ppi 201502ZU4659
This scientific digital publication is continuance of the printed journal
p-ISSN 0254-0770 / e-ISSN 2477-9377 / Legal Depositpp 197802ZU38

La Ciega Historical building. LUZ first headquarter

REVISTA TÉCNICA
DE LA FACULTAD DE INGENIERÍA

"Post nubila phoebus"
"After the clouds, the sun"

LUZ in its 130th anniversary
Established since 1891

An international refereed Journal indexed by:

- SCOPUS
- SCIELO
- LATINDEX
- DOAJ
- MIAR
- REDIB
- AEROSPACE DATABASE
- CIVIL ENGINEERING ABTRACTS
- METADEX
- COMMUNICATION ABSTRACTS
- ZENTRALBLATT MATH, ZBMATH
- ACTUALIDAD IBEROAMERICANA
- BIBLAT
- PERIODICA
- REVENCYT

UNIVERSIDAD DEL ZULIA

VOLUME 44 JANUARY - APRIL 2021 NUMBER 1

Concrete masonry blocks withscrap HDPE as aggregate

Derling Jose Mendoza Velazco[1*], Maribel Cecilia Pérez Pirela[2], Miguel Eduardo Rodríguez Rodríguez[3], Santiago Andrés Ortiz Montero[4]

[1]Facultad de Ciencias Experimentales, Universidad Nacional de Educacion UNAE, Azogues, C.P. 030154, Ecuador.
[2]Facultad de Ingeniería, Universidad Nacional de Chimborazo UNACH, Riobamba, C.P. 060150, Ecuador.
[3]Facultad de Ciencias Humanísticas y Tecnológicas, Universidad Nacional de Chimborazo UNACH, Riobamba, C.P. 060150, Ecuador.
[4]Consultoría y Construcción O & B, Investigador independiente, Ambato, C.P. 180103, Ecuador.
*Corresponding author: derling969@gmail.com
https://doi.org/10.22209/rt.v44n1a04
Received: 23 de junio de 2020 | Accepted: 06 de octubre de 2020 | Available: 01 de enero de 2021

Abstract

The present work aims to study the addition of plastic as a partial component of the coarse aggregate in concrete for the design of ecological concrete blocks and to establish a linear equation, to estimate compressive strength for those block, varying cement, sand, gravel, and plastic volume. For the design of blocks, volume in three proportions were considered (cement / fine aggregate / coarse aggregate), this way four types of mix proportions were made (1/1/1, 1/1.25/2.5, 1/1.5/3 and 1/2/4). Coarse stone aggregate as a partial aggregate component was replaced by flake HDPE type plastic in 0, 25 and 50% replacement to coarse stone ratios. The compressive strength - unit weight of the concrete was measured after 30 days of curing. The research methodology was of a quantitative type of descriptive experimental design. The results were processed through a linear polynomial regression in the parameters analysis routine, using a statistical software SPSS 25 and their accuracy was assessed by INEN Ecuador 0858 and ASTM C39 parameters. The results revealed that 25 and 50% additions of plastic as a coarse aggregate reduced the unit weight of concrete to 9.7 and 12.02% respectively. But in such cases, the reduction of compressive strength was up to 29.17 and 48.5% respectively for effectiveness improvement reducing only the sample unit weight.

Keywords: HDPE; plastic; compression; concrete; brick; linear equation.

Bloques de concreto con sustitución de residuos sólidos de polietileno de alta densidad

