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Durability of Concrete on Base Building Waste

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Abstract: *In this work, the authors discuss the feasibility of using some construction debris to generate high-performance concrete (HPC). Recycled Concrete Aggregate (RCA) of 5-20 mm fraction was used to make the mixtures. Concretes containing RCA were combined with 300 kg/m3 of various cements. The sample specimens of concrete were evaluated for their mechanical qualities and some properties relevant to durability. After 28 days, the compressive strength reaches 55.5 MPa, and after 90 days, it reaches 60.4 MPa.*

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

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Introduction

To reduce greenhouse gas emissions, economical management of natural resources and recycling of waste materials became essential. By increasing the use of recycled concrete aggregate (RCA) and supplemental cementations materials (SCM) in the concrete industry, environmental friendliness can be significantly improved. Due to constraints on quarrying activities and longer delivery distances, the decreasing supply of natural aggregates, which account for approximately 60 to 70 percent of the volume of concrete, is becoming increasingly critical. Concurrently, the disposal of remaining concrete from structure deconstruction is a challenge that must be resolved. The majority of such trash is placed in landfills [1]. When contemplating the future of concrete, the increasing exploitation of industrial waste and recyclable materials in concrete mixtures [2,3] is an essential and predictable trend. Also defined are recommendations for employing coarse RCA in concrete production [19, 20]. Commonly, RCA and waste materials used as SCM are regarded as low-quality components that marginally reduce the price of concrete while diminishing the majority of its key attributes. Some writers contend that RCA is unsuitable for creating concretes with a specified compressive strength of 25 MPa (or even 100 MPa) or greater [21]. Utilizing SCMs (such as fly ash) in concrete production can significantly reduce the permeability of concrete when water and chloride ions are included [23, 24]. Used cements included CEM I 42.5 and CEM I 52.5. In the course of the main research stream, the effect of replacing 2-4 mm of natural aggregate (NA) with the same proportion of RCA was also examined.

Materials and Research

Materials

Utilized Portland cements CEM I 42.5R, CEM I 52.5R from Uzbek Cement Plant in accordance with PN-EN 197. Zerafshan river sand fractions of 0-2 mm and 2-4 mm were utilized as NA. / Procedia Engineering 172 (2017) 595 – 603 597. Crushing concrete fragments with a compressive strength between 35 and 50 MPa yielded RCA. Aggregate met RCAC II (according to DIN 4226-100) and type A specifications (acc. to PN-EN-206:2014). RCA has been sieved into 0-2 mm, 2-4 mm, 4-8 mm, and 8-16 mm fractions. 0-2 mm and 2-4 mm natural aggregate fractions were combined with 4-8 mm and 8-16 mm RCA fractions. Natural aggregate was utilized in an air-dried state. The RCA was weighed and saturated with water at a rate of 3.5% of its air-dry mass. The absorbed water was ignored when computing the W/C and (W+SP)/C+SCM ratios. Utilized was the high-range water reducer Muraplast FK 88. Standard tap water was used for mixing.

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

Material denomination	REC1	REC1	REC1
CEM I 42.5	400		
CEM I 52.5		400	400
metakaolin	120	120	120
natural sand 0-2	200	400	200
natural sand 2-4	200	-	200
RCA 2-4	900	-	200
RCA 4-8	-	400	200
RCA 8-16	-	500	300
SP FK-88 (superplasticizer)	10	10	10
water	200	200	200
W/C (W+SP)/(C+SCM)*)	0.57	0.57	0.57

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

There were six concrete combinations created. In addition to the 300 kg/m3 of cement, 10% metakaolin was also used. The water reducer dosage was 2% by mass of cement, metakaolin, and 50% by mass of fly ash. The proportions for mixtures are shown in Table 1. In line with PN-EN 12350-5, the workability of concrete mixtures was assessed using a flow table test.

Compressive and Tensile Strength Test

Preparing and curing specimens in accordance with PN-EN 12390-2. They were poured into steel molds and double-compacted on a vibrating table. After two days, the specimens were demoulded and water-cured in the laboratory for a total of twenty-eight days. After 28 and 90 days of aging, 150 mm cube specimens were subjected to compressive strength testing in accordance with PN-EN 12390-3. Conforming to PN-EN 12390-6, the tensile splitting strength tests were done on the same type of specimens.

Sorptivity Test and Free Water Absorption

The sorptivity and free water absorption tests were performed on halves of 150 mm cube specimens. Initially, the specimens were soaked with water for around 14 days. The known-weight specimens were stacked in the water-filled jar (the specimens were dipped up to the depth of 3 mm). At defined time intervals after the start of the experiment, the specimens were weighed again to determine their weight gain due to water absorption. Six hours of further mass gain measurements were undertaken [2].

Depth of Penetration of Water under Pressure Test

150 mm cubes were used for water penetration testing. In compliance with PN-EN 12390-8, the tests were carried out after 90 days of aging. Before testing began, the specimens were water-cured for 28 days and then held in laboratory ambient settings for the remaining time. A steady water pressure of 0.5 MPa was applied to one surface of the specimens for 72 hours. At the conclusion of the test, the specimens were cut vertically to determine the maximum water front penetration depth.

