International Conference on Sustainable Materials, Systems and Structures (SMSS 2019)

New Generation of Construction Materials

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SELF – COMPACTING CONCRETE WITH TAILINGS AND FLY ASH AS ECOLOGICAL MATERIAL

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Abstract

Concept of sustainable development, which beside sociological and economic aspects, includes saving of energy, environment protection and preservation of restorable natural resources, presents strategic determination of various economic sectors. During the ore flotation in the mine large amounts of flotation tailings are generated and as waste material disposed in the specially determined areas. With the increase in metal production, the amount of tailings also increases, which is a major environmental problem because it takes up large areas. Great production of fly ash, which is the main residue from combustion of coal, also "managed" by landfilling, is a huge risk and danger for environment. Unlike vibrated concrete, self-compacting concrete contains significant amounts of fine particles, i.e. a mineral additive that greatly affects its performance, where potential use of fly ash is very important ecological aim. Tailing test results showed no pozzolanic activity and so its application in concrete can be only a partial replacement of aggregate.This paper presents the possibility of using tailings and fly ash, which are waste products, in Self – Compacting Concrete. The obtained results indicate that these materials can successfully be used.

Keywords: Self – Compacting Concrete, Tailings, Fly ash, Compressive strength.

1. INTRODUCTION

During the ore flotation in the mine large amounts of flotation tailings are generated and as waste material it is disposed in the specially determined areas in the industrial site. With the increase in metal production, the amount of tailings also increases, which is a major environmental problem because it takes up large areas. Great production of fly ash, which is the main residue from combustion of coal, also "managed" by landfilling, is a huge risk and danger for environment. By its technology, Self – Compacting Concrete (SCC), requires a certain amount of powder component for the production, so the possibility of using fly ash and tailings in the area of the concrete creates space for various research.

It is possible to use copper tailing in cement concrete as a partial replacement of natural river sand (up to 60% substitution) – the copper tailing concrete exhibited good strength and durability characteristics [1]. The effect of the application of copper tailings, which substitute 0%, 5% and 10% of cement mass on the properties of fresh and hardened mortar was investigated [2]. Copper tailings blended mortars showed higher strength and abrasion resistance. The study [3] showed that increasing the tungsten mine waste content in mortar mixes decreased both flowability and compressive strength. The aim of the paper [4] was to study combined effects of prefiring and firing dwell times on the chemical, physical and microstructural properties of artificial lightweight aggregates produced from mining and industrial waste, including polluted mine soli and coal combustion products. The same authors presents a study about the effectiveness of thermal treatment in the immobilization of different chemical elements within the structure of artificial lightweight aggregates manufactured with contaminated soil and fly ash [5].

The utilization of fly ash in the SCC resulted in a lower wet density, mechanical properties and a higher water porosity, carbonation depth and chloride ion diffusion coefficient [6]. Increasing the fly ash content has been found to decrease the compressive strength at all the curing ages tested in investigation [7]. A maximum decrease in the compressive strength of the order of 25% at 28 days of curing.

2. EXPERIMENT

2.1 Materials used in experiment

Self – Compacting Concrete was prepared with: cement CEM I 42.5R Lafarge, natural separated aggregate 0/4mm, 4/8mm and 8/16mm, mineral additive limestone (when tailing was used), superplasticizer (polycarboxylate) and potable water.

For the purpose of this study the tailings was taken from the Pb and Zn mines, from the tailings dump. Complete testing of chemical, physical and mechanical properties of the samples was performed. The chemical composition of the tailings sample was determined by chemical analysis according to SRPS EN 196-2. There active SiO_2 and CaO content was calculated on the basis of the results of chemical analysis according to SRPS EN 197-1 standard. The test results are shown in Table 1.

The physical properties of the tailings were determined in accordance with SRPS B.C1.018 standard. The samples were milled because of a high content of coarse particles so that the residue on the 0.063 mm sieve was up to 10%, and then tested for pozzolanic activity using lime. Pozzolanic activity of the tailing was determined as the strength of mortar samples prepared with 300g of milled tailing sample, 1350g of quartz sand, 150g of hydrated lime and 270g of water. The results of pozzolanic activity were extremely low (flexural strength 0 MPa, compressive strength 0.4 MPa), which confirmed the results of the reactive SiO_2 content calculation. The conclusion is that this material is not suitable for cement replacement in concrete and mortar or as a pozzolanic cement additive. So, tailings can only be used for replacement a part of the fine aggregate.

Table 1: The chemical properties of tailings

Loss on ignition on 950 °C, %	5.61
SiO_2, %	43.26
Al_2O_3, %	11.11
Fe_2O_3, %	15.57
CaO, %	20.01
MgO, %	4.31
SO_3, %	0.32
Na_2O, %	0.92
K_2O, %	1.00
CO_2, %	4.42

When fly ash is added to concrete, pozzollanic reaction starts between silicon dioxide (SiO_2) and calcium hydroxide ($CaOH_2$) or lime, which is a by-product of hydration of Portland cement. The resulting products of hydration fill pores reducing the porosity of the matrix. These products differ from the products formed in concrete containing only Portland cement. In the reactions of Portland cement and water, hydrated lime ($CaOH_2$) is formed first, in the space between particles, because of its limited solubility. In the presence of water, lime reacts pozzollanic with fly ash to form new hydration products with fine pore structures. So, fly ash can be used as pozzolanic cement additive. For the purpose of this study, fly ash was taken from thermal power plant "Obrenovac B" – direct from filter. It's chemical composition is shown in Table 2.

