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Properties of concrete kerbs with recycled aggregate from precast elements

PROPERTIES OF CONCRETE KERBS WITH RECYCLED AGGREGATE FROM PRECAST ELEMENTS

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SUMMARY: The paper presents the possibility of using recycled aggregate from precast concrete paving elements and kerbs in the production of concrete kerb units. Experimental work included several types of concrete consistency class S1, made with different amounts of cement and coarse recycled concrete aggregate. The influence of percentage and grain size of recycled concrete aggregate on concrete compressive strength at different ages was observed. Based on the experimental results, it can be concluded that the use of recycled concrete as an aggregate creates a new composite material that can be used for the production of precast elements. The results show that the replacement of the coarse natural aggregate with aggregate from crushed concrete is possible to produce concrete curbs that meet the requirements of EN 1340, but the class depends on the replacement percentage of the natural aggregate with recycled ones. In this way, the production waste is turned back to process, and the newly created concrete is certainly ecological material.

KEY WORDS: recycled concrete aggregate, concrete, kerbs, precast elements.

1 INTRODUCTION

One of the common ways to achieve more environmentally friendly concrete is crushing concrete to obtain 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.

It has been shown that it is possible to produce single-layer curbs with up to 50% replacement of natural recycled aggregate without any negative effects on their mechanical properties [5].

The possibilities of using concrete with recycled aggregate in the industrial production of various concrete products,

such as concrete pipes, paving elements and curbs, were examined. The results of testing the compressive strength of concrete pipes according to EN 1916 showed that pipes made from recycled aggregates had a strength reduction of 12% for unreinforced and 7.5% for reinforced compared to the corresponding reference pipes. For concrete paving blocks, if the natural aggregate is replaced by 40% recycled, the tensile splitting strength determined by EN 1338 is reduced by 43%. Water absorption is higher for products with recycled aggregate than for reference products. The use of recycled aggregates produces kerbs that meet the criteria of the standard in terms of bending strength according to EN 1340, but are classified as lower than the reference samples. In terms of weather resistence, products with recycled aggregate are satisfactory, as their water absorption was ≤6% [6].

The following non-structural elements were tested: terrazzo flags for internal use, kerb units and paving blocks to the appropriate standards were also performed at 360 days of age. The obtained results confirmed the possibility of using recycled aggregate for the production of these elements. However, the surface of the terrazzo flags is not as good as that of samples produced with natural aggregate [7]. Application of concrete with recycled aggregate is not recommended for the facing (visible) layer [8].

Comparing previous test results of concrete kerbs 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 [9].

The aim of this paper is application of recycled aggregate concrete in the production of kerb units. Some properties of concrete made with different replacement level of natural aggregate by recycled concrete aggregate (25, 50, 75 and 100%), such as compressive strength, water absorption, density, were done. Testing results of kerbs with two types of recycled aggregate concrete (25 and 100% of recycled concrete aggregate) according to EN 1340 were presented.

2 EXPERIMENTAL WORK

Two reference concrete with crushed aggregate from quarries Dobrnja near Banja Luka were prepared. Concrete with aggregate from recycled concrete were designed in such a way that coarse aggregate (fractions 4/8 and 8/16 mm) was replaced with 25, 50, 75 and 100% recycled aggregate.

All the concrete mixtures tested within the experimental research were made using CEM II/B-S 42.5 N cement, manufactured by CEMEX.

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.

Composition of two reference concrete is showed in Table 1.

Table 1: Mix design of reference concrete

Concrete mixture	C2	C3
Cement [kg/m3]	320	360
Water-cement ratio W/C	0.40	0.40
Aggregate-cement mix ratio A/C	6.0469	5.2778

For good quality mix design with the recycled aggregate, it is necessary to know the amount of water absorbed by the recycled aggregate, since it is always higher in comparison with the same fraction of the crushed aggregate. The higher water absorption is the consequence of the presence of residual cement stone on the grains of recycled aggregate.

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.

The effective water-cement ratio is the same for all concrete types, 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.

Concrete kerb units were produced in two layers. Facing layer was consist of quartz sand and cement. For base layer concrete mixture C3 was used. Recycled aggregate concrete were designed in such a way that coarse aggregate (fractions 4/8 and 8/16 mm) were replaced with 25 and 100% recycled concrete aggregate. Dimensions of kerbs were 18x24x100 cm.

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.

