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Lightened structural Eco-block prototype, based on a PET (Polyethylene Terephthalate) core

Prototipo de Eco-block estructural aligerado, basado en un alma de PET (Tereftalato de Polietileno)

CASTELÁN-URQUIZA, Demetrio†*

Tecnológico Nacional de México, Tecnológico de Estudios Superiores de Valle de Bravo, Architecture Division, Km. 30, Federal Highway Monument Valle de Bravo, San Antonio de la Laguna, 51200 Valle de Bravo, Mex.

ID 1st Autor: *Demetrio, Castelán-Urquiza* / **ORC ID:** 0000-0003-0250-7908

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Abstract

Currently Mexico is one of the main countries that produce more waste, being the first consumer of plastic bottles in the world, most of this is generated in homes, buildings, streets, avenues, parks and gardens. Propose the design of a lightweight block, through the reuse of plastic waste, that complies with the NMX-C-404-ONNCCE-2012, for parts for structural use. The axial compression stress tests performed on the specimens, the resistance to axial compression, established in NOM-C-404-ONNCCE-2012, was not fully achieved, obtaining an average resistance of 16.91 kg/cm^2.

Ecological block, PET, Bioclimatic architecture, Sustainability

Resumen

Actualmente México es uno de los principales países que producen más desechos, siendo el primer consumidor de botellas plásticas del mundo, la mayoría de estos se genera en viviendas, edificios, calles, avenidas, parques y jardines. Proponer el diseño de un block aligerado, mediante la reutilización de desechos plásticos, que cumpla con la NMX-C-404-ONNCCE-2012, para piezas de uso estructural. Las pruebas de esfuerzo de compresión axial realizadas a los especímenes, no se alcanzó totalmente la resistencia a la compresión axial, establecida en la NOM-C-404-ONNCCE-2012, obteniendo una resistencia promedio de 16.91 kg/cm^2.

Bloque ecológico, PET, Arquitectura bioclimática, Sostenibilidad

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* Correspondence of the Author (Email: demetrio.cu@vbravo.tecnm.mx)
† Researcher contributing as first author.

Introduction

The project arises from the Interinstitutional Program for the Strengthening of Research and Postgraduate Studies of the Pacific (DELFÍN Program), in the stay of the XXIV Summer of Scientific and Technological Research of the Pacific, at the Tecnológico de Estudios Superiores de Valle de Bravo (TESVB) , with the participation of students, who helped design and build the ecoblock prototype, having as a line of research that of Alternative Materials and Technologies for Construction.

Mohson et al. (2021), comments that construction materials have led architecture since its inception and with the development of construction materials throughout history, it gives architecture a broader field of development, either at the level of plans, facades or sections. From the first man-made dwelling to contemporary architecture, where the building is the true embodiment of building materials, and traditional building materials based on bricks, wood and iron have been greatly developed in terms of appearance and efficiency of use in contemporary architecture, man seeks when using building materials to reduce the amount of materials used and with the highest functional, structural and aesthetic efficiency, in order to invest them optimally, leading to the sustainability of building materials .

Sustainable community planning is a complex process that addresses the key areas of equity, economic, environmental and social sustainability. Today, sustainable communities have become the target nucleus in the vision of building a new world in the face of multiple and diverse challenges. Socio-spatial dimension represents the integration of green space networks in a new development. Protecting and improving existing physical assets are the pillars to achieve this goal (Rasul, 2021).

Currently Mexico is one of the main countries that produces the most waste, being the world's leading consumer of plastic bottles, most of which is generated in homes, buildings, streets, avenues, parks and gardens. Much of the waste ends up in garbage dumps or in the sea, which causes pollution, whether of the air, soil or water.

Plastic products that have a high consumption, such as: plastic bottles, which are normally made of PET (Polyethylene Terephthalate), as well as the bags of some foods that are mostly made of polypropylene.

Over the last few years it has been considered to implement plastic in the construction area, since recently what is being sought is to reduce damage to the environment by looking for alternative materials such as Eco-blocks, taking advantage of the fact that it is one of the the elements most used in construction, it was taken into account for the manufacture of a structural block that is ecological.

