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A Theoretical Strong Ground Motion Prediction Model for Iceland

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Summary

A theoretical ground motion prediction equation (GMPE) has been developed for Icelandic earthquakes. The model uses path and source parameters that are estimated from the acceleration data and/or available seismological information. Lack of data to develop an emprical GMPE was originally the main incentive for developing this model. The theoretical model has been found to provide a better fit to the available Icelandic strong motion data than GMPEs found in the literature and are based on data from other regions of the world. An advantage of the presented theoretical model compared to empirical models are physically intuitive model parameters which can be estimated from aivalable ground motion records. The same model that is used for obtaining PGA can also be used for simulating ground motion time series.

Theoretical model

The model is based on the Brune source spectra for the far-field that have been extended with an exponential term to account for anelastic attenuation. The model is derived using Parseval's theorem and can be written as:

$$\log_{10}(a_{\text{peak}}) = \log_{10}\left(\frac{1}{\sqrt{\pi}}\left(\frac{7}{16}\right)^{1/3}\frac{2C_P\langle R_{\theta\phi}\rangle\Delta\sigma^{2/3}p}{\beta\rho\sqrt{\kappa}}\right) + \frac{1}{2}\log_{10}\left(\frac{\Psi}{T_d}\right) + \frac{1}{3}\log_{10}(M_o) - \log_{10}(\mathcal{R}) \quad (1)$$

Here the peak ground acceleration, a_{peak}, is written in terms of distance from source, $\mathcal{R}$, and seismic moment, M_o. T_d represent the strong motion duration, β is shear wave velocity, $R_{\theta\phi}$ is the radiation pattern, C_p is a partitioning factor ($1/\sqrt{2}$), ρ is the density of the crust, $\Delta\sigma$ is the seismic stress drop and Ψ represents a dispersion function of the variable $\lambda = \kappa\omega_c$, and can be evaluated by a closed form expression. The peak ground acceleration can be evaluated as $a_{peak} = p a_{rms}$ by using a peak factor p obtained by applying the theory of locally stationary Gaussian processes.

T_d is the strong motion duration and can be represented by the following equation:

$$T_d = 1.5\frac{r}{\beta} + \left(\frac{d}{12}\right)^2 \quad (2)$$

Where *r* represent the radius of the fault and *d* epicentral distance.

Geometric spreading function

The distance from source to site, $\mathcal{R}$, is modelled by the following expression:

$$\mathcal{R} = \begin{cases} D_2^{1-n}\ D^n & D_1 < D \le D_2 \\ D & D_2 < D \le D_3 \end{cases} \quad (3)$$

Where $D = (d^2 + h^2)^{1/2}$, *d* is the epicentral distance and *h* is a depth parameter. The parameters D_1, D_2 and D_3 are used to set the limits for the different zones of the spreading function.

The geometric spreading function is used to model the varying rate of attenuation depending on distance from the source. This is demonstrated in Figure 1 where the red curve represents the model for a fixed *R* ($n = 1$).

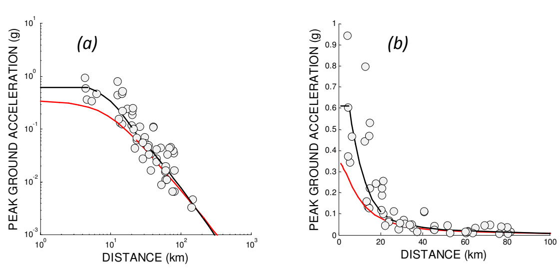

***Figure 1** Model fit to PGA data from an M_w 6.5 earthquake in South-Iceland in a) log-log scale and b) linear scale. For black curve n = 1.4 and the red curve n = 1 for Eq. (3).*

Application to the Ölfus 29 May 2008 (M_w6.3) earthquake

Originally developed for earthquakes smaller than M_w6 [1], the theoretical model was also found to provide an excellent fit to the M_w6.5 earthquakes in South Iceland in June 2000. Here below the results of applying the model to the 29 May 2008 earthquake in Ölfus, South Iceland (M_w6.3) is presented [2]. Table 1 shows estimated model parameters and Figure 3 shows how the model (green curve) fits PGA values obtained at different stations (black dots). The red curve represents a typical empirical GMPE found in the literature and is developed based on data from other regions (Campbell and Bozorgnia, 2007).

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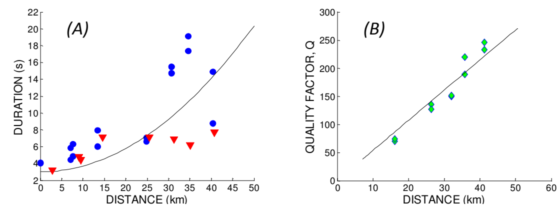

***Figure 2** (A) duration of the earthquake with respect to time. The red triangles represent source duration (S-wave windows), the solid blue circles represent the 95% duration and the solid curve represents the duration model (B) quality factor Q with respect to distance.*

Table 1 **Average values estimated for the 29 May 2008 earthquake**

Parameter	Estimate	Units
M_o	3.4×10^{18}	N m
M_w	6.26	
F_c	0.24	Hz
R	6.4	km
κ	0.053	s
$\Delta\sigma$	73.0	$\times10^4$ Pa
u	79.4	cm

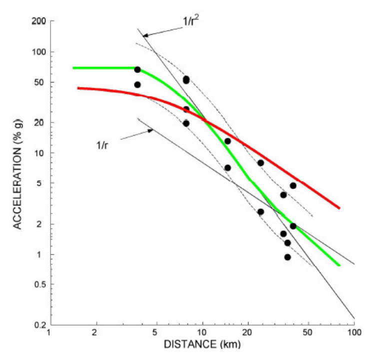

Figure 3 **Horizontal peak ground acceleration (PGA) as a function of epicentral distance (dots) the solid gree curve indicates mean values obtained by the theoretical ground estimation model.** ***The black lines indicate attenuation proportional to 1/r²*** **and 1/r, respectively, where *r* refers to the source distance.**

Reference

[1] Ólafsson, S. and Sigbjörnsson, R. (1999). A theoretical attenuation model for earthquake-induced ground motion. Journal of Earthquake Engineering 3:3, 287-315.

[2] Ólafsson, S. and Sigbjörnsson, R. (2010). Proceeding of the 14th European Conference on Earthquake Engineering.

Acknowledgments

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