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Reusing Plastic Bottles Made of Non-Degradable Waste in Construction A Review

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ABSTRACT—

A larger portion of municipal solid trash is now made up of plastic bottles. While plastic bottles are practical, they also generate garbage that should not be in landfills. Plastic bottles don't biodegrade; therefore they hang around in the environment for a very long time. The trash PET bottles are regarded as urban trash with sustainability qualities that may be utilized as a material rather than certain conventional materials,. Recycling materials used in construction and the consumerism notion are given emphasis. However, for the building to be cost-effective and durable, appropriateness and durability are more crucial than its strength and local availability. The cost of the shelters will be significantly reduced by the use of locally accessible eco-friendly materials, creative design, and building techniques, in addition to improving the appearance and microclimatic conditions such as light and temperature within the shelter. This report discusses the use of plastic waste bottles in construction as bricks that are filled with compacted sand or mud and other materials, the method and technique of use, and their relative advantages over traditional bricks. This allows for the removal and secure reuse of plastic waste bottles for construction.

Keywords— municipal solid**,** plastic bottles**,** environmentally**,** sustainability**,** microclimatic**.**

I. INTRODUCTION

A resource that is not considered renewable is used to make plastics. Because plastic has the virtue of becoming insoluble. Polymers are incredibly long chain molecules joined together chemically to form plastics. It is regarded as a sustainable waste and environmental contaminant since it lasts for 500 years or more in nature, therefore its environmental effects can be lessened by reuse or recycling. The strength and durability of plastics have been demonstrated. Therefore, using plastic bottles as creative building materials might be appropriate. Housing is one of everyone's basic necessities, thus creating aesthetically pleasing, sanitary, cheap homes with the essentials for all social groups is a current concern. Recycling waste materials for construction purposes is becoming more and more important as a result of the use and throws away philosophy of consumerism. However, for the cost-effectiveness and longevity of the building built, appropriateness and durability in addition to its strength and local availability are more crucial. All humans have a basic need for shelter, so visually In addition to improving the appearance and microclimatic conditions within the shelter, locally accessible eco-friendly materials, creative design, and building techniques will significantly lower the cost of the shelters. Due to the fact that arches are load-bearing elements, numerous forms of arched openings may be investigated for use in building. The durability and longevity of plastics, two of their most favourable traits, enable the creation of goods that are very cost-effective over the course of their existence and require little upkeep (Almohana et al., 2022). Producing sustainable concrete with plastic waste. Plastics are a commonly available, affordable, lightweight, and adaptable material. Plastic is now widely used in our daily lives and production of it has increased significantly over the past 50 years. As a result, there is a rise in the production of plastic-related garbage, which threatens the ecosystem. This motivates researchers to utilise this waste as a sustainable material for producing concrete. However, the use of recycled plastic in concrete is a practical way to improve acoustic and thermal insulation, according to a recent study of the literature. The bulkiest and heaviest component of concrete, which accounts for 85% of its weight, is the aggregate. In addition, the plastic is less dense than the aggregate. Consequently, the The effectiveness of thermal and acoustic insulation in lightweight concrete is greatly increased when plastic waste is used as a partial substitute (50% to 75%) for the whole aggregate. Additionally, plastic can be easily placed and used with less labour due to its lightweight nature, and its manufacturing costs are significantly declining when compared to those of typical concrete. The creation of lightweight green concrete that may be utilised as a non-structural component in building construction may be regarded to typically utilise plastic waste as a raw material.

The durability and longevity of plastics, two of their most favourable traits, enable the creation of goods that are very cost-effective over the course of their existence and require little upkeep (Ragaert et al., 2017). In contrast to other materials, these characteristics make it such that people interact with plastics virtually everyday. These are the benefits The plastics sector will quadruple its production in the following ten to twenty years due to resources and the growing global population (Truchot et al., 2018). Then, 700 million tonnes of plastic will be produced overall. be generated by 2050, with Asia, North America, and Europe having the highest production rates (50%, 10%, and 16%), respectively. Furthermore, the buildup of plastics from many sources, including households and the packaging industry, on the surface of the Earth is referred to as plastic trash. Worldwide, over 6.5 billion tonnes of plastic garbage are produced year (Jnr et al., 2018). The Because most plastics are non-biodegradable and take more than 400 years to break down, an accumulation of plastic garbage causes environmental issues. According to Da Costa et al. (2016), in this situation, plastic trash is disposed of in landfills that need a lot of room, which eventually has an effect on the landfill site. Additionally, because of the prevalence of plastic garbage, marine ecosystems, biomes, and human health are now threatened seriously (Singh and Ruj, 2015). Studies have shown that the decomposition of plastic trash results in nanoparticles that are introduced to the food chain and have a detrimental impact on animal health in this respect (Prata et al., 2019). Furthermore, it is necessary to take actual action in order to lessen the environmental load. Recycling and incineration are currently the two major methods for reducing plastic waste (Eriksson and Finnveden, 2009; Jasim, 2017). Regarding the first, burning plastic trash can produce

Table 1

Mechanical characteristics of some of the most common plastic materials (Almohana., 2022; Euractive report on plastics).

