



Waste Plastic Bottle as Construction Material

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Abstract: Disposal of non bio-degradable substance has become an issue of major concern now a days. Mounds of plastic garbage has been created on earth surface. Laterite quarry waste is abundantly available and disposal of waste plastics (PET, PP, etc) is the biggest challenge. Only one in six plastic bottles are properly recycled. On other hand high cost of primary requirement for constructing the houses in places on where people are under poverty line is forming one of most significant problems of people. A suitable approach for this situation is using some part of urban rubbish or waste as required materials for building construction. Plastic bottle is considered as urban junk. but with sustainability characteristic it can be used as construction material instead of some conventional material such as brick in building construction. The paper intends to investigate the application of plastic bottles which is one of the urban waste in building construction and that how it can lead to sustainable development. It also mentions some ways for self standing and insulating them in thermal and sound point of view and some positive points which this material have versus others.

Keywords: Plastic Bottle, Sustainable Material, Construction material, Innovative wall.

INTRODUCTION

Nowadays, human apply all of its potentiality to consume more. The result of this high consumption is nothing unless reducing the initial resources and increasing the landfill. In recent times, human from the one hand is always seeking broader sources with lower price and from the other hand is following the way to get the rid of the wastes. The waste today can be produced wherever humans footprints be existed, and remind him that they have not chosen the appropriate method for exploitation of the nature. At the present time, the possibility of utilizing the renewable resources such as solar, wind, geothermal has been provided for us more than before, and development of this science is making progress. But those energies can be chosen as one of the renewable and alternative energies instead of fossil fuels which are cheap as possible and have fewer environmental impacts. Since no attention to economic issues lead to that the use of these energies be just for groups dedicated to specific segments of society. Whilst many renewable energy projects are large-scale, renewable technologies are also suited to rural and remote areas, where energy is often crucial in human development. With population growth in today's world, the need to the building has increased and to respond to this demand, the countries tend to use the industrial building materials and decline the use of indigenous and traditional materials. These factors in spite of increasing the energy consumption in the industry section; they can also raise the cost of house and are considered as the barrier for users to obtain the basic needs of the life.

The problem of users is losing the power and ability of design and building their own homes by themselves. Two factors that prevent aboriginal people from building their homes are high cost building materials and labor and also

maybe long transportation. One of the solutions for this problem can be Solve In following Manner.

- □ Use of affordable recycled materials in buildings
- □ Using the method of regenerating through proper education to people.

In the past, the glass was common in packing some foods such as milk and etc. They could be returned to the factory for using again for the same purpose. But now by changing the human's disposal culture, glass bottles have been replaced by plastic bottles, as they have increasingly become one of the substances of destruction of the landfills because they decompose in a long time. Two alternative solutions against the plastic bottle disposal are recycling and reusing process. Recycling needs additional energy to treat the materials for producing something usable. Moreover, the recycling process produces wastewater and air pollutants. So the best solution is reusing for which no additional energy is required and does not contribute to pollution. Indeed, when we reuse junk, we are helping to save the obtained energy which would otherwise be wasted. It is focused on not only the financial aspect but also the environmental aspect. Plastics are produced from the oil that is considered as non-renewable resource. Because plastic has the insolubility about 300 years in the nature, it is considered as a sustainable waste and environmental pollutant. So reusing or recycling of it can be effectual in mitigation of environmental impacts relating to it. It has been proven that the use of plastic bottles as innovative materials for building can be a proper solution for replacement of conventional materials. The use of this material has been considered not only for exterior walls but also for the



ceiling of the building. The objective of this paper is to investigate the using of plastic bottles as municipal wastes in the buildings, the key and positive characteristics of this product and the benefits obtained by using it in building. It also intends to compare the characteristics of some construction materials such as brick, ceramic and concrete block with bottle panel.

Plastic have many good characteristics which include versatility, light-ness, hardness, and resistant to chemicals, water and impact. Plastic is one of the most disposable materials in the modern world. It makes up much of the street side litter in urban and rural areas. It is rapidly filling up landfills as choking water bodies.

