Utilisation of PET plastic waste and construction demolition wastes in manufacturing of bricks

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ABSTRACT
The use of waste PET plastics in bricks is a partial solution to the environmental and ecological challenges associated with the use of plastics. The aim of this research is to reduce environmental pollution by using waste PET bottles and construction demolition waste to produce bricks. In this study, PET bottles were first used to replace clay in the production of bricks. The polymeric material was first shredded and melted in an aluminium container at a temperature range of 250ºC - 260ºC and the sand were added in their respective ratios. In another set of studies, the construction and demolition waste materials were used as a partial replacement for sand in the manufacturing of bricks. The test will be carried out which involved the effect of sunlight on bricks, water absorption, compressive strength, efflorescence test, heat resistance test, chemical characteristics of plastic sand bricks using XRD test and leachate resulting from rain of final brick. PET bonded sand with C&D waste is a strong, tough material with compressive strengths up to 19.0 MPa, 17.4 MPa and 21.64 MPa when produced under optimum processing conditions. The plastic C&D waste sand bricks have low alkali content and so a little white patch is formed over the surface.

Keywords:
PET (Poly Ethylene Teryphthalate) Plastic, Sand, Construction and Demolition Waste, Plastic-Sand Bricks, XRD test.

I. INTRODUCTION

Plastic is a part of daily rise of useful and also a hazardous material. During the necessity, plastic very beneficial, but after it is discarded, usually creating all kinds of hazards. Plastic is non-volatile material that remains as a hazardous over centuries. The amount of plastic waste in Municipal Solid Waste (MSW) is increasing rapidly. It is believed that the growth rate is double every 10 years.

This rate of expansion is due to rapid population growth, urbanization, developmental activities and lifestyle oriented. Every year around 40 million tons of solid waste has been set up in India, with an estimated 1.5-2% annual growth rate [8]. About 8 million tons of plastic products are used every year in India [8]. Considering that 70% of total plastic consumption is considered to be about 5.6 million tons of waste per year of plastic waste produced in the country, which is about 15,342 tons per day [8].

Solid waste management is one of the most important environmental concerns in India. Landfills are becoming scarce and the cost in building landfill sites are increasing.

Expanded polystyrene (EPS) based waste, high density polyethylene (HDPE), polyethylene terephthalate (PET) waste bottles, polypropylene fibres and polyethylene bags have all been used in different forms by researchers in bricks. PET plastic is one major component of Municipal Solid Waste (MSW) which is becoming a main research issue for its possible use in manufacturing bricks. Polymer modified bricks has applications in road construction and buildings.

Building construction and demolition activities consume about 50% of raw materials and account for 33% of 900 million tons of waste generated because of these materials in India every year [8]. There is no particular composition of Construction and Demolition Wastes (CDW) because is differs depending on the type of structure and/or demolition process. Generally CDWs include: (1) concrete structure, (2) bricks, ceramics from floors, roofs and partition walls and, (3) in smaller quantities than other materials like glass, wood, plasterboard, asbestos, metals, plastics or hazardous materials [21]. Generally, these wastes are dumped in the garbage dump without any recovery or reuse, leading to major economic and environmental problems.

There is great potential for reuse and recycling of CDWs because most of its components can be of high cost. Since the various materials need their specific ways for their valorisation, the most effective management systems is the use of appropriate waste demolition techniques combined with recycling and re-use. In this way glass, wood, asbestos, metals, plastics, hazardous materials, etc. can be removed, which produces most of the waste particles with concrete and masonry. The waste materials can be recycled into Recycled Aggregates (RA) for use in place of Natural Aggregates (NA) [21].

In this study waste PET plastic bottles found on BVM campus and construction demolition waste were shredded into flakes and was used in the production of bricks.

II. MATERIALS AND METHODS

PET plastic and construction demolition waste from Surat Municipal Corporation were used in these experiments. PET is a resistant material that can be molded and is repeatedly processed under heat. It is a flexible material because there are many different chains that increase the distance between the main chains of C-C, reduce the packaging and attract the molecules.

