PET Bottles for Eco-friendly Building in Sustainable Development

Jayaprakash M C1, Deeksha I M2 and Soumya M R3
1, 2, 3 Civil Engineering, Mangalore Institute of Technology & Engineering, Email Id: jayaprakash@mite.ac.in

Abstract—This paper proposes the use of waste plastic PET (Poly-ethylene Terephthalate) bottles as constructions entity to standardised bricks. As plastics are non-biodegradable its disposal has always been a problem. This is an environmental issue as waste plastic bottles are difficult to biodegrade and involves processes either to recycle or reuse. Green building is one that may represent a regenerative process where there is actually an improvement and restoration of the site and its surrounding environment. The ideal “green” project preserves and restores habitat that is vital for sustaining life and becomes a net producer and exporter of resources, materials, energy and water rather than being a net consumer. Green building is the practice of constructing or modifying structures to be environmentally responsible, sustainable and resource-efficient throughout their life cycle.

Thus, to envisaged the sustainable development and energy consumption in the construction of green building for quality living concept to fulfil the paradigm of the development of country. The present work may give the same sort of solution in the construction of buildings by using waste plastic PET bottles which are dumped on the open land. It may solve the reuse of the waste plastic PET bottles as a benefit to minimise the solid waste in the form of environment friendly green building concept for living as a cost effective material.

Keywords—Waste plastic PET bottles, Green building, Cost effective, Environmental friendly.

I. INTRODUCTION

India is a developing country and population of the country is very huge. India got second place in population in the world. Population is directly effects the other parameters like consumption of energy and utilisation of daily using materials. Now a day’s consumption of energy increased and due to the utilisation of high energy we are facing problem like scarcity of energy. So it is necessary to use alternative method for energy and material.

Increase in population directly affects civil field. As the population increases number of buildings also increases. Considering high population increase in India it is difficult to provide basic needs for the people. One of the main basic needs is shelters. Due to high rate of use there is scarcity of materials. With growing concerns over the growing pollution, there has been an exhaustive search made for means of alternative energy. This has included tapping most of the renewable resources of the earth and using growing technological awareness to create less pollution.

The reusing 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 [6]. It is counted as one of the foundation’s green project and has caught the attention of the architecture and construction industry. Generally the bottle houses are bioclimatic in design, which means that when it is cold outside is warm inside and when it is warm it is cold inside. 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 panels can lead to cost reduction up to 75% compared to building the walls using the brick and concrete block.

The efficient usage of waste plastic in plastic-soil bricks has resulted in effective usage of plastic waste and thereby can solve the problem of safe disposal of plastics, also avoids its wide spread littering and the utilization of quarry waste has reduced to some extent the problem of its disposal [8]. 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.

In this context, the present work has been initiated as a green building model construction using waste PET bottles in the MITE campus as an experimental pilot project work to encourage and awareness about the green building construction to the society. It has been keeping in mind to minimise the waste, reuse, recycle and sustainable development in the field of construction to create less pollution in the developing huge populated country like India.

II. OBJECTIVE

The main objective of this project to implement green design process to establish firm environmental goals for this project. It is important to set specific measurable goals for things like energy efficiency, water conservation and construction waste management.

The Green buildings are designed to reduce the overall impact of the built environment on human health and natural environment by:

- Energy efficiency
- Reducing pollution and environmental degradation
- Recycle–Reuse
- Lower cost (utilities, costs of conversion)
- Reduce carbon consumption
- Encourage community
- Preserve natural systems

III. METHODOLOGY

- Site selection
- Auto CAD for site map
- Selection of materials
- Estimation
- Collection of materials
- Construction of building model
- Analysis the model

3.1 Steps used to fill the soil into bottle

- Soil selection from barrow pit
- The soil used is literate soil which is locally available at the site
- Soil taken from barrow pit and spread it on the field for natural drying, at least for 24 hours
- The diameter of the bottle opening is 2.5cm so the soil is sieved using 10mm (1cm) sieve
- The sieved soil is used for the filling of bottles
• The empty weight reading of the bottle is noted \((W_1)\)
• The bottle is filled up to \(1/3\)rd of its height. Later, compaction is done
• For the proper compaction purpose 10mm diameter iron rod is used and also hand vibration is made
• After filling, the bottle cap is closed tightly
• Filled bottle weight is taken \((W_2)\)

<table>
<thead>
<tr>
<th>PET Bottles</th>
<th>Empty weight of the bottle (Kg) ((W_1))</th>
<th>Soil + Bottle Weight (Kg) ((W_2))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sprite Bottle</td>
<td>0.055</td>
<td>3.13</td>
</tr>
<tr>
<td>Fanta Bottle</td>
<td>0.06</td>
<td>3.13</td>
</tr>
<tr>
<td>Coca Cola Bottle</td>
<td>0.055</td>
<td>3.12</td>
</tr>
<tr>
<td>Pepsi Bottle</td>
<td>0.06</td>
<td>3.2</td>
</tr>
</tbody>
</table>

