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USING POSSIBILITIES OF THE THERMAL POWER PLANT ASH COLLECTED BY WET PROCESS FOR CONCRETES PREPARATION

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Abstract: *The dump ashes (resulted from collecting and transport by wet process of the thermal power plant ashes) represent a pollution agent, occupying great surfaces from the agricultural land and are difficult to recycle. Replacing the aggregate's fine part from concrete is contributing to replacing the natural sand that nowadays is deficitary. This study presents the results of some testing on concretes were the pit natural sand was partially or entirely replaced with thermal power plant ashes. The studied concretes characteristics modifications refer to the mechanical strengths. The strength losses can be compensated by cement dosage increasing or by using of superior class cement.*

Key words: *dump ash; natural sand; compression strength; drying shrinkage.*

1. Introduction

Great volumes of dump from thermal power plants are collected by dry process and used for concrete preparation; dump ash is also collected many times by wet process, separated by sedimentation and then deposited outdoors, thus representing a pollution source with catastrophic implications upon agricultural fields. The situation at Ișalnița (a locality in the Dolj County) and at Holboca (Iași County) is relevant from this standpoint.

Recycling dump ash from thermal power plants collected by wet process can be partially solved by adding it to the aggregate used to prepare concretes or as a cement replacer [1-4]. The use of fly ash from thermal power plants for concretes preparation has been attempted worldwide to replace cement [5-7], to replace the fine particles [8] or to replace both of them [9], [10]. Hence, Faleschini et al. used co-combustion ash to replace concrete cement and, though they obtained less impressive results than by using coal ash, the concrete properties recommended the use of dump ash collected by wet process to replace cement. In 2015, Rivera et al. proposed the partial replacement of both cement and the fine concrete particles and they obtained satisfying results, thus increasing the ash percentage used in the concrete volume.

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Within the Building Materials Laboratory with the Faculty of Civil Engineering and Building Services Iași, a study was conducted on concretes made using thermal power plant dump ash collected by wet process for two types of concrete, while preventing resistance loss from exceeding 10 percent.

This 10% loss limit is justified by a complex study conducted within the Building Materials Laboratory with the Faculty of Civil Engineering and Building Services Iași, which has proven that oftentimes, strength losses for such concretes may exceed by 15-16% those of the concretes tested and imposed by concrete plants.

The innovative part of this project is the replacement of fine concrete particles with thermal power plant ash collected by wet process from Holboca, which is a type 1 thermal power plant, based on solid coal (energetic pit coal). An estimated calculation indicated that for 20% ballast, around 22,000 tons of dump ash resulted annually. In the last 26 years, over 750 million tons of ash resulted in this area, out of which only a small part was capitalized and the unused ash was simply stored.

2. Characteristics of dump ash collected by wet process from the thermal power plant of Holboca Iași

2.1. General characteristics

The material looks as a powder; it has a light grey colour and a variable humidity that decreases from the surface to the deposit, see Figure 1.

Fig. 1. *Dump ash*

2.2. Chemical composition

Coals burning in the ash result in a series of elements that become part of different combinations or oxide composites.

For the ashes obtained from tar, the compositions vary considerably in the content of oxides, except for the calcium oxide that exists in great amount in the lignite.

It must be highlighted that – besides the main components SiO_2, Fe_2O_3, CaO and SO_3 – ashes contain secondary components like Na_2O, K_2O, Fe_2O_3, TiO_2, P_2O_5 and rare elements in relatively small amounts, called “trace elements”.

Ashes have variable oxidic composition. By the SiO_2 and Al_2O_3 ratio and the CaO and SO_3 amounts, ashes can be classified into four classes [9]:

- Alumino-siliceous ashes
- Sulpho-calcic ashes
- Silico-aluminous ashes
- Calcic ashes

Generally, the alumino-siliceous ashes and silico-aluminous ashes are formed by tar combustion and the sulpha-calcic ashes by lignite combustion.

The chemical composition of the ash is presented in Table 1.