Analyze the performance of traditional bricks compared to pet, this in order to establish the differences that can be established based on weaknesses and strengths of each one compared to the different factors established for the analysis, it was found that contemplating the manufacture of bricks, the purpose of concrete strength tests is to determine compliance with the strength specification and to measure its variability, however these variations can also be the result of the procedures followed during dosage, mixing, placement and curing, in addition to these, variations are also introduced in the tests due to the manufacturing effect, the test procedure and the treatment of the test samples Ortiz-Castellanos et al. 2020).

Núñez Crisanto (2021), affirm that the PET brick reduces the ecological problem that originates with the manufacture of conventional brick, the burning of recycled plastic materials would be avoided, avoiding sources of contamination. The material has been transformed, since from waste it becomes a fundamental element in construction.

Sánchez (2019), comments that ecological bricks are very important for ecological architecture. There are ecological bricks made of many different materials and their benefits can also be different, but they all have some advantages in common at an environmental and sustainability level. One type of material recently used to make eco-friendly bricks is plastic bottles.

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Although some companies already sell them in more elaborate formats, having processed the plastic to turn it into brick or billet, they can also be made at home, reusing a large amount of plastic.

Puchoc Amaya and Lagua Pilla (2020), investigated that it is necessary to strengthen environmental awareness, promoting the search for community-scale solutions in those peri-urban areas, where such settlements have been created; considering environmental, technological, institutional and financial aspects, to recover a pleasant, healthy and sustainable environment.

Ecobrick is no exception, as it is the product of PET bottles filled with inorganic material, and other non-biodegradable waste; To be used in masonry as individual blocks, tying each one to form the walls, or crushing the pet and applying it to blocks with a binder, it can be applied in the construction industry favoring the management of inorganic waste in a community.

Sánchez, (2019), describes the advantages of ecological bricks Saving, both when acquiring or manufacturing them by hand as well as by saving energy that they generate In some cases, more insulation capacity from humidity, noise, heat or cold. Lower environmental impact and greater preservation of ecosystems and biodiversity that favors the manufacture of many of them. They are lighter and, in this way, reduce construction times and the effort of workers.

Maure et al. (2018), investigated the manufacture of molten plastic bricks with shavings produced by machining as a constructive element. In this work the material used is polyethylene terephthalate, better known as PET. The manufactured bricks made it possible to check and obtain a good mechanical resistance to compression, in comparison with conventional bricks. On the other hand, they help reduce environmental pollution. It is a self-sustaining proposal because recycled materials (PET and metal shavings) are used as raw materials, promoting the use of available resources, instead of burning or discarding them.

Hossain et al. (2021), investigated that by using recycled materials (locally generated construction and demolition waste and glass waste) and incorporating a small amount of nano-TiO, the authors' research team has successfully developed ecoblocks concrete paving system with good air purification functions, in particular nitrogen oxide (NOx) removal.

Kramný (2021) in his research, comments on the use of BIM technologies and methodology for the standardization of the production and construction of straw panels. He introduces himself to the subject of working with alternative ecological materials such as straw in construction. In addition, the concept of the applicability in Revit is presented as the first step to the use of the production and construction of ecological panels. Based on the knowledge acquired, an economic analysis of the costs of the ecological panel was determined. The work can serve as the basis for the introduction of BIM in the construction and production of houses from straw and other energy applications.

What are ecological bricks or eco-bricks

Bricks are usually a polluting material since, among other things, they require a lot of energy to manufacture, so their environmental impact is important. This does not happen in those ecological bricks also called ecobricks. However, its use today is very rare, although historically more sustainable materials have been used in construction.

There are more and more ecological initiatives that aim to reinvent or replace traditional bricks using sustainable materials or promote greater sustainability that helps us save energy or even reduce our carbon footprint. Among these initiatives are the manufacture of bricks from plastic bottles.

