An Innovative Approach on Pet Bottles Compiled with Waste Materials to Produce Eco-friendly Concrete

S Gunasekar¹, Dr. N. Ramesh¹, Parthiban P², Dr. S. Ramesh¹

¹ Department of Civil Engineering, K.S. Rangasamy College of Technology, Trichengode, India
guna.skr87@gmail.com

² Department of Civil Engineering, Jyothi Engineering College, Thrissur, Kerala, India
parthichevaux@gmail.com

Abstract: PET bottles, such as water bottles, cool drink bottles, and oil storage bottles, are becoming increasingly popular in India. Bottles used to package water take over 1,000 years to biodegrade and, if incinerated, contain poisonous gases. Recycling these PET bottles requires more attention however, this was also among the most famous effective ways to minimize waste. Only PET bottles, however, it's recyclable; all other bottles must be discarded. In fact, only 1 out of 5 containers are able to be sent to the recycle bin. The strength criteria was studied in PET bottles by filled up with different waste materials such as M-sand, Quarry dust, Fly ash, River sand and Construction debris. These filled bottles are inserted in concrete cube mould for minimising the concrete quantity and strength parameters were studied. Based on the experimental work, it was identified that, PET bottles having good compression resistance and also act as a filler material in concrete.

Key words: Compressive Strength Test, Concrete Cube, PET Bottles, Strength Properties, Waste Management, Waste to Wealth Concept.

1. Introduction

Plastic waste materials are a combination of semi-synthetic or synthetic organic substances. Plastic is usually a high-molecular-mass organic polymer, although it can also contain other chemicals. They're generally made synthetically, with the most frequent source being petrochemical products, but many are partially natural [1, 2]. Plastic items are now inextricably linked to human existence. While it brings convenience to human beings, there are also great health and environmental threats. The majority of plastic goods are polymer compounds formed by addition or condensation polymerization. If long-term usage plastic items are utilised, it will induce chronic poisoning in humans. Furthermore, because of the low production cost and short service life of plastic items, a huge amount of waste plastic is wasted each year, causing major environmental concerns. Traditional disposal processes like landfilling and incineration not only waste a lot of resources, but they also cause severe secondary environmental issues. Various recycling processes for waste plastics have been studied in order to produce economic and ecologically beneficial value-added goods that satisfy the demands of sustainable development and green environmental protection [3].

1.1. Waste Plastics from Various Sources

Plastics are a class of semi-synthetic organic molecules that are traditionally made from fossil fuels, however innovative bioplastics may also be made from renewable biomass. Plastics are very corrosion
resistant and easily flexible, allowing them to be moulded into any shape [4]. It’s possible to change their opacity, thickness, flexibility, and thermal characteristics with the right additions. It’s no surprise that plastic has been ingrained in human culture. The various sources of plastic waste generation are shown in Fig. 1.

![Wastes & their Source of Production](image)

Fig. 1. Various sources of Plastics in India. It shows the completer generation of waste plastics with its sources.

1.2. Plastic Identification Code

The various sources of plastic waste generation are shown in Fig. 2.

![Plastic Identification Code](image)

Fig. 2. Plastic Identification Code for various Plastics.

Various sources of Plastics in India. It shows the completer generation of waste plastics with its sources. The Plastics Industries Association (SPI) created the Resin Identification Code for post-consumer plastics in 1988 to promote recycling. It offered a reliable and consistent methodology to identify plastic bottles and containers' resin contents. Most of the plastic package includes six polymers such as polyethylene terephthalate (PET or PETE), high polyethylene density (HDPE), polyvinyl chloride (PVC or vinyl), polypropylene (PP) and polystyrene (LDPE) (PS). In addition, there was a seventh, "other" code in this system. The above-mentioned product is made of a resin different than the six above [5, 6].

1.3. Specification of PET Bottles

Thermoplastics and thermoset plastics are the two main types of plastics used in everyday life. Thermoplastics soften when heated, whereas thermoset plastics harden, keeping the original shape. Soft drink bottles and PVC pipes, for example, are thermoplastics, but electric kettles, plugs, and other thermoset plastics are thermoset [7]. Thermoplastics account for the great bulk of global plastic use, and they may be categorised as indicated in Table 1.