Chemical composition Table 1

No.	Chemical component	Determination method	Values obtained (%)			
			1	2	3	Average
1.	Total silicon dioxide (SiO_2)	g. 3832/2-85	37.0040	36.6900	37.0705	36.9215
2.	Iron trioxide (Fe_2O_3)	Volumetric, 3832/3-85	4.9622	4.9820	5.0104	4.9848
3.	Aluminium trioxide (Al_2O_3)	Volumetric, 3832/3-85 Volumetric, 3832/3-85	37.7650	37.8005	37.6985	37.7546
4.	Calcium oxide (CaO)		2.9380	2.8940	2.8440	2.9203
5.	Magnesium oxide (MgO)	Volumetric, 3832/3-85	0.1880	0.1805	0.1844	0.1845
6.	Sulphur trioxide (S_2O_3)	Gravitational, 3832/5-85	1.4406	1.4366		1.4386
7.	Total sulphur (St)	Gravitational, 3832/5-85 Flam-photometric, 3832/6-85	1.4418	1.4382		1.4400
8.	Sulphur in sulphides (S^{2-})		0.0012	0.0016		0.0014
9.	Sodium oxide (Na_2O)		0.2210	0.2170	0.2174	0.2181
10.	Potassium oxide (K_2O)	Flam-photometric, 3832/6-85 g. 3832/7-85	0.5465	0.5398	0.5460	0.5431
11.	Combustible substances (C)		9.8800	10.0020	9.8032	9.8950
12.	Substances soluble in cool HCl	g. 3832/8-85 dried at 110^0C	7.0532	7.2145		7.1388
13.	Insoluble residuals in cool HCl	Calcination at 1050^0C	87.2170	87.1570		87.1870
14.	Calcination losses (Pc)	g. $(1050\pm10)^0$C	77.6480	77.6720		77.6600
15.	Solubility in water at 20^0C		9.9420	9.8111	10.0261	9.9264

2.3. Mineralogical composition

The main crystalline compounds of the ashes are: mulite (10-16)%, quartz (6-10)%, hematite (2-3)%, magnetite (2-4)%

Based on average composition, the place of the ashes in the CaO-Al_2O_3-SiO_3 ternary system was assessed compared to the Portland aluminous cement and the granular furnace slags. The lower basic character of the ashes and their reduced hydraulic ability were also highlighted.

2.4. Radioactivity of the dump ash

The present radionuclides in the ashes are found in the following concentrations:
C (^{40}K) = 158...472; C (^{226}Ra) = 52...187; C (^{232}Th) = 212 [11]
The ashes radioactivity does not exceed the values of the natural stock.

2.5. Physical characteristics

Aerated bulk density
The variation of aerated bulk density by humidity is presented is the figure 2 [12], [13]:

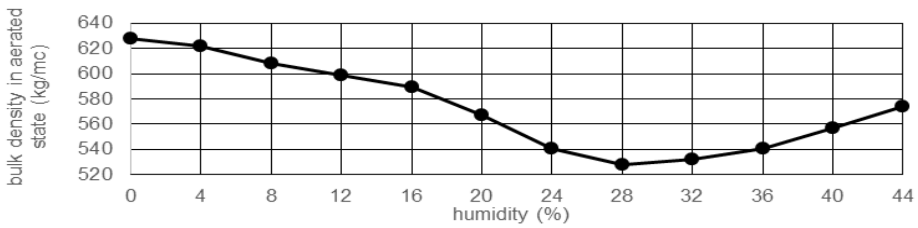

Fig. 2. *Variation of aerated bulk density function of humidity*

2.6. Granularity

The passing through the sieves and the utilized sieves dimensions are presented in Table 2.

The granularity of the dump ash Table 2

Passing through the sieves and sieves size (mm)				
0.09	0.2	0.4	0.65	1
6.9	12.4	88	99.5	100

The granularity curve is illustrated in Figure 3.

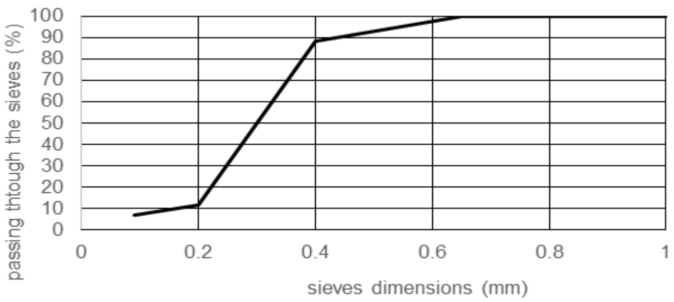

Fig. 3. *Granularity curve*

2.7. Specific surface (Blaine method)

S = 4321cm^2/g [14]

The specific extended surface is due to the irregular shape of the granules, which feature many cracks observable using an optical microscope.

3. Experimental Program and Results

Two concrete compositions corresponding to C8/10 and C20/25 were chosen. Concrete compositions were similar in terms of cement dosage, water, and aggregate. Aggregate granularity was established in such a way as to have a granular material rich in fine particles, in order to replace the fine particles with thermal power plant ash. There resulted eight concrete compositions with different power plant ash contents, as can be seen in the Table 3.

