A Review on Utilization of Plastic Wastes in Making Construction Bricks

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Abstract. Plastic waste is spread at an unprecedented speed due to the rapid use of domestic and industrial plastic items. The environmental pollution resulting from the continued disposal of plastic wastes in landfills has not only created land problems but has also heightened the pollution of marine resources. This paper aims to review and investigate the feasibility of utilizing plastic waste in making construction bricks. The use of plastic waste in making the sand-plastic bricks will enhance the protection of the environment from the effects of plastic waste that normally takes several millennials to degrade. Thermostatic plastic waste; that is, those polymers whose recycling may not affect the environment, including polyethylene (PE) and polyethylene terephthalate (PET), is found to implore lightweight, durable, cost-effective, and low thermal conductor bricks. Compressive strength (CS) and water absorption tests are found as the key test methods for measuring the effectiveness of high-volume content of plastic waste in bricks. Notably, a high percentage of plastic waste in proportion to sand is found to improve the compressive strength of the bricks besides allowing negligible water to seep through.

1. Introduction

Plastics implore quite a hill of benefits that were they to be sparingly used in the manufacture of the various appliances that find use in homes and industries [1][2]. Besides, the lightweight characteristic of a wide array of plastics makes their usability convenient in the making of various cheap and durable products that find their ways into the multitude of homes [3]. Consequently, the use and production of plastics have seen a prolific surge in the last five decades. This points out to the imminent challenge posed by the plastic use on the environment. Notably, plastic pollution has been realized to contribute significantly to the aggravating situation of climate change due to the increase in carbon emissions that have a direct impact on the ozone layer. Owing to the incessant increase in use of plastics; a fact that is projected to double or triple in the next two or three decades, proactive measures need to be taken to enhance mitigation of environmental pollution posed by the use of plastics [1][2]. With the interventions taken to address the escalating problem in the use of plastics, this paper reviews literature on plastic utilization in the building and construction industry as a key step to ameliorating recycling of plastics for the safety of environment for future systems of plants and animals. In particular, plastic waste related issues are articulated in scope analysis, and imminent gaps identified for reviewing the potential market of recycling bricks. The scope of research is to identify the possible alternative uses of recycled plastics and enhance the development of pragmatic and prudent policies geared towards sustainable plastic use in the context of environment protection. More than 30 different types of polymers are invariably mixed with thousands of additives so as to obtain the required quality of plastics for use in several applications intrinsic in a wide gamut of sectors that include but not limited to building and construction, textile,
packaging, and electrical sectors [1]. Notably, polyethylene (PE), polypropylene (PP), polyethylene terephthalate (PET), polyvinyl chloride (PVC) and polystyrene (PS) significantly contribute to the large global use of plastics. Generally, plastics are categorized into thermoplastics and thermoset plastics [4]. Figure 1 shows the global annual plastic production from 1950 to 2015. While thermoplastics (such as PE, PET, and PP) can re-melt once after being re-heated, thermoset plastics do not have the characteristic of getting re-melted once they solidify [5]. To the extent that the consumption of plastics; most of them being made out of non-biodegradable components, is proliferating daily on the accounts of development and human population increase, plastic waste now accounts for significant proportion of municipal solid waste (MSW) in most landfills [2]. Recycling and reusing through a variety of procedures aimed at reducing plastic accumulation in the landfills is one of the processes aimed at reducing significant pollution to the environment.

Recycling of plastics denotes the process of reconverting wastes from plastics into useful products [3][4]. It implores the wide range of processes included in waste management that run from collecting, sorting, grading, classification, cleaning, baling, storing and transportation into the final step of compression molding [1]. The process of compression molding entails a closed application of high pressure to solid plastic waste with the end products becoming of great use in several home and industrial appliances [5]. Unfortunately, whereas more than 500 billion plastic bags enter into the value chain of consumption annually, only about 1% of this gets recycled [6][7]. In addition, compression molding will reduce plastic waste accumulation in landfills thus actually reducing the environmental pollution attributable to plastic production and disposal. Through the process of recycling, and for this case, utilization of plastic recycling to make sand bricks for construction, environmental impact of plastic waste as well as prevention of depletion of the pertinent resources such as clay and sand used for making bricks may be achieved.

