HYBRID GROUND MOTION PREDICTION EQUATIONS FOR PSHA PURPOSES: THE STUDY CASE OF SOUTHERN ITALY

EXECUTIVE SUMMARY

Missions and goals

The objective of the research project is to develop a methodological approach to retrieve ground motion prediction models, based on the integration between recorded and synthetic data. In this framework, we will test this methodology for the study case of Southern Italy, focusing our attention on Calabria and Sicily regions.

The choice of these areas is related to their high hazard level and, on the other side, to the lacking of empirical data needed to fully capture the peculiarities of the ground motion. Moreover, along the Sicily coast many critical infrastructures are present, such as chemical plants and large ports, which strongly increase the risk of technological accidents induced by natural hazards.

The products of the project are a set of new candidate Ground Motion Prediction Equations (GMPEs) for PGA, PGV and SA in the period range T=0.04-4s. Additional products include recorded and synthetic ground motion datasets. The project products can be incorporated in a next generation of the MPS (Italian acronym for National Seismic Hazard Maps).

The project will be coordinate by PhD Giovanni Lanzano. The work can be divided in four working tasks. A task leader has been appointed, with the role of coordinator of each working group activities.

Methods

Task 1 (WG-T1): Empirical flatfile generation (***Rodolfo Puglia**, Chiara Felicetta, Emiliano Russo, Giovanni Lanzano, Chiara Maini*)

i) Creation of a table of ground motion parameters and associated metadata (flatfile) from the European Strong Motion Database (esm.mi.ingv.it) and ITACA (itaca.mi.ingv.it);
ii) Integration between accelerometric and velocimetric data;
iii) Definition and identification of the reference rock conditions to be used for GMPEs calibration;

Task 2 (WG-T2): Ground motion simulation (***Maria D'Amico**, Mara Monica Tiberti, Emiliano Russo, Antonio Gomez-Capera*)

i) Characterization of the source geometry, kinematics parameters and source to site path;
ii) Selection of simulation methods (Finite-fault or like point source) and validation again recorded data or empirical ground motion models or macroseismic field;
iii) Compilation of a database of synthetic waveforms and related ground motion parameters (PGA, PGV, SA);

Task 3 (WG-T3): GMPEs calibration (***Giovanni Lanzano**, Maria D'Amico, Chiara Felicetta*)

i) Development of a set of median GMPEs using recorded dataset;
ii) Development of a set of median GMPEs using simulated dataset;
iii) Integration of the synthetic waveforms in the recorded flatfile;
iv) Development of a set of hybrid GMPEs using recorded and simulated data;
v) Modelling of the standard deviation applicable to the datasets for:

- Within-event standard deviation (ϕ)
- Between-event standard deviation (τ)

Task 4 (WG-T4): Hazard assessment (***Marco Santulin***, *Maria D'Amico, Giovanni Lanzano*)

i) Hazard sensitivity studies to assess the importance of factors, models and parameters that affect the ground motion.

ii) Calculation of the hazard at selected sites (Milazzo ME, Priolo Gargallo SR, Gioia Tauro RC) using the input parameters of MPS04.

Time schedule and Milestone

Task	Months																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
T1	k						*→											
T2										*→								
T3									ws					*→				
T4																ws	*→	*

Milestone: a deliverable for every Task (*) and final report (*); kickoff meeting and 2 workshops (ws) are proposed in time schedule.

Working group

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PROJECT DESCRIPTION

Goals and impact

The scope of the project is the calibration of hybrid GMPEs for Southern Italy (Calabria and Sicily), based on the integration of recorded ground motion parameters with synthetic data. The motivation of this research is to supply the lacking of instrumental observations for moderate to large earthquakes in near fault conditions. It is particularly relevant for the target area where the hazard level is quite high (MPS04 – Stucchi et al. 2011) and the seismic activity has been low in the last decades (http://bollettinosismico.rm.ingv.it; CPTI11 – Rovida et al., 2011).

The impact of these new GMPEs will be a more reliable assessment of the seismic hazard. The prediction models of the ground motion could be employed for the next generation of the shakemaps and MPS (acronym for Seismic Hazard Maps).