Resumen

El presente estudio tuvo como objetivo analizar la adición de plástico como componente parcial del agregado grueso en el concreto, para el diseño de bloques ecológicos, estableciendo una ecuación lineal que estima la resistencia del bloque a la compresión , variando los volúmenes de cemento, arena, grava y plástico. Para el diseño de los bloques se consideró el volumen en tres proporciones (cemento/agregado fino/agregado grueso), de esta forma se realizaron cuatro tipos de proporciones de mezclas (1/1/1; 1/1,25/2,5; 1/1,5/3 y 1/2/4). El agregado grueso de piedra como componente parcial, fue reemplazado por plástico de tipo polietileno de alta densidad (PEAD) en escamas, en proporciones de 0; 25 y 50% de sustitución pétreo grueso. La resistencia a la compresión - peso unitario del concreto, se midió después de 30 días de curado. La metodología de investigación fue de tipo cuantitativo, de diseño descriptivo experimental. Los resultados fueron analizados mediante un análisis de regresión polinomica lineal en los parámetros, aplicando el paquete estadístico SPSS 25, y su precisión fue juzgada por parámetros nacionales e internacionales, INEN Ecuador 0858 y ASTM C39. Los resultados revelaron que las adiciones de 25 y 50% de plástico como agregado grueso, reducen el peso unitario del concreto hasta 9,7 y 12,02%, respectivamente. Pero en tal caso, la reducción de la resistencia a la compresión fue de hasta el 29,17 y 48,5%, respectivamente, para su mejor efectividad, disminuyendo solo el peso unitario de las piezas.

Palabras clave: PEAD; plástico; compresión; concreto; bloque; ecuación lineal.

Introduction

Plastic (HDPE) is a very common material in our daily lives. The use of plastic has substantially increased in the last decade, as it is lightweight, moisture and corrosion resistant, durable and relatively low-budget [1]. HDPE has replaced many traditional materials such as wood, stone, bone, leather, paper, metal, glass and ceramics.Nowadays, almost all the objects used by humans are designed of (or contain) HDPE matérias. As a result, HDPE production increased exponentially from 1964 to 2020 [2]. HDPE production has increased from 15 to 311 million metric tons. If this trend continues, HDPE production is expected to double in 20 years and almost quadruple by 2050 [3]. Along with production, the amount of HDPE waste is also increasing exponentially.

Due to insufficient recycling, millions of tonnes of HDPE waste are generated each year and end up in landfills and the oceans. Between 22 and 43% of HDPE s are disposed of in landfills and at least 8 million tonnes of HDPE s are dumped into the ocean [4, 5]. In Ecuador, the first HDPE s industry began in 1986. Since then, the consumption of HDPE s has been increasing every day. In the city of Quito alone, among total solid waste, HDPE was 4.15% in 2005 and 5.46% in 2014 [6], indicating the increasing rate of HDPE waste. HDPE waste can become a potential resource if it can be recycled. One such attempt is that waste HDPE can be used as concrete aggregate,which may reduce this kind of waste [7].

Several studies have been carried out to evaluate the applicability of different types of HDPE s for construction purposes. Jagdish*et al.*[8] evaluated the properties of concrete with recycled HDPE as a 5, 10, 15 and 20% substitute for stone. They used HDPE and prepared a total of 90 cylinders and 5 beams. Then, after 7, 14 and 28 days of curing, the specimens were evaluated for compressive strength, split tensile strength, flexural strength and dry density. The water/cement ratio was 0.5 and the mix ratio was 1/1.8/3 on a volume basis. According to its result, the maximum reduction in compressive strength was 44% for a 20% substitution of stone with recycled HDPE Concrete tensile and flexural strength was reduced with the increment of percentage in recycled plastic sustitution. Dry density was reduced by 1.5% for every 5% stone replacement. The authors concluded their study by stating that up to 15% substitution of coarse aggregates by recycled HDPE is possible to use for structural application.

Another experiment was conducted Subramani and Pugal [9] on the partial replacement of the coarse aggregate by polyhydroxybutyrate (PHB), which is a biodegradable HDPE [10]. It was shown that 5, 10 and 15% of the coarse aggregate was replaced by HDPE and the water/cement ratio was 0.46. It was observed that 20% of the aggregate can be replaced by plastic waste without long-term detrimental effects and with acceptable strength-building properties. Akila*et al*. [11] demonstrated the great applicability of plastic bags as fine aggregate in concrete. The fine HDPEaggregate was produced by heating (178°C) the HDPE bags followed by cooling (30°C),the liquid waste was then cooled and processed in a shredding machine, which produced HDPE flakes with a fineness modulus of 4.7mm, then 10, 20, 30 and 40% fine aggregate was replaced by the fine HDPE aggregate. After 28 days of curing, the specimens were evaluated for handling, bulk density, ultrasonic pulse rate test, compressive and flexural strength. On the other hand, resistance increased significantly with the presence of HDPE bag waste. It was concluded that the HDPE bag can be successfully used to replace conventional fine aggregates in concrete.