Therefore, ecological bricks are those bricks made from materials or through manufacturing processes that do not have an environmental impact as significant as that of conventional bricks. Within the ecological bricks, there are some more ecological than others according to their sustainability in various aspects. These bricks can offer us the same or greater resistance than conventional bricks and even offer the same advantages in comfort and safety.

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Concrete block

Concrete Blocks are precast modular elements designed for confined and reinforced masonry. The block is made of cement, sand and aggregates, they are of great structural resistance. As a constructive system it is excellent since it is a very versatile product. The block is very suitable for tropical or hot climates. Measurements: 11x14x28 cm.

According to the NMX-C-404-ONNCCE-2012 standard, for parts for structural use, the concrete block is a prefabricated piece with the shape of a straight prism and with one or more vertical holes, for use in simple or structural masonry systems This is due to the possibility of reinforcing the vertical and horizontal pieces. For the erection of walls, in order to give the desired height and width to the wall. In order to build with the block, they are placed one at a time with fresh mortar.

Polyethylene Terephthalate (PET)

Polyethylene terephthalate, polyethylene terephthalate, polyethylene terephthalate or polyethylene terephthalate (better known by its acronym in English PET, polyethylene terephthalate) is a type of plastic widely used in beverage and textile packaging. Some companies manufacture PET and other polyesters under different trademarks that have come into common use, for example, in the United States and the United Kingdom they use the names Mylar and Melinex.

Chemically, PET is a polymer that is obtained through a polycondensation reaction between terephthalic acid and ethylene glycol. It belongs to the group of polyesters called synthetic materials.

It is a linear thermoplastic polymer, with a high degree of crystallinity. Like all thermoplastics, it can be processed by extrusion, injection, injection and blowing, preform blowing and thermoforming. To avoid excessive growth of spherulites and crystal lamellae, this material must be rapidly cooled, thereby achieving greater transparency. The reason for their transparency when cooling rapidly is that the crystals are not fully developed and their size does not interfere ("scattering") with the path of the wavelength of visible light, according to quantum theory.

Objective

Being the general objective, to propose the design of a lightweight block, through the reuse of plastic waste, that complies with the NMX (Mexican Standards) and the NOM (Official Mexican Standards).

The mechanical property of compressive strength, as the independent variable, to be considered as a structural block, established in the NMX-C-404-ONNCCE-2012 standard, despite having PET encapsulated inside, this It will help you to reduce its weight, as well as the material to be used for aggregates, reducing production costs.

Materials

The materials that were used for the construction of the prototypes were from the region of the Municipality of Valle de Bravo, State of Mexico.

- -Toltec brand gray cement.
- -Sand.
- -Tepojal.
- -Water.
- -PET for bottles and Plastics for frying bags.

Tools.

- -Weighing machine
- -Shovel and spoon
- -Vernier

Machinery

- Vibro-Blocquera Machine
- Universal machine brand controls.

Methodology

The experimental methodology is based on the Mexican Standards (NMX) OF MASONRY (ONNCCE, National Agency for Standardization and Certification of Construction and Building, S.C., 2021).

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Standards of reference:

Construction Industry, Masonry and Blocks.

The tests were carried out in the following order, according to the Mexican Standards.

1. (ONNCCE, NMX-C-024-ONNCCE-2012, 2021) Determination of shrinkage by drying of blocks, partitions or bricks and partitions.

2. (ONNCCE, NMX-C-038-ONNCCE-2013, 2021) Determination of the dimensions of blocks, partitions or bricks and partitions.

3. (ONNCCE, NMX-C-036-ONNCCE-2015, 2021), Compressive strength of blocks, partitions or bricks, partitions and paving stones.

4. (ONNCCE, NMX-C-404-ONNCCE-2012, 2021) Blocks, partitions or bricks and partitions for structural use.

5. (ONNCCE, NMX-C-441-ONNCCE-2013, 2021), Blocks, partitions or bricks and partitions for non-structural use.

Experimental prototype

It began by collecting PET bottles and plastic bags at the TESVB, in the recycling bins. The bottles were cleaned, detaching the labels. The PET bottles were cut to fill the bottles with this material, as well as the labels and frying bags.

