Article **Journal Architecture and Design**
June, 2023 Vol.7 No.17 1-8

Alternative material with PET: Comparison of CEB-PET, CEB and Concrete block

Material alternativo con PET: Comparativa del BTC-PET, BTC y Bloque de concreto

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DOI: 10.35429/JAD.2023.17.7.1.8 Received January 10, 2023; Accepted June 30, 2023

Abstract

Climate change has generated the need to propose alternatives that reduce the impact of human activities and the real estate market is one of these, an area of opportunity is the production of construction materials that demand energy and use of non-renewable resources. , taking into account one of the indicators of the 2030 Agenda for Sustainable Development, objective 11, of the 11c that says: Provide support to the least developed countries, so that they can build sustainable and resilient buildings using local materials. The objective was to compare the CEB-PET prototype with respect to the CEB and the concrete block, as an alternative for the construction of walls in Saltillo Coahuila. The methodology was quantitative, quasi-experimental, carrying out laboratory and field work. The results indicate that the CEB-PET has a Compressive Strength of 82,194 kg/cm^2 and can be used as a load-bearing wall; Regarding cost, it can compete with a concrete block and in relation to its application in the work, it is handled in the same way as a concrete block.

Alternative, Sustainable, Prototype

Resumen

El cambio climático ha generado la necesidad de proponer alternativas que reduzca el impacto de las actividades del ser humano y el mercado inmobiliario es uno de estos, un área de oportunidad es la producción de los materiales de construcción que demanda energía y uso de recursos no renovables, tomando en cuenta uno de los indicadores de la Agenda 2030 para el Desarrollo Sostenible, el objetivo 11, de la 11c que dice: Proporcionar apoyo a los países menos adelantados, para que puedan construir edificios sostenibles y resilientes utilizando materiales locales. El objetivo fue comparar el prototipo del BTC-PET respecto al BTC y al bloque de concreto, como alternativa para la construcción de muros en Saltillo Coahuila. La metodología fue de enfoque cuantitativo, cuasiexperimental, realizando trabajo de laboratorio y de campo. Los resultados indican que el BTC-PET cuenta con una Resistencia a la Comprensión de 82.194 kg/cm^2 pudiendo ser empleado de muro de carga; respecto al coste puede competir con un bloque de concreto y en relación con su aplicación en la obra se manipula igual que un bloque de concreto.

Alternativa, Sostenible, Prototipo

Citation: MOLAR-OROZCO, María Eugenia. Alternative material with PET: Comparison of CEB-PET, CEB and Concrete block. Journal Architecture and Design. 2023. 7-17:1-8

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Introduction

Climate change has generated the need to propose alternatives that reduce the impact of human activities, the real estate market is one of these, the production of construction materials demands energy and use of non-renewable resources. In addition to this, the generation of urban waste in cities increases, including Polyethylene terephthalate (PET), that not only is it found in the streets, islands of this waste have also been formed by its excessive consumption. The proposal of the 3 Rs (recycle, reuse and reduce) is the key to reducing the footprint of the human being on the planet along with the construction of land.

According to Vázquez, Guzmán and Iñiguez (2015), they point out that the compressive strength of CEB exceeds traditional adobes by around 500% and in terms of moisture resistance the same thing happens and the reason is because being pressed reduces the number of pores, therefore, absorption is lower. In addition to this, the use of the hydraulic press helps to reduce the production time of the parts. This is achieved by having a machine with a mechanical mixer and a press with a multiple mold (3 simultaneous blocks) can produce 70 to 100 CEB per hour with the participation of 4 workers.

Other works by Roux and Velázquez (2015) corroborate the resistance of CEB with respect to the blocks and bricks used in homes, indicate that 100% of CEB made with CinvaRam are above the resistance of concrete blocks and 90% above the resistance of regional brick.

In Mexico there is the NMX-C-508-ONNCCE-2015 CONSTRUCTION INDUSTRY COMPRESSED EARTH BLOCKS STABILIZED WITH LIME-SPECIFICATIONS AND TEST METHODS, which allow their use in construction as load bearing walls or dividers may or may not be apparent and in the ceilings in vaults.

Seisdedos and López (2008) of Hábitat Tierra-CEETyDeS point out:

The enormous impact of the construction sector on the environment makes it necessary to develop construction techniques with minimal environmental impact, capable of offering a more natural and healthy environment for people. The use of compressed earth blocks (CEB) in building is one of the most suitable current construction systems in ecological terms due to the minimum environmental impact of its Global Life Cycle (pp. 289).

