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Valorization of Plastic Waste through Incorporation into Construction Materials

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ABSTRACT: The growing plastic pollution has prompted the quest to reduce plastic waste sustainably and control the mismanaged plastic stream. The valorization of plastic waste through reusing and recycling has received much attention as a sustainable solution to the global plastic problem, and the construction sector provides an important avenue for such an endeavor. This review aims to present the latest advances in the valorization of plastic waste as construction and building materials through the review of 60 relevant scholarly papers and a content analysis of the papers. In the construction sector, plastic waste can be valorized as additives or raw materials for brick production. As additives, plastic waste is added at different proportions (1%–70%) with other materials, including non-plastic waste, followed by curing to acquire the desired properties. Plastic waste is used as a raw material to contain strength-imparting materials. The former has been reported to have good strengths (5.15-55.91 MPa), chemical, and thermal resistance, whereas the latter may impart lower strengths (0.67-15.25 MPa). Plastic waste is also used as additives for road pavement, primarily as substitutes for concrete-making materials, and was observed to produce desirable strengths (0.95–35 MPa) at appropriate proportions (0.5–25%), indicating the importance of optimizing the plastic contents in the concrete. Plastic waste has been recycled as plastic lumber, plastic-based door panels and gates, as well as insulation materials. Plastic-based construction materials are generally lightweight, resistant to chemicals and heat, and have good sound insulation, but they may pose a fire safety concern.

KEYWORDS: Plastics; recycle; additives; construction; building; valorization

1. Introduction

Plastics have been gaining popularity as packaging materials and containers due to their lightweight, water-resistant, as well as heat- and electricity-insulating properties [1]. In fact, the use of plastics is not limited to packaging and containers. Plastics are also the raw materials for synthetic textiles and are found in consumer products, electrical and electronic equipment, and parts of vehicles and machinery [2]. New products made of plastics emerge rapidly, implying the ever-increasing and versatile applications of plastics for a wide range of purposes. Plastics have found their use in the rising renewable energy sector as materials for wind turbines, solar panels, and wave booms [3]. Besides, plastic materials are commonly encountered in the medical and healthcare sectors, frequently as parts of syringes, artificial limbs, and wound dressing [4]. The military sector also uses plastics for military gear and vehicles. The low cost of plastics has made them popular materials for single-use and disposable items. This leads to the generation of large amounts of plastic waste. Plastic waste in municipal solid waste typically comprises low-density polyethylene (LDPE), high-density polyethylene (HDPE), polypropylene (PP), polyvinyl chloride (PVC), polystyrene (PS), and polyethylene terephthalate (PET) [5].

The amount of plastic waste has increased substantially as compared to 20 years ago, and most of the plastic waste is either landfilled or incinerated. Recycling of plastic waste was reported to be at only 9%, and mismanaged plastics constituted an alarming 22% of the plastic waste generated [6]. The Organization for Economic Cooperation and Development (OECD) countries, for instance, produced 11% of mismanaged macroplastics and 35% of mismanaged microplastics in 2019 [6]. There was an obvious increase in the plastic waste generated during the COVID-19 pandemic, especially when travel restrictions were imposed, mainly because of the packaging associated with higher orders of takeaway, the use of personal protective equipment (PPE), particularly masks, as well as the hike in ancillary plastic waste linked to the medical waste stream [7]. In terms of per capita plastic waste generation, the United States recorded the highest with 221 kg/person/year, while the Japanese and Koreans generated approximately 60 kg of plastic waste per person, respectively, annually [2]. Shortcomings in the collection and disposal of plastic waste have resulted in the entry of this waste into the environment, forming the mismanaged fraction of the waste. The mounting plastic pollution has drawn global attention, particularly with reports pointing to the presence of microplastics in all environmental matrices and in food, triggering environmental and public health concerns [8–10].

