A damage-zone/asperity model of faults: Invariants and scaling Laws

Kiyohiko Yamamoto[1]; Yasuo Yabe[2]

[1] none; [2] RCPEV,Tohoku Univ.

INTRODUCTION: We have proposed a fault zone model that is based on the data obtained by observations and measurements near faults (Japan Seismological Soc., 2003, 2006). Here, we will present the invariants and scaling laws derived from this model.

MODEL OF FAULTS: A fault zone consists of damage zone segments filled with fractured rocks and asperity segments of intact rocks. Damage zones are incompressible, and are free from shear stress. The normal stress applied to a fault is sustained by the whole segments of the fault but the shear stress is supported only by asperity segments. Damage zones elastically behave to quick change in applied displacements.

Strain energy P due to shear stress applied to asperities is stored in asperities and host rocks on both sides of fault zone. Fracture of asperities releases the energy P to make rupture to propagate into damage zones and to form a slip plane in a fault zone. Here, we call the slip plane as a fault plane.

Here, we assume that the width, w, of the fault zone is uniform. Let us write the strength and the strain at fracture of asperities by t_a and e_f, and the surface area of a fault plane and the fraction of asperity area in a fault plane by S and g. Just before asperities fracture, the fault zone has deformed by the displacement Du_{el} (the critical displacement d_c), where

$Du_{el} = e_f*w$....(1)

When a fault plane is formed by faulting, Du_{el} disappears and the displacement Du_s is newly produced between the blocks on the both sides of the fault zone and the energy P is released. Here, P is the sum of the energy P_a released from asperities and that P_b from the blocks. They are expressed by

$P_a = (g*S*t_a*Du_{el}) / 2$....(2-1); $P_b = (g*S*t_a*Du_s)/2$.....(2-2)

The energy W required for rupture propagation is the sum of the surface energy g_s for producing a slip surface, the work W_d done against the normal stress (apparent fracture energy), and the seismic energy E_s. They are respectively written by

$W_d=s_n*S*w*e_f{}^2$....(3-1); $E_s=c*P_b$....(3-2); g_s=about $0.1*W_d$....(3-3)

where s_n is the normal stress and c is the seismic efficiency. For a cycle of faulting, W=P is assumed.

RESULTS: i) The critical displacement and the apparent fracture energy are proportional to damage zone width. ii) Fraction of asperity area is proportional to the inverse of fracture strength of asperities and does not directly depend on fault size. iii) Shear strength of faults and/or stress drop amount due to faulting depend neither on size of fault surface nor fault zone width, directly. Applying the relationship between fault length and fault zone width (Velmilye & Scholz, 1998, JGR), iv) Critical displacement, energy released from asperity, and apparent fracture energy are scaled by fault length.

Adopting the circular crack model by Eshelby (1957) under the assumption that elastic constants of damage zones are identical to those of host rocks, the followings are derived; v) g, t_f, Du_s/Du_{el} are independent of crack size and decrease with a decrease in seismic efficiency. vi) Du_s, P_b, E_s are the functions of fault size and seismic efficiency, and can be scaled by crack size.

Eq. (3-1) suggests that rupture easily spreads upward when the emission of energy from asperities is isotropic and fault zone width is constant. The result (iv) suggests that slow earthquakes have small asperity fraction compared with ordinary earthquakes.

FURTHER PROBLEMS: The scaling law in seismic source parameters requires the relationship between fault zone width and fault length. This relationship is replaced that between asperity size and fault zone width. It is the next problem to clarify what controls this relationship.