Donbas National Academy of Civil Engineering and Architecture

Beneficiated ponded fly ash for concretes with high volume mineral additions

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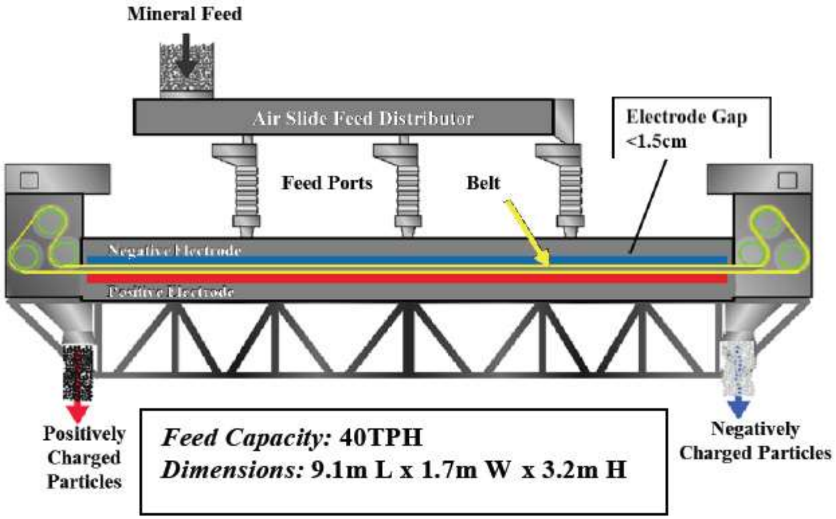
International Scientific Practical Conference

«Materials science, shape-generating technologies and equipment 2020»

(ICMSSTE 2020)

May 25-29, 2020 Yalta, Russia

The utilization of fly ash (ponded ash)



Fly ash (FA) is presently collected or disposed by using either dry or wet systems. High disposal costs, increased interest in improving the environmental impacts are making fly ash utilization an attractive alternative to disposal.

FA particles have a wide size distribution ranging from molecular clusters with diameters of 2 nm up to particles with diameters of about 100 μm. The particles larger than 1 μm mostly contain unburned mineral materials.

Triboelectrostatic beneficiation of FA with high-unburned carbon content can produce low-carbon ash products having value as mineral additions and meeting technical requirements for replacing cement in concrete.

The objectives of this study are: i) to investigate the properties of ponded FA treated in the triboelectrostatic separator, ii) to determine the properties of HVFAC with the nanostructured-carbon-based plasticizing admixture and the ponded FA beneficiated by triboelectrostatic separation technique.

Experimental

Materials

- Ordinary Portland cement (OPC) CEM I 42.5 N
- Ponded fly ash (PFA), Blaine 290 m²/kg, LOI=6.92%
- Quartz sand, fineness modulus of 2.2
- Crushed granite, 10 mm maximum size
- Nanostructured-carbon-based plasticizing admixture “ART Concrete-K”
- SikaAer®PRO-100 air-entraining agent

Methods

- Particle size distribution (PSD)
- Loss-on-ignition (LOI)
- Foam Index Test (FIT)
- Diffraction studies (XRD)
- Standard consistency of cement paste
- Compressive strength of cement paste and concrete

