SSS27-08 Room:103 Time:May 24 12:00-12:15

Estimation of inelastic displacement of a fault zone during an earthquake cycle

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1. Introduction: A damage zone/asperity model of faults was proposed to interpret the source parameters of an earthquake in terms of the physical properties of a fault zone (Yamamoto & Yabe, 2003, 2006 in SSJ meeting). In this model, the apparent fracture energy was calculated by assuming the complete elastic behavior of asperities in fracturing process. Further, the displacement vertical to a fault surface, which is produced by rotation of the damage zone, was calculated by first-order approximation. This approximation was found to cause an over-estimation of the apparent fracture energy. Here, the vertical displacement has been re-calculated by a more exact manner, taking account of inelastic displacement of asperities. Based on the results, the total slip accompanying an earthquake at plate boundary and the relationship between magnitude and recurrence time is examined.

2. A damage zone/asperity model: In this model, a fault zone means the damage zone including asperities. The fault surfaces are the boundaries between the fault zone and the host rocks outside of the fault zone. An asperity fractures at the time that the relative displacement between the surfaces reaches to $u*_c$, $u*_c=u_c+u_{fc}$ = $t(e_c+e_{fc})$, Here u_c and u_{fc}, respectively, are elastic and inelastic components of $u*_c$. t denotes the thickness of the fault zone. The displacements respectively correspond to the strains e_c and e_{fc}. u_c is called the critical displacement. After an asperity has fractured, the displacement between the fault surfaces is newly produced by u_b, which generates seismic waves. The fracturing produces the slip plane in the fault zone. The displacement on the slip plane is expressed by u_c+u_b. This means that the displacement seismological estimated is not equal to the displacement on the slip plane.

The vertical displacement v is produced by rotation of the damage zone accompanying slip-plane propagation. The vertical displacement acts against the normal stress on the fault plane. The apparent fracture energy is almost equal to the work of v acting against the normal stress. The density of the work per unit area w is written by $w=(s_n v)\}\approx s_n(1+2a)e_c u_c/2$, where s_n is the normal stress, and a is the ratio of e_{fc}/e_c. Assuming that s_n is equal to the litho-static pressure and the rigidity of asperities is 30GPa, $e_c\approx 0.01$ is estimated for the depths from 10 to 20 km. For e_c=0.01, it is found that the data of apparent fracture energy versus critical displacement summarized by Ohnaka and Matsu ura (2002) are almost explained for (1+2a)/2?1. This means that the inelastic strain amounts 1/2 of elastic strain at the fracture of an asperity.

3. The recurrence of large earthquakes at plate-boundaries: Two large earthquakes are known to have occurred in the regions along the Sagami Trough. One is the 1703 Genroku earthquake and the other is the 1923 Kanto earthquake (Mw 8.0). The magnitude of the 1703 earthquake ranges from 7.9 to 8.5 depending on researchers. The displacement and the critical displacement of the 1923 earthquake are estimated at about 5.1m and 2.56 m, respectively. The convergence rate of inter seismic period is obtained as about 11.6 mm/year. This estimation is carried out on the assumption that asperities are elastic. Here, the deformation of an asperity, no matter how small asperity, is assumed to contain inelastic component of 0.5 times of the elastic deformation at fracturing. In this assumption, the total rate is 17.4 mm/year. This is almost equal to the inter-seismic slip rate along the Sagami trough presented by Loveless, J.P. and Meade, B.J. (2010).

If this rate of 11.6mm/year is constant at the plate boundary, the potential magnitude of an earthquake, of which recurrence time is 400 years, is estimated at about M8.5. The fault length is about 288 km. This length is almost equal to the length of the Sagani trough.

Keywords: damage zone/asperity model, inelastic displacement, fracture energy, critical displacement, 1923 kanto earthquake, plate boundary