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Study on Strength Behavior of Concrete Blocks with Filled up Poly Ethylene Terephthalate (PET) Bottles

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ABSTRACT

Generation and accumulation of huge amount of plastic waste has become a silent threat to the environment and it has become a serious issue for its disposal. Plastic being a non - biodegradable, its disposal has become a major issue. In order to overcome these issues, many attempts were made to control the use of plastic in the past. But unfortunately, none of them were found to be effective. On contrary to this, one of the major problems facing that we are facing in Construction Industry is unavailability of concrete (cement, sand and coarse aggregate). Series of experiments have been conducted on plastic wastes to check its feasibility with respect to various properties of concrete like strength, ductility, durability, workability when it is partially used with concrete. Though plastic waste is considered as an urban waste or junk, but with its limited properties it can partially replace some of the conventional building material like bricks in construction industry. In some of the countries where people are under/below poverty line can construct their houses by making use of these waste Poly Ethylene Terephthalate (PET) bottles. These PET bottles when filled with waste filler material like construction and demolition waste can be used as bricks when proper casting is done with concrete mix. Various factors like execution time, cost, and flexibility, reducing waste and its utilization and energy efficiency, PET bottles have found to be more effective when compared to conventional building material like bricks or concrete blocks. Construction cost can also be reduced to a certain limit by saving the volume of concrete.

Key words : *Cement, Construction and demolition waste, PET bottles, Compressive strength*

Introduction

Plastic waste being considered as an urban junk with sustainability characteristic can be used as an ingredient in the manufacture of building blocks in construction (Mojtaba Valinejad Shoubi *et al.,* 2013). Being non- biodegradable its disposal has been a problem. Waste plastic bottles are major cause of solid waste disposal. This paper proposed the use of waste plastic PET bottles as in building blocks in an economical way to reduce the cost of concrete block. The present work gives the same sort of solution in the construction of buildings by using waste plastic PET bottles which are dumped on open land (Jayprakash *et al.,* 2016). Global municipal solid waste generation levels at approximately 1.3 billion tonnes per year in 2012 report. The levels are expected to increase to approximately 2.2 billion tonnes per year by 2025 (Muyen *et al*., 2016). With the serious housing shortage but no shortage of plastic bottles littering the streets, the development association for renewable energies decided to build

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a house entirely out of plastic bottles which is bullet and fireproof and also earthquake resistant (JKR, 2005). Waste plastic usage in concrete in the form of plastic coarse aggregates showed acceptable strength properties at the 15-20% replacement level with natural coarse aggregates (Subramani and Pugal, 2015; Praveen Mathew *et al.*, 2016). The plastic aggregates prepared from plastic bags and bottles effectively replace the coarse aggregates in concrete to an extent of 20% (Yalemsew Adela, *et al.*, 2020). Waste plastics material when effectively mixed with Rubber powder and Calcium Carbonate gives the highest compressive strength and sustains high compressive load (Noel Deepak Shiri *et al*., 2015). The mode of failure of concrete changes from brittle to more ductile with the use of waste plastic. Usage of plastic bottles in the construction of masonry blocks has proven to absorb abrupt shock loads (Manhal and Farah Peter, 2016; Simanshu Pandey *et al.*, 2017). Concrete blocks made using waste plastic bottles showed 57% higher compressive strength in comparison with that of hollow concrete blocks (Sina Safinia and Amani Alkalbani, 2016). Using waste plastic in the form of fine aggregates proven to enhance strength of concrete up to a replacement of natural fine aggregates to a level upto 10% (Arivalagan, 2016; Chougule *et al.*, 2017; Mokhtar *et al.*, 2018). Concrete blocks made with line aligned fly ash filled PET bottles showed improved flexural strength to that without PET bottles (Kunal Jadhav *et al*., 2017). Usage of waste plastic in the form of plastic dust brick enhances the strength of bricks in comparison with the clay bricks (Ronak Shah *et al.*, 2017). LDPE fly ash composite brick made of waste plastic possess double the compressive strength to that of conventional clay bricks (Anand Daftardar *et al*., 2017). Usage of plastic aggregates results in reduced weight of bricks and improved water absorption resistance to that of clay bricks (Rita Jaishwal *et al.*, 2018). Paver blocks produced from plastic wastes attain strength quickly in comparison with conventional concrete blocks. This property makes them more suitable in fast construction and water logged areas (Agyeman, *et al*., 2019). Paver blocks with waste plastic show enhanced water absorption resistance in case of exposure to marine environment (Tagbor *et al.*, 2019). Similar to the plastic waste, boron waste used in the concrete as aggregate along with pumice aggregates and sand exhibit improved mechanical properties of concrete up to a replacement level of 9% (Abudalrhman Aldakshe *et al*., 2020). The present study comprises of testing of materials for concrete blocks. Waste PET bottles filled with construction and demolition waste were used in block making. Compressive strength test of those blocks with and without PET bottles were conducted at 7, 14, and 28 days and the results were compared. Cost analysis of the blocks with the usage of waste PET bottles is done in comparison with the conventional concrete blocks.

