International Journal of Science and Research (IJSR)
ISSN: 2319-7064
ResearchGate Impact Factor (2018): 0.28 | SJIF (2019): 7.583

Identifying Short Comings of Single Use Plastic Bottle Masonry and Redesigning the Bottles Geometry to Make it More Efficient

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Abstract: ***India has seen an exponential growth in the use of plastics. This has led to the generation of plastic waste in large quantities. To satisfy the need of containing various liquids cheaply and effectively, the use of single use plastic bottles has become prevalent. Single use plastic bottles are known polluters of the environment; this is because of the numbers in which they are produced. They are designed with a single use in mind and are discarded after use. Simply recycling this plastic material indefinitely is not a viable solution as there are limitations in the recycling process due to which alternate solutions are required. It is also a well-established fact that there is a shortage of affordable housing in India and finding a cheaper building material will help reduce the cost of housing in the country. The research paper theoretically explore the benefits of re designing the structure of the single use plastic bottle in a way that it could be used as a replacement for a brick in the construction industry. Although a lot of research has been carried out exploring various ways the plastic bottles can be used as bricks but all of them use plastic bottles designs available in the market. The paper proposes that a single use plastic bottle designed to be used as brick after its primary purpose has been fulfilled will be more beneficial. This would help to reduce the waste generated by the single use plastic and also provide an efficient building material to help satisfy the ever increasing housing demand in the country.***

Keywords: Single use plastic bottle, Modular plastic bottles, Interlocking bottles

1. Introduction

India is a nation of 138.05 crore people (1) and requires a lot of resources for its sustenance especially in terms of food, fuels etc. A number of such products require packaging to insure secure storage and long shelf life. Plastics are used extensively to cater to the needs of the people both globally and locally. Table 1 shows an estimate of global, sector wise plastic consumption. It indicates that the packaging industry which utilizes single use plastic bottles extensively is the greatest consumer of plastic. Table 2 indicates the rise in plastic consumption in India. The plastic bottles industry has seen an exponential growth over the years due to the utilitarian conveniences it offers to the users and cheap mass production potential it provides to the manufacturers. However, this popularity of the plastic bottle also creates a great polluting potential specially caused by the cheaper single use variety.

Table 1: Estimated Global Plastic Consumption as per Sector

S.No	Sector	Percentage (Metric Ton)
1	Building and construction	18.8
2	Consumer and institutional products	12
3	Electrical and electronic	4
4	Industrial machinery	0.8
5	Packaging	44.6
6	Transportation	6.7
7	Other sectors	13.1
total		100

Table courtesy: Report requested by the Secretariat of the Basel Convention for the first meeting of the Basel Convention Plastic Waste Partnership. Report produced by GRID-Arendal pdf. (Page no 13)

Table 2: Rise of Plastic Consumption in India

Year	Quantity (Ton)
1996	61000
2000	300000
2001	400000
2007	8500000
2017	17800000
Table courtesy : Plastic Waste Management Issues, Solutions and Case Studies (March 2019) (page no 5)	

A strategy based on recycling of plastic bottles is not efficient because virgin plastic can only be recycled 2 to 3 times (2). The thermal stresses experienced by materials during the recycling process damages its molecular structure every time it is recycled. Thus finding an alternative use for the single use plastic bottle becomes imperative.

Extensive research has been carried out to explore secondary uses for the single use plastic bottle. Some explore the possibility of reducing the carbon generated during the production of burnt clay bricks and cement and presents plastic bottles with sand fillings as an alternative material for construction (3). Some papers have compared the structural characteristics of the plastic bottles with the burnt clay brick concluding that they are more cost effective and the compressive strength of the bottle with suitable additive can be at power with that of the burnt clay brick (4). However all the research mentioned above are limited by the design and geometry of the plastic bottles available commercially. The single use plastic bottles used in the tests were never designed to be used as a brick later.

The research paper attempts to explore the benefits of designing a secondary use into the single use plastic bottle. It focuses upon identifying the necessary design characteristics that will help make it a more effective building material. Additionally this would add some

tangible value to the single use bottle after use as a container.