Schematics of the experimental setup

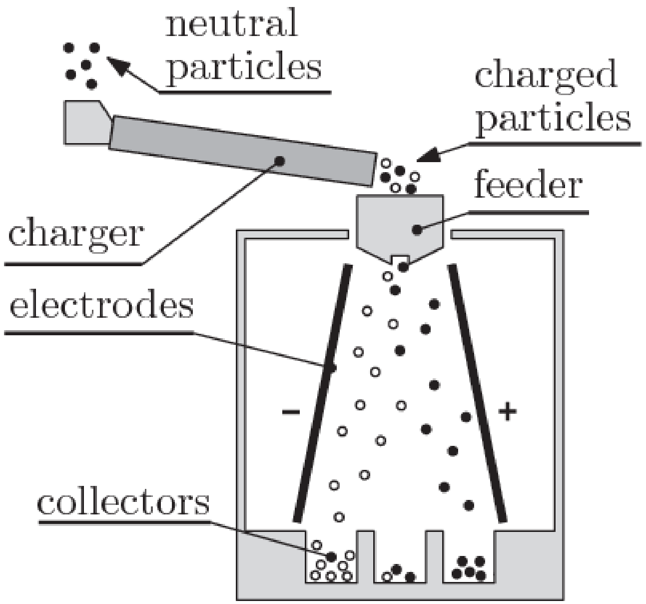
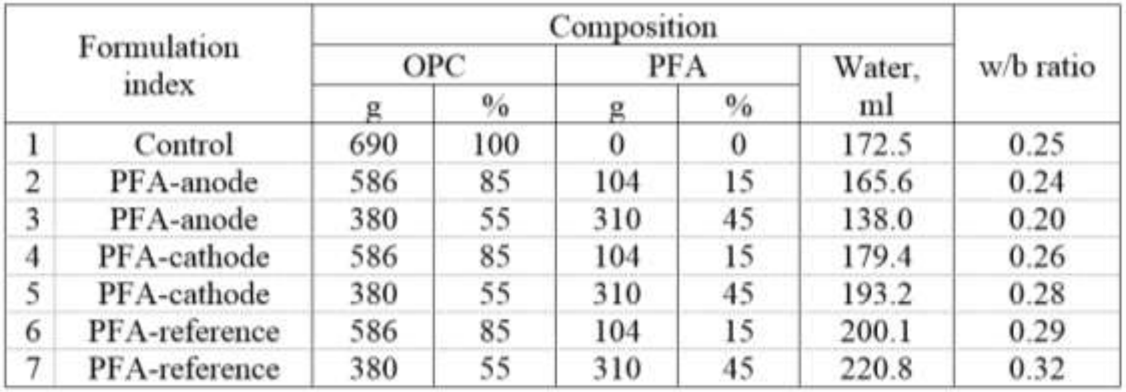


Table 1. The formulations of the cement-fly ash pastes.



Formulation index		Composition					w/b ratio
		OPC		PFA		Water, ml	
		g	%	g	%		
1	Control	690	100	0	0	172.5	0.25
2	PFA-anode	586	85	104	15	165.6	0.24
3	PFA-anode	380	55	310	45	138.0	0.20
4	PFA-cathode	586	85	104	15	179.4	0.26
5	PFA-cathode	380	55	310	45	193.2	0.28
6	PFA-reference	586	85	104	15	200.1	0.29
7	PFA-reference	380	55	310	45	220.8	0.32

