4th International Conference on
Earthquake Geotechnical Engineering
June 25-28, 2007
Paper No. 1654

HAZARD ASSESSMENT AND SEISMIC ACTIONS

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ABSTRACT

In the paper, the definitions of the design seismic actions for different limit states and importance classes given by Eurocode 8 and by Italian construction code are analyzed.
To set the context of the discussion, a brief review of the most common way to assess the seismic hazard and the parameters used to represent the hazard (essentially soil acceleration, $a_{g,}$ related to a fixed return period, or, that is the same, to a fixed probability of exceedance in a given time) is done. Then, the problems involved in the way to assess the seismic actions in the European and Italian codes are highlighted: first, the definition of a fixed factor to obtain the a_g for the damage limit state, starting from the a_g with 10% probability of exceedance in 50 years; second, the definition of fixed importance factors applied to the a_g depending on the different importance classes.
A comparison among the seismic actions obtained by the use of fixed factors and by the calculation of the values of a_g relative to different return periods, for the Italian municipalities, has been done. The results show a great difference among the values obtained, particularly it's possible to observe a great variability of the ratio calculated among the a_g relative to different return periods.

Keywords: seismic actions, return periods, ultimate limit state, damage limit state, fixed factors

INTRODUCTION

In the Eurocode 8 and in the Italian construction code (Ministero delle Infrastutture e dei Trasporti, 2005), the design seismic actions for buildings are defined. The design seismic action is expressed in terms of peak ground acceleration, a_g, (on type A ground, as defined in the codes) associated with a reference probability of exceedance, in 50 years or a reference return period. It depends also on the importance factor, introduced to take into account a differentiation based on consequences of collapse for human life, on their importance for public safety and civil protection in the immediate post-earthquake period, and on the social and economic consequences of collapse. The probabilities (or return periods) are established to be reasonably different for damage limit state and ultimate limit state and (in the Italian code) also depending on the importance building class.

The fundamental problem is that when the a_g values for all return periods are not available, the codes give factors for scaling the a_g having a return period of 475 years (reference design action for the ultimate limit state for conventional buildings and typical parameter used to represent seismic hazard) to obtain the value of the a_g useful for damage limit state (reduction factor) and for different classes of importance (importance factors). This is a problem because the use of fixed factor can't represent in the right way the variation of the a_g values with the return periods for different sites, with the consequence of a under- or over estimate of the design actions.
In the paper are presented the differences, in Italy, among the a_g obtained by the use of fixed factor and the ones obtained directly from the seismic hazard represented for different return periods. These

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results highlight the fact that to describe the seismicity of a site only with a shaking parameter related to a single return period is not correct.

Given the direct connection between the values of the seismic action and the assessment of the seismic hazard, in the paper is also briefly described the internationally most used methodology, pointing out especially its limits.

HAZARD ASSESSMENT AND REPRESENTATION

A better understanding of the reliability of the design seismic actions is possible analyzing the procedure used to assess the seismic hazard. The approach internationally most used and used also to obtain the Italian new hazard map (Gruppo di Lavoro, 2004), is the one proposed by Cornell (Cornell, 1968) and implemented in the software SEISRISK III (Bender and Perkins, 1987). It's based on two fundamental hypotheses:

1. the earthquake epicentres are uniformly spread in every source zone;
2. the earthquake occurrence process is stationary.

The first hypothesis implies, as consequence, a levelling of the seismicity among the different sites; this effect is more evident as the seismic source area increases. The second one influences the definition of the seismic catalogue completeness, when the methods to asses the completeness ranges are dependent on the gap from a stationary behaviour.

In Italy, for example, in the application of the Cornell approach to obtain the new hazard map (Gruppo di Lavoro, 2004), it has been used a logic tree that takes into account the contribution of different attenuation laws, different methods to define the catalogue completeness and to assign to every zone the seismicity occurrence rates. The tree has at the end 16 branches, each one with a weight dependent on the confidence assigned to each hypothesis of the branch.

The result obtained by all these calculations was originally the map of acceleration referred to a return period of 475 years (10% probability of exceedance in 50 years) (Gruppo di Lavoro, 2004).
Later on, other maps of values of acceleration and spectral values relative to different return periods have been produced (Progetto INGV-DPC S1, 2006). All these results are calculated, and then represented, on a grid that cover the Italian territory.

