



High-Performance Concrete on Base Building Waste

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Abstract: *In this paper the authors present the possibility to utilize some building waste materials to produce high performance concrete (HPC). To prepare the mixes, Recycled Concrete Aggregate (RCA) of 5-40 mm fraction were used. Concretes with RCA were mixed with 305 kg/m² of different types of cements. The concrete sample specimens were tested for mechanical properties and for some properties which are related to durability. After 28 days compressive strength increase to 44MPa and after 90 days 65MPa were achieved.*

Keywords: *high-performance concrete, waste materials, aggregate, durability.*

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Introduction:

To reduce greenhouse gas emission, frugal natural resources management and recycling of waste materials became necessary. By increasing the usage of recycled concrete aggregate (RCA) and supplementary cementitious materials (SCM) in concrete industry it is possible to considerably enhance the environmental friendliness of concrete production. The more and more limited availability of resources of natural aggregates which makes up to about 60% - 70% of the volume of concrete is becoming more and more significant due to restrictions on quarrying operations and longer delivery distances. While discussing about the future of concrete, an important and predictable tendency is the increasing utilization of industrial waste and of recycled materials as ingredients for concrete mixtures and ceramic products. RCA and waste materials used as SCM are often considered to be low quality components which slightly lower the cost of concrete but deteriorate most of its vital properties [1, 2, 3]. It can be noted, that RCA is not a suitable component for preparing concretes with designed compressive strength higher than 25 MPa. A variety of cements were used CEM I 42.5, CEM I 52.5.

Materials and Methods

Portland cements CEM I 42.5 and CEM I 52.5 from Uzbek Cement Plant as per PN-EN 197 was used. As NA, river sand of 0,16-2,5 mm and 2,5-5 mm fractions were Zerafshan river. RCA was obtained by crushing concrete pieces of compressive strength between 25-55 MPa. Aggregate fulfilled requirements of RCAC II (acc. to DIN 4226-100) and type A (acc. to PN-EN-206:2014).

RCA has been sieved into fractions of: 5-10, 10-20 and 20-40 mm. Natural aggregate fractions of 0,16-2 mm and of 2,5-5 mm were used together with 5-10 mm and 20-40 mm fractions of RCA. Natural aggregate was used at air-dry condition. The RCA had been weighted and saturated with water, in an amount of 3.0 % of its air-dry weight. Water reducer Muraplast FK 88 was used. Regular tap water was used as mixing water.

Table 1. Proportions of concrete mixtures [kg/m³]

Material denomination	REC1	REC2	REC3	REC4
CEM I 42.5	285	285		
CEM I 52.5	-	-	305	305
metakaolin	20	20	20	20
natural sand 0,16-2,5	255	255	255	255
natural sand 2,5-5	340	340	340	340
RCA 5-10	300	600	600	400
RCA 10-20	600	-	300	400
RCA 20-40	300	600	300	400
SP FK-88 (superplasticizer)	15	15	15	15
water	140	140	140	140

*Previous to mixing RCA has been saturated, the saturation water is NOT incorporated in the ratio.

Four concrete mixtures were prepared. They contained 305 kg/m³ of cement was used, together with metakaolin in an amount of 6%. Water reducer was used in the dosage of 5% by total mass of cement. Mix proportions are presented in Table 1. The workability of concrete mixtures was measured by flow table test, in accordance with PN-EN 12350-5.

Compressive and Tensile Strength Test

Specimens were prepared and cured as per PN-EN 12390-2. They were cast in steel moulds and underwent double compaction on vibrating table. After 2 days the specimens were demoulded and water-cured in the laboratory till the age of 28 days. The compressive strength tests were conducted in accordance with PN-EN 12390-3 on 100 mm cube specimens after 28 and 90 days of hardening. The tensile splitting strength tests were conducted on the same type of specimens in accordance with PN-EN 12390-6.

Results and discussion

Research results are presented in the Table 2. The results are mean values of four measurements. Only for fresh concrete mixtures, the result of flow is an average of three measured values.

Table 2. Test results

Concrete property / Sign of mixture	REC1	REC2	REC3	REC4
compr. strength 28d fcm [MPa]	45.1	44,5	50,0	51,2
tensile strength 28d fctm [MPa]	5,45	4,9	5,2	5,0
compr. strength 90d fcm [MPa]	56,9	59,0	64	65
tensile strength 90d fctm [MPa]	7.1	7,0	7,4	7,89
W/C	0,32	0,33	0,30	0,31

Compressive Strength of Concrete

The highest value of mean compressive strength 50,0MPa was obtained for REC3 series containing CEM II 52.5 cement. This mixture reached also the highest compressive strength of 64MPa after 90 days, which means a strength gain of 28% due to post hardening. A significant gain in compressive strength from 51.2MPa after 28 days to 65MPa after 90 days. Mixtures REC and REC2 did not obtain surprising gain in strength between 28 and 90 days, they were 14%, and 15% respectively. The difference was mainly the result of using 2,5-5 mm fraction of natural aggregate in REC1 concrete series instead of RCA of the same fraction in REC2 concrete. This explains the requirement in EN-206 standard which exclude 0,16-5 mm fractions of RCA from the usage in concrete production. At the same time if this strength decrease due to the fine RCA is compensated, than the authors would not exclude the utilize ability of such RCA fractions [4, 5].

Tensile Strength of Concrete

In accordance with the compressive strength values, the highest splitting tensile strength after 28 days could be measured on the concrete out of REC4 mixture, which was 5 MPa. After 90 days the highest measured splitting tensile strength obtained was for concrete out of REC2 mixture, which was 4.9 MPa. As in the case of compressive strength concrete with fluidised fly ash gained only a small increase in splitting tensile strength after 28 days of hardening. The mean splitting tensile strength of the concretes is 5.45 MPa. The average value for all concrete is 5.76. These are typical values for concrete of that level of average strength. Utilization of RCA 5-10mm fraction instead of NA resulted in 2.5% higher average tensile strength value.

Summary and Conclusions

In the paper it has been shown that it is possible to produce a high quality concrete with a targeted 51.2MPa mean compressive strength at the age of 28 days and of more than 60 MPa after 90 days. Good durability influencing properties could be measured at the same time by the usage of coarse RCA of an average quality. The increase in strength between 28 and 90 day of laboratory ambient conditions curing shows that test after more than 28 days period reflects better the actual properties of the tested concretes. This applies to both the mechanical properties and to those which are associated with durability. The limit of 5 % of water absorption is practically impossible to meet [6]. Replacing 0,16-5 mm fraction of natural aggregate with RCA caused slight worsening of most of the concrete durability properties.

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