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GREEN CONCRETE WITH FLY ASH AND PLASTIC WASTE

BY

ALEXANDRU TIMU* and MARINELA BARBUȚĂ

"Gheorghe Asachi" Technical University of Iași,
Faculty of Civil Engineering and Building Services

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Abstract. In the paper are presented the mechanical strengths of fly ash cement concrete with chopped plastic bottles as substitution of fine aggregate. The densities of fresh and hardened concrete are analyzed for classifying concrete. Mechanical strength, flexural strength and split tensile strength were experimentally determined. The concrete was characterized as structural concrete and the design values of mechanical strengths were computed on the base of experimental values. Also the diagram in axial compression is presented and the longitudinal elasticity modulus was computed as comparison with normal concrete of the same grade.

Keywords: Portland cement concrete; density; bending tensile strength; split tensile strength; modulus of elasticity.

1. Introduction

The use of wastes in constructions and Building materials industry is a necessity having in view the problems related to the environment protection. Numerous types of wastes are today used for producing building materials or for improving different properties of traditional materials. Silica fume, fly ash,

*Corresponding author: *e-mail:* alexandru.timu@gmail.com

rice ask, slag, glass, etc. are used for obtaining concretes or mortars with higher strengths, self-healing, more durable, fire resisting, etc. (Alireza Khaloo *et al*., 2016; Barbuţă *et al*., 2014; Chung-Chan Hung & Yen-Fang Su, 2016; Lopez & Ivan Escalante-Garcia 2016; Jiankiang Wei & Meyer 2016; Marin *et al*., 2014; Xin Yu *et al*., 2016; Han *et al*., 2016). Most of the wastes are incorporated in cement or concrete as inert components, as replacement of aggregates or as fiber (Cai *et al*, 2016; Cordeiro & Sales, 2015; Mirzahosseini & Riding, 2015; Chowdhury *et al*., 2015; Kumar Prusty *et al*., 2016).

The use of wastes of polyethylene terephthalate bottles (PET) is a prioritary problem because they are in a huge quantity abandoned or stored (Sharma & Pal Bansal, 2016; Chowdhury *et al*., 2013; Othman *et al*., 2013; Ismail & Al-Hashmi,2008). The Pet wastes are non-biodegradable and their re-use as fibers, chopped Pet or granules in cement or concretes has became a reality (Benosman *et al*., 2013; Foti, 2011; Rahmani *et al*., 2013). The concretes prepared with PET wastes present some advantages such as: corrosion resistance, high tensile strength, reduced weight, reduced segregation, reduced water absorption, improved ductility, good phonic protection, etc. (Benosman *et al*., 2013; Rai *et al*., 2012; Cordoba *et al*., 2013). The concrete with PET waste find application in manufacturing of non-structural elements, blocks, panels for façade, etc. (Vargas *et al*., 2014; Ingrao, 2014; Saikia & Brito, 2013).

The paper presents the mechanical properties and elasticity characteristics of concrete prepared with fly ash as cement replacement and chopped PET as aggregate substitution.

2. Experimental Program

For the experimental tests a mix of cement concrete was used with the following components: cement – 324 kg/m^3, aggregate sort 0,...,4 mm – 803.16 kg/m^3, sort 4,...,8 mm – 384.12 kg/m^3, and 8,...,16 mm – 558.72 kg/m^3. The water was 180 l/m^3 and as super-plasticizer additive was used Master Glenium SKY 617 from BASF. The cement used for the obtaining of all mixes was type CEM IIB-M-S-LL-42.5N, according to Romanian Standard (SR EN 197-1:2011). The mix with chopped PET wastes was prepared with addition of 10% fly ash from the total cementitious quantity and with 10% substitution of aggregate sort 0,...,4 mm. The fly ash, used also in other experiments (Marin *et al*., 2014) was from Electrical Plant Holboca Iasi and had the following properties: colour gray, spherical particles of sizes between 0.01 to 100 μm; specific surface is between 4,800 – 5,200 m^2/g, the density is between 2,400 and 2,550 kg/m^3.

The chopped PET obtained as sub-product in the process of re-cycling the PET bottles had sizes between 0,...,4 mm. The mix was prepared by introducing in the mixer the aggregates, the cement and the fly ash. After a short mixing of dry components, the chopped PET was added and then the water and superplasticzer.

The samples types cubes of 150 mm sizes, cylinders of 100 mm × × 200 mm sizes and prisms of 100 mm × 100 mm × 550 mm were poured for determining the density, compressive strength, flexural strength, splitting strength, characteristic diagram and elasticity modulus according to Romanian standard (SR EN 12390-7:2005; SR EN 12390-3:2005; SR EN 12390-5:2005; SR EN 12390-6:2010). The experimental tests were done at 28 days on three samples for each determination.

3. Test Results and Discussion

The experimental values of densities of fresh and hardened concrete and mechanical strengths are given in Table 1.

