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Substitution of Natural Aggregates by Crushed Concrete Waste in Concrete Products Manufacturing

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***Abstract*—**This paper is aimed to the use of different types of industrial wastes in concrete production. From examined waste (crushed concrete waste) our tested concrete samples with dimension 150 mm were prepared. In these samples, fractions 4/8 mm and 8/16 mm by recycled concrete aggregate with a range of variation from 0 to 100% were replaced. Experiment samples were tested for compressive strength after 2, 7, 14 and 28 days of hardening.

From obtained results it is evident that all samples prepared with washed recycled concrete aggregates met the requirement of standard for compressive strength of 20 MPa already after 14 days of hardening. Sample prepared with recycled concrete aggregates (4/8 mm: 100% and 8/16 mm: 60%) reached 101% of compressive strength value (34.7 MPa) after 28 days of hardening in comparison with the reference sample (34.4 MPa). The lowest strength after 28 days of hardening (27.42 MPa) was obtained for sample consisting of recycled concrete in proportion of 40% for 4/8 fraction and 100% for 8/16 fraction of recycled concrete.

***Keywords*—**Recycled concrete aggregate, re-use, workability, compressive strength.

I. Introduction

MONITORING a normal growth in population, the amount and type of waste materials have increased accordingly. Many of the non-decaying waste materials will remain in the environment for hundreds, perhaps thousands of years. The non-decaying waste materials cause a waste disposal crisis, thereby contributing to the environmental problems. The problem of waste accumulation exists worldwide, specifically in the densely populated areas. Most of these materials are left as stockpiles, landfill material or illegally dumped in selected areas [1]. In fact, concrete is the world's most consumed man made material and its use is expected to increase substantially. However, the production of concrete is not environmentally friendly and therefore significant environmental advantages may be realized if alternate, environmentally sensitive materials are identified for use in concrete [2].

During the last few decades society has become aware of the deposit problems connected with residual products, and demands, restrictions and taxes have been imposed. And as it is known that several residual products have properties suited for concrete production, there is a large potential in investigating their possible use in concrete products manufacturing. Well-known residual products such as silica fume, fly ash, sediments, etc. may be mentioned [3]-[5].

There are three basic directions how to produce environmentally friendly concrete:

1. To increase the use of conventional products and to minimize the clinker content.
2. By developing new green cements and binding materials.
3. Concrete with inorganic residual products [4].

Cement, which is an integral part of all standard concrete products, is the most significant and harmful factor and environmental burden when producing concrete or concrete products. Replacing energy consuming Portland cement with recyclable materials and minerals offers two distinct benefits to the environment - it significantly reduces the amount of CO_2 released into the atmosphere and it minimizes massive landfill disposal [6], [7]. In contemporary concrete production successful reduction of cement is usually done by replacing a part of the required cement content with fly ash [8], [9], silica fume and others wastes with pozzolanic properties [10], [11].

Aggregates are used in large quantities in concrete production with a great potential to replace primary aggregates with secondary and recycled materials. The properties of secondary and recycled aggregate are in many ways different from those of primary aggregate and this could lead to varying properties when incorporated in concrete composites. In many cases, specifications that use recipe mixtures and prescribed materials prevent the wider utilisation of recycled materials [12]-[15]. Recycled concrete aggregate (RCA) is generally produced by two-stage crushing of demolished concrete, and screening and removal of contaminants such as reinforcement, paper, wood, plastics and gypsum. Concrete made with such recycled concrete aggregate is called recycled aggregate concrete (RAC). When demolished concrete is crushed, a certain amount of mortar and cement paste from the original concrete remains attached to stone particles in recycled aggregate. This attached mortar is the main reason for the lower quality of RCA compared to natural aggregate. Technology of RAC production is different from the production procedure for concrete with natural aggregate. Because of the attached mortar, recycled aggregate has significantly higher water absorption than natural aggregate. Therefore, to obtain the desired workability of RAC it is necessary to add a certain amount of water to saturate recycled aggregate before or during mixing, if no water-reducing admixture is applied. One option is to first saturate recycled aggregate to the condition — water saturated surface dry, and

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the other is to use dried recycled aggregate and to add the additional water quantity during mixing. The additional water quantity is calculated on the basis of recycled aggregate water absorption in prescribed time [16], [17].

The aim of this work is to experimentally verify the suitability of the substitution of fractions 4/8 mm and 8/16 mm natural aggregate by alternative raw-waste material. For this purpose, we chose the crushed concrete waste. In verifying the replacement of selected fractions exact recipe for the concrete was followed. Main concrete characteristics such as workability, density and compressive strength were studied.

