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STRENGTH DEVELOPMENT OF SELF-COMPACTING CONCRETE INCORPORATING HIGH VOLUME OF CALCAREOUS FLY ASH

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ABSTRACT
In this paper the strength development of self-compacting concrete with high volume of calcareous fly ash was investigated. The ultrasonic pulse velocity was also measured and relationships between these were investigated. The results show that compressive strength of the self-compacting concrete samples decreases by increasing the fly ash content in the early period, but with increasing the age of samples the reduction of compressive strength becomes lower. The results further indicate that there is very good correlation between compressive strength and ultrasonic pulse velocity of the samples after 14 days or more.
Keywords: self-compacting concrete, calcareous fly ash, compressive strength

1. INTRODUCTION
Self-compacting concrete (SCC) is a new type of cement composite which is, due to its extraordinary properties, classified as a high performance concrete. SCC flows under its own weight and fills all voids bypassing reinforcement, and retains the horizontal surface without the need for compaction using vibrating devices. SCC differs from conventional concrete in improved flowability properties and resistance to segregation, easier placement, insured structure compactness, higher strength and increased durability and hence increased cost effectiveness. It is particularly suitable for complex structures and the use of this concrete reduces the construction time, workload, construction site equipment and noise, and also improves the quality [1-7].
Fly ash is a by-product from the burning of pulverized coal in the power plants. Fly ash is a very fine, powdery material, composed of glassy spherical particles. As a mineral additive for concrete, fly ash improves the properties of concrete in two ways: one part of the added fly ash acts as a fine aggregate fraction (physical effect), and the other part acts as a cementing component (pozzolanic and/or hydraulic reactions – chemical effect). Apart from that, fly ash improves the workability and strength, reduces the need for water, reduces sensitivity to changes in water content and slows the release of the hydration heat. Due to slower pozzolanic reaction of fly ash, concretes with fly ash are characterized by slightly lower early strength [8,9,10].

2. EXPERIMENTAL WORK
For the preparation of SCC mixtures the following locally available raw materials were used: Portland-cement CEM I 52,5 N (Cement plant „Kakanj"), calcareous fly ash (Power plant „Kakanj"), three-fraction crushed limestone aggregate (0-4, 4-8, 8-16 mm), polycarboxylate-ether-based superplasticizer (SP) and viscosity modifying admixture (VMA). The characteristics of all the concrete components, as well as fresh concrete mixtures properties, are given elsewhere [11]. Projected classes of consistency were: SF3, VF1, PA2, SR2 [1]. In this investigation, the UCL method [12] was selected for proportioning of the SCC mixtures and concrete composition is shown in Table 1. The concrete samples were tested at the age of 1, 2, 14, 28, 56 and 90 days. Before they were used for testing compressive strength, the samples were subjected to the testing of ultrasonic pulse velocity.

Table 1. The composition of the self-compacting concrete mixtures

Components	Concrete composition for 1 m^3					
	SCC I	SCC II	SCC III	SCC IV	SCC V	SCC VI
Cement replacement with fly ash (%)	27,5	35	42,5	50	57,5	65,0
Cement CEM I 52,5 N (kg)	290,00	260,00	230,00	200,00	170,00	140,00
Fly ash (kg)	110,00	140,00	170,00	200,00	230,00	260,00
Filler (kg)	74,00	70,00	66,00	62,00	58,00	54,00
Water (dm^3)	176,20	177,94	176,16	176,18	176,19	176,20
Aggregate 0-4 mm (kg)	941,58	934,82	941,58	941,58	941,58	941,58
Aggregate 4-8 mm (kg)	316,58	317,52	316,58	316,58	316,58	316,58
Aggregate 8-16 mm (kg)	475,25	476,28	475,25	475,25	475,25	475,25
SP (dm^3)	4,39	4,58	4,54	4,51	4,48	4,45
VMA (dm^3)	1,73	1,72	1,70	1,69	1,68	1,67

3. RESULTS AND DISCUSSION

The results of testing compressive strength and ultrasonic pulse velocity of the *SCC* samples are shown in Table 2. It can be observed that the compressive strength decreases by increasing the fly ash content in the first period (up to 28 days). After 56 days, samples with 35 and 42,5 % of fly ash (SCC II and SCC III) surpassed the compressive strength values of the reference samples (SCC I). Also, after 90 days the samples with 50 % of fly ash (SCC IV) achieved the higher compressive strength values than the reference samples (SCC I). The early strengths of the samples with 57,5 and 65 % of fly ash content (SCC V and SCC VI) are very low, but after 28 days these samples achieved the compressive strength values acceptable for some practical applications. From the results shown in Table 2 it can be observed that the ultrasonic pulse velocity of the self-compacting concrete samples decreases by increasing the fly ash content in the periods of 1, 2, 14 and 28 days, and has similar values to the reference samples in periods 56 an 90 days.

