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New experiments on shear properties of fibre-concrete

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Abstract

Concrete reinforced by dispersed fibres (or simply fibre-concrete) is relatively new material. The motivation for adding fibres into concrete is to reduce natural brittle character of concrete. The biggest benefit of dispersed reinforcement is in its positive influence on fracture energy and ductility. The behaviour of fibre-concrete exposed to bending moment (or combination of bending moment and shear force) was investigated many times and it is well understood. Nevertheless, none of realized experiments investigated the performance of fibre-concrete in pure shear mode. In this context, it should be noted that in many real applications fibre-concrete is affected by significant shear forces. In order to remedy this situation, the new arrangement of experiment was proposed: large-scale tubes to which pure torsion is applied. In thin walls of designed simply supported tubes the pure shear is produced by application of torque. During experiments, not only ultimate shear strength was measured, but also the descending post-peak curve of transmitted stress was observed. These results enable to derive the stress–strain relation in the whole range of stress-strain diagram in the pure shear mode.

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1. Introduction

Concrete is the most widely used construction material in the world. Individual components of this composite material were significantly upgraded through the last 100 years.

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Concrete evolution beneficially influenced its mechanical and technological properties and extended the concrete durability. However, the brittle character of concrete is still one of the weakest points of this material. In order to improve this disadvantage, the dispersed reinforcement with sufficiently high Young modulus is applied.

By adding dispersed reinforcement the brittle character is reduced and concrete gain ability to carry load after crack propagation. This phenomenon is documented by increase of fracture energy. Many researchers focused on this topic [1,2].

Real applications of fibre-concrete are frequently arranged to carry shear forces. Unfortunately, no realized experiment investigated the performance of fibre-concrete in pure shear mode without any flexural effects. Realization of these specific conditions in case of prism beam, loaded by vertical transverse load, is not feasible. In such an arrangement, the shear is always accompanied by bending effects. From the theoretically strict point of view, the pure shear is obtained only in the region of neutral axis. However, until now, the realized experiments investigating shear behaviour of fibre-concrete were based on beam type experiments only [3,4,5].

For the full understanding of fibre-concrete performance, it is necessary to carry out the pure shear experiments. Moreover, advanced nonlinear analysis of quasi-brittle materials employs constitutive laws describing the complex material behaviour. The newly proposed experiments enable calibrating these sophisticated material laws.

Beam loaded by transverse load does not allow realization of pure shear mode, so it was proposed special arrangement of the experiment. The appropriate solution proved to be to large-scale thin-walled tubes loaded by torsion moment. The torque is induced by couple of opposite forces applied at cantilevers which are monolithically connected and perpendicularly oriented to the tube.

The experimental fibre-concrete tubes are of constant thickness and of constant radius along the entire length, so shear flows are in individual cross-sections identical. Effort was to design thin-walled tubes with large radius in order to ensure nearly same stress in inner and outer side surface of the tube. This requirement was hardly to satisfy because of technology limits. The minimal thickness of a concrete tube must respect the size of used fibres. Larger fibres demand thicker wall (ideally more than 1.5 times of fibre length) in order to avoid oriented fibres in concrete. These opposed requirements resulted in the subsequent solution.

2. Arrangement of the specimen

The whole specimen is manufactured monolithically. Fibre-concrete specimen consists of the middle part (the tube) and the end parts (cantilevers perpendicular to the tube axis). Cantilevers enable to support the specimen and also to introduce the torque. The specimen is placed in horizontal position.

Each cantilever is loaded by a couple of inverse forces producing torsion effects in the tube (one force is action from hydraulic jack and 3 other ones are reactions). It was necessary to arrange boundary conditions of statically determinate structure in order to avoid restrained torsion that is accompanied by additional stress in tubes. In Figure 1, the scheme of specimen including reactions from supports is drawn. Support *A* represents a hinge capable to move in the *y* direction. Support *B* is elastic bearing, which allows *x*-axis displacement. Support *C* is realized by a rod transmitting only vertical tension.

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