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BETONSKI BLOKOVI I PLOČE ZA POPLOČAVANJE SA RECIKLIRANIM AGREGATOM IZ PREFABRIKACIJE

Rezime:

U ovom radu je prikazana mogućnost korišćenja recikliranog agregata iz betonskih blokova i ivičnjaka u proizvodnji betonskih elemenata za trotoare. Eksperimentalni rad uključuje nekoliko vrsta betona napravljenih sa različitim količinama cementa i recikliranog agregata od betona. Na osnovu rezultata ispitivanja pretpostavljeno je da je moguće izraditi betonske blokove i ploče u skladu sa evropskim standardima. Rezultati pokazuju da se zamenom prirodnog agregata, agregatom od drobljenog betona mogu proizvesti betonski elementi koji ispunjavaju zahtjeve EN 1338 i EN 1339, ali klasa zavisi od procenta zamene prirodnog agregata recikliranim.

Ključnereči: agregat od recikliranog betona, blokovi za popločavanje, ploče za popločavanje

CONCRETE PAVING BLOCKS AND FLAGS MADE WITH RECYCLED AGGREGATE FROM PRECAST ELEMENTS

Summary:

The possibility of using recycled aggregate from precast paving blocks and curbs in the production of concrete elements for the pedestrian areas is shown in this paper. Experimental work has included few types of concrete made with different amounts of cement and recycled concrete aggregate. Based on the testing results it was assumed that it is possible to produce the concrete paving blocks and flags comply with European standards. The results show that replacing natural aggregate with crushed concrete aggregate produces concrete elements which meet the requirements of EN 1338 and EN 1339, but class depends of percent of replacement natural aggregate by recycled.

Key words: recycled concrete aggregate, paving blocks, paving flags

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1. INTRODUCTION

One common means for achieving a more environmentally-friendly concrete is crushing concrete to produce coarse aggregate for the production of new concrete. In this way the consumption of natural resources as well as the disposal of waste concrete in landfills is reduced. As the matter of fact, the use of recycled-aggregate concrete is becoming increasingly interesting in civil construction as regards to sustainable development. Many studies show that it is possible to use crushed concrete as coarse aggregate, which has already been accounted for in the regulations of many countries [1].

Research showed that up to 30% coarse or 20% fine recycled concrete-derived aggregate had no effect on the concrete strength [2]. Concrete made with recycled aggregate (RA) or recycled concrete aggregate (RCA) also needs to be tested in order to confirm that it has adequate freeze–thaw and sulphate resistance for its intended use. The maximum strength class of concrete made with RCA should not be more than C50 [2].

Results of the investigation of Poon et al. show that the production of non-structural precast concrete blocks is possible with low grade recycled aggregate [3]. By combining recycled aggregate of brick and concrete (50:50%) it is possible to produce concrete for paving for pedestrian areas and (25:75%) for traffic [4].

In the production of precast concrete elements there are some mistakes in production which result in products that do not have certain required properties. Such products cannot be used and they most often end up at the landfill. One of the ways to reduce the formation of landfills is recycling. By crushing concrete aggregate from the concretes obtained, which can be used as a component material in the production of concrete after being fractionated.

Comparing previous test results of concrete paving blocks and flags made of ordinary concrete and properties of concrete with recycled concrete as aggregate it can be concluded that this kind of concrete can be used for the production of elements for pedestrian areas [5].

The aim of this paper is application of recycled concrete in the production of paving elements. Some properties of concrete made with different replacement level of natural aggregate by recycled concrete (25 and 100%), such as compressive strength, water absorption, density, were done. Testing results of concrete paving flags and blocks according to EN 1338 and EN 1339 were presented.

2. EXPERIMENTAL WORK

Two referent types of concrete with crushed aggregate were prepared (Table 2). Recycled aggregate concrete were designed in such a way that coarse aggregate (fractions 4/8 and 8/16 mm) was replaced with 25 and 100% recycled concrete aggregate.

Concrete were made using CEM II/B-S 42.5 N.