Plastic bottles make up approximately 11% of the content landfills, causing serious environmental consequences . Due to the consequences some of the plastic facts are as follow:

- More than 20,000 plastic bottles are needed to obtain one ton of plastic.
 - It is estimated that 100 million tons of plastic are produced each year.
 - □ The average European throws away 36 kg. of plastics each year.
 - □ Some plastic waste sacks are made from 64% recycled plastic.
 - □ Plastics packaging totals 42% of total consumption and every year little of this is recycled.
- According to ENSO Bottles, in the 1960's plastic bottle production has been negligible but over the years there was an alarming increase in bottles produced and sold but the rate of recycling is still very.

1) Plastics are produced from the oil that is considered as non-renewable resource. Because plastic has the insolubility about 300 years in the nature, it is considered as a sustainable waste and environmental pollutant. So reusing or recycling of it can be effectual in mitigation of environmental impacts relating to it. It has been proven that the use of plastic bottles as innovative materials for building can be a proper solution for replacement of conventional materials. The use of this material has been considered not only for exterior walls but also for the ceiling of the building. The objective of this paper is to investigate the key and positive characteristics of this product and the benefits obtained by using it in building. It also intends to compare the characteristics of some construction materials such as brick, ceramic and concrete block with bottle. One can use solar bomb (bottle filled with bleaching powder solution) will be fitted on the roof for light source.

LITERATURE REVIEW

Nowadays, large amount of plastic bottles are wasted and disposed every day. People are thrown away them without considering that what those plastic bottles can have impact on the humans and/or environment. Andreas Froese, the founder of Eco-Tec Environmental Solution, in searching for finding an inventive solution to junk, established the

innovation of building plastic bottle houses .The first bottles house was built using 10000 glass beer bottles by William F. peck in 1902 in Tonopha, Nevada [5]. After that the newer innovative concept has been using plastic bottle instead of glass bottles in constructing the houses. This innovative idea took to account for some reasons such as providing a cost-efficient construction method for pauperized third-world countries, reusing the plastic bottles due to their not indecomposable characteristic, and etc. The first plastic bottles house in Africa was constructed in the village of Yelwa in Nigeria by Andreas Forese. Forese used the plastic bottles instead of bricks, bound the bottles together with string and at the end applied the plaster [6].

Anyway beside the Eco-Tec, various other institutions and groups have initiated the concept of reusing the plastic bottles for building construction. However nowadays, the concept has spread to countries all over the world. Various kinds of homes have been built from plastic bottles such as: ecological house constructed using 800 0 bottles in Honduras; an Eco-Tec home in Bolivia constructed using the PET and wine bottle; a house of waste plastic bottles built in Serbia by Tomislav Radovanic; Taiwan's plastic bottle building; ecological bottle house built using 1200 PET plastic bottles or the walls near the Iquazu Falls, Misiones, Argentina; and etc [4]. The purpose of this paper is to look into the using of plastic bottles as a municipal waste in the buildings, the key and positive characteristics of this product and the benefits obtained by using it in building. It also intends to compare the characteristics of some construction materials such as brick, ceramic and concrete block with bottle panel.

Basic Construction Materials And Properties.

This construction require some of the basic materials which ensures a stable, eco friendly structure and also results in cheap construction as compared to brick wall. Materials uses for

Bottlewall masonry construction are :

- 1) Soil
- 2) plastic
- 3) Cement
- 4) Nylon rope
- 5) Water

SOIL

Soil is the basic element in any construction project so before using it in our project we have to study the basic properties of the soil and go through different tests, so as to check whether the soil sample selected is suitable for the given project.

Properties of soil

- Soil Texture:

Soil texture can have a profound effect on many other properties and is considered among the most important physical properties. Texture is the proportion of three mineral particles, sand, silt and clay, in a soil. These particles are distinguished by size, and make up the fine mineral fraction.



