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PROPERTIES OF SELF-COMPACTING CONCRETE CONTAINING TYPE C FLY ASH

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ABSTRACT
This paper presents results of investigation of possibility of use Class C fly ash in self compacting concrete (SCC) production. The results of fresh and hardened properties of SCC show that replacement of milled dolomite filler by fly ash lead to increase of SCC compressive strength, dynamic modulus of elasticity and density, while consistency of fresh SCC mixtures are not significantly changed. The results further indicate that economical benefits can be achieved by cement content reduction.

Keywords: Self compacting concrete (SCC), fly ash, Class C, slump-flow, L-box, density, compressive strength, dynamic modulus of elasticity

1. INTRODUCTION
Self compacting concrete (SCC) is an innovative type of cement based composite that drastically reduces construction time, the noise pollution, amount of work required to compact the concrete mixture and equipment on the site. SCC flows under the influence of its own weight without segregation. Because of the way SCC flows, it deaerates and fills all voids bypassing the reinforcing bars and eventually retains horizontal surface without the use of vibrating devices. Better workability and resistance to segregation of components, higher strength in the hardened state, easier placing and increased durability are just some of the characteristics that differ self-compacting concrete from conventional concrete [1,2]. Products made with SCC have an excellent finish, and are virtually free of larger voids. Also, SCC is especially convenient for concrete structures heavily congested with rebar. Apart from flowability, stability or resistance to segregation of fresh scc mixture is its most important properties [3].
The high flowability of SCC is generally attained by using superplasticizers (high range water reducing admixtures). The stability of the fresh concrete mixture can also be attained using admixtures that modify the viscosity of the mixture, but increasing the total quantity of fines in the concrete is necessary. Increased fines contents can be achieved by increasing the content of cementititious materials or by incorporating inert fillers (stone dust form limestone, quartz, granite) or fly ash and blast furnace slag which possess *pozzolanic* reactivity and/or latent hydraulic reactivity [4,5].
Fly ash is a very fine, powdery material, composed of spherical particles. Fly ash is generated in large quantities as by-product from the burning of pulverized coal in powerplants. It is removed from the plant exhaust gases primarily by electrostatic precipitators or baghouses and disposed off in the ash ponds or in the open lands. Because of the environmental problems presented by the fly ash, considerable amount of research has been undertaken on this subject worldwide. In this paper, the utilization of fly ash in SCC production has been investigated.

Fly ash improves the properties of concrete in two ways:

- physical effects associated with increasing the content of fine particles-particles in concrete mixture
- pozzolanic and/or hydraulic reactions.

ASTM C618 defined two classes of fly ash are defined by: Class F and Class C. The main difference between these classes is the amount of calcium, silica, alumina, and iron content in the ash. Class F fly ash is pozzolanic in nature, and contains less than 20% CaO, while Class C fly ash generally contains more than 20% CaO [6].

2. EXPERIMENTAL WORK

The investigation was conducted on three concrete mixtures. Compositions of the concrete mixtures are shown in Table 1. All mixtures had the same water-cement ratio (0,48) and the same amount of binder and aggregate fractions. Mixture "I" included only milled dolomite as filler. Filler in mixture "II" is consisted of 50% milled dolomite and 50% fly ash from Power plant "Kakanj", while in mixture "III" milled dolomite is totally replaced by fly ash.

Table 1. Composition of SCC mixtures

	I	**II**	**III**
Cement CEM II/A-M (S-V) 42,5 [kg]	410	410	410
Water [kg]	196,8	196,8	196,8
w/c ratio	0,48	0,48	0,48
Superplasticizer [kg]	4,1	4,1	4,1
Agreggate [kg]			
• fraction 0/4 mm	805,6	805,6	805,6
• fraction 4/8 mm	241,7	241,7	241,7
• fraction 8/16 mm	563,9	563,9	563,9
Filler [kg]	173,4	86,7	-
Fly ash [kg]	-	86,7	173,4

Physico-chemical properties of fly ash used and the requirements prescribed by ASTM C618 for Class C fly ashes are shown in Table 2.

Table 2. Physico-chemical properties of fly ash from Power plant "Kakanj"

	Content [%]	ASTM C618
Ignition Loss	0,95	max. 6,0 %
SiO_2	39,8	$SiO_2 + Fe_2O_3 + Al_2O_3 \geq 50\%$
Fe_2O_3	7,15	
Al_2O_3	20,48	
TiO_2	0,66	
CaO	25,6	
CaO (free)	0,96	
MgO	1,64	
MnO	0,01	
BaO	0,11	
K_2O	1,69	
Na_2O	0,32	
Cl^-	0,04	
SO_3	1,57	

Fresh concrete mixtures were subjected to folowing testing:

- Slump-flow test (EN 12350-8:2010),
- L-box test (EN 12350-10:2010),
- Air content (EN 12350-7:2009),
- Density (EN 12350-6:2009).

Results of fresh SCC tests are given in tables 3-5.

Table 3. Results of slump-flow test

SCC mixture	I	II	III
D_{max} (mm)	840	810	760
T_{500} (s)	0,91	1,5	2,6
Class SF	SF3	SF3	SF3

Table 4. Results of L-box test

SCC mixture	I	II	III
H_1 (mm)	92	94	95
H_2 (mm)	88	83	84
H_2/H_1	0,96	0,88	0,88
Class PA	PA1	PA1	PA1

Table 5. Density and air content of SCC mixtures

SCC mixture	Density, kg/m^3	Air content, %
I	2425	1,4
II	2450	1,25
III	2535	1,2

Concrete cubes are made from each mixture and tested after 28 days. Density of hardened concrete were measured according to EN 12390-7:2009, and compressive strength according to EN 12390-3:2009. The dynamic modulus of elasticity was also estimated based on ultrasonic pulse velocity measurements (EN12504-4:2004). Hardened properties of SCC are shown in Table 6.

Table 6. Hardened properties of SCC

SCC	I	II	III
Density (kg/m^3)	2448,3	2464,4	2476,7
Compressive strength (MPa)	*62,1*	*66,1*	*76,1*
Dynamic modulus of elasticity (GPa)	53,7	57,1	58,3

3. CONCLUSIONS

Partial or complete replacement of milled dolomite by fly ash leads to a slight increase in viscosity of concrete mix, which is manifested by a smaller measure of slump-flow and reduced ability to pass through narrow openings (L-box). However, these changes are not substantial and class of SCC consistency remains the same.

The introduction of fly ash in the SCC mixtures led to an increase in compressive strength of concrete at 28 days, dynamic modulus of elasticity and density. This increase in strength is particularly distinct in samples in which only fly ash is used as filler. It raises the possibility of cement content reduction, which would significantly reduce the cost of concrete.

4. REFERENCES

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