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Properties of concrete with partial replacement of natural aggregate by recycled concrete aggregates from precast production

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Abstract

Recycled concrete aggregates (RCA) can be used as a replacement of natural aggregates for a concrete production to save natural sources and also to decrease amount of demolition waste which has to be landfilled. Precast production generates some percentage of defected elements which are carted off and recycled with other demolition waste. In this study defected elements are separately recycled into RCA with beneficial properties and used directly into new mixtures for precast elements. Results from testing of RCA and application into new concrete mixtures are presented. It was proved that the replacement of raw aggregates by RCA up to 20% has no negative influence on physico-mechanical properties of concrete.

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Keywords: Concrete recycling; recycled concrete aggregates (RCA); defected elements from precast production; mechanical performance

1. Introduction

Trend of the last decade is recycling of waste materials into secondary raw materials, waste separation and ecological disposal of unrecyclable waste. Modernization of old buildings and new constructions of structures which are higher, larger and with high tech equipment is accompanied by rising amount of demolition waste from old structures and obsolete technical equipment. This construction and demolition waste (C&DW) has to be stored on landfills which doesn't have inexhaustible volume capacity and therefore we have to search for new solutions in reuse of old building materials such as concrete or mortar are. Construction industry in EU is sector with highest

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consumption of natural resources and also with the greatest production of waste, around 900 million tons of waste per year [1]. Landfills for C&DW are reaching their volume capacity limits and it is not allowed to store C&DW with municipal refuse. Fundamental problems of recycling are the clearliness and quality of sources. Impurities in demolition waste for production of secondary raw materials play a main role in sense of quality of new secondary raw materials. Concrete is the most used building material in the world and aggregates constitute around 70% of its volume. Natural aggregates (NA) can be easily replaced by recycled concrete aggregates (RCA) generated from C&DW and lead toward savings of natural resources. Ecological aspects of RCA usage are savings of NA and space on landfills and economical aspect is presented by the price of recycling and separation process in comparison with price of aggregate exploitation which is more significantly energy-intensive.

As it was already mentioned, the quality of the recycled concrete aggregates is based on quality and source of construction and demolition waste from which are the RCA produced. Commonly C&DW from different places is collected in recycling plant, mixed and from such a mixed C&DW is produced RCA with relatively high percentage of impurities, for instance bricks, plastic and asphalt. Such RCA is not allowed to be used as aggregates for a concrete production, because the properties do not comply with the conditions given in European Standard ČSN EN 12 620+A1 [2]. If the RCA want to be used for a concrete production, it has to contain 90% or more crashed concrete, bulk density higher than 2,000 kg/m^3 and maximum absorption capacity 10% or less. These conditions are valid for Czech Republic, for other countries it can vary, see Table 1. Solution how to obtain RCA with suitable properties is recycling in-situ or separation of C&DW by source and content on a recycling plant. First suggested solution is much more valuable, because the RCA can be directly used in same place and cut down costs of transportation. This first solution can be also applied in precast production where defected elements can be crushed, assorted into fractions and directly used in new mixtures.

Table 1. Regulations for RCA for concrete production in selected European countries. [3]

Property	Belgium	Germany	Netherlands	Portugal	Czech Republic
Composition (*% by weight*)	≥ 95% crashed concrete	≥ 90% crashed concrete	≥ 95% crashed concrete	≥ 90% crashed concrete	≥ 90% crashed concrete
Bulk density (*kg/m^3*)	≥ 2,200	≥ 2,000	-	≥ 2,200	≥ 2,000
Absorption capacity (*%*)	≤ 10 ± 2	≤ 10	-	≤ 7	≤ 10
Content of fines particles (*%*)	1.5	-	1.0	4.0	-

Properties of the recycled concrete aggregates depend on the source, quality of the waste material, percentage ratio of components and also on the sieve-fraction of aggregates. Bulk density is lower by 10 to 15% in comparison to natural aggregates, water absorption capacity is higher by 5 to 10% in comparison to NA for coarse fraction and from 7 to 12% in case of fine fraction 0–4 mm. Fractions with maximum grain size of 4 mm content usually around 20% of fines (particles smaller than 0.25 mm), which can be beneficial for production of self-compacting concretes. Pavlů [3] proved by her research, that RCA from different sources have different properties, which was further supported by our research where the results showed that properties of demolition concrete has influence as well. Other research carried by Abbas et al. [4] reported that approximately 20% particles of RCA fraction size 4.75–9.5 mm are composed of residual mortar, and in case of coarse fractions more than 50% is constituted by less than 15% residual mortar.

Many studies present results from testing of concrete with partial or total replacement of natural aggregates by recycled concrete aggregates, but the practical use of such a concrete is rare to find. As the properties of RCA differ from NA it is necessary to make some changes in composition of mix design, mixing method and curing of RC (concrete with recycled concrete aggregates). Due to higher water absorption capacity of RCA it is advice to increase water-cement ratio (w/c ratio) or minimalize the time of mixing and moulding of fresh RC. Second option of production is similar to preparation of light weight concrete with light weight aggregates, which has even higher water absorption capacity. [5,6] Study from Amorim, Brito and Evangelista [7] proved only slight influence of curing conditions on further strength properties of RC and verified that dry curing conditions are not positive for RC neither for conventional concrete (CC). Decrease of the strength and durability of RC is caused mostly by weak interfacial transition zone (ITZ) which can be avoided by enhancement of the strength of bond between old mortar