2. Effect of High Volume Content of Plastic Wastes in Sand Bricks

Extant literature growth points out to the feasibility of recycled plastic waste for making concrete construction materials due to high versatility of the plastic [8]. Such an avenue of recycling plastics is however constrained by the immiscibility of some attributes inherent in the different types of polymers [3]. Thermostats such as polyethylene (PE), high density polyethylene (HDPE), polyethylene terephthalate (PET) and polypropylene (PP) are structurally strong and can be re-molded for concrete bricks that are resistant to surface reaction as is the case with polyvinyl chloride (PVC). In addition, the integration of plastic waste into the construction industry through high volume addition of content significantly reduces the economic cost of construction since most of these polymers fetch low prices compared to sand and soil harvesting, which also face the risk of depletion [9]. Moreover, the use of plastic waste in making construction bricks is a sustainably affordable practice for mitigating environmental effects of pollution from incineration of plastics and landfills. Satisfactory results from concrete mixing using plastic waste has been achieved by mixing of fine aggregates, coarse aggregates, and partially replacing fine aggregate with ‘shredded fibers of polythene bags’ [10].

Empirically, most studies implore the use of plastic waste for making concrete bricks enhances the compressive strength (CS) of building materials, an attribute that supports use of plastic waste for making building and construction materials. Table 1 shows the percentage of decrease for compressive strength against the percentage of plastic content used.

| Percentage of Plastic Content used (%) | Average CS in MPa | Percentage of decrease for CS (%) |
|----------------------------------------|------------------|----------------------------------|
| 5                                      | 43.82            | -11.76                           |
| 10                                     | 40.60            | -7.34                            |
| 15                                     | 37.32            | -8.06                            |

Through plastic recycling more safety to the environment is harnessed to the environment using the right policy and also integrating the appropriate technology. Plastics for recycling are subject to resin composition, a value that is found in every bottle that indicates its safety or unsafety upon recycling [8].
In particular, low density polyethylene (LDPE), high density polyethylene (HDPE), polypropylene (PP), and polyethylene terephthalate (PET) are considered safe materials for recycling due to low toxic content.

3. Potential Additives – Materials and Methods

The various materials may be combined in desired proportions in making of plastic bricks [5]. However, the compressive strength, determined by the various factors relating to porosity as well as sound insulation of the brick infer the potential values of plastic waste to be impregnated in plastic concrete. The traditional bricks made from sand with plastic-sand bricks made from impregnating sand with plastic wastes were compared and found that plastic-sand bricks conjured higher compressive strength than the ancient type of bricks [11]. The following additives are available for use in making plastic bricks [5]:

- 5 – 15 % of gypsum with accumulative purity not below 35%
- Quick lime (hydrated lime) that should have 40% minimum purity
- Up to 20% of coarse sand
- Fly ash kept well between the recommended safety limits. In particular, it should possess a specific gravity between 2.54 and 2.65 gm/cc and fineness ranging between 350 to 450 m²/Kg.
- Plastic wastes that may be mechanically crushed into small bits or using a crusher machine to refine them into desired sizes. Notably, the small plastic particles are sieved before being mixed with the other materials in making bricks.

During the manufacturing process, up to 55% of fly ash is mixed with 10 -15% of lime, 5 – 10% of gypsum, and varying degrees of plastic waste and sand depending on the coarseness of sand [4]. After a period that ranges between 7 – 28 days of curing the bricks with water, the absorption test is conducted to measure the porosity of the bricks in regards to water percolation. It is desired that the weight of a brick soaked in water should not exceed the dry weight of the brick by 20% for good and effective bricks that can build durable and energy efficient bricks [4]. The compressive strength test is imperative to ascertaining the fitness of plastic bricks when compared with various proportions of plastic waste. The compressive strength of fly ash plastic strength was found to be significantly high when compared with the commercial bricks. The fly ash plastic bricks were also found to be more effective in reducing water percolation into a building due to their reducing porosity [4][5].