- **Soil Colloids:**

Soil colloids refer to the finest clay in a soil. Colloids are an important soil fraction due to properties that make them the location of most physical and chemical activity in the soil. One such property is their large surface area. Smaller particles have more surface area for a given volume or mass of particles than larger particles. Thus, there is increased contact with other colloids and with the soil solution. This results in the formation of strong friction and cohesive bonds between colloid particles and soil water, and is why a clay soil holds together better than a sandy soil when wet.

- **Soil Structure:**

Soil structure is the arrangement and binding together of soil particles into larger clusters, called aggregates or pads. Aggregation is important for increasing stability against erosion, for maintaining porosity and soil water movement, and for improving fertility and carbon sequestration in the soil. Granular structure consists of loosely packed spherical pads that are glued together mostly by organic substances.

PLASTIC BOTTLE

In this paper plastic bottles are used as a fundamental element, so we have gone through every property of the PETE bottles so as to ensure a stable structure.

Properties of PETE bottle

Polyethylene Terephthalate Ethylene (PETE) bottles is thermoplastic materials. This type of plastic are polymers and with or without cross linking and branching, and they soften on the application of heat, with or without pressure and require cooling to be set to a shape. Following are properties of plastic bottle:

- 1) Wax like in appearance, translucent, odorless and one of the lightest plastics.
- 2) Flexible over a wide temperature.
- 3) Heat resistance.
- 4) Chemically stable.
- 5) Do not absorb moisture.
- 6) Transparent.

CEMENT

Cement is the important binding material. In these paper it is use to bind the plastic bottles to make the masonry wall more durable so that the quality of cement is check by following properties.

Properties of cement

- **Fineness:**

Fineness or particle size of Portland cement affects Hydration rate and thus the rate of strength gain. The smaller particle size, and the greater the surface area-to-volume ratio so that the more area available for water-cement interaction per unit volume. The effects of greater fineness on strength are generally seen during the first seven days.

- **Soundness:**

Soundness is defined as the volume stability of the cement paste. Cement paste strength is typically defined in three ways: compressive, tensile and flexural. These strengths can be affected by a number of items including: water cement ratio, cement-fine aggregate ratio, type and grading of fine aggregate, curing conditions, size and shape of specimen, loading conditions and age.

- **Setting Time:**

The initial setting time is defined as the length of time between the penetration of the paste and the time when the needle penetrates 25mm into the cement paste.

NYLON ROPE

Nylon rope has a very high tensile strength so that it is use as the main binder for PETE bottles masonry

Properties of Nylon rope

Nylon rope is gotten from coal, Petroleum, air and water. It is a polyamide thermoplastic produced by series on condensation reaction between an amine and organic acids. the properties of nylon as follow:

- 1) Good abrasion resistance.
- 2) Tough and strong but flexible too.
- 3) High impact strength.
- 4) Absorb water which causes reduction in strength and impact properties
- 5) Resistant to most of the solvents and chemicals
- 6) High softening temperatures and thus molding becomes difficult.

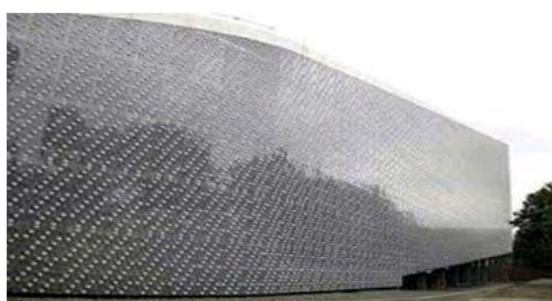
WATER

Water is in a similar way like cement, an active component in mortar. For cement-sand mortar, without water no hydration can be attained, hence no strength can be achieved. Water is responsible for the workability of a fresh mortar. 20% of the overall weight of the cement and soil was used to determine the quantity of water to be used in the mix. A slump test and a flow test were conducted to evaluate the consistency of the fresh mortar.