With the help of an automatic digital vernier and an analog vernier, the necessary measurements of the PET bottles were carried out in order to be able to know more in detail the volume they had, since in the elaboration of the block it was necessary to know how much volume they occupy inside, to make an approximation in volume of the material to be used per unit.

Once enough material was obtained, a suitable size was selected to meet the specifications of the net area of a hollow block, however, it is considered a hybrid block, since the gross area includes the material used, together with the PET.

The sizes chosen were one liter and 355 ml bottles. which were filled with other plastics, which had been previously collected. To fill a one-liter container, approximately 25 to 30 PET bottles were needed, which corresponds to 1,569 ml.

Before making the mixture for the prototype, a granulometry test was required for the coarse aggregate (gravel or turf). In order to select the nominal size requested by standard. Since all the necessary materials were had to make the mixture, the physical prototype was made, the dosage by volume percentages of the materials used in the cement packages was used for a compression resistance of f'c = 200 kg/cm^2, for each package of cement, 6 cans of 19 liters of tepojal, 4 cans of 19 liters of sand and 2 cans of 19 liters of water are added to produce one cubic meter of concrete.

The materials were emptied into the block, which already has a section of molding of 6 blocks, in figure 1, the arrangement of the pet bottles in the molds is shown with a standard measure of 12x20x40 cm, by means of From it, it was possible to carry out the compaction and vibrating of the material, so that the block will be with the appropriate measures, the mixture was done manually.

Figure 1 355 ml bottles of pet inside the block
Source: Own elaboration

To place the PET containers inside the block, first a layer of mixture was placed in the mold, then the plastic bottle was included, to finish it was covered with another layer of mixture, giving it a rod at the ends, in the figure 2, the final result of the block is appreciated.

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Figure 2 Dry blocks
Source: Own elaboration

The three specimens were allowed to dry in the sun for 28 days. Figure 3 shows the axial compression stress test of the specimens, in the universal machine.

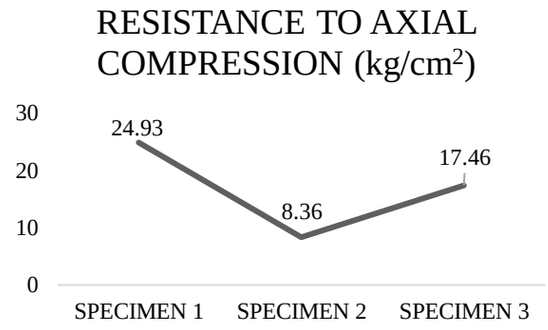
Figure 3 Axial compression test
Source: Own elaboration

Results

The results obtained from the axial compressive stress of the specimens are shown in table 1 and graph 1, giving a resistance to axial compression of specimen 1 of 24.93 kg/cm^2, specimen 2 of 8.36 kg/cm^2 and specimen 3 of 17.46 kg/cm^2, these data indicate that they are well below the Mexican standard NOM-C-404-ONNCCE-2012, to be considered a solid block, to be used in structural masonry.

Specimen	Axial load (kg)	Resistance to axial compression (kg/cm^2)
1	11,967.9	24.93
2	24,016.0	08.36
3	8,383.2	17.46

Table 1 Results of axial compression test
Source: self made



Graphic 1 Graph of resistance to axial compression xial
Source: Own elaboration

To be considered a solid structural block, the standard sets the compressive strength, individual minimum of 120 kg/cm^2 and for hollow block of 70 kg/cm^2.

Conclusions

Derived from the tests carried out on the specimens, the resistance to axial compression, established in NOM-C-404-ONNCCE-2012, was not fully achieved, obtaining an average resistance of 16.91 kg/cm^2.

Its use will not be in a structural way, although it can be used as a light block, it was observed in the axial compression test, that the PET bottle did not suffer total deformation, it helped to reduce the weight of the block to 10 kg on average and the amount of raw material, likewise to use solid waste.

The results of these tests can be improved by modifying the calculation of the mixture by reducing the amount of volume of the PET or it could be filled with another material such as sand or compacted clay, which would cause an increase in its volumetric weight.

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