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DYNAMIC SOURCE PARAMETERS AND CHARACTERIZED SOURCE MODEL FOR STRONG MOTION PREDICTION

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SUMMARY

Heterogeneous slip characterization of inland crustal earthquakes (Mw5.4-7.6) shows a scaling relation between total area of asperity, which has rather larger slip than the total area, and seismic moment from source inversion results using strong motion data (e.g. Somerville et al., 1999; Miyakoshi et al., 2000). Irikura and Miyake (2001) proposed characterized source model based on this scaling relation for strong motion prediction. The availability of the characterized source models has been proved through the strong motion simulation in near-source area in the broadband frequency band (BB) for e.g., the 1995 Kobe (Kamae and Irikura, 1997) and for the 2000 Tottoriken-Seibu (Ikeda et al., 2002) earthquakes. In those simulations, they assumed stress drops only for the asperities by forward simulation of the high frequency contents of the records. When constructing a characterized source model for BB strong motion, we need rules to set stress parameters. We examine dynamic source parameters such as stress parameters by mapping method of spatiotemporal shear-stress distribution on the fault plane from a spatiotemporal slip distribution from kinematic waveform inversion. Dynamic source parameters averaged over on- and off-asperity areas are estimated from a viewpoint of characterized source model. Average effective stress values of on- and off- asperity areas are estimated as 10-20MPa and about 5MPa. Stress parameters on the asperities seem to be increasing with asperity depth. Stress parameters on the asperities coincide with the ones that were used for forward ground motion modeling (e.g. Kamae and Irikura, 2001, Ikeda et al., 2002). Characterization of stress parameters contributes the development of characterized source model.

INTRODUCTION

It is one of the important issues to construct an appropriate source model for strong motion prediction of scenario earthquakes. Recent dense strong motion network data enable us to analyze detail source rupture process of destructive earthquakes. Obtained source rupture processes were found to be heterogeneous and those heterogeneities control near-source strong ground motions. Somerville et al.[1] characterized

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source slip models of mainly California earthquakes from strong motion waveform inversion results. They defined asperity which is an area whose final slip is larger than 1.5 times of average slip value. They found total asperity size is followed by a scaling relation. Recent events such as the 1999 Chichi, Taiwan, and Kocaeli, Turkey, the 2000 Tottori-ken Seibu earthquake, and other moderate-size crustal earthquakes are found to follow the relation （Miyakoshi et al.[2]）. Irikura and Miyake[3] proposed characterized source model based on this scaling relation for strong ground motion prediction. The characterized source model consists (plural) asperity area(s) with higher stress drop on the fault. Off-asperity or background area (outside of asperity area) has lower stress drop. Irikura et al.[4] interpret the characterized source model by means of the source dynamics using multi-asperity source model that is extended from the asperity model by Das and Kostrov[5]. The availability of the characterized source models has been proved through the strong ground motion simulation in near-source area in the broadband frequency band (BB) for e.g., the 1995 Kobe (Kamae and Irikura[6]) and for the 2000 Tottoriken-Seibu (Ikeda et al.[7]) earthquakes.

In those simulations, they assumed stress drops only for the asperities by forward simulation of the high frequency contents of the records. When constructing the characterized source model for the broad-band strong motion simulation, we need rules to set stress parameters, or dynamic source parameters, on and off asperity area. Here we estimate the spatiotemporal shear-stress time histories on the fault plane using spatiotemporal slip histories obtained from the waveform inversion (e.g. Bouchon [8]). Characteristics of the stress parameters on- and off-asperity areas are discussed from a viewpoint of characterized source model.

ESTIMATION OF STRESS PARAMETERS

We estimated spacio-time stress histories of the four events, the 1995 Hyogoken-Nanbu (Kobe) (Japan)[9], the 1999 Chichi (Taiwan)[10], the 1999 Kocaeli (Turkey)[11], and the 2000 Tottoriken-Seibu (Japan)[12] earthquakes. Those source models are obtained by strong motion velocity records in the period range of 1(or 2) to 10s. Geodetic data is combined for the case of the 2000 Tottoriken-Seibu earthquake.

Fig. 1 shows a schematic stress time history curve together with the definition of stress parameters. The static and dynamic stress drops and the effective stress are shown.

