KnE Engineering
ESTEC Conference Proceedings
6th Engineering, Science and Technology Conference (2017)
Volume 2018

Knowledge E
Engaging minds

Conference Paper

Setting time of ecological bricks with different percentage PET

Andrea Maldonado[1], Angela Corvalan[1], Delia Cohenca[2], and Magna Monteiro[1]

[1]Polytechnic Faculty, National University of Asuncion, San Lorenzo, Central, Paraguay
[2]Research Center in Mathematics - CIMA, Asunción, Paraguay

Abstract

Raw materials and products environment friendly has led many authors to develop the area of bio-construction, especially in civil construction, using alternative materials to obtain new achievements. PET (Polyethylene terephthalate) bottles, widely used worldwide, have made it possible to produce very ambitious technological products for their energy and economic efficiency. This study is based on the application of discarded PET bottles for application in ecological building bricks. For this, samples with different PET percent were prepared. The samples were prepared in triplicate. These samples were subjected to tests to verify the optimum setting time/PET ratio. The tests were performed according to international standards and compared to the values of conventional bricks.

Keywords: Environment friendly, set-up tests, bio-construction.

Corresponding Author:
Andrea Maldonado
andreabeatrizmn@gmail.com

Received: 15 November 2017
Accepted: 5 January 2018
Published: 4 February 2018

Publishing services provided by Knowledge E

Selection and Peer-review under the responsibility of the ESTEC Conference Committee.

1. Introduction

Recycling is the process of using recovered material to manufacture a new product (Hopewell et al, 2009). It is process that can transform the waste into new products, to prevent waste of potentially useful materials, the best action is to reduce the consumption of fresh raw materials, reducing energy usage and the air pollution (from incineration) and water pollution (from landfilling). Recycling is a modern key component for waste reduction and is the third component of the "Reduce, Reuse and Recycle" hierarchy.

There are some ISO standards related to recycling such as ISO 15270:2008 for plastics waste and ISO 14001:2004 for environmental management control of recycling practice.

Materials to be recycled are either brought to a collection center or picked up from the curbside, then sorted, cleaned, and reprocessed into new materials bound for manufacturing (Banerjee, 2015; Xiaohan, 2013; Morillas et al., 2016). Materials can be re-processed and transformed secondary raw materials. These re-processed consist in the reintroducing into system, of part of the material and energy that would otherwise be considering wastes.

Among the solid-waste materials, plastics have been receiving a lot of attention because in its great majority not be biodegradable. Plastics are inexpensive, lightweight and durable materials, which can readily be molded into a variety of products, which find use in a wide range of applications. Polyethylene terephthalate (PET) is one of the most common consumer plastics and is widely employed as a raw material to fabricate products such as blown bottles for soft-drink use and containers for packaging of food and other consumer goods. PET is a non-degradable plastic in normal conditions. PET bottles replaced the glass bottles as storing vessel of beverage due to its light weight and easiness of handling and storage.

PET bottles are largely responsible for the increase of solid waste (Frigione, 2010), results from economic activities based on quantity, mass production and waste disposal. Each country is seeking to develop a sustainable system for PET bottles and the best alternatives in which to dispose of them.

Recycling of PET bottles after their collection consists of the following steps (Coelho et al, 2011):

- Recovery: discarded packages become raw material.
- Recapturing value: post-consumer PET waste is crushed into flakes, enhancing its value. Thus, the product is much more condensed, maximizing its transportation and its reuse.
- Transformation: the flakes are manufactured into a new product.

The recycled PET can be used to manufacture various products such as producing fibers, strapping, bottles, containers, alloys and compounds. Various technologies have been developed for PET bottles and plastic waste (Coelho et al, 2011). Unfortunately, nowadays the recycling of PET bottles is much less than the sales of virgin PET production for common uses.

Waste utilization has become an attractive alternative to disposal given the scarcity space for landfilling and its ever increasing cost; research is being carried out on the utilization of waste products in concrete. The use of waste products in concrete not only makes it economical, but also helps in reducing disposal problems (Siddique et al, 2008).

The development of new materials utilizing recycled plastics is important for both building and plastic recycling industries. With the use of concrete and Polyethylene terephthalate (PET) in construction, a new technology is developed.

