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THE INFLUENCE OF RECYCLED CONCRETE AGGREGATE ON THE PROPERTIES OF SELF – COMPACTING CONCRETE

Abstract: In the last years, due to the environmental protection and sustainable development requirements becoming stricter and broader, a large number of researches worldwide has been conducted mainly focused on the potential of application of the old concrete as an aggregate for production of conventionally vibrated or self – compacting concrete. The presence of old cement mortar significantly affects a number of physical and mechanical properties, of both recycled aggregate and concrete with recycled aggregate. Available data from the literature, and own previous researches are used in this paper to show the influence of recycled concrete aggregate on the characteristics of self – compacting concrete in the fresh and in the hardened state.

Key words: Recycled concrete aggregate, self – compacting concrete, sustainable developement

UTICAJ PRIMENE RECIKLIRANOG AGREGATA NA SVOJSTVA SAMOUGRAĐUJUĆEG BETONA

Rezime: Poslednjih godina problem zaštite životne sredine i zahtevi održivog razvoja postaju sve striktniji, te je sproveden veliki broj istraživanja širom sveta sa fokusom na potencijalnoj primeni starog betona kao agregata za spravljanje vibriranog ili samougrađujućeg betona. Prisustvo starog cementnog maltera značajno utiče na svojstva kako recikliranog agregata, tako i betona sa ovim agregatom. Dostupni podaci iz literature, kao i sopstvena eksperimentalna istraživanja su korišćeni u ovom radu za prikazivanje uticaja recikliranog agregata na svojstva samougrađujućeg betona u svežem i očvrslom stanju.

Ključne reči: reciklirani agregat, samougrađujući beton, održivi razvoj

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1. INTRODUCTION

Due to the changes in the requirements and planning of concrete structures, excessive amount of construction and demolition (C&D) waste is generated in urban areas worldwide. Annually, 900 million tonnes of C&D waste is estimated in Europe, USA and Japan [1]. The control and management on C&D waste is becoming a worldwide challenge, especially for the major urban centres. Considering the environmental pollution and the consumption of limited natural sources it is crucial to reuse and recycle C&D waste. The production of recycled concrete aggregate from C&D waste is important issue since it provides an alternative mean to the dependence of construction industry on natural aggregates and the critical shortage problem of natural aggregate sources. It is estimated that in the Republic of Serbia, about 1 million tons of construction and demolition waste is annually produced. This waste ends up in landfills of municipal waste, and is also used as inert material for coverage of waste at landfills. Recycling construction waste actually does not exist [2].

Self – compacting concrete (SCC), according to many authors "the most revolutionary discovery of concrete industry of the 20th century", does not need vibrating when placing and compacting. Under the influence of its own weight, it completely fills all parts of the formwork, even in the presence of dense reinforcement. With self–compacting concrete, its most important characteristics are in its fresh state. When designing mixes, emphasis is placed on the ability of concrete to be levelled out only under the influence of its own weight and to fully fill the formwork of any shape and dimensions without leaving voids, to pass through dense reinforcement without blocking, to retain a homogenous structure without separating aggregate from paste or water from the solid phase, as well as without the tendency of coarse aggregates to "fall" through the concrete mass under the influence of gravity (segregation). Therefore, the key characteristics of fresh SCC are floating, viscosity (expressed by floating rate), passing ability and resistance to segregation [3].

The potential use of recycled aggregates in the SCC composition increases the ecological value and partly solves the issues of waste disposal sites generated by construction and demolition of structures. Since this aggregate differs from the natural aggregate in its sharp-edged shape of grains and the layer of old cement paste which envelops them, its application will cause certain specificities in the design and characteristics of fresh self-compacting concrete, which is the subject of this paper.

2. RECYCLED CONCRETE AGGREGATE

Technological process for the production of recycled aggregates involves crushing pieces of old concrete (Figure 1) to a certain grain size and their sieving, which is preceded by the separation of metal parts, using magnetic separator, and manual or mechanical removal of foreign substances. Grains of recycled aggregate, obtained by this recycling process, consist of grains (or grain parts) of natural aggregates and cement mortar of original concrete which partially or completely wraps them. The amount of cement mortar in recycled aggregates ranges from 25% to 65% (expressed in volume percentages) and it differs among different fractions – the finer fraction, the greater the amount of cement mortar. Water absorption of coarse recycled aggregate ranges from 3.5% to 10%, and of small aggregate from 5.5% to 13% [4].

