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Numerical simulation of shear bands formation in ground due to strike-slip fault

NODA, Toshihiro[1*] ; YAMADA, Shotaro[1] ; ASAOKA, Akira[2] ; SAWADA, Yoshihiro[2] ; KAWAI, Yuta[1]

[1]Nagoya University, [2]Association for the Development of Earthquake Prediction

When a strike-slip fault occurs, flower structures denoting petaloid patterns of shear bands appear inside the ground above the fault, and also the Riedel shear structures showing en-echelon shear bands appear on the surface of the ground. Ueda[1)] conducted model experiments accounting a strike-slip fault and showed evolution process of shear bands inside the model ground using X-ray CT scan system. Also, Sawada and Ueda[2)] numerically simulated evolution of flower structures etc., using a large-deformation analysis where an elasto-perfectly plastic model with the Mohr Coulomb failure criteria was used.

In this study, referring the research work by Sawada and Ueda[2)], evolution of shear bands was numerically investigated by using a soil-water coupled finite deformation analysis code ***GEOASIA***[3)] on which the SYS Cam-clay[4)] was mounted as an elasto-plastic soil model. In the analysis, since the rate-type equation of motion is precisely time-integrated, progressive failure will be analyzed as a nonlinear dynamic problem, and then generation and/or propagation of waves induced by shear bands formation[5)] will also naturally be developed in the analysis. The constitutive model used is capable of describing a wide variety of soils within the same theoretical framework. Here are shown numerical examples in which soil is taken as a non-coupled material with liquid.

First considered was a 3D FE mesh with one element in strike direction of a fault (i.e. y-direction) shown in Fig.1. The right-lateral strike-slip fault was assumed to be located below the three elements at the mid bottom of the ground. As for the boundary conditions, periodic boundary was taken directly above the fault on the x-z planes of the ground, and displacement was applied to the y-direction on the other parts of the x-z planes with a constant rate of 10^{-6}m/s on the opposite side across the fault. Also, x-z and y-z planes were frictionless. In this case, the ground exhibited localization of deformation and the shear bands grow from the bottom in a logarithmic spiral manner (" flower structures "). Then, the formation was attributed to plastic swelling behavior of soil element.

Next used were the other 3D meshes with forty elements in the strike direction (Fig.2) so as to investigate evolution of shear bands and effect of homogeneity/initial-imperfection in ground on the evolution. Here, as the boundary conditions, periodic boundary was assumed on the mutually opposite x-z planes and displacement was applied to the nodes located at the bottom with the same rate on the opposite side across the fault, while the same material constants were used. The imperfection was given to some elements directly above the fault by slightly altering a material constant of them. In the imperfection case, flower structures occurred inside the ground, thereafter Riedel shear structures appeared on the surface. The parts of the Riedel shear exhibited more significant upheavals than its surroundings. Furthermore, in the other numerical cases, angle between the Riedel shear and the strike varied with the different material constant.

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3) Noda, T. et al.(2008): Soil-water coupled finite deformation analysis based on a rate-type equation of motion incorporating the SYS Cam-clay model, Soils and Foundations, 48(6), 771-790.

4) Asaoka, A.et al.(2002): An elasto-plastic description of two distinct volume change mechanisms of soils, Soils and Foundations, 42(5), 47-57.

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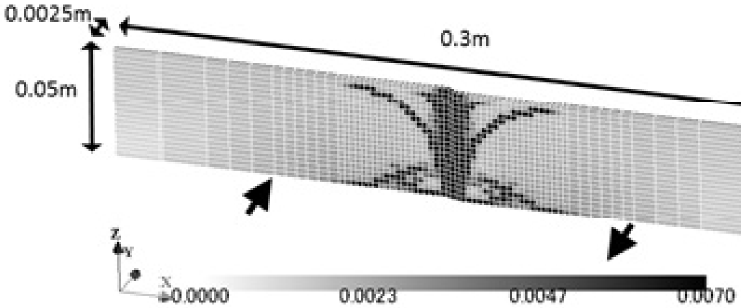

Fig.1. Occurrence of flower structure

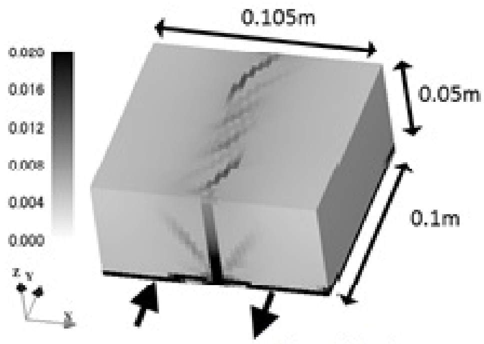

Fig.2. Occurrence of Riedel shear after flower structure, ground with initial material imperfection