This study proposes a technological alternative for production of components for civil construction, ecological and more economical than traditional components. This technology is based on the utilization of waste, specifically PET bottles, for their application as a raw material in ecological building bricks. Given the fact that one of the raw materials for the manufacturing of these bricks is recycled waste product, is environmental friendly because it offers a sustainable destiny to non-biodegradable waste, which is a constant threat to the environment; it reduces the contamination of the environment, contrary to what normally occurs when natural raw materials are used for civil construction. Through this specific type of recycling, the consumption of PET is rationally reduced. The generation of solid waste is minimized, selecting materials that are recyclable and generating sustainability in civil construction (Ruiz and Angel, 2009).

2. Materials and Methods

Ecological building bricks are a variation of traditional concrete. Their manufacture consisted of mixing the following components: Portland cement, water, sand and PET (Polyethylene terephthalate) flakes replacing natural aggregates, such as gravel (Neville, 2011), among others. The samples were made with different percentages of PET flakes and in different particle sizes. The samples were produced in triplicate and subjected to the setting test to analyze the amount of water absorbed and the optimal time of fraugation with the proportion of PET used.

The manufacture of the samples was divided in three parts: obtaining the raw material - the bottles of PET (Polyethylene terephthalate) used as raw material were collected from restaurants and university canteens, a total of 464 bottles of PET were collected. Preparations of the samples - the PET bottles, after being collected, had their lids and labels removed, underwent a washing process and were ground with the aid of an industrial mill (Robot50, Paraguay), with double sieves (Gilson Company, TS18 model). The PET(Polyethylene terephthalate) flakes were ground twice, in order to obtain a suitable flakes to be used as an optimum aggregate in the mixture for the preparation of the samples. After, were again submitted to a second wash to remove the fine powder. The samples were made in PVC cylindrical molds with a height/diameter ratio of 2.18, approximately, as shown in figure 1. The PET flakes of different granulometries are separated into plastic bags and are identified according to the size of the sieve where they were retained respectively.

The mixture, for manufacturing the Ecological bricks, was done by volume, using the ratio 1: 3: 1 (López, 2003), i.e. for each volume of Portland cement three equal volumes of sand and an equal volume of water are placed. This ratio is considering optimal for a standard mortar mix. Samples are made in a ratio of 40% PET flakes - 60% sand, 50% PET flakes - 50% sand, 60% PET flakes - 40% sand. The PET flakes to be used vary in granulometry size, the sieved granulometry sizes of 1.2 mm, 2.4 mm and 4.8 mm are used.

The mixture was placed in PVC plastic molds with lubricant to facilitate the demolding of the samples after 24 hours. After the demolding of the samples, each sample was weighed and then goes through the curing process.

Figure 1: Samples of the ecological building bricks.

Table 1 shows the granulometric fractions of the PET flakes retained on each sieve compared to the initial amount. Equation 1 was used to determine the modulus of fineness, according to the Manual of Materials for civil works (Alonso et al, 2011). The sizes of each sieve standardized were 19.5, 12.5, 6.4, 4.8, 2.4 and 1.2 mm, respectively.

$$\text{Fineness Module} = (\text{Sum of the percentage of accumulated retained})/100, \quad (1)$$

DOI 10.18502/keg.v3i1.1440

Table 1: The total mass of flackes PET sieved in accordance with ASTM E11.

Sieves (mm)	Mass (g)	Retained%	Accumulated Retained (g)	Accumulated Retained%
19.5	25	0.156	25	0.159
12.5	400	2.547	425	2.706
9.5	952	5.889	1350	8.596*
4.8	8905	56.701	10255	65.297
2.4	3560	22.667	13815	87.865
1.2	1120	7.131	14935	95.097
Blind Background	770			

In accordance with the eq. 1, the fineness modulus obtained was 2.57 mm, approximately.

The maximum aggregate size is the magnitude associated with the particle size distribution of the aggregate, corresponding to the normal aperture in mm of the normal or intermediate series. The aggregate presents a percentage of accumulated retained equal or immediately below 10% by mass (Alonso et al, 2011). In the results obtained, 8.59% (9.5 mm) represents the maximum size of the aggregates.