The commercial river sand with a density of 2.65 $g.cm^{-3}$ was used as fine aggregates and sand was sieved with a standard sieve of 1 mm.

Waste materials, including construction and demolition waste were collected from the local demolition site of Surat Municipal Corporation. Concrete and masonry waste was separated from waste that can be recycled, i.e., steel, plastic and other things at the

source or at disposal site. The larger sizes of collected C&D waste were crushed manually to small particles. Crushed material was screened with standard sieve of 1 mm size.

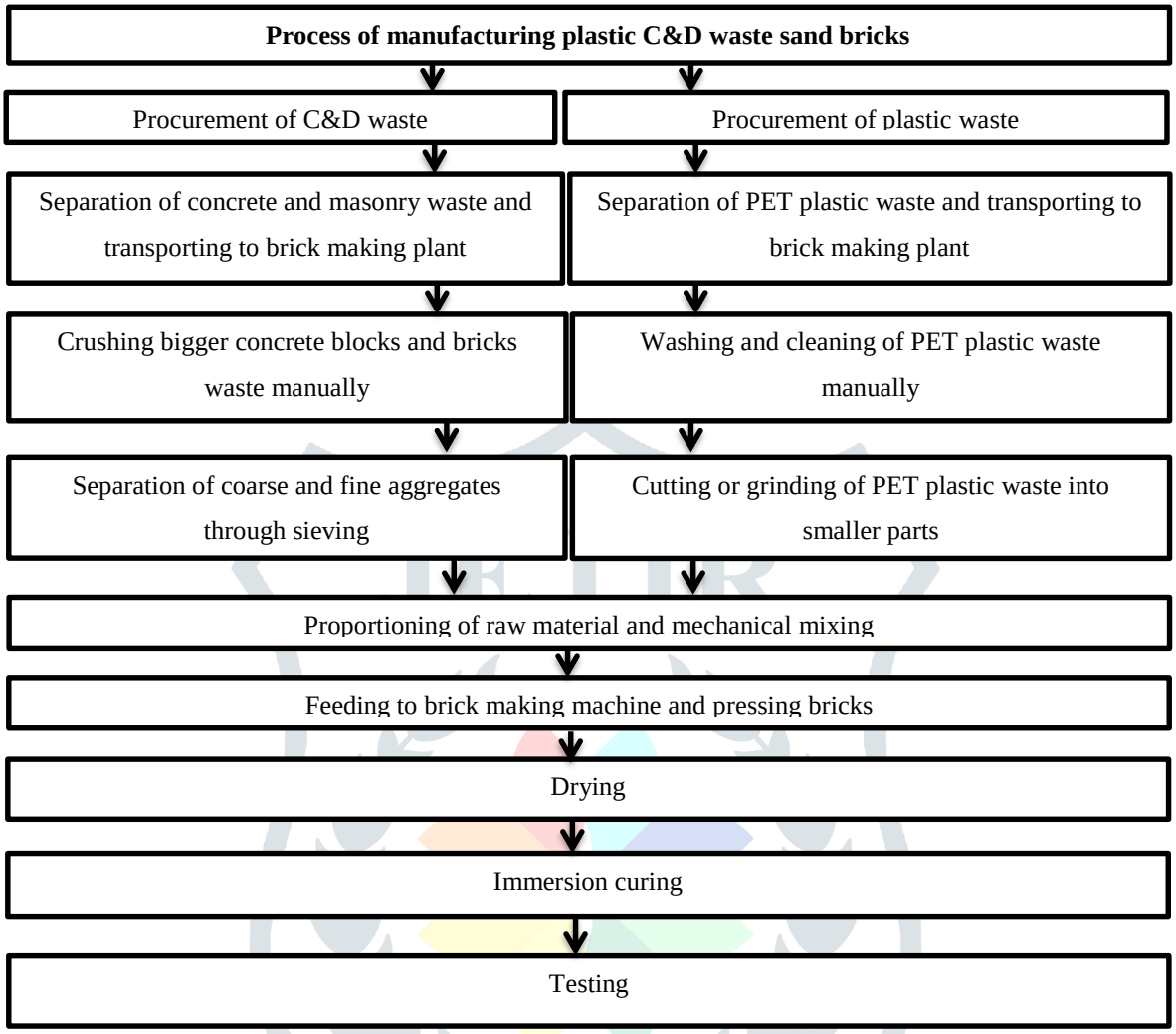


Figure 1: process of manufacturing of plastic C&D waste sand brick.

