DYNAMIC OFF-FAULT BRITTLE DAMAGE DUE TO EARTHQUAKE AND ASSOCIATED RADIATION

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Earthquakes occur on a fault where the earth is already weakened and deformation tends to localise. Typical faults consist of a narrow fault core of extremely granulated rock, where earthquake slip localises, surrounded by a fractured crust (off-fault damage zone or simply damage zone) whose fracture density decreases with distance away from the fault core[4]. This damage zone exhibits a unique mechanical and hydraulic behaviour which does affect earthquake ruptures [5]. The earthquake ruptures, in turn, impart a wide range of loading rates on the surrounding damage zone which affect the hydro-mechanical properties of the damage zone. A visual comparison of the microstructure around a fault zone and the same in new dynamic loading experiments, where the high strain rates expected around earthquakes can be reproduced in the lab, elucidates the fact that dynamic earthquake ruptures are an important source of the fracture damage around a fault. A consensus is now emerging among seismologists, geologists and rock mechanicians that there is an intimate hydro-mechanical interplay between the earthquake rupture and the damage zone around it. This results in a complex mechanical and hydraulic system that is dominated, and controlled, by fractures. The traditional earthquake cycle models, involving 100's of years of fault loading resulting in violent energy release via earthquakes that last for a few seconds to minutes, however, treat this off-fault damage zone passively making the resulting seismic hazard estimates unreliable. There is thus an urgent need to comprehensively understand, and quantify, the earthquake cycle that accounts for the coupling between an earthquake, on a fault, and the fracture damaged zone, around a fault, leading to reliable estimates of seismic risks and ground motion hazard.

To better model the dynamic off-fault damage, the micromechanical damage mechanics formulated by [1], and generalized by [3] has been extended to allow for a more generalised stress state and to incorporate an experimentally motivated new crack growth (damage evolution) law that is valid over a wide range of loading rates [2]. This law is sensitive to both the crack tip stress field and its time derivative. Incorporating this feature produces additional strain-rate sensitivity in the constitutive response. The model is also experimentally verified by predicting the failure strength of Dionysus-Pentelicon marble over wide range of strain rates. We then implement this constitutive response to understand the role of dynamic brittle off-fault damage on earthquake ruptures. We show that off-fault damage plays an important role in asymmetry of rupture propagation and is a source of high-frequency ground motion in the near source region [6].

References

[1] M. F. Ashby and C. G. Sammis. The damage mechanics of brittle solids in compression. *Pure Appl. Geophys.*, 133(3):489–521, 1990.

[2] H. S. Bhat, A. J. Rosakis, and C. G. Sammis. A micromechanics based constitutive model for brittle failure at high strain rates. *J. Appl. Mech.*, 79(3), 2012.

[3] V. S. Deshpande and A. G. Evans. Inelastic deformation and energy dissipation in ceramics: A mechanism-based constitutive model. *J. Mech. Phys. Solids*, 56(10):3077–3100, 2008.

[4] T. M. Mitchell and D. R. Faulkner. The nature and origin of off-fault damage surrounding strike-slip fault zones with a wide range of displacements: a field study from the Atacama fault system, northern Chile. *J. Struct. Geol.*, 31(8):802–816, 2009.

[5] Richard H. Sibson. Crustal stress, faulting and fluid flow. *Geol. Soc. Spec. Publ.*, 78(1):69–84, 1994.

[6] M. Y. Thomas and H. S. Bhat. *Dynamic off-fault damage and seismic radiation*. in prep., 2016.