Exploring the Current Practices of Post Consumer PET Bottles and the Innovative Applications as a Sustainable Building Material – A Way Ahead

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ABSTR ACT

PET stands for polyethylene terephthalate and PET bottles are occupying an indispensable position in common man's life. Food processing industries across the world are using PET bottles as effective containers for storing juice, beer, carbonated and non carbonated drinks. The different parameters which determine the form of PET bottles during designing, manufacturing and production phases are cost per unit, need, volume, color, intrinsic velocity, size, shape etc. Irrespective of a wide range of applications, initiatives in recycling post consumer PET is sporadic. The disposal of PET bottles in the environment, significantly contributes to ecological imbalance. Interpreting the negative impacts and adopting the principles of Reuse B and C by Romans, pioneers are searching for rational and technical solutions to check this issue. In construction industry, hybrid actors are using PET bottles as moulds for developing alternative blocks. Technocrats are recycling PET products physically in to fibers, pellets and flakes for partial replacement of fine and coarse aggregates in conventional building materials. This paper intends to consolidate such initiatives addressing building systems, materials and artifacts. It discusses an overview of such applications and other intuitive trends which are emerging in Indian context.

INTRODUCTION

The technology of storing liquid products for transportation, distribution and use is defined as packaging. Our ancestors used baskets and storage units made of natural fibers and indigenous materials like stone, earth etc. Use of paper and metal plated containers for such applications dates back to the 10th century (Packing, 2012). Glass bottles, plastic containers and polyethylene are used predominantly in today's context. Polyethylene terephthalate, a versatile material is playing a primary role in packaging industry in today's context, simultaneously increasing the production process. The drawbacks during the disposal phase is raising a question, whether the invention is a boon or a bane, revolving around the societal benefits (Andrady & Neal, 2009) and the negative impacts in the environment (Webb, Arnott, Crawford, and Ivanova, 2012).

HISTORY

According to the archaeologists, a novel concept, "Post consumer packing material as a resource, specifically in construction", is traced from the Hellenistic age. Interpreting the problems posed by disposal of 'amphorae', Romans came up with an innovative idea to reuse them in architecture (Will,

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1977). While doing so, the pointed base pots were either modified or unmodified. Romans classified reuse as A, B and C (Pena, 2007). When the amphorae were used as a storing unit, it was reuse A. Reuse B and C, denoting the applications in other fields without modification and with modification respectively. The beginning of 19th century witnessed similar application of glass and PET bottles in construction.

AN INSIGHT TO PET

Plastic is a commonly preferred packing material for various goods in today's fast moving contemporary world. They are classified in to seven categories based on recyclability (Society of plastics, 2013) and polyethylene terephthalate denoted as PET, PETE or PETP ranking number one. The credit of inventing PET goes to chemists Whitefield and Dickson, the employees of Calico Printer's Association in 1941 and was patented only in 1973 by Wyeth. Semi crystalline thermoplastic polyester, durable, low gas permeability, chemically and thermally stable, easily processed and handled, transparent, wear and tear resistant and non biodegradable are the general characteristics of PET. Based on its versatility, it is primarily used in textiles, films, utility ware, sportswear etc. Food processing industries prefer PET as it is hygienic, strong, lightweight (Petresin, 2013) and devoid of phthalates, dioxins, bisphenol A, cadmium, lead and other endocrine disruptors (NAPCOR, 2013). As PET is used predominantly in the form of bottles for storing carbonated and non carbonated drinks, this paper addresses to reuse the PET bottles in construction industry.

PET BOTTLE

Cap, neck, shoulder, body, hip and feet are the basic parts of a PET bottle (bottle biology, 2013). Containers for storing carbonated and non carbonated drinks have different intrinsic velocity, wall thickness, color and level of copolymer. With respect to the physical form, PET bottles used for storing carbonated drinks are designed with an additional twist in the neck, thicker wall, higher intrinsic value, lower copolymer level and a petaloid base (Bristogianni, 2012).

POST CONSUMER PET – REUSING VS RECYCLING

According to the Environmental Protection Agency, recycling, incineration and landfill are the general ways of disposing plastics are disposed in today's context. Each method has its own disadvantages and drawbacks (Webb et.al, 2013). Its disposal is disturbing the ecological balance, directly or indirectly affecting the health of all living creatures (Rustagi, Pradhan & Singh, 2011).

