STUDY OF HIGH STRAIN RATE BEHAVIOUR OF MICRO-CONCRETE

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Abstract:

Concrete materials are widely used in structures as buildings, nuclear power stations, shelters, bridges... These structures have to be optimized regarding extreme conditions as blast or impact loadings. Consequently, the knowledge and understanding of the tensile behaviour of concretes at high strain rates need to be improved.

When concrete is subjected to high strain rates in tension (beyond s^{-1}), its tensile strength increases significantly. Phenomenon of spalling has been applied for approximately one decade to characterise the dynamic strength of concrete materials [1, 2, 3]. During such test, a cylindrical specimen of concrete is placed at the end of a Hopkinson bar, Fig. 1. A compressive pulse is generated by impact of a striker at the opposite end. A large part of this pulse is transmitted to the specimen and the other small part is reflected into the Hopkinson bar. When the transmitted pulse (negative) reaches the free end of the specimen, it is reflected as a tension pulse (positive). Superposition of both waves induces a tensile loading at a specific distance in the specimen that leads to its failure.

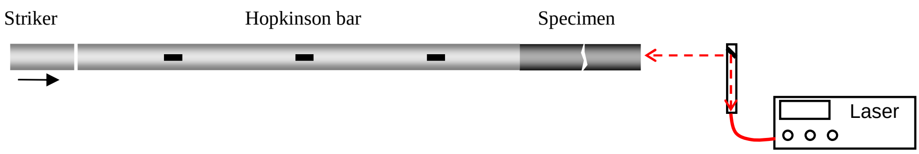

Fig.1 Principle of a modified experimental arrangement used for estimation of dynamic strength in tension

In this work, spalling tests are performed to investigate the tensile behaviour of a micro-concrete (maximum aggregate size: 5 mm) in the range of 10 s^{-1} to 100 s^{-1}. A specific methodology was applied to process experimental data. First, a laser displacement gage was used to measure the axial velocity on the rear face of the specimen, Fig.1. An example of the record is shown in Fig. 2. The spalling strength is deduced from Eq. (1) in which ρ and C_0 are respectively the density and the speed wave of the concrete and ΔV corresponds to the difference between the maximum and the rebound velocities. This equation was checked by numerical simulation of the tests in which an arbitrary failure criterion was used.

$$\sigma_{spall} = \frac{1}{2}\rho C_0 \Delta V \quad (1)$$

The transmitted pulse is reconstructed using incident and reflected pulses recorded from gages located on the Hopkinson bar, [1]. This pulse is implemented in a numerical simulation that involves the specimen alone assuming a purely elastic behaviour of the concrete. This calculation allows deducing the state of stress and strain rate before failure. Because failure is signalled by an increase of the mass velocity on the rear specimen face, Fig. 2, the failure time is also obtained. Thus, the strain rate at failure is also extracted from the numerical analysis. Finally, several tests performed with dry and wet specimens are compared with data available in the literature.

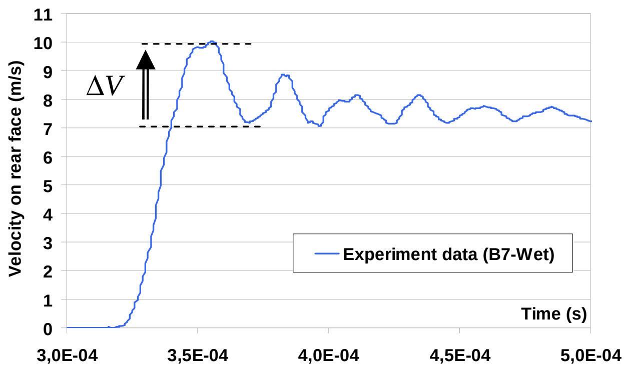

Fig.2. Velocity on the rear face measured by laser gage during test

Several Edge-On Impact (EOI) tests have been also performed to characterise the multiple fragmentation of dry and wet concrete tiles. This setup allows studying damage mechanisms in brittle materials like ceramics [4], rocks [5], and ultra-high strength concrete [6], under impact loadings. Post-mortem observations were performed after infiltration with a coloured hyperfluid resin. The cracking pattern is compared to those revealed in spalled specimens.

An anisotropic damage model was developed based on a micromechanical description of dynamic fragmentation process [7, 6]. In this work, this model is used to simulate the damage process of concrete specimens during spalling tests and EOI tests. The model allows explaining the increase of strength with loading rate. Moreover, different experimental data like velocity measured on rear face of specimens by the laser and the damage patterns are crosschecked with data obtained from the numerical simulations. Finally, the modelling is used to highlight the possible roles played by microstructure on the dynamic response of concrete materials under such high loading rates.

References

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