

Possible Number of Dwelling Units Using Waste Plastic Bottle for Construction

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Abstract—Unlike other metro cities of India, Bhubaneswar—the capital city of Odisha, is expected to reach 1-million-mark population by now. The demands of dwelling unit requirement mostly among urban poor belonging to Economically Weaker section (EWS) and Low Income groups (LIG) is becoming a challenge due to high housing cost and rents. As a matter of fact, it's also noted that, with increase in population, the solid waste generation also increases subsequently affecting the environment due to inefficiency in collection of waste by local government bodies. Methods of utilizing Solid Waste - especially in form of Plastic bottles, Glass bottles and Metal cans (PGM) are now widely used as an alternative material for construction of low-cost building by Non-Government Organizations (NGOs) in developing countries like India to help the urban poor afford a shelter. The application of disposed plastic bottle used in construction of single dwelling significantly reduces the overall cost of construction to as much as 14% compared to traditional construction material. Therefore, considering its cost-benefit result, it's possible to provide housing to EWS and LIGs at an affordable price. In this paper, we estimated the quantity of plastic bottles generated in Bhubaneswar which further helped to estimate the possible number of single dwelling unit that can be constructed on yearly basis so as to refrain from further housing shortage. The estimation results will be practically used for planning and managing low-cost housing business by local government and NGOs.

Keywords—Construction, dwelling unit, plastic bottle, solid waste generation, groups.

I. INTRODUCTION

SHELTER is regarded as the most important necessities for survival next to food and clothing [1]. Yet homelessness has plagued many metropolitan cities beyond estimation in India. In 2012 itself, India's housing shortage was estimated to be nearly 18.78 million households [2]. In addition, among this, 95% are pertaining to EWS and LIG. Overcrowding in urban areas eventually leads to chronic problem of shortage of houses in urban areas. Most metropolitan cities in India have been facing housing shortages due to over-growing density and lack of potential to meet the housing demands by local government. High rent by real estates has forced many underprivileged people to build slums illegally, leading to unhygienic environment. Hence, it is important to find alternative methods of providing affordable housing to these groups with better standard of hygiene and amenities.

Reference [3] reveals typical evidence on application of waste plastic bottle used as an alternative construction material to build livable dwelling unit and possibly affordable to under-financed groups. The project is mostly supported by NGOs.

Andreas Froese, an environmental consultant, has produced many such buildings in different parts of world, using disposed plastic bottles [4]. In a technical paper, "*New alternatives in construction: earth filled pet bottles*", A. Froese reveals that cost of construction using such techniques can reduce to as much as 40% if built from foundation till the standard wall height [5], though it may vary in other nations depending on cost of other ingredients. In an earlier paper, an experimental research was taken up to find out the number of waste plastic bottle that can be used to build single dwelling unit with carpet area of 37 sqm [6]. It was also concluded that such structure can withstand cyclone and also considered safe during earthquake. In this article, we estimated the number of such dwelling units that can be possible to be built in respective to the city lifestyle, so as to provide affordable housing to EWS and LIG, taking Bhubaneswar as a study area.

II. HOUSING SCENARIO IN BHUBANESWAR CITY

A. The City Recognition

Bhubaneswar is the capital city of Odisha, an eastern state of India. Along with popular planned city - Jamshedpur and Chandigarh, modern Bhubaneswar was originally planned by internationally acclaimed urban planner Otto H. Koenigsberger in 1946 [7]. However, part of the city is not yet successfully planned due to uncontrolled population growth rate for last few decades. Often regarded as Temple City of India for its extraordinary history and exquisite temples, Bhubaneswar has now a population of 881,988 (2011) with 837,737 under metropolitan area, is on its way to become trade and commercial hub of eastern region of India along with its twin city, Cuttack. The city is classified as 'Y' city and with 50% growth rate it is expected to have reached million-plus mark population by now according to projection by urban planner group from Indian Institute of Technology, Kharagpur, India [8], [9].

B. Housing

A comprehensive development plan was submitted to Bhubaneswar Development Authority (BDA), under the state government by a group of urban planners from Department of Architecture and Planning, Indian Institute of Technology, Kharagpur in September 2007 [10]. The report indicates that only about 59% of the households (h.h) live in Pucca houses. In overall, 68% of h.h are satisfied with the rent structure whereas the rest 32% face income-expenditure imbalance to support

their rent [10]. Consequently, the demand for dwelling unit requirement increased. Considering the h.h size to be 4.5, it was estimated the total dwelling unit required is 239,106 [10].