According to Kamaruddin*et al.* [12] there are positive effects when applying HDPE to concrete. For Roni *et al.* [13] the production costs of the concrete blocks vary considerably depending on the quality, strength and utility purposes of the blocks, the standard model of dimension 40x20x20cm^3 costs 14 US cents. For this purpose, the cited authors prepared 12 cubes of dimension 150x150x150 mm^3 with a fix water to cement ratio, and variable HDPE replacement percentage (0, 10, 30 and 50%). Using a maximum size of 13 mm of HDPE aggregate.Among the results it was shown that the apparent density of the mixture is reduced with the gain in HDPEsubstance, so the apparent density is lower than in conventional concrete. Similarly, the reduction in bulk density was directly related with plastic substitution. This material bulk density diminished by 2.5, 6 and 13% respectively, hence the reduction in density was due to the low unit weight of HDPE.

In this study, compressive strength and unit weight of concrete were classified where four mix ratios (based on volume) were used with HDPE as a partial replacement (25 and 50%) of the coarse aggregate. The aim was to find out which mix ratios can be used for both structural and non-structural purposes [14, 15]. A mathematical model was also proposed, the suitability of which was evaluated using different statistical parameters. The classification of the concrete blocks is presented below (Table 1), according with the regulations from the government of Ecuador [14, 15].

Table 1. Nominal and real dimensions of concrete blocks by Ecuatorian regulations.

Type	Nominal dimensions of the Ecuadorian Institute of Normalization			Realsdimensions		
	Lenght (cm)	Width (cm)	Height (cm)	Lenght (cm)	Width (cm)	Height (cm)
A, B	40	20,15,10	20	39	19,14, 09	19
C, D	40	10,15, 20	20	39	09,14,19	19
E	40	10,15,20,25	20	39	09,14,19,24	20

Materials and methods

To carry out the study, selected raw materials were as follow, portland cement Type I ASTM C150, with 65% Chimborazo® cement which has 35% gypsum, in order to delay the setting time, fine aggregate with a fineness module of 2.7, coarse aggregate of 19mm, Wasted HDPE virgin type (without having been reprocessed) with a melt flow index (MFI) of 77g/10min, a standard density of 0.963 g/cm^3, with a bending modulus of 15.396 Kg/cm^2, a tensile strength of 155 Kg/cm^2 *izod* pendulum impact resistance of 13 Kg.cm/cm and an elongation of 555%, in the same way the HDPE has a fineness modulus of 5.91mm, unit weight of 3.5 KN/m^3, with respect to the water/cement ratio by weight of 0.61 without air included.

To mix the materials, they were selected based on the volume of cement / fine aggregate/coarse aggregate (crushed stone and recycled HDPE s) mixing ratio to the four proportion sets:1/1/1; 1/1.25/2.5; 1/1.5/3 and 1/2/4. For eachproportions, the coarse aggregates were replaced by 0, 25 and 50% flaked HDPE, standard percentage measurements recommended by Olonade*et al*. [16] for the design of concrete blocks with HDPE aggregates.

A clean and dry cylindrical mould with a diameter of 1000 mm and a height of 1000 mm was used to prepare the proportion samples. Three proportion samples were designed for each replacement. The concrete was mixed by hand. The moulded material was placed in blocks of rectangular dimension 40x20x20cm^3, then it was rested for a period of 24 hours at room temperature. The blocks or prototypes were carefully removed from the rectangular mould. Immediately after removal from the mould, the blocks were completely immersed in a curing tank for 30 days, method recommended by Akinyele and Ajede [17] when applying the UTC-0960 plastic curing tank with amean control temperature between 38 and 40ºC with ±2ºC accuracy. According to Shirish [18] the curing of concrete blocks with supplementary materials such as HDPE, lime, gypsum, ashes among others, applying a large curing tank with dimensions of 800x1800x950 mm^3, can be developed within a prolonged time of between 28 and 30 days, which were used during this study.