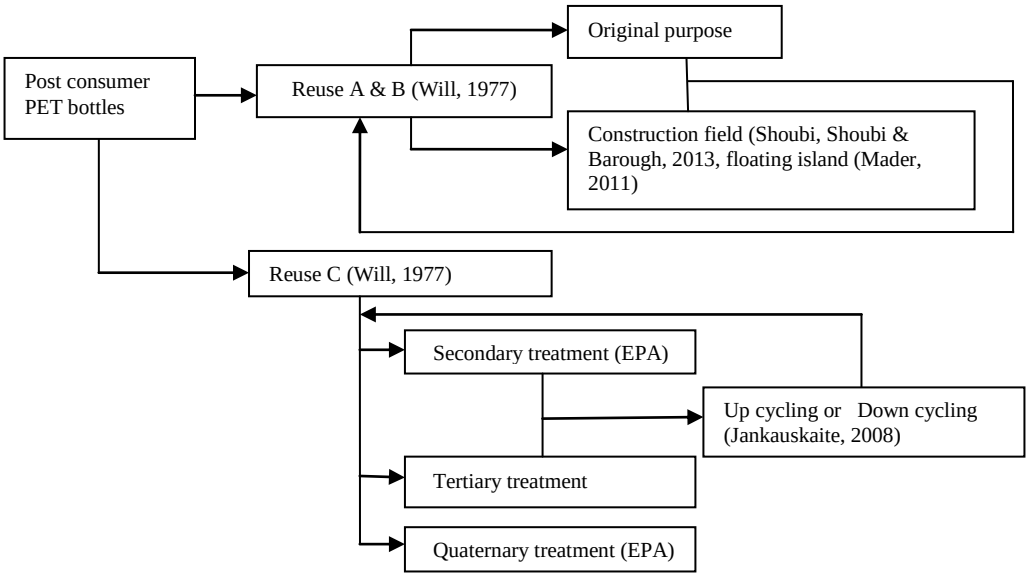


Figure 1: Reusing and recycling of PET at a macro level

Recycling is classified as primary – re extrusion of pre consumer scrap; secondary or physical or mechanical treatment; tertiary or chemical treatment where the chemical structure is altered and quaternary treatment, focusing on energy recovery. Reusing is the most preferred option as the consumption of energy and resources are always less (Al-Salem & Baeyens, 2009) as in Figure 1.

Reusing PET bottles for packing continuously is not preferable; however the idea of reusing them in a different field requires innovation. PET bottle bricks as an alternative building material, a less energy intensified process, is successful in construction process. A rational and a pragmatic perception is the requirement in today's context to address multifaceted issues simultaneously.

POST CONSUMER PET AND THE AVANT-GARDE PERCEPTIONS

Innovators and researchers are adopting different strategies to reuse and recycle PET bottles. Up cycling and down cycling are the processes involved in the manufacturing of new products with the treated PET bottles. While applying such concepts, the consumption of energy and the negative impacts generated during the production phase need to be kept to the minimum. Investigations on effective reusing or recycling of such used bottles in the construction sector, marks the beginning of the next industrial revolution. A holistic, pragmatic approach rich in aesthetic values (Pramar, 1973), as the focal point, the vision of the architects and environmentalists, technocrats, product designers and artists are interpreted in Table 1.

Table 1: Unique perceptions

Post consumer PET bottles	Hybrid actors - Holistic	Technocrats-Rational approach	Product designers-Innovations	Artists-Aesthetic expressions
Unmodified / Reuse B	Partly objective and subjective, Aesthetic values	Objective, Economical, Utilitarian	Subjective, Partly functional and Emotional	Subjective, Aesthetic, Emotional
Modified / Reuse C (secondary and tertiary)				
Approach	Ecocentric	Problem solving	Transforming the overlooked	Promoting Awareness
Examples	Bottle bricks with different fillers, PET bottle as a filler	Partial replacement in building materials	Screens, lamp shades, planter boxes, chandeliers, furniture etc	Murals, sculpture

EXPLORING THE 'ECOCENTRIC' APPROACH

'Ecocentric' approach is one among the six competing logics of sustainable architectural practices - built forms are parasitic in nature and revolve around the post consumer waste (Guy &Farmer, 2001). With self sufficiency and incorporating the principles of a living organism, Reynolds designed 'earthships' in 1970s. With his attitude towards post consumer waste as a resource, he developed building systems by using tires, glass bottles and aluminium cans. Creating the base for a man made floating island (Mader, 2011) with PET bottles is an exceptional eco centric idea.

