Comparison of Predicted Significant Strong Motion Duration with Data from the 2011 Mineral, Virginia Earthquake

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Objective:

The objective of this study is to compare the significant duration of the motions recorded during the 2011 Mineral, Virginia, earthquake to those predicted by an empirical relationship developed by the authors that correlates significant duration to earthquake magnitude, site-to-source distance, and local site conditions (i.e., rock vs. stiff soil) for stable continental regions (e.g., central/ eastern North America; CENA).

Significant Duration:

Significant duration is one of the most frequently used definitions by engineering seismologists and earthquake engineers for quantifying strong motion duration. It is commonly defined as the time interval between 5% and 75% ($D_{5\text{-}75}$: Somerville et al. 1997) or 5 and 95% ($D_{5\text{-}95}$: Trifunac and Brady 1975) of the normalized cumulative squared acceleration, $H(t)$; $H(t)$ is given by:

$$H(t)=\frac{\int_0^t a^2(t)\,dt}{\int_0^{t_d} a^2(t)\,dt} \quad \text{(Eq. 1)}$$

where $a(t)$ is the ground motion acceleration time history, and t_d is the total duration of the acceleration time history. Fig. 1 illustrates the determination of the $D_{5\text{-}75}$ and $D_{5\text{-}95}$ for an acceleration time history using the $H(t)$ plot, commonly referred to as a Husid plot (Husid 1969).

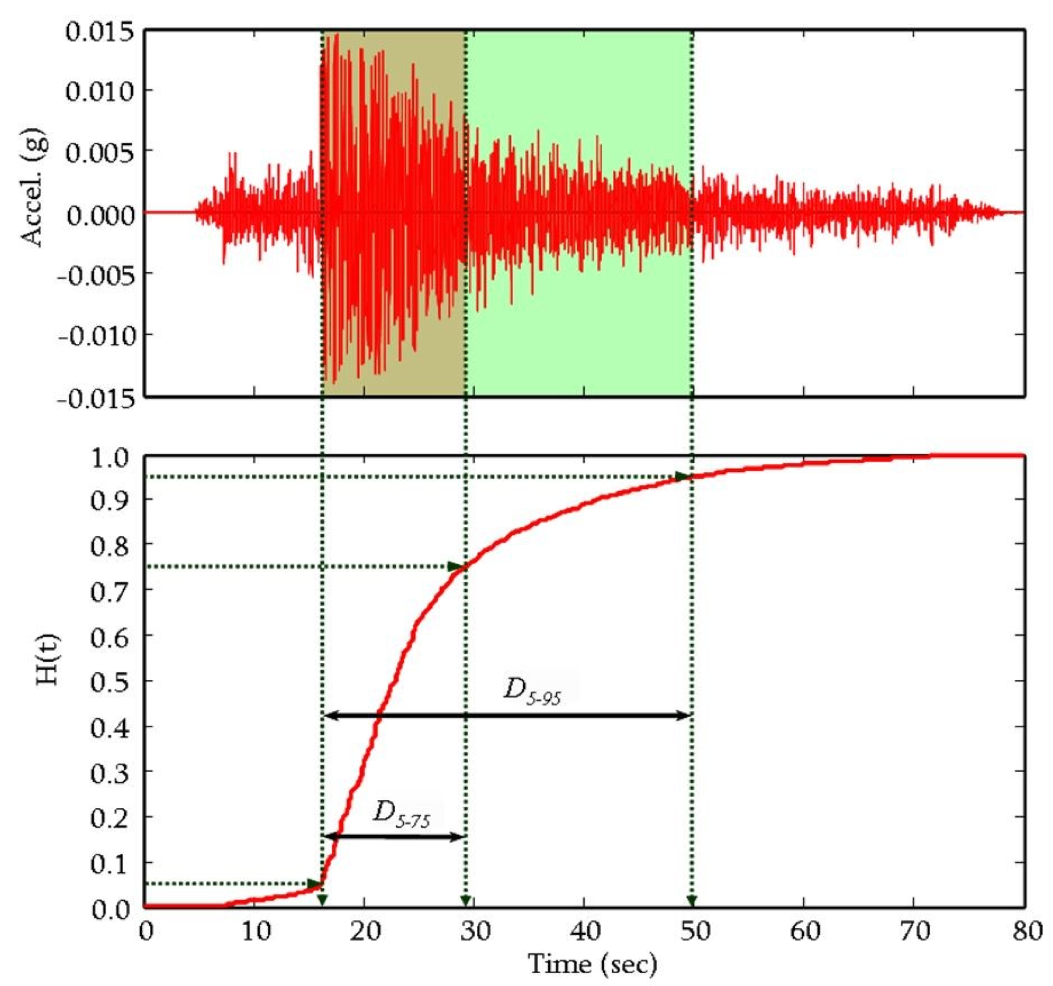

Fig. 1. Signification duration determination using the Husid plot for a ground acceleration time history (1125A54E: M5.9; R91.4km) from the 1988 Saguenay earthquake.

