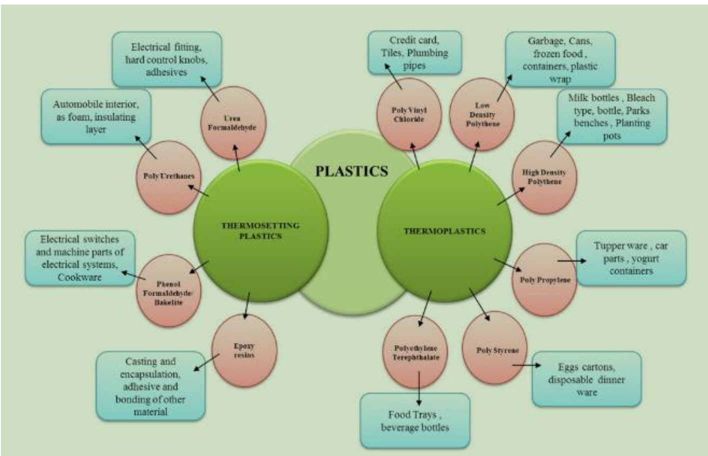

Fig. 1 Classification of plastic

2.2. USES OF WASTE PLASTIC

As the importance of environmental sustainability grows, the engineering industry is becoming more interested in reusing and recycling plastic waste and polymers. This is especially important in the construction industry, which is largely reliant on raw materials and generates significant amounts of plastic trash [13,19]. Furthermore, increased building material costs have pushed the use of plastic waste as a value-added commodity in construction applications. This provides an alternate method for the disposal of plastic waste and has been used in civil engineering as soil stabilizers and alternative aggregates for the construction of concrete and asphalt. Plastic trash can be utilized to replace some of the traditional stabilizers, aggregates, or lightweight concrete pavement, as well as in reinforced Geo-pavements or low-volume asphalt pavements [13]. Less garbage sent to landfills improves resource management and, as a result, lowers building costs. Furthermore, these green replacements have a good environmental impact. Plastic trash can also be used to make high-quality polymers such as vehicle parts, household appliances, fabrics, building insulation, and films. Hence, the treatment and recycling of plastic waste can be separated into four major categories: recycling, chemical, mechanical, and waste-to-energy recovery.

2.3. PROBLEMS RELATED TO PLASTIC WASTE

Because of its disposal and manufacture, plastic trash offers substantial environmental issues, resulting in pollution and negative consequences on human, animal, and plant health [20–24]. Since the 1950s, the worldwide plastic output has expanded considerably, and it is estimated that over 8 million tons of plastic rubbish wind up in the ocean each year, killing millions of marine animals [25,26]. Plastic trash distribution is linked to human population growth, which leads to increasing demand for plastic things and, as a result, more environmental damage [27,28]. The manufacture of plastic garbage involves the use of considerable amounts of fossil fuel, which contributes to growing CO2 levels in the environment Furthermore, the disposal of plastic waste in landfills contributes to increased greenhouse gas emissions [29,30]. Developing countries, notably those in Asia and Africa, confront significant plastic pollution issues due to the lack of effective waste collection programs [31]. To combat these consequences, there is an increasing need to decrease plastic waste through recycling and reuse, and the United Nations is planning a global treaty to limit plastic pollution [26]. The negative consequences of plastic waste emphasize the significance of finding sustainable uses for plastic trash, such as its usage as a building material.

III. RELATED STUDIES

PET bricks were cast with PET ratios of 0.5%, 1%, 1.5%, and 2%, and their corresponding curing times were 7 days, 14 days, and 28 days. The PET bricks also underwent tests for compressive strength, bulk density, modulus of rupture, impact resistance, and water absorption on the corresponding days 7, 14, and 28 notably. Compared to most tests, the PET Bricks produced better and ideal results at a PET ratio of 1%. Terms in Index Pet, fly ash, quarry dust, bulk density, and rupture modulus(Suganya et al., 2015).