The entire proportion preparation procedure was carried out in accordance with the American Society for Testing and Materials (ASTM) international standards for cement and concrete, where the standardized test for compressive strength of concrete block specimens corresponds to various ASTM standards C39, C31, C150, C617, C1077 and C1231 [19]. After 30 days of curing, the blocks were removed from the curing tank. The blocks were then measured for weight and compressive strength. The results were finally compared with the applicable NTE INEN standards [20-28].

Results and Discussion

This section presents the results analysis of the plastic addition as a partial component of the coarse aggregate in concrete, for the design of ecological concrete blocks. After 30 days of curing it was observed that both the compressive strength and the unit weight were reduced as the percentage of HDPE for the four mixing ratios increased (Figure 1).Based on the results obtained, and described by Shirish [18] and NTE INEN standards [20, 21], the proposed use of the mix proportions is shown in Figure 2.

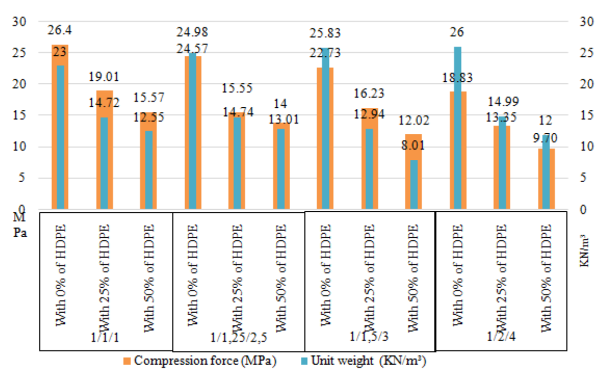

Figure 1. Compressive strength and unit weight variationwith increasing HDPE percentage for each proportion. with increasing plastic susbstitution for each mix proportion.

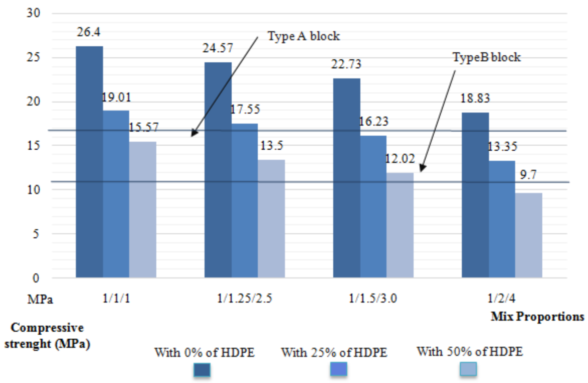

Figure 2. Compressive strength applied to concrete blocks designed with HDPE as partial substitution of coarse aggregate

In Figure 2, the results of compressive strength obtained with the blocks created, by replacing the coarse stone aggregate in 3 mix proportions i.e., 1/1/1, 1/1.25/2.5 and 1/1.5/3 ratio, all with 25% of HDPE substitution are shown; these specimens have the resistance of a type A block. According to NTE INEN 0638 [29] type A blocks are used in exterior,CMU block load-bearing walls and have aMPa ≥16. Except for the mix 1/2/4 ratio with 25% of HDPE substitution, which shows a MPa of 13.35, a value below the 16 MPa index.

The results of compressive strength obtained with the concrete blocks of mix proportions 1/1/1, 1/1.25/2.5 and 1/1.5/3 ratio, with 50% of HDPE substitution, demonstrated the strength of a type B block. According to NTE INEN 0862[30] type B blocks are used in exterior cladded load bearing walls and interior cladded or non-cladded load bearing walls, they have a 16≤ MPa ≥11, with the exception of the specimen with proportion 1/2/4 ratio and 50% of HDPE substitution, which showed a MPa of 9.7 a value below the 11MPa index.