1.4. Research significance

The necessity for scientific disposal of waste plastics has been recognised since the 1980s, and numerous attempts to discover acceptable techniques of plastic waste management have been made since then. As an alternative to landfill incineration (while taking care to suppress the ensuing hazardous gases and chemicals) and recycling, there are now two major techniques for handling plastic wastes. Burning plastics is severely discouraged since it releases harmful chemicals such as furans, mercury, dioxins, and polychlorinated biphenyls into the atmosphere. When PVC is burned, it
releases harmful halogens and CO₂, polluting the air and contributing to global warming. Second one is to finding the alternative use of PET Bottles in construction industry.

Table 1. Specification and Properties of PET Bottles.

| Particulars                                | Specifications                                                                 |
|--------------------------------------------|-------------------------------------------------------------------------------|
| Molecular Basic Formula                    | (C_{10}H_{8}O_{4})_n                                                          |
| Density limit                              | 1.4 g/cm³ (20°C), crystalline: 1.455 g/cm³, amorphous: 1.370 g/cm³            |
| Melting Maximum Point                      | 250°C                                                                         |
| Solubility condition in Water              | Practically Nil (Insoluble)                                                   |
| Thermal Property (Conductivity)            | 0.15 - 0.24 W m⁻¹ K⁻¹                                                        |
| Refractive Limit (Index) (ηD)              | 1.57 to 1.58                                                                  |
| Tensile Strength (σt)                      | 55 – 75 MPa                                                                   |
| Young’s Modulus (E)                        | 2800 – 3100 MPa                                                               |
| Notch Test                                 | 3.6 kJ/m²                                                                     |
| Elastic Limit                              | 50 – 150 %                                                                   |
| Glass Temperature                          | 75°C                                                                          |
| Linear Expansion Coefficient (α)           | 7x 10⁻⁵ / K                                                                   |
| Vicat B                                    | 170°C                                                                         |
| Water Absorption (ASTM)                    | 0.16                                                                          |

1.5. Need of the study
The disposal of waste plastic is a major problem and it is non-biodegradable. So, it is mandatory to think of an alternative [9]. In addition to that, burning of waste plastic causes environmental pollution [2]. It consists mainly of low-density polyethylene which never decomposes [9]. So, it is necessary to choose an alternate. Bottles may be used to replace bricks, which is a good way to recycle plastic. Bottles offer a number of benefits over bricks and other building materials. The cost of a bottle is much less. The outstanding property of bottles is that they are non-brittle and re-usable. They can take on large weights without breaking since they are not fragile. Thus, they can take up shock loads and are much easier to build.

2. Materials Properties and Preparation of Specimens
The various materials used for entire research work are M-Sand in table 2, Quarry Dust in table 3, River Sand in table 4, Fly ash and Construction Debris in table 5 [8]. The various materials properties are listed below and various results for compressive strength of PET Bottles compiled with various waste materials are shown in fig. 3.

2.1. M-Sand

Table 2. Crushing strength of the PET bottles filled with M-sand.

| Bottle ID | Weight (Kg) | Load (kN) | Area (mm²) | Crushing Strength (N/mm²) |
|-----------|-------------|-----------|------------|---------------------------|
| Bottle 1  | 1.282       | 269       | 14600      | 18.42                     |
| Bottle 2  | 1.284       | 280       | 14600      | 19.17                     |
| Bottle 3  | 1.280       | 274       | 14600      | 18.76                     |
2.2. Quarry Dust

Table 3. Crushing strength of the PET bottles filled with quarry dust.

| Bottle ID | Weight (Kg) | Load (kN) | Area (mm$^2$) | Crushing Strength (N/mm$^2$) |
|-----------|-------------|-----------|---------------|-----------------------------|
| Bottle 1  | 1.153       | 190       | 14600         | 13.01                       |
| Bottle 2  | 1.169       | 213       | 14600         | 14.58                       |
| Bottle 3  | 1.162       | 204       | 14600         | 13.97                       |

2.3. River sand

Table 4. Crushing strength of the PET bottles filled with river sand.

| Bottle ID | Weight (Kg) | Load (kN) | Area (mm$^2$) | Crushing Strength (N/mm$^2$) |
|-----------|-------------|-----------|---------------|-----------------------------|
| Bottle 1  | 1.118       | 111       | 14600         | 07.60                       |
| Bottle 2  | 1.107       | 103       | 14600         | 07.05                       |
| Bottle 3  | 1.115       | 107       | 14600         | 07.33                       |