Scope & Limitations

- The research focuses on single use plastic bottles designed to contain volumes ranging from 0.7 liter to 2.6 liter.
- The research focuses on design elements only, structural analysis of the said design elements are beyond the scope of the paper.

2. Methodology

The methodology to identify the design elements to be integrated into the single use plastic bottles to turn it into a more efficient building material is as follows:

Material data

The Primary polymers used for producing single-use plastic bottles are 1. Polyethylene Terephthalate (PET or PETE or Polyester) 2. High-Density Polyethylene (HDPE) 3. Polypropylene (PP) (5).

The above mentioned materials are preferred for their inherent properties such as.

- They are highly unreactive and do not corrode or rust.
- They are insoluble in water and have excellent water retaining properties.
- They can be engineered to possess high tensile stresses.
- They are light in weight but are reasonably strong.
- They can be easily moulded into various shapes.
- They are very hard to decompose.
- They are very bad conductors of heat and electricity.

Table 2: Comparison of Burnt clay and Plastic Bottle Brick as a Building Unit

Unit	Criteria		Burnt Clay Brick	Plastic bottle Brick
1	Design	a	Designed to be used as a building material and are available in standard sizes and shapes.	Designed to be used as a container for liquids and are available in extremely variable sizes and varied in shape.
		b	Designed with frogging or other similar indentation to ensure maximum adherence to mortar.	Designed in such a way that it is easy to be carried around and protect the content within.
2	Materials Used	a	Clay and other trace minerals.	Plastic resins of different type's form the outer layer and can be filled with any filler material available locally or otherwise.
3	Physical and Structural Properties	a	Has a rough porous surface and absorbs water and moisture.	Has a smooth non porous surface and does not absorbs water and moisture.
		b	It's rectangular in shape with flat surfaces.	It's principally has a cylindrical geometry and un uniform sides
		c	Has high compressive strength and low tensile strength.	The compressive strength is adjustable using different filler material has some tensile properties.
4	Masonry	a	The masonry of variable thickness can be fashioned in a manner that vertical joints can be broken.	Can be built by stacking it one on top of the other. Vertical joints cannot be easily be broken.
		b	Can be designed to have the capacity to form interlocking joints.	The capacity to form interlocking joints is not designed.
		c	easy to build strong corners and 'T' junctions	difficult to build strong corners and 'T' junctions or 90 degree turns in the masonry
		d	mortar used as building material	although mortar is used as building material further reinforcement is usually added

Source : Author

3. Analysis of Tabled Data

- The material characteristics of single use plastics mentioned above indicate that the physical and chemical properties that make it a major pollutant are also desirable in a good construction material.
- Sr.no 1 of Table 2 indicates-

a) As indicated in Fig.1 Lack of standardization in design reduces the effectiveness of plastic bottle bricks when compared to clay bricks. The builder may be forced to source bottles of similar make and geometry creating logistical difficulties.

Figure 1: Designs of plastic bottles are available
Image courtesy: Author

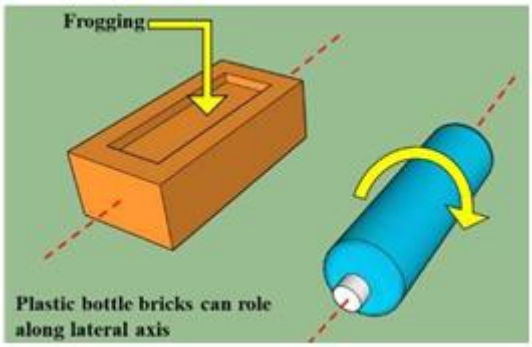

Figure 2: Design of clay brick and plastic bottle brick
Image courtesy: https://saaviaimpex.com

b) Additionally burnt clay bricks are designed with recesses called frogging as shown in Fig.2. This improves its adherence with mortar as area of contact is increased. Plastic bottles do not have the feature reducing its capacity to form strong bonds.

- Sr.no 2 of Table 2 indicates-

c) The versatile nature of the plastic bottle makes it more effective as it can be filled with any filler material available on or off site.