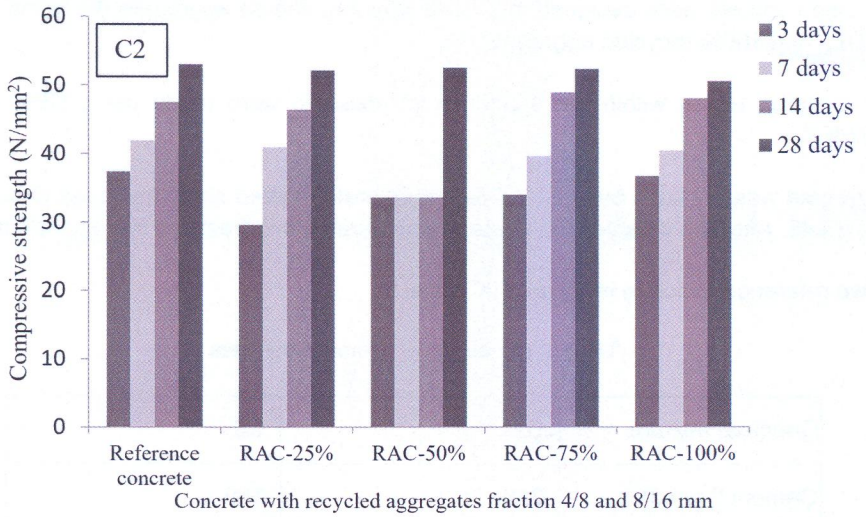

Figure 1: Compressive strength of concrete C2

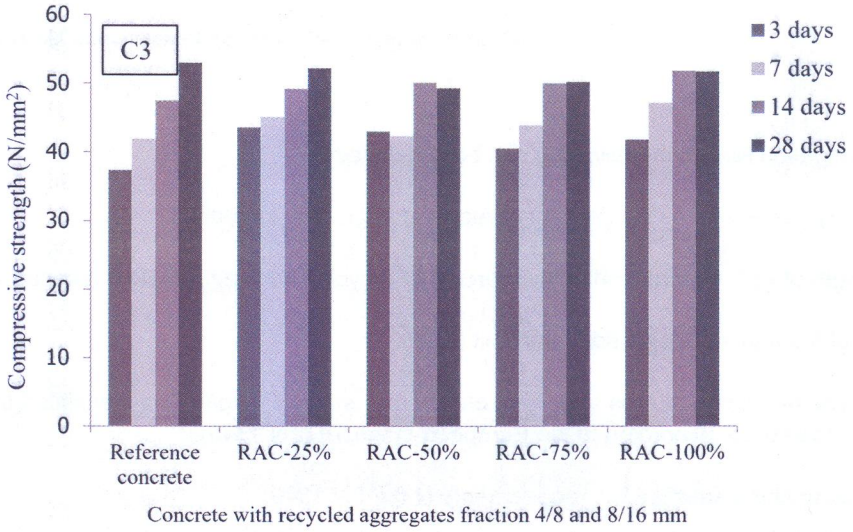

Figure 2: Compressive strength of concrete C2

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%.

3.1.1 Concrete kerbs

Concrete paving blocks and flags were tested in terms of the following properties:

- Weather resistance,
- Bending strength,
- 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 ≤ 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 ≤ 18 cm^3/50 cm^2 per Bohme test and met the wear resistance class 4.

Minimum bending strengths of concrete kerbs 18x24x100 cm according to EN 1340: 2003 / AC: 2006 were 4.9 MPa and 5.5 MPa, and the characteristic bending strengths were 5.3 and 5.6 MPa depending on which percentage of the natural aggregate was replaced by the recycled concrete aggregate, 100% or 25 %. Therefore, all types of kerbs met the criteria for Class 2 for bending strength classes according to EN 1340: 2003 / AC: 2006 because their minimum strengths were greater than 4.0 MPa and the characteristic strengths were greater than 5.0 MPa.

4 CONCLUSIONS

The possibilities of using recycled concrete as aggregate for production concrete kerb units were presented in this

paper. From the investigation results the following can be concluded:

The concrete density decreased as the percent of recycled aggregate increased.

The bending strength of kerbs decreased as the percent of recycled brick aggregate increased.

Water absorption of the kerbs not exceeded the limit of 6%.

Mass loss for all type of concrete kerbs after freeze/thaw test was ≤ 1.0 kg/m^2, so it satisfied the requirements for the best class for weather resistance according to the European standard (EN 1340).

Abrasion resistance of kerbs satisfied the requirements of the EN 1340.

It was possible to use up to 100% of recycled concrete as coarse aggregate to prepare concrete kerbs which meet the requirements of EN 1340 for bending strength Class 2.

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 kerb units. 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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