Table 2. The results of testing compressive strength and ultrasonic pulse velocity

Self-compacting concrete samples		SCC I	SCC II	SCC III	SCC IV	SCC V	SCC VI
Compressive strength (MPa)	1 day	16,2	14,0	11,5	8,6	3,2	0,9
	2 days	25,0	23,5	21,2	19,1	10,9	4,0
	14 days	51,3	49,0	45,5	36,8	29,5	25,0
	28 days	57,4	56,4	53,2	47,3	41,6	33,9
	56 days	59,6	67,6	66,7	56,7	54,2	44,7
	90 days	61,2	71,0	74,2	65,7	57,4	46,4
Ultrasonic pulse velocity (m/s)	1 day	4587,1	4491,0	3916,4	3722,1	3521,1	2645,5
	2 days	4559,3	4559,3	4545,5	4437,8	4166,7	3968,3
	14 days	4983,4	4918,0	4870,1	4807,7	4761,9	4716,9
	28 days	5119,5	5102,0	5067,6	5033,6	4934,2	4885,9
	56 days	5172,4	5154,6	5154,6	5119,5	5084,7	4918,0
	90 days	5281,7	5263,1	5300,4	5226,5	5154,6	5136,9

1.1. The correlations between compressive strength and ultrasonic pulse velocity

The correlations between compressive strength and ultrasonic pulse velocity are shown in Figures 1 and 2. It can be observed that the correlations between compressive strength and ultrasonic pulse velocity for samples of age 1 and 2 days significantly differ from correlations in later periods. As opposed to that, for samples of age 14, 28, 56 and 90 days the correlation between compressive strength and ultrasonic pulse velocity is almost identical, indicating that the structure is greatly stabilized. The correlation between compressive strength and ultrasonic pulse velocity of the samples of age 14, 28, 56 and 90 days is shown in Figure 2, and in this case the corresponding equation can be used for prediction of compressive strength on the basis of ultrasonic pulse velocity test results.