### 3.2 Methodology for construction

• Selection of eco-friendly site is identified in the study area (MITE, campus) for the construction of the green building model
• Excavation is made up to the feet
• Laterite stones are used for foundation work. And the foundation is constructed using cement mortar
• Above the ground level two stone layers of foundation is constructed
• Upon this, PET bottles are placed one by one and bonding is made from bottle to bottle using winding wires. Finally when completes one round, it is tied to the iron rod
• Iron rod is placed on each corner of the wall as a support
• Mortar is prepared by gently adding the water into the soil till it attains desired workability
• After the construction of each layer, 1cm thick layer of mortar is applied on it
• Iron rod is used for the window and door and welding is done with the desired dimension before it is placed
• The wall is made with 23 layers of PET bottles
• Roof fabrication and welding is done by using support angles separately. Then the roof (waste sheets) is placed on the walls
• Soil plastering is done for two aces of all four walls
• Pointing of the PET bottle work is made for the aesthetic view
• Coating is done with the cement paste to act as a fire resistance
• Finally, the bottom edges of the PET bottles and roof sheets are painted with green colour

### IV. PROPERTIES OF PET BOTTLES

#### 4.1 Deformation Capacity

Introducing PET makes concrete ductile thus increasing its ability to deform before failure. So it makes useful in situation where it is subjected to harsh condition like expansion and contraction and regular wear and tear.

#### 4.2 Energy Consumption
The inclusion of recycled concrete is advantageous from energy point of view as it keep interior temperature cooler when outside temperature is raised as compared to conventional concrete.

4.3 Modulus of Elasticity

The value of modulus of elasticity decreased with raise in plastic aggregate content. Also, increasing w/c ratio reduces modulus of elasticity.

Also plastics act as freeze thaw resistant aggregates increasing the concrete entities life. Toughness and Impact resistance was also increased as compared to conventional concrete mixtures. Also an amazing aspect was observed in the thermal conductivity of the reinforced concrete and an increase in thermal insulation was registered of the concrete. It was also found that it has comparable alkali resistant when used in normal concrete [3]. Cracking due to drying shrinkage was delayed indicating bridging properties of PET fibers and delayed macro crack formation.

4.3 Blocks with PET replacement have following features as compared to conventional blocks

1. Greater weather resistant due to chemically inert PET and HDPE;
2. Less stress or load on foundation (due to lighter blocks);
3. Economical foundation (since the stress on foundation is less)
4. Less manual labour in making blocks (mixture is lighter);
5. Less cost of transportation (due to lighter blocks);
6. Good sound insulation;
7. Variable strengths (dependent on size and nature of plastic aggregate);
8. Better shock absorption; and
9. Deduction in the dead load of concrete structure which allows the contractor to reduce the dimension of columns, footings and other load bearing elements. (Sanisah S. 2013).

V. RESULT AND CONCLUSION

<table>
<thead>
<tr>
<th>Details</th>
<th>For green building Rate (Rs)</th>
<th>For conventional building Rate (Rs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filled Bottles &amp; brick respectively</td>
<td>8855</td>
<td>14,300</td>
</tr>
<tr>
<td>Foundation work</td>
<td>1872</td>
<td>2628</td>
</tr>
<tr>
<td>Soil mortar and cement mortar respectively</td>
<td>88</td>
<td>4143</td>
</tr>
<tr>
<td>Window and door work</td>
<td>4900</td>
<td>4500</td>
</tr>
<tr>
<td>Roof work (using G.I sheets and Al sheets respectively)</td>
<td>7440</td>
<td>14550</td>
</tr>
<tr>
<td>Flooring and steps work (using concrete and tiles respectively)</td>
<td>1060</td>
<td>2583</td>
</tr>
<tr>
<td>Plastering work(mud and cement plastering respectively)</td>
<td>577</td>
<td>5728</td>
</tr>
<tr>
<td>Painting work (oil paint)</td>
<td>850</td>
<td>1090</td>
</tr>
<tr>
<td>Labour for construction</td>
<td>5950</td>
<td>5950</td>
</tr>
<tr>
<td>Transportation charge</td>
<td>536</td>
<td>828</td>
</tr>
<tr>
<td><strong>Total cost including solar in Rs.</strong></td>
<td><strong>34,500</strong></td>
<td><strong>58,000</strong></td>
</tr>
</tbody>
</table>

*Cost reduction for the green building comparing to conventional building 40.5%
Table 3 Cost estimation of the present work.