Table 2. Average CS determined from different proportions of plastic waste and fine aggregate in making construction bricks and [5].

| Proportions | Fly Ash (%) | Lime (%) | Gypsum (%) | Fine aggregate (%) | Plastic Waste (%) | Percentage of plastic waste | Compressive Strength (N/mm²) |
|-------------|-------------|----------|------------|-------------------|------------------|---------------------------|----------------------------|
| A           | 55          | 15       | 5          | 25                | 0                | 0                         | 4.15                       |
| B           | 55          | 15       | 5          | 20                | 5                | 5                         | 4.5                        |
| C           | 55          | 15       | 5          | 15                | 10               | 10                        | 4.0                        |
| D           | 55          | 15       | 5          | 10                | 15               | 15                        | 3.8                        |
| E           | 55          | 15       | 5          | 5                 | 20               | 20                        | 3.25                       |

As evidenced in the table, the other aspects of the brick composition were kept in constant proportion while fine aggregate and plastic waste were intermittently varied in order to determine the effect of the varying degrees to the compressive strength. The tests of compressive strength implied that plastic waste (proportionate use) may increase the compressive strength of construction bricks while additional amounts may affect the quality [5][8]. Therefore, following from the results of compressive strength and percentage of plastic used in the mix, a percentage of five implores higher compressive strength while an increase in the composition of plastic in the brick results in reduced CS. However, water absorption seemed to achieve a balanced value that was desirable for all proportions of plastic waste in the mix.
Table 3. Percentage of water absorption across varying proportions of plastic waste.

| Proportion | % of plastic waste | Average water absorption |
|------------|--------------------|--------------------------|
| B          | 5                  | 9.2                      |
| C          | 10                 | 9.1                      |
| D          | 15                 | 9.9                      |
| E          | 20                 | 10.7                     |

The compressive strength of bricks impregnated with 5 – 10% of plastic waste improved significantly than in the conventional sand bricks thus suggesting that additional volumes of plastic waste in making construction bricks may increase the durability and thermal-insulating properties of construction materials [4].

Mondal et al. use RIC 7 type polymers which are produced from the chemical reaction between Bisphenol A (BPA) and Phosgene (COCl₂). As such, these polycarbonates are poor thermal and electrical conductors besides being non-flammable thus finding veritable use in the making of computers and their peripherals including CDs, DVDs, as well as electrical communication components [8]. However, the toxic level in RIC 7 type of plastic is often deemed to result in hazardous materials hence limiting their recyclability. In regard to the possibility of their use in making construction bricks, they may significantly result in great reduction of environmental pollution resulting from landfilling by these plastics. The end-of-useful-life plastic waste from disposed computers was collected and mixed in various proportions with fly ash, sand, and cement. 25% of the mix comprised of water [8]. The computer waste was mechanically broken into smaller granules and the mix heated in separate batches of 90 and 110 degrees for a period of 2 hours. The investigative experiment for different plastic percentages (65%, 75%, 85%) was conducted by weight of soil and percentage change in bitumen (4%, 8%, and 12%) and performed compressive strength and water absorption tests for 9 bricks that were air dried for a period of 24 hours [12]. Their findings, reported in the table 5 below, surmised that compressive strength was achieved at higher percentages of plastic waste. In particular, 85% plastic waste composition mixed with 12% bitumen gave optimal results of 6.56 N/mm² which was at parlance with the second class bricks [12].

Table 4. Percentage of plastic waste with compressive strength [12].

| Percentage of plastic waste | Percentage of Bitumen (%) | Compressive Strength in N/mm² |
|----------------------------|---------------------------|-----------------------------|
| 65%                        | 4                         | 3.56                        |
|                            | 8                         | 4.15                        |
|                            | 12                        | 4.47                        |
| 75%                        | 4                         | 5.18                        |
|                            | 8                         | 4.68                        |
|                            | 12                        | 5.67                        |
| 85%                        | 4                         | 6.42                        |
|                            | 8                         | 4.69                        |
|                            | 12                        | 6.56                        |

Similarly, an increasing association between high volume content of plastic waste in plastic bricks and compressive strength was found [12]. Notably, 50%, 60%, 70%, 75% and 80% percentage of plastic was mixed with a constant proportion of 2% bitumen and compressive strengths and water absorption tests conducted on the air dried bricks of size 23cm * 10cm * 8cm. At 2% bitumen and 60% proportion of plastic waste, the plastic bricks were found to conjure porosity while compressive strength was overwhelming at 11.01 N/mm² [12]. In addition, the various percentages of plastic waste imbibed with soil were mixed with 2%, 5% and 10% of bitumen [12]. The findings inferred similar results as were found in the other studies. Notably, a brick made by 70% integration of plastic waste with soil and 2% bitumen was found to have an impressive compressive strength of 8.16 N/mm² which was stronger than contemporary sand bricks [12].
Bhushaiah, Mohammad & Rao (2019) experimented on bricks made out of thermoplastic ingredients (PE, PP, and PET) and varied the proportions of plastic waste between 0 – 20% during batching [13]. Fly ash, sand, and mortar (cement) constituted the remaining proportion of the brick. After the bricks were cured under water for four weeks, they were then baked between a range of temperatures between 90º C to 110º C for a maximum period of two hours [13]. In these regard, they found the resulting bricks to exhibit high degree of porosity, lightweight, mechanical strength and low thermal conduction. The plastic-infused bricks were found to have high compressive strength similar to normal sand bricks; in addition, they significantly reduced water absorption compared to the normal bricks mad of sand and cement only [13]. In addition, they found that plastic bricks had low rate of efflorescence, a quality that enhances their thermal conductivity besides making construction cost-effective.