Properties of beneficiated ponded fly ash

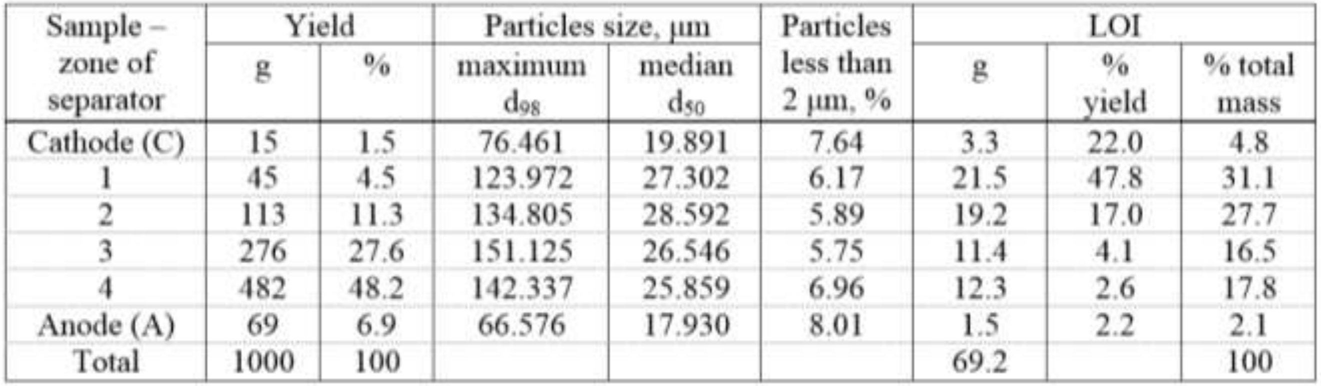
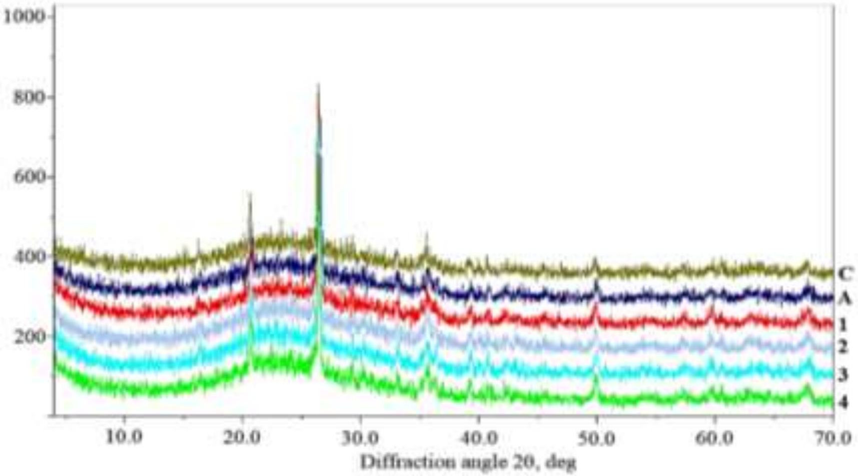


Table 2. Particle size and loss-on-ignition data for yields obtained after triboelectrostatic separation of PFA

Sample – zone of separator	Yield		Particles size, μm		Particles less than 2 μm, %	LOI		
	g	%	maximum d_{98}	median d_{50}		g	% yield	% total mass
Cathode (C)	15	1.5	76.461	19.891	7.64	3.3	22.0	4.8
1	45	4.5	123.972	27.302	6.17	21.5	47.8	31.1
2	113	11.3	134.805	28.592	5.89	19.2	17.0	27.7
3	276	27.6	151.125	26.546	5.75	11.4	4.1	16.5
4	482	48.2	142.337	25.859	6.96	12.3	2.6	17.8
Anode (A)	69	6.9	66.576	17.930	8.01	1.5	2.2	2.1
Total	1000	100				69.2		100

