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Use of Waste Plastic Bottles (PET) as a Construction Material

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Abstract : Concrete masonry units can be of conventional brick, fly ash bricks, solid and hollow concrete blocks which are made of raw materials available which are obtained from natural resources. Over exploitation of these natural resource leads to environmental problems. On the other hand use of plastic bottles (PET) is quite increasing. Plastic bottles are difficult to reuse, recycle and non-biodegrade and hence creates an environment issue [1]. To overcome the above problems of over exploitation of natural resources and environmental issue due to the use of non bio-degradeable plastic bottles, attempt has been made to use plastic bottles in concrete masonry units and such innovative concrete masonry blocks are called as Plastic Bottle Blocks.
Keywords : plastic wastes; plastic bottle blocks; PET.

1.0 Introduction

A. Exploitation of natural resources

Natural resources are the resources that occur in nature and exist without the actions of mankind. Among the natural resources, land resources are depleted more mainly for construction activities. A typical concrete mixture consists of 30 to 35 percent sand and 45 to 50 percent gravel. Growth in the construction industry has increased demand for aggregates to be used in concrete. As the land based aggregate sources diminish, marine sand reserves become increasingly exploited.

B. Non- biodegradable plastic bottles

Plastics are mainly highly polymerized compounds consisting of carbon and hydrogen, made from substances such as petroleum and natural gas. Plastic has become the most common material since the beginning of 20th century and in modern life plastic has become an essential material. The various forms of plastics present in the earth namely plastic bottles and tubes, packs and caps, foil-type plastics, such as grocery bags and large fibre bags etc.

Out of the various forms, plastic bottles are commonly used with the commercial name “Polyethylene terephthalate (PET)” bottles. PET bottles are used for storing carbonated beverage and water. After its use the PET bottles becomes as a waste and it should be disposed in proper manner. But there is an environmental issue as waste PET bottles are difficult to reuse, recycle and biodegrade.

Problems in reuse

The earthquake forces developed at different floor levels in Bacteria from user’s hand and mouth accumulate when the bottle is not washed between repeated uses. Repeated hot water washing and handling of

PET bottles may breakdown the plastic, leaching toxic compounds such as DEHA in to the beverages. This results in potential health risk due to high bacteria levels found on the bottle and leaching of plastic compounds in to the beverages.

Problems in recycling

The earthquake forces developed at different floor levels in Recycling represents a potential means of reducing the negative environmental impact of plastic disposal. However, presently, only a very small percentage of plastic is actually recycled. Approximately 15 to 27 percent of PET bottles are recycled annually. Following are the problems occurred in recycling PET bottles.

- Major chemicals that are used in making plastic are highly toxic and are a serious threat to living beings. Therefore recycling of PET bottles is a hazard which put back toxic waste in the market place and eventually in to the environment.
- Recycling of PET bottles is uneconomical, dirty and labour intensive.
- Recycling cause skin and respiratory problem resulting from exposure to inhalation of toxic fumes due to hydrocarbons and residues released during process.
- A recycled PET bottle degrades in quality and necessitates the production of more new PET bottle to make original product.

Problems in disposal

The major problem with disposing of plastic is that it is non-biodegradable. The reason behind this is that the plastic is so durable and hence it differs from biodegradation of paper and organic substances. Plastic photodegrades, which means that the sun breaks plastic down into smaller pieces of plastic, rather than down to the basic elements which make up the plastic. Combined with the fact that plastic is non- biodegradable, this makes the presence of plastic in landfills a critical issue. Plastic accounts for approximately 25 percent of all refuse in landfills. This fact alone makes the disposal of plastic a major problem.

2.0 Effective use of Pet Bottles in Construction

Earthquake causes shaking of the ground. So a building resting on it will experience motion at its base. Though the base of the building moves with the ground, the roof has a tendency to stay in its original position as shown in Fig. 3. But since the walls and columns are connected to it, they drag the roof along with them. This tendency to continue to remain in the previous position is known as inertia. In the building, since the walls or columns are flexible, the motion of the roof is different from that of the ground. The inertia force experienced by the roof is transferred to the ground through the columns, causing forces in columns. Cost is primary requirement for constructing the house. But due to the requirement of high cost for construction, it becomes the main disadvantage. Today the construction industry is in need of finding cost effective materials for increasing the strength of structures. In places where people are below poverty line, it is becoming one of the most significant problems in constructing a house. Also the provision of good quality housing is recognized as an important responsibility, for the welfare of people in any country. Hence to provide good quality housing to people below poverty line, it is essential in seeking for cost effective materials in construction.