Empirical development of equation

From test result, the second objective is answered by the proposal of a linear polynomial regression in the parameters (Equation 1) using the Statistical Package for the Social Sciences (SPSS) software, version 25.

$$f_c' = -35520{,}66V_C - 98859{,}50V_A - 55353{,}74V_{Pi} - 71313{,}92V_{Pl} + 181{,}29 \quad (1)$$

In this equation, the 30-day compressive strength (in MPa) was maintained as a function of volume (in m^3) of cement (V_C), sand (V_A), stone (V_{Pi}) and HDPE (V_{Pl}). Values of input variables are shown in Table 2 (as used in the experiment).

For Ruma and Well [31] Pearson's correlation coefficient can take values between -1 and 1. The correlation of a variable with itself is always equal to 1. For Pearson's correlation, an absolute value of 1 indicates a perfect linear relationship. A correlation close to 0 indicates that there is no linear relationship between the variables. The value obtained of 0.97 indicates an acceptable value in the linear type covariation.

As a second efficiency criterion, the coefficient of determination was applied, according to Harel [32] it is defined as the proportion of the total variance of the dependent variable that can be explained by the independent variable. The coefficient of determination, also called R2, reflects a model goodness of fit to the variable that it tries to explain. It is important to note that R2ranges between 0 and 1. Our result of R2 was 0.94 as a coefficient close to 1, it means a good fit.

In the third criterion of efficiency, the mean absolute error (MAE) was developed for validation, resulting a value of 0.93, allowing to determine the measure of the differences in average between the predicted and observed values [33].

The efficiency coefficient (E) and the modified efficiency coefficient measure mainly the effectiveness, but also the efficiency of the linear empirical equation, in the search for the maximum efficiency potential, through the reduction or increase of waste HDPE as coarse aggregate substitution with a value of 0.94 and 0.77 both with an oscillating value of 1≥ E >5,which is consider efficient according to Geethu and Santhoshkumar [34].

Finally, among the efficiency criteria, the index of agreement (D) and the modified index of agreement with values of 0.99 and 0.88 were applied, which represent a contribution to the linear equation, basically by incorporating its correction formula that excludes concordance due exclusively to randomness.This correction is related to marginal distributions according to Mohammad *et al.* [33]. It should be noted that Equation 1 is valid within the range of applicable parameters shown in Table 4.

Table 2. Input variables (volume in m³) and compressive strength (in MPa).

Mixingproportion ratio	HDPEcontent (%)	Cement (m^3)10-4	Sand (m^3)10-4	Stone (m^3)10-4	HDPE (m^3)10-4	Compressivestrength(MPa)	
						Experimental data	Equation data
1/1/1	0 HDPE	8.3	8.3	8.3	0.0	26.40	23.81
	25 HDPE	8.3	8.3	6.3	2.0	19.01	20.62
	50 HDPE	8.3	8.3	4.2	4.2	15.57	16.56
1/1.25/2.5	0 HDPE	5.0	6.7	13.3	0.0	24.57	23.68
	25 HDPE	5.0	6.7	9.7	3.4	17.55	18.25
	50 HDPE	5.0	6.7	6.65	6.65	13.50	13.06
1/1.5/3	0 HDPE	4.5	6.8	13.6	0.0	22.73	22.80
	25 HDPE	4.5	6.8	10.1	3.5	16.23	17.22
	50 HDPE	4.5	6.8	6.8	6.8	12.02	11.95
1/2/4	0 HDPE	3.6	7.0	14.4	0.0	18.83	19.59
	25 HDPE	3.6	7.0	10.8	3.6	13.35	13.85
	50 HDPE	3.6	7.0	7.2	7.2	9.70	8.10

It should be noted that all volumetric values in Table 2 correspond to specimens of hollow concrete block of 40x20x20 cm³. The accuracy of the proposed linear polynomial regression in the parameters (Equation 1) is shown in Table 3, from which it can be said that it fits well the experimental data.

