Distribution and properties of fractures in and around the Nojima fault in Hirabayashi GSJ borehole

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A borehole penetrating the Nojima fault was drilled in 1996, one year after the M 7.2 1995 Kobe earthquake. The major fracture distribution detected by a borehole imaging tool (FMI) in the borehole was compared with the S-anisotropy from aftershocks.

The strike of fractures within the fault zone is rather dispersed and there is no clear trend. The dominant dip angle is 35 - 40º and the fracture dip distribution is described by a normal distribution. The fracture frequency is 4.80/m, which is about 1.1 times larger than outside the fault zone.

The fault zone is classified into two specific zones. These are fault core and the damaged zone. The fault core is at the center of Nojima Fault zone and the damaged zone surrounds the fault core. The fracture properties are different between the fault core and damaged zone. Furthermore, the upper and lower part of the fault core and damaged zone have several differences. The fractures of both the upper and lower fault core have a trend of N45ºE, which is almost parallel to the strike of Nojima fault. However, the trend of fracture dip angel of the lower fault core is not same as that of the upper fault core. The lower fault core is dominated by low dip angle fractures of about 30 degrees. The fracture frequency of the lower fault core is about 1.3 times larger than that of upper fault core. While the seismic anisotropy in the fault core is rather weak, the fast shear azimuths of the lower fault core are localized in N10-40ºW. The fractures in the fault core have a N45ºE strike trend with a low dip angle (25 - 30 degrees). According to Crampin (1978), a medium with aligned fractures of low dip angle, less than 60 degrees, has a shear wave anisotropy which is perpendicular to the aligned fractures. Therefore, the shear wave anisotropy detected by the DSI logging is considered to be caused by the aligned fractures with low dip angles. The trend of the fracture spacing in both the upper and lower fault core is not clear when fitted with to the theoretical curves.

The fracture distribution of the damaged zone is different from that of the fault core. The strike of fractures in the upper damaged zone is concentrated in N45ºW, which is similar to the trend of strike of outside fault zone. The dominant fracture dip angle of both the upper and lower damaged zone is about 40 degrees and the distributions of dip angle fit the normal distribution. These features of fracture dip angle are quite different from those of fault core and outside fault zone. The distributions of fracture spacing have a good fit a curve of negative exponential curve with the coefficient value determined from the mean fracture frequency per meter. The distributions also fit a power law distribution with high value of 0.92 - 0.94 for the correlation coefficient. These features of the fracture spacing in the damaged zones have resulted from the superposition of random and clustered distributions.

There are significant differences in the fracture distribution between within and outside fault zone. Fractures inside fault zone have a complicated distribution, fracture system is almost random except in a narrow depth interval where the strike is almost parallel to the Nojima fault.

Yamamoto et al., (2002) showed that the friction coefficient is smaller than 0.15 from the stress measurements in several boreholes at the Nojima fault. Although we do not exactly know the mechanism of these fracture system normal to the fault, our present model suggests these fracture system is due to complete reduction of shear stress. This may be justified from that these are open fracture system.