Since the problem associated with plastic disposal is a great problem and the continued risk in reuse of plastic and recycling does not provide ideal solution due to health risk and other associated problem discussed above, the present project is an attempt to provide solution to the never ending global plastic disposal problem by making construction out of the PET bottles which are easily available and have properties of thermal and electrical insulator substances. These houses present low cost, ecofriendly housing to poor and needy people and are equally strong as brick houses. They are an effective solution for the reduction of PET bottles from the environment and will solve the various problem related with the disposal of plastic.

2.1Importance of wall in buildings

Wall structure plays important roles in supporting the superstructures, separates spaces in buildings into sections and delineates a space in open air. For any such walls, the components are usually made up of building blocks. These building blocks, technically known as masonry units, can be of conventional brick, fly ash bricks, solid and hollow concrete blocks which are made of conventional raw materials available which are obtained

from natural resources. Some examples for these natural resources are the use of clay for making bricks, and river sand for making cement-sand blocks.

Cement and bricks manufacturing process will contribute to a high emission of carbon dioxide (CO2) which may lead to global warming. The alternative way that can solve the problem is by replacing the use of building blocks like conventional brick, fly ash bricks, solid and hollow concrete blocks in building construction by plastic bottles filled with sand as we called it "plastic bottle blocks".

2.2Non- biodegradable plastic bottles

PET bottle blocks refer to the blocks made with sand filled plastic bottles with mortar in between them. Walls in houses are constructed using such PET bottle blocks "Fig. 1"

Fig. 1 – Houses constructed using PET bottles

Following are the step by step procedure in construction of houses with PET bottles.

- Capped PET bottles are collected from garbage.
- Plastic bottles are cleaned and tightly packed with sand (or inorganic wastes) and capped. This sand filled bottle will work like brick.
- According to the length of walls, the number of bottles are determined and arranged.
- The bottles are tied to each other with the help of ropes or threads.
- Mud plaster or cement mortar or cement concrete is used between the bottles for binding.
- The inner and outer of walls are plastered leaving out a small projection of the end of the bottle so that it gives aesthetically pleasing effect.

3.0 Review of Literature

Mojtaba Valinejad Shoubi et al. (2013) investigated the application of plastic bottles as one of the urban wastage in building construction and its sustainable development. It was proposed to fill the bottles with sand and use bottles with mortar. Hence bottle blocks were casted. Different types of walls varying in size and orientation of the bottles were built. The compression strength and fracture behavior of each wall was measured and compared. It was found that PET bottle walls can bear up to 4.3 N/mm² when the bottles are filled with sand which is the weakest filling material. The bottles bear one third of the load while the plasters bears two thirds.

Shilpi Saxena and Monika Singh (2013) concentrated on making a procedure for preparing bottle blocks. They concluded that by utilizing PET bottles in construction recycled materials, thermal comfort can be achieved in very low cost housing.

Aditya Singh Rawat and Kansal R. (2014) investigated the mechanical behaviour of the plastic bottle by comparing the compressive strength of plastic bottle with brick. PET bottles were collected from possible sources and were filled with locally available soil by tamping it. The bottles were tightly capped and sealed. Compressive strength test was determined on UTM for PET bottles and brick. The results were compared and analysed. It was

found that the PET bottle has compressive strength nearly equal to that of a standard brick. Also the cost of construction in case of PET bottle is more economical than standard bricks and the weight of a unit bottle brick was found to be less than that of a standard brick.

Sean M. Wonderlich (2014) studied about utilization of 500-mL plastic bottles from five different water companies (Dasani, Aquafina, Ozarka, Nestle and Great Value) in wall construction in the form of blocks. The bottles were placed inside moulds of size 200-mm wide by 200-mm high by 400-mm long and concrete mix of 17% cement, 75% sand and 8% water is poured. Compressive strength tests were made. Blocks made of 'Great value' bottle showed high strength.

Aditya Raut et al. (2015) ccompared different factors such as time of execution, load capacity, flexibility, reducing waste, cost and energy efficiency of plastic bottles to some conventional building materials such as brick, concrete and ceramic blocks. Blocks using bottle were made and tested. It was found that time of execution was faster with bottle block. Bottle blocks were 20 times stronger than normal bricks. Plastic bottle blocks are low in cost by 45%.