1. MIX DESIGN

To find the modified bricks with highly compressive strength, various mix proportions are made and tested using compressive testing machine [CTM]. In this study two mix designs were prepared with three different materials. The first mix proportions were in the ratio of (1:1, 1:2, 1:3, 1:4, and 1:5). These are the proportion of PET plastic waste and river sand respectively. The second mix proportions were in the ratio of (0%, 25%, 50%, 75% and 100%). These are the ratio which represents the construction & demolition waste material, river sand respectively.

Table: 1 Mix designs of PET plastic and sand

Sr. No.	Designation	Ratio	Sand Particle size (d)	Percentage Replacement of sand with plastic (%)
1	PS50.00	1.1	d<1.00mm	50.00
2	PS66.70	1.2	d<1.00mm	66.70
3	PS75.00	1.3	d<1.00mm	75.00
4	PS80.00	1.4	d<1.00mm	80.00
5	PS83.30	1.5	d<1.00mm	83.30

Table: 2 Mix designs of PET plastic, sand and C&D waste

Sr. No.	Designation	Ratio	Sand Particle size (d) (mm)	Percentage Replacement of CDW with sand (%)
1	P25S75CDW0	1:3:0	d<1.00	0
2	P25S56.25CDW18.75	1:2.25:0.75	d<1.00	25
3	P25S37.5CDW37.5	1:1.5:1.5	d<1.00	50
4	P25S18.75CDW56.25	1:0.75:2.25	d<1.00	75
5	P25S0CDW75	1:0:3	d<1.00	100

2. BATCHING

The waste PET bottles are cleaned with water and dried to remove the excess water present inside the PET plastic. The river sand and C&D waste are sieved by using 1 mm sieve as a fine aggregate. The sand, C&D waste and the PET plastic bottles are weighed in different proportions. Then the PET plastic bottles for melting process are taken.

3. MELTING OF PLASTIC

After batching the PET plastic bottles, wastes were taken for melting process that was thrown into the container and allowed to melt at 250^0 C. The first step of melting process is related to the arrangement of the container and the fuel required. The container is placed over the setup and heated to remove the excess moisture which present in the container.

4. MIXING

Mixing of materials is important for uniform production and brick reinforcement. Mass should be homogeneous, uniform in colour and consistent. Generally there are two types of mixing, Hand mixing and machine mixing. For this project work, I adopted hand mixing for production of modified bricks. PET plastic bottles are added once a time into the container while adding all the plastic content needed to make a modified bricks from a mixture. The mixture has very short setting time. When PET bottles are turned to molten state; the river sand and construction demolition waste are added to the container. Sand and C&D waste are added during mixing period. Therefore, mixing process should not consume more time and to save fuel consumption.

5. MOULDING

The mixture was poured into the brick mould. The mixture was compacted by using tamping rod or steel rod and the surface of brick was finished with trowel. The sides of the mould are lubricated until the bricks are removed easily before placing in the mould. The mould was removed after 24 hours. The mould was in uniform shape and the size of the mould which used for a design was 230×100×75 mm. The mould were installed and placed on the base plate.