C.Role of Government and Current Housing Schemes

A central government sponsored program called VAMBAY, provides the funds for construction and slum-upgradation for EWS and LIG [11]. Fig. 1 shows a typical prototype house made by VAMBAY for a shelter to EWS.



Fig. 1 A VAMBAY prototype at Sampur Chhaka [12]

According to this program, minimum plot sizes of around 30-35 sq. mt. will be provided to EWS. Plotted development schemes is for LIG housing under which 35-50 sq. mt plots with 75% ground coverage and 2 dwelling units/plot will be considered [10]. It implies that land and construction funds are supported by government and other schemes. Other scheme like Indira Awas Yojna (IAY) and Swarnajayanti Gram Swarozgar Yojana (SGSY) are also popular for providing self-help groups to implement their own house and receiving funds from the Central Government [13], [14].

III.PLASTIC BOTTLE WASTE AS ALTERNATIVE CONSTRUCTION MATERIAL

Though the housing schemes are meant to provide housing among EWS and LIG, there are little chances it will be affordable due to cost of development and high market price. Alternative low-cost housings are the most effective method to reduce the total cost of housing. Recently, Plastic bottle waste is widely gaining its importance as an alternative construction material due to its zero commercial value. In India, a non-profit organization called Samarpan foundation have been credited for helping the poor and underprivileged people build affordable shelter [15]. Their project work includes using PET bottle waste to construct various types of buildings. They are in process of registering under Patent Act, 1970. They claim the use of Nylon-6 fish net construction makes the structure earthquake resistant and it can replacing steel; and costing only 1% of overall steel structure. With recent news of earthquake disaster that took place in Nepal on 25th April, 2015, an earthquake testing was taken place using PET bottles as building material which was successful [16]. The use of PET bottles and Nylon-6 fish net is shown in Figs. 2 and 3. It implies that if all of slums

are replaced with plastic bottle waste construction, the affordability rate by EWS and LIG will improve due to low-cost benefit.



Fig. 2 Laying of plastic bottle [15]



Fig. 3 Using Nylon fishing net [15]

IV.OBJECTIVES

The following are the main objectives of the research:

- To find the quantum of plastic bottle waste generation in Bhubaneswar city.
- To estimate the number of dwelling unit that can be possibly constructed with plastic bottle waste.

V. METHODOLOGY

The generation of plastic bottle waste is estimated through a survey on certain group of households belonging to different income groups. Based on their daily lifestyle, the number of plastic bottle consumption per month was evaluated. According to secondary source data on Bhubaneswar, the plastic bottle waste generation is estimated according to population. Referring to the earlier research on number of plastic bottles required to build a single dwelling unit [6], a methodical analysis was taken up to find the number of dwelling units that can be built depending on the amount of plastic bottle waste generation in the city.

VI.DATA AND ANALYSIS

A primary household survey was carried out in March, 2015 taking any urban dwellers under Bhubaneswar Municipal Corporation (BMC) as target groups. It was possible to physically reach to 142 individuals to find their day-to-day consumption of carbonated drinks and packaged water and also to 5 whole-sellers where mostly plastic bottle are being sold in

form of soft-drinks and capped mineral water. Though plastic bottles are available in many sizes and has number of purpose of packaging, this research is mainly concerned to those bottles that can be used for construction purpose [4]. Fig. 4 shows the quantity of different packaged drinks consumed by different groups irrespective of their income. From the figure, it is observed that glass bottles are highest in consumption (52% all combined) which clearly indicates the consumer to be among youngsters and college goers. The next most frequent demand is on plastic bottles belonging to 300ml, 600ml (around 11%) and 1 liter category while water bottle of 1 liter is most common. According to the survey, it is found that a person consumes an average of about 8 plastic bottles per month. Thus, accordingly the total amount of plastic bottle waste generation can be evaluated as follows:

At city level;

- Population of Bhubaneswar city = 881988
- Total number of plastic bottle used = 881988×8 per month = 7055904 Per month