The authors have then reproduced the entire procedure above described (Gruppo di Lavoro, 2004, Progetto INGV-DPC S1, 2006), to have the availability of the same results for a wider range of return periods.

SEISMIC DESIGN ACTIONS

It's now possible to focus the attention on the details of what is established by Eurocode and by the Italian construction code about the seismic design actions.

The Italian code distinguishes the buildings (and the other constructions) in two classes of importance: the first (class 1) includes essentially buildings residential, not crowded, not "strategic" and without a relevant industrial risk; the second (class 2), includes all the buildings that are strategic, public, socially important, or crowded, or with relevant industrial risk. For each one of these classes, the code establishes different design seismic actions: in particular it defines the shape of the design spectra and the peak ground accelerations (a_g) for the ultimate limit state and for the damage limit state, fixing the return periods (or the exceedance probability in 50 years) as shown in table 1.

Table 1. Return periods (years) and exceedance probability in 50 years (in brackets) of the a_g to be adopted for the two importance classes and the two limit states (Italian code)

	Class1	Class 2

Ultimate Limit State	475 (10%)	975 (5%)
Damage Limit State	72 (50%)	140 (30%)

Furthermore, the code establishes that if the values related to the different return periods are not available, it's possible to obtain the seismic actions for the damage limit state dividing by 2.5 the values obtained for the ultimate limit state.

Similar indications with some differences, are provided for by Eurocode, from which the Italian code derives. For the damage limit state, the Eurocode recommends a return period of 95 years (10% probability of exceedance in 10 years) leaving the freedom to each country to define other values. Another important difference is that four importance classes are defined but the corresponding return periods are not given. The values of the seismic actions are obtained applying importance factors (0.8 for class I, 1.0 for class II, 1.2 for class III and 1.4 for class IV) to the values of a_g with a return period of 475 years for the ultimate limit state and 95 years for the damage limit state. The same reduction factor (2.5) is suggested to obtain the actions for the damage limit state from the actions related to the ultimate limit state.

The use of fixed factors instead of values directly calculated for different return periods, can create problems to have a correct interpretation of the seismicity of the single sites: in particular, in some sites the actions will be overvalued and in other underestimated. The ratio between the a_g having a return period related to the ultimate damage state and damage limit state and for the different importance classes (Figures 1,2,3,4) have been calculated to highlight these effects,. The values of a_g used to calculate the ratio are the ones related to the Italian municipalities, derived by the authors from the values on the grid.

In Figure 1 is possible to observe that the ratio between the values of a_g related to the ultimate limit state (475 years of return period) and the damage limit state (72 years of return period) for buildings belonging to the class 1, as defined in the Italian code, ranges in all the country from 1.55 to 3.40 instead of the 2.5 defined by the code. The same thing happens for buildings in class 2, shown in Figure 2, where the related ratio ranges from 1.55 to 3.15.

In Figure 3 the ratio between the values of a_g related to the ultimate limit state for buildings belonging to the class 2 (975 years of return period) and class 1 (475 years of return period), is shown. The values obtained range from 1.14 to 1.55. Similarly, in Figure 4 the values of the ratio for the damage limit state for the two importance classes (respectively 140 and 72 years of return periods) are represented: they range from 1.14 to 1.65. These results highlight that also the fixed importance factors are not realistic.