Materials

Cement

Ordinary Portland Cement of grade 53 is used as a binder in the manufacture of concrete blocks.

Manufactured Sand (M-sand)

Manufactured sand obtained from crushed stone powder is used as a fine aggregate in the present study. Being an effective replacement for natural river sand, this can exhibit good fresh and mechanical properties in concrete.

Coarse Aggregate

Angular coarse aggregates of size below 10mm are used in the preparation of concrete for the blocks. The aggregates conform to IS383:2016.

PET Bottles

PET bottles which are a polymer of ethylene glycol and terephthalic acid are used in the present study. Good chemical resistance, high degree of impact resistance, and tensile strength makes these suitable to be used in concrete blocks. The maximum temperature it can bear is up to 200 degree Celsius. Square and circular shaped waste PET bottles are used in the preparation of concrete blocks.

Construction and Demolition Waste

Construction waste is anything that is generated as a result of construction, and then abandoned, regardless of whether it has been processed or stockpiled. Construction are at the core of all our demand, i.e. water, energy, and material, but they also create waste. This waste, generated in the construction, maintenance, and disposal phases of a building, is called construction and demolition (C&D) waste.

The tests carried out on fine aggregates, coarse aggregates, and OPC as per relevant IS codes are

tabulated in Tables 1, 2, and 3.

Table 1. Tests on OPC

Tests on Cement	Result
Normal Consistency	32.5 %
Initial setting time of cement	75 minutes
Final setting time of cement	600 minutes
Fineness of Cement	4.5 %
Specific gravity of Cement	3.12

Table 2. Tests on Fine Aggregates

Tests on Fine Aggregates	Result
Specific Gravity of Fine Aggregate	2.57
Sieve Analysis of Fine Aggregate	3.39
Moisture Content of Fine Aggregate	4 %

Table 3. Tests on Coarse Aggregates

Tests on Coarse Aggregates	Result
Specific Gravity of Coarse Aggregate	2.67
Moisture Content of Coarse Aggregate	3 %
Aggregate Impact Test	18.29 %
Aggregate Crushing Value Test	33.33 %
Angularity Number	7

Table 4. Test on Fresh Concrete

Test on Fresh Concrete	Result
Slump Test	True slump

Methodology

Blocks with PET bottles (Circular, Square) and blocks without PET bottles were casted

In this study, the first step taken was collection of waste PET bottles from hotels, stores, waste collectors and other resources. Once after the bottles are collected, they must be filled with the locally available C & D waste in order to provide them with structural strength. Once all the collected bottles are filled with prepared C & D waste and tamping it in installment, they are tightly capped and sealed. Now by using these circular and square PET bottles blocks were casted. To check the structural strength various tests are performed and compared among three sets of specimens, i.e., the block with circular bottles, block with square bottles and the block without PET bottles. Comparative cost analysis is also done.

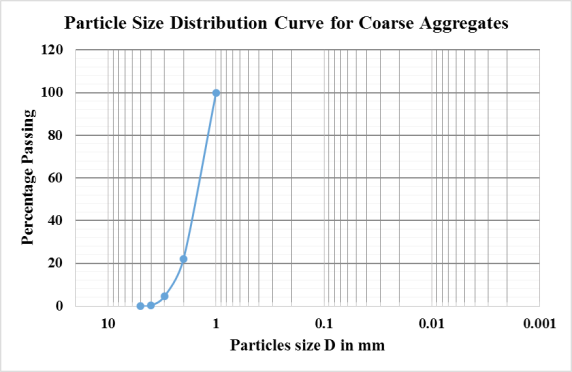

Fig. 2. Grading Curve for Coarse aggregates

Modification of size of the block

The standard size of blocks available in market is 40cmx20cmx20cm and the blocks prepared of size 25cmx25cmx10cm the reason being the size of bottle, as the size of bottle is 6cm diameter and 20 cm height so an additional cover of 5cm (50 mm) is provided which would serve as sufficient cover.