Diffractograms of ponded fly ash after triboelectrostatic separation



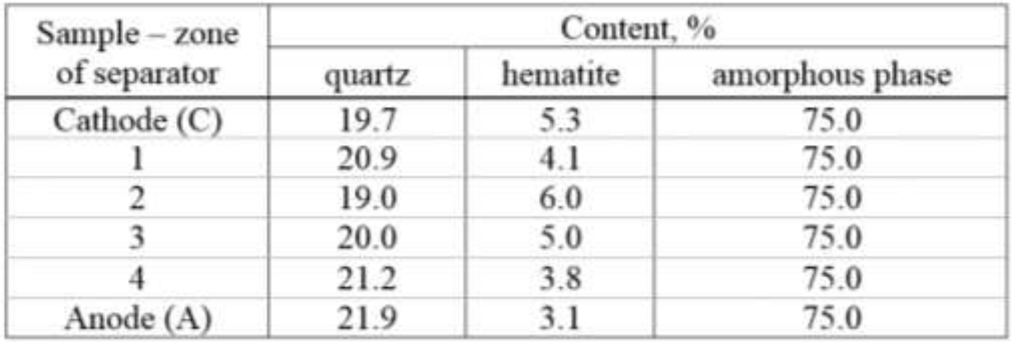


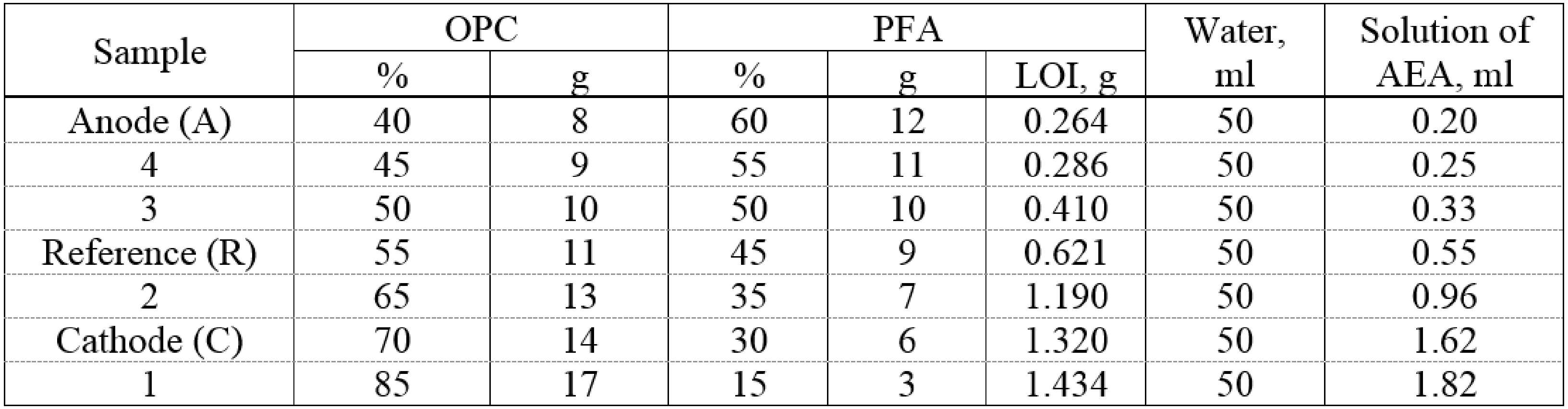
Table 3. Proportions of crystalline phases and bulk amorphous material presented in PFA.

Sample – zone of separator	Content, %		
	quartz	hematite	amorphous phase
Cathode (C)	19.7	5.3	75.0
1	20.9	4.1	75.0
2	19.0	6.0	75.0
3	20.0	5.0	75.0
4	21.2	3.8	75.0
Anode (A)	21.9	3.1	75.0

All samples of PFA are identical in the bulk amorphous material. The differences in the content of the crystalline phases are of a minor nature. In particular, the highest amount of quartz along with the smallest amount of hematite are in the cells located in the operation zone of anode electrode. This could beneficiate the fly ash as pozzolana since ultrafine particles of quartz may exhibit pozzolanic properties as well as play the role of nucleation centers.