Material	Specific Gravity	Tensile Modulus (GPa)	Tensile Strength (MPa)	Yield Strength(MPa)	Elongation at Break (%)
Polyethylene (low density)	0.92 - 0.93	0.17 - 0.28	8.3 - 31.4	9.0 - 14.5	100 - 650
Polyethylene (high density)	0.95 - 0.97	1.06 - 1.09	22.1 - 31.0	26.2 - 33.1	10 - 1200
Polyvinyl chloride	1.20 - 1.58	2.40 - 4.10	40.7 - 51.7	40.7 - 44.8	40 - 80
Polytetrafluoroethylene	2.14 - 2.20	0.40 - 0.55	20.7 - 34.5	–	200 - 400
Polypropylene	0.90 - 0.91	1.14 - 1.55	31.0 - 41.4	31.0 - 37.2	100 - 600
Polystyrene	1.04 - 1.05	2.28 - 3.28	35.9 - 51.7	–	1.2 - 2.5
Polymethyl methacrylate	1.17 - 1.20	2.24 - 3.24	48.3 - 72.4	53.8 - 73.1	2.0 - 5.5

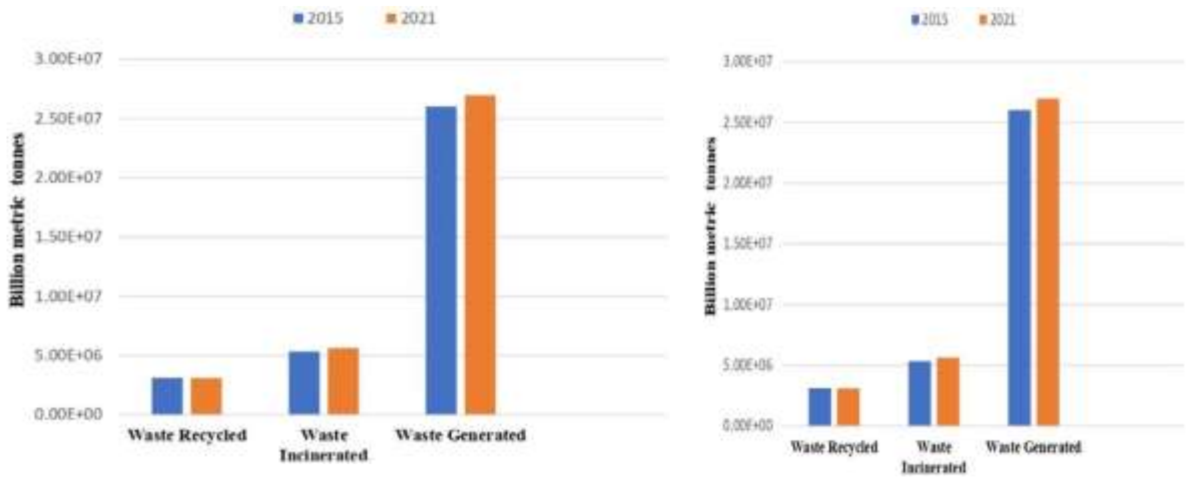

Fig. 1. Waste recycling and treatments estimation up to 2021 (Geyer et al., 2017; Sunil et al., 2020; Cestari and Sibele (Almohana et al., 2022).