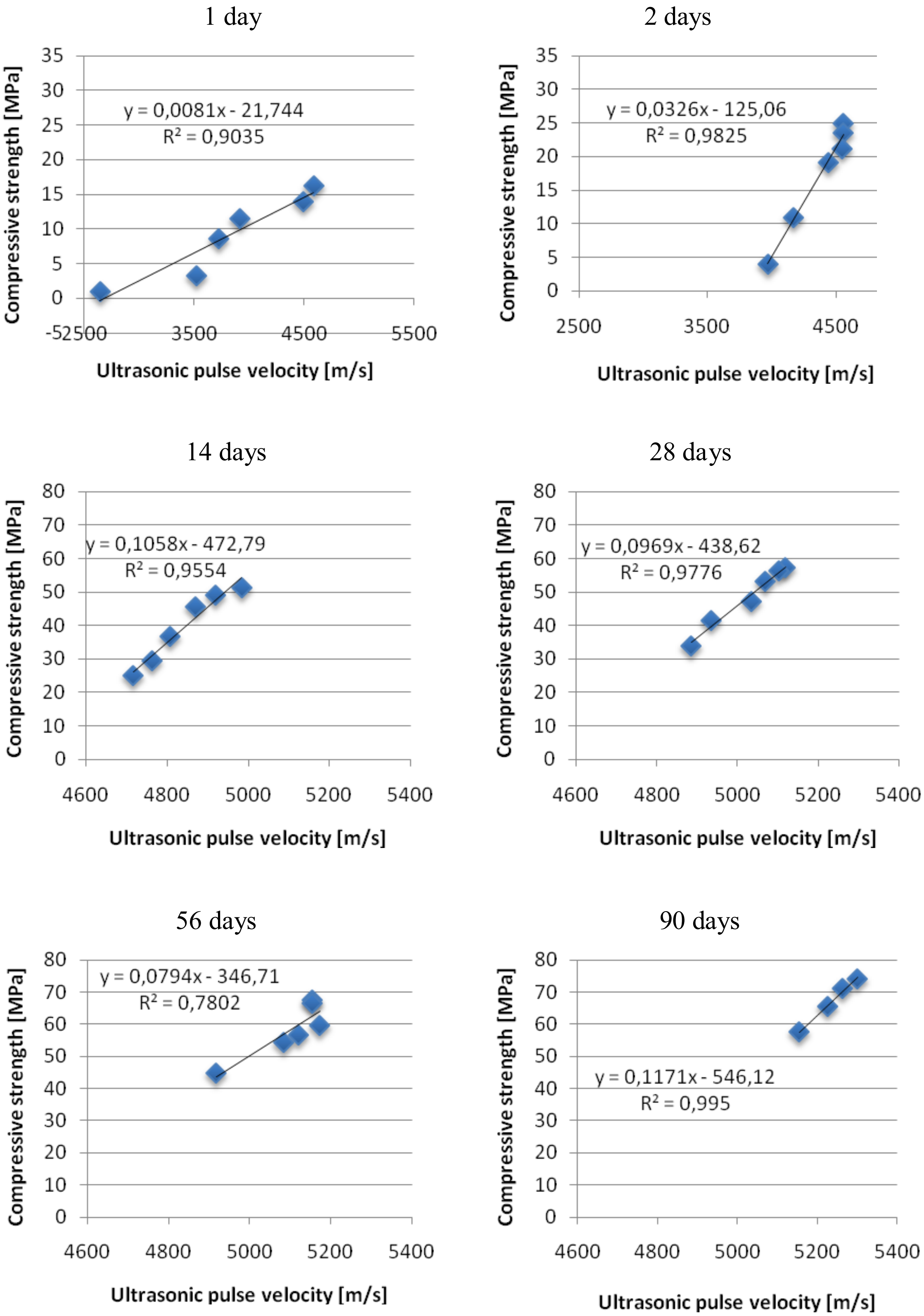

Figure 1. The correlations between compressive strength and ultrasonic pulse velocity

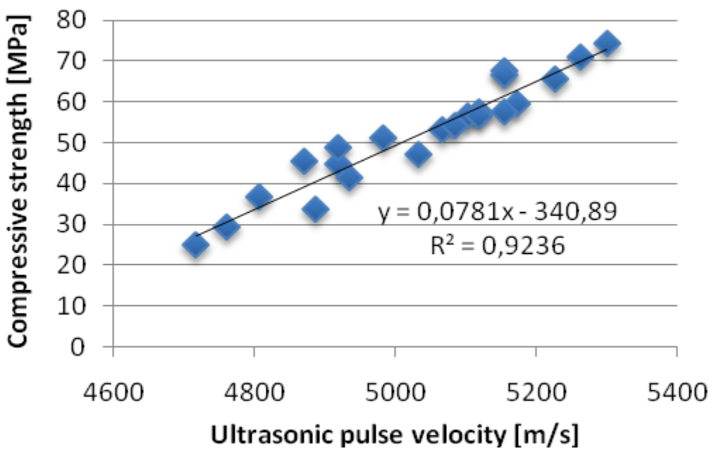

Figure 2. The correlation between compressive strength and ultrasonic pulse velocity of the samples of age14, 28, 56 and 90 days

4. CONCLUSION

Compressive strength of the SCC samples decreases by increasing the fly ash content in the early period (up to 28 days).Those results were expected since the samples with the higher fly ash content contain less hydraulic component (cement). After 56 days, samples with 35 and 42,5 % of fly ash surpassed the compressive strength values of the reference samples (SCC I). Also, after 90 days the samples with 50 % of fly ash achieved the higher compressive strength values than the reference samples. The early strength of the samples with 57,5 and 65 % of fly ash content are very low, but after 28 days these samples achieved the compressive strength values acceptable for some practical applications. Compared to the reference samples, the decrease of compressive strength was 27,5 % after 28 days (SCC V) and 40,9 % (SCC VI). With increasing the age of samples the reduction of compressive strength becomes lower, so that after 56 days the compressive strength is 9,1 and 25,0 % lower than reference samples, and after 90 days it is 6,2 and 24,2 % lower for those samples, respectively. The investigation results showed that there is a strong correlation between compressive strength and ultrasonic pulse velocity of the samples after 14 days or more.

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