

Ultra-fast *in-situ* X-ray phase contrast imaging of dynamic failure of geomaterials using versatile Split Hopkinson Pressure bar systems

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1. Introduction

Quasi-brittle geomaterials, such rocks, cements and cohesive granular systems are frequently exposed to dynamic loading, either of natural origin (earthquakes, meteorite impact and volcanic eruptions) or man-induced risks (mining, blasting and hydraulic fracturing). Results of decades research show that the high loading rate induces microstructural changes leading to higher macro-mechanical strength compared to that under static conditions. Nevertheless, there seems to be no global consensus on the leading mechanisms for such behaviour, which seems to be linked to the lack of bulk material measurements that were up-to-recently only available on the sample surface [1]. With the development of high-energy synchrotron sources with high brilliance, short electron-bunch duration and high-energy, matter can be probed during transient dynamics by capturing through volume information with high temporal and spatial resolution [2]. In this work, materials under high-rate loading (*i.e.* compression, tension and shear) have been probed by ultra-high-speed X-ray phase contrast imaging (UHS XPCI) using radiation source at the ID19 beamline of the ESRF. Split Hopkinson Pressure bar (SHPB) system [2] have been used to study the dynamic fracture response of materials such as granite, concrete and sandstone. The results provide a unique insight into interactions between microstructural heterogeneities and the dynamic cracking processes lead by the intrinsic heterogeneous nature of these materials.

2. Materials and Methods

UHS XPCI is achieved with the bunch operation mode during which 4 or 16 electron bunches are within the

synchrotron storage ring producing 704 or 176 ns spaced intense X-ray flashes with a sufficient photon flux over a large field of view 12.8x8 mm². Phase-contrast modality is captured by exploiting the source coherence and long propagation distance from the sample to detector (~10 m). The tested materials are red granite, dry Vosges sandstone and ultra-high strength concrete cylindrical samples (D=5 mm and L=9mm).

3. Results and Conclusion

Figure 1 shows different failure response under dynamic compression of three geomaterials. While granite, containing low distribution of defaults, fails in multiple fracturing, UHSC fracture seem to be driven by high porosity zones. On the other hand, the Vosges sandstone failure seems more diffuse representative of a cohesive granular assembly.

4. References

- [1] Xing H. Z. et al., Rock Mech. Rock Eng., (2016)
- [2] Olbinado M. et al., Opt. Express, (2017)
- [3] Cohen A. et al., J. Instrum., (2019)

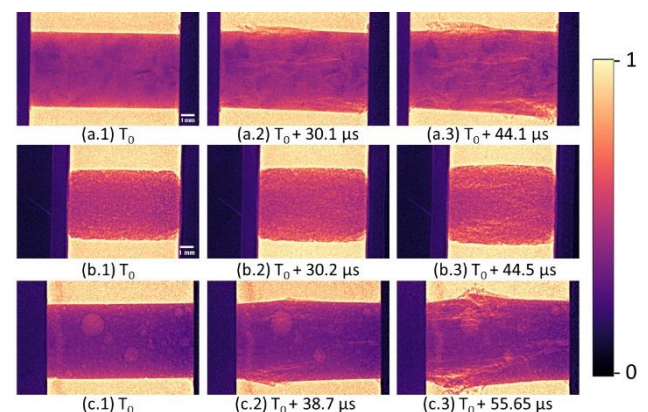


Figure 1. UHS XPCI SHPB compression tests (a) granite; (b) Vosges sandstone; (c) UHSC.