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PRELIMINARY RESULTS OF RISK TARGETED DESIGN MAPS FOR ITALY

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ABSTRACT

We present in this paper a preliminary study on the application of the Risk Targeted approach to the definition of design ground motions for Italy. The study has been carried out for the limit state of collapse, using the reference hazard adopted by the Italian norms. The Risk Targeted approach aims at calculating design ground motions that would ensure uniform collapse probabilities in different regions of Italy. Since the performance of buildings designed according to the most recent norms is presently unknown we tested different fragility curves and different target collapse probabilities, based on previous works from different authors carried out in the US and in France. The results obtained with the reference hazard study show that the method applied in the US, aiming at a uniform probability of collapse of 1% in 50 years, would require an increase in design ground motion in large parts of Italy, and in particular in the low seismicity regions. The method proposed for France, which assumes more resistant buildings than the previous one, and which aims to a lower target of collapse probability (0.05% in 50 years) would lead to lower design ground motions in large parts of Italy, with decrease of up to 30% of the present one. At the same time this method yields a large increase of design ground motions in two relatively small areas in southern Italy.

INTRODUCTION

In this paper we present the preliminary results of the application of the Risk Targeted approach towards a new definition of design ground motions for Italy. In Italy at present design ground motions are defined following the conventional approach requiring the design to be conducted for ground motion levels corresponding to an uniform mean return period throughout the national territory. This design paradigm does not ensure the same level of safety against earthquakes for all buildings everywhere in Italy. The aim here is to compare the earthquake ground motion values defined by the building code across Italy with those calculated using an approach that ensures a uniform nominal probability of collapse. The latter values are called Risk-Targeted Ground Motions.

As described in Luco et al. (2007) the ultimate capacity of a building (expressed here in terms of PGA that brings it down although other intensity measures could also be used) designed according to a single ground motion level corresponding to a given mean return period is a random variable affected by a large uncertainty. This uncertainty makes it possible for the building to survive or to collapse for ground motions that have a rather wide range of PGA values around the design PGA level. Hence, the probability of collapse of a building depends on the probability of exceedance of many values of PGA and not only the design one. In other words, the slope of the hazard curve in the neighbourhood of the design PGA levels has an influence on the probability of collapse of the building at a given location.

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Since at present the probability of collapse of buildings designed according to the NTC08 in Italy is unknown, firstly we experimented for Italy Luco's procedure, that assumes that buildings have 10% chances of collapse should they experience the 2475yr design ground motion level. Then we have tested the procedure proposed by Douglas et al.(2013) for France, that assumes lower percentiles for the collapse capacity (0.001% for the 475 yrs design ground motion). The resulting risk-targeted ground motions are compared and contrasted.

FRAGILITY CURVES FOR COLLAPSE FOR ITALIAN BUILDINGS

The current building code for Italy (Norme Tecniche per le Costruzioni 2008, hereafter NTC08; http://www.cslp.it/cslp/) requires the definition of the design ground motion based on the importance of the structure, its life expectancy, and the damage limit state considered. In particular, for the limit state of collapse the code requires the design seismic input for ordinary buildings to be a ground shaking with a 5% probability of exceedance in 50 years, i.e. a 975 years mean return period (RP) ground motion level.

The reference seismic hazard study adopted by the norms is the one published by the Italian Institute of Geophysics and Volcanology (INGV) in 2004 (MPS04; http://zonesismiche.mi.ingv.it, and Stucchi et al., 2011). The INGV published hazard data for 9 return periods (from 30 to 2475 years) for PGA and spectral ordinates up to 2 seconds on a grid of sites with 5 km spacing covering Italy. The seismic hazard model was obtained using a standard probabilistic approach, and the epistemic uncertainty was captured through a logic tree. The median horizontal PGA and spectral ordinates on rock provide the seismic input of reference for the building code. To test the application of the Risk Targeted approach to the Italian case we used this reference hazard study, and used the hazard curves for the median PGA on rock to derive the design ground motion level for the limit state of collapse for each site of the hazard grid.