Properties of beneficiated ponded fly ash

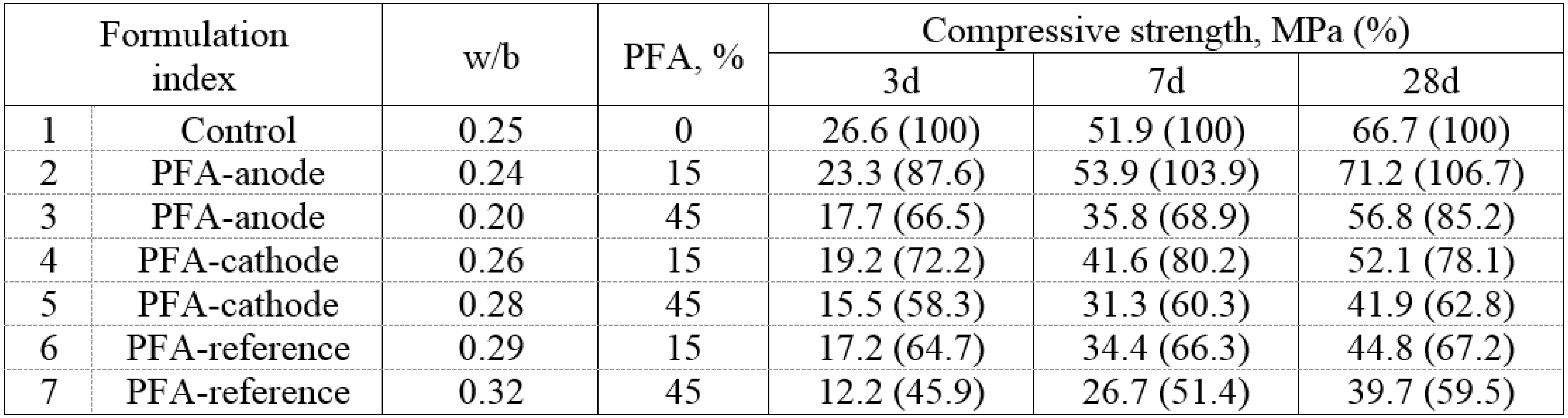
Table 4. Proportions of cement-fly ash mixtures and foam index.



Sample	OPC		PFA			Water, ml	Solution of AEA, ml
	%	g	%	g	LOI, g		
Anode (A)	40	8	60	12	0.264	50	0.20
4	45	9	55	11	0.286	50	0.25
3	50	10	50	10	0.410	50	0.33
Reference (R)	55	11	45	9	0.621	50	0.55
2	65	13	35	7	1.190	50	0.96
Cathode (C)	70	14	30	6	1.320	50	1.62
1	85	17	15	3	1.434	50	1.82

High amount of unburned carbon (LOI) affects the required dosage of air-entraining admixture significantly but not a high content of fly ash. The higher LOI content in the fly ash sample the higher the amount of diluted AEA is needed to produce a stable foam.

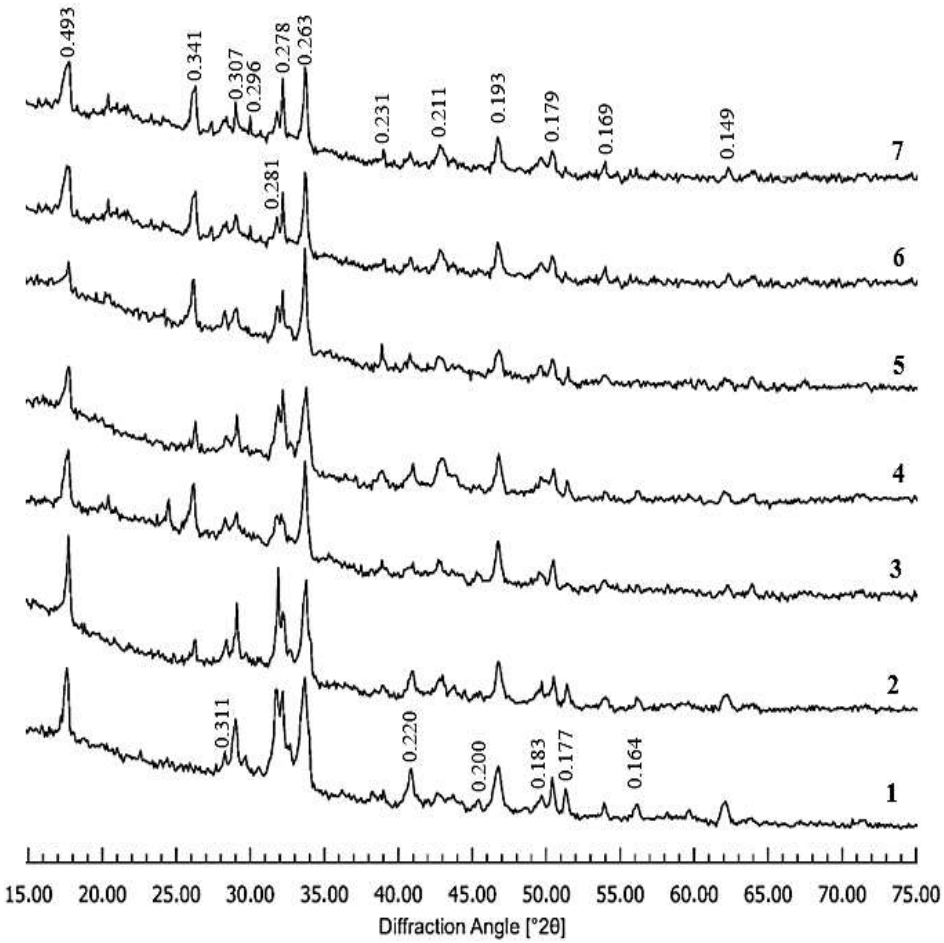
Table 5. Compressive strength of cement pastes.