The use of plastic bottles (PET) as building components in place of conventional concrete blocks is investigated from a structural and thermal perspective. The bottles were filled with either dry sand, saturated sand, or air and mortared with cement to create stable masonry walls with low thermal conductivity before the tests were carried out. The impact of the infill material on the plastic bottle masonry blocks' compressive strength and bulk unit weight revealed a negligible effect on the strength. Calculations revealed that despite the gross strength of the air-filled bottle blocks being substantially lower than that of typical blocks (670 KN/m^2 vs. 3670 KN/m^2), they can still be employed as viable construction components for bearing walls or partitions walls for one roof slab. Air-filled bottles outperformed traditional block construction in terms of thermal insulation, which might be used as a thermal insulation material [4].

an attempt was made to make bricks using waste plastics in the range of 60 to 80% by weight of laterite quarry waste and 60/70 grade bitumen added in the range of 2 to 5% by weight of soil in molten form, and this bitumen-plastic resin was mixed with laterite quarry waste to make bricks. High-density polyethylene (HDPE) and polyethylene (PE) bags are cleaned and mixed with sand, cement, and fly ash with water and sound insulation properties [33]

study shows combining heated plastic trash with heated stone dust in a mold to produce bricks and tiles. the study discovered that the properties of bricks and tiles are considerably superior to regular bricks and tiles, such as low water absorption, high compressive strength, smooth surface, unbreakable, lightweight, and so on. [34]

This endeavor to utilize waste plastics and demolition waste results in the development of a revolutionary technology known as plastic pavement block. Ordinary paver blocks can be substituted with plastic paver blocks because they have advantages such as replacing cement, lowering costs, being easier to manufacture, and emitting fewer greenhouse gases. Because plastic pavement blocks do not require curing, they consume less water. Reusing discarded plastic helps to reduce landfill, which helps to reduce soil pollution. Because it involves closed burning, it reduces air pollution to a larger extent. Three alternative plastic replacement ratios are investigated in this study. When the three ratios are compared, it is discovered that the percentage of plastic 25%, sand 50%, and demolition debris 25% has produced good strength. Plastic paver blocks are an added benefit for new construction techniques [35]

A project made use of five different types of waste materials: recycled concrete coarse aggregate (RCCA), recycled concrete fine aggregate (RCFA), crushed glass (CG), crumb rubber (CB), and ground granulated blast furnace slag (GGBS). According to the results of tests on the qualities of blocks mixed with various degrees of waste materials, it is concluded that incorporating both RCCA and RCFA into the block can reduce its strength while increasing its water absorption. Replacement levels for RCCA and RCFA are indicated to be 60% and 20%, respectively. Crushed glass, used as a coarse aggregate in concrete paving blocks, can increase the strength of the blocks while decreasing water absorption. Except for slide resistance, the addition of crumb rubber significantly degrades the characteristics of the blocks [36].

This study looked at whether soil and various amounts (0, 1, 3, and 7%) of shredded waste plastic might be combined to create compressed earth bricks (CEB). To ascertain the engineering qualities of the soil, tests on specific gravity, particle size distribution, Atterberg limits, and compaction were performed on the soil. The compressive strengths and erosion rates of the CEB constructed from soil alone and soil mixed with various amounts of shredded waste plastic belonging to the 6.3 mm and >9.6 mm size categories were measured. The ground was deemed to be clayey sand (SC). The CEB with 1% waste plastic of diameters 6.3 mm or smaller had the maximum compressive strength, which was equal to an increase of 244.4%. The sample with 1% waste plastic of diameters 6.3 mm likewise had the lowest erosion rate among the CEB samples stabilized with shredded waste plastic. The use of 1% shredded waste plastic with particle sizes of 6.3 mm was advised if the outer surfaces of walls made with the CEB are shielded from erosion. Waste plastic that would have been an environmental hazard could be used to make stronger, more reasonably priced bricks for building affordable housing [37].

