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Temporal change in Q value of a fracturing rock sample under a triaxial condition (2)

Nana Yoshimitsu[1*], Hironori Kawakata[1], Naoki Takahashi[2], Manabu Takahashi[3]

[1]Ritsumeikan University, [2]Sumitomo Mitsui Construction Co., Ltd., [3]AIST

Transmitting wave has been used to estimate fracturing rock interior at laboratory experiments. In most of previous studies, narrowband recording with piezoelectric transducers has been carried out, and only the first wave amplitude, the maximum amplitude, and phase velocity were studied. Broadband recording enables us to estimate spatio-temporal change in attenuation factor, such as Q, of fracturing rock sample. Scattering attenuation of seismic wave gives us information of the heterogeneous structure.
Yoshimitsu et al. (2009, EPS) studied transmitting characteristics of waves under a triaxial compressive condition and found that the first wave amplitude rapidly decreased after the peak stress, with a recording system for broadband waves (Kawakata et al., 2009, IASPEI). Using the same data, Yoshimitsu et al. (2009, SSJ) estimated temporal change in Q from transmitting wave of broadband raw data. In this study, we performed sensor correction and improve the method to estimate precise Q.

We prepared a cylindrical Westerly granite sample (50 mm in diameter, 100 mm long). A confining pressure of 80 MPa was maintained under a dry condition at an ambient temperature. P wave type broadband transducers were put into the metal vessels that were attached to the top and bottom surfaces of the sample. We repeatedly applied 50 V pulses to the top transducer every 1/40 s, and recorded the transmitting waves at 100 MS/s with the bottom transducer. Loading control was continued when a stress decrease of 8 MPa after reached the peak stress (710 MPa). Waves are originally recorded without stacking. After removing the data in which large AE contaminated the initial phase, we stacked waves about 100 times (i.e., the temporal resolution is as high as 2.5 s). The spectra of stacked waves appeared flat in the 200 - 1000 kHz with high S/N.

For the wave correction, we obtained sensor characteristic of the transducer by a laser Doppler vibrometer that can measure the absolute particle velocity of a vibrating plane with a flat sensitivity up to 6 MHz. Then, we deconvolved observed waves with the sensor characteristic of transducer, and obtained waveforms of absolute particle velocity.
Because there are reflected waves from the sample surface, we cannot consider the rock as a semi -infinite medium. Thus, we use direct wave for Q estimation instead of coda. Stacey et al. (1975, Geophys. Surveys) empirically proposed the relation among Q, initial pulse rise time, and travel time. This relationship is consistent with the theoretical formulae of pulse-shaped impulse response presented by Azimi et al. (1968, Phys. Solid Earth). For Double couple source, such as general earthquakes, the pulse-shaped impulse response is particle displacement. On the other hand, a transducer generates velocity pulse due to single force cycle. For the laboratory data, integral of displacement waveform correspond to the pulse response by Azimi et al. (1968). In spite of double integration of the corrected velocity waveforms, we differentiated theoretical waveform twice, and derived a new equation among Q, rise time for velocity waveform (due to single force cycle source), and travel time. Then, using the rise time of corrected velocity waveform, we estimated Q.

This is the first study of temporal change in precise Q under a triaxial loading with high time resolution. At the first stage of loading, Q slightly increased from about 23. It is suggested that original crack in the sample closed. After dilatancy started and new cracks generated, Q started to decrease. At the peak stress, Q became down to about 17.5. This experiment was carried out under dry and ambient temperature conditions, so that change in Q should be change in scattering attenuation rather than intrinsic attenuation.
After the peak stress, Q seemed to decrease corresponding to the stress decrease, while circumferential and volumetric strain change rates were almost constant.

Keywords: laboratory experiment, triaxial compression test, Q value, fault formation process, transmitting elastic wave