6. CURING

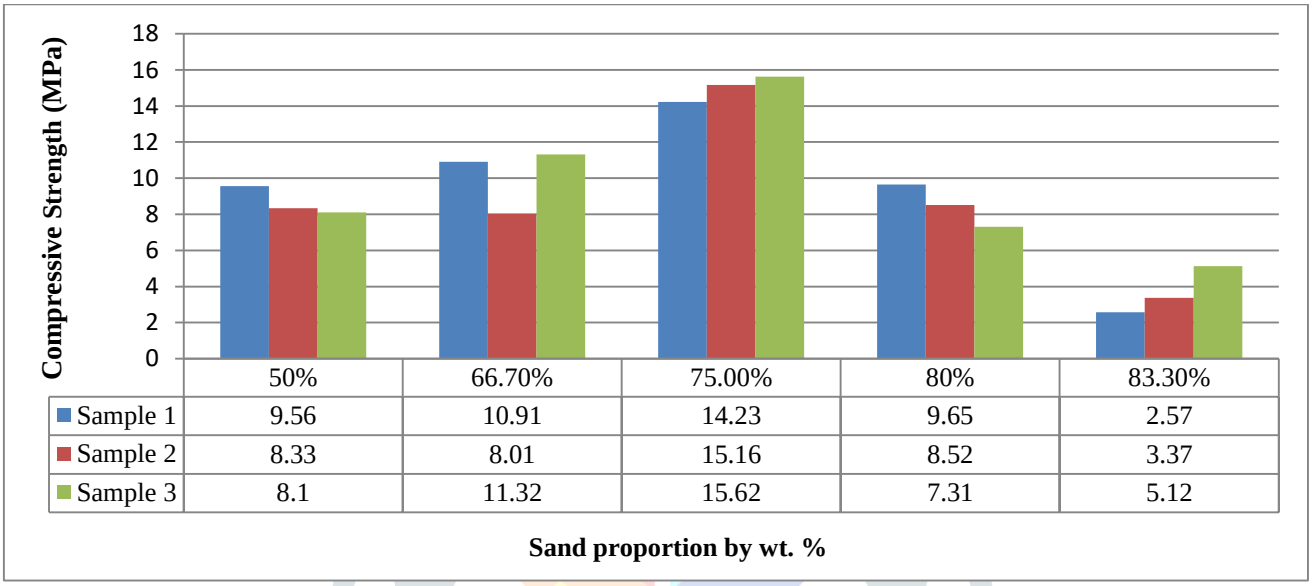
The test specimens were allowed to dry for 24 hours. These specimens were reserved in ordinary solid curing containers and allowed to cure for 7, 14 and 28 days.