Interpreting the role of PET bottles and 'Reuse B'

Following Reynolds' strategies, Froese initiated to construct small structures with PET bottles firmly held in position with nylon ropes in 2001 (Pachecho, 2013). PET bottle buildings are bio climatic, cost effective, non brittle, easy maintenance, resistant to abrupt shock loads; strong, durable, versatile, easy handling and reusable are the characteristics of such built structures (eco tec, 2002). Habitable spaces, activity centers, learning centers and latrines are constructed using PET bottle bricks at Honduras, Nigeria, Central America, Philippines and India. Architects and technocrats are searching for a variety of solutions to reuse post consumer PET bottles in building envelopes for permanently built forms, temporary structures and interiors as in Figure 2.

With a holistic approach, PET bottle bricks are being made with a variety of filling materials such as adobe or sand (eco tec, 2002, May 4), liquefied adobe, inorganic waste (Saraswat, 2013), sand and cork (Shoubi et al, 2013). PET bottles are stacked one on top of the other to build green houses (Alvarado,

2010). When adobe is used as a filling material in PET bottles, it should be tightly compacted with a stick as well as a compressor and then tightly closed (Can steel, 2014).

A unique brick with PET bottle itself as filler (Mehta and Ellis, 2007) is developed by Lima. Bottles are effectively used to replace the concrete in roofs and investigations on the monolithic casting of such discarded transparent containers is in the progress (Radu & Christiana, 2011) and as fillers in slabs (Pandya, 2012) as shown in Figure 2.

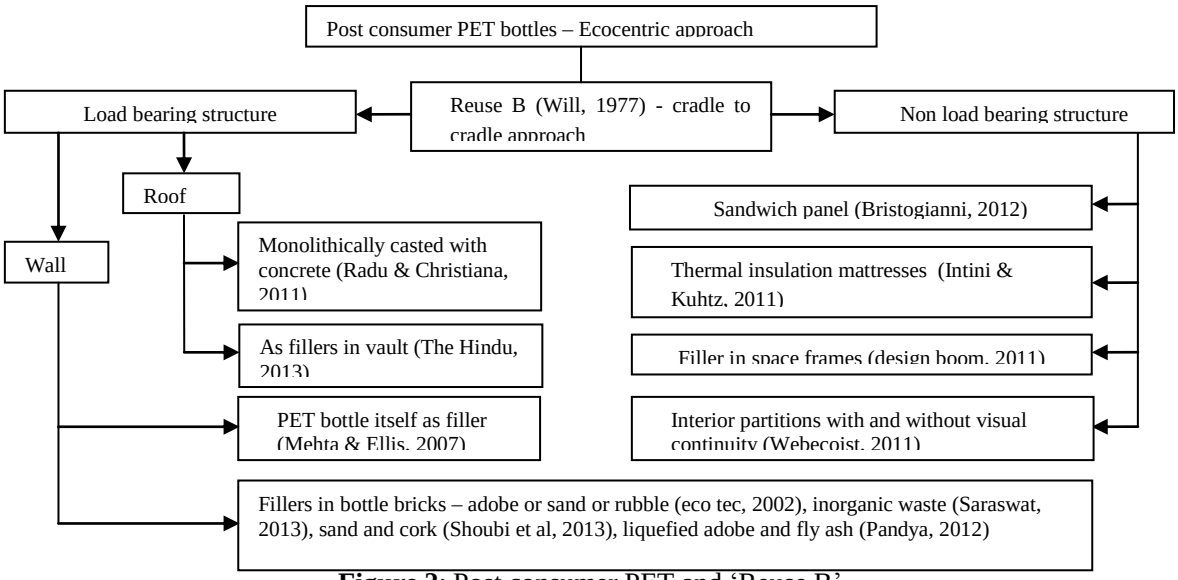
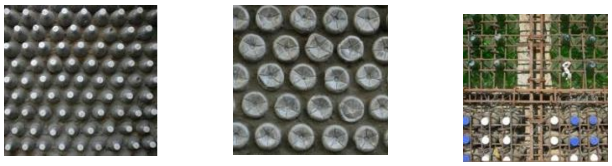


Figure 2: Post consumer PET and 'Reuse B'

They are used as sandwich panels in the constructing emergency shelters (Bristogianni, 2012), as partitions with and without visual continuity and also as fillers in concrete roofs and space frames changing the perception of 'post consumer packaging waste. PET bottle partitions, designed in Danone office and in Morimoto restaurant, is a value addition initiative. In Morimoto restaurant, experiencing the two storied partition integrated with LED lights is a unique idea, bewildering the visitors to think about the workmanship and material (webecoist, 2011).

PET bottles and 'Reuse B' in Indian context

In a country like India the development is uncontrolled, unorganized, use of virgin construction materials increasing day by day increasing the proportion of the shelterless. Architects and others are adopting the ideals of ecocentric practices, zoning on the experimentation (Chan,2007) with post consumer waste. According to Antonoides (1992), materials are the flesh, bones and skin of the built forms and are categorized based on their influence on the structure and function. Initiators like Yatin Pandya, Prashant Lingam and Patrick San Francesco are the eye openers to experiment with post consumer PET bottles in constructing small scale buildings like activity centers, learning and habitable spaces for social causes in different Indian contexts.