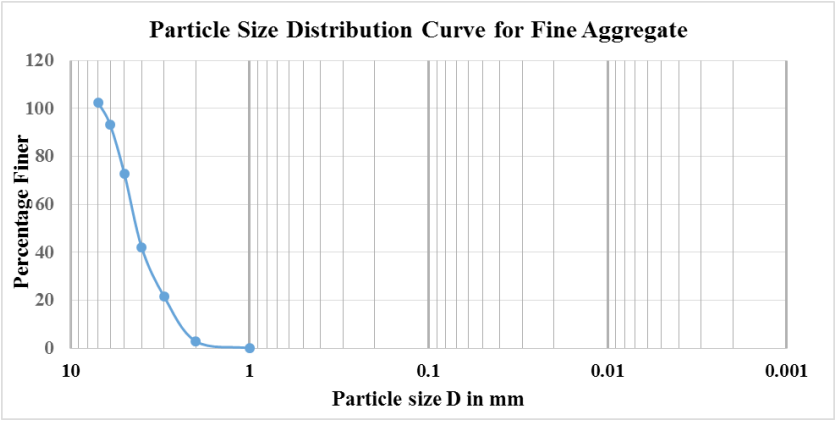

Fig. 1. Grading Curve for Fine aggregates

Fig. 3. Block Mould

Compression Test on the Blocks

Compression test was carried out for the three set of specimens that is the Block with Circular PET bottles, the Block with Square PET bottles and the Block without PET bottles in order to know the compression strength for the curing periods of 7,14 and 28 days.

Results and Discussion

Compressive strength

The blocks were tested under compression testing machine and compressive strength of each is tabulated in Table 5

As seen in the above graph we can conclude saying that the concrete blocks with circular bottles have gained higher strength compared to blocks without PET bottles and blocks with square PET bottles for all days 7,14 as well as 28 days.

Cost analysis of concrete blocks with and without PET bottles

Comparison of Cost among Block without Pet Bottles and Block with Square Bottles

Volume of the concrete required to fill the block = 0.00625m^3

Cost of project block without PET bottle = Y = 0.00625 * 5000 = Rs. 31.25

Block with square Pet bottle

Volume of the concrete required to fill the block= 0.00289m^3

Cost of block with square PET bottle = 0.00289 * 5000 = Rs.14.45

Amount saved per block = Rs.16.8

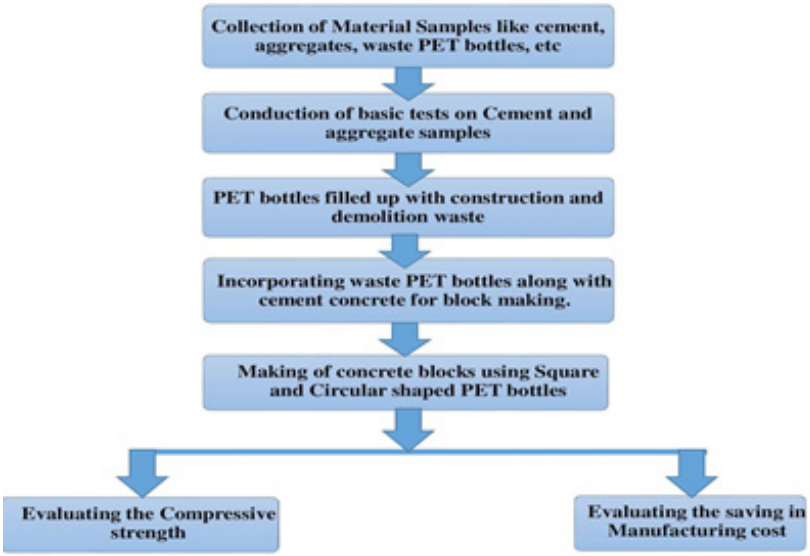

Fig. 4. Research Methodology

Table 5. Compressive Strength values in N/mm^2

Curing period, Days	Concrete block without PET Bottles, N/mm^2	Concrete block with Circular PET bottles, N/mm^2	Concrete block with Square PET bottles, N/mm^2
7	12.50	14.35	13.50
14	15.10	17.60	16.55
28	16.55	19.25	18.40