The recycled aggregate was obtained by crushing damaged prefabricated elements made of concrete consistency S1, a class of strength C 35/45. After the crushing, concrete was separated into fractions 0/4 mm, 4/8 mm and 8/16 mm. Particle size distribution is shown in Table 1.

Table 1 – Particle size distribution

Fraction mm	Sieve size (mm)									
	0.125	0.25	0.5	1	2	4	8	16	31.5	45
0/4	9.8	17.2	29.5	51.9	86.9	99.9	100.0	100.0	100.0	100.0
4/8				0.2	0.2	1.0	94.0	100.0	100.0	100.0
8/16				0.1	0.1	0.1	2.4	94.2	100.0	100.0

Table 2 - Concrete mix proportion

Concrete mixture	C1	C2
Cement [kg/m3]	330	320
Water-cement ratio W/C	0.40	0.40
Aggregate-cement mix ratio A/C	5.7272	6.0469

Workability is not important for precast elements, so required consistency measured by slump test was 1.0 cm. Water to cement ratio depends on percentage and fractions which were replaced by recycled concrete aggregate.

Concrete paving blocks and flags were made in steel moulds. Blocks and flags were produced in two layers. Facing layer is consist of quartz sand and cement. For blocks base layer concrete mixtures C1 and for flags mixtures C2 were used. Dimensions of blocks were 20x30x8 cm and 30x30x6 cm for flags.

The effective water-cement ratio is the same for all types concrete, but due to the increased absorption of water in the recycled aggregate, the amount of water increased from 3-15% depending on the mixtures used and the amount of recycled aggregate.

3. RESULTS AND DISCUSSION

3.1. CONCRETE PROPERTIES

The consistency of the fresh concrete was class S1 according to standard SRPS ISO 4103/1997.

The samples for testing concrete compressive strength were made. Concrete was compacted with vibration in metal cube-shaped molds with an edge length of d = 150 mm, and the samples were cured in water at a temperature of + 20 ° C until they were tested according to SRPS EN 12390-2 standard.

Testing of concrete compressive strength at the age of 3, 7, 14 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 2350 to 2400 kg/m^3. The results of the testing are shown in Figures 1-2.