Multiple solutions have been proposed to reduce plastic waste, with special attention to the mismanaged and microscale fractions. Source reduction and substitution of plastics have been promulgated as long-term and sustainable solutions to the vexing plastic pollution problem [11]. In the meantime, before comparable environmentally friendly substitutes for plastics become widely available, plastic waste generation will persist, and plastic pollution is likely to stay as long as mismanagement of plastics is not adequately addressed [12]. Recycling plastic waste has been identified as a viable method of reducing plastic waste volume by converting discarded plastics into new products or materials [13]. It is closely linked to waste valorization, which centers on enhancing the value of a waste material by changing it into something of greater value, such as a chemical or raw material, a fuel, or a source of energy [14]. Recycling can be viewed as a form of waste valorization, allowing waste products to be processed into materials and objects of higher value and functionality. Similarly, reusing a waste product in a beneficial way without reprocessing it is also a form of waste valorization, and it simply involves repurposing the waste product [15]. Nonetheless, the attachment of values to recycled and reprocessed plastic products may be challenging, and in actuality, the "recycled" or "valorized" products may not always have higher values than the original plastic products [15]. While attaching a value to a "valorized" product derived from plastic waste is beyond the scope of this study, it looks at how plastic waste has been valorized via recycling and reusing without attempting to value the valorized products.

There have been attempts to valorize plastic waste by turning it into valuable chemicals through microorganisms [14]. Pyrolysis of plastic waste provides an alternative method of valorizing it through heating household plastic waste at different temperature ranges in accordance with the types of pyrolysis to yield plastic-derived oil as a potential fuel [16]. Plastic waste can be photocatalytically valorized using solar energy to turn the waste into chemicals and fuels. This process involves photocatalysts absorbing light to energize charge carriers, allowing the initiation of redox reactions that result in the formation of fine chemicals and hydrogen from photocatalytic plastic, as well as the production of oxygenated chemical feedstocks or C_2 fuels [17]. Alternatively, plastic waste can be subjected to fluid catalytic cracking and hydrocracking to produce liquid fuels, gasoline, and diesel [18]. Other than thermochemical conversion, plastic waste can be valorized through mechanical means into plastic products, and this is commonly conducted with single-polymer plastics. Compositionally complex and contaminated plastic waste is more difficult to mechanically valorize, and mechanical recycling may compromise the quality of the products. The common items produced from mechanical plastic recycling are grocery bags, pipes, and gutters [19].

It is possible for plastic waste to be recycled as or added to construction materials. Studies have pointed to the potential use of plastics as additives in bricks [20], mortars and concrete [21], and pavement concrete [22]. Reviews in this genre are also available. For instance. Ogundairo et al. presented a review on the prospects of plastic waste as a bitumen modifier, soil stabilizer, and brick strengthening agent [13], while Singh et al. reviewed the development of composite materials from waste PET and marble dust [23]. However, there have been very few attempts to conduct a literature review on the utilization of plastic waste in different construction materials. With the intent to fill this review gap, this article aims to systematically present the valorization of plastic waste through recycling and reprocessing it as construction materials or additives to construction materials. Unlike existing reviews that often focus on a particular aspect of plastic waste valorization in the construction sector, especially for the making or modification of masonry, this review provides an integrated account of the latest advances in valorizing plastic waste for different types of construction and building materials. It provides novel recommendations to spur further advancement in the valorization of plastic waste in this area.

2. Methods

This paper presents a literature review of the potential valorization of plastic waste as construction materials or additives to construction materials. It included only scholarly articles, encompassing journal articles and conference papers written in English and published predominantly in the past 10 years that had been peer-reviewed [24, 25]. Desktop search for the papers was conducted with three journal databases, namely Scopus, Web of Science, and Science Direct, using keywords consisting of valorization, recycling, plastic waste, construction, and construction materials. The keywords were used in combination to refine the search.

A total of 114 papers were retrieved from the journal databases and were later screened for their relevance. The inclusion criteria are as follows: 1) The papers should be about recycling or valorizing plastic waste; 2) The recycling and valorizing of plastic waste must be for construction and building purposes; and 3) The papers should ideally make recommendations about advancing plastic waste valorization as construction materials or additives to construction materials. After screening, only 60 papers were included in this review. Content analysis was performed on the papers to extract the information for this review.

3. Discussion

The valorization of plastic waste has been commonly reported through its potential use as additives for bricks and tiles as well as in road construction. This section therefore centers on these two major avenues of valorizing plastic waste, with attention also given to other emerging uses of plastic waste in the construction sector.

