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High velocity testing of concrete composites

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Abstract. The aim of this study is a new test method focused on dynamic behaviour of brittle materials especially concretes and their composites. Modified Hopkinson testing device was developed. The dynamic test conditions were simulated with advance of explicit numerical solution. The tensile test was performed as the so-called Brazilian test and standard tensile test as well.

Introduction

Besides quasi-static loads, many concrete structures are subjected to short duration loads, such as the impacts from missiles and projectiles, wind gusts, earthquakes etc. The aim of this paper consists in an experimental study of the influence of non-metallic fibers both on quasi static and dynamic mechanical properties. The concrete specimens with carbon, aramide, glass, polyprophylen and wollastonite fibers have been tested.

The response of the given materials to the quasi-static compressive and flexural loading has been studied. The dynamic loading was realized using of the Split Hopkinson Pressure Bar technique (SHPB). Three kinds of dynamic tests were carried out: a classical compressive test, tensile – splitting test (Brazilian test) and classical tensile test.

Material and Experimental Technique.

Five material types with reinforcing fibers were prepared (including SIFCON matrix):

- Aramid fibers with length of 1 mm. Their volume content is 1.5%.
- Carbon fibers with length of 3 mm. Their volume content is 1.5%.
- Recycled glass laminate fibers length < 0.3 mm. Their volume content is 3%.
- Polypropylen fibers, length 3 mm. Their volume content is 1.5%.
- Wollastonite fibers, length < 0.3 mm. Their volume content is 2%.

The dynamic mechanical properties were obtained using of the Split Hopkinson Pressure Bar technique (SHPB). The used specimens had the form of the cylinders, whose diameter and thickness were 30 and 15 mm respectively. The position of the specimen is shown in the next picture.

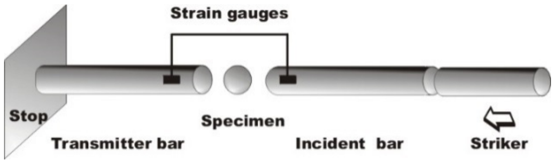
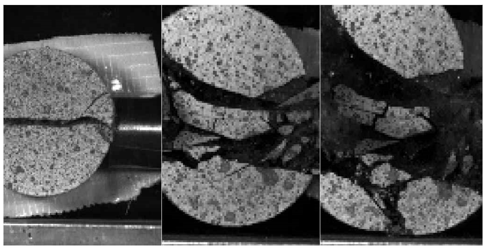


Fig.1. Experimental arrangement of the dynamic tensile – split test (Brazilian test).

This arrangement, which is known as the Brazilian test, or diametric compression test, is a typical indirect tensile test, which was developed to determine the tensile strength of brittle materials such as rock, ceramics and concrete [1-2]. In this case the diametral loading generates tension perpendicular to the load plane, which eventually causes the specimen to split. To obtain a detailed dynamic deformation and fracture process of the brittle specimens in the dynamic Brazilian test, using a high-speed camera, requires a high frame rate. For a high-speed camera, there is a compromise between the frame rate and image resolution. The fracture of the specimens during the Brazilian test was recorded using the high-speed photography (160000 frames per second).



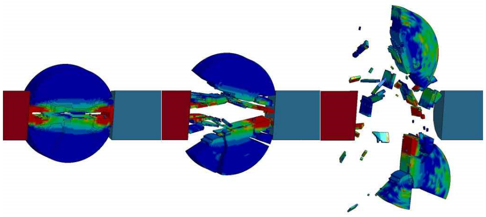


Fig.2. Result comparison

A relatively good agreement between experiment and numerical simulation was found at the beginning of the specimen fracture. The next development of the specimen fracture differs from the results of the numerical simulation. Experimental records show that the specimen fracture is not plane symmetric. This is probably a consequence of the material inhomogeneity

Numerical simulation of the tests on the indirect tensile strength has been performed using LS DYNA 3D finite element code. The concrete composite material has been described in terms of Winfrith concrete model. Its main advantage consists in the fact that this model does not need much knowledge on the concrete.

New experimental device was developed. It enables classical tensile test with sample with diameter about 50mm. The longitudinal pressure wave from the punch impact is transferred to the material sample and the loading sensors.

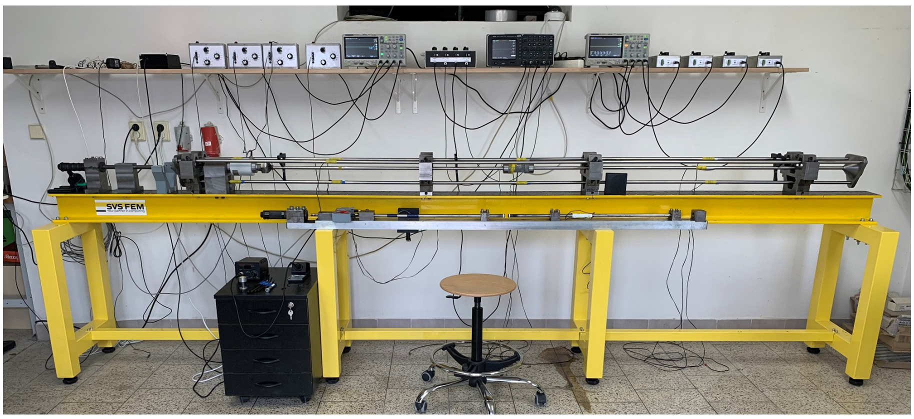


Fig. 3: Tensile Split Hopkinson Bar device

The specimen is connected to measuring bars by bonding joint. It was developed during set of quasi static tests.

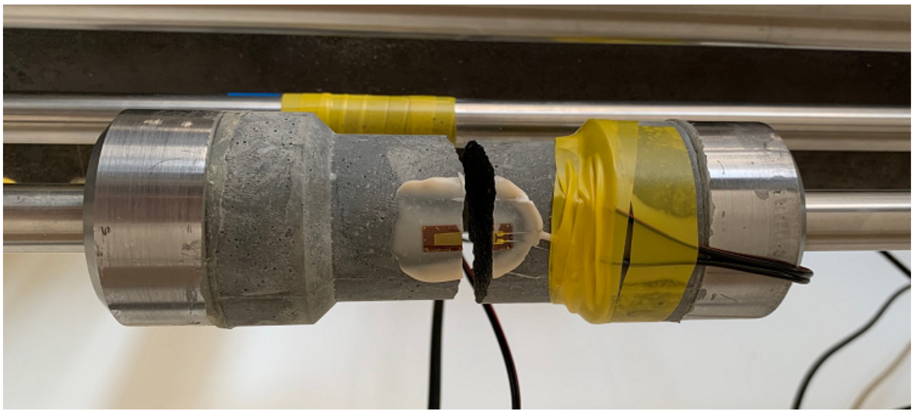


Fig. 4: Specimen after test

The stress history from the specimen is evaluated by four independent methods.

1. directly from a strain gauge installed on the specimen
2. indirectly from strain gauges installed on the measuring bars (standard evaluation from Hopkinson test principle
3. indirectly from a force transducer installed on the back measurement bar
4. optically with high speed extensometer

Conclusions

Static and dynamic properties of concrete reinforced by different fibers were evaluated. The fiber reinforcement of the concrete leads to the improve of its mechanical properties like the compressive strength and tensile strength.

References

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