ASH CONCRETE WITH POLYSTYRENE WASTE

Costin CADERE[1], Roxana Dana BUCUR[2], Marinela BARBUTA[1]

e-mail: rbucur@uaiasi.ro

Abstract

The paper presents the experimental results of mechanical strengths obtained on the concrete prepared with different types of wastes. Fly ash was used as cementitious material and polystyrene granules were used as substitution of aggregates. The properties of concrete such as density, compressive strength, flexural strength and splitting strength were investigated having in view the waste substitution. The results show that the concrete with fly ash and polystyrene granules in reduced dosages had characteristics of structural concrete.

Key words: fly ash, polystyrene waste, concrete, mechanical strengths

In construction industry one of the most used materials is concrete due to its advantages such as: durability, fire resistance, reduces cost, etc. An important problem related to concrete is that of cement, because it is used in huge quantities and its production mean emission of CO2 in the atmosphere (Andrew R.M., 2018; Jaffar *et al* 2015; Altwair N.M., Kabir S., 2010) One possibility of reduction of cement consumption is to replace it with other materials, such as: silica fume, fly ash, slag, cinder, etc (Başak M. *et al*, 2011, Barbuta M. *et al*, 2015; Dinakar P. *et al*, 2008; Qasrawi H. *et al*, 2009). Another component of concrete, aggregate can also be replaced partially or totally with different materials for saving the natural resources (De Castro S., De Brito J., 2013; Ismail Z.Z. *et al*, 2008, Kumar Prusty J. *et al*, 2016). Depending on the type and dosage of material that replaces the aggregate, structural or lightweight concrete can be obtained. The type of material used for replacing aggregate, can improve different properties such as density, thermal, acoustic, fire resistance, etc. (Herki B.A. *et al*, 2013; Ingrao, C., 2014; Naughton A., Fan M., Bregulla J., 2014). For replacing aggregates different types of materials can be used. Lightweight aggregates used in structural lightweight concrete are typically expanded shale, clay, or other products such as air-cooled blast furnace slag. The use of different types of wastes as replacement of aggregates such as: polystyrene granules, chopped tires, saw dust, chopped plastic, etc. is also a way for obtaining structural or lightweight concrete (Chowdhury S. *et al*, 2015; Xie J.H. *et al*, 2015; Akçaözoglu S. *et al*, 2010, Khaloo A.R. *et al*, 2008).

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

MATERIAL AND METHODS

For the experimental tests a mix of cement concrete was used having the following dosages of components: cement-324 kg/m^3, sand (0-4 mm): 803.16 kg/m^3, aggregate sort (4-8 mm): 384.12 kg/m^3 and aggregate sort (8-16 mm): 558.72 kg/m^3. The water was 172 l/m^3 and as super-plasticizer additive was used Master Glenium SKY 617 from BASF. The cement used for the obtaining the concrete was type CEM IIB-M-S-LL-42.5N, according to Romanian Standard. The concrete mix with polystyrene granules waste was prepared with addition of 10% fly ash from the total cementitious quantity and with 10% substitution of aggregate sort 0-4 mm and 20% substitution of aggregate sort 4-8 mm. The fly ash, used also in other experiments was from Electrical Plant Holboca Iasi and had the following properties: color dark-gray, spherical particles of sizes between 0.01 to 100 µm and the density are between 2400 and 2550 kg/m^3.

The polystyrene granules had sizes between 0-4 mm and were obtained by cutting the waste and sifting them by sizes. The mix was prepared as follows: the granules of polystyrene were firstly slightly moistened and then were introduced near the aggregates, cement and fly ash in the mixer and were mixed. Then were added water and superplasticizer. The fresh mix was poured in

[1] "Gheorghe Asachi" Technical University, Iasi
[2] "Ion Ionescu de la Brad" University of Agricultural Sciences and Veterinary Medicine, Iasi

formworks types cubes of 150 mm sizes, cylinders of 100 mmx200 mm sizes and prisms of 100mmx100mmx550 mm for determining the density, compressive strength, flexural strength, splitting strength and characteristic diagram according to Romanian standard. The experimental tests were done on three samples for each determination at 28 days, according to Romanian standards.

RESULTS AND DISCUSSION

The experimental test values of densities of fresh and hardened concrete and mechanical strengths at 28 days are given in *Table 1*.

