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Reusing waste plastic bottles as an alternative sustainable building material

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ABSTRACT

Plastic bottles (PET) are examined both structurally and thermally to be utilized as building units, replacing traditional concrete blocks. Tests were conducted after filling the bottles with either dry sand, saturated sand, or air, bound by cement mortar to produce stable masonry walls of reduced thermal conductivity.
The effect of the infill material on the bulk unit weight and the compressive strength of the plastic bottle masonry blocks showed slight effect of the used infill material on the strength. Although the gross strength of these plastic bottles is much less than the traditional blocks, 670 kN/m^2 compared to 3670 kN/m^2, but calculations showed that the blocks of air filled bottles still can be used as suitable construction units for partition walls or as bearing walls for one roof slab.
Thermal wise, air filled bottles showed better thermal insulation than the tradition block construction, which could act as thermal insulation material.

Introduction

Industrialization, economic development and population growth, have led to an increase in, and diversification of waste disposal. Most are disposed of at dump-sites leading to environmental issues that are both cumulative and disruptive to the ecological structure. For centuries, waste was considered as an unavoidable consequence of materialism that had to be collected, and buried. Basically, out of sight, was out of mind. Disposal has made way, where possible, to recycling and reuse. There is a need to close the material cycle loop by transforming waste into a material resource (Fischer-Kowalski, 1998).

Waste management that optimizes waste streams and material flows challenges sustainable urban development where there is a growing consensus that waste should be regarded as a valuable resource. It has been argued that the concept of 'waste' should be substituted by the concept of 'resource', and Braungart and McDonough point out that the practice of dumping waste into landfill is indicative of a failure to design recyclable, sustainable products and processes. All eco-cities have to embed zero-waste concepts as part of their holistic, circular approach to material flows (Braungart and McDonough, 2002).

According to Abou Elseoud (2008), GCC (2004), and EMEA (2007), Plastic wastes account for 12% to 16% of the waste in the Arab countries. Thousands of plastic materials, particularly plastic bottles, are improperly disposed of each day resulting in large volumes of plastic waste accumulating in the natural environment, dumped in rivers, buried, and burned, releasing toxic contaminants into the environment. This has become a solid waste management challenge in most countries (Abou Elseoud, 2008).

Recycling technology has been the solution of choice in many cases but it may not always be economically viable, and for this reason the research embarked on utilizing plastic bottles as an alternative building material. Accordingly, this paper will examine the use of plastic bottles in construction, both structurally and thermally as an architecturally innovative sustainable building approach.

Background

Several references reviewed the waste management practices and discussed building with recycled plastic bottles. Katdare (2011), demonstrated that environmental concerns prompt many of us to seek environmentally friendly alternatives, as we explore green alternatives, and seek to respect our ecology by utilizing plastic bottles as a building material. Alvarado (2010) also discussed building with recycled materials that, apart from plastic bottles, involve other recyclable material s, including expired powder milk and even horse manure. See Fig. 1.

Some solid waste materials are non-perishable, however, if they are reused or recycled as a building material, they would become an effective solution, responding effectively to the requirement to consider nature. Such alternative construction materials could also be an effective

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Fig. 1. Use of plastic bottles wastes in building (Katdare, 2011; Alvarado, 2010).

thermal insulator especially for harsh climates as the arid ones. This study offers the dual advantage of disposal of such waste materials without damage to the environment and also for the thermal enhancement of structures built with such waste materials. Consequently, it is important to examine the structural durability of these waste bottles and their thermal behavior.

Material and methods

Masonry polyethylene terephthalate (PET) plastic bottles block specimens of an average length, diameter and capacity of 30 cm, 9 cm and 1.5 l respectively were used. The mean shell (skin) thickness of the bottles is 0.5 mm plastic. The average weight of the air filled bottle is 0.33 N, while the weight of the bottle filled with dry sand, and saturated sand is 22.45 N and 32.54 N respectively.

Testing specimen preparation

The work was conducted by preparing masonry bottle blocks with 10 mm vertical and horizontal bonds of mortar as a binder, using block manufacturing facilities at the engineering material testing laboratory at the University of Nizwa. For each bottle infill type (dry sand, saturated sand and air) at least three block samples were prepared. Each sample has been constructed by eight plastic bottles and configured as interlocking pieces, as shown in Fig. 2.

Subsequently, a wooden mold was prepared and the bottles have been located and bound by a 10 mm mortar bond. For the mortar, prescribed portions of cement and sand were weighed out in a metal pan and a specific amount of water was added in the proportions of: 1:2:0.54, sand: cement: water. Then the blocks of 300 × 300 × 300 mm were molded, and the block samples were left in the molds for 24 h at laboratory temperature (20 ± 2 °C), then removed from the molds and cured by immersion in a water tank for an additional 27 days.

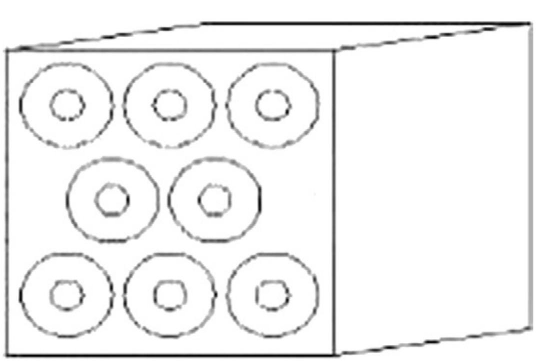

Fig. 2. Arrangement of bottles per each block sample.

The arrangement of bottles, casting of the cement mortar, shapes of the testing samples and the curing process are shown in Fig. 3.

So as to check the increase of strength of the blocks, some bottle samples have been perforated. The idea was to increase the friction between the bond and bottles. The perforated dry bottles blocks were casted in similar way to all previous blocks and the strength determined for 28 day curing.

Strength study

The masonry blocks were subjected to unconfined compressive loading using a compression machine of 3000 kN capacity and of an accuracy of 0.10 kN. The loading was applied on the block in a manner of the bottles laying horizontally and subjected to a diametric compression mode, which simulates the way they are used in wall construction. The compressive strength of the blocks was determined as: $_c = P/A$.

Where,

$_c$	is compressive strength,
P	is load at failure and
A	is cross sectional area

In addition, the wet bulk unit weight of the masonry blocks was determined at the time of testing for all types of blocks. Fig. 4 shows the mode of testing in the laboratory.

Thermal study

The thermal study was calculated for the chosen three bottle block samples with different bottle infill; dry sand, saturated sand and air filled bottles. Accordingly, a model has been simulated with a building simulation software to examine the thermal performance for plastic bottles constructed room versus a traditionally built one.

Thermal resistance calculations

The thermal resistance was calculated according the following equation:$R = L/kA$

Where;

R	is the thermal resistance (°C/W)
L	is the wall thickness (m)
K	is the thermal conductivity (W/m°C) and
A	is the area (m^2)

Building thermal simulation

Energy simulation software tools are an important support used for building designers to reduce the cost of energy in buildings. Energy simulation software tools are an important support used for building designers to reduce the cost of energy in buildings (Sousa, 2012).