Formulation index		w/b	PFA, %	Compressive strength, MPa (%)		
				3d	7d	28d
1	Control	0.25	0	26.6 (100)	51.9 (100)	66.7 (100)
2	PFA-anode	0.24	15	23.3 (87.6)	53.9 (103.9)	71.2 (106.7)
3	PFA-anode	0.20	45	17.7 (66.5)	35.8 (68.9)	56.8 (85.2)
4	PFA-cathode	0.26	15	19.2 (72.2)	41.6 (80.2)	52.1 (78.1)
5	PFA-cathode	0.28	45	15.5 (58.3)	31.3 (60.3)	41.9 (62.8)
6	PFA-reference	0.29	15	17.2 (64.7)	34.4 (66.3)	44.8 (67.2)
7	PFA-reference	0.32	45	12.2 (45.9)	26.7 (51.4)	39.7 (59.5)

Cement paste hydration

XRD patterns of cement pastes with addition of PFA



The relative intensity of tricalcium silicate (as compared with control sample) of the cement pastes with 15 % replacement CP-2, CP-4, and CP-6, respectively: d = 0.278 nm (2θ = 32.17°) – 85.6, 93.4, 87.9 %; d = 0.177 nm (2θ = 51.59°) – 84.4, 94.3, 88.1 %; d = 0.164 nm (2θ = 56.00°) – 91.3, 102.2, 113.9 %. A similar pattern holds for the cement pastes containing 45 % PFA: CP-3, CP-5, and CP-7, respectively: d = 0.278 nm – 81.8, 90.7, 93.1 %; d = 0.177 nm – 96.3, 106.7, 96.2 %; d = 0.164 nm – 107.3, 113.8, and 120.4 %.

The relative intensity of the Portlandite (CH) diffraction peaks: d = 0.493 nm (2θ = 17.98°), d = 0.311 nm (2θ = 28.66°), d = 0.263 nm (2θ = 34.05°) as well as calcium hydrosilicate phases (CSH(B) and C2SH2): d = 0.307 nm (2θ = 29.06°), d = 0.281 nm (2θ = 31.82°), d = 0.183 nm (2θ = 49.79°); d = 0.220 nm (2θ = 40.99°), d = 0.211 nm (2θ = 42.90°), d = 0.200 nm (2θ = 45.31°). The results indicate that PFA collected from the anode plate is more reactive as compared with the samples from the cathode plate as well as the reference PFA.