Background : The first bottle house was constructed in 1902 by William F. Peck in Tonopah; Nevada. The house was built with 10,000 bottles of beer, which were 90% alcohol and 10% opium. The Peck house was demolished in the early 1980's. The use of empty vessels in construction dates back to ancient Rome, which had structures with amphorae embedded in concrete. This was not done for aesthetic reasons, but to lighten the load of upper levels of structures empty, and to reduce concrete usage. The first plastic bottle construction project in Africa was pioneered in Uganda by Butakoola Village Association for Development (BUVAD) in 2010 in Cayuga district. The idea followed a BUVAD community survey in 2009 that revealed that many farmers in Kayunga were experiencing low crop yields due to poor soil fertility, which was a result of the presence of waste plastics, such as bottles and polythene bags, in the soil.



Dec 2nd, 2010 proving that there are all kinds of uses for recycled PET plastic, Taiwan-based Er. Arthur Huang processed 1.8 million used plastic bottles into honeycomb-shaped bricks for a boat-shaped exhibition hall called the Eco-ARK. Built for Taipei's flower show, Eco-ARK was constructed for just one-third the cost of a conventional structure. Once locked together, the bricks are extremely strong.



May 2011 Samarpan Foundation has constructed a children school in New Delhi, using hundreds of used PET bottles instead of conventional bricks.



METHODOLOGY

Construction Process

Collection and cleaning of waste plastic bottle
The gathering phase is the simplest, requiring the homeowner to calculate the number of bottles they will require and to then collect the bottles and necessary equipment.

Prepare

The prepare phase then requires the homeowner to fill the collected bottles with sand and prepare the ground upon which the construction will take place.

Construct

1.Lay, 2cm (3/4 inch) of cement onto the foundations of which the wall is being built.

2. Place plastic bottles on top of this cement with a 1cm (1/3 inch) space between bottles.
3. Pour cement on top of these bottles being careful to fill in all gaps, ensuring that the cement is 2cm (3/4 inch) above the top of the bottles.
4. Place the next layer of plastic bottles in between the bottles below, as shown in Figure 7 (over).
5. Pour cement on top of these bottles being careful to fill in all gaps, ensuring that the cement is 2cm (3/4 inch) above the top of the bottles.
6. Repeat steps 1-5 until the wall is at the desired height.
7. Once the wall is built and dried completely render the sides to achieve the desired outward aesthetic look.

Cost Comparison between Brick Masonry Wall and Bottle Masonry Wall

Here, we consider 10 sq. meter Masonry works for calculation of quantities.

Brick Masonry wall

1) Number of bricks

Actual size of brick = 19 cm x 9 cm x 9cm
 Normal size of brick (with mortar joint) = 20 cm x 10 cm x 10 cm
 Volume of brick masonry = Area x thickness of wall
 = 10 x 0.23
 = 2.3
 No. of Brick = $\frac{\text{Volume of brick masonry}}{\text{Volume of 1 brick with mortar}}$
 = $\frac{2.3}{0.2 \times 0.1 \times 0.1}$
 = 1150 Nos.

2) Mortar

Actual volume of bricks in brick masonry = 1150 x (0.19x0.19x0.19)
 = 1.76m³
 Volume of wet mortar = 2.3 - 1.76
 = 0.531m³
 For frog filling, cut bricks, for bonding, wastage etc increase this quantity by 15%
 Volume of wet mortar = 1.15 x 0.531
 = 0.610m³
 Volume of dry mortar reduces by 25% when water is added
 Volume of dry mortar = 1.25 x 0.610
 = 0.763m³

3) Material for 1:3 brick work

Quantity of brick = 2.3m³
 Proportion 1:3
 Volume of dry mortar = 0.763m³
 1:3 = 4
 C: S
 Cement = (1/4) x 0.763 = 0.190m³
 No. of bags = $\frac{0.190}{0.035}$
 = 5.45 bags
 For 1 bag of cement
 Weight = 50kg
 Volume = 0.035m³
 Sand = (3/4) x 0.763 = 0.237m³

Sr. no	Material	Quantity	Rate	Per	Amount(Rs.)
1	Brick	1150 nos.	5	1 no.	5750
2	Cement	5.45	300	1 bag	1635
3	Sand	0.237	250	1 m ³	59.25
				Total	7444.25