3.1. Materials and additives for masonry.

Numerous studies have been performed on the addition of plastic waste to masonry in an attempt to reduce the volume of plastics bound for landfills and incinerators. Experiments on green bricks have been conducted with varying ratios (80:20, 70:30, and 60:40) of PET scrap plastic waste and foundry sand, and it was found that bricks with a 70:30 ratio demonstrated the highest compressive and tensile strengths [26] (Table 1). The addition of waste PET to recycled crushed glass in the same ratios was also reported to increase the tensile and compressive strengths by as much as 70.15% and 54.85%, respectively, relative to those of conventional clay bricks. The presence of plastics in the bricks conferred substantial hydrophobicity to render undesirable water absorption minimal while imparting chemical and mechanical resistance [27]. The addition of 1% PET-sized blocks (6.3 mm) to compacted earth blocks raised their compressive strength by 244.3% and reduced their disintegration rate (Table 1) [28]. The potential of plastics as additives in masonry was further tested by incorporating plastic bottles into concrete blocks of 200 x 200 x 400 mm. Curing the blocks for 28 days showed the blocks with plastic added had an average weight of 24.85 kg and a compressive strength of 10.03 MPa, as compared to 20.08 kg and 6.38 MPa for the standard blocks (Table 1). This implies that plastics can improve the weight and strength of masonry in some cases [29]. Furthermore, in a study involving the mixing of plastic waste and manufacturing sand to make plastic-manufacturing sand bricks at 1:1 and 1:2 ratios, the bricks were observed to have the highest compressive strength (55.91 MPa) at 1:2 ratio, marking an 88.59% higher strength than regular bricks (Table 1). The bricks also had lower water absorption than regular bricks [30].

In addition, a study examined the effects of adding 20% to 30% PP by weight to river sand, manufacturing sand and ash respectively in the making of pavement bricks. It revealed that the bricks composed of 30% PP and 70% fly ash had the highest compressive strength (22.85 MPa) and hardness (6.087 Brinell hardness number) (Table 1). The bricks were thermally stable up to 80°C [31]. Another experiment employing plastic waste particularly PET and PP to manufacture bricks was conducted where 65 to 80% of the plastic waste by weight was mixed with soil quarry waste and bitumen of 2 to 5%. The findings showed the highest compressive strength (10 N/mm^2) was achieved at 70% plastic waste and 5% bitumen, and PP yielded higher compressive strength than PET (Table 1). The bricks produced demonstrated ozone, ultraviolet and chemical resistance [32]. A drawback of bricks made of PET and sand was highlighted by Selvamani et al. after they found that these bricks combusted readily though acquiring a maximum compressive strength of 8.06 N/mm^2 at a PET-sand ratio of 1:3 (Table 1) [33]. In a separate study, the compressive strength and modulus of rupture value of fired bricks were reported to decrease when PET was mixed with lateritic clay at percentages varying from 5% to 20%, thus implying that plastic waste might decrease the strength of bricks depending on the materials it is mixed with [34].

Table 1. Optimal plastic proportions and comprehensive strengths of masonry containing plastic waste.

Plastic Waste Type	Optimal Proportion by Weight	Role of Plastic Waste	Optimal Compressive Strength (MPa)	Reference
PET scrap	30%	As aggregates in the making of green brick	38.14	[26]
PET	30%	As aggregates in brickmaking	42.01	[27]
PET sized 6.3 mm	1%	As aggregates to compacted earth blocks	244.3% increase	[28]
Waste plastic bottles	Not applicable	As concrete substitute in hollow blocks	10.03	[29]
Plastic waste	1:2 plastic waste to manufacturing sand ratio	As aggregates in the making of plastic manufacturing sand bricks	55.91	[30]
PP	30%	As aggregates in brickmaking	22.85	[31]
PET and PP Waste	70%	As aggregates in brickmaking	10	[32]
PET bottles	1:3 plastics to sand ratio	As material in plastic sand bricks	8.06	[33]
PET	0%	As aggregates in making fired bricks	5.15	[34]
Polycarbonates (PC), PS and mixed plastics	1% (decrease with increasing plastic waste content)	As aggregates in brickmaking	25.9 – 31.01 (baked); 27.62 – 33.75 (unbaked)	[20]
Waste polyethylene (PE), nylon 66 and PET	Not specified	As aggregates in the making of plastic bricks	15.5 (kN)	[35]
LDPE	3:1 LDPE to ceramic aggregates	As aggregates in brickmaking	22	[36]
PE	10%	As aggregates in the making of composite brick	20.34	[37]
PET bottles	Not applicable	As containment for aggregates	15.25	[38]
PET bottles	Not applicable	As containment for sand	0.67	[39]
HDPE and PET of < 1 mm	1%	As additives in brickmaking	5.04 (HDPE); 4.50 (PET)	[40]
PET	60%	As a substitute for clay and cement binder in the making of interlocking bricks	84.54% of control	[41]