State of the art

In the last decades, the calibration of reliable GMPEs became a critical issue in Probabilistic Seismic Hazard Assessment (PSHA). For example, in the United States, two large research projects (NGA-West and NGA-East) were developed in order to provide ground motion characterization (GMC) models for different areas of US. In particular, NGA-East project (Goulet et al. 2011) provides a set of new GMPEs for median and standard deviation of Ground Motions (GMs) and their associated weights in the logic trees for use in PSHA for Central and Eastern North-American Region. Differently from NGA-West project, where the GMPEs are retrieved only on empirical basis, NGA-East research products include the use of synthetic data to fill the lacking of observations, especially for moderate to large earthquakes in near field conditions.

On the European side, in the framework of the SeIsmic Ground Motion Assessment (SIGMA; project-sigma.com) project, five GMPEs (Douglas et al. 2014) were derived based on record chosen from a common strong-motion database of European and Middle-Eastern waveforms (RESORCE, Akkar et al. 2014). Strong effort was done in order to obtain a representative dataset. Nevertheless, in areas characterized by high hazard level, where few significant earthquakes occurred in the recent years, the integration between empirical and synthetic ground motion parameters is recommendable.

In this regard, some efforts were done in the calibration of physics-based GMPEs, which are particularly effective in showing important ground motion features in near source regions (NERA EU Project; Dalguer et al. 2014; Dalguer et al. 2013). Indeed, when the site is very close to the fault, the rupture processes are predominant and the finite-source effects, such as directivity, hanging wall/foot wall, radiation-pattern and slip distribution dominate the GMCs. Therefore, the empirical GMPEs are generally incapable to captures such features, because the strong motion recorded data in near source are few.

In last years in Italy, many efforts has been done in order to develop a national accelerometric database (ITACA, itaca.mi.ingv.it/), which also contains waveforms of seismic events with moderate to large magnitude (e.g. Friuli 1976-1977, Irpinia 1980), sometimes with a dense spatial covering in near fault conditions (e.g. L'Aquila 2009, Emilia 2012).

On the basis of the abovementioned dataset, tools for the ground motion prediction has been derived (Bindi et al. 2011 is the reference model for Italy). Moreover, for the purpose of hazard assessment, the variability at single site was investigated (Luzi et al. 2014; Pacor et al. 2014a; Lanzano et al. 2014), in order to reduce the standard deviation of the ground motion model.

Recently, GMPEs for specific areas of the Italian territory, as the Northern Italy, were proposed (Pacor et al. 2013a; Pacor et al. 2013b; Lanzano et al. 2015). In the framework of the ENEL project aimed at the seismic design of a critical infrastructure in Porto Empedocle (AG), the ground motion characteristics of Sicily was

also investigated (Pacor et al. 2014b). In this work, the integration between accelerometric and velocimetric data has been done with the aim to rank existing GMPEs. One of the project prerogatives was to select the most reliable GMPEs, useful for specific site PSHA.

Finally, in the framework of the MASSIMO project (Musacchio et al., 2013; Buongiorno et al., 2014), in order to provide synthetic ground-motion models for earthquakes in magnitude range and distance for which the finite-fault effects are predominant, numerical simulations by deterministic-stochastic method (DSM, Pacor et al., 2005) has been performed at selected cities (Cosenza, Vibo Valentia and Reggio di Calabria). The analysis of the synthetic ground motion variability could by employed to integrate PSHA, to evaluate the probability of exceedance from statistical analysis of a huge number of possible rupture scenario occurring on specific composite faults (D'Amico et al., 2015).

Methods and procedures

The scheme of our proposal retraces the flow chart of the NGA-East project. In the following sections, each task is described in detail.