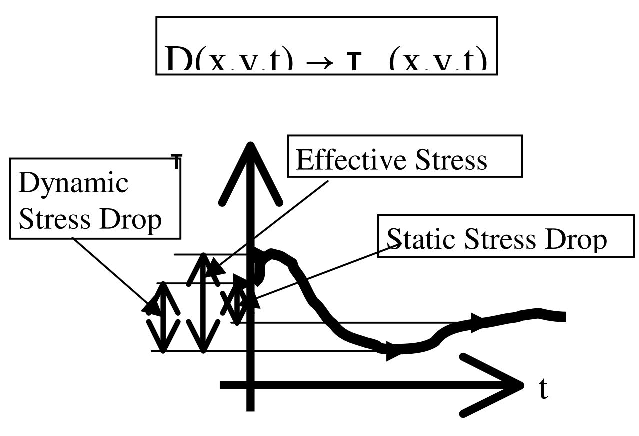

Fig. 1: Schematic stress time history curve together with the definition of stress parameters. The static and dynamic stress drops and the effective stress are shown.

Following Bouchon's method [8], we calculate the spatiotemporal stress histories using the spatiotemporal slip histories obtained from the kinematic source inversion. From the obtained spatiotemporal stress histories, we can estimate stress parameters, as shown in Fig. 1. In Fig. 2, we are showing the obtained stress parameters together with the final slip distribution for the case of the 2000 Tottoriken-Seibu earthquake. Following Somerville's slip criteria for extracting the asperity, three asperity area are found for this event. Larger values of stress parameters (static and dynamic stress drops and effective stress) are observed on the asperity area, whereas smaller stress parameter vales are observed at off-asperity area. Negative static stress drop area is observed at near the hypocenter. This area is overlapping with the area of previous earthquake swarm of 1989, 1990, and 1997. Moreover, this event has a small rupture initiation with about 3s duration. This negative static stress drop area corresponds to the released stress area before this earthquake and causes the moderate rupturing.

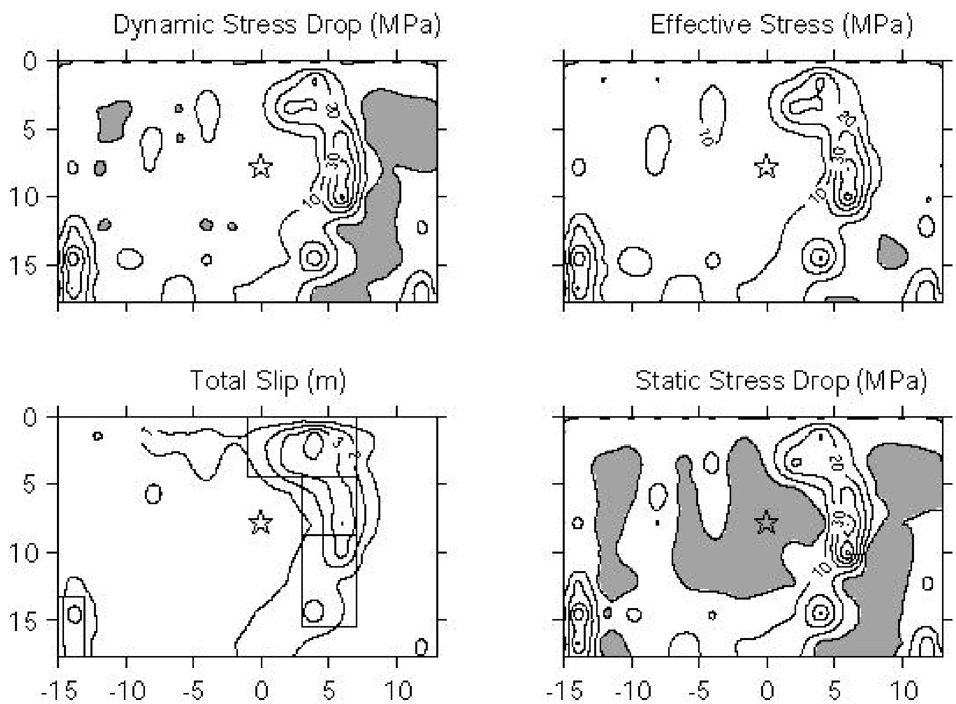

Fig. 2: Estimated stress parameters of the 2000 Tottoriken-Seibu earthquake. Final slip (bottom left), static stress drop (bottom right), dynamic stress drop (top left), and effective stress (top right), respectively. Stars indicate the rupture starting point. Four square areas in the final slip distribution show the asperity area as determined by the Somerville' s criteria.