II. Material and Methods

Portland cement CEM II 32.2, aggregate prepared from crushed and washed concrete waste and natural aggregates were used as raw materials in our experiment.

Washed recycled concrete aggregate was created as a crushed and sorted waste from building and roads demolition. This material was obtained from recycling plant Rail and Transport Buildings, Ltd. Kosice, Slovakia. This secondary raw material, fraction 4/8 and 8/16 mm, was wash and used as natural aggregate replacement in concrete mixtures.

Three different fractions of natural aggregate (0/4 mm, 4/8 mm and 8/16 mm) from company VSH, (Slovakia) was used for concrete samples preparing. Natural aggregate was evaluated according to the standard STN EN 12 620 Aggregates for concrete.

To manufacture of concrete samples Portland slag cement CEM II/B-S 32.5 R from cement factory of Povazie, Ladce, Slovakia was used, according to the Slovakian standard STN EN 197-1 Cement. Part 1: Composition, specifications and conformity criteria for common cements.

Table I shows proposal composition of 1 m^3 of concrete for strength class C 16/20.

As an additive to concrete samples plasticizer Stacheplast was used. It is a plasticizer based on lignin, which specifically regulates the hardening of concrete samples with a strong plasticizing effect. The amount of water in the mixture was indicative. For mixture resulting consistency required slump grade was followed (S3).

TABLE I
Composition of 1 m^3 of Concrete Class C 16/20

Composition	C 16/20 XC1, (SK)-Cl 0,4-Dmax16
CEM II/ B-S 32.5 R [kg]	300
Water [l]	165
0/4 mm [kg]	950
4/8 mm [kg]	220
8/16 mm [kg]	700
Plasticizer [l]	2.15

Ten different mixtures based on recycled concrete aggregate (called R1-R10) at solid/liquid ratio of 0.55-0.6 (important was achieved slump grade S3); including admixture Stacheplast was performed in our study. Sample R1 was reference sample prepared only with natural aggregate. In the other mixtures (R2-R10) natural aggregate fractions, 4/8 and 8/16 mm were replaced by washed recycled concrete aggregate. The replacement variation in the experimental mixtures was in range 0 to 100%, as it is shown in Table II.

TABLE II
Percentage Replacement of Natural Aggregates by Washed Recycled Concrete Aggregates in the Mixture

Sample	Recycled concrete aggregate	
	4/8 mm [%]	8/16 mm [%]
R1	0	0
R2	100	20
R3	100	40
R4	100	60
R5	100	80
R6	100	100
R7	20	100
R8	40	100
R9	60	100
R10	80	100

Experimental mixtures were processed in the laboratory mixer with a horizontal rotary drum with a capacity of 150 l. Compounding process was chosen as follows: to a mixing drum machine aggregate in the order of fractions 8/16 mm, 4/8 mm, 0/4 mm were put. After a careful mixing of the all components concrete mixture were placed into cleaned plastic forms. Thus prepared forms were then over 15s compacted on a vibrating table. After filling, cubic forms were labelled and placed on a flat surface next 48 hours. After 48 hours, the cube bodies were removed from the forms and then placed in a water bath. In order to realize the experiment program 48 pieces of test cubes with dimensions of 150x150x150 mm were made. Hardening time of samples contained recycled concrete aggregates was 2, 7, 14 and 28 days. Compressive strength testing intervals for samples with recycled concrete aggregates is given in Table III. The actual test compressive strength of the samples was carried out on the hydraulic bench press ELE 2000.

TABLE III
Compressive Strength Testing Intervals for Samples With Recycled Concrete Aggregates

Sample	Days
R1	2, 7, 14, 28
R2	2, 7, 14, 28
R3	14, 28
R4	14, 28
R5	14, 28
R6	2, 7, 14, 28
R7	2, 7, 14, 28
R8	14, 28
R9	14, 28
R10	14, 28

The most important descriptive characteristic of fresh concrete is workability. For the purpose of this experiment Slump test was selected and performed, according to the Slovakian standard STN EN 12350-2. In the test, fresh concrete was compacted in the form of a hollow truncated cone. The aim of the test is to determine the suitability of the composition of the concrete mixture for transport, shaping and compacting, or the values of workability of fresh concrete. The measured values of slump test of fresh concrete by this method are given in Table IV. As it is evident, in the investigated samples slump grade S3 was achieved.

