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Laboratory tests of foam concrete slabs reinforced with composite grid

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Abstract

Nowadays foam concrete is commonly used as replacement of compacted soil to fill excavations, underground channels. There are also attempts to structural use of this material; among the examples are precast walls and slab foundations. The high degree of thermal insulation makes foam concrete a perfect material for use in the passive houses design. Unfortunately, foam concrete cannot be reinforced as easily as traditional concrete. Because of low resistance to concentrated stresses it is difficult to ensure sufficient bond of reinforcement. The idea of solid foam concrete slab presented in the paper incorporates bi-directional composite reinforcing mesh placed in tensile zone of the slab where transverse fibers are ensuring anchorage for fibers in main direction. This method of reinforcement, apart from the increase of bearing capacity, should reduce the risk of uncontrolled failure due to cracking. The paper describes the results of preliminary laboratory tests of nine slabs made of foam concrete reinforced with meshes made of carbon fibers. The results obtained at the initial stage show great potential of this method of reinforcement. There was a significant increase in capacity and less brittle failure mode.

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Keywords: foam concrete, floor slab; composite reinforcement; carbon fibre grid

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1. Introduction

Foamed concrete is a type of lightweight cellular concrete in which low density is achieved by increased volume of pores in the microstructure of the material obtained by introduction of technological foam. This type of concrete is also cement-based but it contains lightweight fine aggregates to further decrease the density of the product.

Depending on its composition and production technology, foamed concrete can be obtained in a wide range of densities, starting from <300 kg/m^3 to even up to 1900 kg/m^3. Density of foamed concrete is a measure used for its qualification because it influences most of its major properties. An extensive characterization of foamed concretes and state-of-the-art review of their properties was presented by Narayanan and Ramamurthy [1], Ramamurthy et al. [2] and most recently Mugahed Amran et al. [3]. From these overviews it can be easily concluded that the most important property of foamed concrete is its thermal conductivity which makes the material a good thermal insulator. In general, thermal insulation properties of foamed concrete increase with decreasing density (increased air pores volume). However, at the same time, the mechanical properties of concrete decrease. Compressive strength of foamed concrete can range from <1 MPa for density of <300 kg/m^3 to ~20 MPa for densities approaching limit value of 2000 kg/m^3.

Given this trade-off between strength and insulation properties, foamed concretes with low densities are very popular in use. Their applications are mainly geotechnical, where the strength of some MPa and corresponding stiffness of the material are sufficient to use it as a replacement of soil. Among many others, the examples of application of foamed concrete as a subbase layer in road construction [4] or industrial concrete floors [5] can be referred. Combining with good thermal properties, foamed concrete subbase was proposed by the Authors to be used in construction of sandwich foundation slabs in energy-efficient residential buildings [6, 7]. Nevertheless, it appears that foamed concretes with higher densities, thus higher values of mechanical properties, can be competitive with ordinary concretes in structural applications, especially when fibre reinforcement is applied [3], yet still providing beneficial thermal insulation properties. In the last few years several proposals of structural applications were made independently worldwide. All of them are related to panel elements subjected to either axial loading (walls) or flexural loading (one-way slabs).

The first concept, proposed by Mugahed Amran et al. [8, 9], is a sandwich panel made of two foamed concrete wythes separated with polystyrene filling. This concept originates from non-bearing cladding systems in which prefabricated panels are made of concrete wythes separated with insulation material. The structural (concrete) components of the panel are joint together with steel shear connectors. These connectors ensure integrity and composite action of the panel as well as ductility of the element. Foamed concrete of ~1800 kg/m^3 density and ~25 MPa compressive strength was used. Behavior of the panel under axial [8] and flexural [9] loading was investigated. The results of the experiments showed that the behavior of the foamed concrete panels was similar to what would be expected from reinforced concrete solid walls and slabs. Desirable increase in ductility in comparison to RC was reported in slabs. In both cases, the importance of steel connectors, which should ensure composite action of the panels, was strongly emphasized. It was concluded that the proposed foamed concrete sandwich panels have a potential to be used as an alternative to ordinary concrete walls and slabs, and can be designed with analogical approaches given that composite action can be assumed.

Another concept comprises sandwich panels made by filling thin-wall corrugated steel forms with foamed concrete. Such panels were investigated to be used as either wall panels [10] or slab panels [11]. Corrugated steel was used as formwork but its main role was to increase ductility of the panel and prevent its otherwise brittle failure. Foamed concrete used in wall panels by Othuman Mydin and Wang [10] was of relatively low density (1000 kg/m^3) characterized with cylindrical compressive strength of only ~5 MPa. However, the test results showed there is composite work of steel faces and concrete core, and proved that such parameters of concrete are sufficient to provide capacity of the sandwich panel which enables it to be used as a wall panel in low-rise buildings. Similar low-density foamed concrete (targeted density of 1000 kg/m^3 with compressive strength of ~5 MPa) was used by Flores-Johnson and Li [11] in production of corrugated steel–foamed concrete slab panels. In this case the importance of the bond between steel and concrete was also emphasized because it ensures required composite action of the panel.