As mentioned above, the risk targeted ground motions were estimated at first using the parameters proposed by Luco et al. (2007) for the US. The collapse capacity is represented as a lognormally distributed random variable with standard deviation β=0.8 and with 10^{th} percentile equal to the 2475 yrs design ground motion level. This parameter of the distribution was estimated based on the fact that US buildings designed with the conventional approach have at most a 10% chance of collapse should they experience the design ground motion level. More recent studies (Douglas et al., 2013) suggest a lower probability of collapse (0.001%) for European buildings under the less severe 475yr design ground motion, and a significantly lower variability of the capacity (β=0.5).

The 0.001% probability of collapse adopted by Douglas was used in this study to estimate a corresponding collapse probability under the 975 yrs design ground motion used in the Italian norms. To do this the original parameters of Douglas where used to build the capacity curves for a set of Italian cities with different seismicity levels (Table 1). For each of these capacity curves then, the probability of collapse corresponding to the design ground motion with 975 RP was calculated. The mean value of these collapse probabilities was around $8*10^{-5}$, which has been rounded off to 10^{-4} (0.01%) and adopted in this study to parameterise the capacity curves with the Douglas method. A similar procedure has been followed to estimate the parameters of the capacity curves according to the Luco's method. In this case the probability of collapse under the 975 yrs design ground motion is estimated to be equal to 0.05 (5%).

Figure 1 shows the two possible Cumulative Density Functions for the collapse capacity of a general building designed for the 5% in 50 years ground motion level for a low seismicity and a moderate seismicity site (Milano and L'Aquila, respectively). For each site we compare the two curves, one designed according to Luco's parameters, with β=0.8 and parameterised with the 5% (C5.0%) probability of collapse for the design ground motion, the other according to Douglas, with β=0.5 and 0.01% (C0.01%) probability of collapse.

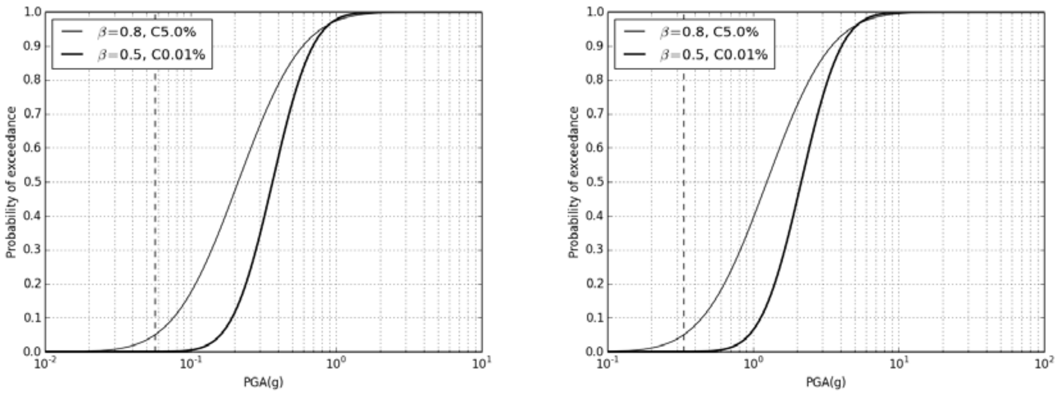

Figure 1. Capacity curves for a low seismicity site (Milano, left) and a moderate seismicity site (L'Aquila, right) in Italy. The dashed line represents the design ground motion (5% in 50 years).

