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Damage and cracking of synthetic and natural glasses subjected to triaxial deformation

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Glass is an ideal elastic-brittle material. Although cracking in glass has been much investigated, going back to the pioneer work of Griffith, investigations under confining pressure have not been done so far. Besides, as glass results of the solidification of variable fused silicate mix, the impact of thermal cracking in this material cannot be neglected.

Our study aims at investigating thermo-mechanical cracking effects on elastic wave velocities and mechanical strength, both under pressure, to document damage evolution on glass. We performed the experiments on a triaxial cell at room temperature, with and without pore fluid pressure, on borosilicate glass. The crack evolution has been monitored with: (i) elastic wave velocity measurements and (ii) acoustic emissions (MiniRichter system). We also measured the global mechanical behavior of our synthetic glass samples with strain gages.

The original glass, produced in ideal conditions of slow cooling that prevent from any crack formation, exhibits a linear and reversible mechanical behavior and isotropic elastic velocities, as expected. It also presents a high strength as it fails at about 700 MPa of deviatoric stress for a confining pressure of 15 MPa. The damage develops progressively, with increasing acoustic emission rate, parallel to the deviatoric stress orientation and probably starts on the rare air bubbles trapped in the amorphous matrix.

We choose to apply to some original glass samples a reproducible method (thermal treatment with a thermal shock of $\Delta T = 100$, 200 and 300°C) which creates cracks with a homogeneous distribution. The impact of the thermal treatment is clearly visible through the elastic wave velocity measurements as we observe crack closure under hydrostatic conditions (at about 30 MPa). Anisotropy is also observed for increasing deviatoric stress. For ΔT higher than 200°C, the glass mechanical behavior becomes non linear and records an irreversible damage. The total damage observed with the acoustic emissions in these samples underlines the combination of the thermal and the mechanical cracks which drive to the sample failure. The preliminary results obtained with pore fluid pressure show a very small permeability even for a high damage level ($10^{-21} \leq \phi \leq 10^{-17}$).

However, the glass amorphous structure makes it very different from any rock structure. In order to quantify these differences and to compare glass to rock, we managed to find a micro-crystallized basalt (Seljadur basalt, Iceland) with very low porosity ($k \leq 2\%$) and close chemical composition, and studied its behavior in the same experimental conditions. We show that a micro-crystallized rock remains different from a glass in terms of mechanical behavior but exhibits dynamical elastic parameters close from the glass ones.