When compared to its equivalents, the production of plastic sand bricks and paver blocks uses significantly fewer natural resources. Customers have a cheap alternative in the form of plastic sand bricks and tiles. Bricks made of synthetic sand absorb no water at all. At a compressive force of 96 KN, the plastic sand block has a compressive strength of 5.6 N/mm^2. River sand, M-sand, and fly ash are the three types of sand used. These concrete kinds are very inexpensive and greatly lessen the negative environmental effects of plastic. Building with foundry sand brick will cut overall costs from 20% to 25% [38].

This study combines single-use plastic waste with M Sand to create Plastic M Sand bricks. The plastic additive dosage (Waste plastic: M Sand) is changed from 1:1 (C1 type) to 1:2. (C2 type). The mix ratios are determined through trial casting. Plastic M Sand bricks were tested for compression, water absorption, soundness, and hardness to assure performance in strength and durability assessments. The performance of plastic M Sand bricks in various tests was compared to that of regular bricks. The compression test results show that the mixed combination C2 type bricks have the greatest strength of 55.91 MPa, which is 88.59% greater than standard bricks and 18.7% greater than C1 type bricks. The Water absorption test, on the other hand, reveals that C1-type bricks outperform C2-type bricks and normal bricks. According to the test results, increasing the amount of plastic added to the M Sand bricks improves their performance in the water absorption test, but the behavior of the bricks under compression improves up to a dose of 1:2. (C2 type) [39].

Melted plastic bags were used as a replacement for cement in the production of construction building bricks and concrete blocks. Using waste plastic in making bricks and blocks is advantageous due to its extreme versatility and ability to be tailored to meet specific technical needs and it is lightweight compared to other competing materials which reduces fuel consumption during transportation. Also replacing cement with waste plastic will reduce environmental problems associated with the disposal of waste plastic as well as those associated with the cement industry. The results also showed that bricks and concrete blocks with similar plastic contents (50%) have similar thermal conductivity values. The results also showed that, for similar plastic contents (50%), the concrete blocks had a lower bending moment (1442.55 Nm.) and lower bending stress (8.65 N.m^2) than bending moment (1711.25 Nm.) and bending stress 10.26N.m^2) of the bricks [40].

This study examines a potential remedy for the problems raised above, namely the conversion of plastic trash into construction blocks that can be built quickly and at a cheaper cost. A study was carried out to determine how effective combining waste elements including bottom ash, copper slag, and ceramic in various ratios with LDPE (Low-Density Polyethylene), (the main source of waste and least recyclable plastic), to form blocks. This study evaluates the mechanical characteristics of various raw material mix proportions to determine the ideal composition. The superiority of the newly designed composite block over the traditional brick in terms of building quality, economic feasibility, and environmental sustainability is also examined in this article [41].

The current research focuses on the creation of waste masonry bricks made from PET plastic waste (PPW) and recycled broken glass (RCG). The bricks were created by altering the dry mass of RCG by 20%, 30%, and 40%. The test findings revealed that WM bricks had an average tensile and compressive strength increase of 70.15% and 54.85% when compared to traditional clay brick strength values. For the same compressive strength, the splitting tensile strength of WM bricks is relatively higher than that of regular bricks. The drying and wetting cycle in an acidic solution reduced the mass of clay bricks by 12.4%, however, no mass loss was detected in WMBs due to the hydrophobic and deformability properties of the RCG and scrap plastic. Beyond the optimum strength index, the tensile and compressive strength of the WM bricks has a linear proportionality relationship. The findings also indicated a suitable scientific approach to converting wastes into green-efficient masonry bricks that meet SANS 227 for load-bearing constructions such as retaining walls and multi-story buildings [42]

This article presents the findings of an experiment examining the use of foundry sand (FS) and scraps of plastic wastes (SPW) in the manufacture of environmentally friendly bricks for masonry buildings. A variation of sets of bricks was made using 20%, 30%, and 40% of the mass of FS. The produced bricks performed tests for tensile and compressive strength following acid and water soaking to determine how durable they were in comparison to traditional burnt clay bricks. The investigation's findings demonstrated that all FS and SPW-produced bricks had 85% better strength than burnt clay bricks. The outcome also demonstrated that SPW bricks had a compressive strength that is twice as strong as clay-fired bricks because they both recorded 29.45 MPa and 14 MPa, respectively [43]