Table 2: The chemical properties of fly ash

SiO_2, %	53.84
Al_2O_3, %	30.29
Fe_2O_3, %	3.6
CaO, %	5.15
MgO, %	3.0
SO_3, %	1.86
Na_2O, %	0.51
K_2O, %	0.83
P_2O_5, %	0.23
TiO_2, %	0.73

2.2 Self-Compacting Concrete

Composition of concrete mixtures is shown in Table 3. Two different types of Self – Compacting Concrete were made: A: SCC–T_% - Self – Compacting Concrete made with Portland cement and a partial replacement of 10 and 20% of fine aggregate with tailings; B: SCC-L – Self Compacting Concrete made with lime as mineral addition; SCC-FA – Self Compacting Concrete made with fly ash as mineral addition. The criteria in the mixture design was achieving slump - flow class SF1 for type A (spreading from 550 to 650 mm), and SF2 for type B, which includes the usual application of concrete and involves spreading from 660 to 750 mm, according to SRPS EN 206-1.

Table 3: Compositions of concrete mixtures

	Concrete mixture	Cement kg/m³	0/4mm kg/m³	4/8mm kg/m³	8/16mm kg/m³	Lime kg/m³	Fly ash kg/m³	Tailing kg/m³	Superpl kg/m³	Water kg/m³
A	SCC-T_0%	350	782	434	521	100	0	0	3.6	180
	SCC-T_10%	350	703.8	434	521	100	0	78.2	3.6	180
	SCC-T_20%	350	625.6	434	521	100	0	156.4	3.6	180
B	SCC-L	400	770.86	306.28	532	120	0	0	4.94	170.8
	SCC-FA	400	770.9	306.3	532	0	120	0	4.94	193

3. RESULTS AND DISCUSSION

3.1 Properties of fresh concrete

The properties of fresh concrete are shown in Table 4. Slump flow test, testing with V-funnel and L-box and sieve segregation were done according to SRPS EN 12350-8, SRPS EN 12350-9, SRPS EN 12350-10 and SRPS EN 12350-11.

Table 4: The properties of fresh Self – Compacting Concrete

	Concrete mixture	Slump-flow mm	V funnel sec	L-box H2/H1	Sieve segregation (%)	Density in the fresh state (kg/m³)
A	SCC-T_0%	610	6.7	0.84	6.8	2335
	SCC-T_10%	600	7.1	0.91	6.6	2371
	SCC-T_20%	600	7.6	0.96	5.5	2375
B	SCC-L	730	6.3	1.0	12.4	2418
	SCC-FA	700	5.8	0.96	11	2288

By Slump-flow test is checked first of the four key characteristics of SCC: flowability. Spreading was between 600 to 610 mm, and it ranked all the projected mixtures with tailings in class SF1. Mixture with fly ash “fitted” in class SF2 corresponding to the most common use of concrete in construction.

V –funnel test represents checking of the mixture viscosity. Time period less than 9 seconds puts them in a class of viscosity VF1. There was no segregation nor any accumulation of water at the surface that could be collected.

L-box test is used for checking of the third key property: the passing ability of SCC between reinforcing bars without blocking. All mixtures meet the criterion for the relative height of the concrete at the ends of L-box is at least 0.8; and how the testing was done with three reinforcing bars (which is a requirement for densely reinforced structures) their class is PA2. The test results are in the range from 0.84 – 1.0). Resistance to segregation as a fourth property of fresh SCC has been tested in sieve paste. The results show that all blends/mixtures are resistant to segregation and belong to the class SR2 (<15%).

It should be noted that the usage of tailings did not affect self – compacting properties of concrete a lot, while fly ash increased slump-flow.

3.2 Compressive strength

Testing compressive strength of concrete at the age of 3, 7 and 28 days was carried out according to SRPS EN 12390 -3 standard. Bulk density of hardened concrete was tested according to SRPS EN 12390-7 standard and ranged from 2262 to 2462 kg/m^3. The test results are shown in Figure 1 and Figure 2.