<table>
<thead>
<tr>
<th>Details</th>
<th>Cost of present green building work (Rs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bottles cost (Rs. 2 per bottle)</td>
<td>2600</td>
</tr>
<tr>
<td>Foundation work (2 bags cement cost)</td>
<td>820</td>
</tr>
<tr>
<td>Soil mortar</td>
<td>-</td>
</tr>
<tr>
<td>Window and door work (material cost)</td>
<td>500</td>
</tr>
<tr>
<td>Roofing work (fabrication cost)</td>
<td>4000</td>
</tr>
<tr>
<td>Flooring and steps work (using concrete, only cement cost)</td>
<td>410</td>
</tr>
<tr>
<td>Plastering work (mud and cement coating, only cement cost)</td>
<td>410</td>
</tr>
<tr>
<td>Paint</td>
<td>850</td>
</tr>
<tr>
<td>Labour charge for construction</td>
<td>5000</td>
</tr>
<tr>
<td>Transportation</td>
<td>300</td>
</tr>
<tr>
<td><strong>Total Cost (Including Solar) in Rs.</strong></td>
<td><strong>16,590</strong></td>
</tr>
</tbody>
</table>

**Note:** It has been used locally available soil, locally available waste stones, sand, aggregates and waste steel rods free of cost in this present project work.

*Cost reduction for the green building comparing to conventional building 71.38%*

5.1. Experimental Work

5.1.1 In-situ density of soil by sand replacement method

Table 4 Bulk density of sand

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Sample Details Calibration</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Weight of sand + cone pouring cylinder $W_1$ gm</td>
<td>6940</td>
<td>6900</td>
</tr>
<tr>
<td>2</td>
<td>Volume of calibrating container (V) in cc ($d=10cm, h=15cm$)</td>
<td>1178</td>
<td>1178</td>
</tr>
<tr>
<td>3</td>
<td>Weight of sand in cone portion $W_2$ gm</td>
<td>330</td>
<td>330</td>
</tr>
<tr>
<td>4</td>
<td>Weight of sand + cylinder after pouring $W_3$ gm</td>
<td>5050</td>
<td>5000</td>
</tr>
<tr>
<td>5</td>
<td>Weight of sand to fill calibrating containers $W_a = (W_1-W_3-W_2)$ gm</td>
<td>1560</td>
<td>1570</td>
</tr>
<tr>
<td>6</td>
<td>Bulk density of sand $Y_s = \frac{W_a}{V}$ gm/cc</td>
<td>1.32</td>
<td>1.33</td>
</tr>
</tbody>
</table>

Table 5 Bulk density of soil

<table>
<thead>
<tr>
<th>S. No</th>
<th>Measurement of Soil Density</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Weight of wet soil from hole $W_w$ gm</td>
<td>1920</td>
<td>1920</td>
</tr>
<tr>
<td>2</td>
<td>Weight of sand + cylinder before pouring $W_1$ gm</td>
<td>6940</td>
<td>6900</td>
</tr>
<tr>
<td>3</td>
<td>Weight of sand + cylinder after pouring $W_4$ gm</td>
<td>5065</td>
<td>5065</td>
</tr>
<tr>
<td>4</td>
<td>Weight of sand in hole $W_b = (W_1-W_2-W_4)$ gm</td>
<td>1545</td>
<td>1545</td>
</tr>
<tr>
<td>5</td>
<td>Bulk density of soil $Y_b = \left(\frac{W_w}{W_b}\right) \times Y_s$ gm/cc</td>
<td>1.64</td>
<td>1.69</td>
</tr>
</tbody>
</table>
Table 6 Dry density of soil

<table>
<thead>
<tr>
<th>S. No</th>
<th>Water content determination</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Empty weight of the container (W₁) gm</td>
<td>75</td>
<td>70</td>
</tr>
<tr>
<td>2</td>
<td>Weight of wet soil+ container (W₂) gm</td>
<td>80</td>
<td>75</td>
</tr>
<tr>
<td>3</td>
<td>Weight of dry soil + container (W₃) gm</td>
<td>79</td>
<td>74</td>
</tr>
<tr>
<td>4</td>
<td>Moisture content (%) = (W₂-W₃)/(W₃-W₁)</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>5</td>
<td>Dry density of soil ϒₙ = ϒₐ / (1+W) gm/cc</td>
<td>1.31</td>
<td>1.31</td>
</tr>
</tbody>
</table>

Bulk density of soil by sand replacement method = 1.66gm/cc
Dry density of soil by sand replacement method = 1.31gm/cc

5.1.2 Compaction test

Standard compaction test:
i. Diameter of mould, D = 10cm
ii. Height of mould, h = 12.8cm
iii. Volume of mould, V = 1005.3cc
iv. Empty weight of the cylinder = 4784gm

