

Recycling of Waste PET Bottles as a Voluminous Alternative Material for Making Composite Panels

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Abstract

PET Bottles are finding more and more applications in disposable packaging mainly in beverage segment. As on today not only cola companies are using PET bottles but also fruit juice, mineral water and liquor industries have accepted PET bottles for packaging of their product. The transparent polyethylene terephthalate (PET) bottles have become increasingly common and are used for mineral water, soda waters and soft drinks. These bottles are of – course, very user friendly but environmental hazards are associated with PET Bottles. Huge consumption of these commodities causes volumetrically large PET wastage on daily basis. They contribute a large part in urban garbage. In this paper, an effort has been made to recognize the possible application by recycling waste PET bottles for manufacturing of composite panels. These panels can be manufactured using waste PET bottles as a low cost voluminous filler alternative material instead of costly foam core. PET bottles have a good compatibility with many other matrix materials. These composite panels can be manufactured under different sizes and modules and hence they can be used for various economically feasible architectural and building applications. Various building applications of these composite panels have also been discussed in this paper.

Keywords: *Recycling, PET Bottles, Composite Panels*

1 1 Introduction

PET is used as a raw material for making packaging materials such as bottles and containers for packaging a wide range of food products and other consumer goods. Examples include soft drinks, alcoholic beverages, mineral water, detergents, cosmetics, pharmaceutical products and edible oils. PET is one of the most common consumer plastics used (Wikipedia, 2010). For the first time PET soda bottles were introduced by Pepsi and then followed soon by Coca-Cola in America, but PET Bottles (Polyethylene Terephthalate) were introduced for soft drink packaging first time in India in around mid nineties and since then they have revolutionized the way of packaging for beverage segment. The recent development in PET – PEN blends have made it possible for beer packaging too. Most containers are glossy clear transparent, while some are green in colour. These bottles are use and throw in nature ranging from 250ml to 2.5 liters in size.

The low weight of these PET bottles helps to reduce transportation costs and its convenience has gained it higher consumer acceptance than glass. As a result PET is substituting glass in packaging all over the world as well as in India. As mentioned in wikipedia that worldwide, approximately 1.5 million tons of PET is collected per year. Petcore, the European trade association that fosters the collection and recycling of PET, forecasts that in Europe alone, collection will exceed one million tons by 2010. The estimated increase in consumption in India is about 45,000 tonnes. Huge consumption of these commodities causes volumetrically large PET wastage on daily basis, hence there is a need to manage the large amount of PET waste that would be generated (Narayan, 2001). Alongside efforts to prevent global warming by reducing CO₂ emissions, waste treatment has become widely recognized as an important issue for building a recycling- oriented society (Hotta, 2003).

2 Recycling and Sustainable Development

Recycling turns materials that would otherwise become waste into valuable resources. In addition, it generates a host of environmental, financial, and social benefits which are necessary for sustainable development. Sustainability is a relationship, or balancing act, between many factors (social, environmental and economic realities and constraints) which are constantly changing. The sustainability concept, as described in the Common Future (Brundtland Commission Report, 1987) states that:

Sustainable development is a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development, and institutional change are all in harmony and enhance both current and future potential to meet human needs and aspirations. Sustainable development “...meets the needs of the present without compromising the ability of future generations to meet their own needs.”

Jain and Lee (2009) mentioned that previously, the primary factors in materials selection for engineered systems were based on performance requirements and economics (e.g., construction and maintenance costs). The sustainability approach to design and construction challenges architects and engineers to weigh environmental factors, energy/resource consumption, social factors, economic considerations, and performance criteria. When identifying appropriate metrics for sustainability, one is likely to encounter a myriad of proposals and ideas each potentially yielding unique results; however, in general, measures are typically centered on factors that account for the following:

- Minimum resource use
- Low environmental impact
- Low human and environmental health risks
- Sustainable site design strategies
- Higher performance

3 Recycling of Waste PET Bottles as a Lost Cost Voluminous Filler Material for Composite Panels

Polyethylene Terephthalate (PET) is a thermoplastic material, but it cannot be straightforwardly reprocessed to make new bottles. The increase in Acetal Aldehyde content while melting PET in recycling extruder causes serious objection for packaging of soft drinks etc. Another problem with PET bottles is their large volume to mass ratio. According to Central Pollution Control Board of India, a 10,000 tonnes capacity exists for manufacturing of PET bottles and assorted containers. Because of durability and glass-like clarity of PET bottles and containers, a major share of these becomes a long-term asset for the users. However, around 50 per cent of current consumption of PET bottles used is available for recycling. Considering the average weight of 27 g per bottle, 3000 tonnes of PET would amount to 115 million numbers of bottles going into waste that largely remains uncollected and unsold. This figure will multiply many times by 2010 (CPCB, 2010).