TABLE IV
THE MEASURED VALUES OF FRESH CONCRETE SLUMP TEST

Sample	Slump [mm]	Slump grade
R1	165	S3
R2	170	S3
R3	155	S3
R4	150	S3
R5	160	S3
R6	160	S3
R7	155	S3
R8	160	S3
R9	160	S3
R10	165	S3

III. RESULTS AND DISCUSSION

Table V shows the average values of density of each sample after 28 days of hardening. It is evident that the density of the reference sample is almost identical to the density of the sample called R6, in which natural aggregates by crushed concrete waste had been completely replaced. The lowest density reached sample R10, containing 80% of recycled material in 4/8 mm fraction and 100% of recycled aggregates in 8/16 mm fraction. Average density of all samples is in the range from 2245 kg/m^3 to 2344 kg/m^3.

TABLE V
AVERAGE VALUES OF DENSITY AFTER 28 DAYS OF HARDENING

Sample	Average weight [kg]	Average density [kg/m^3]
R1	7.736	2342
R2	7.732	2320
R3	7.659	2309
R4	7.608	2256
R5	7.660	2258
R6	7.847	2344
R7	7.705	2320
R8	7.814	2332
R9	7.627	2288
R10	7.600	2245

Fig. 1 shows compressive strength of samples prepared with recycled concrete aggregates after hardening.

Only in the four concrete samples (R1, R2, R6 and R7) start-up compressive strength after 2 and 7 days of hardening was observed.

From the analysis of obtained results follows, that samples R1 and R2 after 7 days of hardening meet the minimum strength of 20 MPa according to standard STN EN 206-1, but samples R6 and R7 fulfil this requirement after 28 days. From Fig. 1 it is evident that all samples meet the requirement of a standard (compressive strength 20 MPa), already after 14 days of hardening. The highest compressive strength after 28 days of hardening reached sample R4 (34.68 MPa; 100% recycled fraction 4/8 mm, and 60% recycled fraction 8/16 mm), but this is only slightly different from the strength of the reference sample R1 (34.41 MPa). The lowest strength reached sample R8 (40% recycled fraction 4/8 mm and 100% recycled fraction 8/16 mm).

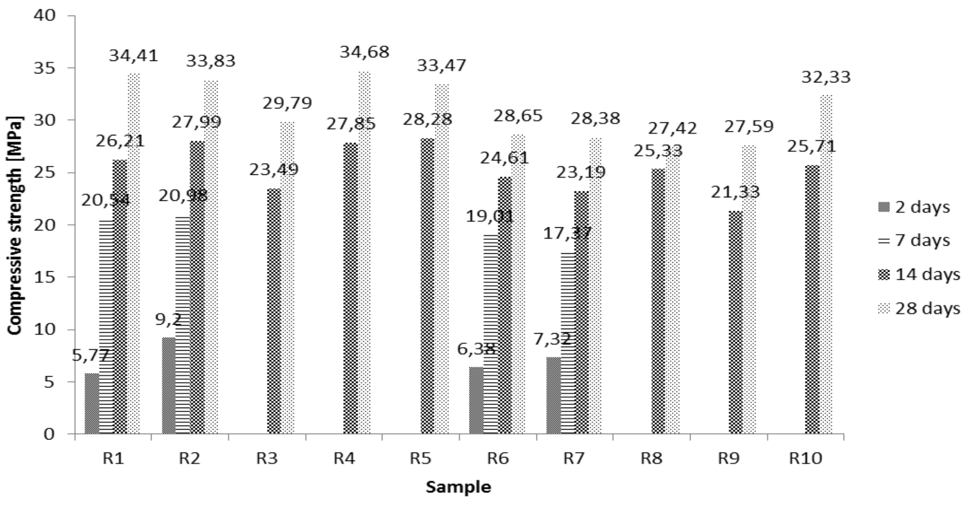

Fig. 1 Compressive strength samples prepared with recycled concrete aggregate after 2, 7, 14 and 28 days of hardening

IV. CONCLUSION

The production of concrete is not environmentally friendly and therefore significant environmental advantages may be realized if alternative, environmentally sensitive materials are identified for use in concrete products manufacturing.

This paper presents the results obtained from the research focused on the utilization of crushed waste concrete aggregates as a partial or full replacement of 4/8 and 8/16 mm natural aggregates fraction in concrete strength class C 16/20. Main concrete characteristics such as workability, density and compressive strength were studied.

The most important descriptive characteristic of fresh concrete is workability. For the purpose of this experiment Slump test was selected and performed. The amount of water in the mixture was indicative. For mixture resulting consistency required slump grade S3 was followed.

The density of concrete is a measure of its unit weight and it varies depending on the amount and density of the aggregate, the amount of entrained air and the water and cement content. Average density of all samples is in the range of 2245 kg/m^3 to 2344 kg/m^3. The density of the reference sample is almost identical to the density of the sample, which had been completely replaced by recycled concrete aggregates. The lowest density reached sample R10, containing 80% of recycled material in 4/8 mm fraction and 100% of recycled aggregates in 8/16 mm fraction.