HAZARD CURVES

The INGV hazard curves are provided for 9 Return Periods, from 30 to 2475 years, with PGA ranging roughly from 0.01 to 0.6g throughout the national territory. The capacity curves based on the design ground motion with 975 RP span a wider range of PGA values. According to McGuire (2004), the part of the capacity curve that contributes most to the probability of failure is between the design ground motion and the median of the capacity curve. The hazard curves available for the risk calculations however do not provide the values up to the ground motion level corresponding to the median capacity. Extrapolation of hazard curves is always discouraged but here it is unavoidable. The extrapolation has been performed up to the 10^{-5} Annual Frequency of Exceedance (AFE). For the part of the curve towards the high AFE values, the extrapolation was performed up to a PGA of 0.01g only when the PGA values corresponding to a 30yr RP where higher than this value.

To test the error introduced by the extrapolation on the calculation of the probability of collapse we have used the hazard curves provided by the European project SHARE, which are calculated for a wider range of AFE. We used the full curve provided by SHARE and extracted the curves for the 9 RP used by INGV for a set of Italian cities. We then calculated the Risk Coefficient, Cr, both with the full hazard curves and with the subset of 9 points, using an extrapolation algorithm for the latter. The Cr is the coefficient between the design Risk Targeted Ground Motion calculated for a uniform collapse probability and the design ground motion at the 975 years RP (PGA_{975}).

The calculations have been carried out using two capacity curves with two target collapse probabilities, one parameterised with β=0.8 and C5%, with a target collapse of 1% in 50 years (Luco's parameters), the other with β=0.5 and C0.01%, with target uniform collapse probability of 0.05% in 50 years (Douglas' parameters).

Using Douglas parameters (Fig. 2, right) the Cr obtained with the extrapolated curve is larger than the one obtained with the original curve for all the cities selected. This means that, by adopting the extrapolated hazard curve, the resulting RTGM required to obtain a uniform collapse probability will be larger than the ones actually obtained when considering the full hazard.

The results obtained with Luco's parameters (Fig. 2, left) are less variable and very small differences are visible between the Cr obtained with the full or the extrapolated curve for all cities considered. It is likely then, that the results we will obtain by using the INGV hazard, extrapolated using the same method shown here, will be more reliable when using the Luco's parameters rather than the Douglas. We cannot however quantify exactly the influence of using the linear extrapolation with the INGV data, since the shapes of the INGV and SHARE hazard curves are sometimes very different.

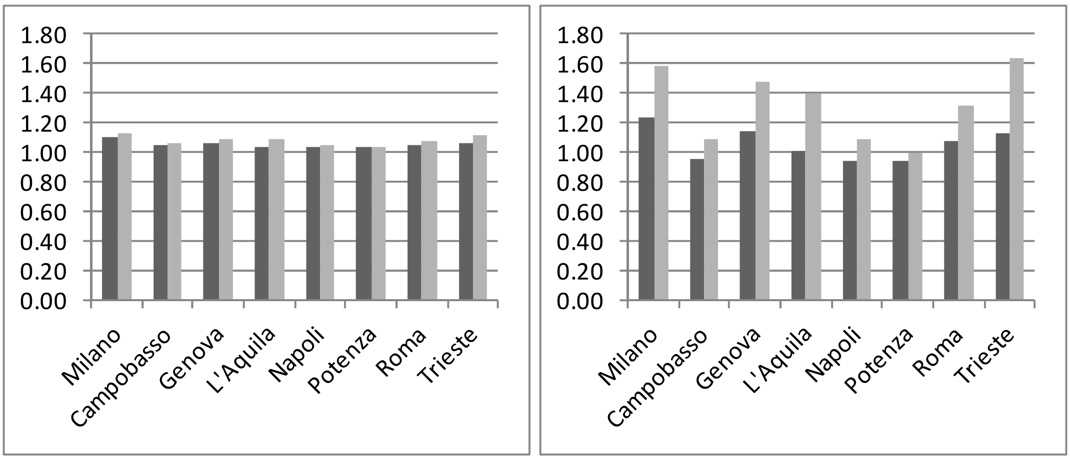

Figure 2. Cr calculated with the SHARE hazard (dark grey) and with a subset of SHARE hazard extracted for 9 return periods, 30-2475 yrs (light grey). On the left, Cr calculated with Luco's parameters(target collapse of 1% in 50 years, capacity with β=0.8 and C5%).On the right, Cr calculated with Douglas parameters (target collapse of 0.05% in 50 years, capacity with β=0.5 and C0.01%).