The choice of materials is particularly important in making bricks with plastic added, as different mixes of materials could yield widely variable properties. Mondal et al. added thermoplastic waste comprising PC, PS, and thermoplastic mix to sand, ash, and Portland cement at different ratios for brickmaking and revealed that 0–10% thermoplastics, 60–70% sand, and a combined 15% fly ash and Portland cement by weight produced bricks that are lightweight, porous, and thermally resistant. A compressive strength of more than 17 MPa was attained (Table 1) [20]. This contrasts with the combustible and low-strength natures of plastic-containing bricks reported in certain studies [33, 34]. Similarly, using river sand instead of red soil and crushed stones in combination with plastic waste such as PP, nylon 66, and PET yielded a comparatively higher compressive strength of 15.50 kN, 0% water absorption, and excellent sound insulation (Table 1) [35]. This, again, points to the importance of the materials selected in conjunction with plastic waste, or more specifically, the types of plastic waste, in brickmaking. However, in the study of Kognole et al [35], PET, which was previously reported to reduce brick strength, was found to be a viable material.

Recycling plastic waste and other types of waste together for brickmaking is beneficial to reduce the overall amount of waste bound for disposal. This prospect was probed in a study that investigated the mixing of LDPE with bottom ash, ceramic, and copper slag, all of which are waste materials. A compressive strength of approximately 16 MPa and a water absorption rate of 4.2% were attained when LDPE and bottom ash were mixed at a ratio of 3:1 (Table 1) [36]. LDPE-ceramic aggregates mixed at the same ratio with 10% oil yielded 22 MPa of comprehensive strength and 4.9% water absorption, while blending 2 parts of LDPE to 1 part of copper slag with a coupling agent added produced 21.4 MPa of compressive strength and 4.5% water absorption. These properties meet most of the standards for bricks [36]. Besides, composite bricks produced from pulverized waste polyethylene (PE) and fly ash showed better resilience than red and ash bricks. The water absorption of the bricks was reported to decrease as the PE content increased. With a 10% PE content, the bricks had maximum wet and dry compressive strengths of 20.34 MPa and 21.02 MPa, respectively (Table 1). Furthermore, they are cheap to produce [37].

The recycling of plastic bottles without chemical conversion was tested by filling the bottles with compressed recycled aggregates derived from construction and demolition waste of varying sizes and water contents. The study revealed that aggregates with sizes less than 425 m and 5% water content had a significantly higher compressive strength than those with sizes ranging from 425 to 4.75 m with the same water content (15.25 N/mm^2 versus 9.84 N/mm^2) (Table 1). A 5% water content conferred on the aggregate-filled bottles a compressive strength like that of the common red clay brick (17 N/mm^2) [38]. Another similar attempt at filling PET bottles with dry sand, saturated sand, or air was made where cement mortar was applied as binding material. The results revealed bottle blocks with compressive strengths in the order of air-filled (670 kN/m^2) > dry sand (623 kN/m^2) > saturated sand (609 kN/m^2), but in comparison to that of a standard block (3660 kN/m^2), the strengths of the bottle blocks were substantially lower (Table 1). Nonetheless, the bottle blocks, particularly the air-filled ones, are potentially useful as partition walls and thermal insulators [39]. There has also been interest in recycling PET bottles as eco-bricks by stuffing plastic bags in the bottles to a weight greater than 220 g, without the conventional thermal process of brickmaking, which is energy intensive and environmentally unfriendly. The eco-bricks have a lower compressive force (40.1 kN) than conventional bricks but performed well in sound reduction [40]. Pulverized HDPE and PET waste with sizes ranging from 1-3 mm to 3-6 mm was added to unfired clay bricks at 0, 1, 3, 7, 15, and 20% by weight. Plastic grains of 1 mm were found to increase the water absorption coefficient by 17% and the compressive strength by 28%. The addition of plastics reduced the bricks' bulk density below 1.75 g/cm^3, making them lightweight [41].