Figure 2: Modified bricks

III. RESULTS

1. COMPRESSION STRENGTH

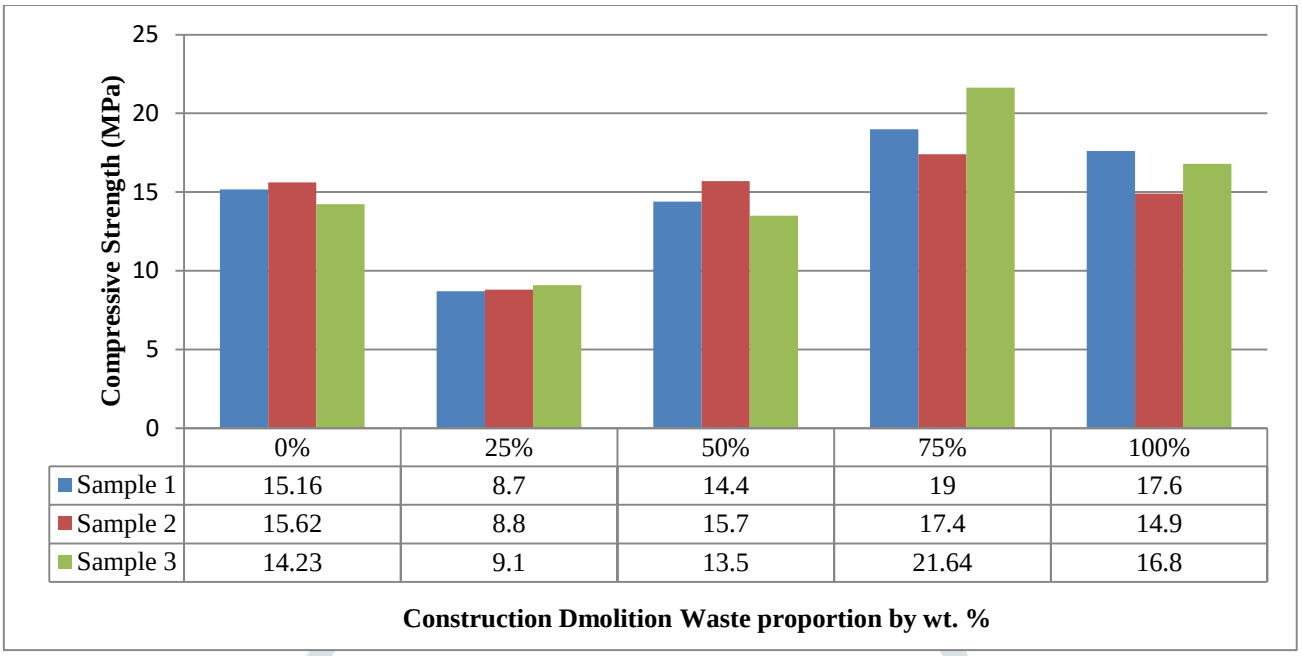
For each mix of modified bricks, a set of three specimens were tested for compressive strength. Test was carried out as recommended by IS 3495(1). Dimensions of modified bricks were measured to the nearest 1 mm and recorded for test. Samples were immersed in water for 24h at room temperature. After removal of the specimens from water, excess moisture was removed from the surface. Then the surfaces of the modified bricks were filled with cement-sand mortar (1:3). Sample of modified bricks were stored under the damp jute bags for 24h and then immersed in clean water for 3 days. Excess moisture was wiped off, before testing, the samples. Then samples were placed in compression testing machine and load was applied axially at a uniform rate. Maximum load at failure was recorded. The compressive strength determined using compression testing machine for the specimens is shown in fig. (3) and fig. (5).



	50%	66.70%	75.00%	80%	83.30%
Sample 1	9.56	10.91	14.23	9.65	2.57
Sample 2	8.33	8.01	15.16	8.52	3.37
Sample 3	8.1	11.32	15.62	7.31	5.12

Figure 3: Compressive strength of bricks with proportion of PET plastic and sand

Figure 4: Modified brick sample showing the development of the shear plane in sample.

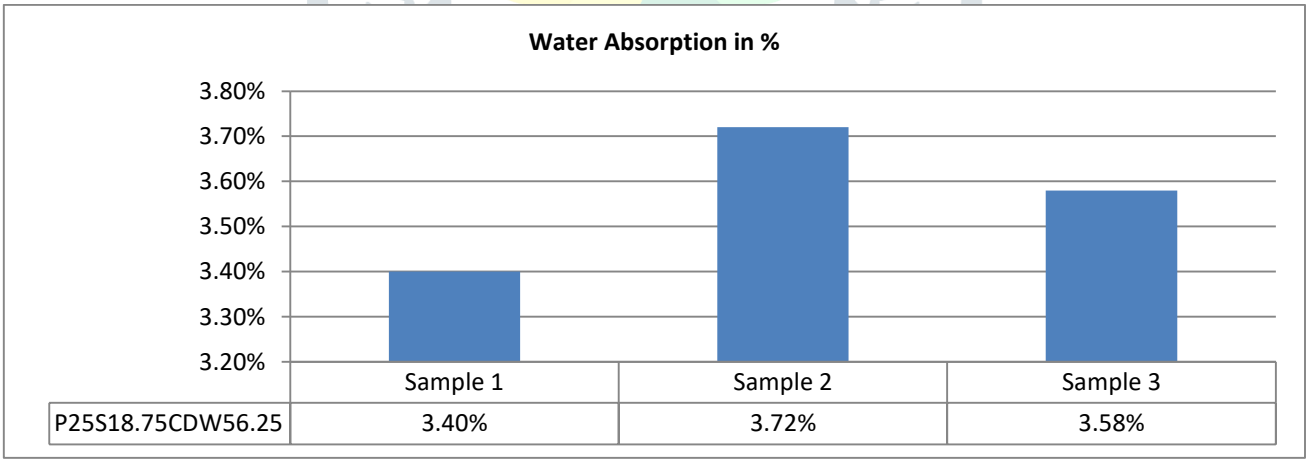


	0%	25%	50%	75%	100%
Sample 1	15.16	8.7	14.4	19	17.6
Sample 2	15.62	8.8	15.7	17.4	14.9
Sample 3	14.23	9.1	13.5	21.64	16.8