Mardiha Mokhtar et al. (2015) put forward the importance of using bottle blocks in wall instead of using clay bricks. Their main concern was to study the strength of bottle bricks [2]. Compression test and temperature test was carried out for 1.5 L bottle brick, 250 ml bottle brick and common clay brick. Results showed that the strength of 1.5 L bottle bricks and 250 ml bottle bricks are 3 and 4 times stronger than that of common clay brick. Temperatures of outdoor walls were recorded as 36ºC. From this results, it was concluded that plastic bottle have a potential to be as a construction material on wall.

4.0 Experimental Programme

4.1About the Project

In using plastic bottles as a construction material in wall, common practice is to assemble the plastic bottles in rows with concrete placed in between them. Mojtaba Valinejad Shoubi et al. (2013) insisted the use of bottle brick in the form of blocks called as Bottle blocks as the blocks are prefabricated and hence higher quality and high bonding between the plastic bottles and concrete can be attained. Further there is an ease and less timing in arranging the blocks rather than arranging the bottles. In previous references, variation is made in the bottles by using waste PET bottles of different companies [3]. In our project, it is proposed to vary the pattern of placing the bottles and to compare them with conventional solid and hollow blocks. Parameters like compressive strength, self weight for PET bottle blocks with different pattern, solid and hollow blocks are found out and the best type of block to be used in wall construction is suggested [4,5].

4.2 Materials

Cement

OPC 43 grade cement conforming to IS: 12269 – 1987 [6] was used for the project. Specific gravity, initial setting time and final setting time were found to be 3.15, 45 min and 380 min respectively.

Quarry dust

Fine aggregate used in this project is quarry dust passing IS Sieve 4.75 mm. Specific gravity, bulk density and zone were found to be 2.55, 1720 kg/m^3 and II respectively.

Aggregate Chips

Coarse aggregates used in this project are natural crushed angular aggregate. The size of coarse aggregate is chosen as 10mm in order to achieve uniformity of the aggregates used. Specific gravity, bulk density and water absorption were found to be 2.98, 1610 kg/m^3 and 2% respectively.

Water

The quality of water is important, because impurities in it may interfere with the setting of the cement and it may adversely affect the strength of the concrete or cause staining of its surface which lead to corrosion of the reinforcement.

PET bottles

PET bottles available locally were used. The properties of PET bottle are shown in "Table I"

Table 1 Properties of Pet Bottles

Sl. No.	Description	Value
1	Name	Polyethylene terephthalate
2	Molecular Formula	$C_{10}H_8O_4$
3	Composition	Polyester of terephthalic acid and ethylene glycol
4	Appearance	White or light cream material
5	Density	1.332 gm/cm3
6	Nature	Heat resistant and chemically stable
7	Name	Name

Nylon ropes

Nylon rope is obtained from coal, petroleum, air and water. It is a polyamide thermoplastic produced by series of condensation reaction between an amine and organic acids.

4.3Mix ratio

The mix ratio adopted as per IS 2572:2005 is 1:3:6 with water cement ratio of 0.5. The block masonry is composed of one part of cement, three parts of crusher powder and 6 parts of 10mm coarse aggregate.

4.4Preparation of Specimens

Description of specimens

Following are the details of various labels,

- Core Pattern Block (CPB) - 8 bottles filled with sand and placed at the core of mould
- Equal Spacing Pattern Blocks (EPB) - 8 bottles filled with sand placed at equal spacing in the mould
- Zig Zag Pattern Blocks (ZPB) - 8 bottles filled with sand placed at zig zag spacing in the mould
- Solid Blocks (SB) - mould is completely filled with the mix
- Hollow Blocks (HB) - mould is filled with the mix leaving voids at the core

Collection of waste plastic PET bottles

In this study, the first step taken was collection of waste PET bottles from stores, waste collectors and other possible sources. We have collected waste PET plastic bottles of 400ml capacity. The collected bottles are shown in "Fig. 2"

Fig. 2 – Collected waste plastic PET bottles

Filling up of plastic bottles with sand

The plastic bottles are filled with dry river sand in three layers by giving 25 blows for each layer using a wooden stick or small sized steel rod for tamping. The bottles are sealed with caps after they are filled with river sand as in "Fig 3"

Fig. 3 – Plastic bottles filled with sand

Arrangement of PET bottles in different pattern

"Fig 4" shows the arrangement of bottles in core pattern. Plastic PET bottles are placed exactly placed is positions where core appears in conventional hollow blocks.

Fig. 4 – Arrangement of bottles in Core pattern

"Fig 5" shows the arrangement of bottles in equal spacing pattern. Plastic PET bottles such that they are equally spaced with respect to the other.