3. Research Results

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

3.1. Workability of Concrete

After 60 minutes, the flow values of all concrete compositions were within the specified parameters. The differences between the flow values of concrete mixes evaluated 15 and 60 minutes after mixing for series REC1, REC2, and REC3 were rather small. They were 1.09%, 4.21%, and 4.5%, respectively, in comparison to the 15-minute measurements. Comparing recipes REC1 and REC2, 2-4 mm fraction of RCA has a significant impact. To attain a flow value of 385 mm after 60 minutes (which is close to the desired value), extra water dose was required. However, this resulted in a concrete flow figure of 501 mm for the 15-minute measurement. The decrease in flow value was large, at 25.96%. Based on these results, it is evident that by utilizing an adequate binder mixture and a superplasticizer in tandem, it is possible to produce a concrete mixture with a modest drop in its one-hour flow value even when employing RCA as the sole coarse aggregate.

Table 2. Test results

Concrete property / Sign of mixture	REC1	REC1	REC1
Flow "d" after 15 min [mm]	213	231	222
Flow "d" after 60 min [mm]	385	370	376
compr. strength 28d fcm [MPa]	41.8	38.9	38.5
tensile strength 28d fctm [MPa]	4.5	4.1	3.9
compr. strength 90d fcm [MPa]	64.86	51.09	52.66
tensile strength 90d fctm [MPa]	5.97	6.76	7.73
W/C (W+SP)/(C+SCM)*	0.57	0.57	0.57

3.2. Compressive Strength of Concrete

The REC4 series using CEM II 52.5 A-M (S-LL) cement exhibited the highest mean compressive strength of 59.54 MPa. This mixture had its peak compressive strength of 71.78 MPa after 90 days, which represents a 20.57 percent increase in strength due to post-hardening. The compressive strength increased significantly from 62.01 MPa after 28 days to 71.06 MPa after 90 days. According to the authors, defining simply the strength after 28 days for concretes containing CEM II and CEM III cements does not accurately reflect the true strength properties. Between 28 and 90 days, the strength of mixtures REC1, REC2, and REC3 increased by 10.40%, 16.08%, and 4.50%, respectively. Still, the 28-day compressive strength of these latter mixtures met the target with 57.11 MPa for REC1, 54.53 MPa for REC2, and 58.75 MPa for REC3. Similarly, the compressive strength of the REC5 and REC6 mixtures at 28 days was only 52.66 MPa and 51.09 MPa, respectively, which is below the intended value of 55 MPa. However, after 90 days, concrete containing CEM III (REC5) obtained a compressive strength of 64.86 MPa, which is 2.87 percent and 2.46 percent greater than those achieved by REC1 and REC2 mixtures, respectively. They were both mixed with CEM I regular Portland cement of the same strength class. After 28 and 90 days, the mixture REC6 containing fluidized fly ash instead of metakaolin reached the lowest strength values, which were 51.09 MPa and 52.26 MPa, respectively. Intriguingly, the rise in strength between 28 and 90 days is only 2.29 percent. Comparing concrete series comprised of REC1 and REC2 mixtures revealed that REC1 obtained 4.5% more compressive strength than REC2. In REC1 concrete series, 2-4 mm fraction of natural aggregate was utilized as opposed to RCA of the same fraction in REC2 concrete series. This clarifies the EN-206 regulation prohibiting the use of 0-4 mm RCA fractions in the manufacturing of concrete. Nonetheless, if this drop in strength due to fine RCA is compensated, the authors would not rule out the use of such RCA fractions. 600 Wojciech Kubissa et al., Procedia Engineering 172, 595–603 (2017).

3.3. Tensile Strength of Concrete

In agreement with the compressive strength values, the REC4 concrete mixture had the highest splitting tensile strength after 28 days, measuring 4.10 MPa. The mixture of REC5 concrete had the highest recorded splitting tensile strength after 90 days, measuring 4.62 MPa. The increase between 28 and 90 days ranged from 1.36% to 25.28% for REC6 and REC5 concretes, respectively. As with compressive strength, the splitting tensile strength of concrete containing fluidized fly ash increased marginally after 28 days of hardening. The ratio of fcm(28)/ftm(28) ranged from 5.90 (for the REC1 mixture) to 7.81. (for REC6 mixture). The concretes have a mean splitting tensile strength of 6.67 MPa. The ratio of fcm(90)/ftm(90) varied from 5.97 (for REC2 concrete) to 7.73 (for REC6 concrete), with a mean value of 6.76 for all concrete. These are typical values for concrete with an average strength of this level. Using RCA 2-4 mm fraction as opposed to NA increased the average tensile strength by 1.9%.

Summary and Conclusions

The research demonstrates that it is possible to make high-quality concrete with a mean compressive strength of 55 MPa at 28 days of age and greater than 60 MPa after 90 days. With the use of coarse RCA of average quality and the inclusion of Class F fly ash as SCM, it was possible to simultaneously assess the durability-influencing qualities of the mixture. The increase in strength between 28 and 90 days of laboratory curing in ambient settings demonstrates that the actual qualities of the tested concretes are more accurately reflected by tests conducted after a time longer than 28 days. This holds true for both mechanical and durability-related aspects. The 5% water absorption requirement is virtually impossible to satisfy. Substituting 2-4 mm of natural aggregate with RCA caused a minor decrease in the most of the durability qualities of concrete, with the exception of sorptivity, which decreased by 20%.

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