Investigation of the tensile and shear damage of concrete at high strain-rates

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Tensile fracturing (mode I) and shear fracturing (mode II) are usually observed in plain-concrete structures subjected to blast loading or impact loading of a rigid projectile. During the last years, several experimental configurations have been developed to characterize the dynamic response of concrete under shear and tensile loading at strain-rates ranging from few tens to one hundred of 1/s. On the one hand, Split Hopkinson Pressure Bar (SHPB) devices can be used to perform Punch Thought Shear tests for studying the dynamic shear response of concrete. In this configuration a mechanical balance of the concrete sample is achieved by using a pulse-shaper technique. A metallic ring was first employed as passive confinement of the sample. However, the level of confinement depends on the dilation of the tested concrete under shear loading. More recently a pre-stressed metallic ring was used to master the level of confinement in the concrete sample. Finally the dynamic shear strength of concrete is investigated as function of the free water content and the level of strain-rate.

On the other hand, the tensile strength of concrete can be investigated by means of the spalling technique. In such test the specimen remains in an unbalance state as it is loaded by means of a single Hopkinson bar on one end and is let free on the opposite end. A spherical–cap ended projectile hits the Hopkinson bar so a compressive wave travels along the bar and is partially transmitted to the concrete cylinder. It is reflected as a tensile pulse travelling backwards. When the reflected pulse exceeds in amplitude the incident one, a dynamic tensile loading develops in the specimen leading to the tensile fracturing of the sample. The spalling test is instrumented by means of strain gauges glued on the sample and a laser interferometer that is pointed out towards the free end of the specimen to record the velocity profile in the axial direction. The one-dimensional wave speed, the dynamic Young's modulus, the tensile strength and the strain rate are identified one-by-one. More recently, a new processing method was proposed based on the use of an ultra-high speed camera and the Virtual Fields Method. The acceleration field is deduced based on full-field measurement at the surface of the sample. The axial stress can be calculated in any visualized cross-section of the sample with the ultra-high speed camera that makes possible to derive the local stress-strain curve and to deduce the tensile strength and the facture energy of the concrete without any assumption on the behaviour of the tested sample. This configuration allows reaching strain-rates from 30 to 150/s. Finally, the experimental results reveal a strong influence of free water and strain-rate on the dynamic tensile strength of common concrete.