Gutiérrez, Medina and Arteaga Medina (2011) comment that:

Materials that use earth will endure in construction, because of their economy, because they are resistant – with a study of the material and structure, and with a coherent design – and because earth is an abundant, recyclable and productive material. In terms of strength, this element is not far from competing with other types of materials, because due to its perforations it can be reinforced and stabilized; Reinforcement can be with a rod, drafted by a mixture of fluid cement (pp. 67).

It is for this reason that, masonry with CEB is an economical construction technique that presents better resistance and durability properties than those built with adobe, it also has a great potential for industrialization of its units (Herrera Villa, 2018).

Roux and Velázquez (2016) indicate that:

In thermal delay tests they found that BTC improve the feeling of thermal comfort inside homes, considerably better than concrete block and fired brick, since it has a thermal delay of up to 5 h against half an hour than these. It is found that, throughout the day, the BTC will present a lower temperature on the outside of the wall, as well as inside the house when exposed to a heat source than the other materials tested (pp. 11 and 12).

Pastormerlo and Souza (2013) (cited by Roux and Velázquez, 2016, pp.12) point out that with CEB walls a house will be cooler in summer and hotter in winter, due to the thermal mass of this material that is 1740 kJ / m3, against 1360 kJ / m³ of brick and 550 kJ / m³ of the concrete block, in addition to consuming less energy resources by having a thermal delay higher than conventional materials (concrete blocks and annealed bricks).

Where the use of these low embodied energy materials (Bradley et al, 2018) compared to clay bricks, reduce the amount of energy required in construction and transportation, being an abundant and recyclable natural resource (Hegyi et al, 2016; Mansour et al, 2017).

Ramos Rivera and López Zerón (2019):

When performing comparative test they found that bricks formed by soil only or compressed earth block (CEB) provided considerably higher compressive strength (double) than traditional clay bricks. On the subject of absorption, CEB bricks with soil and cement can be qualified as moderate weathering. According to this parameter, this type of bricks can be used for masonry walls that are exposed to the weather in a moderate way (pp. 92 and 93).

Bestraten Castells and Hormias Laperal (2012).

They carried out tests to compare the resistance of adobe vs CEB, finding that the resistances of CEB are significantly improved by the introduction of cement in the composition and compression of the raw material, being able to multiply by 3.8 the capacity of adobe (pp.10).

With this in mind, Auza and Chambi (2012) warn of the advantages of using a certain percentage of PET with a certain type of clay soil, from a sustainable, economic aspect in the design of the pavement.

So much so that Andrade and Morocho (2023) recommend that to have a better use of PET in a reinforced mortar, the percentage should be low to improve its resistance.

Consequently, López and Pascual (2023) suggest considering the size of the particles for a better obtaining in the physical-mechanical properties, they must pass through sieve No. 4 to be more manageable, than if larger particles are used.

Similarly, the application of fire retardants in construction materials used in closed spaces should be considered (FibraPlus, 2017) as it increases the ignition resistance of plastic. Some plastics, especially those that could generate fire, contain flame retardants, in proportions of 5 to 30% (Teuten, et al, 2009).

Above all, to avoid human losses due to fires in construction, work has begun with materials with additives so that when exposed to the heat source the chances of its propagation decrease, one of these are halogenated compounds that have been effective for years in several types of polymers including PET (Buezas, 2010). Flame retardants act in three ways, for example, they form a crystalline barrier on the surface of the material, displacing oxygen in combustion reactions or form water molecules that stop the process, this inhibits combustion, prevents the formation of flames and fumes (Buezas, 2010; Wäger, Schluep, Müller and Gloor, 2011).

Consequently, an area of opportunity is generated in the production of new construction materials that demand energy and use of non-renewable resources, taking into account one of the indicators of the 2030 Agenda for Sustainable Development, goal 11, of the 11c that says: Provide support to the least developed countries, so that they can build sustainable and resilient buildings using local materials, it aims to make a comparison of a Block of Compressed Earth with PET (CEB-PET) with the Concrete Block and a CEB, starting with the hypothesis that including particular PET to the prototype will obtain a better resistance of the material, without emitting toxic gases, at a low cost to be used in construction in the city of Saltillo, Coahuila.