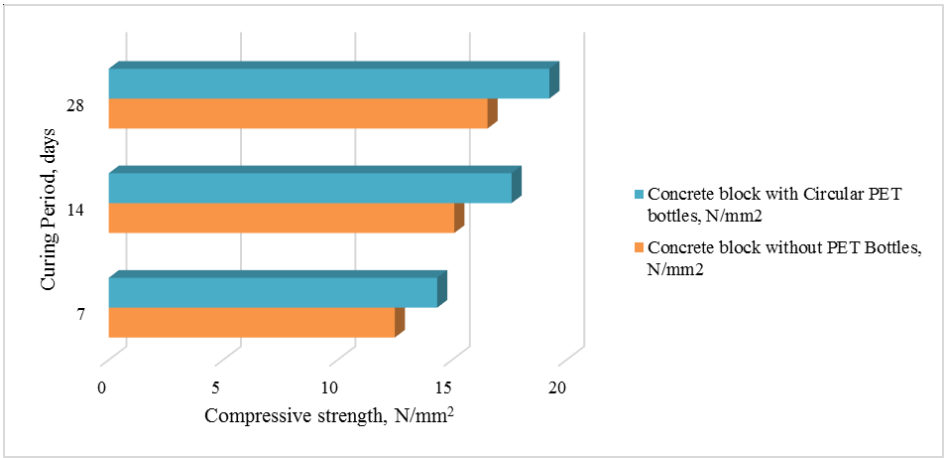

Fig. 5. Compressive Strength variation for Concrete block with and without circular PET bottle

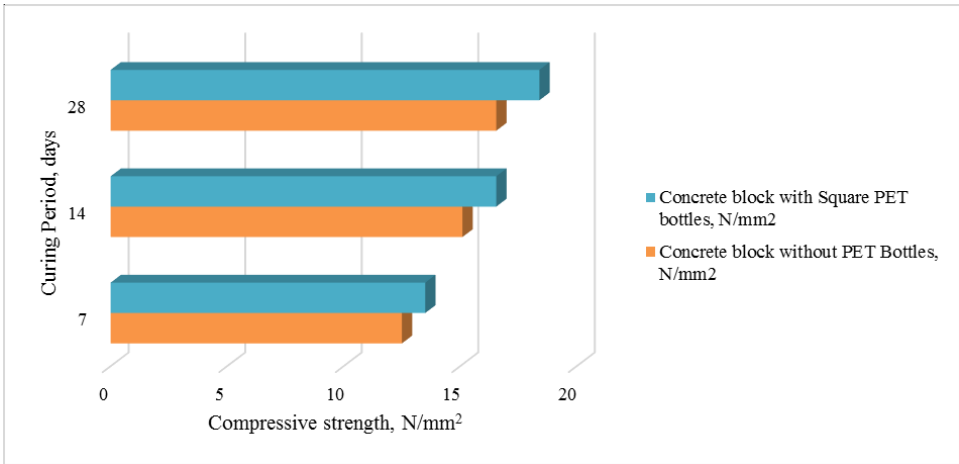

Fig. 6. Compressive Strength variation for Concrete block with and without square PET bottle

Block With Circular Pet Bottle

Volume of the concrete required to fill the block= 0.003058 m^3

Cost of block with square PET bottle = 0.003058 * 5000 = Rs.15.29

Amount saved per block = Rs.15.96/-

Table 6. Comparison of Cost of Blocks

Block type	Unit Cost, Rs.
Block without PET bottle	31.25
Block with Square PET bottle	14.45
Block with Circular PET bottle	15.29

As we can observe from the table mentioned that cost of Block with square pet bottle costing 14.45/- works out to be cheaper when compared to blocks without PET bottles.

Conclusion

Based on the experimental results and discussions carried out in the previous sections the following conclusion can be made.

- Compression strength of the block without PET bottle 16.55 N/mm^2 is found to be increased to 18.38 N/mm^2 in the case of block with square PET bottle. Whereas it is increased to 19.26 N/mm2 in the case of block with circular PET bottle. So, we can conclude that the block with circular PET bottle has gained the strength by 13 to 15% when compared to blocks without PET bottles.
- Cost saving in concrete blocks with PET bottles is observed to be 54% for block with square pet

bottles and 51% for block with circular pet bottles. Such high reduction in cost of concrete is contributed by the Construction and Demolition (C&D) waste filled the PET bottles. Though procurement of these waste materials involve cost, it is relatively very low in comparison with the cost of concrete. Hence it is not considered in the present research work.

- Usage of waste PET bottles contribute to reduction in accumulation of non-biodegradable plastic in the environment.
- Ample availability of C & D waste and waste PET bottles makes the production of such blocks more feasible and results in reduced construction cost.
- Though the concrete blocks possess satisfactory compressive strength, due to the uncertainty of bonding between plastic and concrete, the application of such blocks to be limited to non-structural members only.

6. Scope for further work

- Bonding between the concrete and PET plastic material can be studied which turns out to be a deciding factor with respect to strength and durability of concrete blocks.
- Supplementary cementitious materials can be used in the production of concrete blocks with PET bottles.

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