2.4. Construction Debris

Table 5. Crushing strength of the PET bottles filled with construction debris

| Bottle ID | Weight (Kg) | Load (kN) | Area (mm$^2$) | Crushing Strength (N/mm$^2$) |
|-----------|-------------|-----------|---------------|-----------------------------|
| Bottle 1  | 1.105       | 352       | 14600         | 24.10                       |
| Bottle 2  | 1.112       | 363       | 14600         | 24.86                       |
| Bottle 3  | 1.109       | 357       | 14600         | 24.45                       |

2.5. Comparison of Crushing Strength

Fig. 3. Various results for compressive strength of PET Bottles compiled with various waste materials.
2.6 Comparison of Crushing Strength of Conventional brick with PET bottles filled with Construction debris

The selected 250 ml PET bottles were filled up with construction debris and placed in the loading plate of the UTM [10] for crushing strength test and the results are tabulated in Table 6.

Table 6. Comparison of Crushing Strength of Conventional brick with PET bottles

| Material            | Crushing Strength (N/mm²) |
|---------------------|---------------------------|
| PET Bottles         | 24-25                     |

3. Mortar Cubes and PET Bottle Cubes Preparation

The following fig. 4 (a) and (b) images shows that the activities of preparation of specimens such as concrete cubes with PET Bottles compiled with waste materials [11].

![Fig. 4 (a) and (b) Explains the reparation of specimens with and without PET Bottles.](image)

4. Results and Discussion

The engineering industry's utilization of plastic waste for building purposes has a significant potential for reducing global ecological contamination and pollution [13, 14]. PET Bottles can be recycled and used for construction purposes. Thus, PET bottles were used in our project with filler materials inside, replacing bricks. Three soft drink bottles [12] of the same kind were filled with construction debris, river sand, M sand, quarry dust and fly ash with partial replacement of sand. The crushing strength of the bottles was determined and it was found that construction debris filled bottles gave a higher value [15]. The various results arrived during the research are listed below in table 7.

Table 7. Crushing Strength Test

| Cube ID                  | Crushing Strength (N/mm²) |
|--------------------------|---------------------------|
|                          | 7 Days   | 14 Days | 21 Days |
| C C (Conventional Mortar cube) | 4.37     | 5.73    | 6.87    |
| PET C (PET Bottle Cubes)  | 5.79     | 6.19    | 7.45    |
| PET B (PET Brick)         | 4.63     | 4.94    | 5.23    |

The following Fig. 5 shows the results of Comparison of Crushing Strength Values of concrete cubes filled with PET bottles.
5. Conclusion

Polyethylene terephthalate (PET) bottles have a wide range of applications in every walk of life including feeding bottle of babies, storage containers, drinking water bottles etc. These can be recycled by using these construction purposes. Thus, PET bottles were used in our project with filler materials inside, replacing bricks. Three soft drink bottles of the same kind were filled with construction debris, river sand, M sand, quarry dust and fly ash with partial replacement of sand. The crushing strength of the bottles was determined and it was found that construction debris filled bottles gave a higher value.

From the results, it was found that,

1. The bottles filled with construction debris had given a higher value of crushing strength. Thus, the value of crushing strength of a PET bottle filled with construction debris would be 24 MPa to 25 MPa which is three times higher than the conventional bricks crushing strength with a value of 8 MPa to 9 MPa. Among the five materials, construction debris filled PET bottles proved to withstand a heavier stress.

2. The crushing strength of PET bottle cubes showed 7.45 N/mm$^2$ which is 1.08 times greater than the crushing strength of conventional mortar cube.

Finally, it was concluded that pet bottles filled with construction debris gave better resistance to higher stress and exhibited more compressive strength. Besides, the structure built with PET bottles has an added advantage of being fireproof and earthquake resistant.

Only a few research have looked at the impact of plastic particles in concrete. This research has aided in the knowledge of how to reduce the number of raw materials used in concrete. The impacts of varying percentages of plastic fibre additions and material composition in concrete mixes should be investigated in future study. In addition, more research is needed to see if the same effects occur in various plastic forms.

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