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A Crustal Deformation Analysis for the 1999 Chi-Chi Earthquake, Taiwan, in Consideration of the Spatial Slip Distribution

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1. Introduction

Recently, we can get information of spatial slip distributions on earthquake faults based on waveform inversion analysis using broadband seismogram. The result of those analyses make clear that the common existence of a non-uniform slip distribution, and cause the discussion on asperity or barrier. The purpose of this study is to elucidate the influence of a spatial slip distribution on a crustal deformation pattern. In this meeting, we report a crustal deformation analysis for the 1999 Chi-Chi Earthquake, Taiwan, in consideration of the slip distribution.

2. Crustal deformation of the Chi-Chi earthquake

On September 21, 1999, the Chi-Chi earthquake (Mw=7.6) occurred near the town of Chi-Chi, Nanto prefecture, Taiwan. It appeared N-S striking surface rupture as long as 80 km along the Chelungpu fault, which forms a western limit of the highland in the hold and thrust belt. The height of the vertical discontinuity of this rupture was about 2 m in average, and it was relative large in the northern part with a maximum 8 m height at the Shi-kang Dam area.

We supposed a spatial slip distribution on the fault plane as the cause of such local crustal deformation pattern, and carried out the following FEM analysis to ascertain the hypothesis.

3. Model and boundary conditions

We took a model area with an X-axis (240 km) perpendicular to the strike, Y-axis (300 km) along the strike, Z-axis (22 km) in vertical, and divided it into 294300 hexahedral elements. One of the dividing planes is parallel to the fault plane (dip 29 E), and another plane is parallel to ground surface. The horizontal size of the elements is 12 km at the surrounding area, and it changes smaller into the center of the model up to 1 km. The vertical size of the elements is uniquely about 1.5 km, because of an equally dividing to 15 layers. Total number of variables of this model is 944964.

We supposed an elastic body to this model, whose elastic coefficients are commonly adopted ones for upper crust (Young's modulus : 6.95e+09 [kgf/m**2], poisson's ratio : 0.2812) . However, we suppose the Young's modulus as three-order smaller as above value only for the 5 parallel layers under the fault plane.

The boundary conditions are fix for the side planes and free for the bottom.

4. Analysis with the finite element model

We gave the forced displacements as large as the spatial slip distribution (Ma et al., 2000) with a direction of the rake (66 deg.) on the bottom of the hanging wall, and calculated the vertical displacements on the ground.

As a result of this calculation, we can see a larger uplift at closer to the surface rupture on the hanging wall, and find the maximum uplift value around Shi-kang area in northern part. On the other hand, we can see a little subsidence on the foot wall, but the order is relative very small. This result is consistent well with the observed distribution of crustal deformation (ex. Shin et al., 2001). However, the maximum value of calculated uplift is about 3 m, and totally small than observed one. It is possible to change a little amount for the calculated values by means of supposed elastic coefficients. And it is necessary to introduce a non-flat shape into the modeled fault plane for the better solution.

Anyway, we can conclude that a crustal deformation by an earthquake strongly depends on a spatial slip distribution on a fault plane.

References

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