- Sr.no 3 of Table 2 indicates-

d) Plastic bottle bricks exhibit superior moisture and water resistant properties compared to burnt clay bricks due to its non-porous and smooth outer surface.

e) Clay bricks are stable along the longitudinal and lateral axis because of their rectangular shape whereas plastic bottles are not stable along the lateral axis due to its predominantly cylindrical form as observed in Fig.2.

- Sr.no 4 of Table 2 indicates-

f) Burnt clay bricks can be laid in ways that break vertical joints in the masonry. Fig.3a indicates how vertical joints are broken with the help of brick bats (indicated in red) Preventing the formation of a continuous vertical joint (indicated by the dotted red line) making the masonry stronger. This arrangement cannot be created using plastic bottle bricks as indicated in Fig.3b vertical joints cannot be effectively broken.

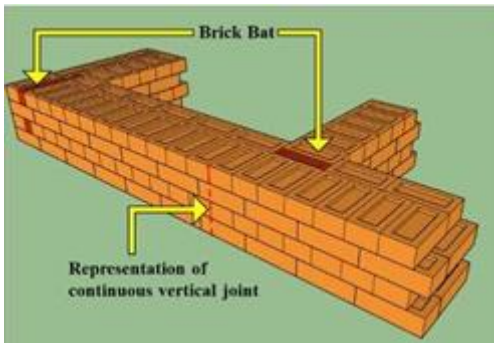

Figure 3 (a): Elements of brick masonry
Image courtesy: Author

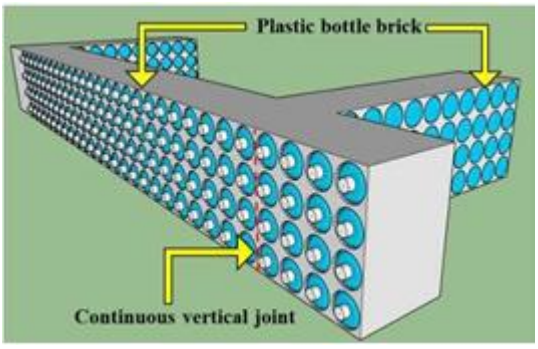

Figure 3 (b): Elements of plastic bottle masonry
Image courtesy: Author

g) Specialized burnt clay bricks with interlocking joints are sometimes produced allowing mortar less construction. Plastic bottle bricks are not designed to allow this provision.

h) It is extremely difficult to build 90 degree corners using plastic bottle bricks, as seen in Fig.4a it has to be curved at the corners. Alternatively the orientation of the bottles has to be changed as observed in Fig.4b. This causes the masonry to become weaker as there is no interlocking of the wall faces, also making it difficult to constructing strong 'T' junctions.

Figure 4 (a): Corners in plastic bottle masonry
Image courtesy: building with bottles: an earth day update APRIL 22, 2011

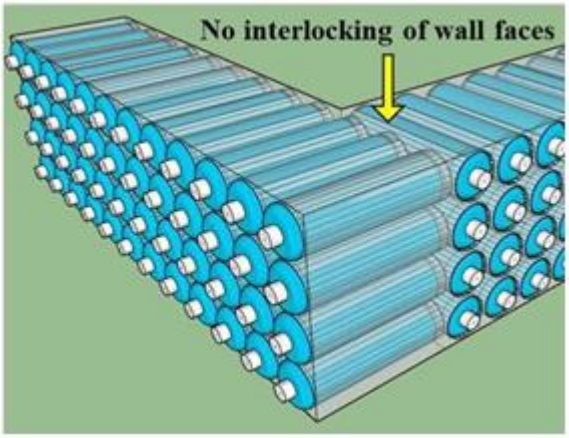

Figure 4 (b): Lack of interlocking joints in plastic bottle masonry
Image courtesy: Author

This problem is not observed in walls constructed with brick masonry. As observed in Fig.5 every alternate course the two wall faces are interlocked with the help of a tie brick (indicated in green) making the junction stronger than the ones built with plastic bottle brick. Additionally corners are constructed easily because of the modular nature of the bricks and the use of brick bats.

