Deformation behavior of an asperity prior to its fracturing expected from a fault zone model

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Introduction:

Distribution of slip-defect (back-slip) has been revealed for some regions along plate boundaries. Further its temporary change has been found as well. If the slip-defect is caused by an asperity on plate boundary, it is important to know the behavior of the change, for the study of earthquake generation. According to the damage zone asperity model of fault, an asperity has inelastically deformed by half the elastic deformation until its fracturing. This suggests the possibility to estimate the fracturing time of the asperity, or, that of earthquake occurrence.

The model is as follows: An asperity is in a fault damage zone within parallel boundary planes to the host rocks. The fault planes mean these boundary planes, here. The rigidity of damage zone except for the asperity is zero, and that of the asperity is the same as the host rocks.

In this study, we will discuss the inelastic behavior of an asperity prior to the fracturing under the two conditions. One of them is the condition of stress increasing at a constant rate and the other is that of displacement increasing at a constant rate.

Method:

For the damage zone of constant thickness *w*, elastic and inelastic displacements respectively are written by $w{\cdot}e_e$ and $w{\cdot}e_i$. The strength of asperity is written by $s{\cdot}e_c$, *s* being rigidity. The strain e_c is the critical strain. The total strain is written by e_t. We define $re=e_e/e_c$, $r_i=e_i/e_c$, and $r_t=e_t/e_c$. Thus, $r_t=r_e+r_i$ and fracture of an asperity occurs at $r_e=1$ regardless of the conditions.

Here we put $ri=c{\cdot}g(re)$. g is proportional to the crack density at applied stress re and expressed by $g=(r_e/f)^m$, $r_e=r/(1-g)$.

The function g is called the modified power function. Here, *m* is the power and *f* is the inverse of internal friction coefficient of intact rocks. *c* is determined so as to $c{\cdot}g=0.5$ at $r_e=1$. The function is derived from the experiment of compression tests of rocks. We can obtain the relation of strains to time by $r_t=t_d{\cdot}t$ for displacement condition, and by $r_e=t_s{\cdot}t$ for stress condition. t_d and t_s respectively are the inverses of recurrence time of the earthquakes that have the same magnitude as the target earthquake. *t* is lapse time from the preceding earthquake occurring near the target earthquake.

Results:

We have no knowledge about the *m*-value of asperities. The value obtained from the crack density change under compression test is about 11 for granodiorite, those from strength change with specimen size are about 4.4 for coal and about 5.8 for quartz diorite. Further, the values of *m* are between 4 to 8 from the activity of small earthquakes prior to a volcanic eruption and prior to earthquakes of larger than 7 in *M*. From these data, the *m* value of asperity is roughly inferred to be between 4 and 12.

In the case of stress condition, the amount of inelastic deformation reaches at 10% of elastic one when lapse time reaches to about 83% of recurrence time for $m=5$, 92% for $m=10$ and 96 % for $m=20$ (Fig.1).

In the case of displacement condition, for $m<5$, increasing rate of stress gradually decreases with an increase in lapse time. For $m>5$, the increasing rate becomes conspicuous for lapse time lager than 60% of recurrence time. When the lapse time is lager than 95%, the increasing rate decreases to less than half of the rate at small lapse time(Fig.2).

Discussion:

We have not concluded whether assumption of constant stress or that of constant displacement is appropriate for discussing the dynamical process in the crust. For both conditions, the high-rate increase

in the displacement is expected prior to the earthquake occurrence. This displacement takes place in the same direction as the coseismic displacemrnt. This may make us to underestimate the increasing rate of slip-defect.
In the case of the displacement condition, it may be difficult to recognize the existence of slip-defect from the analysis of the data during a short period near the earthquake occurrence because of the small increasing rate of stress.
According to the damage zone asperity model of fault, Magnitude of an earthquake is determined by damage zone thickness. Thus, without interaction between earthquakes, the reccurrence time may be derived from the thickness and the convergence rate between plates.

Keywords: back-slip, asperity, inelastic strain, recurrence time, fault damage zone, power function distribution

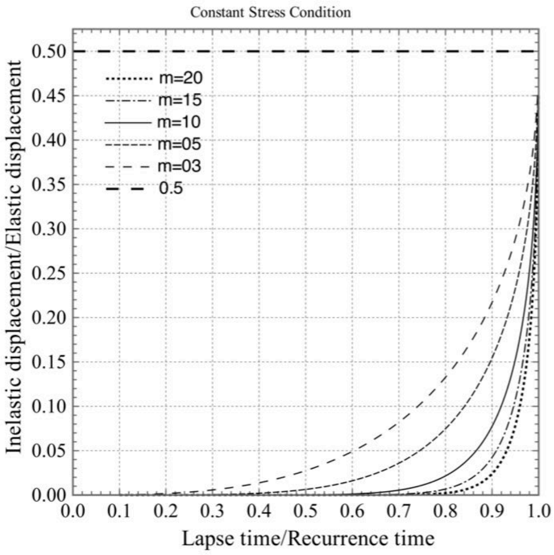

Fig. 1 Relation of Inelastic displacement of an asperity to lapse time under constant stress increasing rate.

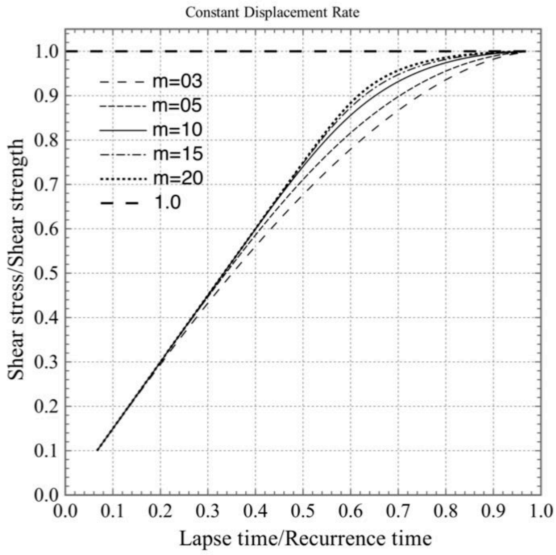

Fig. 2 Relation of shear stress on an asperity to lapse time under constant displacement increasing rate.