The Cr calculated with the INGV hazard model and the Luco' s and Douglas parameters for the cities selected are shown in Fig. 3. The PGA_{975} for the INGV study are lower than the corresponding PGAs for SHARE (Table 1). The resulting Cr values obtained with the Luco's method are greater than 1 for the cities considered, and in particular in Milano, which is the city with lowest seismicity among the ones shown here. The results obtained with Douglas range between a Cr of 0.77 (Milano) to just above 1 for Campobasso, and they are mostly lower than the Cr calculated with the Luco's parameters.

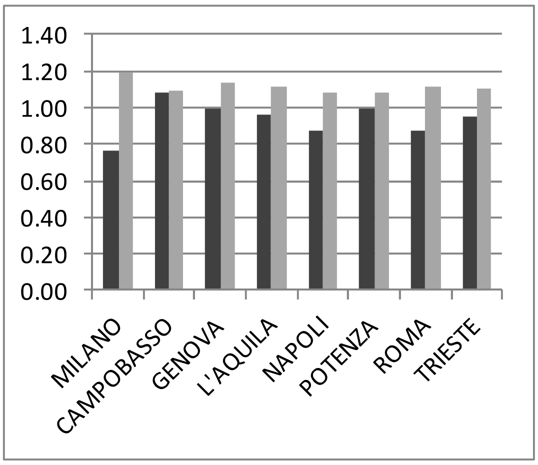

Figure 3. Cr calculated with the INGV hazard with Douglas parameters (dark grey) and Luco's (light grey). Douglas: target collapse of 0.05% in 50 years, capacity with β=0.5 and C0.01%. Luco: target collapse of 1% in 50 years, capacity with β=0.8 and C5.0%.

Table 1. Design ground motion (RP 975) from SHARE and INGV for the cities shown in Fig. 2 and Fig. 3

Location	PGA_{975} (g) SHARE	PGA_{975} (g) INGV
Milano	0.139	0.057
Campobasso	0.322	0.297
Genova	0.175	0.087
L'Aquila	0.406	0.334
Napoli	0.327	0.213
Potenza	0.407	0.262
Roma	0.313	0.203
Trieste	0.225	0.138

RISK COEFFICIENT MAPS FOR ITALY

In this section we compare the design ground motion values defined by the building code across Italy with those calculated to ensure a nominal uniform probability of collapse in the whole territory. The maps are shown here in terms of Risk Coefficient, using the Luco's and Douglas parameters to build the capacity curve, and calculated for the target uniform probabilities of 1% and 0.05% in 50 years respectively.

The Cr map generated with the Luco's parameters (Fig. 4) shows values that are mainly above 1, meaning that, using this capacity curve, the probabilities of collapse with the present design ground motions are greater than 1% in 50 years in most of Italy. The design ground motions should therefore be increased to reach this target collapse probability. In particular the higher coefficients are reached in the low seismicity regions, such as the area west of Milano.

The map generated with Douglas parameters (Fig. 5) shows a different picture. The Risk Coefficients are below one for most of the regions, with design ground motions that could be lowered by up to 30% of the present ones. In limited areas however design ground motions should be increased by a factor of 1.3 to 1.6 to reach the 0.05% in 50 years target collapse probability. In both Cr maps it is evident the effect of the seismic zones used by the INGV hazard study.

