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Fracture Mechanical Properties of Cement Based Composites with Various Amount of Waste Aggregates

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Abstract

The importance of sustainability and recycling has become increasingly recognized and understood in academia and industry over the last several decades. Recycling of construction and debris waste is one of many avenues that provide a great opportunity to prevent waste material from entering landfills and reduce the construction industry reliance on decreasing natural resource supplies. The research program focused on fracture parameters of cement based composites with various amount of waste aggregate was conducted. There were prepared composites based on specifically composed aggregates (mixture of natural sand and red waste ceramic aggregate). There was utilized simplex experiment design. Altogether, 6 mixtures of aggregates were prepared. The aim of this contribution is to present and compared basic fracture parameter values. Flexural and compressive strength and fracture toughness were of special interest. All of these tests are important for a practical application of concrete with ceramic aggregates for structures.

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Keywords: Cement based composites; fracture mechanics; waste aggregate; stress intensity factor, fracture properties;

1. Introduction

Ceramic materials have been used for a long time for a multitude of uses and continue to be a common material used for making goods such as earthenware and sanitary ware [1] [7]. Ceramics are also commonly used as a building material, for example ceramic floor and wall tiles, and various clay building bricks. Ceramic waste from construction industry is probably the most important part in the global volume of construction and demolition waste [5] [6] [14]. The most promising recycling process of ceramic waste is using it as a coarse aggregate for concrete [2]. Worldwide, there is a growing research effort to successfully harness ceramic waste in construction industry [10]. Replacing traditional coarse aggregates by waste ceramic aggregates (WCA) also significantly influences the homogeneity of

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mechanical properties of cast concrete (populations of results are characterized by significantly higher standard deviation) and mechanical properties themselves [5] [19]. This phenomenon limits applications of concrete based on WCA only to construction elements characterized by less demanding mechanical characteristics.

The aim of the contribution is to introduced the pilot fracture mechanical properties of the set of various concrete with waste aggregates. The research program is based on red ceramic waste that is ground and replace different amount of natural aggregates in concrete. The variables being monitored for all concrete in the contribution are flexural strength, compression strength and fracture toughness. The influence of possible replacement of natural aggregates by waste ceramic aggregates on mentioned fracture properties is discussed.

Nomenclature

3PBT	three-point-bend test
a	crack length [mm]
E	Young's modulus [MPa]
K	stress intensity factor [MPam$^{1/2}$]
K_{IC}	fracture toughness [MPam$^{1/2}$]
L	length of the specimen [mm]
LEFM	linear elastic fracture mechanics
P	load/force [N]
P_{max}	maximal value of the load [N]
S	span of the specimen [mm]
SIF	stress intensity factor
t	thickness of the specimen [mm]
W	width of the specimen [mm]
α	relative crack length [-]
σ	stress [MPa]

2. Materials and specimens

To evaluate the mechanical properties of concrete made with ceramic material, concrete test specimens were made in various moulds appropriate for the test plan. The composition of 1 m^3 of fresh studied concrete mixtures is introduced in Tab. 1. There are mixtures marked from 1 to 6, 1 – only natural aggregates and 2-6 with various amount of ceramic waste. All studied mixtures were prepared in laboratory mixer in 30 liter volume. Immediately after the mixing, the fresh concrete was placed into steel moulds. For compressive strength tests 150 mm × 150 mm × 150 mm cubes were prepared. For flexural strength and fracture toughness tests beams of 40 mm × 40 mm × 160 mm were made. The specimens were unmoulded at the age of 24 hours and given to laboratory cellar with constant temperature of +20°C±1°C. They were stored in these conditions until the test started.

After the preparation the bulk density of each mixture was measured and the results are shown in Tab. 2, where the average values, median and average deviation are shown. One of the advantage of using the ceramic waste is that the value of density decrease with increase value of replacement of sand by ceramic waste and therefore for the same volume of concrete has less weight.