STRESS PARAMETERS IN THE CHARACTERIZED SOURCE MODEL

We have done the same procedure to obtain spatiotemporal stress histories for other three earthquakes. Next, we estimate those stress parameters for four events and obtain average and standard deviations of the stress parameters over on- and off-asperity areas from a viewpoint of characterized source model. Obtained stress parameter values are summarized in Table 1. We have found stress parameters are about 10-20MPa on the asperity and about 5MPa at off the asperity. The effective stress is slightly larger than the dynamic stress drop and the latter is slightly larger than the static stress drop. This means strength excess that the difference between the yielding stress and the initial stress, and the difference of dynamic and static friction level are smaller than stress drop. In the table, the stress parameter values on the asperities used for forward ground motion modeling ([6], [7], [13]) are also shown. The stress parameter obtained here coincide with the ones that were used for forward ground motion modeling. Characterization of stress parameters here can directly give the stress parameter on the characterized source model.

Table 1: Summarized stress parameter values for the 1995 Kobe, the 1999 Chichi, the 1999 Kocaeli, and the 2000 Tottoriken-Seibu earthquakes. Average and standard deviation (in parenthesis) of each stress parameter on- and off-asperities are listed up. Stress parameter values on the asperity, obtained from the forward ground motion simulations.

EVENTS	1995 Hyogoken Nanbu (Kobe)			2000 Tottori-Ken Seibu			1999 Chichi, Taiwan			1999 Kocaeli, Turkey		
Stress Parameter	$\Delta\sigma s$ AV.(SD.)	$\Delta\sigma d$ AV.(SD.)	σeff AV.(SD.)	$\Delta\sigma s$ AV.(SD.)	$\Delta\sigma d$ AV.(SD.)	σeff AV.(SD.)	$\Delta\sigma s$ AV.(SD.)	$\Delta\sigma d$ AV.(SD.)	σeff AV.(SD.)	$\Delta\sigma s$ AV.(SD.)	$\Delta\sigma d$ AV.(SD.)	σeff AV.(SD.)
On Asperity (in MPa)	13(13)	15(12)	17 (12)	19(18)	20(19)	22 (17)	11(10)	13(9.4)	15(8.9)	16(16)	19(14)	21(14)
Off Asperity (in MPa)	4.3(5.7)	6.4(5.0)	7.5(7.0)	1.4(7.7)	1.4(6.0)	5.6(6.4)	3.8(10)	7.0(9.7)	8.8(9.6)	3.5(7.6)	6.7(7.0)	7.9(7.1)
Stress parameters on asperities for forward waveform modeling (in MPa)	15 (Kamae and Irikura, 1998)			28, 14 (Ikeda et al., 2002) 16 (Furumura et al., 2001)			10 (Kamae and Irikura, 2002)					

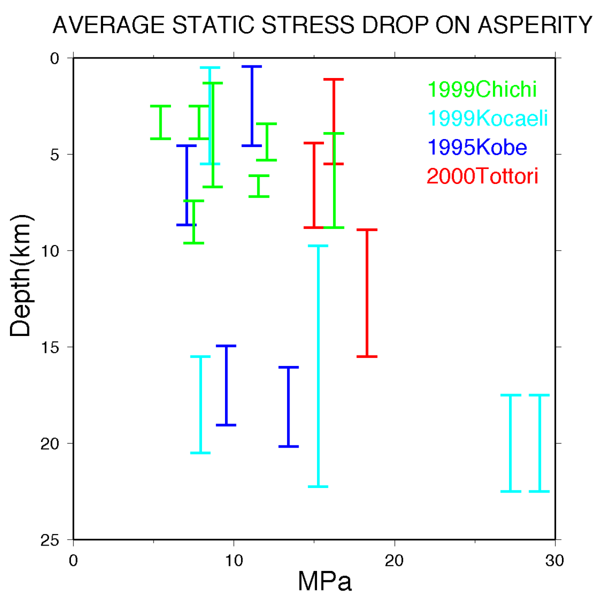

Fig. 3: Depth dependence of average static stress drop values on the asperities for the four events.

In Figure 3, static stress drops on the asperity for all events as a function of asperity depth. Slightly increasing of stress drop values with depth are observed in an event e.g. the 1999 Chichi earthquake, however, there are differences among the events. Upper bound values of static stress drop are about 20MPa except two deep small asperities of the 1999 Kocaeli earthquake and that characteristic of stress parameters on the asperity can give the constraint of the model parameter for the characterized source model to predict strong ground motions.

SUMMARY

We obtain those stress parameters for four inland crustal events and estimate average values on and off asperity areas. Average stress parameter values of on- and off- asperity areas are estimated as 10-20MPa and about 5MPa, respectively. Stress parameters on the asperities seem to be increasing with asperity depth. Stress parameters on the asperities coincide with the ones that were used for forward ground motion modeling. Characterization of stress parameters discussed here can give the stress parameters of the characterized source model.

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