Table 1

Sample	$f_{c,\text{cube}}$ N/mm^2		$f_{c,\text{ cyl}}$ N/mm^2		f_{ti} N/mm^2		f_{td} N/mm^2		Density of fresh concrete, kg/m^3		Density of hardened concrete, kg/m^3	
BCPET	30.9	32.6	29.89	29.93	1.79	1.79	2.29	2.32	2,300	2,234	2,177	2,201
	32.8		30.66		1.75		2.32		2,200		2,224	
	34.2		29.24		1.82		2.42		2,202		2,215	

With the values of compressive strength experimentally determined the 5% characteristic f_{ck} can be computed with:

$$f_{ck} = f_{c,\text{mean}} - 1.64\sigma, \tag{1}$$

where: σ is the standard deviation of values and 1.64 – the probability density from the standardized normal curve,

$$f_{c,\text{mean}} = \frac{\sum_{i=1}^{n} f_{c(i)}}{n} = \frac{30.9 + 32.8 + 34.2}{3} = 32.6, \tag{2}$$

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n}\left(f_{c(i)} - f_{c,\text{mean}}\right)^2}{n}} = 1.63, \tag{3}$$

$$f_{ck} = 32.6 - (1.64 \times 1.63) = 29.93 \text{ N/mm}^2. \quad (4)$$

The mean tensile strength, f_{ctm} is determed with relation:

$$f_{ctm} = 0.30 f_{ck}^{2/3} = 0.30 \times 29.93^{2/3} = 2.88 \text{ N/mm}^2. \quad (5)$$

The characteristic strength to axial tension with fractile 5%, noted $f_{ctk,0.05}$ and with fractile of 95%, $f_{ctk,0.95}$ respectively is obtained function the mean value f_{ctm} with relations (6) and (7):

$$f_{ctk,0.05} = 0.7 f_{ctm} = 0.7 \times 2.88 = 2.02 \text{ N/mm}^2, \quad (6)$$

$$f_{ctk,0.95} = 1.3 f_{ctm} = 1.3 \times 2.88 = 3.74 \text{ N/mm}^2. \quad (7)$$

The strength to axial tension f_{ct} can be established function de splitting strength, f_{td} with relation:

$$f_{ct} = 0.9 f_{td} = 0.9 \times 2.32 = 2.09 \text{ N/mm}^2. \quad (8)$$

According to data obtained the fly ash concrete with 10% chopped PET as substitution of fine aggregate can be characterized as structural concrete for a grade of C20/25 according to Romanian standard (SR EN 1992-1:2004).

The characteristic diagram was obtained by testing the cylinders in axial compression , Fig. 1.

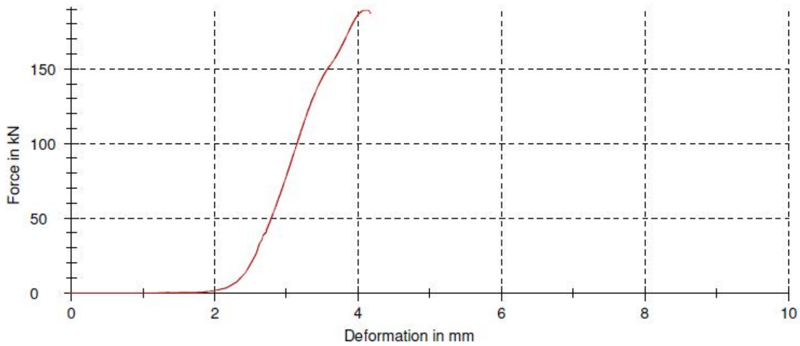
Fig. 1 –Experimental test in compression of concrete with chopped PET.

The characteristic diagram is presented in Fig. 2.

Test results:

No.	F_{max} kN	dL at F_{max} mm	F_{Break} N	dL at break mm	d_0 mm	S_0 mm²
1	189	4,1	187000	4,2	100	7853,98

Series graph:



Statistics:

Series n = 1	F_{max} kN	dL at F_{max} mm	F_{Break} N	dL at break mm	d_0 mm	S_0 mm²
$\bar{x}$	189	4,1	187000	4,2	100	7853,98
s	-	-	-	-	-	-
ν	-	-	-	-	-	-

Fig. 2 – Characteristic diagram of concrete with chopped PET.

The fly ash concrete with chopped PET had plastic deformations from the first stages of loading and the characteristic diagram had curved shape.

With the experimental data the elasticity modulus of concrete with chopped PET was determined: E_c = 27,138 N/mm^2 (SR EN 13412:2007). In comparison with the normal concrete of the same grade, the experimental concrete presented a smaller values (according to SR EN 13412:2007 for the grade C20/25 the elasticity modulus is 30,000 N/mm^2).

4. Conclusions

The mechanical and deformation characteristics of fly ash concrete with 10% chopped PET as substitution of fine aggregate were experimentally determined. The mechanical strengths such as compressive strength, flexural strength and splitting strength had shown that this type of concrete is a structural concrete with good values of strengths and the density over

2,000 kg/m^3. The elasticity modulus was smaller than that of the normal concrete of the same grade.

The chopped PET in a dosage of 10% as substitution of aggregates sort 0-4 mm influenced the characteristics of concrete, but they are comparable with that of normal concrete.

The principal advantage of this type of concrete is the possibility of use of PET waste as component in concrete mix. As other authors had demonstrated the concrete with PET waste can find application in building materials domain for non-structural elements, pavements, blocks, etc.

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BETON ECOLOGIC CU CENUŞĂ DE TERMOCENTRALĂ ŞI DEŞEURI DE PLASTIC

(Rezumat)

În lucrare sunt prezentate caracteristicile mecanice ale betoanelor de ciment cu cenuşă de termocentrală şi tocătură de sticle de plastic ca înlocuitor de agregat fin. Densitățile betonului proaspăt şi întărit sunt analizate pentru a clasifica betonul. Caracteristicile mecanice, rezistența la întindere prin încovoiere şi la întindere prin despicare au fost determinate experimental. Betonul a fost clasificat ca şi beton structural şi au fost calculate rezistențele mecanice de calcul pe baza valorilor experimentale. De asemeni este redată diagrama efort-deformație la compresiune axială şi a fost determinat modulul de elasticitate longitudinal a cărui valoare a fost comparată cu cea a betonului tradițional de aceeaşi clasă.