Although waste PET bottles can be recycled by special recycling plants situated at Madras, Gajraula, Kanpur and Mumbai, but we emphasized on the use of complete bottle (along with caps) to produce some economically feasible product, without any change in its physical form. These panels can be a very durable solving five issues at the same time (Nienhuys):

- Reduction in waste PET Bottles (environmental waste).
- Thermal insulation of houses and installations.
- No importation and transportation of expensive insulation materials.

- Reduction in the cost of energy used for heating and cooling of buildings.
- No burning of waste causing air pollution.

3.1 PET Bottles as a filler material

There are a number of filler insulation materials, which can be being used in manufacturing composite panels. They are:

- Rigid polyurethane (PUR)
- Rigid polyisocyanurate (PIR)
- Extruded polystyrene (EPS)
- Expanded polystyrene (XPS)
- Phenolic foam
- Mineral fibre

Of these, only rigid polyurethane and polyisocyanurate insulation (collectively called urethanes) expand and autohesively bond to the faces during the manufacturing process. A separate adhesive has to be used to bond the other insulation materials. The autohesive properties make urethane particularly suitable for filling panel profiles and edge details and it is therefore the most commonly used core for composite panels. All the rigid foam insulation materials are produced using chemical blowing agents (Brydson, 1995).

But in our case the waste PET Bottles has replaced the costly foam core. PET Bottles can be considered as “Voluminous Filler Material” and hence they will reduce the amount of matrix material. Another main advantage of waste PET Bottles is that these empty bottles contain large volume of air, which acts as insulating material and provides excellent thermal insulation.

3.2 Compatibility of PET Bottle with matrix materials

As given by (Olesky, 1964), the compatibility between the matrix material and filler material is governed by the thermodynamics. A negative value of Gibb's free energy ($-\Delta G$) is essential thermodynamic condition for compatibility. On detailed investigation we can conclude that if the solubility parameters (δ) are in close range, we can expect the compatibility between matrix material and filler. The solubility parameters for some of the well-known polymers are given in Table 1.

Table 1: Solubility Parameters of various polymeric materials

S. No.	Polymer Matrix Material	δ	S. No.	Polymer Matrix Material	δ
1	PP	7.9	12	Polysulphide Rubber	9.0 – 9.4
2	PE	8.0	13	Polychloroprene Rubber	9.2 – 9.4
3	PS	9.1	14	Polyvinylidene Chloride	9.8–12.2
4	PMMA	9.2	15	Acetal Resin	11.1
5	PC	9.5	16	ABS	6.05
6	PVC	9.5	17	SAN	5.2
7	Nylon – 6,6	13.6	18	HIPS	5.2
8	Polyisoprene (NR)	8.1	19	PAN	15.4
9	SBR	8.4	20	EVA	8.6
10	Polybutadine (PB)	8.4	21	PVA	9.5
11	PTFE	6.2	22	CA	10.9

The value of solubility parameter (δ) for PET is approximately 10.7. It has been found that Waste PET Bottles do not have good compatibility with Plaster of Paris and cement – mortar mixture. But when the matrix of waste PET bottles is tied up with thin wires of steel and encapsulated with either Plaster of Paris or cement – mortar mixture there was considerable improvement in panel's strength. Steel wires tied over PET bottles; act as linkage between matrix of PET bottle and matrix material. Steel wire mesh also can be used for better strength of panel.

4 Design Details of a Composite Panel

Nowadays Structural Insulated Panels (SIPs) are getting wide acceptance among architects because of their thermal efficiency and faster construction of buildings. They are prefabricated insulated structural elements for use in building walls, ceilings, floors and roofs. SIPs are usually foam core panels, covered with suitable skin materials on both sides as shown in Fig. 1. The most common types of sheathing or skins materials are Oriented Strand Board (OSB) and plywood. Some manufacturers produce panels with fiber-cement sheathing. Composite

panels can have facing made up of 3mm ply or veneer and the edging made up of aluminum sections or PVC profiles (Fig. 2).

The shape and size of PET bottles composite can be square or rectangular in nature. They can be prefabricated in different sizes such as 300mm X 600mm, 300 X 900mm, 450mm X 600mm, 450mm X 900mm, 600mm X 600mm, 600mm X 900mm etc. The total thickness of the panel comes out to be approximately 100mm (Fig. 3).