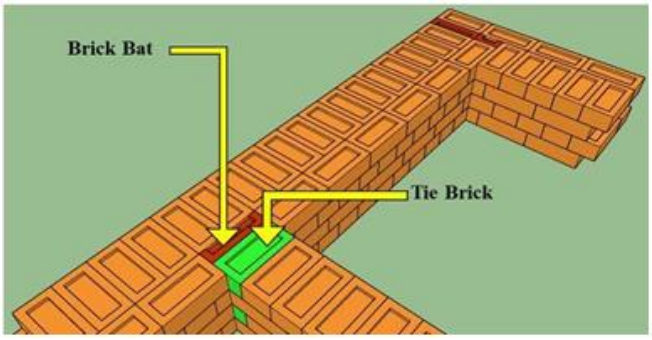

Figure 5: Interlocking joints observed in 'T' junctions and corners in brick masonry
Image courtesy: Author

i) Excessive mortar is required while constructing plastic bottle wall due to the cylindrical profile of the bottles leaving openings between them. The rectangular profile of burnt clay bricks allow it be placed flush to the other not leaving spaces in between.

4. Experiment

The analysis provides essential design features to re designed single use plastic bottle;

1) **Geometric profile**: The bottle must have a geometry similar to the burnt clay brick to ensure ease of use.
2) **Modularity**: The bottle must have a modular design to facilitate bottles of different volumetric capacities to be used without any difficulty.
3) **Forging**: Provision for frogging to ensure better adherence to mortar.
4) **Inter locking joints**: Provision to enable the bottles to form interlocking joints facilitating mortar less construction.
5) The essential features provided may form hypothesis or design requirements for single use plastic bottles to be used as a construction material.

Geometric profile

The earliest use bricks dates back to 7000 BC (6). The rectangular geometry is a tried and tested aspect of brick design, hence adopting the same is more logical and efficient. In order to ensure similarity with the burnt clay brick a rectangular profile is adopted in dimensional aspect. Size of brick considered to be length -23cm, breadth – 11.5cm and height of 7.5cm.

Therefore volume excluding the frogging will be (l x b x h)
23 x 11.5x 7.5 = 1,983 cu cm or 1.98 liters

As seen in Fig.6 the same dimensions are adopted for the re designed plastic bottles. Additionally a conical necking is added to make it easy to add a bottle cap. This adds a volume of 0.035 liters bringing the total capacity of the bottle to 2.015 liters. The dimensions for bottle cap and threading for it are excluded and can be variable as per requirement. Compensating for the thickness of the plastic bottles, air inside it while filling it etc. the bottle can contain a minimum of 2 liters.