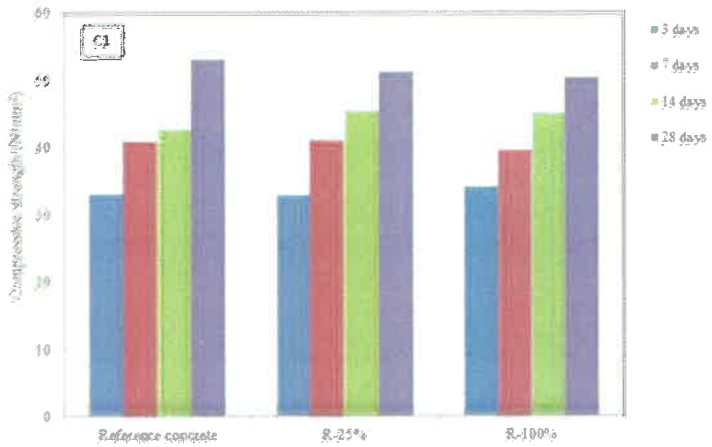

Figure 1 - Compressive strength of concrete C1

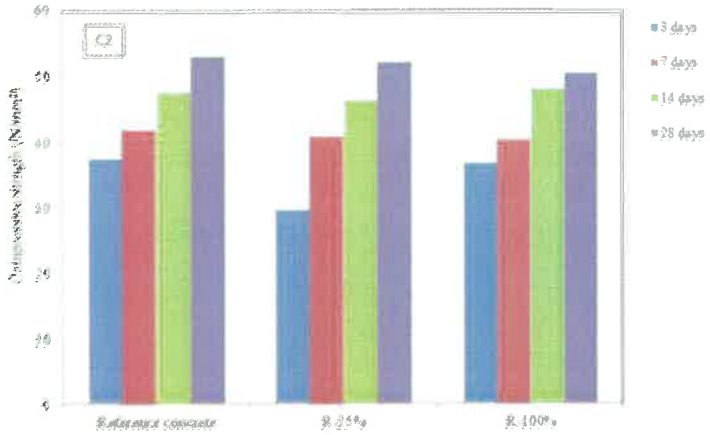

Figure 2 - Compressive strength of concrete C2

Water absorption of aggregate reflects to amount of water necessary to provide concrete with same consistency, i.e. for concrete with greater amount of recycled aggregate the required amount of water is greater. Properties of concrete depend of the quality of recycled aggregate. In this case, concrete which was used for the production of recycled aggregate had compressive strength class C 35/45. That is the reason why concrete with recycled aggregate had compressive strength which is not significantly different compared to reference concrete. All concrete types also satisfied compressive strength class C 35/45. For samples with 100% recycled coarse aggregate decrease of strength was 4%, while for samples with 25% recycled coarse aggregate decrease was only 2%.

3.2. CONCRETE PAVING BLOCKS AND FLAGS

Concrete paving blocks and flags were tested in terms of the following properties [6-7]:

- Weather resistance,
- Tensile splitting strength for blocks, bending strength for flags,
- Abrasion resistance.

Weather resistance is determined by tests for freeze – thaw resistance with de-icing salt and for water absorption. Abrasion resistance is determined by the Wide Wheel Abrasion test, or as an alternative by the Böhme test.

All types of concrete products had a water absorption of less than 6% and a loss of mass after the freeze / thaw cycle $\leq$ 1.0 kg/m^2 and meet the requirements for both Class 2 and Class 3 resistance to weather resistance.

For all types of concrete elements, the volume loss was $\leq$ 18 cm^3/50 cm^2 per Bohme test and met the wear resistance class 4.

The minimum tensile splitting strength for concrete paving blocks 20x30x8 cm according to EN 1338 was from 3.1 MPa to 3.6 MPa, and the characteristic tensile strength T ranging from 3.7 to 4.2 MPa, depending on the percentage a coarse natural aggregate replaced by a recycled concrete aggregate, 100% or 25%. Accordingly, all types of blocks met the standard criteria, since the characteristic tensile splitting strength T was greater than 3.6 MPa and a minimum $\geq$ 2.9 MPa.

The minimum tensile strength of the concrete paving flags 30x30x6 cm according to EN 1339 was 3.3 MPa and 3.8 MPa, and the mean 3.6 MPa and 4.4 MPa, depending on which percentage of the natural aggregate was replaced by the recycled concrete aggregate, 100 % or 25%. Accordingly, tile flags with 100% recycled large aggregate have met the criteria for bending strength class 1 according to EN 1339, since their minimum strength was greater than 2.8 MPa and the mean strengths greater than 3.5 MPa. The flags with 25% recycled coarse aggregate have met the criteria for bending strength class 2 according to EN 1339, since their minimum strength was greater than 3.2 MPa and a mean of 4.0 MPa.

4. CONCLUSIONS

The possibilities of using recycled concrete as aggregate for production concrete paving blocks and flags are presented in this paper. From the investigation results the following can be concluded:

- The concrete density decreased as the percent of recycled brick aggregate increased.
- The compressive and tensile splitting strength of concrete blocks and bending strength of paving flags decreased as the percent of recycled brick aggregate increased.
- Water absorption of the paving blocks and flags not exceeded the limit of 6%.
- Mass loss for all type of concrete blocks and flags after freeze/thaw test was$\leq$ 1.0 kg/m^2, so it satisfied the requirements for the best class for weather resistance according to the European standards.
- Abrasion resistance of paving elements satisfy the requirements of the European standards
- It was possible to use up to 100% of recycled concrete as coarse aggregate to prepare concrete paving blocks which meet the requirements of EN 1338.

- The production of concrete paving flags is possible with recycled concrete as aggregate. The quality of elements depend of replacement level of natural aggregate. It is possible to get paving flags, according to EN 1339, bending strength Class 1 with 100% recycled concrete as aggregate and Class 2 for bending strength with replacement levels up to 25%.

Based on the obtained results it can be concluded that the use of aggregate from recycled concrete is possible. Concrete made with this type of aggregate can be used for the production of elements for pedestrian areas and various non-structural elements. In this way, the environment is protected, and the waste produced in its own production is re-used as a component material for concrete.

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