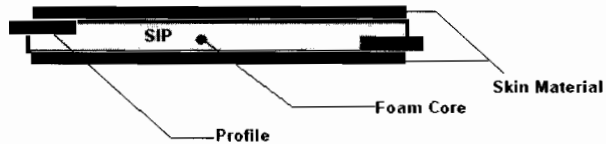


Figure 1: Conventional Structural Insulated Panel

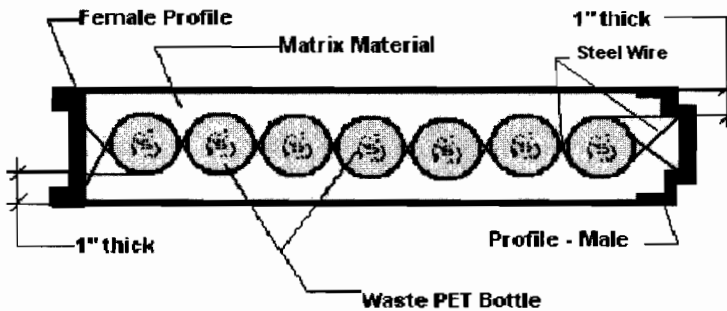


Figure 2: Structural Insulated Panel using Waste PET Bottles as Voluminous Filler

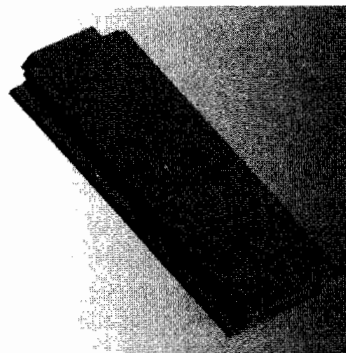


Figure 3: Three-Dimension model of a Composite Panel

5 Building Applications Of Composite Panels

PET Bottles composite panels can be pollution free and environment friendly composite material to a large extent. Due to its lightweight, high strength to weight ratio, corrosion resistance, low manufacturing cost and other advantages, PET Bottles based composites can be an important composite material in architectural applications, construction industry and civil engineering works. These panels can be manufactured in various modular sizes and can be used in many applications as per requirement. Some of the possible applications have been summarized as follows:

Low-density insulation boards, medium-density boards, hard boards, block board and other building components such as walling units and roofing panels can be manufactured using PET Bottles composites.

An important application can be for roof terracing. These panels can be laid over the Reinforced Cement Concrete (R.C.C) roof slab and panel joints can be finished with epoxy or cement mortar. This will eliminate the traditional cumbersome method of roof terracing i.e. laying of brick tiles over the mud phuska. This will act as thermal insulation on the roof top, which heats up the interior space and thus it helps in natural cooling and conservation of energy.

They can also be used in cladding of wall exteriors, especially on the south or southwest facade of the building in hot & dry and composite types of climate to provide thermal insulation to the building facade from the direct solar radiation. They can be installed or erected on a framework as architectural treatment of façade like aluminum composite panels are used nowadays and can also be as vary therm wall.

These panels are expected to be used in place of galvanized iron and asbestos sheets. Their thermal insulation is better than these conventional sheets. System is ideally suited for providing durable and economical roofing / flooring in the low cost houses especially for economical weaker section of society in rural / urban areas or hilly regions.

They can also be used as shuttering panels for formwork in reinforced cement concrete construction as substitute for steel panels or ply board sheets.

They can be used as lightweight partitions, false ceiling, colorful laminated panels and lining in interior decoration in buildings.

They can also be used for providing temporary shelters during the rehabilitation work in the case of natural disasters such as Earthquakes, Cyclones and Tsunamis and during the organization of some Indian religious congregations such as Kumbh and Maagh Mela etc.

6 Technological Gap and Future Research

The PET bottles composite panels should not be used as substitutes for conventional structural systems. The concept must exploit the advantages offered by composite panels in terms of lightweight, tailorability, and connectability. In developing innovative design concepts, the way in which performance specifications on structural sub-systems can be utilized needs to be further studied.

The performance and cost of complete PET Bottles composite panels are controlled by their connections and joineries, and little research has been performed to develop connection strategies and details which in the end do not form the weak link in the overall structural system and which are simple, durable and strong. In the research and development of connections, emphasis must be placed on developing light weight, modular, simple, and reliable connectors which can be assembled quickly in order to benefit the construction and assembly process. The economic impact of design concepts in which significant savings can be realized due to systems that reduce assembly costs should be studied. The use of computer simulation to demonstrate new construction methodologies that can show economic advantages should be explored. Industry & design experts are of the view that with the adoption of advanced technologies and some extent of standardization, these problems could be easily taken care of.

7 Conclusion

Waste PET bottles composite panel can be an economical alternative material for various architecture, building and civil engineering applications. Still more research and development is required for the prefabrication to the finalization of the complete process for upscaling of technology from lab scale to commercial level.

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