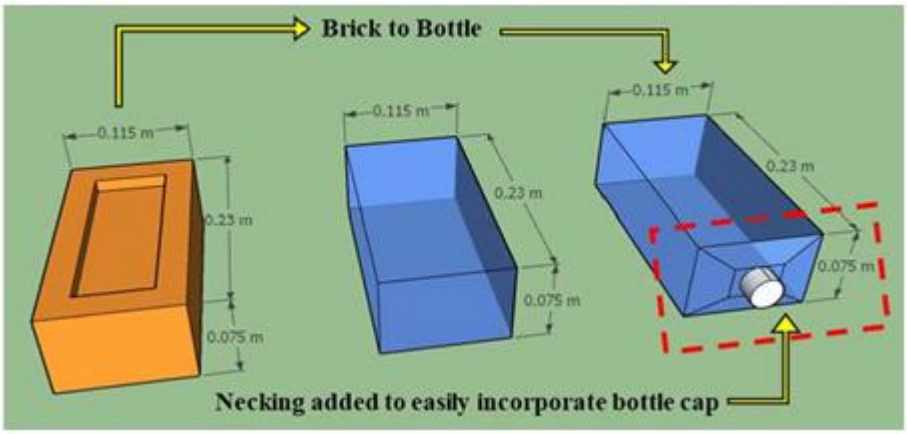

Figure 6: Derivation of the plastic bottle form
Image courtesy: Author

Modular design

To make the bottles modular, volumetric modules are added. They can be projected outwards or pressed inwards to increase or decrease the volume. As indicated in Fig.7a this allows the dimensions of the bottle to remain constant but the capacity to be changed. Each module can incorporate a volume of 0.15 liter. Each 2 liter bottle can incorporate four such volumes enabling the bottles to hold a volume range of 1.4 liters to 2.6 liters in 0.15 liters intervals. For applications where the volumetric capacity requirement is less than or close to 1 liter. The 2 liter bottle is divided in half as indicated in Fig.7b. Allowing the bottles to hold 0.7 liter to 1.3 liters.

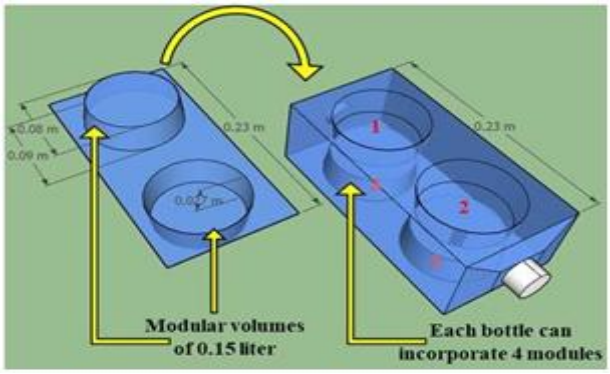

Figure 7 (a): Design and placement of modular volumes

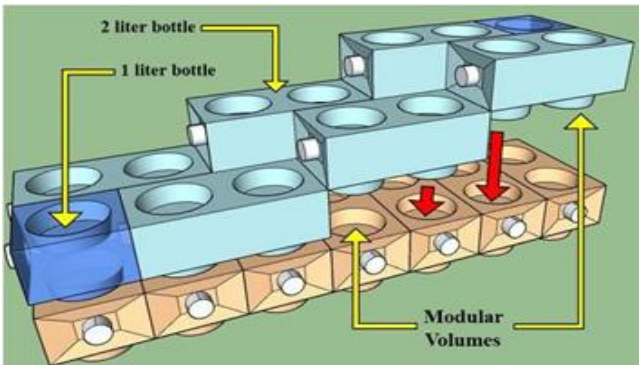

Figure 8 (a): Interlocking joints with modular plastic bottles

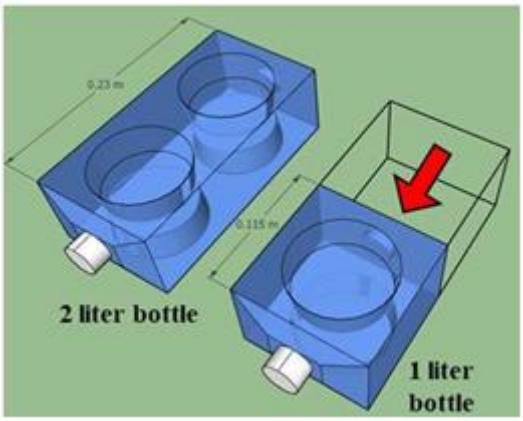

Figure 7 (b): Design of bottles for 1.3 to 0.7 liter capacity
Image courtesy: Author

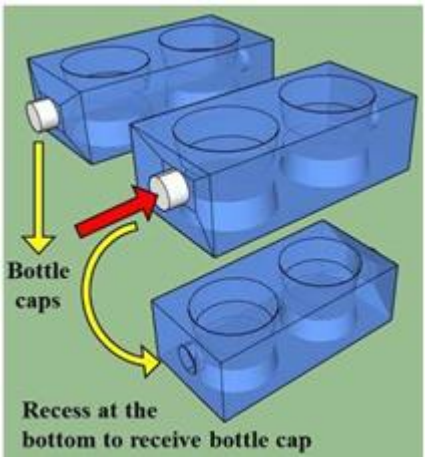

Figure 8 (b): linear joinery of modular plastic bottles
Image courtesy: Author

Forging: The provision for forging is provided by the modular volumes indicated in Fig.7a. Due to the flexible nature of plastic use in the manufacturing of bottles, the volumetric modules can be pressed inwards to provide forging where ever necessary.

