Analysis of stress and failure around step-overs and slip-gaps for strike-slip fault systems

Badie Rowshandel, California Geological Survey, Sacramento, CA

Designing for surface rupture and displacement in the immediate vicinity of active faults is essential for reduction of loss of life and property during earthquakes. The primary rupture zones in the 17 August 1999 Izmit and 12 November 1999 Duzce earthquakes were relatively simple and narrow along most of their lengths. The majority of buildings along the paths of rupture either collapsed or heavily damaged (Aydin and Kalafat, 2002). Losses of life and property in the above earthquakes could have been significantly reduced by simply avoiding construction within a narrow zone around the fault. Understanding the extent of failure zones and the distributions and orientations of secondary ruptures around faults are detrimental for analysis of fault displacement hazard. Existence of discontinuities in fault geometry, such as bends, step-overs, and slip-gaps, affects the extent and the direction of primary and secondary ruptures and failure zones. These earthquakes provide some very useful information on the impact of geometric discontinuities on rupture distribution, which can be built into fault displacement/rupture hazard analysis models (e.g., Petersen, et al. 2005). For example, reports from these earthquakes indicate that surface ruptures of the order of 5 meters were arrested by step-overs of 4-5 km wide, ruptures of 1-1.5 meters were arrested at 2-4 km wide step-overs, and a rupture of 3 meters propagated through a step-over of width 1-2 km (Lettis, et al., 2002). Barka and Kadinsky-Cade (1988) had proposed 5 km as the widest step-over and 30° as the largest bend angle that can be generally jumped by an earthquake.

In this study, quantitative investigations of the extent and the distribution of primary and secondary ruptures and zones of failure around strike-slip faults with different geometric discontinuities are made. The distribution of stress is obtained by a simple two-dimensional linear elastic analysis of crustal rocks surrounding slipping faults of various geometries, using boundary element method. Various failure criteria applicable to intact and fractured rocks are then employed to estimate the extents and the patterns of failure zones. Preliminary results suggest that, depending on the failure criterion, fault geometry, and rock strength parameters used, rupture jump across/along step-overs and gaps up to several kilometers is possible. Using the extent of failure zones, probability density functions for the distribution of secondary ruptures around primary faults, for probabilistic fault displacement hazard analysis are developed. Results also imply that detailed characterization of the rocks in the step-over and gap areas would improve estimates of the critical size of step-overs and slip-gaps, and lead to more reliable density functions for the distribution of secondary ruptures for input into probabilistic fault displacement hazard analysis models.

Aydin, A. and D. Kalafat, *Surface ruptures of the 17 August and 12 November 1999 Izmit and Duzce earthquakes in Northwestern Anatolia, Turkey: Their tectonic and kinematic significance and the associated damage*, Bull. Seis. Soc. Amer., Vol. 92, No. 1, pp. 95-106, 2002.

Petersen, M., T. Cao, T. Dawson, A Frankel, C. Wills, D. Schwartz, *Mapping fault rupture hazard for strike-slip earthquakes*, 13th World Conference on Earthquake Engineering, Vancouver, Canada, August 1-6, 2004.

Lettis, W., J. Bachluber, R. Witter, C. Brankman, C.E. Randolph, A. Barka, W.D. Page, and A. Kaya, *Influence of releasing step-overs on surface fault rupture and fault segmentation: Examples from the 17 August 1999 Izmit earthquake on the North Anatolian Fault*, Turkey, Bull. Seis. Soc. Amer., Vol. 92, No. 1, pp. 19-42, 2002.

Barka, A.A., and K. Kadinsky-Cade, *Strike-slip fault geometry in Turkey and its influence on earthquake activity*, Tectonics, Vol. 7, No. 3, pp. 663-684, 1988.