Another study investigated the potential of PET and polyurethane (PU) as substitutes for clay and cement binders in interlocking bricks. PET bottles were reduced to fragments of 0.75 mm, which were subsequently mixed with PU and condensed into interlocking bricks [42]. A PET to PU ratio of 60:40 yielded a compressive strength of 84.54% that of the control and a tensile strength of 1.3 MPa (Table 1). The thermal conductivity ranged between 0.15 and 0.3 W/mK, indicating their suitability as partition walls. Owing to their relatively lower strengths, these bricks are more appropriately used for non-load-bearing purposes [42]. This study implied physical processing of the bricks, though the processing methods were not clearly detailed.

3.2. Additives for road pavement.

Plastic waste, in addition to its use in masonry, could and has been used as road pavement materials with varying degrees of success. Recycled plastic-bound concretes composed of recycled HDPE and PP were manufactured devoid of asphalt binder or Portland cement. Recycled PP-bound concrete achieved a compressive strength of 30 MPa, threefold that of asphalt binder concrete (Table 2) [43]. In terms of bending strength, recycled PP was 300% and 500% higher than that of plain cement concrete and asphalt concrete, respectively. The plastic-bound concretes were also more moisture-resistant. In comparison to recycled PP, recycled HDPE was not as effective at confining the aggregates in concrete. The potential application of plastic waste as a substitute for cement is beneficial for reducing the large amount of CO_2 generated during the production of cement [43].

Table 2. Optimal plastic proportions and comprehensive strengths of road pavement materials containing plastic waste

Plastic Waste Type	Optimal Proportion by Weight	Role of Plastic Waste	Optimal Compressive Strength (MPa)	Reference
Recycled HDPE and PP	22%	As substitute for Portland cement concrete and asphalt concrete	30	[43]
Recycled PET flakes	1%	As substitute for sand	20.72	[44]
Plastic waste and E-waste	4.5 to 6% (plastic waste); 7.5% to 15% (E-waste)	Plastic waste as substitute for bitumen; E-waste as substitute for aggregates	Not specified	[45]
Recycled plastic aggregate	25%	As aggregates in concrete	35	[46]
Granulated recycled high-impact polystyrene (HIPS) and LDPE wastes	10%	As substitute for sand	30 (with 28 days curing)	[47]
Plastic bag	0.5%	As concrete additive	3.55 (with 28 days curing)	[48]
PP, HDPE, PVC	25%	As aggregates in concrete	26.9 (PVC); 25.4 (PP); 19.5 (HDPE)	[49]
Ground, flaky, pelleted LDPE, HDPE, PET and PP	1%	As subgrade soil stabilizer	1.15 (pelleted HDPE); 0.95 (pelleted PP); 0.96 (flaky HDPE)	[50]
Recycled hard plastics	6%	As asphalt concrete modifier	2.05 (Indirect tensile strength) (surface course) 1.94 (Indirect tensile strength (base/binder course)	[51]