Figure 5: Compressive strength of bricks with proportion of PET plastic, sand and C&D waste

2. WATER ABSORPTION

Water absorption testing was carried out as per IS 3495(2). Three samples of modified bricks were tested for water absorption. These specimens were dried in a ventilated oven at a temperature of 105˚C to obtain constant mass. After that samples are cooled to room temperature and weighed (w1). To find out the wet weight of modified bricks the completely dried specimens are immersed in clean water at a temperature of 27±2˚C for 24h. then the specimens of modified bricks are removed and traces of water are cleaned with a damp cloth and weighed (w2). Water absorption was calculated for a modified bricks as the percentage reduction in weight w2 over weight w1. Water absorption of bricks with proportion of P25S18.75CDW56.25 is shown in fig (6).



	Sample 1	Sample 2	Sample 3
P25S18.75CDW56.25	3.40%	3.72%	3.58%

Figure 6: water absorption of modified bricks

3. EFFLORESCENCE

The efflorescence of modified bricks was evaluated according to IS 3495(3). For this test, the brick should be upright in water with one end. The depth of immersion in water is 2.5 cm and all the arrangement should be kept at room temperature of 20-30o C until they evaporates. When the water is completely absorbed and evaporated from the plate, put the same quantity of water in dish and allows it to absorb and evaporate as before. After examine, the plastic C&D waste sand bricks (modified brick) have low alkali content and so a little white patch is formed over the surface. Fig. (7) shows the effect of effloresce on modified bricks.

Table 3: Effect of efflorescence on bricks

Ratio of PET plastic, sand and C&D waste	Effect of efflorescence
1:3:0	Slight
1:2.25:0.75	Slight
1:1.5:1.5	Nil
1:0.75:2.25	Slight
1:0:3	Nil

Figure 7: Modified brick sample showing the effect of effloresce.

4. HEAT RESISTANCE TEST

The plastic is highly susceptible to fire but in case of plastic C&D waste sand bricks the presence of sand and C&D waste impart insulation. There was no change in the structural properties of modified bricks up to 180˚C but above this temperature visible cracks was seen and also the strength reduced with increased in temperature.

5. SUNLIGHT EFFECT

To show the effect of sunlight on modified bricks, 3 numbers of bricks were put in direct contact with sun for 3 months. There was no deformation or crack formed by sunlight and there was no variation in compressive strength.

6. LEACHATE RESULTING FROM RAIN

Two identical tanks were used for the test, one with brick and one without brick. The one without brick gives background values of pH and pollutants in water without presence of the brick. Both tanks were aerated with an air stone diffuser and an air pump for 30 minutes prior to the start of the test to dissolve carbon dioxide from air to simulate rain water. The pH of the water of both tanks was measured using a conductivity probe as shown in table(3). The tanks were continuously aerated for 5 days with loss of water due to evaporation made up by adding distilled water to maintain the set volume. The test ended after 5 days. Samples of water were collected at 0hr, 20hr and 120hr. The samples were sent for metal analyses to a local laboratory. The metals measured include Hg, Cd, Cr, Ag, Ni, As, Ba, Pb, Se and Zn in table (4). Total conductivity and pH of the water was also measured at 0 and 120hr.