Table 3. Efficiency criteria value as accuracy measurement.

Efficiencycriterion	Values
Pearson'scoefficient, R	0.97
Coefficient of determination, R^2	0.94
Mean absolute error, MAE	0.93
Efficiency coefficient, E	0.94
Modified efficiency coefficient	0.77
Index of agreement, D	0.99
Modified index of agreement	0.88

Table 4. Range of applicable parameters for Equation 1 (for 40x20x20 cm³ hollow blocks).

Parámetro	**Rango de volumen en una muestra (m^3) x 10^{-4}**
Cemento	$3,6 \leq V_C \leq 8,3$
Arena	$6,7 \leq V_A \leq 8,3$
Piedra	$4,2 \leq V_{pi} \leq 14,4$
Plástico	$0 \leq V_{Pl} \leq 7,2$

Among the results it can be shown that the compressive strength of concrete blocks involving HDPE as a partial substitute is likely to be significantly lower than ordinary or standard concrete.It is much clearer to say that when the percentage of HDPE content as a partial substitute increases, the compressive strength of concrete decreases.In terms of bulk density for ordinary and HDPE substituted concrete it was shown that the later has a lower weight compared to ordinary concrete as it is made partially of plastic. This shows that HDPE will be a good platform to produce lightweight concrete, yielding compressive strength within standards.

Although researchers like Edmund et al. [35], manage to obtain a satisfactory compressive strength, it may be that, due to the low percentage of HDPE content used, as well as the types of HDPE used, an important value or coefficient can be obtained, as some HDPE materials are harder and stronger than others like polypropylene. Apart from the low percentage of HDPE used, Edmund et al. [35] recommend the addition of HDPE plasticizer solution to increase or improve the mixture with the HDPE as a substitute for coarse aggregate or stones. Likewise, HDPE can be recommended as a substitute for fine aggregates in concrete, producing a much better result compared to the substitution of coarse aggregate.

Conclusions

The study provides an opportunity to reduce environmental pollution due to the rapid increase in HDPE waste in the Republic of Ecuador. Therefore, recycling HDPE waste into concrete as coarse aggregate can be an effective solution to eliminate a large amount of HDPE that can greatly reduce environmental pollution and produce an environmentally categorized concrete, named as green concrete.

The addition of HDPE decreases the unit weight of the concrete, can be used to produce lightweight concrete masonry units (CMU),with 25 and 50% of HDPE replacement of coarse aggregate, the concrete compressive strength is sufficient to be used for high load non-structural purposes, such as single-story or level buildings or flats.

Finally, it can be mentioned that the production costs of concrete masonry units (CMU) with flake-HDPE substitution have a lower economic value than conventional CMU, which have a value of 14 cents, while the blocks of this work have a value of 11 cents each. The production value decreases by 3 US cents, but the processing and access of HDPEto be used as partial sustitute of coarse aggregate, benefits the environment by binding plastic to cement.

References

[1] Chalmin, P.: "The history of plastic: from the Capitol to the Tarpeian". Field Actions Science Reports, Vol. 19 (2019), 6-11.

[2] Chuanxiu, J., Zhang, M. and Lu, P.: "Preparation and characterization of polyurethane-/MMT nanocomposite-coated urea as controlled-release fertilizers".Polymer-PlasticsTechnology and Materials, Vol. 59, No. 9 (2020), 975-984.

[3] Moriet, A., Bleriot J., Opsomer, R., Widmer, S., Banks, I., DeSmet,M., Murphy, J., Struchery, M., Swartz, S. and Vanthournout, H.: "The New Plastics Economy Rethinking the future of plastics". World Economic Forum, Geneva-Switzerland (2016).

[4] Van Emmerik, T. and Schwarz, A.: "Plastic debris in rivers". WIREsWater, Vol. e1398, (2020), 1-13.

[5] Gourmelon, G.: "Global Plastic Production Rises". Recycling Lags, Vital Signs, Vol. 11, (2015), 1-7.

