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Fracture energy of foamed concrete based on three-point bending test on notched beams

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Abstract

A series of static loading tests was performed to determine the fracture properties of foamed concrete of varying density. Beams with dimensions of 100×100×840 mm with a central notch were tested in three-point bending. Then, remaining halves of the specimens were tested again as un-notched beams in the same set-up with reduced distance between supports. The tests were performed in a hydraulic displacement controlled testing machine with a load capacity of 5 kN. Apart from measuring the loading and mid-span displacement, a crack mouth opening displacement (CMOD) was monitored. Based on the load – displacement curves of notched beams the values of fracture energy and tensile stress at failure were calculated. Subsequently, the flexural tensile strength was obtained on un-notched beams with dimensions of 100×100×420 mm. Moreover, cube specimens 150×150×150 mm were tested in compression to determine the compressive strength.

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Keywords: fracture energy; foamed concrete; three-point bending; notched beams

1. Introduction

Foamed concrete can be defined as a cementitious material with minimum of 20% (by volume) [1] of mechanically entrained foam in the mortar suspension in which air-pores are entrapped in the matrix by means

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of a suitable foaming agent. Foamed concrete is widely known for its low self-weight and excellent acoustic and thermal properties [2]. For many years, it has been used worldwide for backfill to retaining walls, insulation to foundations and roof tiles, sound insulation, etc. However, in the last years foamed concrete has become a promising material [3] also for structural purposes e.g. for stabilization of weak soils [4] and as a base layer in a sandwich solution for foundation slabs [5].

Due to favourable properties of foamed concrete, many interests and studies were conducted to investigate its strength, mechanical, acoustic and thermal properties. However, these studies do not cover the investigation of fracture energy which is the main parameter governing the damage and fracture mechanisms. Only limited number of studies can be found in literature. Rahman and Jaini [6] performed studies of fracture energy of foamed concrete on notched beams with the density of 1400−1600 kg/m^3. The fracture energy of foamed concrete with compressive strength of 6.4−14 MPa was relatively high around 18−25 N/m. Furthermore, Hengst and Tressler [7] stated that for lightweight concrete, the fracture energy is only a fraction of the normal weight concrete.

The main aim of the research was to determine the fracture energy and mechanical properties of foamed concrete of varying density. The knowledge is required for further numerical simulations of structural behavior and modelling of cracking. This work was supported by the on-going research project “Stabilization of weak soil by application of layer of foamed concrete used in contact with subsoil” (LIDER/022/537/L-4/NCBR/2013) financed by The National Centre for Research and Development within the LIDER Programme.

2. Material and methods

2.1. Materials

An ordinary Portland cement (CEM I 42.5 R) was used in this research. Water used was fresh, clean and drinkable water. Foam was produced by mixing the foaming agent and water in predefined proportions in a foam generator. Subsequently, the foam was mixed with cement in a concrete mixer. After casting in steel molds, the specimens were covered and stored in a curing room at 20±1ºC and 95% humidity for the first 24 hours. Subsequently, the beams were removed from the molds and stored in ambient conditions for 28 days before testing. In this study, four different concrete mixes resulting in varying densities were used, see Table 1. All concrete mixes produced had w_{eff}/c of 0.44.

Table 1. Mix proportions, density and compressive strength of produced specimens.

Specimen type	Cement (c) [kg/m^3]	Water (w) [dm^3/m^3]	Foaming agent [dm^3/m^3]	w_{eff}/c*	Density (ρ) [kg/dm^3]	Compressive strength [MPa]
A	750	300	30	0.44	1024 ± 1.0	5.9 ± 0.2
B	634	241	38		882 ± 0.5	4.4 ± 0.2
C	514	190	36		662 ± 2.0	2.4 ± 0.3
D	386	143	27		488 ± 0.5	0.6 ± 0.2

* – w_{eff}/c includes foaming agent in a liquid state

In total 32 specimens were fabricated, five beam and three cube specimens for the same mix. The beams measured 100×100×840 mm. A 3 mm wide mechanical notch was fabricated with a depth (a) of 42 mm, resulting with a notch to beam depth ratio (a/d) of 0.42. For standardized fracture energy tests [8], the required a/d ratio ranges from 0.45 to 0.55. However, using deep notched beams specimens with foamed concrete may produce undesirable test results, such as large statistical variation and crack initiation under self-weight. The cubes measured 150×150×150 mm. Before testing all manufactured specimens were measured and weighted. Table 1 presents the densities calculated as well as the values of compressive strength determined based on the cube specimens.