Properties of HVFAC

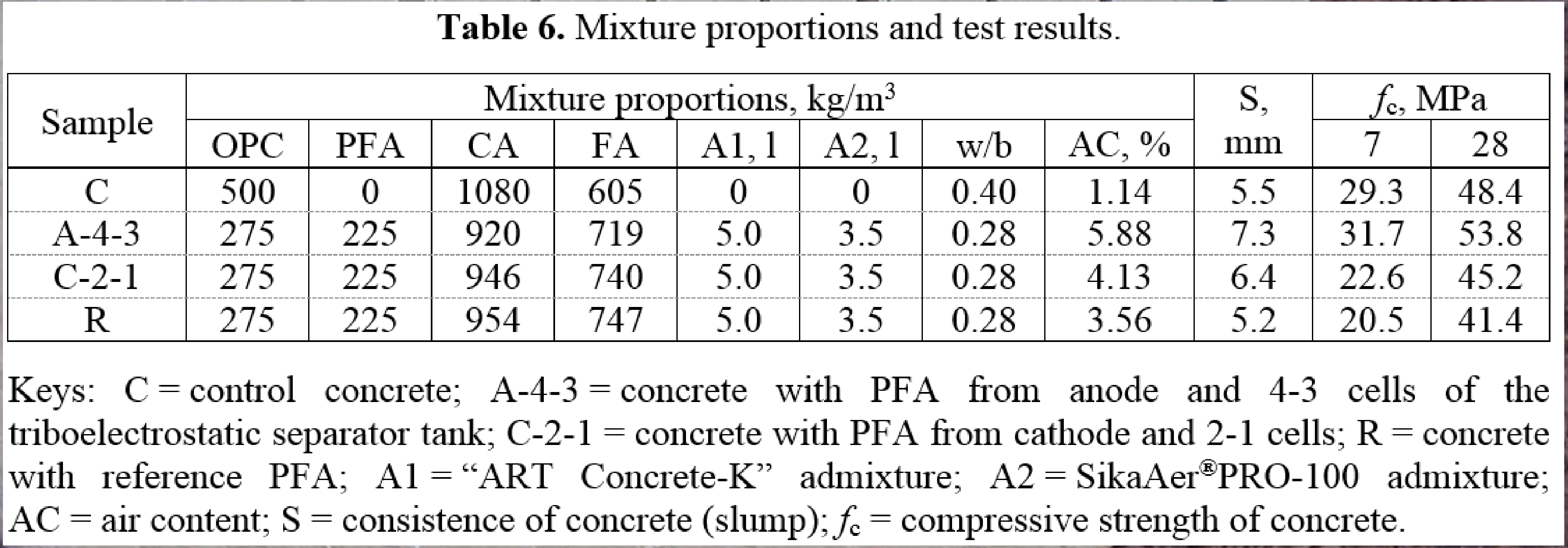


Table 6. Mixture proportions and test results.

Sample	Mixture proportions, kg/m³								S, mm	f_c, MPa	
	OPC	PFA	CA	FA	A1, l	A2, l	w/b	AC, %		7	28
C	500	0	1080	605	0	0	0.40	1.14	5.5	29.3	48.4
A-4-3	275	225	920	719	5.0	3.5	0.28	5.88	7.3	31.7	53.8
C-2-1	275	225	946	740	5.0	3.5	0.28	4.13	6.4	22.6	45.2
R	275	225	954	747	5.0	3.5	0.28	3.56	5.2	20.5	41.4

Keys: C = control concrete; A-4-3 = concrete with PFA from anode and 4-3 cells of the triboelectrostatic separator tank; C-2-1 = concrete with PFA from cathode and 2-1 cells; R = concrete with reference PFA; A1 = "ART Concrete-K" admixture; A2 = SikaAer®PRO-100 admixture; AC = air content; S = consistence of concrete (slump); f_c = compressive strength of concrete.

Conclusions

From the results of this study, it is possible to conclude that triboelectrostatic beneficiation of ponded fly ash with increased-unburned carbon content (LOI = 6.92 %) can produce low-carbon ash product (LOI = 2.52 %) meeting technical requirements for the high replacing level of cement (45 %) in concretes. The beneficiated ponded fly ash has an improved granulometric and phase composition, a decreased content of unburned carbon that accelerates the hydration process of cement, increases the rheological properties of cement paste and the ability of AEA to hold the required involved air. In a combination with the nanostructured-carbon-based plasticizing admixture the beneficiated PFA exhibits high rate of strength increase when is used in HVFAC.