Methodology to be developed

The approach was quantitative, quasi-experimental and conducting laboratory and field work. For the stress tests, the criterion (NMX – C – 404 – ONNCCE – 2005) was taken to identify its type.

ISSN 2531-2162

An estimate of the mathematical cost was made to obtain the value of CEB-PET in the market taking into account the equipment, hours of work and material used.

In order to determine its feasibility in the construction process, a specialized workforce was hired to build a module of 1.4m x 2.22m x 2.36m, taking into account the execution time, the handling process and the opinion of the master builder.

Finally, tests in a chemistry laboratory were considered to determine if the PET when heated could release any toxic:

– Infrared test, the sample of the soil-PET material was placed in four crucibles, then introduced to a muffle and the temperature was raised to 100, 200, 300 and 400°C, in order that the material lost all moisture and organic material. When the muffle reached 100°C, one of the four crucibles was removed and carried to infrared (IR) analysis, the background was first performed, to eliminate the possible effects of air on the sample. The test was performed from 600 to 4000 cm-1, then at 200°C the second crucible was removed and the test was performed in the same way, then at 300°C and finally at 400°C.

– Thermogravimetric analysis, this test was performed on a PerkinElmer analysis equipment, with a temperature of 30 to 800°C and a nitrogen gas flow of 20 mL/min

– Direct fire test to the PET dust samples with the goal of injecting the smoke for analysis, consists of applying a flame from a Bunsen burner for 10 seconds to one end of the specimen held vertically in a vertical position with tweezers and removed until the fire is extinguished and repeated again (in total there are 3 samples) and a classification is made depending on several aspects such as the self-extinguishing of the flame, the dripping of the inflamed material or its reaction.

Results

Resistance to compression tests were carried out for structural use in buildings, with previously produced prototypes. The ITAL MEXICANA S.A machine was used for the test with the CEB-PET, figure 1.

Figure 1 Endurance to comprehension test, 2022, brand
Own Elaboration

Resulting in a Compression Resistance of 82,194 kg / cm^2, being greater than required. For infrared (IR) testing, dry samples were taken at 100, 200, 300 and 400°C of the material, Figure 2.

Figure 2 Image of the samples, 2022
Own Elaboration

ISSN 2531-2162

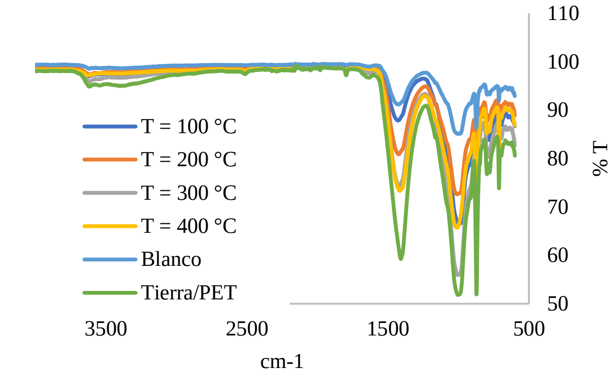

Figure 1 PET soil IR test, 2022
Own Elaboration

In graph 1, the characteristic peaks of PET are observed at the wavelengths of: 1600, 1100, 1000 and 750 cm-1, where the peaks of 1000 and 750 cm-1 are spliced with the peaks of white (soil without PET), and it is observed that the soil without PET does not present the peak of 1600 cm-1 of PET. Another characteristic that can be identified in the graph is that, as the temperature of permanence of the sample in the muffle increases, the peaks become less intense, that is, the characteristic groups of the compound are being lost. The peak of 1000 cm-1 that presents the soil corresponds to the inorganic groups of oxides, it can be silicon, selenium, chlorine hypochlorite etc; However, in order to determine it, an elemental analysis of the compound is needed.

In relation to thermogravimetric analysis (TGA)

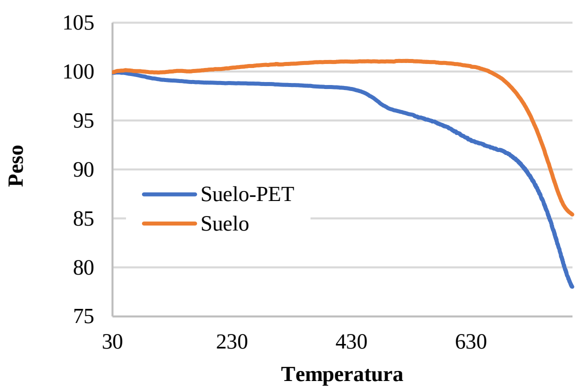

Figure 2 Thermogravimetric test result, 2022
Own Elaboration

In graph 2, the weight losses in the CEB, composed with PET are observed, since the soil contains inorganic compounds that are lost at very high temperatures, the losses presented in the graph are given by the PET.