This article presents the results of a study on the use of industrial wastes in the creation of substandard building materials. To accomplish this, a thorough geotechnical assessment of several easily accessible industrial wastes, including dolomitic waste (DW), silica fume (SF), and river sand (RS), deployed in various ratios by the mass percentage of fly ash (FA) waste to produce FA bricks, was carried out. Findings imply that the use of these industrial wastes in the manufacture of FA bricks not only exhibited certain excellent qualities but also demonstrated the potential to significantly advance society's objectives for sustainability [44]

Thermoplastics such as High-Density Polyethylene (HDPE) and Polypropylene (PP) are employed in the current work to make the plastic brick employing the physical recycling method. Standard tests are carried out in the first phase of work to investigate the plastic brick's physical, mechanical, and thermal properties. The wall was tested by IS 1905:1987 using a universal testing machine (UTM). It was noteworthy to note that the compressive strength of the HDPE and PP bricks was 11.19 N/mm^2 and 10.02 N/mm^2, respectively, which were in good agreement with the compressive strength of the first-class conventional brick, which was 10.5 N/mm^2. It was also noted that HDPE brick has the maximum compressive strength. The ultimate load for the plastic brick wall was 197.50 KN with a shear failure at 45°, while the conventional brick wall experienced a vertical collapse at 153.95 KN force. A fire-resistance test was done on a plastic brick wall and a conventional brick wall to see whether the specifications of the Nation Building Code (2005): Part 4: Table 1 were met. Even after 30 minutes of heating at the four corners and center, the plastic brick wall showed a greater temperature difference than the typical brick wall. The study kicks off a new line of research in the field of sustainable plastic waste management [45].

IV. MAJOR FINDINGS OF REVIEW

1. Reuse of plastic waste for making bricks:
- Can address the problem of plastic pollution by diverting waste from landfills or the environment
- Is cost-effective and can create employment opportunities in waste management

2. Benefits of adding plastic waste to clay bricks:
- Improves strength, durability, and insulation properties of bricks
- Can make bricks more sustainable and energy-efficient than traditional bricks

3. Use of plastic waste in brick manufacturing can reduce carbon footprint:
- Traditional brick production involves high energy consumption and significant greenhouse gas emissions
- Plastic waste can reduce energy requirements and carbon emissions associated with brick production

Overall, the reuse of plastic waste in brick manufacturing can provide several environmental and economic benefits, but it is crucial to ensure the process is safe and does not compromise the quality of bricks.

V. DISCUSSION

Undoubtedly, the use of waste plastic as a construction material has been a hot topic in recent years. Many studies have demonstrated that plastic trash can be utilized as a replacement for traditional construction materials such as burnt clay bricks and concrete blocks, with comparable or even better qualities, as we have discussed in this talk.

Bricks constructed from plastic waste and sand, for example, have been demonstrated to have stronger compressive strength and lower water absorption than regular clay bricks. Furthermore, the use of plastic waste in building materials has been found to improve thermal qualities such as thermal conductivity and heat capacity.

Overall, these findings indicate that plastic trash has the potential to be a useful resource in the construction sector, helping to reduce the amount of plastic waste in landfills and minimizing the environmental implications of traditional building materials. However, more research and development are required to optimize manufacturing processes and ensure the safety and longevity of these new building materials.

VI. CONCLUSION

Finally, several research has proven that using waste plastic as a construction material yields positive outcomes. It can assist to reduce plastic waste in the environment while also providing a cost-effective and long-lasting alternative to standard building materials. However, potential downsides such as the production of harmful gases during combustion and the limited biodegradability of plastic must be considered. Further study and innovation are required to address these difficulties and fully realize the promise of waste plastic as a sustainable building material.

DECLARATION

No conflicts of interest to the best of our knowledge.

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