The possibility of using recycled PET flakes as aggregates in Portland cement was probed, with the aggregates added at increasing weight percentages (1–10%) to Portland cement. The maximum compressive strength of 20.72 MPa was attained at 1% PET (Table 2) [44]. The increasing plastic contents of Portland cement reduced the density of the concrete. The same has been reported in other studies involving the addition of plastics to bricks. The presence of plastics tends to reduce the density of bricks or concrete, conferring lightweight properties to the construction materials [44]. In a separate study, plastic waste was used as a substitute for bitumen in amounts ranging from 4.5 to 6%, while E-waste was used as a substitute for aggregates at 7.5% to 15% by volume of the mold. The melting point of the bitumen-plastic mixture was observed to be higher than bitumen alone, thus conferring flexibility to the road in winter and maintaining its good shape. There was a 6.7% decrease in the penetration value of the bitumen and an 8.6% increase in its softening point when 6.5% plastic waste was added [45]. Prior to this, the feasibility of using plastic electronic waste as a replacement for aggregates was tested, and it was revealed that adding 10% plastic electronic waste to cement yielded optimal hardness and durability [52]. Increasing the plastic content from 0 to 20% resulted in a drop in compressive strength (18.55 to 10.72 N/mm^2), flexural strength (3.14 to 2.74 N/mm^2), and split tensile strength (2.14 to 1.91 N/mm^2). This suggests an optimal proportion of plastic is crucial to impart the desirable properties to the concrete [52].

Using digital microscopy, it was discovered that substituting fibrous LDPE waste and quarry dust for natural sand in proportions ranging from 0% to 100% resulted in a less porous, more refined, and dense matrix in comparison to a conventional concrete mix. The lamellar and crystalline structures of LDPE and the fine quarry dust particles were deemed to result in a dense and refined matrix, with the former providing better strength carrying capacity [53]. Again, the importance of optimizing the proportion of plastics in concrete is highlighted by Basha et al., where the authors evaluated the mechanical and thermal properties of eighteen concrete samples with the contents of recycled plastic aggregate ranging from 25 to 100%. The authors revealed that adding 25% recycled plastic aggregate gave the concrete a maximum compressive strength of 35 MPa while reducing the thermal conductivity to 1.1–0.5 W/mK as compared to 1.7 W/mK for the control concrete (Table 2) [46]. An attempt was made to use granulated recycled high-impact polystyrene (HIPS) and LDPE wastes as sand replacement in proportions ranging from 0 to 50% by weight for concrete production. The concrete samples were examined in their fresh and hardened states [47]. There was a decreasing trend in workability, density, and compressive strength with increasing weights of recycled plastic granules. Nonetheless, curing the concrete samples with 10% recycled plastics for 28 days yielded a satisfactory strength of 30 N/mm^2 (Table 2) [47]. A similar study using shredded plastic bags as concrete additives at 0–5% by weight showed the attainment of a maximum compressive strength of 26.1 MPa and a maximum flexural strength of 3.55 MPa after a curing duration of 28 days when 0.5% plastic bags were added (Table 2). While water penetration and abrasion resistance improved, increasing the proportions of plastic waste in concrete appeared to compromise mechanical properties [48].

Concrete samples containing PP, HDPE, PVC, and natural aggregate were tested for their mechanical, thermal, and acoustic properties. Concrete containing 75% plastic particles exhibited low dynamic modulus and thermal conductivity. The hardened density was reduced to the greatest extent (46% lower than the control at 1318 kg/m^3) when PP contents were high [49]. After 28 days of curing, the compressive strengths of concrete samples with PP, HDPE, and PVC fell in the ranges of 5.2–25.4 MPa, 4–19.5 MPa, and 12–26.9 MPa, respectively. Plastic additives conferred better acoustic qualities on the concrete [49]. Generally, plastic waste is commonly employed either as a substitute for aggregates and sand or as an additive to concrete, and it could confer the desired strength at the right proportions, though the compressive and flexural strengths tend to decrease with increasing proportions of plastics in the concrete. Frequently, the presence of plastics in concrete reduces its density and thermal conductivity while improving its sound-insulating property. In addition to plastic types, the shapes of plastics also seem to determine the compressive strength achieved when used as a subgrade soil stabilizer. Pelleted HDPE was found to yield the highest compressive strength (1.15 MPa) at 1% compared to the flaky and ground forms, and the compressive strength decreased with increasing plastic contents [50]. The addition of recycled plastic to the asphalt mixture was also reported to produce greater tensile strength than the control, indicating the potential use of plastic waste as an asphalt concrete modifier without compromising the strength [51].