Therefore, it can be said that approximately 7055904 plastic bottles waste is being generated every month after use, or

$$\Rightarrow 7055904 \times 12 = 84670848 \text{ plastic bottles / year}$$

The expected number of plastic bottle waste per year is 84670848

A. Disposal Methods of Plastic Waste

The questionnaire consisted of different types of disposal methods which helped in analyzing the possible amount of plastic bottle waste being actually disposed. Fig. 5 gives the illustration about the plastic bottles of different sizes and the method of their disposal by the target groups set with different categories (a, b, c, d, e and f*). It is found that in category 'e',

re-using the bottle for the storage purpose is most convenient way of disposing. However, considering the health effect due to multi-use of same plastic bottle, it could be suggested these should be disposed off; hence, this method automatically comes under disposal at municipality solid waste management. It is also observed in category 'a' that no one returns the plastic bottle back to shopkeeper after use, so it's phenomenal that people have to dispose it somewhere other than at the shop. In case of category 'c', the consumer simply throws away the plastic bottle waste in an empty or an un-official dumping area. There are little or no possibilities of collecting the trash from un-official dumping area. Hence, except for category 'a', 'c' and 'f', the rest of categories ultimately lead to official dumping at the landfill or recycling. For instance, in category 'd', among 142 users, 22% of plastic bottles of 100-300 ml capacity and 22% of 1-liter capacity are thrown in the dustbin provided by municipality. Similarly, in category 'b' 17% of 1 liter plastic bottles and 13% of 1.5 - 2 liter plastic bottles are taken to home and disposed in dustbin.

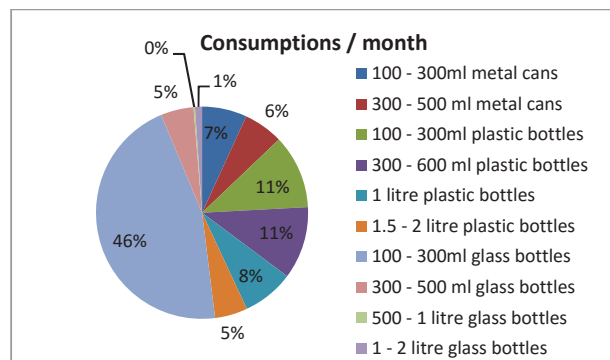


Fig. 4 Consumption of carbonated drinks from different package categories

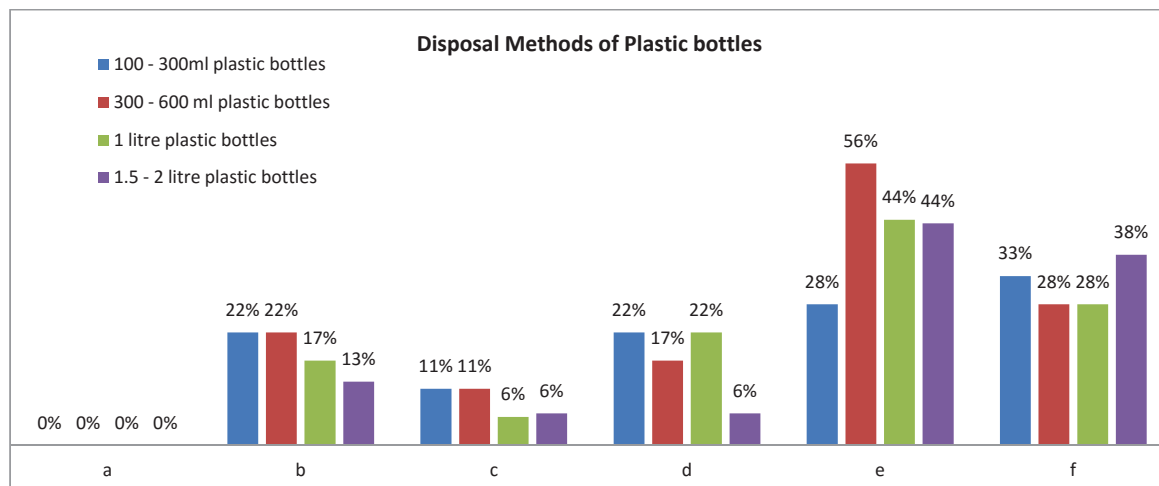


Fig. 5 Disposal methods of Plastic bottle waste: (a) "I give it back to shopkeeper"; (b) "I take it on my way home and dispose in dustbin"; (c) "I throw it where I find an empty space or dumping scene"; (d) "I throw it in the dustbin provided by Municipality/Government"; (e) "I re-use it for water storage and other fluids at home"; (f) "I do not buy product of this type"