Table 7 Dry unit weight of soil

<table>
<thead>
<tr>
<th>S. No</th>
<th>Dry unit weight determination</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Weight of cylinder + compacted soil (W₁), gm</td>
<td>6430</td>
<td>6549</td>
<td>6612</td>
<td>6560</td>
</tr>
<tr>
<td>2</td>
<td>Weight of compacted soil (W₂) gm</td>
<td>1646</td>
<td>1765</td>
<td>1828</td>
<td>1776</td>
</tr>
<tr>
<td>3</td>
<td>Bulk unit weight of compacted soil Y(gm/cc)</td>
<td>1.64</td>
<td>1.75</td>
<td>1.82</td>
<td>1.77</td>
</tr>
<tr>
<td>4</td>
<td>Water content(W)</td>
<td>12</td>
<td>18</td>
<td>22</td>
<td>24</td>
</tr>
<tr>
<td>5</td>
<td>Dry unit weight Yₙd = Yₙ / (1 + W), (gm/cc)</td>
<td>1.46</td>
<td>1.48</td>
<td>1.49</td>
<td>1.43</td>
</tr>
</tbody>
</table>

Graph 1. Determination of maximum dry density
Maximum dry density = 1.49 gm/cc
Optimum moisture content = 22%

5.1.3 Compressive strength

Considering contact area as cylinder for PET bottles
Area of cylinder = L × B
Length of the bottle = 350 mm
Diameter of the bottle = 110 mm
Area of the bottle = 38500 mm²

**Trial 1:**
Failure load = 520 KN
Compressive strength = P/A
= (520 × 10³) / (350 × 110)
= 13.5 MPa

**Trial 2:**
Failure load = 340 KN
Compressive strength = P/A
= (340 × 10³) / (350 × 110)
= 8.83 MPa

The average value obtained by the compressive strength test is as follows:

<table>
<thead>
<tr>
<th>Load (kN)</th>
<th>Area (mm²)</th>
<th>Compressive Strength (MPa)</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>520</td>
<td>38500</td>
<td>13.5 MPa</td>
<td>11.16 MPa</td>
</tr>
<tr>
<td>340</td>
<td>38500</td>
<td>8.83 MPa</td>
<td></td>
</tr>
</tbody>
</table>

*Average compressive strength of the soil filled PET bottle = 11.16 MPa

**Note:** Compressive strength of the brick as per (IS1077:1992 Common burnt clay building bricks) Specification amendment No.1 May 2008.
Minimum compressive strength of the brick = 3.5 MPa
Ultimate compressive strength of the brick = 14 MPa

---

5.2 Design of green building model

*According to yield line theory IS456 (Page no. 41)
\[ \frac{1}{A} = \frac{2}{2} = 1 < 2, \text{ (Hence it is two way slab)} \]

Total area = \(2 \times 2 = 4 \text{m}^2\)

Area of each triangle,

\[ A_1 = \frac{1}{2} \times 2 \times 1 = 1 \text{m}^2 \]

Roof load intensity considered 1 kN/m\(^2\)

Load distribution 25% on each wall

Total load on side wall = \((25/100) \times (4 \times 1) = 1 \text{ kN/m}\)

Total load on per metre of wall = total load/length

= 1/2

= 0.5 kN/m

Ultimate compressive strength of the filled bottle = 11.16MPa

Designed compressive strength = \(11.16 / 1.5\)

= 7.44MPa

Compressive strength = \(1 \times 10^3 / (2000 \times 300)\)

= 1.66 \times 10^{-3}\)

= 0.0016MPa < 7.44MPa

*Hence, present green model is safe structure like conventional building.*

---

*Fig.2 Photographic view of green building model*
VI. CONCLUSION

- As per the experimental observations concluded that no curing time is required if waste PET bottles are used as building material as compared to bricks which require 28 days curing time.
- Reusing 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 while baking of bricks there are a major issue of carbon emission which is negligible in using PET bottles and also reducing the CO$_2$ emission. In manufacturing the cement by reducing the percentage of cement by use of mud mortar and mud plastering for construction work.
- Weight of a unit bottle brick (3kg) was found to be less than that of a standard conventional brick. Compressive strength of the bottle brick (11.16Mpa) is also more than that of a standard conventional brick.
- From the present green model cost analysis cost reduction up to 71.38% possible by using waste materials and locally available materials so highly cost effective.
- Concept of PET bottles which is replacing the brick is cost effective, energy efficient and commercially feasible. Using PET bottles is also Bio-climatic which means that when it is cold outside is warm inside and vice versa and thus we can say it is a Green construction. Green buildings are always eco-friendly for quality living.

REFERENCES