【Memoirs of Construction Engineering Research Institute Vol.62(Research Overview)Nov.2020】

# SPATIOTEMPORALLY COMPLEX BUT ORDERED RUPTURE EVOLUTION IN SOLIDS WITH MULTIPLE NUCLEATION SOURCES

Koji Uenishi

## ABSTRACT

*In this contribution, we summarize our new findings obtained through the latest experimental study on the mechanical behavior of multiple rupture nucleation sources that widely spread in rock-like brittle solids under remote loading. By observing every individual local interaction of ruptures and recording global stress-strain relations, we have revealed that the secondary and further ruptures may develop, owing to the extension of the main rupture, at spatiotemporal distances from the main one in a complex but ordered manner.*

## 1. INTRODUCTION

In a real geological fault system, not only a few large-scale fault planes but also many adjoining small-scale rupture segments, which may serve as additional nucleation sources of earthquakes and alter the global characteristics of rupture processes, can exist. However, the mechanical roles played by such rupture segments (hereafter cracks) that locally preexist in brittle solid media like rocks have not been fully understood yet. Therefore, as we reported in an earlier contribution[1)], in this series of experimental study, we have been studying the connection between the global and local properties of multiply present rupture segments in brittle solids, and in particular, we have been examining the mechanical interaction of every individual crack as well as the collective stress-strain relation as a whole. Here, we investigate the mechanical behavior of the local, secondary and further ruptures initiated by the evolution of the main rupture in a multiple crack system[2)].

## 2. EXPERIMENTAL FINDINGS

Using a tensile testing machine and utilizing the experimental technique of dynamic photoelasticity in conjunction with high-speed cinematography, we have recorded rupture development in a rectangular photoelastic polycarbonate specimen with multiple small-scale cracks that may possibly model a normal faulting process. For different combinations of the initial density and distribution pattern of cracks, we have observed the evolution of the main rupture and the ensuing generation of secondary and further ruptures. In a typical, vertically dipping case under quasi-static tension (Fig. 1), we have recognized that after the specimen is completely split into two ("1" in the figure), the secondary rupture is induced at a relatively remote position from the main rupture plane and propagated into the direction opposite to that of the main one ("2"). Then, the propagation of the secondary rupture is arrested, but surprisingly, this arrested secondary rupture resumes its propagation, in 200 microseconds in this case ("3"). Since the specimen is totally divided into two by the main rupture, the external quasi-static load exerted to the specimen until the complete split becomes zero when the secondary rupture is nucleated. That is, the spatiotemporally complex initiation, propagation, arrest and reactivation of the secondary rupture are obviously not influenced by additional external load but they are due to the main rupture-induced dynamic waves. Although the tensile testing machine provides the global stress-strain relation with a sharp stress drop upon split of the specimen, we cannot precisely trace the development of the secondary and further ruptures only through this collective stress-strain curve. Thus, the results suggest that we should observe not only the global behavior but also the local interaction in dynamic rupture processes[2)].

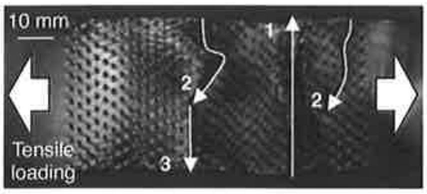


Fig. 1 Dynamic rupture development in a brittle solid with multiple small-scale cracks under static tensile loading, modeling normal faulting with the dip angle of 90 degrees.

## 3. CONCLUSIONS

In summary, although undistinguishable in the global stress-strain relation, the local, dynamic process of rupture evolution in a brittle solid with vertically dipping small-scale cracks under quasi-static tension typically consists of three stages, as illustrated in Fig. 1: Propagation of the main rupture that results in the total split of the specimen (surfacing rupture) ("1"); initiation, propagation and arrest of propagation of the secondary rupture ("2"); and reactivation of propagation of the secondary rupture after a certain period of time ("3"). Further investigation suggests that the seemingly complex reactivation of propagation of the secondary rupture is controlled in an ordered manner by the surface-type waves that are generated upon surfacing of the main rupture, reflected at boundaries and then propagated along the surfaces of the secondary rupture[3)].

## REFERENCES


1) Uenishi, K. (2018). Complexities of Fracture Development in Brittle Rock-Like Solid Materials. *Memoirs of Construction Engineering Research Institute*, Vol. 60, pp. 187-188.
2) Uenishi, K., Y. Fukuda, and K. Nagasawa (2019). Secondary Rupture at a Distance from the Primary One without Further External Loading. In: Proceedings of the 2019 Seismological Society of Japan Fall Meeting, S08P-19, Seismological Society of Japan, Tokyo, Japan.
3) Uenishi, K., Y. Fukuda, and K. Nagasawa (2020). Dynamic Fracture Development in a Multiply Cracked Solid. To appear in *Procedia Structural Integrity*.


## AUTHOR


Koji Uenishi    Staff, Dr. rer. nat., Professor,   Fracture Dynamics