Simulation of Riedel shear bands considering strong non-linearity of ground and geometrical barrier on strike-slip fault

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Displacement of strike-slip fault causes a series of echelon cracks on ground surface called Riedel shear bands. Fig. 1 is a typical example of Riedel shear bands which is simultaneously generated with Kumamoto earthquake, 2016. And appearance of Riedel share bands accompanies development of multiple slip surfaces called flower structures. While the authors have successfully simulated Riedel shear bands with consideration of initial material imperfection on strike-skip fault[2)], Woodcock et al.[3)] indicated that development of the flower structures is significantly affected by the existence of geometrical barrier called jog on strike-slip fault. For example, Fig. 2 describes left strike-slip fault with discontinuity of fault zone. The jog on the far side will be expanded with accumulation of fault displacement and it causes depression of the ground surface like Fig. 3(a), whereas the jog on front side will be compressed and it causes bulge of the ground surface like Fig. 3(b). These typical topographies generated on jogs are called "pull-apart" and "push-up". This research aims to simulate characteristic aspects of subsidiary fault triggered by the existence of local distribution of jog on strike-slip fault.
Numerical simulation is implemented by an elasto-plastic finite deformation analysis code ***GEOASIA***[5)].
Finite element mesh with consideration of bending fault zone is indicated on Fig. 4. Material parameters for SYS Cam-clay model are set to obtain brittle behavior as shown on Fig. 5. Shear strain distribution at the end of the calculation is indicated on Fig. 6(a). Furthermore, analysis results of models magnified in y directions are also prepared. Results for these models are also included in Fig. 6(b), (c).
In original mesh, Riedel shear bands appear above push-up. Additionally, the red-colorized local shear band is covered by green-colorized global shear band. Such fractal aspect of Riedel shear bands is already known by Tchalenko[6)] and Ueta's model experiment[7)] in Fig. 7.
In doubled mesh, Riedel shears are secondarily connected by P-shears[8)]. Appearance of P-shears is also observed in Ueta's model experiment[7)] and the example of Kumamoto earthquake as shown in Fig. 1(b) actually includes clear P-shear.
In tripled mesh, high angle shears are actively generated on push-up side and low angle shears passively appear on pull-apart side. It can be confirmed in Fig. 8 that the angles of each shear band equals to theoretical solutions derived from Mohr-Coulomb criterion.
In conclusion, characteristic deformation of subsidiary fault including fractal shear, P-shear, low/high angle shears can be successfully simulated by considering the existence of jog on strike-slip fault.
(Acknowledgement) Numerical simulations in this paper are conducted by utilizing supercomputer system in Kyoto University, Japan. And we received Grant-in-Aid for Scientific Research (Grant-in-Aid for Scientific Research (A): No. 17H01289).
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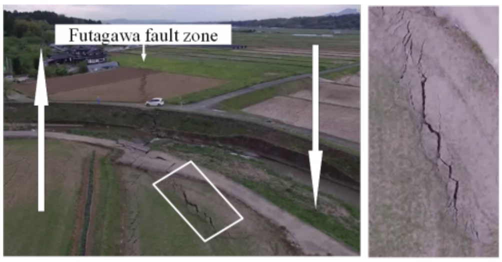
Keywords: strike-slip fault, Riedel shear bands, elasto-plasticity



(a) Futagawa fault zone (b) Shear band

Fig. 1 Echelon cracks generated in Kumamoto earthquake[1)]

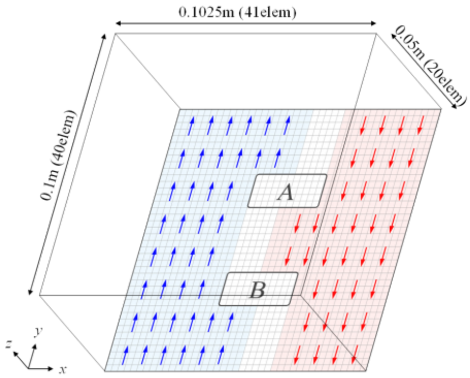
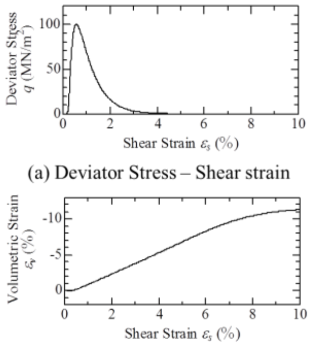


Fig. 4 Finite element mesh and boundary conditions



(a) Deviator Stress – Shear strain

(b) Volumetric strain – Shear strain

Fig. 5 Drained triaxial behavior

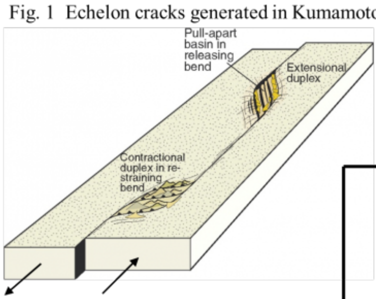


Fig. 2 Jog on strike-slip fault[4)]

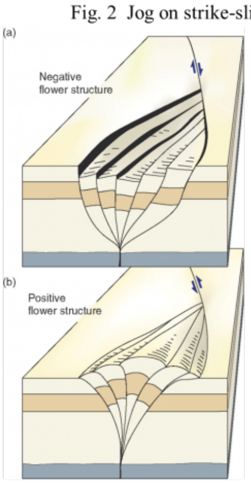
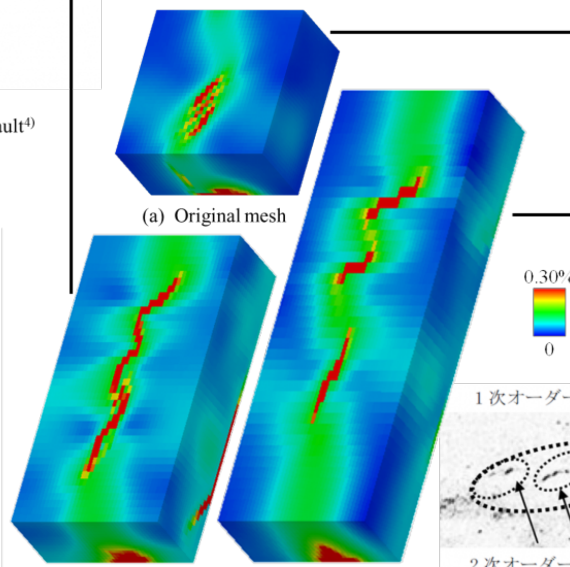


Fig. 3 Flower structures[4)]



(a) Original mesh

(b) Doubled mesh (c) Tripled mesh

Fig. 6 Shear strain distributions

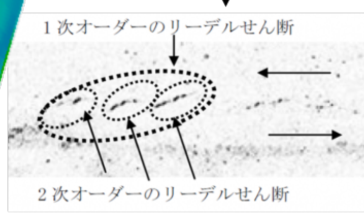


Fig. 7 Fractal shear[7)]

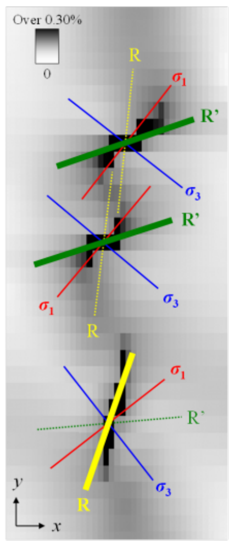


Fig. 8 Principle stress

