АКАДЕМИЈА НАУКА И УМЈЕТНОСТИ РЕПУБЛИКЕ СРПСКЕ

НАУЧНИ СКУПОВИ
Knjiga XLII

ОДЈЕЉЕЊЕ ПРИРОДНО-МАТЕМАТИЧКИХ И ТЕХНИЧКИХ НАУКА
Knjiga 35

САВРЕМЕНИ МАТЕРИЈАЛИ

А·Н·У·Р·С

Бања Лука 2018

Научни скуп

САВРЕМЕНИ МАТЕРИЈАЛИ

Зборник радова

ACADEMY OF SCIENCES AND ARTS OF THE REPUBLIC OF SRPSKA

SCIENTIFIC CONFERENCES
Book XLII

DEPARTMENT OF NATURAL-MATHEMATICAL AND TECHNICAL SCIENCES
Book 35

CONTEMPORARY MATERIALS

Banja Luka 2018

АКАДЕМИЈА НАУКА И УМЈЕТНОСТИ РЕПУБЛИКЕ СРПСКЕ

НАУЧНИ СКУПОВИ
Књига **XLII**

ОДЈЕЉЕЊЕ ПРИРОДНО-МАТЕМАТИЧКИХ И ТЕХНИЧКИХ НАУКА
Књига **35**

САВРЕМЕНИ МАТЕРИЈАЛИ

А·Н·У·Р·С

Бања Лука **2018.**

INFLUENCE OF TAILINGS AND FLY ASH ON THE STRENGTH OF SELF-COMPACTING CONCRETE

Iva Despotović[1], Ksenija Janković[2]
[1]Visoka građevinsko-geodetska škola Beograd, Srbija
[2]Institut IMS Beograd, Srbija

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. In that way great contribution is expected from construction industry. Self-compacting concrete has significant environmental advantages in comparison to the vibrated concrete: absence of noise and vibrations during installing provides a healthier working 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.

Key words: 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.

The research [8] presents findings on the influence of high-calcium fly ash (HCFA) on selected properties of fresh and hardened SCC and high performance SCC. HCFA was used as an additive for concrete (up to 30%) or as a main constituent in cement. Studies have confirmed the possibility of HCFA use in self-compacting concrete, while maintaining the assumed workability of fresh concrete and compressive strength of hardened concrete. HCFA should be processed by grinding, and its amount in the mixture should not be higher than 30% of the cement's mass.

The influence of HCFA and silica fume as a binary and ternary blended cement on compressive strength and chloride resistance of SCC were investigated in study [9]. HCFA (40–70%) and silica fume (0–10%) were used to replace part of cement at 50, 60 and 70 wt.%. The results show that binary blended cement with high level fly ash generally reduced the compressive strength of SCC at all test ages. Fly ash decreased the charge passed of SCC and tends to decrease with increasing fly ash content, although the volume of permeable pore space (voids) and water absorption of SCC were increased.

2. EXPERIMENTAL WORK

2.1. Component materials

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.

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
Insoluble residue in HCl/Na_2CO_3, %	66.37
Insoluble residue in HCl/KOH, %	46.15
Content of reactive SiO_2, %	16.04
Content of reactive CaO, %	14.15

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.

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 209-1.

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

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. Bulk density in the fresh state ranged from 2300 to 2370 kg/m^3.

Table 4: The properties of fresh Self – Compacting Concrete

	Concrete mixture	Slump-flow (mm)	V funnel (sec)	L-box (H2/H1)	Sieve segregation (%)
A	SCC-T_0%	610	6.7	0.84	6.8
	SCC-T_10%	600	7.1	0.91	6.6
	SCC-T_20%	600	7.6	0.96	5.5
B	SCC-L	730	6.3	1.0	12.4
	SCC-FA	700	5.8	0.96	11

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 or bleeding noticed.

L-box test (Figure 1) 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 (Figure 2). 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 densified the mixture.


Figure 1. L-box test, Figure 2. Sieve segregation test

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 3 and Figure 4.