II. Plastic waste in concrete

One way to address some of the issues with solid waste management is through the productive use of waste materials (Davis and Cornwell, 1998). Reusing trash is significant from a variety of perspectives. It lessens environmental pollution, aids in the conservation and sustainability of nonrenewable natural resources, and aids in the reuse and recycling of energy production processes. Wastes and industrial byproducts should be viewed as potentially valuable resources that just need to be treated and used in the right way. Plastic trash are some of these wastes; as they take so long to biodegrade, disposing of them has a detrimental impact on the environment; one obvious way to mitigate this is to use the materials in other sectors (Hassani et al., 2005). The advantageous use of these materials in building is made possible in large part by concrete. It's crucial to understand that not all waste materials are advantageous to integrate into concrete, either as aggregates or as a component of the cementitious binder phase. are some of these wastes, and disposing of them harms the materials that are appropriate for such usage (Anon., 2003). Microcracks and faults abound in concrete. The fast spread of microcracks under an applied stress is thought to be the cause of concrete's poor tensile strength. It is logical to anticipate that adding closely spaced fibres will significantly enhance both the tensile strength and the flexural strength of concrete. These fibres would stop microcracks from spreading, delaying the development of tensile cracks and boosting the material's tensile strength (Yin and Hsu, 1995). According to Banthia and Trottier (1995), fibre reinforced concrete performs better than its unreinforced counterpart because it has a better ability to absorb energy during fracture, whereas an unreinforced plain matrix fails in a brittle fashion at all instances of cracking stress. The term "toughness" is frequently used to describe this energy-absorbing quality of fibre reinforced concrete. Reina and Fowler (1996) discovered that reinforced polymer concrete (PC) made with unsaturated polyester resins based on recycled polyethylene terephthalate (PET) may achieve extremely strong flexural strength. Polypropylene is exclusively utilised as synthetic fibres to strengthen the durability of concrete, according to Soroushian et al. (1995). Hnslolu and Aar (2004) looked at the viability of adding polymer additives to asphalt concrete using different plastic wastes that contained high density polyethylene (HDPE). The findings show that bituminous binders treated with waste HDPE offer superior resistance to permanent because to their high levels of stability and Marshal Quotient; they also aid with the recycling of plastic trash and environmental preservation. De Assunço et al. (2004) employed sodium polystyrenesulfonate (NaPSS), which is made from old polystyrene cups, as an additive in concrete in previous studies. The outcomes shown that NaPSS may be used successfully as a plasticizer or as an additive to reduce water content in concrete. The Concrete slump increased by up to 300% when NaPSS was 0.3% of the cement weight. According to Tam and Tam (2006), technology is being developed that will allow construction materials to gradually include recycled plastic constituents to improve strength, durability, and impact resistance. Jo et al. (2006) looked at the mechanical characteristics of as well as the flexural and compressive strength of polymer concrete when utilising an unsaturated polyester resin derived from recycled PET, which helps to lower the material's cost and conserve energy. Pezzi et al. (2006) assessed the chemical, physical, and mechanical parameters of concrete using plastic material particles added as aggregate. The findings demonstrated that the inclusion of The mechanical properties of concrete are not significantly altered by the presence of polymeric components in fractions of less than 10% of the volume of the cement matrix.

Table 2

Physical and mechanical properties of plastic waste (Guendouz.et.al (2016) report on plastics)

Properties Plastic powder		Plastic fibers
Diameter (mm)	1.5	0.5
Length (mm)	/	4
Apparent density(kg/m3)	350	950
Bulk density (kg/m3)	450	1230
Fineness modulus	2.8	/
Young’s modulus (MPa)	1900	2400
Tensile strength (MPa)	45	60
Melting point(°C)	135	260

The problems with plastic

- Numerous aspects of our society are affected negatively by the increasing rate of plastic manufacture. It has an effect on human health, threatens our wildlife and oceans, and adds to waste and pollution problems.

***Waste and plastic* pollution**

- Every week, 10 billion plastic bags are used worldwide.
- Plastics don't degrade; instead, they break up and become a persistent pollution in our environment.

Health impacts

- There have been reports of micro plastics in food intended for human consumption. Up to 5 grammas of plastic could be consumed weekly by the average individual.
- Micro plastics have been discovered in human organs and the placentas of unborn children, and they may also be inhaled.
- Plastic food packaging contains toxic compounds including phthalates and BPA.