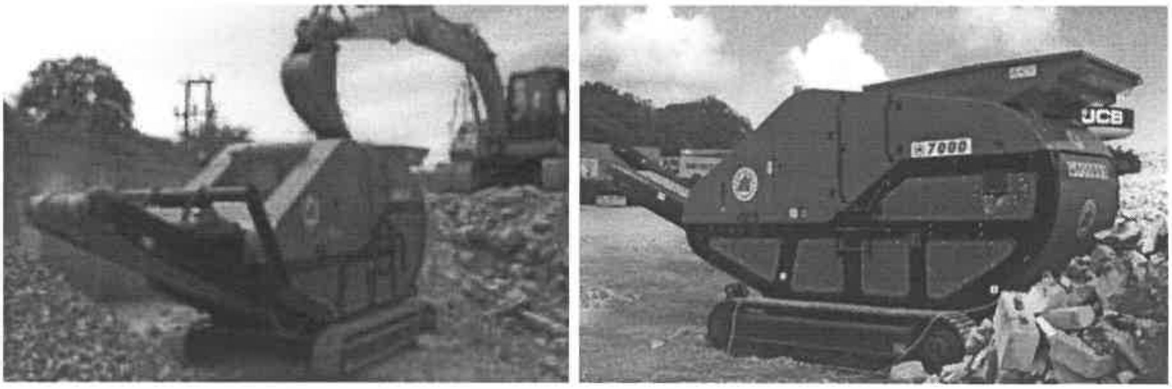

Figure 1 - Production of recycled aggregate [5]

The presence of old cement mortar, which is of less density and higher porosity than grains of natural aggregates, significantly affects a number of physical and mechanical properties, of both recycled aggregate and concrete with recycled aggregate, i.e. causes " worse" properties of recycled aggregate compared to natural aggregate. Therefore, numerous researches have been carried out worldwide with the aim of improving recycling technologies and obtaining recycled aggregates that would be practically identical to natural aggregate in their properties or quality. Some of them are: submerging in HCI (hydrochloric acid) solution at 0.1 molarity for 24 h at 20 °C, submerging in water glass ($Na_2O \cdot \eta SiO_2$ sodium silicate) for 30 min, submerging in cement–silica fume slurry for 30 min, the implementation of two-stage mixing approach [1].

3. EXPERIMENTAL RESEARCH

3.1. Composition of Concrete Mixes

For the purposes of the experimental work, nine three-fraction concrete mixes have been made. Cement PC 42.5R (Holcim Popovac) has been used as well as mineral additives: lime (manufacturer "Jelen Do"), fly ash (from the power plant "Nikola Tesla B" in Obrenovac), and silica fume (product of Sikafume , a manufacturer of building chemicals SIKA); natural aggregate (Luka "Leget", Sremska Mitrovica), recycled aggregate obtained by crushing demolished retaining wall in the quarry Ostrovica, near Nis. Control concrete was made with each of the additives and a natural aggregate; in mixes K50, P50 and S50, fraction 8/16mm was replaced by the recycled aggregate, and in mixes K100, P100 and S100, both coarse fractions (4/8 and 8/16) were replaced by recycled fractions. In all the mixes, superplasticizer ViscoCrete 5380 (manufacturer SIKA) has been used, which was dosed according to the manufacturer. The criterion in the designing mixes was to achieve the same consistency of concrete, i.e. slump-flow class SF2, which includes the usual uses of concrete and involves spreading from 66 to 75cm. While making concrete mixes, the aggregate was first mixed with half of the required water for a period of about 30 seconds, and then other components were added. When used recycled aggregate, the amount of water which was absorbed by the aggregate in 30 minutes (II fraction 2.22%, III fraction 1.5%) was added, although this principle could not be consistently applied. Composition of concrete mixes is shown in Table 1. The fresh concrete tests were done for density, fluidity - slump flow test according to EN 12350-8, viscosity – T500 test according to EN 12350-8, the ability of the passage between the reinforcement – L box test according to EN 12350-10, segregation resistance – Sieve segregation test according to EN 12350-11 [6].

Table 1 – Concrete mixes

	cement (kg/m^3)	lime (kg/m^3)	fly ash (kg/m^3)	sil. fume (kg/m^3)	0/4mm (kg/m^3)	4/8mm (kg/m^3)	8/16mm (kg/m^3)	water (kg/m^3)	VSC5380 (kg/m^3)
EK	400	120	0	0	770.86	306.28	532	170.8	4.94
EP	400	0	120	0	770.86	306.28	532	192.66	4.94
ES	400	0	0	52	770.86	306.28	532	185.71	4.94
K50	400	120	0	0	809.14	306.28	505.43	182.86	5.08
P50	400	0	120	0	809.14	306.28	505.43	214.28	5.08
S50	400	0	0	52	809.14	306.28	505.43	197.14	5.08
K100	400	120	0	0	809.14	306.28	505.43	189.5	5.08
P100	400	0	120	0	809.14	306.28	505.43	221	5.08
S100	400	0	0	52	809.14	306.28	505.43	208.6	5.08

3.2. Test results

The test results for concrete in the fresh state are shown in Table 2.