2.1. Curing process

Curing is the process by which the concrete is to be kept saturated until fresh cement spaces, originally filled with water, are replaced by the products of cement hydration. Curing is intended to control the movement of temperature and humidity in and out of the concrete. It also seeks to avoid the concentration of forge until the concrete reaches a minimum resistance that allows it to withstand the forces induced by it. The lack of curing of concrete drastically reduces its strength. At longer cure time, the resistance achieved by the concrete is higher (Harmsen, 2002).

Samples are removed from the water, in which they were placed, at 1, 7, 14 and 28 days of curing and weighed each respectively. At 28 days of curing the concrete is expected to acquire a final strength (López, 2003), so the samples were finally removed and allowed to dry for 48 hours at room temperature for further testing. After 48 hours of drying, they were weighed again to determine the absorption capacity of the samples. The water absorption capacity of the samples is defined as the ratio of the weight of water absorbed to their own weight when dry. It is expressed according to the definition:

$$\text{Water absorption capacity} = (P_{sat} - P_{seco})/P_{seco} \times 100, \quad (2)$$

where P_{sat} is the weight of the saturated sample and P_{seco} is the weight of the dry sample (Verduch, 1975).

3. Results and discussion

At present, durability parameters have acquired as much importance as resistance parameters. Durability is defined as the ability of the already hardened mixture to withstand, without deterioration, the stresses caused by physical and chemical agents, which can attack the concrete, not only on its surface, but also within its mass. The durability of concrete is intimately related to its porous structure and to the chemical nature and proportion of its component materials. The durability of concrete is directly related to the ease with which aggressive agents enter and move inside. Depending on the magnitude of the driving forces of this process three transport mechanisms can be distinguished: permeability, diffusion and absorption. In this project the absorption capacity of the manufactured samples is studied (Sakurai et al, 2010).

The volume of pore space in concrete, as distinct from the ease with which a fluid can penetrate it, is measured by absorption; the two quantities are not necessarily related. Absorption is usually measured by drying a specimen to a constant mass, immersing it in water, and measuring the increase in mass as a percentage of dry mass. One reason for this variation in the values of absorption is that, at one extreme, drying at ordinary temperature may be ineffective in removing all the water; on the other hand, drying at high temperatures may remove some of the combined water. Absorption cannot, therefore, be used as a measure of quality of concrete, but must good concretes have absorption well below 10 percent by mass (Neville, 2011).

Taking into account that the aggregate for the samples were PET flakes, a polymer which would melt at high temperatures, the method of drying was at ordinary temperature, i.e. room temperature, for 48 hours.

The results obtained from the absorption capacity of the samples are shown in Table 2.

According to Neville (2011), better concretes have absorption well below 10% by mass. Then, ignoring the mortar samples, the samples with particle size of 1.2 mm

Table 2: Absorption capacity of the samples

Samples	Particle size (mm)	Average saturated weight (g)	Average dry weight (g)	Average water absorption capacity (%)
Mortar	-	593.33	576.66	2.89
	1.2	563.33	533.33	5.62
PET 40	2.4	566.33	539	4.88
	4.8	563.33	496.66	13.42
	1.2	526.66	495	6.40
PET 50	2.4	551.66	508.33	8.52
	4.8	535	473.33	13.03
	1.2	515	470	9.23
PET 60	2.4	523.33	465	12.54
	4.8	533.33	471.66	13.07

show the best absorption capacity of water, followed by the samples with particle size of 2.4 mm.

Conclusion

Considering the Paraguayan Standard NP 17 027 77 (2^{nd} Edition, 2015) for solid ceramic bricks, which are manufactured essentially on the basis of non-metallic inorganic substances and do not have gaps, one of the general requirements for it is that bricks must have characteristic capacity values of water absorption not greater than 25%. This shows that the results obtained from the tests are favorable for the manufacture of ecological bricks, since these do not exceed the value of 13.5%. For later work, it is recommended the use of different percentages of aggregate used and the different sizes of remaining granulometry.

