UNIVERSITY OF ICELAND
FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING

EARTHQUAKE ENGINEERING RESEARCH CENTRE
UNIVERSITY OF ICELAND

Elastic response spectra of near-fault ground motions

Sigurður U. Sigurðsson[1], Rajesh Rupakhety[1], and Torfi G. Sigurðsson[2]

1) Earthquake Engineering Research Centre, University of Iceland, IS-800 Selfoss, Iceland, 2) Mannvit Engineering, Ormsvelli 5, 860 Hvolsvöllur, Iceland

Introduction

Earthquake ground motions recorded in near-fault zones differ from those observed in the far-fault region. The development and verification of methods to aid structural design for near-fault regions is therefore of significant value, both regarding economical aspects as well as safety issues. The primary aim of this work is to research important characteristics of near-fault ground motions and structural response by the use of recorded ground motions affected by forward directivity. The main objective is to present a mathematical model for elastic response spectra of forward directivity affected ground motions as a continuous function of vibration period of oscillators.

Dataset

The near-fault strong-motion data used in this work was collected and uniformly processed by [1]. It consists of ground-motion records obtained from 36 worldwide earthquakes, resulting in a total of 106 records, all of them showing distinct velocity pulses.

Spectral shape model

The spectral shape model (denoted by PSV_n) investigated in this work is constructed as a continuous function of several parameters. It models pseudo-velocity spectrum normalised by peak ground velocity (PGV) as:

$$PSV_n = \left[I_1 e^{-\frac{1}{2}\left(\frac{\ln(T_n)+C}{W}\right)^2} + I_2 \left[\left(1-\left(\frac{T_n}{T_m}\right)^{\theta}\right)^2 + 4D_m^2\left(\frac{T_n}{T_m}\right)^{\theta} \right]^{-\frac{1}{2}} \right] T_n \qquad (1)$$

where T_n is the natural period of a single-degree-of-freedom (SDOF) system. The model is calibrated with the mean spectral shapes of recorded data, grouped into six magnitude bins. Furthermore, the calibration is done for nine different levels of viscous damping of SDOF systems.

Calibration

The variation of model parameters with earthquake magnitude (M_w) and viscous damping ratio (ζ) were systematically investigated, thereby applying suitable constraints to reduce the numbers of free parameters. It was found that the model parameters W and C were fairly independent of M_w and ζ and were assigned values of 1.0 and 1.4, respectively. The other parameters were constrained according to figures 1 and 2. See [1,2,3] for details.

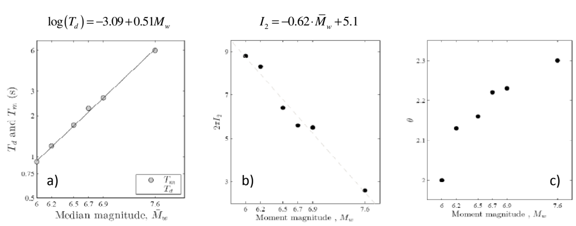

Figure 1 *The model parameters T_m, I_2 and θ are plotted against the median magnitude of the six magnitude bins in a), b) and c) respectively. These parameters are not affected by damping levels.* ***a)*** *The relationship between T_d (The predominant period of ground motion) and moment magnitude is plotted along with a thin line revealing that T_m is equivalent to T_d. The T_d-M_w relationship printed above the graph was found by regression analysis of the same data.* ***b)*** *A linear relationship between I_2 and M_w is obtained by using standard least-square regression. The relationship is shown by dashed gray line and its equation is printed above the graph.* ***c)*** *θ is assigned a constant value for each magnitude bin.*

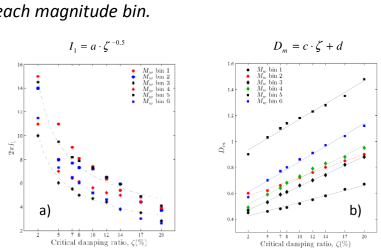

Figure 2 *The model parameters I_1 and D_m are plotted against ζ in a) and b), respectively.* ***a)*** *The relationship between ζ and I_1 can be expressed by the equation printed above the graph. This function is plotted in the figure with dashed lines for two values of a.* ***b)*** *A linear relationship between D_m and ζ, obtained by using standard least-square regression is printed above the graph.*

Results

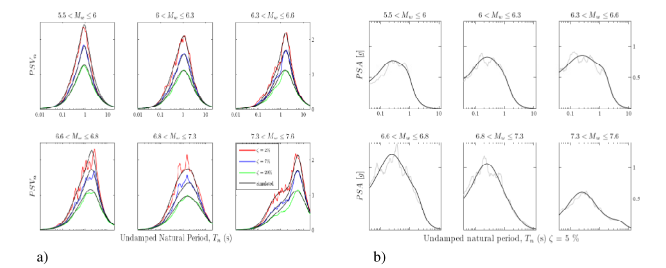

Figure 3 ***a)*** *Comparison between the mean spectral shapes of recorded ground motion (colored lines) and the proposed model (black lines) for six magnitude bins and three levels of critical damping* ***b)*** *Same as in a) but for pseudo spectral acceleration and 5% of critical damping (recorded ground motion in grey and the model in black lines).*

Comparison to Eurocode 8 spectra

Since seismic design codes are mostly based on far-field data, it is of significant interest to compare the codified spectral shape to the simulated shape of this study, as well as that of recorded ground motions. A comparison to *Eurocode 8* (EC8) normalised elastic spectra (PSA_n) is plotted in figure 4. The figure reveals that Eurocode spectral shapes are over conservative in the high frequency region and under estimate the peak response at periods close to T_d.

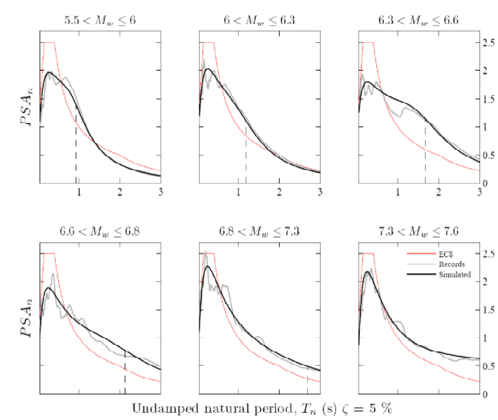

Figure 4 *Comparison of near-fault spectra to EC8 spectra. The centre of the velocity sensitive part is indicated with dashed lines positioned at periods equal to the value of the parameter T_d (outside the axis limit in the sixth bin).*

Conclusions

The model under investigation is simple and effectively captures spectral shapes of near-fault ground motions.

Spectral shapes of near-fault ground motions can be significantly higher than the EC8 recommendation in the vicinity of the predominant period, which increases with magnitude.

Acknowledgements

The first author was financially supported by a research grant from Landsvirkjun's Energy Research Fund. The second author acknowledges a grant from the research fund of the University of Iceland.

References

[1] R. Rupakhety, Contemporary issues in earthquake engineering research, PhD-Thesis, School of Engineering and Natural Sciences, University of Iceland, Reykjavík (2010)

[2] R. Rupakhety, S. U. Sigurðsson, A. S. Papageorgiou and R. Sigbjörnsson, About response of structures to near-fault ground motions, Bulletin of Earthquake Engineering (submitted for publication) (2010)

[3] S. U. Sigurðsson, Near-fault ground motions and structural design issues, MSc-Thesis, School of Science and Engineering, Reykjavik University (2010)