Simulations of P-SV waves scattered by 2-D cracks using the finite difference method

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When seismic scattering by cavities is numerically simulated, the boundary integral equation method (BIEM) is preferably used, partly because of its high accuracy. In our preceding study (Suzuki et al., 2003), however, we applied a standard scheme of the finite difference method (FDM) to the simulations of SH waves scattered by many 2-D parallel cracks, with a very simple manner of representing cracks. We then showed that the scheme kept practically sufficient accuracy. We also measured the scattering attenuation and velocity dispersion of direct waves from the syntheses, and compared them with the prediction by a single scattering theory (Kawahara & Yamashita, 1992). The results indicated that the theory is valid for any realistic crack densities (up to 0.1; Crampin, 1994). In this study, we apply FDM to P-SV wave scattering and carry out the similar examinations as before.

In the FDM computation, we employ a standard velocity-stress scheme of second order in both space and time based on a staggered grid (Virieux,1986). We again define a crack simply as a stress-free plane, and assume their orientations to be either horizontal or vertical. Differently from the SH wave cases, normal and shear stresses cannot be explicitly made zeros simultaneously at the grid points corresponding to a crack plane. This makes our manner of representing cracks slightly less simple, though it remains simpler than those previously proposed (e.g., Coates & Schoenberg, 1995). The propagation of incident P-SV waves is always fixed in the upward direction.

For checking the accuracy of our FDM scheme, we first calculate the displacement discontinuity along a crack due to incident quasi-monochromatic waves. We compare the results with those by BIEM that are expected to be true. We find good coincidence in general, indicating that the accuracy of our scheme is satisfactory.

Next, we let plane P or SV waves be incident from below on many cracks with horizontal or vertical orientations, and synthesize seismograms by FDM along a horizontal station array at the opposite side. We then evaluate the attenuation and phase velocity using the technique of Kawahara et al. (2002). They are compared with the prediction by the P-SV wave version of the single scattering theory (Kawahara, 1992). In conclusion, the experimental results agree well with the theory for any cases as far as the crack densities are sufficiently low, indicating that the theory holds also for P-SV wave scattering.

Finally, we investigate the validity ranges of the theory by repeating the above experiments with increasing the crack densities. It is shown that the theory is always valid for SV waves with the densities less than 0.1, as in the case of SH waves. In contrast, the theory clearly underestimates the experimental values for P waves when the densities exceeds about 0.05, suggesting the narrower validity range than those for S waves.

References

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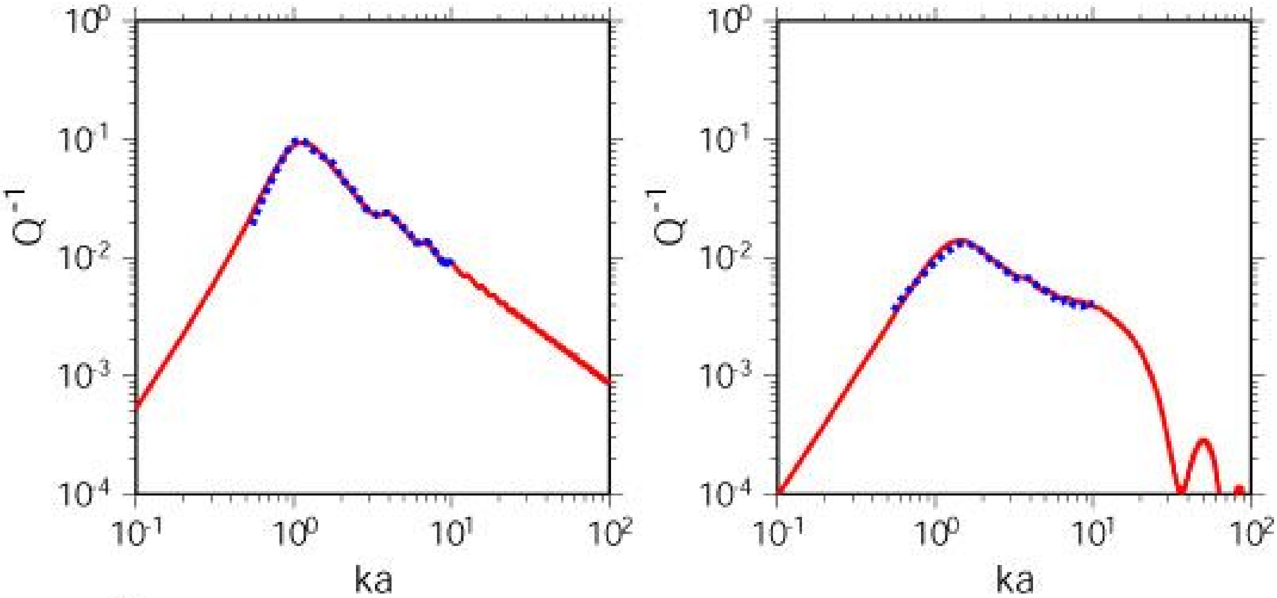

Figure.

Scattering attenuation 1/Q of (left) P waves incident on horizontal cracks, and (right) SV waves incident on vertical ones. The crack density is 0.0125. The red solid and blue dotted curves indicate the theoretical and experimental estimates, respectively.