Task 1 (WG-T1): Empirical flatfile generation

The main issue of the first task is the compilation of a qualified database of recorded waveforms: it will be mainly based on the European Strong Motion Database (esm.mi.ingv.it) and ITACA (ITalian ACcelerometric Archive, itaca.mi.ingv.it/; Luzi et al. 2008; Pacor et al. 2011). The accelerometric dataset will be integrated by velocimetric data, because the strong motion data are lacking and the velocimetric networks managed by INGV or other institutions are denser. Data collection includes the reviewing and processing of earthquake recordings (Puglia et al. 2014) from stations on various site conditions (rock and soil) and the compilation of available metadata into a flatfile (magnitude, distance, site conditions, etc.). The ground motions will be adjusted to the reference rock conditions using scale factors (Moscatelli et al. 2014). The metadata will be updated and completed as much as possible, in order to implement more complex functional forms for GMPEs testing and calibration.

Task 2 (WG-T2): Ground motion simulation

The prerogative of the WG-T2 will be to perform deterministic shaking scenarios at selected sites in order to produce a flatfile of synthetic ground motion parameters and related metadata. The main use of the numerical simulations of the ground motion is to constrain the scaling of the low frequency behavior for seismic events not represented in the database (e.g. large magnitude in near source). The WG-T2 is responsible for selecting the more appropriated methods for the numerical simulation of the ground motion (Boore, 2003; Pacor et al. 2005; Gallovic and Brokesova, 2007 among others) and for developing the validations requirements (Seismological Research Letters, Vol. 86, n°1, 2015). In this framework, we will also use fault geometry derived from macroseismic intensity field of past strong earthquakes, not included in seismogenic fault databases (DISS3.1.1). It will imply the validation of *ad hoc* relationships between GMP and Intensity Points (IP).

The WG-T2 is also responsible to:

1) Define the inputs for finite-fault simulations (DISS3.1.1 or Macroseimic Intensity Field of historical earthquakes).
2) Select models for the kinematic inputs (nucleation points, rupture velocity, slip distribution).
3) Associate the more appropriate path parameters (Q, geometrical spreading).
4) Select representative 1D crustal velocity structure.

Task 3 (WG-T3): GMPEs calibration

The WG-T3 will develop a set of median GMPEs for Southern Italy, using the results of the previous tasks. In particular, three subsets of GMPEs will be retrieved:

a) Empirical GMPEs based on the flatfile of recorded waveforms developed in Task 1;
b) Physics-based GMPEs based on the flatfile of simulated waveforms developed in Task 2;
c) Hybrid GMPEs based on the flatfile integrating the recorded and simulated data;

The results of the GMPEs calibration will be compared among them and with respect to other significant existing GMPEs. The goodness of fit will be evaluated on the basis of the total residuals, calculated as the difference between observations and predictions. The standard deviation (σ) of the total residuals of GMPEs has a strong influence on the results of PSHA. The sigma will be decomposed in the within-event and the between-event components in order to make a comparison between the standard deviations of empirical and synthetic data. These values will be finally compared to those evaluated for other world regions (Rodriguez-Marek et al. 2011; Al-Atik et al. 2010; Luzi et al. 2014).

Task 4 (WG-T4): Hazard assessment

The WG-T4 will combine all the products from other tasks with the aim of performing a series of sensitivity studies on model and/or parameters to evaluate their impact on the seismic hazard assessment.

Some significant test sites in Southern Italy will be selected because of the presence of critical infrastructures (Milazzo ME, Priolo Gargallo SR, Gioia Tauro RC).

The final step will be to evaluate the impact of the employment of the hybrid GMPEs in the assessment of the seismic hazard.

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BUDGET SUMMARY

The funding will be equally divided in three item costs:

1. Travels (missioni);
2. Equipment (beni e servizi);
3. Other direct costs (studi e ricerche)
4. Indirect costs

In this case, the item "other costs" also concerns the funding of one or more study periods (3-4 months) in other foreign research institutions (i.e. United States Geological Survey, USGS).

A scheme of the cost breakdown is given in the following table.

Cost Category	**First Year**	**Second Year**	**Total**
Equipment	4.200 €	1.800 €	6.000 €
Travel	5.100 €	2.100 €	7.200 €
Other Direct Cost	8.300 €	3.500 €	11.800 €
Indirect Cost	0	0	0
Total cost	17.600 €	7.400 €	25.000 €

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