A New Multidimensional Attenuation Relationship for Instrumental Seismic Intensity

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Matsu’ura et al. (2011) and Noda et al. (2016) proposed a multidimensional attenuation relationship of the velocity response spectra for wide range of distance and period, by using the attenuation term proportional to depth of subducting slab. In this study we propose an attenuation relationship for JMA seismic intensity in the same way.
We constructed database using strong-motion records from K-NET and KiK-net, which have peak ground velocity of 0.1 cm/s or more. The database was divided into three groups by seismic source types of Inter-Plate, Intra-Plate, and Very Shallow (VS) earthquakes in Japan. Inter- and Intra-Plate earthquakes occurred on and in subducting Pacific plate. We used the same formula of attenuation relationship as that of velocity response spectra after comparing trends of seismic attenuation between the velocity response and instrumental seismic intensity.

$$INT = Ac + Aw \cdot Mw - b \cdot \Delta - \beta \cdot \log(\Delta) - d \cdot \min(\delta, 250) \pm \sigma$$

where INT is instrumental seismic intensity, Mw is moment magnitude, Δ is hypocentral distance (km), and δ is depth of upper boundary of the Pacific plate. Ac, Aw, b, β and d are regression coefficients, and σ is standard deviation. For earthquakes with Mw > 7.5, we adopted Δ that is closest distance to the fault rupture. We set the upper limit of δ at around 250 km depth, and it improved the consistency with observation. The coefficient β in the attenuation term which is proportional to log(Δ) is often fixed around 2 in other previous studies of attenuation relationship for INT, but in this study we estimated β by regression analysis. The final combination of regression coefficients was determined by AIC, because the optimal combination depends on the seismic source type.
For Inter-Plate, the combination of coefficients Ac, Aw, b, β and d got an optimal solution. The standard deviation in the case using the combination was 0.643 and the AIC was also superior, whereas that using conventional simple form (combination of Ac, Aw, b, β) was 0.691. For Intra-Plate, the combination of coefficients Ac, Aw, β and d got an optimal solution. The attenuation relationship of Intra-Plate could explain the observation by the attenuation terms of coefficient β and d (without coefficient b) because there was few data at the short distance. The standard deviation in the case using the combination of Ac, Aw, β and d was 0.644, whereas that using combination of Ac, Aw, b and β was 0.751. For the Inter- and Intra-Plate, we found that the attenuation term proportional to δ was an effective term to account for the difference in attenuation such as anomalous seismic intensity distribution. On the other hand, for VS, the term proportional to δ was not effective, and the combination of coefficients Ac, Aw, b, β was got an optimal solution with standard deviation of 0.677.
We compared these results with observed one or other previous studies in order to verify the obtained relationship. In the Inter- and Intra-Plate earthquakes using the attenuation term proportional to the plate depth in this study, the residuals between observed and predicted by this study is smaller than that by other studies over a wide range of distances. On the other hand, in VS earthquakes without attenuation term proportional to plate depth in this study, the seismic intensity predicted by this study and by other studies are in the same range, and the difference of the residuals between the predicted and observed of for each study was small. These suggest that the attenuation term proportional to δ in this study is

effective to explain observed data.
We will perform further study for a correction term of ground amplification to predict seismic intensity more accurately at arbitrary sites.This study was conducted as an entrusted research from Ministry of Education, Culture, Sports, Science and Technology. We used strong-motion records from NIED K-NET and KiK-net.

Keywords: Ground Motion Prediction Equation (GMPE), Attenuation term proportional to plate depth, Selection by AIC

Type	Ac	Aw	b	β	d	σ
VS	2.096	0.962	0.00287	2.409	-	0.677
Inter-Plate	4.726	0.674	0.00171	2.416	0.00527	0.643
Intra-Plate	2.509	1.444	-	3.576	0.00883	0.644