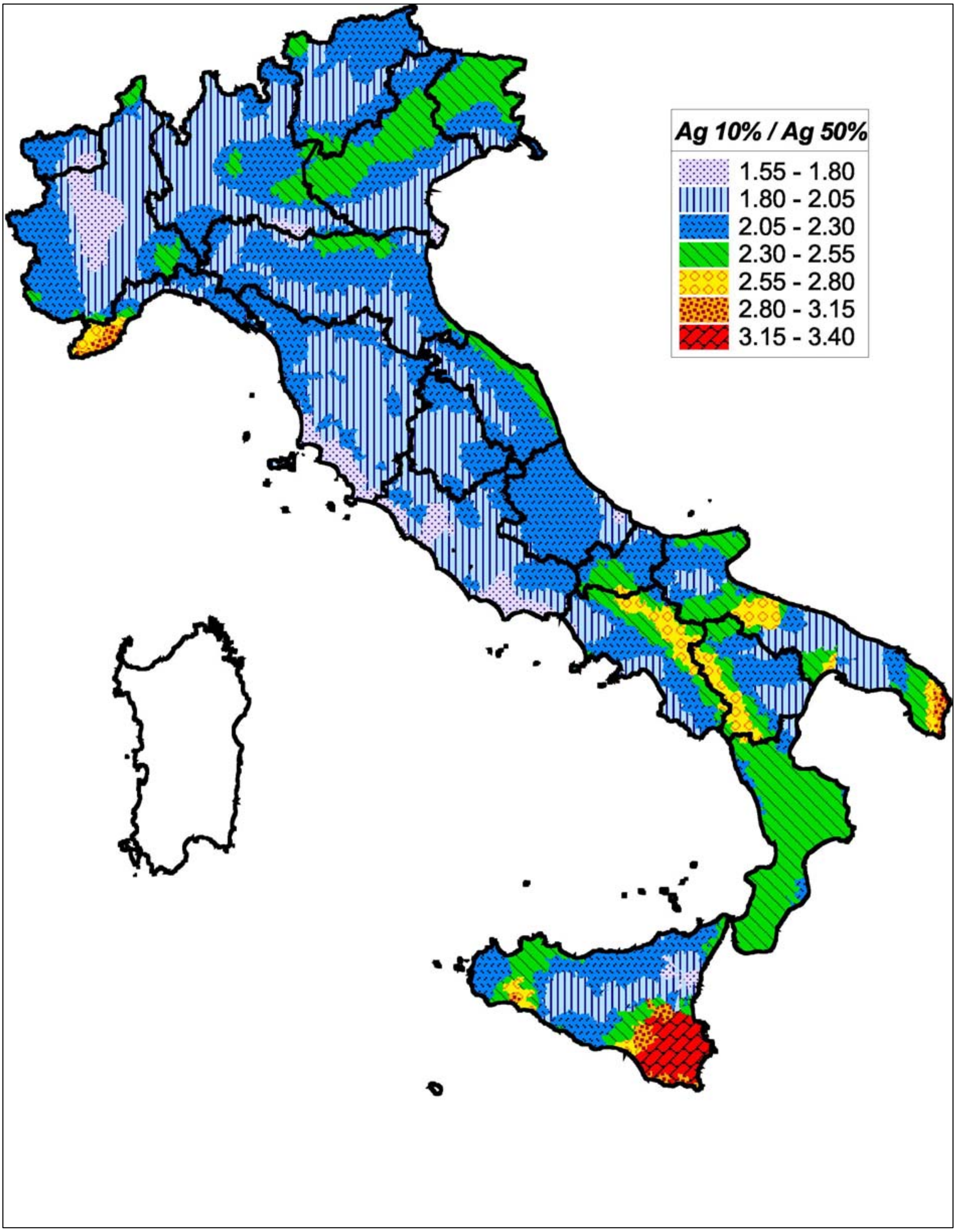

Figure 1. Ratio between a_g relatives to return periods of 475 years and 72 years (as to say a_g having a probability of exceedance of 10% and 50% in 50 years) in Italy