Ground Motion Database:

In total, 620 representative horizontal earthquake motions for CENA were used to develop the empirical significant duration relationship in this study. The ground motions were from a dataset assembled by McGuire et al. (2001). Figure 2 shows the earthquake magnitude and site-to-source distance distribution of the ground motion dataset. Because of the paucity of recorded strong ground motions in stable continental regimes, only 28 of the motions in the dataset are recorded motions, with the remaining 592 motions being "scaled" western North America (WNA) motions. Dr. Walter Silva scaled the motions using response spectral transfer functions generated from the single-corner point source model.

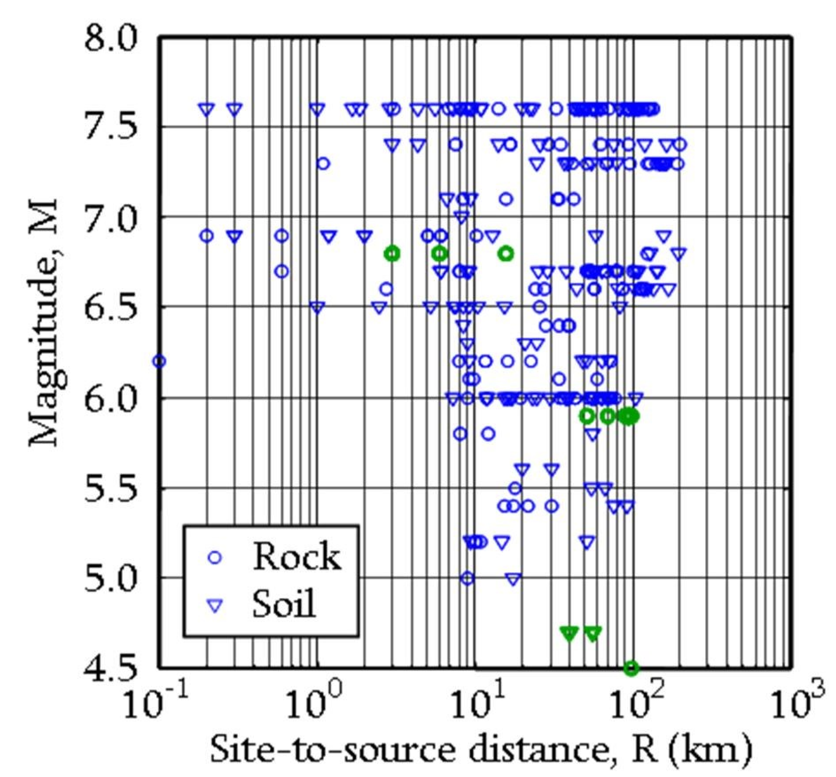

Fig. 2. Earthquake magnitude and site-to-source distance distribution (recorded motions shown in bold).

Regression Analyses:

The non-linear mixed-effects (NLME) regression technique was used to develop the empirical relationships in this study. The NLME regression method allows regression models to account for both random effects that vary from subset to subset and fixed-effects that do not; in this study, a subset consists of motions recorded during a given earthquake. This regression method produces unbiased fittings for each subset having different numbers of ground motion recordings. This is important because of the number of motions from each earthquake can widely vary. After considering numerous functional forms of the predictive relationship in the NLME regressions, the proposed model given by Eq. 2 was found to provide the best fit.

$$\ln D_{5-75} \text{ or } \ln D_{5-95} = \ln\{C_1 + C_2\exp(M-6) + C_3R + [S_1 + S_2(M-6) + S_3R]S_S\} \quad \text{(Eq. 2)}$$

where, $D_{5\text{-}75}$ and $D_{5\text{-}95}$ are in seconds; C_1 through C_3 and S_1 through S_3 are regression coefficients; M is the moment magnitude; R is the closest distance to the fault rupture plane (km); and S_S is a binary number representing local site conditions: S_S = 0 for rock sites and S_S = 1 for soil sites. The values for the regression coefficients and the standard deviations of the inter-event (τ_{ln}), intra-event (σ_{ln}), and total ($\sigma_{ln\ total}$) errors are presented in Table 1.

Table 1. NLME regression results.