Acknowledgment

Authors thank the financial support of CONACYT/PROCIENCIA/Paraguay (Proyecto 14-INV-404) and the FIUNA Materials Laboratory (Faculty of Engineering UNA) for technical support in the sieving of the aggregates.

References

[1] Alonso, O. B., Alonso, E. B., Cazal, A. A., Flores, F. D., Holden, R. A. R. (2011). *Manual de Materiales de Obras Civiles. Hormigón, Armadura y Encofrado*. Tomo I Volumen II, Ciudad de Asunción, República del Paraguay.

[2] Banerjee, R. (2015). "Importance of Recycling" *International Journal of innovative research in electrical, electronics, instrumentation and control engineerinf*, Vol. 3, No. 6.

[3] Coelho, T. M., Castro, R., Gobbo Jr, J. A. (2011). "PET containers in Brazil: Opportunities and challenges of a logistics model for post-consumer waste recycling" *Resources, Conservation and Recycling.* Vol. 55, pp. 291-299.

[4] Frigione, M. (2010). "Recycling of PET bottles as fine aggregate in concrete" *Waste Management.* VOL. 20, pp. 1101-1106.

[5] Harmsen, T. E. (2002). *Diseño de Estructuras de Concreto Armado*. 3^{th} Edition, Pontificia Universidad Católica del Perú, Fondo Editorial.

[6] Hopewell, J., Dvorak, R. and Kosior, E. (2009). "Plastics recycling: challenges and opportunities" *Philosophical Transactions of The Royal Society B*, 364, 2115-2126. DOI: 10.1098/rstb.2008.0311.

[7] López, L. G. (2003). *El concreto y otros materiales para la construcción*. Universidad Nacional de Colombia, Manizales, Colombia. ISBN 958-9322-82-4. http://www.bdigital.unal.edu.co/6167/ (2017)

[8] Morillas, A. V., Pérez, M. V., Valdemar, R. M. E., Contreras, M. M., Islas, S. H., Guillén, M. Y. L. O. y Filguera, H. J. A. (2016). "Generación, Legislación y Valorización de Residuos Plásticos en Iberoamérica" *Rev. Int. Contam. Ambie.* 32 (Especial Residuos Sólidos) 63-76. DOI: 10.20937/RICA.2016.32.05.05

[9] Neville, A.M. (2011). *Properties of Concrete*, 5^{th} Edition, Pearson Education Limited, England.

[10] Norma Paraguaya NP 17 027 77 (diciembre, 2015). *Ladrillos cerámicos macizos. Requisitos Generales,* 2^{nd} Edition, INTN.

[11] Ruiz, J. L. V. and Angel, F. C. (2009). "Elaboración de Concreto Ligero con Agregado PET" *El Portulano de la Ciencia*. Año VIII. No. 22, pp. 811-824.

[12] Sakurai, C., Barreda, M., Sota, J. (2010). *Absorción por Succión Capilar del Hormigón Endurecido.* LEMaC. Centro de Investigaciones Viales, Estructura y Materiales de Construcción. Tesis de Becarios. Universidad Tecnológica Nacional, Facultad Regional de La Plata. ISBN: 978-950-42-0133-5.

[13] Siddique, R., Khatib, J., and Kaur, I. (2008). "Use of recycled plastic in concrete: A review" *Waste Management.* Vol. 28, pp. 1835-1852.

[14] Xiaohan, Y. (2013). "Procedimiento de Reciclaje y Punto Verde" *Treball de Fi de Grau, Escola Politècnica Superior d'Edificació de Barcelona, Universitat Politècnica de Catalunya*. http://hdl.handle.net/2099.1/23631. (2017)

[15] Verduch, A. G. (1975) *"Métodos de ensayo para la determinación de la capacidad de absorción de agua de los ladrillos (H2T 2/75c)".* Materiales de Construcción. *Vol 25, No 159, pp. 631-654.* http://materconstrucc.revistas.csic.es/index.php/materconstrucc/article/viewFile/1264/1395. *(2017)*

Authorization and Disclaimer

Authors authorize ESTEC to publish the paper in the conference proceedings. Neither ESTEC nor the editors are responsible either for the content or for the implications of what is expressed in the paper.