Table 2 – Test results for concrete in the fresh state

	density (kg/m^3)	Slump-flow cm	T500 s	L-box H1/H2	Sieve segregation,%
EK	2418	73	4	1	12.4
EP	2288	70	4	0.94	11
ES	2416	66	6	0.91	6.8
K50	2362	70	5	0.96	12
P50	2279	70	5	0.95	7.8
S50	2324	67	5	0.94	5.2
K100	2347	69	5	1	10
P100	2298	66	6	0.91	5.5
S100	2359	66	6	0.92	7.5

Testing compressive strength was carried out on the cubes with edges of 15cm. The test results for compressive strength after 2, 7 and 28 days are shown in Chart 1.

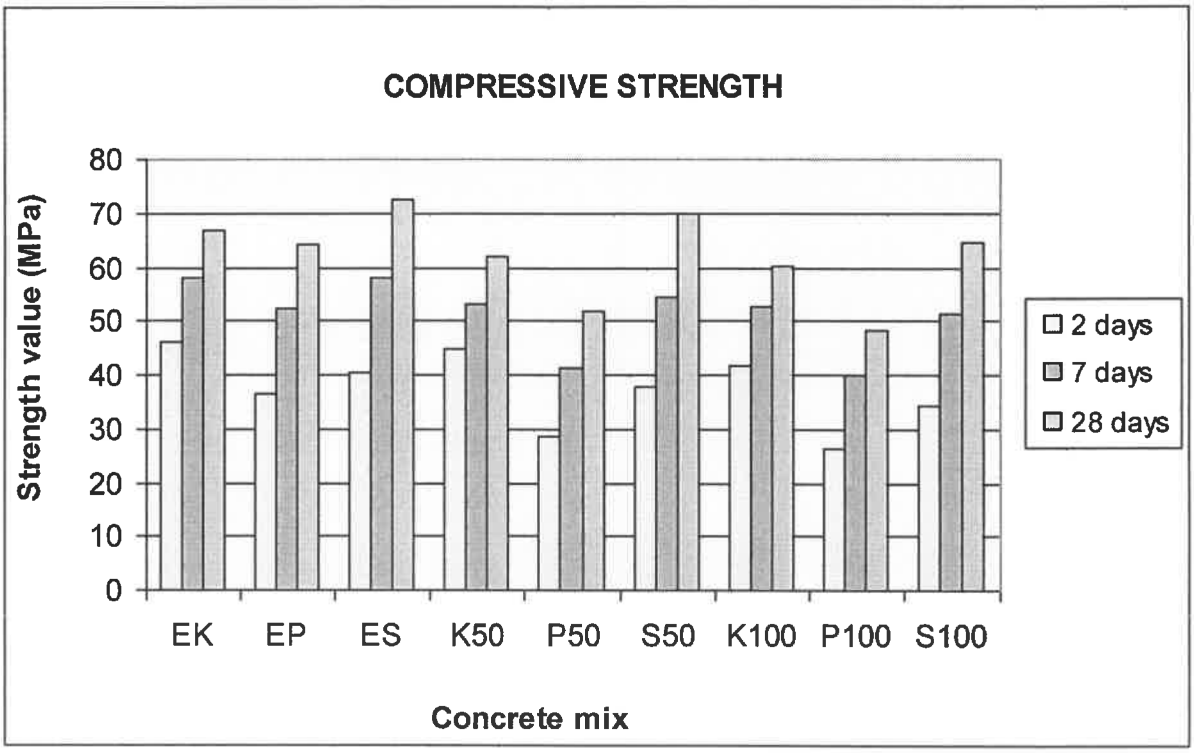

Chart 1: Compressive strength

4. THE RESULTS ANALYSIS

While designing concrete mixes, in order to obtain the same consistency because of the use of recycled aggregate, it was necessary to intervene in two directions: to increase the amount of water and to reduce the amount of III fraction by 5%, simultaneously increasing the amount of sand by 5%. Without these interventions in the composition, it was impossible to achieve self-compacting of mixes because of the sharp-edged grain shape of recycled aggregates and granulometric composition itself (recycled aggregate had 7% of oversized grains).