(a) (b) (c)

Figure 3: (a) Front elevation (b) Rear elevation (c) PET bottles as fillers in roofs

A multi activity center at Ahmedabad by Yatin Pandya, Principal architect, Footprints EARTH, firmly believing in recycling waste as environmental, economic and architectural imperative as one of the sustainable principles, is playing a vital role in building the centre with waste materials. PET bottle bricks filled with fly ash are one of the materials for the envelope. A technique of using PET bottles as fillers in flat roofs and as bricks in walls integrated with aesthetic values as in Figure 3.

Hyderabad based entrepreneurs Prashant Lingam and Aruna, designed a prototype shelter using bamboo and PET bottle bricks covering an area 225 square feet. Bamboo is used as structural members and nearly four thousand PET bottles with earth is used in the construction. A typical bonding with bottle bricks is shown in Figure 4. They are aspiring to promote this as a model house under Indira Awas Yojana, a scheme initiated by the Government of India for housing.

(a) (b)

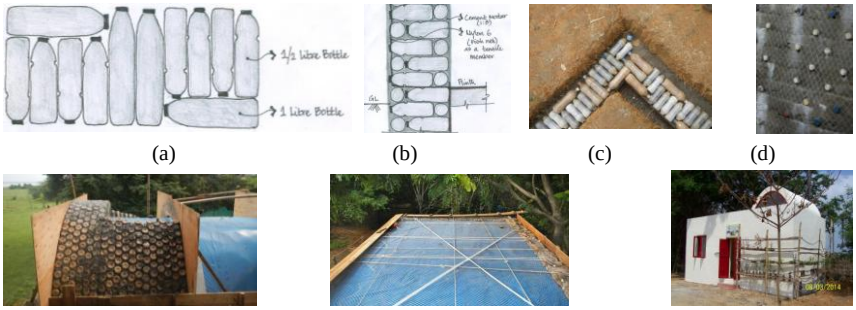
Figure 4: (a) A model house (b) a typical course of PET bottles

In Delhi, a learning centre as shown in Figure 5 was constructed by a non government organization, 'Samarpan Foundation' founded by Mr. Partick San Francesco using six thousand PET bottles with a prefabricated roof. A typical bonding is developed using one liter bottles for walls as well as flooring. The designed space roofed with simplified steel trusses and prefabricated sheets.

(a) (b) (c)

Figure 5: (a) Alternative courses with PET bottles (b) PET bottles and flooring (c) School

A model house of area 250 square feet is constructed using PET bottle bricks in Chennai. Figure 6 shows the unique bond developed by the Foundation, replacing steel reinforcement with 3cm X 3 cm Nylon 6, to improve the tensile strength. Techniques for constructing a vault and flat slab using PET bottles are developed. For the construction of one cubic feet volume of load bearing wall we require sixteen half liter bottles and nine one liter bottles.



(a) (b) (c) (d)

(e) (f) (g)

Figure 6: (a) Typical course (b) Typical section (c) L Junction (d) 3cm X 3cm nylon 6 for additional tensile strength (e) Vault construction (f) Flat slab (g) A housing prototype

In our University Campus, we in collaboration with Samarpan developed a typical bond for the construction of a compound wall as shown in Figure 7. Further, PET bottle columns, where three half liter bottles and one liter bottles are stacked vertically in a typical course with nylon 6 as the reinforcement, runs around the column in clockwise and anticlockwise direction as shown is casted at the Council of Scientific and Industrial Research, Chennai for structural and seismic investigation.

(a) (b) (c)

Figure 7: (a) & (b) Footing for compound wall (c) PET bottle column

ROLE OF PET IN 'REUSE C' FOR DEVELOPING ALTERNATIVE BUILDING MATERIALS

Innovative applications of physically recycled post consumer PET

The secondary recycling is classified as physical reprocessing, melting and reforming. Investigations on mechanical, thermal, electrical, light weight properties of such materials with physically modified PET granules, pellets, fibers as partial replacement for fine or coarse aggregates are progressing. Such developed materials and composites are effectively used in pavement and roads.With respect to melting and reforming or re engineering, PET bottles with inherent interlocking property are designed and developed by Miniwiz with properties like translucent, insulating, light, strong and mechanically recyclable material. It is created in order to tackle three environmental problems – waste accumulation, resource scarcity, greenhouse gas emissions simultaneously (Hegenwald, Ackermann, Neugebaue, Finkbeiner, 2013). Reusability, recyclability, non toxicity, low volatile compounds, on site production, scratch resistant, easy maintenance, simple installation and affordability are the distinctive features of this building material (Miniwiz, 2011).