3.3. Other emerging uses of plastic waste.

Recycled commingled plastics have been experimented with as wood replacements. The replacement, otherwise called plastic lumber, was found to demonstrate wood-like properties but was more durable than wood due to the water and chemical resistance of plastics [54]. The replacement materials are suitable for railroad ties, fences, and benches, among others. However, the cost of processing plastic waste into plastic lumber could be prohibitive, thus creating a barrier to its wide application [54]. With advances in the manufacturing of plastic lumber, the cost has been significantly reduced, and plastic lumber products are starting to emerge in the market. Unlike steel, plastic lumber does not require spraying and is lighter and stronger. It also burns less hotly than wood [54].

Besides, door panels have been produced from plastic waste by mixing pallet or pulverized plastic waste with cellulose fiber or wood flour. The resultant mixture is a thermoformable wood-plastic matrix that can be shaped into door panels. With the success of producing door panels from recycled plastics, the recycled plastics have been used to make gates that offer durability as well as noise and heat insulation [55]. Such gates have made their debut in the market.

There has been increasing interest in searching for more sustainable insulation materials for buildings, and recycled plastics are one of the candidates. Expanded polystyrene (EPS) was advocated as an insulation material for buildings but encountered limitations due to its low density and fire safety concerns [56]. Fire safety is an important occupational safety requirement globally and is becoming even more important as the global surface temperature warms and heat waves occur more frequently [57–59]. Improvements in the fire resistance of EPS leading to its feasible application as insulation material could significantly enhance buildings' energy efficiency while ensuring the safety of their occupants. Furthermore, plastic-based floor tiles and roof tiles have been rolled out, and they offer the benefits of easy installation and cleaning. Their light weights facilitate transportation and lower hauling costs [60]. In addition, the presence of plastics reduces thermal conductivity, as has also been reported for bricks and concrete, thus offering better heat insulation.

4. Conclusions and Recommendations

While plastics are one of the most important inventions of the 20th century, having revolutionized material engineering, they have created unprecedented environmental pollution. Mismanagement of plastic waste has resulted in the leakage of a massive amount of used plastic items into the environment, harming the ecosystem and public health. The prospect of valorizing or recycling plastics through multiple avenues offers the hope of reducing the amount of plastic waste heading to landfills. However, the recycle rate remains low, and there are technical and economic barriers to overcome before the valorization of plastic waste becomes commonplace in the construction and building industry. The barriers are:

1) Plastic waste often contains non-plastic materials or chemicals, such as papers, wood, and prints, and different types of plastics, both recyclable and non-recyclable, could appear on the same plastic item. The separation of these materials is an important step in the recycling of plastics. However, the production of certain materials, such as eco-bricks, may not require stringent separation of different plastic types from a plastic item, though removal of non-plastic materials is often necessary.
2) Construction and building materials containing recycled plastics may be more expensive to manufacture, and the high costs could deter the purchase of these materials.
3) The presence of waste materials in construction and building materials may give rise to the perception that these materials are inferior, even though they could have better performances, such as durability and thermal insulation, than conventional materials.
4) Optimization of the proportions of plastics in bricks, concrete, and tiles is crucial to achieving the desired strengths, and it requires multiple trials to determine the optimal plastic proportions as well as the mixes of raw materials used to produce the building materials.
5) Plastics could limit the application of certain construction and building materials as their presence often reduces the density and weight of those materials.
6) Plastics might be associated with fire safety concerns due to their flammability.

In view of the barriers, it is recommended that:

1) Studies on optimizing the proportions of plastics in construction and building materials could be continued.
2) The mixing of plastic waste with different waste materials in the production of construction materials could provide the co-benefit of reducing other types of waste.
3) Testing different combinations of raw materials, including non-plastic waste and plastic waste, is critical to identifying the formula that produces construction materials with desirable properties.
4) A life cycle analysis of valorizing plastic waste as construction materials could provide more information about the environmental benefits of such a practice, particularly in reducing greenhouse gas emissions associated with construction material production.
5) Since plastic-based construction materials have certain properties that are different from conventional construction materials, new standards could be developed to control their quality.

6) It is essential to promote public acceptance of plastic-based construction materials and plastic recycling practices through environmental education and market-based mechanisms such as incentives, tax reductions, etc.

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Competing Interest

The author does not identify any completing interests.

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