Table: Cost Estimation of Brick Wall Masonry

Plastic Bottle Masonry wall

1) Number of bottle

Actual size of bottle = 24cm x 8 cm φ
 Normal size of bottle (with mortar joint) = 24 cm x 9 cm φ
 Volume of bottle masonry = Area x thickness of wall
 = 10 x 0.24
 = 2.4m³
 No. of Bottle = $\frac{\text{Vol. of bottle masonry}}{\text{Vol. of 1 bottle with mortar joint}}$
 = $\frac{2.4}{0.24 \times (\pi/4 \times 0.09^2)}$
 = 1572

2) Mortar

Actual volume of bricks in brick masonry = 1150 x (0.19x0.19x0.19)
 = 1.76m³
 Volume of wet mortar = 2.3 - 1.76
 = 0.531m³
 For frog filling, cut bricks, for bonding, wastage etc increase this quantity by 15%
 Volume of wet mortar = 1.15 x 0.531
 = 0.610 cubic meter



Volume of dry mortar reduces by 25% when water is added
Volume of dry mortar = 1.25×0.610
= 0.763m^3

3) Material for 1:3 brick work
Quantity of brick = 2.3m^3
Proportion 1:3
Volume of dry mortar = 0.763m^3
1:3 = 4

C:S
Cement = $(1/4) \times 0.763 = 0.190\text{m}^3$ For 1 bag of cement
Weight = 50kg
Volume = 0.035m^3
= $\frac{0.190}{0.035}$
= 5.45 bags

Sand = $(3/4) \times 0.763 = 0.237\text{m}^3$ Here, consider 1000 ml bottle
Soil = $1990 \times 0.0001 = 1.99\text{m}^3$ 1ml=liter=1cm³

4) No. of Labour

One labour can made 400 bottles per day (filling soil in bottles).
Total no. of bottles = 1572
Numbers of labour needed = $(1572/400) = 4$ nos.

Sr. no	Material	Quantity	Rate	Per	Amount(Rs.)
1	Plastic bottle	1572 nos.	0.5	1 no.	786
2	Cement	5.45	300	1 bag	1635
3	Sand	0.237	250	1m ³	59.25
4	Soil	1.99	100	1m ³	199
5	Labour work	4	300	1 person	1200
				Total	3879.25

Table: Cost Estimation of Plastic Bottle Wall Masonry

1. Comparison between the walls by Plastic Bottles wall and Brick Wall for construction Time and speed of Execution for 5 persons team-one working day for plastic wall is 15% faster and for brick wall 120 sq.m.



Sr. No	Factors	Considerations	Plastic Bottle Wall	Brick Wall
1	Time and speed of Execution	5 persons team-one working day	15% faster	120 m ²
2	Material and equipment costs	Implementation and installation of materials and equipment	Saving in cement, water, grinder and fitting	More weight, more materials
3	Transportation Costs	Displacement in the building	Lighter and higher volume, easy and cheap displacement	Greater weight and less volume, hard and costly displacement
4	Execution cost	Using calculations of panel	Less manpower and indigenous	More human resources- the higher cost
5	Strength and load Capacity		20 times more than brick	Greater wall thickness, lower strength
6	Resistance to Earthquake	Earthquake has a direct relationship with the weight of each structure	Low and Integrated weight without falling debris	High weight and loss of material
7	Cleaness and beauty of work		Very clean execution, no construction waste	High volume of construction waste
8	Flexibility		High flexibility	Low flexibility
9	Material waste		No wastage	High and unusable

Table: Comparison between the Wall by Plastic bottle and Brick.

2. Material and equipment cost for plastic bottle wall is less as compared to brick wall. Transportation cost for plastic bottle wall construction is less than brick wall. Plastic bottle wall construction require less manpower as compare to brick wall and require high cost. Strength and load capacity for plastic bottle wall construction is 20 times more than brick wall construction.