[6] Veletanga, F.: "Estudio de la huella ecológica de plástico PET (Tereftalato de polietileno) del barrio Nueva Aurora en la Parroquia de Guamaní en el distrito metropolitano de Quito". Universidad Central de Ecuador., Ecuador, (2017).

[7] Awoyeraa, P. andAdesinab, A.; "Plastic wastes to construction products: Status, limitations and future perspective".Case Studies in ConstructionMaterials, Vol. 12, No. e00330, (2020), 1-11.

[8] Jagdish, K., Gohil, G and Patel, N.: "Experimental study on the use of plastic waste as a partial replacement of coarse & fine aggregate in concrete". International Journal for Research in Applied Science & Engineering Technology (IJRASET), Vol. 6, No. 4 (2018), 3561-3567.

[9] Subramani, T. andPugal, V.: "Experimental study on plastic waste as a coarse aggregate for structural concrete".International Journal of Application or Innovation in Engineering & Management, Vol. 4, No. 5 (2015), 2319 – 2347.

[10] Chávez- Romero, S., Aulestia-Viscarra, Sh., Cando, W., Bucheli, J. and Fernández, L.: "Evaluación de las propiedades mecánicas de una mezcla asfáltica en caliente modificada por vía seca con tapas plásticas de polipropileno". Revista Técnica. De la Facultad de Ingenieria, Vol. 42, Nº 3, 2019, 104-151.

[11] Akila, S., Ajithkumar, C., Deepankumar, S., Jeeva, P. andSenthilkumari, T.: "Use of plastic waste as partial replacement of fine aggregate in concrete mixture". International Journal of Advanced Science and Engineering Research, Vol. 3, Issue: 1 (2018), 214-219.

[12] Kamaruddin, M., Abdullah, M., Zawawi, M andZainol, M.: "Potential use of plastic waste as construction materials: recent progress and future prospect". IOP Conference Series: MaterialsScience and Engineering, Vol. 267, No. 012011, (2017), 1-10.

[13] Roni, S., Stryjer, R., Weizman, A. and Nutt, D.: "Spon's Architects' and Builders' Price Book 2013". Taylor & Francis Group, Londres, 2013.

[14] Norma Ecuatoriana de la Construcción – NEC: NEC-SE-HM Estructuras de Concreto Armado. Ministerio de Desarrollo Urbano y Vivienda, (2014).Retrieve date (20-12-2020).Available in: https://www.habitatyvivienda.gob.ec/wp-content/uploads/downloads/2014/08/NEC-SE-HM.pdf.

[15] Instituto Ecuatoriano de Normalización, INEN, Casilla 17-01-3999 – Quito-Ecuador, (1993). Retrieve date (20-12-2020). Disponible en: https://www.compraspublicas.gob.ec/ProcesoContratacion/compras/PC/bajarArchivo.cpe?Archivo=HKyt7OeS6AGvSpdetlVqXsIX2kvlaTo-prEqTB-tPRc.

[16] Olonade, K., Jaji, M. &Adekitan, O.: "Experimental comparison of selected pozzolanic materials". African Journal of Science, Technology, Innovation and Development, Vol. 9, Nº 4, (2017) 381-385.

[17] Akinyele, J. &Ajede, A.: "The use of granulated plastic waste in structural concrete". African Journal of Science, Technology, Innovation and Development, Vol. 10, Nº 2, (2018) 169-175.

[18] Deo, S.: "Mix design approach for high 28 days' strength, high-volume, low-lime fly

ash concrete". Road Materials and Pavement Design, Vol. 16, Nº 3, (2015) 707-715. DOI: 10.1080/14680629.2015.1026381

[19] American Society for Testing and Materials (ASTM): "Annual Book of ASTM Standards"., West Conshohocken, (2015).

[20] Servicio Ecuatoriano de Normalizacion, Norma tecnica de ecuatoriana, (NTE INEN 0157): "Cemento hidráulico. Determinación de la consistencia normal". Método de Vicat. Ecuador, (2009)

[21] Servicio Ecuatoriano de Normalizacion, Norma tecnica de ecuatoriana, (NTE INEN 0158): "Cemento hidráulico. Determinación del tiempo de fraguado". Método de Vicat, Ecuador, (2009).