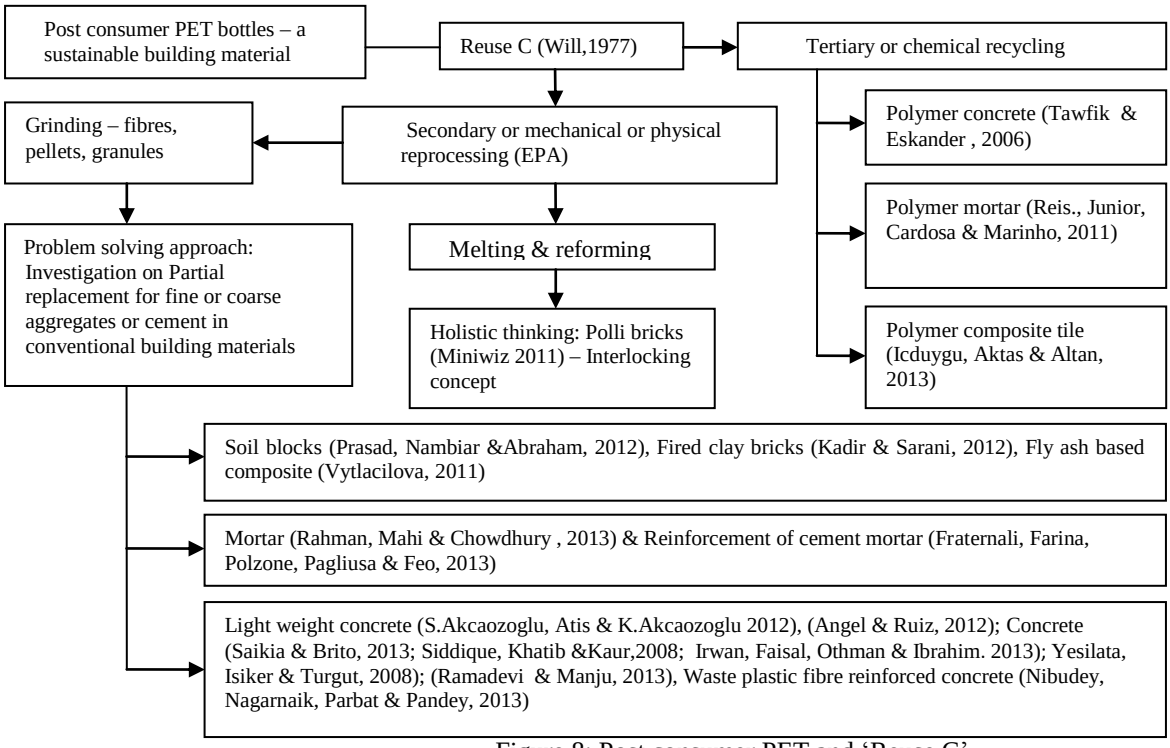


Figure 8: Post consumer PET and 'Reuse C'

Innovative applications of chemically recycled PET

Investigations on polymer concrete (Tawfik & Eskander, 2006), polymer mortar (Reis et al, 2011) or polyester composite tiles (Icduygu et al, 2013) are emerging, where the chemical composition of the PET is modified through chemical treatment as in figure 8. Applications in the construction of habitable spaces need to be addressed and impacts created during the treatment and production phase is to be investigated.

CONCLUSION

The initial perception on the use of PET bottles in construction is changing day by day. A paradigm which emerged as PET bottle bricks in the construction of load bearing walls with steel trusses and prefabricated metal sheet is at present witnessing flat roofs with nylon 6 replacing steel reinforcement and intuitive vault construction. Apart from this ingenious bonds and columns using PET bottles gives a new direction to think about beams, foundation and simple trusses. With a holistic approach, designing phase of PET bottles with interlocking property is innovative. Even though research on the effective use PET in developing new material as an option, solutions exploring the application of PET bottles as structural members, foundation, retaining walls and secondary elements like street furniture, kerbs, road dividers, pavements and other landscape elements is to be looked in to. Strategies, approaches and practices integrating the relationship incorporating a total rethinking on junk as a resourceful building material integrating waste need to be nurtured and shall be enhanced. The Governing bodies shall

formulate policies to propagate this eco centric approach via appropriate practices, research investigations on the properties of the materials and construction techniques.

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