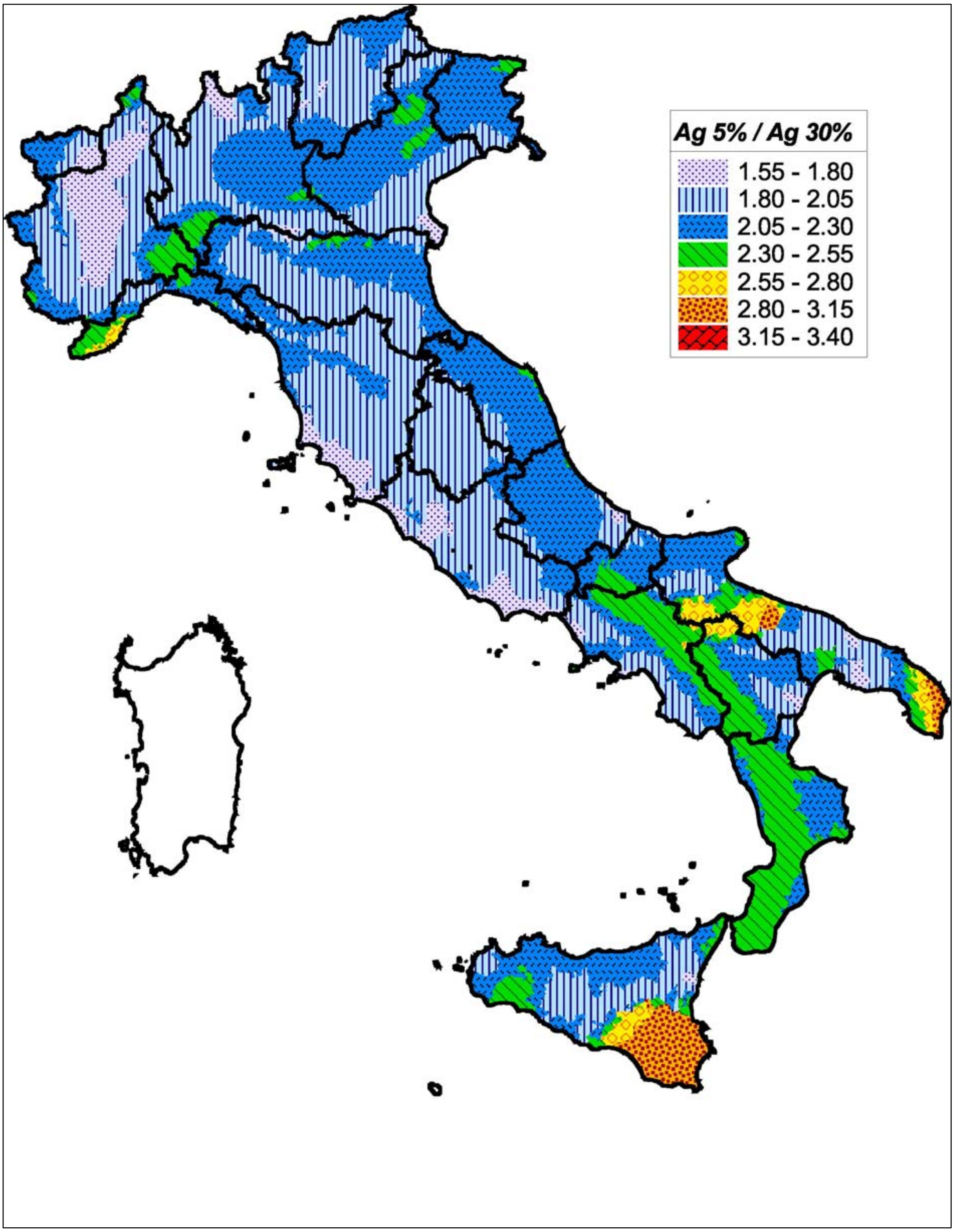

Figure 2. Ratio between a_g relatives to return periods of 975 years and 140 years (as to say a_g having a probability of exceedance of 5% and 30% in 50 years) in Italy