The first weight loss is 1.69%, at 448°C; the second weight loss occurs at 596°C with a loss of 2.3% of weight.

From the test performed on the PET sample over direct fire, it is turned on and off immediately without releasing smoke to inject.

Test results:

– TGA shows material loss, possibly organic matter and PET.
– The IR shows that there is no chemical change in the material when exposed to high temperatures.
– It is determined that the PET used has some retardant.

For the calculation of the cost of a CEB-PET, the following data were taken and processed, table 1.

CEB cost (unit)		
Material	Cantidad	Cost ($)
Soil	18.2 Kg.	2.22
Cal	0.6 Kg.	1.1
Cement	0.6 Kg.	2.32
Pet	0.6 Kg.	1.2
Water	2 LITRES	0.56
Labor	3 PEOPLE	0.01
Electricity	Cost of 1 peso per hour	0.001
Machinery	$42,500 (20 years) / 1,657,500 ceb	0.02
Local (installation)	100 pesos per day (rent)	0.01
		7.441
	30% PROFIT	2.23
		9.671

Table 1 Cost, 2022
Own Elaboration

In the construction process for CEB

The execution time for the construction of a module of 3.11 m 2 by 2.36 m high was 3 days, of normal days, its handling by labor was documented, figure 3 to 6, when questioning if there was any difference in its use indicated that it is equal to a normal concrete block and the weight is similar, Figure 7.

ISSN 2531-2162

Figure 3 and 4 CEB-PET mobility by skilled labor, 2023
Own Elaboration

Figure 5 and 6 Placement of CEB-PET by skilled labor, 2023
Own Elaboration

Figure 7 CEB-PET module developed by skilled labor, 2023
Own Elaboration

For the comparison, the data of the other materials were collected and the data of each one were observed, Table 2.

Material	Dimension	Resistance to comprehension (NMX-ONNCCE-2005)	Cost per piece
CEB-PET	20 x 40 x 12	82.194 kgf/cm^2 (obtained in the laboratory 2022)	$ 9.68
CEB	20 x 40 x 12	71.43 kgf/cm^2 (obtained in the laboratory 2015 y 2020)	$14.00
Concrete block	14.5 x 39.5 x 19	31.66 kgf/cm^2 (Morales 2008)	$ 11.10 o 13. 77 It depends if it is wholesale

Table 2. CEB-PET, CEB and concrete block
Own Elaboration, 2022.

Gratitude

We thank FONCYT for supporting the Project, the UAdeC, the direction of the Faculty of Architecture (2020 to 2022) to the collaborators of chemists and donors who made the work possible.

Financing

Funding: This work has been funded by FONCYT 2021 C15, key to Project COAH-2021-C15-C007. Evaluation of the thermal behavior of a CEB-PET, BTC and concrete block for Saltillo, Coahuila

Conclusions

It was tested with the objective of the hypothesis. According to the results it can be indicated that there is viability for its use in construction, since it does not generate any problem in its handling by labor, in addition it can be assured with the tests that the PET included in the prototype does not allow the spread of fire in the constructions or gives off smoke or toxic gas that damages the health of the inhabitant, as highlighted by Teuten, Buezas, Wäger among other authors.

It coincides with the characteristics of PET and soil, along with the percentage indicated by Auza, Chambi, López, Pascuales, Andrade and Morocho. The resistance obtained from CEB-PET is optimal, as indicated by López, Pascuales, Andrade, Morocho, Rivera, Zerón, Vázquez, Guzmán, Iñiguez, Roux, Velázquez, Bestraten and Hormias for its use as a load-bearing wall and its cost highlighted by Gutiérrez, Medina, Arteaga Medina and Herrera Villa, therefore, it can compete with the concrete block, in addition, there are tests carried out that demonstrate its good thermal behavior and the reduction of the impact of PET as urban waste that will be published in other publications.

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