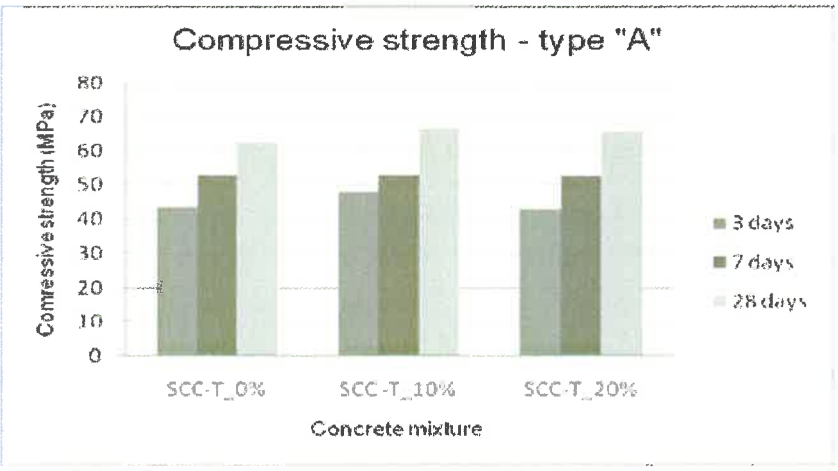

Figure 3. Compressive strength of concrete "A"

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.

Influence of fly ash on concrete compressive strength: when fly ash is added to concrete begins pozzolanic reaction between silicon dioxide (SiO_2) and calcium hydroxide ($Ca(OH)_2$) i.e. lime, which is a by-product of Portland cement hydration. Light pozzolanic reaction takes place during the first 24 hours at 20°C. Therefore, given amount of cement with increased fly ash results in lower early strength. The presence of fly ash slows reaction of alite within the Portland cement in the early stage. However, the production of alite would later accelerate thanks to the formation of hydration core on the surface of fly ash particles.

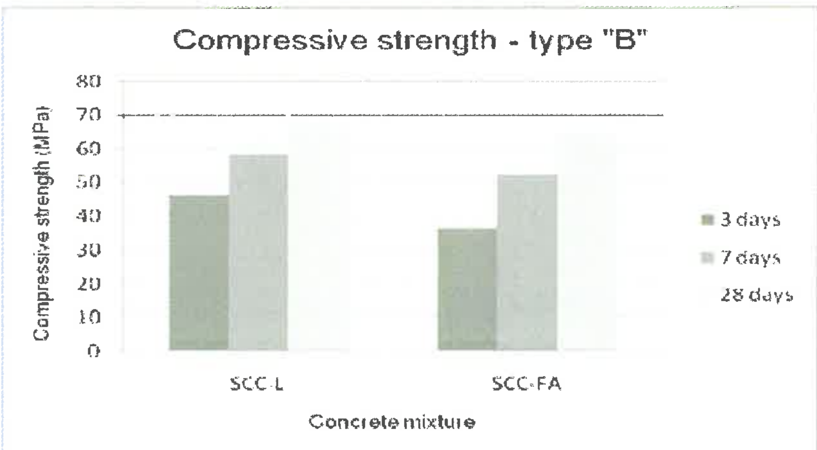

Figure 4. Compressive strength of concrete "B"

Calcium hydroxide is imprinted on the surface of the glassy particles having its reaction with SiO_2 or SiO_2 Al_2O_3- grid. 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.

ACKNOWLEDGMENTS

The work reported in this paper is a part of the investigation within the research project TR 36017 "Utilization of by-products and recycled waste materials in concrete composites in the scope of sustainable construction development in Serbia: investigation and environmental assessment of possible applications", supported by the Ministry for Science and Technology, Republic of Serbia. This support is gratefully acknowledged.

REFERENCES

[1] Thomas, B. S. et al: *Strength and durability characteristics of copper tailing concrete*, Construction and Building Materials, Vol.48 (2013), pp. 894-900.

[2] Onuaguluchi, O.; Eren, O.: *Recycling of copper tailings as an additive in cement mortars*, Construction and Building Materials, Vol.37 (2012), pp.723-727.