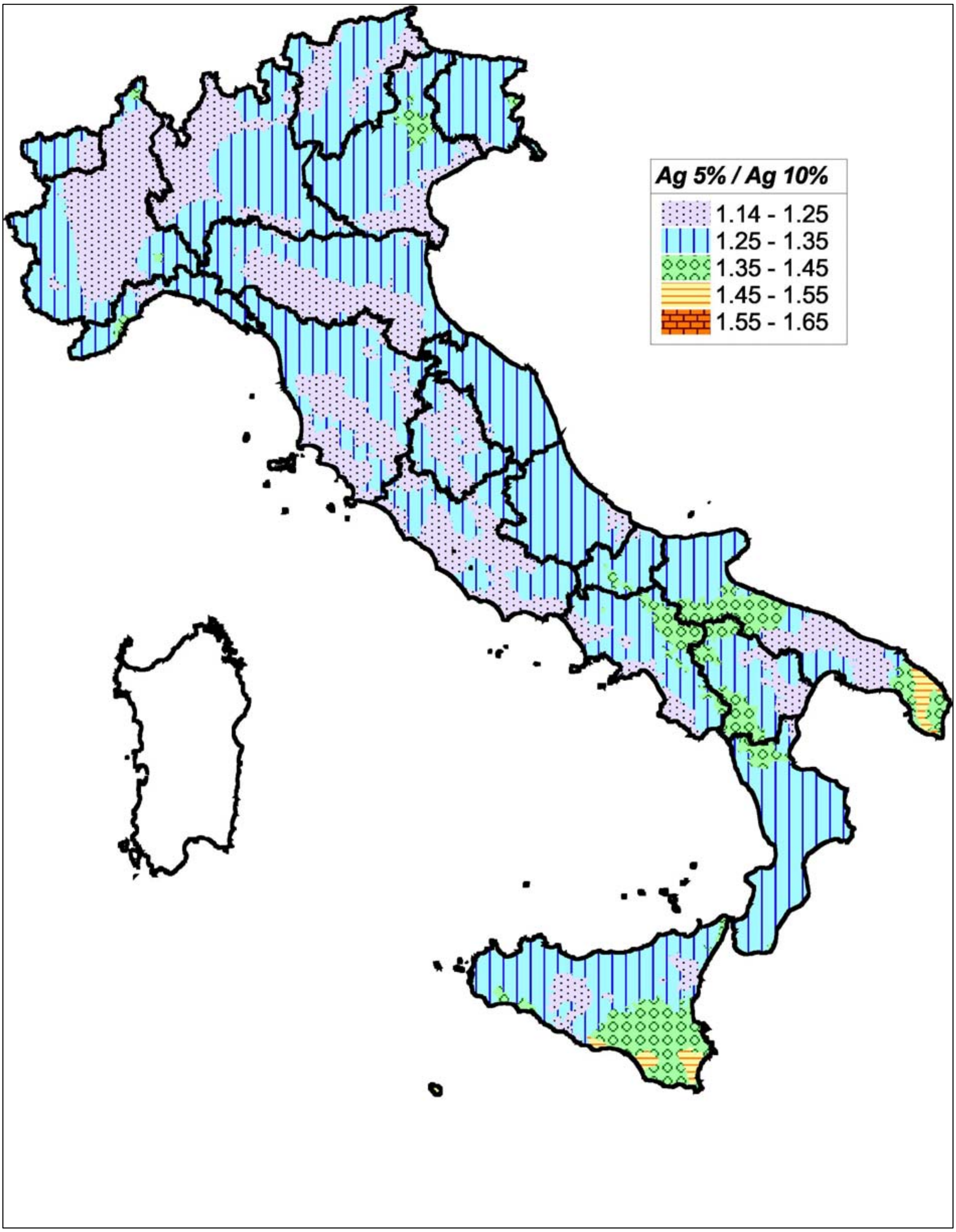

Figure 3. Ratio between a_g relatives to return periods of 975 years and 475 years (as to say a_g having a probability of exceedance of 5% and 10% in 50 years) in Italy