Soundness test is another important test carried out to test the efficiency of plastic bricks. In particular, the soundness test is used to denote the sound absorption rate of bricks obtained from integrating plastic waste with other additives since it is always recommended that walls of buildings should have desired levels of soundness [13]. The acoustic tests of bricks impregnated with plastic wastes indicated high absorption of sound levels hence reducing noise in the buildings [13]. They performed both acoustic and mechanical tests and concluded that plastic bricks designed with characteristic triangular holes performed better by increasing sound absorption compared to the contemporary bricks.

Table 5. Absorption of sound levels vs different types of bricks.

| Properties      | Commercial brick | Hollow brick | Hexagonal brick | Triangular brick |
|-----------------|------------------|--------------|-----------------|------------------|
| Noise level (dB) | 42.1             | 32.1         | 30.1            | 29.9             |
| Absorption Level (%) | 15.8            | 37.6         | 39.8            | 40.2             |

In addition, the triangular bricks significantly absorbed more sound compared to the design of the other bricks hence proving to be a better design for use in the making of plastic bricks [15]. In most buildings, design of the walls requires the inclusion of an additional insulating wall to enhance thermal resistance and sound absorption, a criterion that can increase the cost of buildings. Fortunately, by using the design of plastic bricks that have moderate porosity, additional benefits of retaining internal heat while at the same time shielding the internal environment from unprecedented sound levels [15].

4. Challenges of Recycling Bricks

Despite recycling of plastic wastes imploring a lot of environmental benefits, there are critical factors that must be taken into account to enhance the effectiveness of the process. The environmental impact of recycling some plastics is considered too hazardous and toxic to allow for their efficient recycling. In particular, RIC 7 type of plastics that are used in the making of computers and other peripherals release toxic gases if heated to the degree that allows melting, and this could tremendously overshadow the benefits that might be achieved through impregnating of such plastics in the sand bricks [8]. Besides, polyvinyl chloride (PVC) and polystyrene (PS) release toxic gases to the environment besides being corrosive due to reacting with the environment [15]. Posed with the above challenges in the varying properties that are inherent in most plastics, there are no clear guidelines in packaging and recycling process that ensures separation of thermostatic and thermoset plastics from the source [3]. Notably, Hopewell et al. (2009) contends that most plastic packaging may not be successfully recycled if collected at the end of life due to high toxic levels. In this regard, most designs are environmentally unfit for recycling thus finding their disposal streams channeled to the landfills, a factor that is constrained again by land availability [3]. Moreover, disparity in information is also considered a critical block to effective and economic recycling of plastic waste that may find use in the construction industry [3].

5. Conclusion

As the use of plastic in making several consumptive products designed for homes and industries is set to increase in the forthcoming years, plastic recycling gives positive promises on saving the marine and land environments from imminent pollution. The construction industry may particularly take advantage of the available technologies to make cost-effective and low thermal-conductor bricks that will be effective for making buildings in homes and schools. Several studies that have investigated the implicit
properties of plastic bricks have conjured that such bricks resulting from compression modelling to be lightweight, durable, of high compressive strength compared to commercial bricks, of good sound absorbing properties, and most importantly, low thermal conductivity. As such, the attributes, in addition to the fact that the materials used result in low cost construction, point to the need for use of plastic waste in making construction bricks. Besides, use of plastic waste will also protect non-renewable resources such as sand and clay from being over-used to the point of depletion. To the extent that methodologies used in making plastic bricks are cost effective and environment friendly, this paper finds that utilization of plastic waste for making construction bricks is not only economical but also environmental strategy of mitigating hazardous effects of improper disposal of plastic waste.

Acknowledgement
The work described in this paper was substantially supported by a grant from the Research Grants Council of the Hong Kong Special Administrative Region, China (UGC/FDS16/E05/19).

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