[22] Servicio Ecuatoriano de Normalizacion, Norma tecnicaecuatoriana, (NTE INEN 0488): "Cemento hidráulico. Determinación de la resistencia a la compresión de morteros en cubos de 50 mm de arista". Ecuador, (2009).

[23] Servicio Ecuatoriano de Normalizacion, Norma tecnicaecuatoriana, (NTE INEN 0490): "Cementos hidráulicos compuestos". Ecuador, (2011).

[24] Servicio Ecuatoriano de Normalizacion, Norma tecnicaecuatoriana, (NTE INEN 0855): "Áridos. Determinación de impurezas orgánicas en el árido fino para concreto". Ecuador, (2010).

[25] Servicio Ecuatoriano de Normalizacion, Norma tecnicaecuatoriana, (NTE INEN 0856): "Áridos. Determinación de la densidad, densidad relativa (gravedad específica) y absorción del árido fino". Ecuador, (2010).

[26] Servicio Ecuatoriano de Normalizacion, Norma tecnicaecuatoriana, (NTE INEN 0857): "Áridos. Determinación de la densidad, densidad relativa (gravedad específica) y absorción del árido grueso. Ecuador, (2010).

[27] Servicio Ecuatoriano de Normalizacion, Norma tecnicaecuatoriana, (NTE INEN 0858): "Áridos. Determinación de la masa unitaria (peso volumétrico) y el porcentaje de vacíos". Ecuador, (2010).

[28] Servicio Ecuatoriano de Normalizacion, Norma tecnicaecuatoriana, (NTE INEN 0860): "Aridos. Determinación del valor de la degradación del árido grueso de partículas menores a 37,5 mm mediante el uso de la máquina de los Ángeles". Ecuador, (2011).

[29] Servicio Ecuatoriano de Normalización, Norma técnica ecuatoriana, (NTE INEN 0638): "Bloques huecos de hormigón, definiciones, clasificaciones y condiciones generales". Ecuador, (1993).

[30] Servicio Ecuatoriano de Normalizacion, Norma tecnicaecuatoriana, (NTE INEN 0862): "Áridos para concreto. Determinación del contenido total de humedad". Ecuador, (2011).

[31] Ruma, F. and Well, A.: "Many faces of the correlation coefficient". Journal of Statistics Education, Vol. 5, No. 3 (1997), 1-13.

[32] Harel, O.: "The estimation of R2 and adjusted R2 in incomplete data sets using multiple imputation". Journal of AppliedStatistics, Vol. 36, No. 10 (2009), 1109-1118.

[33] Mohammad, K., Nopiah, Z.M., Ahmad Basri, N.E., Basri, H., Abushammala, M.F.M., and Maulud, K.N.A.: "Solid waste forecasting using modified ANFIS modeling", Journal of the Air & Waste Management Association, Vol. 65, No. 10 (2015), 1229-1238.

[34] Geethu, V. andSanthoshkumar, S.: "An efficient FPGA realization of seizure detection from EEG signal using wavelet transform and statistical features". IETE Journal of Research, Vol. 66, No. 3 (2020), 315-325.

[35] Edmund, T.S.J., Jun Hon, C., Hejazi, F., and Jaafar, M.S.: "Waste plastic as partial replacement for aggregates-a review". IOP Conf. Series: Earth and EnvironmentalScience, Vol. 357, No. 012018 (2019), 1-7.

UNIVERSIDAD
DEL ZULIA

REVISTA TECNICA

OF THE FACULTY OF ENGINEERING
UNIVERSIDAD DEL ZULIA

Vol. 44. N°1, January - April 2021, pp. 04 - 56

This Journal was edited and published in digital format on December 2020 ***by Serbiluz Editorial Foundation***

www.luz.edu.ve
www.serbi.luz.edu.ve
www.produccioncientifica.luz.edu.ve