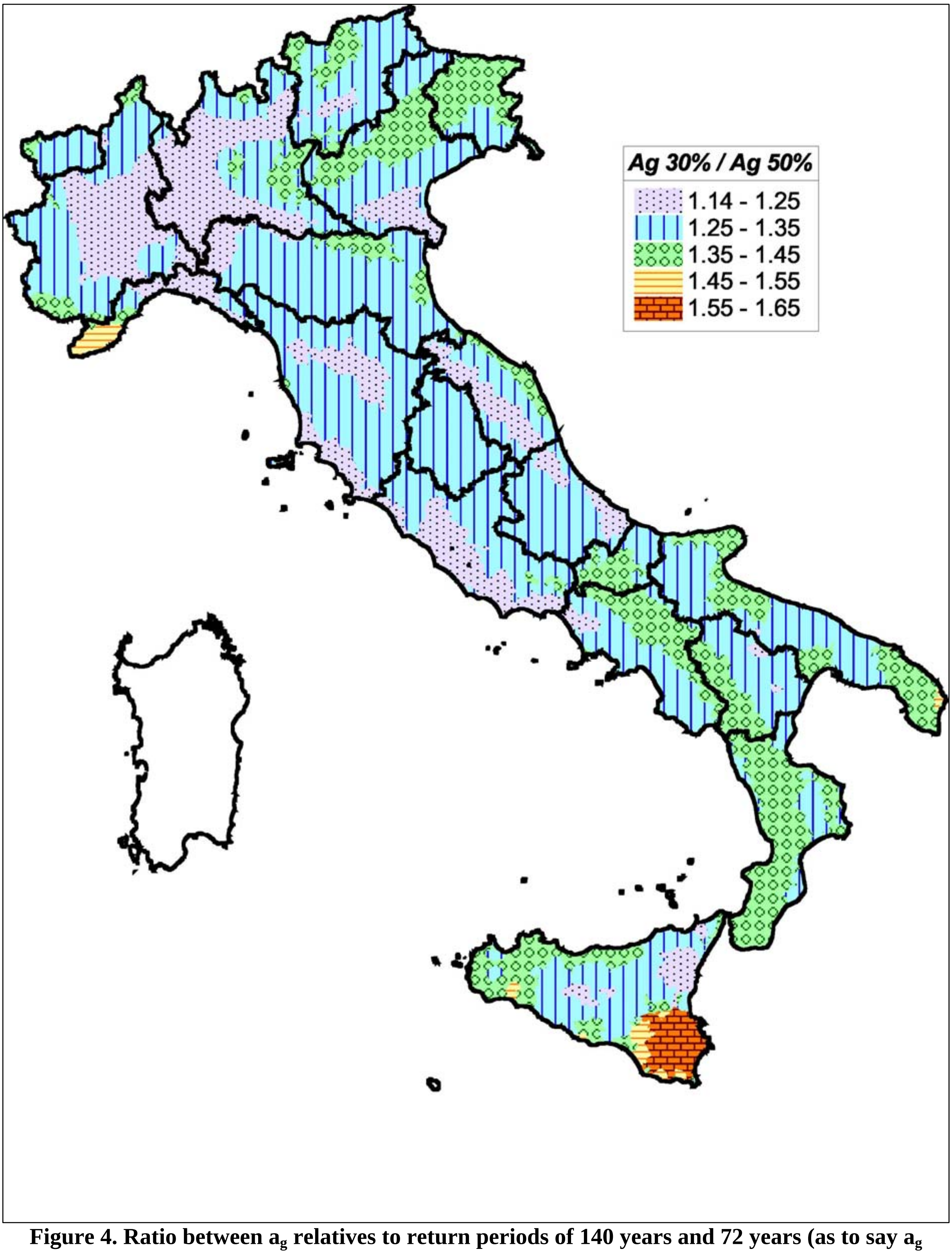

Figure 4. Ratio between a_g relatives to return periods of 140 years and 72 years (as to say a_g having a probability of exceedance of 30% and 50% in 50 years) in Italy

Another way to show the inconsistencies given by the use of fixed factors in the definitions of design seismic actions is described in tables 2(a) and 2(b). In the tables are presented the maximum and minimum values of return periods associated to the a_g related to the ultimate limit state (Table 2(a)) and the damage limit state (Table 2(b)) for the different importance classes as defined in the Italian code (only class 1) and in the Eurocode 8 (classes II, III, IV), obtained by using fixed factors (reduction factor and importance factors). It's interesting to see a great variability of the values: for example, for the damage limit state, the maximum value is about 5 times the minimum one, for the class 1- II. In the same way, also in terms of probability there is a great variability (from 0.38 to 0.92 for class 1 and damage limit state). It is evident that there are large differences, from site to site, in the exceedance probabilities deriving by the use of fixed factors.

Table 2. Maximum and minimum values, among the Italian municipalities, of the return periods for a_g obtained by fixed factors from the a_g having 475 years of return period (in brackets the corresponding probability of exceedance in 50 years)

(a) Ultimate limit state

	Class 1 - Class II	Class III	Class IV
	a_g 475	(a_g 475)* 1.2	(a_g 475) * 1.4
max	475 (0.10)	1134 (0.04)	2603 (0.02)
min	475 (0.10)	629 (0.08)	834 (0.06)

(b) Damage limit state

	Class 1 - Class II	Class III	Class IV
	(a_g 475) / 2.5	(a_g 475) / 2.5 * 1.2	(a_g 475) / 2.5 * 1.4
max	106 (0.38)	153 (0.28)	219 (0.20)
min	20 (0.92)	32 (0.79)	52 (0.62)

CONCLUSIONS

All the considerations illustrated in the paper demonstrate that for the definition of the seismic actions the use of values of acceleration related to a single return period and scaled with fixed factors is not correct. It has been clearly described that the use of this procedure can create very large differences in the design actions relative to same limit state and importance class, among the sites of a country. The consequence is that, to define the seismic actions, the hazard assessment must be performed for all the values of the return periods related to different limit states and importance classes.

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