Compressive strength testing intervals for samples with recycled concrete aggregates were 2, 7, 14 and 28 days. The highest compressive strength after 28 days of hardening (34.68 MPa) reached sample, which contained 100% of recycled material in 4/8 mm fraction and 60% of recycled aggregates in 8/16 mm fraction. This achieved value was only slightly different from the compressive strength of the reference sample (34.41 MPa). The lowest compressive strength reached sample, which was prepared with 40% of recycled fraction 4/8 mm and 100% of recycled fraction 8/16 mm.

Results show that it is possible to replace the two fractions (4/8 mm and 8/16 mm) of natural aggregates by recycled concrete aggregates to prepare lower strength classes of recycled aggregate concrete.

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References

[1] M. Batayneh, I. Marie and I. Asi, "Use of selected waste materials in concrete mixes," Waste management, vol. 27, pp. 1870-1876, 2007.

[2] M. Berry, D. Cross, and J. Stephens, "Changing the Environment: An Alternative "Green" Concrete Produced without Portland cement," in *World of Coal Ash Conf.*, Lexington, KY, USA, 2009, pp. 1-11.

[3] M. Glavind, and C. Munch-Petersen, "Green concrete in Denmark," *Structural Concrete,* vol. 1, no.1, pp. 1-6, 2000.

[4] A. Srivastava, *Seminar report on Green Concrete.* Kanpur: Harcout Butler Technological Institute, 2011 (Online). Available: http://www.scribd.com/doc/49302384/Seminar-Report-Green-Concrete.

[5] N. Junakova and M. Balintova, "The study of bottom sediment characteristics as a material for beneficial reuse," *Chemical engineering*, vol. 39, pp. 637-642, 2014.

[6] M. Ondova and A. Estokova, "Analysis of the environmental impact of concrete-framed family house using lca method," *Ciencia E Tecnica Vitivinicola*, vol. 29, no. 7, pp. 267-376, 2014.

[7] A. Sicakova and K. Urban, "Trends in types and technologies of concretes for prefabrication," in *Improving the efficiency of construction through MMC technologies: Proceedings of scientific papers*, TU: Kosice, 2014, pp. 71-78.

[8] M. Ondova and A. Sicakova, "Review of current trends in ways of fly ash application", in *SGEM 2014: Geoconference on Ecology, Economics, Education and Legislation*, Sofia: STEF92 Technology, 2014, pp. 603-610.

[9] N. Stevulova and J. Junak, "Alkali-activated binder based on coal fly ash, "Chemicke *listy*, vol. 108, no. 6, pp. 620-623, 2014.

[10] J. Anderson, H. Meryman, and K. Porsche, "Sustainable Building Materials in French Polynesia," *International Journal for Service Learning in Engineering,* vol. 2, no. 2, pp. 102-130, 2007

[11] M. Blanco-Carrasco, F. Hornung, and N. Ortner. *Qatar: Green Concrete Technologies. Towards a Sustainable Concrete Industry in Qatar*, 2010 (Online). Available: http://www.strabag.de/databases/internet/_public/files.nsf/SearchView/61609E5C572EDF8DC12578870037C6F3/$File/green-concrete.pdf.

[12] J. Junak and N. Stevulova, "Natural aggregate replacement by recycled materials in concrete production," *Visnik Nacional'nogo universitetu L'vivska politechnika: teorija i praktika budivnictva*, no. 756, pp. 63-68, 2013.

[13] V. Vaclavik, V. Dirner, T Dvorsky and J. Daxner, "Use of blast furnace slag, "Metalurgija, vol. 51, no.4, pp. 461-464, 2012.

[14] P. Demeter, D Baricova and A. Pribulova, "Potential cupola slag utilization in the production of concrete," *Prace Instytutu Metalurgii Zelaza*, vol. 64, no.5, pp. 13-14, 2009.

[15] J. Junak and A. Sicakova, "Glass waste as an alternative to natural aggregate," in *International Multidisciplinary scientific Geoconference*, Sofia: STEF92 Technology, 2014, pp. 321-326.

[16] M. Malesev, V. Radonjanin and S. Marinkovic, "Recycled concrete as aggregate for structural concrete production, "Sustainability, vol. 2, no. 5, pp. 1204-1225, 2010.

[17] M. Boltryk, D. Malaszkiewicz and E. Pawluczuk, "Basis technical properties of recycled aggregate concrete," in *Proceedings of the 9th International Conference: Modern building materials, structures and techniques*, Vilnus, Lithuania, 2007.