AOGS 2005

A New Parameter, Shaking Intensity Magnitude, and Its Potential for Earthquake Early Warning

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The main purpose of the earthquake early warning is to provide reliable shaking intensity before S wave arrivals. The shaking intensity is usually estimated by applying hypocentral distance and magnitude to empirical regression equations. However, magnitude, which is calculated from amplitude of displacement, is not the best index physically to estimate shaking intensity, which is defined from amplitudes of filtered accelerogram. Here, we propose to define new earthquake magnitude, "shaking intensity magnitude (M_I)", which is defined from observed shaking intensity with taking account of geometrical spreading and attenuation by Q, as expressed in the following equation,

$$M_I = I_{JMA}/2 + \log(r) + \pi * f * T_S/Q/ln(10) + a, \quad (1)$$

where I_{JMA} represents the shaking intensity in JMA scale, r the hypocentral distance, f the target frequency, Ts the S wave travel time, a the constant value to adjust M_I to JMA magnitude (M_{JMA}). I_{JMA} is calculated from 60-sec 3-component accelerogram by using the frequency-domain filter defined by JMA. We determined M_I for 164 earthquakes by averaging M_I in Eq.(1). Then we estimated shaking intensity at each station by using the regression equation of M_I and that of M_{JMA}. Comparing observed shaking intensity with estimated one at each station, we found that the averaged error of shaking intensity by M_I is 0.3, which is nearly half of that by M_{JMA}. Next, we developed a method to calculate M_I by using only P wave data so as to introduce M_I to our early warning system. We designed an AR-filter, which converts observed velocity seismogram to filtered accerelogram of JMA definition with taking into account the instrumental correction, and calculated shaking intensity for P wave part (I_P). Then, we estimated I_{JMA} from I_P by using an empirical relation.

By reproducing waveform data of 66 large earthquakes stored on the disk with similar speed of the actual observation, we operated our automatic system. The result shows that the averaged error between M_I by I_P and M_I by I_{JMA} is 0.11, and the error between M_I by I_P on the first solution, which is determined from a few stations within a few seconds, and that on the final solutions is 0.41. This indicates that to use of M_I is more effective to estimate accurate shaking intensity than M_{JMA}.

Keywords: shaking intensity magnitude; early warning system; shaking intenisty