Table 1

Experimental test values of densities and mechanical strengths of fresh and hardened concrete

Sample	$f_{c,cube}$ N/mm^2		$f_{c,\ cyl}$, N/mm^2		f_{ti} N/mm^2		f_{td} N/mm^2		Density of hardened concrete, kg/m^3	
	Test results	Medium value								
BCPol	22.95	22.89	17.89	17.83	1.42	1.36	1.99	1.92	2039	2033
	22.91		18.24		1.35		1.90		2029	
	22.81		17.36		1.31		1.87		2031	

With the values of compressive strength experimentally determined the 5% characteristic f_{ck} can be computed with eq. 1:

$$f_{ck} = f_{c,mean} - (1.64 \cdot \sigma) \quad (1)$$

Where σ is the standard deviation of experimental test values and 1.64 is the probability value from the standardized normal curve.

$$f_{c,mean} = \frac{\sum_{i=1}^{n} f_{c(i)}}{n} = \frac{22.95+22.91+22.81}{3} = 22.89 \quad (2)$$

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n}(f_{ci}-f_{c,mean})^2}{n}} = \sqrt{\frac{\sum_{i=1}^{n}(f_{ci})^2}{n} - (f_{c,mean})^2} = 1.63 \quad (3)$$

Where n=3

$$(f_{c,mean})^2 = 22.89^2 = 523.9521 \quad (4)$$

$$\sum_{i=1}^{n}(f_{ci}^2) = 22.95^2 + 22.91^2 + 22.81^2 = 1571.87 \quad (5)$$

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n}(f_{ci})^2}{n} - (f_{c,mean})^2} = \sqrt{\frac{1571.8666}{3} - 523.9521} = 0.058 \quad (6)$$

$$f_{ck} = 22.89 - (1.64x0.058) = 22.79\ N/mm^2 \quad (7)$$

The value of mean tensile strength, f_{ctm} is determined with relation (8):

$$f_{ctm} = 0.30 \cdot f_{ck}^{2/3} = 0.30 \cdot 22.79^{2/3} = 2.41\ N/mm^2 \quad (8)$$

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 (9) and (10):

$$f_{ctk,0.05} = 0.7 f_{ctm} = 0.7 \cdot 2.41 = 1.687\ N/mm^2 \quad (9)$$

$$f_{ctk,0.95} = 1.3 f_{ctm} = 1.3 \cdot 2.41 = 3.13\ N/mm^2 \quad (10)$$

The strength to axial tension f_{ct} can be established function de splitting strength, f_{td} with relation (11):

$$f_{ct} = 0.9 f_{td} = 0.9 \cdot 1.92 = 1.73\ N/mm^2 \quad (11)$$

According to data obtained the fly ash concrete with polystyrene granules as substitution of fine aggregate and coarse aggregate sort 4-8 mm can be characterized as structural concrete for a grade of C16/20 according to Romanian standard [23].

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

Figure 1 **Experimental test in compression of concrete with polystyrene granules**

The characteristic diagram is presented in *Figure 2*

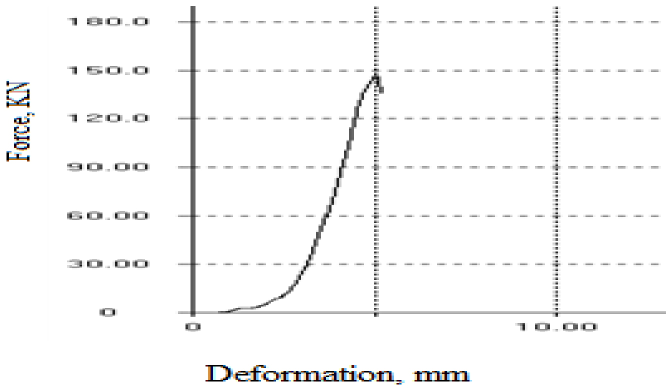

Figure 2 **Characteristic diagram of concrete with polystyrene granules**

The fly ash concrete with polystyrene granules had plastic deformations from the first stages of loading. The behavior in compression can be characterized as an elastic one, before the failure the sample presented an important deformation. Cracks were developed especially at the top of the cylinder, parallel with the compression force (*figure 1*).

CONCLUSIONS

The mechanical and deformation characteristics of fly ash concrete with 10% polystyrene granules as substitution of fine and coarse aggregate were experimentally determined. Analyzing experimental values of compressive strength, flexural strength and splitting strength it can observe that this type of concrete is of grade C16/20, according to standard and it can be used as structural concrete. The density of 2033 kg/m^3 classifies concrete with polystyrene granules as a normal concrete.

The use of fly ash in concrete and the substitution of aggregate with waste of polystyrene granules is important step in re-cycling and protecting resources and environment by reducing the cement and natural aggregates consumption.

ACKNOLEGMENTS

This work was supported by a grant of the Romanian National Authority for Scientific Research and Innovation, CCCDI - UEFISCDI, project number 109 BM / 2017.