B. Quantity of Plastic Bottle Waste Generation

Since, earlier it is discussed that 1.5L category bottle is taken as sample dimension for construction, thus in further calculation we used the same size to find the result. Among all categories we can consider only categories b, d and e which favor collection efficiency. In category b, at city level, out of total 84670848 plastic waste generated annually, 13% of 1.5 / 2L bottle waste are disposed at home, i.e., $13\% \times 84670848 = 11007210$. Similarly, for category d around 6% of total bottle waste are 1.5/2L size bottle that goes to municipality bins, i.e., $6\% \times 84670848 = 5080251$ and for category e, it is around 44% $\times 84670848 = 37255173$ plastic bottle waste of 1.5L size. Thus, in BMC area, the estimated number of plastic bottle waste being collected and transported for final dumping is $11007210 + 5080251 + 37255173 = 53342634$ annually.

VII. RESULT AND DISCUSSION

A. The Dwelling Units

A dwelling unit with carpet area of 37 sqm for a family of four was drafted with minimum basic space requirement [6]. Assuming plastic bottle masonry, the number of plastic bottles that can be possibly used to construct the wall for a carpet area of 37 sqm was found to be 8521 using 1.5 liter capacity bottle as a replacement to brick [6].

- Number of plastic bottle waste generated annually = 53342634
- Number of bottles used for construction of single dwelling unit = 8521

Therefore, possible number of dwelling unit that can be constructed using plastic bottle waste in a year is:

$$= 53342634 \div 8521 = 6260 \text{ Dwelling units (as in 2015)}$$

B. Future Phase of Housing

As the population and density of a city grows, the waste generation also grows. The decadal growth of Bhubaneswar city is approximately 44% and the daily Solid waste generation is 400 gram per capita per day (gpcd) [17], [18]. Currently, the city generates around 328 Metric Ton (MT) per day (2011) and is estimated to reach 423 MT/day by 2021. Hence, the estimated quantity of plastic bottle waste generation in 2021 will be;

$$(53342634 \times 423) / 328 = 68792482 \text{ annually.}$$

So, possible number of dwelling units in the year 2021

$$68792482 / 8521 = 8073 \text{ Dwelling units.}$$

An algebraic method of finding growth rate of plastic bottle waste for 2015 to 2021 has been derived as;

$$p_{2021} = p_{2015} \times (1 + i)^n \quad (1)$$

where p_{2021} : Number of plastic bottle estimated in the year 2021; p_{2015} : Number of plastic bottle in the year 2015; i : Growth rate; n : Number of period. Therefore, from (1):

$$\begin{aligned} 68792482 &= 53342634 \times (1 + i)^6 \gg (1 + i) \\ &= \sqrt[6]{68792482 / 53342634} \end{aligned}$$

$$\gg i = \sqrt[6]{1.3} - 1 \gg i = 1.04 - 1 = 0.04469 \text{ or } 4.47\%$$

Thus, it can be expected, an increase of plastic bottle waste at a rate of 4.47% will also proportionally increase the development of dwelling units.

C. Costing

The estimated cost of single dwelling unit with carpet area of 37 sqm was found to be 2,14,388 INR (3385 USD) [6]. The total cost of 65 dwelling units for the year 2015 would be $65 \times 214388 = 13935220 \text{ INR}$ or 217755.53 USD (05-August 2015 conversion).

VIII. CONCLUSION

Recently, Bhubaneswar city has been selected under smart city scheme under the new central government. Though Bhubaneswar city is taken as study area, which is expected to reach million mark populations, the methods and techniques of using waste plastic bottle for construction can be applied on any million-plus city of India where housing shortage and excess solid waste generation is concerned. Popular metro cities like Mumbai, Chennai etc., are choked with slums growth and its lack of hygienic sanitation has led to breeding of harmful disease. High price of construction material, land cost, income-expenditure imbalance, and climatic conditions can be the main factor contributing to housing problems.