	C_1	C_2	C_3	S_1	S_2	S_3	τ_{ln}	σ_{ln}	$\sigma_{ln\ total}$
$D_{5\text{-}75}$	0	2.23	0.10	-0.72	-0.19	-0.014	0.46	0.35	0.58
$D_{5\text{-}95}$	2.50	4.21	0.14	-0.98	-0.45	-0.0071	0.37	0.32	0.49

Virginia Earthquake Motions:

Figure 3 shows a comparison of $D_{5\text{-}75}$ and $D_{5\text{-}95}$ values computed from motions recorded at 15 strong motion stations during the 2011, M_w5.8 Mineral, Virginia earthquake with those predicted using Eq. 2. Note that the predicted durations are only plotted up to 200 km, the model's maximum applicable distance, while the durations of the recorded motions are plotted for distances up to ~800 km. Nevertheless, there is good overall agreement between the predicted and recorded motion durations.

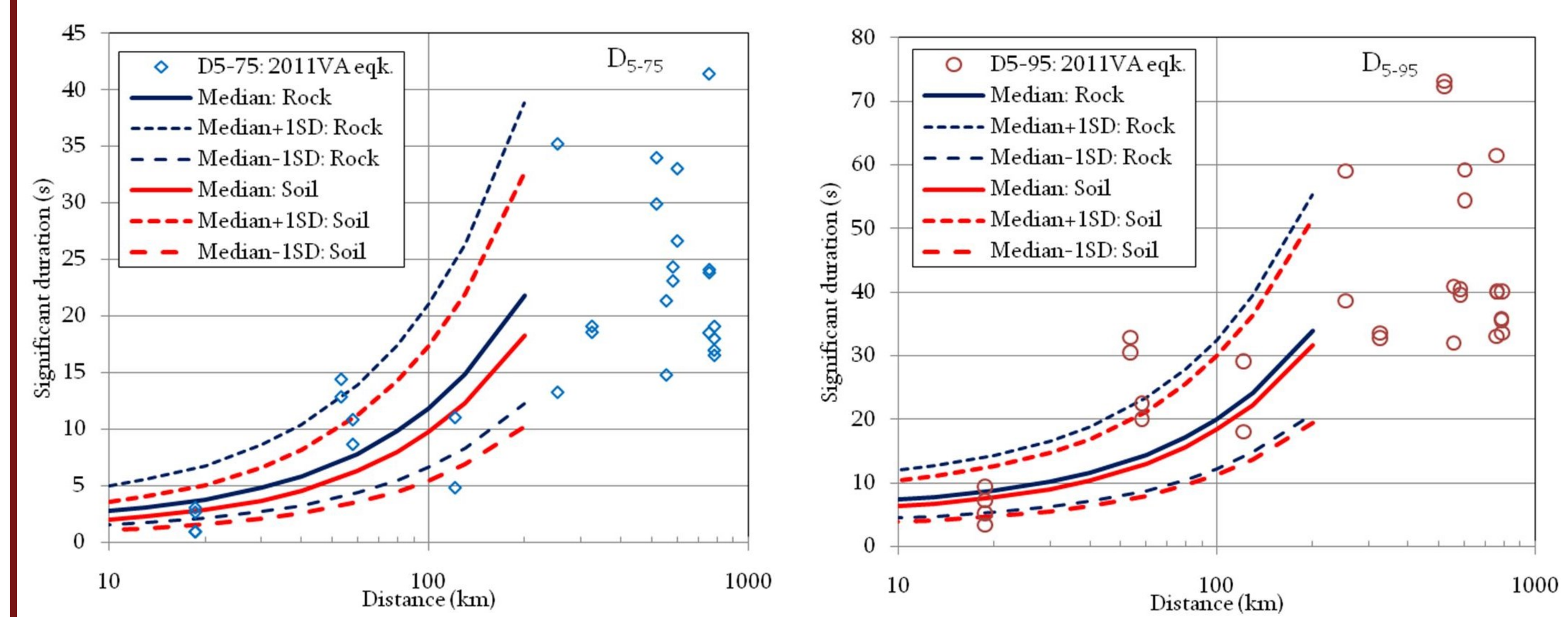

Fig. 3. $D_{5\text{-}75}$ and $D_{5\text{-}95}$ comparisons of this study's model for CENA and the 2011 Mineral VA earthquake motions.

Conclusions:

An empirical predictive relationship for significant duration of horizontal strong ground motions in stable continental regions has been developed as part of this study. The durations predicted by the proposed model are in good agreement with those computed for motions recorded during the recent M_w5.8 Mineral, Virginia earthquake, where the latter motions were not used in the development of the predictive relationship.

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