Benefits of Plastic Bottle Masonry wall

The most important benefits of these alternative innovative materials compared to conventional materials such as brick can include:

A. Good construction ability : The walls built by these bottles are lighter than the walls built by brick and block, and that makes these buildings to show a good response against earthquake. Due to the compaction of filling materials in each bottle, resistance of each bottle against the load is 20 times higher compared to brick. And these compressed filling materials, makes the plastic bottle to be prevented from passing the shot that makes the building as a bulletproof shelter.

B. Low cost : Constructing a house by plastic bottles used for the walls, joist ceiling and concrete column offers us 45% diminution in the final cost. Separation of various components of cost shows that the use of local manpower in making bottle walls can lead to cost reduction up to 75% compared to building the walls using the brick and concrete block. It must be noted that the sophisticated manpower can lead to reducing the construction time and the relative costs also become lower.

C. Non-brittle characteristic: Using the non-brittle materials can reduce construction waste. Unlike brick, plastic bottle is non-brittle. So due to the frangibility property, the percentage of producing construction waste in brick is more than plastic bottles.

D. Absorbs abrupt shock loads: Flexibility is a characteristic which makes the buildings performance higher against the unexpected load. Since the plastic bottles are not fragile, they can be flexible and tolerates sudden loads without failure. This characteristic can also increase the buildings bearing capacity against the earthquake.

E. Green Construction: Plastic bottles can cause the green construction by saving energy and resources, recycling materials, minimizing the emission, having significant operational savings and increasing work place productivity.

CONCLUSION

1. Use of innovative materials with sustainable application such as plastic bottles can have considerable benefits including finding the best optimization in energy consumption of the region, reducing environmental degradation.

2. Generally the bottle houses are bio-climatic in design, which means that when it is cold outside is warm inside and vice versa.



3. Re-using the plastic bottles as the building materials can have substantial effects on saving the building embodied energy by using them instead of bricks in walls and reducing the CO₂ emission in manufacturing the cement by reducing the percentage of cement used.

4. Plastic bottles can cause the green construction by saving energy and resources, recycling materials, minimizing the emission, having significant operational savings and increasing work place productivity.

5. Cost compression between bottles wall is roughly half than conventional brick masonry. i.e., Total cost of 10 sq m Brick masonry wall is Rs. 7444.25 and total cost of 10 sq m Bottle masonry wall is Rs. 3879.25.

REFERENCES

- [1] Mojtaba Valinejad Shoubi., Azin Shakiba Barough.; 'Investigating the Application of Plastic Bottle as a Sustainable Material in the Building Construction', International Journal of Science, Engineering and Technology Research (IJSETR) Volume 2, Issue 1, January 2013 ISSN: 2278 – 7798.
- [2] Shilpi Saxena., Monika Singh.; 'Eco-Architecture: PET Bottle Houses', International Journal of Scientific Engineering and Technology Volume No.2, Issue No.12, pp: 1243-1246 1 Dec 2013, ISSN: 2277-1581.
- [3] Puttaraj Mallikarjun Hiremath., Shanmukha shetty.; 'Utilization Of Waste Plastic In Manufacturing Of Plastic-Soil Bricks', International journal of technology enhancements and emerging engineering research, volume 2, issue 4, ISSN 2347-4289.
- [4] Pratima Patel., Akash Shah.; 'Sub stainable development using waste PET bottles as construction element' www.wastebottleconstruction.com.
- [5] Arulmalar Ramaraj., Jothilakshmy Nagammal.; '30th INTERNATIONAL PLEA CONFERENCE' 16-18 December 2014, CEPT University, Ahmedabad
- [6] Vikram Pakrashi.; 'Experimental Characterization of Polyethylene Terephthalate 1 (PET) Bottle Eco-Bricks'.
- [7] Andreas Froese (2001), 'Plastic bottles in construction who is the founder of ECO-TEC', Available from: <http://www.eco-tecnologia.com>.
- [8] Samarpan foundation, 'House construction with plastic bottles, New Delhi', Available form: www.samarpanfoundation.org
- [9] How-To Make a Bottle Brick www.earthbench.org