As compared to traditional brick construction, plastic bottle waste construction reduces the overall cost by 14%. The remaining profit can be genuinely used on self-employment to help them stabilize their financial crisis.

The following actions should be considered for proposing plastic bottle masonry:

- According to Management of Solid Waste Rule 2000, collection and segregation of waste bottles from other solid waste should be taken into consideration.
- Plastic bottle waste can be of any size. Learning about construction with different plastic bottles can provide a platform for self-employment and scope for construction of more dwelling units.
- Waste dustbin should be provided for efficient collection of waste to ensure maximum number of plastic bottles collected for re-use, instead of dumping them unnecessarily.
- The plastic bottle masonry should be provided solely for EWS and LIG depending on their financial condition.
- Participation of NGOs and other private organization should be encouraged to handle construction works.
- Affordable housing schemes should include Plastic bottle masonry as part of housing scheme to reduce burden on solid waste management.

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REFERENCES

- [1] Government of India, Ministry of Housing and Urban Poverty Alleviation (MHUPA), "Preamble - National Urban Housing and Habitat Policy", New Delhi, 2007, pp-1.
- [2] Government of India, Ministry of Housing and Urban Poverty Alleviation (MHUPA), "Affordable housing in Partnership-Scheme guidelines", New Delhi, September 2013, pp. 2-3.
- [3] D. J. Pati, K. Iki, and R. Homma, "Solid Waste As A Potential Construction Material for Cost-Efficient Housing in India", in *Proc. 3rd World Conference on Applied Sciences, Engineering and Technology*, 27-29 September 2014, Kathmandu, Nepal, ISBN 13: 978-81-930222-0-7, pp 240-245.
- [4] Retrieved, <http://www.eco-tecnologia.com/projects>, on October, 2014.
- [5] D. R. Valencia, C. L. Perez, E. Cortes and A. Froese, "New alternatives in construction: earth filled pet bottles", *APUNTES*, vol.25 num.2, Colombia, 2012, ISSN 1657-9763, pp-292-303.
- [6] D. J. Pati, K. Iki and R. Homma, "Costing and Quantum Analysis on Utilization of Re-Usable Solid Waste as Construction Material in India", yet to be published in *Proc. Global Academic Network, Hong Kong Conf.*, 29-31 January 2015.
- [7] Department of Architecture and Regional Planning, "Perspective Plan Bhubaneswar-Cuttack Urban Complex, vision-2030, Status Report", Indian Institute of Technology, Kharagpur, November 2006, pp 1-7
- [8] Census of India, 2011.
- [9] Ministry of Finance, "Office Memorandum", Department of Expenditure, Government of India, New Delhi, 29 August, 2008
- [10] Department of Architecture and Regional Planning, "Perspective Plan Bhubaneswar-Cuttack Urban Complex, vision-2030", Indian Institute of Technology, Kharagpur, September 2007, Vol-2.
- [11] Valmiki Ambedkar Awas Yojana (VAMBAY), "Ministry of Urban Development Govt. of India Guidelines", New Delhi.
- [12] Department of Architecture and Regional Planning, "Perspective Plan Bhubaneswar-Cuttack Urban Complex, vision-2030", Indian Institute of Technology, Kharagpur, November 2006, Vol-1, pp 71-80.
- [13] Government of India, Ministry of Rural Development, "Indira Awas Yojna (IAY)-Guidelines", New Delhi, June 2013.
- [14] Government of India, Ministry of Rural Development, "Swarnjayanti Gram Swarozgar Yojana (SGSY)-Guidelines", New Delhi
- [15] Retrieved, <https://samarpanfoundation.org/projects/48/affordable-construction>, on May 2015.
- [16] Retrieved, <https://samarpanfoundation.org/projects/83/rebuild-nepal-eco-construction-programme>, May 2015.
- [17] C. R. Mohanty, U. Mishra & P. R. Beuria, "Municipal Solid Waste Management in Bhubaneswar, India –A Review", *International Journal of Latest Trends in Engineering and Technology*, Vol. 3 Issue 3 January 2014, ISSN: 2278-621X (online version).
- [18] Department of Architecture and Regional Planning, "Perspective Plan Bhubaneswar-Cuttack Urban Complex, vision-2030, Status Report", Indian Institute of Technology, Kharagpur, November 2006, pp 100-102.