III. Literature review

Chaurasia (2019) to determine Heating and burning produce CO2 emissions that contribute to global A research was undertaken by Chaurasia (2019) to determine the advantages of employing municipal plastic waste in construction, with a particular focus on contrasting the behaviour of plastic waste bottle panels with brick, ceramics, and concrete blocks. A plastic waste bottle masonry wall and roof were built using dirt, plastic waste bottles, cement, nylon robe, and water as the primary components to create a sturdy, environmentally responsible structure and affordable construction. Additionally, a circular toilet construction with an interior diameter of 1000 mm, a height of 1450 mm, and a wall thickness of 270 mm was built. The study also involved building two (2 No.) hanging garden walls with dimensions of 4000 mm x 4000 mm using the same basic materials. A total of 825 people

Dhage-Niranjan et al. (2018), PET plastic bottles were utilised in place of traditional bricks. The process involved filling used plastic bottles from hotels, shops, and rubbish collectors with locally accessible sieved soil before sealing them with a tamping tool. The price and structural durability of the soil-filled used PET bottles compared favourably to the traditional clay-burned brick. In summary, it was noted that:

Safinia and Alkalbani (2016) With the primary goal of assessing the viability of using the plastic waste bottles as a substitute in the construction of concrete blocks, Safinia and Alkalbani (2016) conducted a study by employing plastic trash bottles in concrete blocks. Compressive strength tests were performed on conventional hollow concrete blocks with dimensions of 200200400 mm that were purchased from the market. Additionally, identical-sized concrete blocks that had vertically stacked plastic bottles implanted within them were made in accordance with ASTM C140 specifications and examined after 7, 14, and 28 days, respectively. After 28 days, the standard hollow blocks had an average weight of 20.08 kg and a compressive strength of 6.38 MPa, but the plastic bottle block had an average weight of 24.85 kg and a compressive strength of 10.03 MPa.

Mokhtar et al. (2016) on the use of plastic bottles as a wall construction for greenhouses as a substitute for other methods of lowering CO2 emissions. Sand was used in the experiment to fill old plastic bottles and was compressed using a tamping rod. Compressive characteristics, taking into account both indoor and outdoor temperatures, were identified and contrasted with conventional clay bricks. The plastic brick's maximum compressive strength was measured at 38.34N/mm2, which was almost three to four times more than the maximum value for ordinary clay bricks (8.58N/mm2). Additionally, an eco-house was built using both clay bricks and plastic bottle bricks. Similar findings are indicated by the internal and outside temperature readings taken from the eco-houses.

Fataniya et al. (2015) In order to test the compressive strength of cement masonry blocks substituted with used plastic water bottles with a 1000 mL capacity, Fataniya et al. (2015) undertook a research. The following four varieties of blocks, each 400 mm long, 200 mm wide, and 200 mm tall, were made to the identical dimensions.

Jalaluddin (2017) looked into the usage of plastic trash in novel ornamental materials (eco-friendly) and civil structures, and he came to the conclusion that PET bottle construction is a major component of plastic roadways. Implicit in the research's conclusions is the observation that by using plastic trash as a modifier, we may achieve a decrease in the amount of cement and sand by their weight, hence lowering the overall building budget. According to the study, modified concrete's strength was discovered to be higher than ordinary cement concrete at its optimal modifier amount of 5%.

Raghuchandra et al. (2017) set out to look at the use of plastic bottles as a sustainable building material. To this end, their research demonstrated that using recycled plastic bottles instead of bricks in walls could significantly reduce the amount of energy used to construct a building. This could also result in a decrease in the amount of CO2 released during the production of cement, which would decrease the amount of cement used. The construction sector has taken note of this as a result of their results. The bottle homes often have a bioclimatic design.

Mojtaba et al.(2013) concluded that utilising recycled plastic bottles as construction materials can significantly reduce the amount of energy required to manufacture cement by using them instead of bricks in the walls and lowering the amount of cement used overall. The architectural and construction industries are interested in it since it is one of the foundation's green projects. The bottle homes are often bioclimatically designed, which means that when it's cold outside, it's warm inside, and vice versa when it's hot outside. We may reduce the overall cost of building a house by 45% by using plastic bottles as the walls, joist ceiling and concrete column. When different cost factors are separated, it can be seen that employing local labour to create bottle panels can result in cost savings of up to 75% when compared to using brick and concrete blocks to construct walls.

Shilpi et al.(2013) concluded that thermal comfort may be attained in extremely inexpensive houses by employing recycled PET bottles in construction, benefiting inhabitants for those who cannot afford to acquire and run heating and cooling equipment. Plastic is not biodegradable, poisonous, the best insulator against heat and electricity, and it is not truly recyclable. PET bottles made of plastic are used in the bottle brick technique. Giving access to affordable and high-quality housing can help India's impoverished.