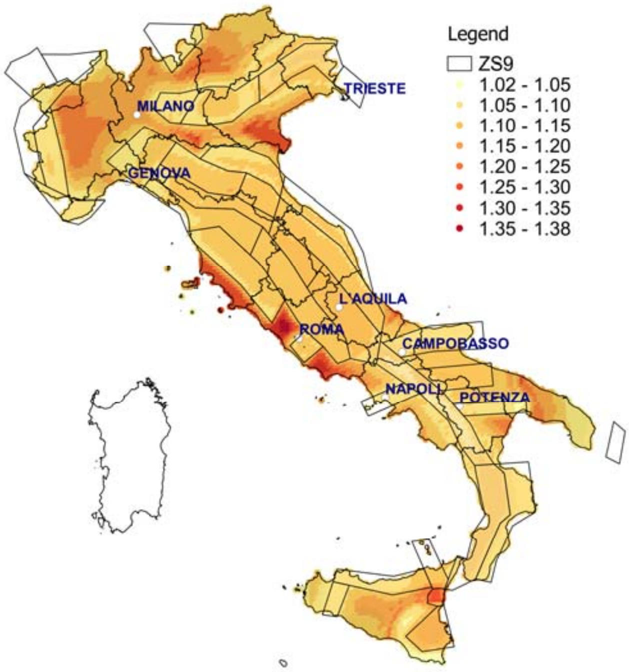

Figure 4. Cr calculated with the INGV hazard for target collapse of 1% in 50 years, capacity with β=0.8 and C5%. Overlaid are the ZS9 seismic zones used in the INGV hazard study.

CONCLUSIONS

In this study we have explored the Risk Targeted approach for the definition of design ground motions, aimed at defining seismic actions that would ensure a uniform collapse probability in all regions of Italy. We have explored two different options for the capacity curves used in the calculations, one proposed by Luco for the western US and one proposed by Douglas for France. The former assumes a larger variability in the curves and a larger collapse probability for buildings subjected to the design ground motions than the latter. Also the two authors suggest two different target probabilities of collapse, namely 1% in 50 years for Luco and 0.05% in 50 years for Douglas. By using the reference hazard study adopted by the Italian building code we produced Risk Coefficient maps assuming the parameters and target collapse probabilities proposed by these two authors. The Risk Coefficients obtained with the Luco's approach yield to adjustments in the design ground motions which are in the order of 1.1 to 1.4 times the present design ground motions in most of the Italian regions, with the highest coefficients reached in the low seismicity regions. The application of the Douglas approach yields mostly coefficients lower than one in many regions, but also to some large increase in ground motion in two limited areas in southern Italy.

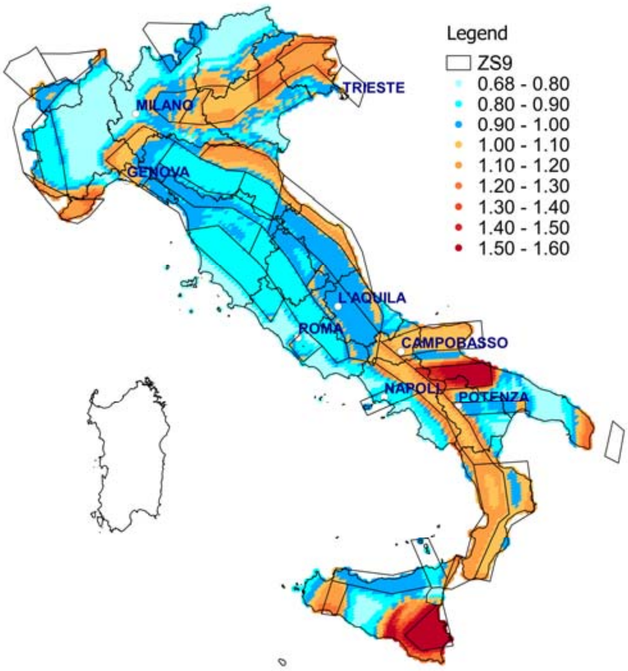

Figure 5. Cr calculated with the INGV hazard for target collapse of 0.05% in 50 years, capacity with β=0.5 and C0.01%. Overlaid are the ZS9 seismic zones used in the INGV hazard study.

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