Slump –flow test: Fresh concrete was spread from 66 to 73cm which designed mixes of class SF2 which fits in most common use of concrete in construction. To achieve the same consistency, when lime was used as a mineral addition, the use of the recycled aggregate III fraction caused an increase in water-cement ratio from 0.43 to 0.46, while in the case of using I and II recycled fractions, water-cement ratio was 0.47. When fly ash was used as a mineral additive, water-cement ratio increased from 0.48 to 0.55, and when used silica fume, the increase of the water-cement ratio was from 0.46 to 0.49 and 0.52, due to the use of recycled aggregate. The slightest movement was recorded in mixes with silica fume, where it is necessary to take into account their smallest water-cement ratio.

T500 is the time that concrete reaches 500mm, and it is measured when doing slump-flow test. It represents a check of viscosity of the mix; the recommended interval for class SF2 is from 3.5 to 6.0s, and all mixes "fit" into it. Since the use of recycled aggregate caused reduction of spreading concrete, all mixes with recycled aggregates had longer period of time T500, compared to the control concrete mix, regardless of the type of used mineral additive.

L – box test: due to the application of recycled aggregates, horizontality of the concrete decreases, whereby the combination of lime and recycled aggregate gave the best results.Blocking of aggregate grains between reinforcement rods was not recorded in any case.

Segregation test: reduced spreading of fresh self-compacting concrete, due to the use of recycled aggregates, means greater resistance to segregation, regardless of the type of applied mineral additive.

When using III and II and III recycled fractions, density in the fresh state is reduced by 2.3% and 2.9% (with lime), reduced by 0.4% and increased by 0.4% (with fly ash), and reduced by 3.8% and 2.4% (with silica fume).

Considering mixes with lime, it can be concluded that the differences in the obtained compressive strength, when using natural and recycled aggregate, are relatively small, 4.51 MPa (6.8%) and 6.38 MPa (9.6%) – comparison of control concrete with mixes in which one or both coarse fractions are replaced. In mixes with fly ash, the difference is 12.3 MPa (19.2%) and 16.8 MPa (26.2%). Greater difference in strength among mixes with fly ash can be explained by the uneven quality of recycled aggregate, which represents a major problem of their application. In the group of mixes with silica fume, the difference between the control concrete mix and other two mixes was 2.61 MPa (3.6%) and 7.81 MPa (10.8%). The fastest increment of strength was found in mixes with silica fume. In all concrete mixes with natural aggregate, a failure was recorded through cement paste, while in mixes with recycled aggregate, the failure was found through aggregate, no matter which mineral additive was used.

5. CONCLUSIONS

Use of recycled aggregates solves the problems of over-exploitation of natural aggregates and of disposing of concrete waste. Increased porosity, caused by the presence of the old cement paste, and sharp-edged grain shape of recycled aggregates, adversely affect the properties of fresh self-compacting concrete, so it is necessary to increase water-cement ratio and/or intervene in the amount of I fraction. An additional quantity of water is determined by measuring the water absorption of the recycled aggregate.

Reduction of compressive strength depends on the quality of the applied recycled aggregate and it is possible to achieve a reduction of only a few percent compared to the concrete mixes with natural aggregates. The more qualitative the original concrete was, the better characteristics the newly made concrete will have. It is preferable that the aggregate is made of concrete of the same brand so that its quality will be as uniform as possible. In order to remove cement stone from an aggregate grain, a number of advanced recycling technologies have been developed.

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REFERENCES

[1] Guneyisi E, Gesoglu M, Algın Z, Yazıcı H: Effect of surface treatment methods on the properties of self-compacting concrete with recycled aggregates, Construction and Building Materials, 64 (2014), p.172-183

[2] Trumić M, Trumić M. (2011): Uloga pripreme u reciklaži otpada i održivom razvoju Srbije: Stanje i perspektive pripreme mineralnih sirovina u Srbiji, Inženjerska Akademija Srbije, Beograd, str. 73-93

[3] EFNARC, ERMCO, EFCA, CEMBUREAU, bibm: The European Guidelines for SCC:Specification, Production and Use; May 2005, p68.

[4] Radonjanin V., Malešev M., Marinković S.: Mogućnosti primene starog betona kao nove vrste agregata u savremenom građevinarstvu, ZAŠTITA MATERIJALA, 51 (2010) broj 3, str. 178 – 188

[5] www.concreterecycling.org

[6] Despotović I.: Uticaj različitih mineralnih dodataka na osobine samougrađujućeg betona, doktorska disertacija, Građevinsko- arhitektonski fakultet, Niš 2015.