[3] Choi, Y. Et al.: *Utilization of tailings from tungsten mine waste as a substitution material for cement*, Construction and Building Materials, Vol. 23 (2009), pp. 2481-2486.

[4] Gonzales-Corrochano, B. et al.: *Effect of prefiring and firing dwell times on the properties of artificial lightweight aggregates,* Construction and Building Materials, Vol.53 (2014), pp.91-101.

[5] Gonzales-Corrochano, B. et al.: *Effect of thermal treatment on the retention of chemical elements in the structure of lightweight aggregates manufactured from contaminated mine soil and fly ash,* Construction and Building Materials, Vol.35 (2012), pp.497-507.

[6] Hui Z. et al.: *The properties of the self – compacting concrete with fly ash and ground granulated blast furnace slag mineral admixtures,* Journal of cleaner production, Vol.95 (2015), pp. 66 -74.

[7] Singh N., Singh S.P.: *Carbonation resistance and microstructural analysis of Low and High Volume Fly Ash Self Compacting Concrete containing Recycled Concrete Aggregates,* Construction and Building Materials, Vol.127 (2016), pp.828-842.

[8] Ponikiewski T., Golascewski J.: *The influence of high-calcium fly ash on the properties of fresh and hardened self-compacting concrete and high performance self-compacting concrete,* Journal of cleaner production, Vol.72 (2014), pp. 212 -221.

[9] Wongkeo W. et al.: *Compressive strength and chloride resistance of self-compacting concrete containing high level fly ash and silica fume,* Materials and Design, Vol. 64 (2014), pp. 261–269.

И. Деспотовић, К. Јанковић

УТИЦАЈ ЈАЛОВИНЕ И ЛЕТЕЋЕГ ПЕПЕЛА НА ЧВРСТОЋУ САМОУГРАЂУЈУЋЕГ БЕТОНА

Апстракт: Концепт одрживог развоја, који осим социолошког и економског аспекта подразумева и уштеду енергије, заштиту животне средине и очување природних ресурса, представља стратешко опредељење многих привредних грана. У том смислу је посебно значајан допринос грађевинарства. Самоуграђујући бетон има бројне предности у односу на вибрирани бетон: одсуство буке и вибрација током уграђивања обезбеђује здравије радно окружење. За разлику од вибрираног бетона, самоуграђујући бетон садржи знатну количину финих честица – минерални додатак, који знатно утиче на карактеристике бетона, при чему је употреба летећег пепела еколошки веома значајна. Испитивања јаловине показују одсуство пуцоланске активности, те се она у бетону може примењивати само као делимична замена агрегата. У овом раду је приказана могућност употребе јаловине и летећег пепела, који су индустријски нус-производи, у самоуграђујућем бетону. Добијени резулати показују да се ови материјали могу успешно користити.

Кључне ријечи: Самоуграђујући бетон, јаловина, летећи пепео, чврстоћа при притиску.

CIP-Каталогизација у публикацији
Народна и универзитетска библиотека
Републике Српске, Бања Лука

620.1(082)

МЕЂУНАРОДНИ научни скуп Савремени материјали
(10 ; 2017 ; Бања Лука)
Савремени материјали : [зборник радова] / [Међународни научни скуп], Бања Лука, [9-10. новембар 2017. године] ; редакциони одбор Рајко Кузмановић ... [и др.] ; главни уредник Рајко Кузмановић ; одговорни уредник Драгољуб Мирјанић. - Бања Лука : Академија наука и умјетности Републике Српске, 2018 (Лакташи : Графомарк). - 568 стр. : илустр. ; 24 cm. - (Научни скупови ; књ. XLII. Одјељење природно-математичких и техничких наука ; књ. 35)

На спор. насл. стр.: Contemporary Materials. - Текст на срп. и енгл. језику. - Текст ћир. и лат. - Тираж 300. - Библиографија уз сваки рад. - Abstract.

ISBN 978-99938-21-98-4

COBISS.RS-ID 7388952