	Sample of water with brick (A)	Sample of water without brick (B)

	0hr	120hr	0hr	120hr
TDS (ppm)	2.0	101.5	1.4	5.2
pH	5.6	6.9	5.5	6.72

Table 4: Total conductivity and pH of water samples

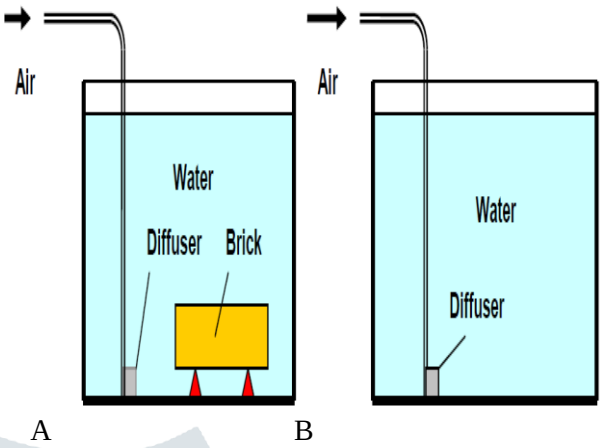


Figure 8: Apparatus for testing simulated rain water leachate from brick

Table 5: Heavy metal test by (Instrument ICP-OES)

Test parameters	Sample A (mg/L)	Sample B (mg/L)	Instrument detection limit (mg/L)
Mercury	BDL	BDL	0.0610
Chromium	BDL	BDL	0.0071
Nickel	BDL	BDL	0.0150
Barium	0.0213	BDL	0.0040
Selenium	BDL	BDL	0.0750
Cadmium	BDL	BDL	0.0027
Silver	BDL	BDL	0.0070
Arsenic	BDL	BDL	<0.053
Lead	BDL	BDL	0.042
Zinc	0.0067	BDL	0.0059

7. CHEMICAL CHARACTERISTICS OF PLASTIC SAND BRICK USING XRD TEST

Table 6: Chemical characteristics of plastic sand brick using XRD test

Sr. No.	**Angle**	**d value**	**FWHM**	**Rel. intensity**	**Intensity**	**Chemical present**	**h k l value**
1.	20.913˚	4.2443Å	0.196	30.3%	14348.210	SiO_2	1 0 0
2.	26.688˚	3.33758Å	0.167	100.0%	47414.800	SiO_2	1 0 1
3.	36.629˚	2.45138Å	0.198	16.8%	7982.165	SiO_2	1 1 0
4.	43.228˚	2.09121Å	0.800	2.2%	1030.330	MgO	2 0 0
5.	71.431˚	1.31954Å	0.276	1.9%	916.622	$CaSO_4$	2 2 4
6.	29.962˚	2.97987Å	0.497	10.9%	5185.646	Fe_2O_3	2 2 0
7.	59.999˚	1.54062Å	0.233	12.9%	6132.190	Al_2O_3	1 2 2

IV. CONCLUSION

On the basis of result obtained during the experimental investigation, following conclusion was drawn:

1. Making bricks from sand, PET plastic waste and C&D waste can be an alternative to the available traditional clay bricks.
2. The re-use of C&D and PET plastic wastes in the development of new building material addresses the issue of solid waste management and contributes to the growing demand for building materials in a sustainable way.
3. Modified bricks have lower water absorption which is 3.40%, 3.72%, and 3.52% when compared with those of normal clay bricks.
4. With an increase in the proportion of PET plastic waste up to 25% and C&D waste up to 75% with sand gives maximum compressive strength.
5. Modified bricks composition P25S18.75CDW56.25 have higher compressive strength (19.0, 17.4, 21.64 MPa) than normal clay bricks.
6. From the water absorption test results of modified bricks it is observed that the water absorption also decreases with increase in percentage of plastic content.
7. Modified bricks can help reduce the environmental pollution thereby making the environment clean and healthy.
8. The plastic C&D waste sand bricks (modified brick) have low alkali content and so a little white patch is formed over the surface.
9. Rain causes negligible amount of leachate of pollutants (heavy metals) from modified bricks. Modified bricks immersed in rain water for 5 days cause little pollution to rain water. The water is still so pure that it passes the EPA standard for drinking water quality. This should alleviate any concern that modified bricks cause water pollution.

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