Puttaraj et al.(2014) Examined that effective use of waste plastic in plastic-soil bricks has led to effective use of plastic waste and can solve the issue of safe disposal of plastics, as well as avoid its widespread littering, and the use of quarry waste has reduced the issue of its disposal to some extent. Oil, a resource that is not considered renewable, is used to make plastics. Plastic is regarded as a sustainable waste because of its 300-year natural insolubility. and an environmental hazard. Reusing or recycling it can therefore be effective in reducing its negative effects on the environment. It has been established that using plastic bottles as cutting-edge building materials may be a viable alternative to traditional resources.

Pratima et al.(2014) In comparison to bricks, plastic bottle walls have been shown to be less expensive and to have superior strength. The non-recycled PET bottles wind up in landfills or as litter, and they take around 1000 years to decompose. This has led to plastic pollution issues, which are now getting worse along with the plastic bottle business, in landfills, waterways, and on the side of the road.

Arulmalar et al.(2014) The original view of using PET bottles in building is changing daily, according to research. Using PET bottle bricks instead of steel trusses and prefabricated metal sheet, a paradigm that first appeared in the building of load-bearing walls is now being used to flat roofs using nylon 6 in place of steel reinforcement and intuitive vault construction.6 Despite research on the efficient use of PET in creating new materials as a possibility, solutions It is important to look at the use of PET bottles as secondary elements such street furniture, road dividers, pavements, and other landscape elements as well as structural members, foundations, and retaining walls. The ruling bodies must

Vikram Pakrashi et al.(2015) Examined Eco-brick is a material that may be used for building with a variety of potential uses. Bricks may be made with regulated weight and packing reasonably simply. Eco bricks have compressive strengths that are comparable to those of standard concrete cubes, making them comparatively strong. It was shown that the weight of Eco-brick maintained a close connection with the load at failure and with specific strength. Eco-bricks possess a decent specific strength. Despite being light, they are sturdy enough to support the weight.

Andreas Froese et al.(2001) concluded that the bottles act like bricks and provide a framework for buildings or pillars when they are filled with soil or sand. Different sorts of walls with varied bottle sizes and orientations are constructed. Each wall's fracture behaviour and compression strength are tested and compared. When PET bottles are filled with sand, the least durable filler material, the walls may support up to 4.3 N/mm2. bottles support one-third of the load, whereas plaster two thirds of it. The space between each bottle is filled with cement- or clay-based plaster, and the home is finished off with a wood- or corrugated-metal roof. Because only locally produced goods are utilised, even low-income households may afford the dwellings. The technique has also shown itself to be quick to develop and earthquake resistant thus far.

Yahaya Ahmade et al.(2015) The interior of the building maintains a constant temperature of 18 degrees Celsius (64 degrees Fahrenheit), which is appropriate for tropical climates, and the construction has the extra benefit of being fireproof, bulletproof, and earthquake resistant.

Seltzer et al.(2016) revealed that William F. Peck's Bottle House in Nevada (USA) is the earliest known instance of a bottle-built structure. Around 1902, it was constructed, and it took 10,000 beer bottles to complete it. Glass bottles were employed as the main building material for these structures, and mortar composed of adobe, sand, cement, clay and plaster was used to bind the glass bottles together.

Job Bwire & Arithea Nakiwala et al.(2017) It has been suggested that baked bricks, tiles, concrete, and rocks, among other building materials, have all been necessary. Did you know, however, that a house made of plastic bottles may save you more money and be just as robust as or even stronger than brick homes? Innovative home made from water bottles aims to be affordable and help with environmental management.

V. CONCLUSION

From the aforementioned literature analysis, we learned that using novel materials with environmentally friendly applications, like plastic bottles, may have several advantages. These advantages include determining how to best optimize the region's energy usage and halting environmental damage. By recycling materials, reducing CO2 emissions, and conserving energy, plastic bottles may contribute to green building.

The study contends that managed handling of waste materials with a tiny particle size will lead to sustainable development. Plastic bottle blocks are less expensive to use for building walls than traditional bricks, and they also have more strength. With an increase in the waste plastic percentage at all curing ages, the compressive strength values of all waste plastic concrete combinations tend to fall below the values for the reference concrete mixtures. This may be explained by a weakening of the bond between the cement paste and the waste plastic's surface. Additionally, waste plastic is a hydrophobic substance that may prevent cement from fully hydrating. Due to pollution, plastic wastes have an effect on the ecosystem on a worldwide scale. The dispersal of this garbage into parks, rivers, and streets is a significant contributor to the degradation of water and soil, which harms both human health and the aesthetic appeal of cities. This motivates scientists to use plastic garbage to stop its spread. Researchers in civil engineering can concentrate on employing plastic waste in the production of concrete specifically.

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