REFERENCES

Akçaözog˘lu S., Atis C.D., Akçaözog˘lu K, 2010 - *An investigation on the use of shredded waste PET bottles as aggregate in lightweight concrete,* Waste Management, vol. 30 (2), 285–290.

Altwair N.M., Kabir S., 2010 - *Green concrete structures by replacing cement with pozzolanic materials to reduce greenhouse gas emissions for sustainable environment*, American Society of Civil Engineers, 6th International Engineering and Construction Conference, Cairo, Egipt, 269-279.

Andrew R.M., 2018 - *Global CO2 emissions from cement production*, Earth Syst. Sci. Data, 10, 195–217, 2018, https://doi.org/10.5194/essd-10-195

Barbuta M., Marin E., Cimpeanu S.M., Paraschiv G., Lepadatu D., Bucur R.D., 2015 - *Statistical Analysis of the Tensile Strength of Coal Fly Ash Concrete with Fibers Using Central Composite Design, Advances in Materials Science and Engineering*, p. 1-7.

Başak M., Semra Çoruh Osman Nuri Ergun, 2011 - *Use of selected industrial waste materials in concrete mixture*, Environmental Progress and Sustainable Energy,30(3):368-376.

Chowdhury S., Mishra M., Suganya O., 2015 - *The incorporation of wood waste ash as a partial cement replacement material for making structural grade concrete: An overview,* Ain Shams Engineering Journal, vol. 6, 429–437

De Castro S., De Brito J., 2013 - *Evaluation of the durability of concrete made with crushed glass aggregates*, Journal of Cleaner Production, Vol. 41, 7–14.

Dinakar P., Babu K.G., Santhanam M., 2008 - *Durability properties of high volume fly ash selfcompacting concrete, Cement & Concrete Composites*, vol. 30 (10), p. 880–886.

Herki B.A., Khatib J.M., Negim E.M., 2013 - *Lightweight Concrete Made from Waste Polystyrene and Fly Ash,* World Applied Sciences Journal, vol. 21 (9), 1356-1360

Ingrao, C., 2014 - *Recycled-PET fiber based panels for building thermal insulation: environmental impact and improvement potential assessment for a greener production.* Sci. Total Environ. 493, 914-926.

Ismail, Z.Z., Al- Hashmi, E.A., 2008 - *Use of plastic waste in concrete mixture as aggregate replacement.* Waste Manag. 28, 2041-2047

Jaffar A.N., Anwer M., Alwi S.K.K., Anjum M. N.,Raja M.R., Hussain A., Ming Xu., 2015 - *The greenhouse gas emission Produced by cement Production and its impact on Environment: A review of Global cement processing, International Journal Research* 2 (2),, 488

Khaloo A.R., Dehestani M., Rahmatabadi P., 2008 - *Mechanical properties of concrete containing a* *high volume of tire-rubber particles*, Waste Management, vol. 28 (12), 2472–2482.

Kumar Prusty J., Kumar Patro S., Basarkar S.S., 2016 - *Concrete using agro-waste as fine aggregate for sustainable built environment* - A review, International Journal of Sustainable Built Environment, 5, 312-333

Naughton A., Fan M., Bregulla J., 2014 - *Fire resistance characterization of hemp fiber reinforced polyester composites for use in the construction industry*, Composites:Part B 60 546-554

Qasrawi H., Shalabi F., Asi I., 2009 - *Use of low CaO unprocessed steel slag in concrete as fine aggregate, Construction and Building Materials*, vol. 23 (2), p.1118–1125.

Xie J.H., Guo Y.C., Liu L.S., Xie Z.H., 2015 - *Compressive and flexural behaviours of a new steel-fibre-reinforced recycled aggregate concrete with crumb rubber, Construction and Building Materials*, vol. 79, p. 263–272.

Romanian Standard Association, SR EN 197-1:2011, *Cement, Part 1: Composition, specifications and conformity criteria for common cements.*

Romanian Standard Association, SR EN 12390-7:2005 - *Testing hardened concrete. Density of hardened concrete.*

Romanian Standard Association, SR EN 12390-3:2005, *Testing hardened concrete.* Part 3: *Compressive strength of test specimens*, 2011

Romanian Standard Association, SR EN 12390-5:2005 – *Testing hardened concrete*. Part 5: *Flexural strength of test specimens, 2009.*

Romanian Standard Association, SR EN 12390-6:2010, - *Testing hardened concrete*. Part 6: *Split tensile strength of test specimens,* 2005

Romanian Standard Association, SR EN 1992-1:2004 - *Design of concrete structures*.