Concretes compositions Table 3

Composition		Cement (kg/m^3)	Water (l/m^3)	Ash (kg/m^3)	Aggregate – type (kg/m^3)						
					0 -0.25	0.25 – 0.5	0.5 - 1	1-2	2-4	4-8	8-16
A1	A_1^0	185	140	0	162	244	244	203	284	406	485
	A_1^3	185	140	60	101	244	244	203	284	406	485
	A_1^6	185	140	123	40	244	244	203	284	406	485
	A_1^9	185	140	183	0	223	244	203	284	406	485
	A_1^{12}	185	140	241	0	165	244	203	284	406	485
	A_1^{15}	185	140	304	0	102	244	203	284	406	485
	A_1^{18}	185	140	365	0	41	244	203	284	406	485
A2	A_2^0	280	140	0	155	235	235	196	274	392	470
	A_2^3	280	140	59	96	235	235	196	274	392	470
	A_2^6	280	140	118	37	235	235	196	274	392	470
	A_2^9	280	140	170	0	214	235	196	274	392	470
	A_2^{12}	280	140	235	0	155	235	196	274	392	470
	A_2^{15}	280	140	290	0	96	235	196	274	392	470

All concrete compositions were prepared at the same time and stored in the same manner. Sample preserving consisted in introducing the moulds for 24 hours in a 90%-humidity atmosphere in the wet air box and subsequently demoulding in potable water tanks up to the testing moment. The testing temperature was 20°C throughout the entire process (SR EN 206-1, 2002, SR EN 1504-1, 2006; C 155, 2013).

The compression strengths were determined on cubic samples having the dimension of 15 mm using a hydraulic testing machine produced by TECHNOTEST.

Notations: for example 1 represents the number of the receipt and 3 the number of month.

The obtained results are presented in Table 4.

Volumic mass and the compression strength for each composition Table 4

Composition		Volumic mass (kg/m^3)	Compression strength (N/mm^2)
A1	A_1^0	2330	12.9
	A_1^3	2330	12.9
	A_1^6	2325	12.7
	A_1^9	2320	12.5
	A_1^{12}	2314	12.2
	A_1^{15}	2310	12
	A_1^{18}	2309	11.7
A2	A_2^0	2350	35.4
	A_2^3	2350	35.2
	A_2^6	2340	34.6
	A_2^9	2330	33.6
	A_2^{12}	2325	32.4
	A_2^{15}	2320	31.5

The following variation curves for the compression strength in time were obtained, as can be seen in Figures 4 and 5.

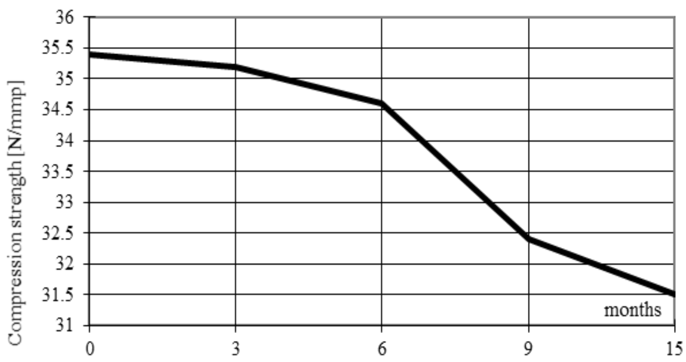

Fig. 4. *Compression strength variation for A1 mixture*

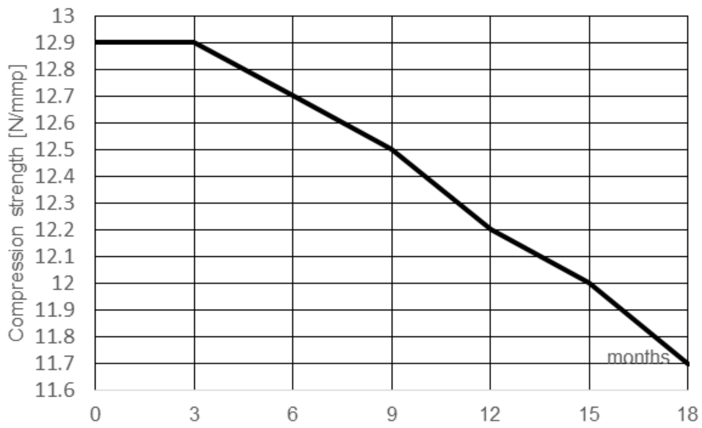

Fig. 5. *Compression strength variation for A2 mixture*

The results of mechanical strengths testing have proven that 50% of the fine part of the aggregate can be replaced in order to meet the condition required – preventing resistance loss from exceeding 10 percent – because this way the radioactivity of concrete composite remains within acceptable limits.

4. Conclusions

Throughout the research, the following observations were made regarding these types of concrete:

• Overall concrete pH decreased due to a slow reaction between the thermal power plant dump ash and the basic components within the cement stone, not to carbonation manifesting from the surface towards the inside.

• After 10 years, concrete strength increased to 28 days, which confirms the chemical reactions and the cement stone elements.

• The use of thermal power plant ash collected by wet process to prepare lower-class concrete composites is actually a viable solution for recycling this material, given that it represents a major polluting factor.

• The measurement results can be used in practice for the dump ashes utilization and to replace the pit sand that for the present is deficitary.

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