Inter locking joints: As indicated in Fig.8a interlocking joints can be formed due the modular nature of the bottles.

The modular volumes can be manipulated either to form projections or recesses which can fit into each other. A recess is provided at bottom of the bottle to receive the lid of the next bottle allowing end to end joinery. Additionally the necking provided can be pushed inwards forming a flush surface as indicated in Fig.8b. The modular design also enables the formation of strong 'T' junctions by breaking the vertical joints and 90 degree corners as observed in Fig.9.

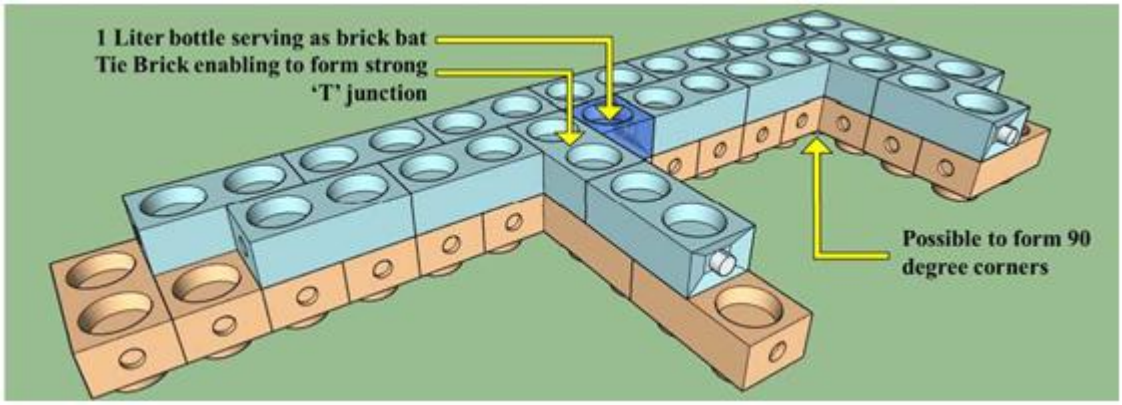

Figure 9: Interlocking joints in 'T' junctions and corners in redesigned plastic bottle masonry.
Image courtesy: Author

5. Result & Discussion

The above experiments indicate that effective & deliberative redesign of the single use plastic bottle can replace the burnt clay bricks in a number of applications.

- It is easier for a builder to utilize plastic bottles produced by different manufacturers which is currently not possible due to variations in geometry.

- The design incorporates all features of burnt clay bricks with additional capacity to form interlocking mortar less joints.
- The modular nature of the design allows the plastic bottle bricks to form strong 'T' junctions and corners in a manner seen in brick masonry.
- The similarity in dimension and building method to burnt clay bricks prevents the need of specialists for brick laying.
- Although the modular plastic bottle design has its merits, it does not provide any incentives to the manufacturer. Government intervention either in form of regulation or incentives becomes vital.

6. Conclusions

It is an established fact that single use plastic is one of the major contributors to the environmental pollution in the country. Single use plastic bottles form a major component of the plastic waste generated. The re utilization of discarded plastic bottle will help reduce the effects of plastic pollution. Research has already proven that discarded plastic bottles can be used as a building material in the construction industry. Unfortunately current designs of plastic bottle available in the market are not as efficient as burnt clay bricks. A re designed modular plastic bottle will reduce the efficiency gap. Additionally standardization of the modular plastic bottle design will make it logistically convenient for builders allowing them to source the material produced by different manufacturers.

Adopting a modular plastic bottle design will also help reduce carbon emissions as every burnt clay brick replaced will help reduce carbon dioxide generated to manufacture it. Additionally the littering of plastic bottles is reduced as there is an incentive to collect and sell it to a market in search of cheap and abundant building material. As research is manifestation of the pursuit of knowledge born out of never ending questions. The paper concludes with the question that although rectangular profile of bricks has prevailed for centuries, is it the most efficient design.

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