Analysis of shear bands formed in sedimentary overburden by strike-slip faults

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Surface displacement due to shallow inland earthquakes often causes damage to structures. The behavior of unconsolidated sediment overlying active faults is important in surface displacement. A number of model tests were performed to examine the deformation of sediment subjected to fault displacement (e.g. Ueta et al., 2000). In the case of strike-slip faults, the sequence and three-dimensional geometry of shear bands in overlying sediment are complicated. For example, with the increase of the base fault displacement, (1) Riedel shears, (2) low-angle Riedel shears and P shears, and (3) shears aligned with the base fault develop at surface. Although the development of shear bands due to strike-slip faults has partly been simulated (Nakagawa and Hori, 2002, Saomoto et al., 2005), it has not been completely reproduced numerically, and the mechanism of surface fault rupturing by strike-slip faults has not been fully elucidated.

In this study, DEM (distinct element method) analysis was conducted to simulate small-scale model tests of strike-slip faulting. Development of shear bands and its mechanism were investigated. 887,965 spherical distinct elements with radii of 1.5, 2, and 2.5 mm were generated inside the model (57.6 cm long and 35.1 cm wide) and gravitational force was applied. The height of the pack of distinct elements was 21.5 cm. One half of the base (57.6 cm long and 17.6 cm wide) and one sidewall (57.6 cm long and 21.5 cm high) displaced horizontally at 2.5 cm/s with respect to the stationary ones. The displaced and stationary bases corresponded to the bedrock fault. The density of elements, normal and tangential spring constants were assumed to be 2400 kg/m^3, $1.0*10^5$ N/m, and $3.0*10^4$ N/m, respectively. Normal and tangential damping coefficients of 0.80 Ns/m and 0.44 Ns/m were used respectively. The friction coefficient was assumed to be 0.5. Besides normal and tangential force, rolling resistance was taken into account between particles in contact (Iwashita and Oda, 1998).

In the analysis, a shear zone striking at about 15 degrees to the basement fault was observed at surface as the basement displacement exceeds 4.0 cm. With increasing basement displacement (over 6 cm), shear zone striking at lower angle (7-8 degrees) to the basement fault developed at surface. These shears corresponded with Riedel shears and low-angle Riedel shears observed in model tests. In the sediment model of distinct elements, concave-upward shear zones which developed from the basement fault on both sides of the fault were observed first and were followed by a helicoidally shaped shear. The geometry and sequence of these shears agreed with ship shape shears and Riedel shears observed in the model of dense sand by X-ray tomography. The helicoidally shaped shear propagated through the sediment model and broke the surface.

The stress distribution was computed using the forces acting between distinct elements. It was found that the development of ship shape structures and Riedel shears was attributable to the stress due to dilatancy and the shear in the vertical plane along with the lateral shear. The results also corroborated that secondary lower-angle shears developed under the stress field which Riedel shears reoriented.