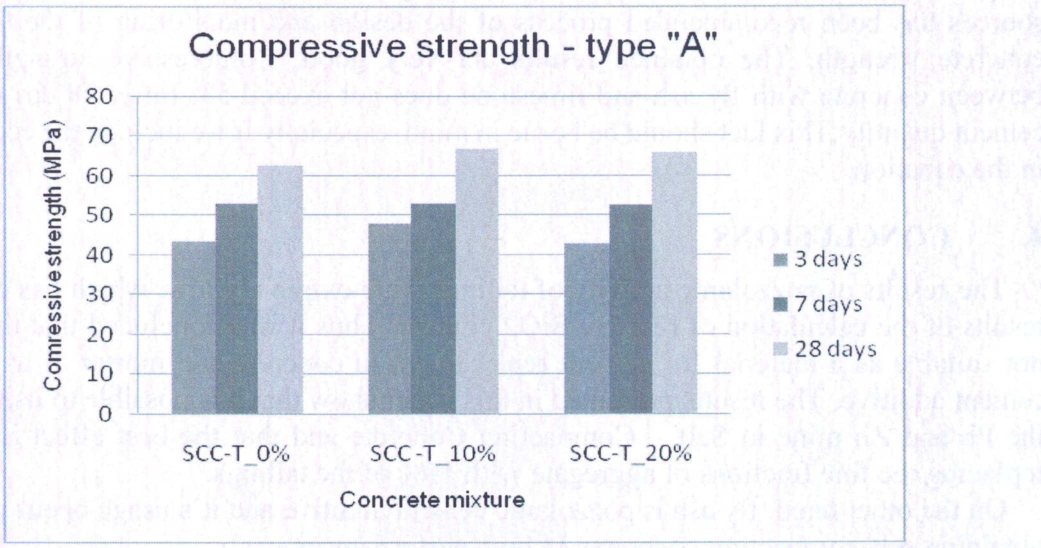

Figure 1: Compressive strength of concrete "A"

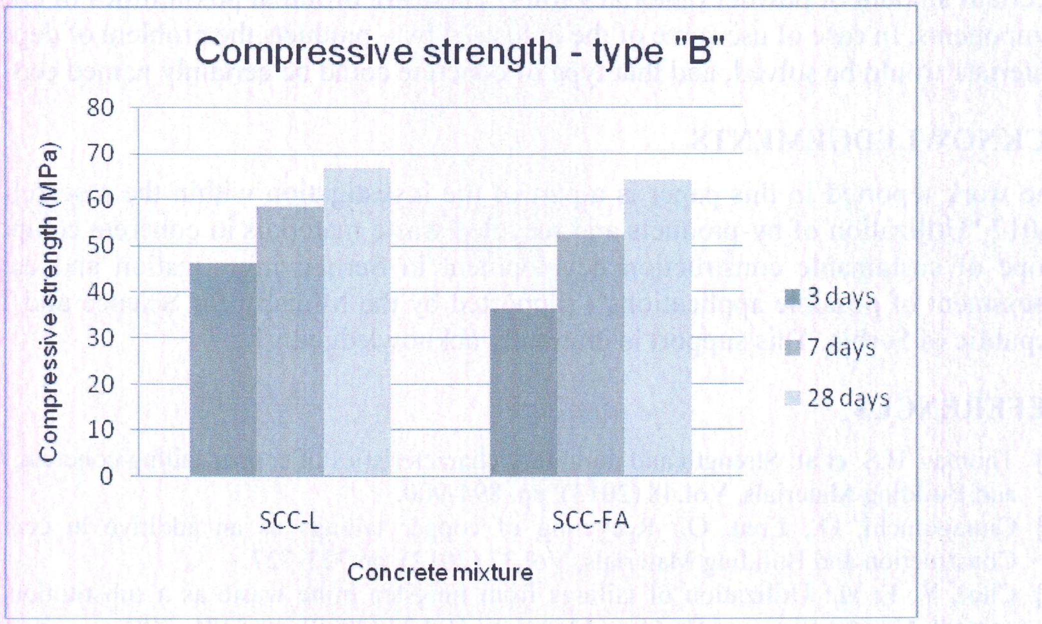

Figure 2: Compressive strength of concrete "B"

The differences between obtained results do not exceed 10%. Concrete with 10% and 20% addition of tailings achieved higher strengths when compared to the reference concrete at 28 days of age.

Slower growth of concrete strength with fly ash prevents its application, at the expected high early strength, which can be solved by applying the accelerator. At the available literature sources has been recommended process of the design and monitoring of the 90 - day long concrete strength. The obtained results are very good: Compressive strength differences between concrete with fly ash and limestone does not exceed 5% (after 28 days) at the same cement quantity.This fact should be borne in mind, especially if we include the economic factor in the equation.

4. CONCLUSIONS

The results of pozzolanic activity of tailings were extremely low, which has confirmed the results of the calculation of reactive SiO2 content. Thus it was concluded that this material is not suitable as a material for cement replacement in concrete and mortar or as a pozzolanic cement additive. The results presented in this paper show that it is possible to use tailings from the Pb and Zn mine in Self – Compacting Concrete and that the best effect is achieved by replacing the fine fractions of aggregate with 10% of the tailings.

On the other hand, fly ash is pozzolanic cement additive and it's usage opens possibility for obtaining self-compacting concretes of high performances.

Self-Compacting Concrete, also an innovation in the field of concrete technology, contains a certain amount of powder material - filler. There are different possibilities of choosing these components. In case of use some of the industrial by – products the problem of depositing these materials would be solved, and that type of concrete could be certainly named eco-friendly.

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