Fig. 5 – Arrangement of bottles in equal spacing pattern

"Fig 6" shows the arrangement of bottles in Zig zag pattern. Plastic PET bottles are placed in zig zag pattern.

Fig. 6 – Arrangement of bottles in Zig zag pattern

Casting & Curing of specimens

Once the needed quantities are taken, the mix materials are mixed either by hand mix or machine mix. After the completion of mixing, the mix is placed into wooden moulds which are cleaned and coated with oil already. The size of the wooden mould is 400x200x200 mm. The bottles are arranged in three different patterns namely core pattern, zig-zag pattern and equal spacing pattern. The bottles are placed in their respective positions for each pattern and tied with nylon ropes inside the wooden mould. The mix is filled in the moulds, by three layers in which, each layer is tamped by 25 times with a tamping rod for compaction. After that, wooden mould is left undisturbed for 24 hours. "Fig 7" shows the casted specimen. The specimens are taken out from the moulds after the final setting time is reached. After that, the specimens are placed in curing tank for curing purpose. The water or solution in which the specimens are submerged, are renewed every seven days and maintained.

Fig. 7 – Casting of specimens

Testing of specimens

The compressive strength test on block specimens was conducted in compression testing machine as per IS 516: 1964. Compression strength test is the important test which gives an idea about all the characteristics of blocks. The compression testing machine is provided with two steel bearing plates with hardened faces. The bearing surface of machine was wiped off clean and other loose sand or other materials are removed from the surface of the specimen. The specimen was placed in machine in such a manner, load is applied to opposite sides of the blocks. The axis of the specimen was carefully aligned at the centre of loading frame. The load was applied without shock and increased continuously at a rate of approximately 140kg/cm2 / min. until the resistance of the specimen decreases and the specimen fails. The measured compressive strength of the specimen is calculated by dividing the maximum load applied to the specimen during the test by the cross sectional of the specimen. The progress of compression strength test is shown in "Fig 8"

Fig. 8 – Compression strength test

5.0 Results and Discussions

5.1Compression Strength

The 7^{th} day compression strength of the various specimens was presented in "Table II".

Table 2 7th day compressive strength

Sl. No.	Description	7th day compressive strength
1	SB	2.232
2	HB	1.340
3	CPB	1.965
4	EPB	2.054
5	ZPB	1.786

From the observations it is seen that the compressive strength of solid blocks (SB) is the highest with strength of 2.232 N/mm^2. Among the blocks made with PET plastic bottles, blocks in which the bottles are arranged with equal spacing (EPB) got better results. Also the compressive strength of blocks in which the bottles are arranged with core pattern (EPB) and blocks in which the bottles are arranged with zig zag pattern (EPB) is higher than that of hollow blocks (HB).

5.2Weight

The weight of the various specimens was presented in terms of percentage difference of weight when compared to Solid Blocks (SB) which are presented in "Table III"

Table 3 Percentage difference in weight

Sl. No.	Description	Weight
1	SB	-
2	HB	12.6
3	CPB	11.2
4	EPB	10.8
5	ZPB	10.3

From the observations it is seen that when compared to weight of solid blocks (SB) all other PET bottle blocks varied from 10.3% to 12.6%. All difference in weight had more or less similar value because the number of mud filled bottles and quantity of concrete is same.

5.3Crack Pattern

For zig zag pattern PET bottle block, the edge distance (cover distance between the bottle and the face of the block) is very small. This lead to the immediate failure and the end surface get pulled out as indicated in "Fig 9". Hence the load carrying capacity of zig zag pattern PET bottle block is less compared to other PET bottle blocks.

Fig. 9 – Crack pattern of Zig Zag Pattern Blocks (ZPB)

6.0 Conclusions

From this experimental study it is found that the compressive strength of solid blocks (SB) is the highest with strength of 2.232 N/mm^2. Among the blocks made with PET plastic bottles, blocks in which the bottles are arranged with equal spacing (EPB) got better results of 4.107 N/mm^2.

Hence from the experimental results it can be concluded that solid blocks made of concrete shows high compressive strength and hence can be used in wall construction.

But owing to the main scope of our study (i.e.) low cost building, avoiding exploitation of natural resources and efficient use of plastic wastes as a construction material it is proposed the blocks made of mud filled bottles which are arranged with equal spacing called as "Equal spacing PET bottle block" is considered to be used as a construction material with giving suitable considerations to strength aspects also.

7.0 References

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