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SEISMIC ZONATION CRITERIA IN ITALY: ANALYSIS ON METHODOLOGIES AND PARAMETERS

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SUMMARY

In the paper, Italian new seismic zonation criteria, and new temporary zonation map, are analyzed and some characteristics and limits are pointed out. The principal problem related to criteria, is the use of PGA with 10% of exceedance probability in 50 years (corresponding to a return period of 475 years), to define the different seismic zones. In this way the different kinds of seismicity that can characterize the territory are not considered. This fact implies that the two main objectives of a seismic zonation: people safety and reducing damages, are not individually evaluated ad so large difference in the accepted risk for municipalities belonging to the same zone are determined. This situation is also found in the zones defined in the temporary map. Alternative criteria, leading to a zonation based on parameters and procedures that permit to highlight the two aspects above mentioned and then more suitable to prevent seismic effects in every area at the same level, are proposed.

INTRODUCTION

In May 2003, in Italy, new seismic zonation criteria, a temporary map of seismic zonation and a new seismic code have been established with an apposite law (Ordinanza [1]). Criteria provide that the territory has to be subdivided in four different zones, identified by values of peak ground acceleration (PGA) with 10 per cent of exceedance probability in 50 years (corresponding to a return period of 475 years), according to the suggestion of Eurocode 8.

A zonation map depends on many factors: the quantity and the quality of seismic and geological data, the methods used for hazard assessment, the selection of the zonation criteria, all having significant weight.

The paper is focused on the criteria influence on the result. The use of only one parameter, depending on a single return period, to define the seismic zone, doesn't allow to consider the differences in seismic activity that characterize one country; this is particularly true for Italy. In fact, in Italy, some areas are affected by frequent earthquakes of limited violence and never suffered, at least in the last 1000 years high magnitude earthquakes, whereas in other areas earthquakes are rarer but more violent; characteristics that can be instead highlighted by mean of other and appropriated parameters.

The consideration of different kinds of seismicity is directly connected to the aims of seismic zonation that are: first people safety, depending on buildings collapse; second the reduction of damages to buildings and

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structures. A better characterization of every area is in fact useful to have firstly more equity in the remaining accepted risk and secondly a better efficiency in the use of resources for preventive measures.
As a consequence of the consideration above done, the proposal of alternative and more articulated criteria is necessary to have a seismic zonation that guarantee, in every area, the same level of prevention from seismic effects.
The temporary map is also analyzed to point out characteristics and limits and to compare this one with the map resulting from criteria application.

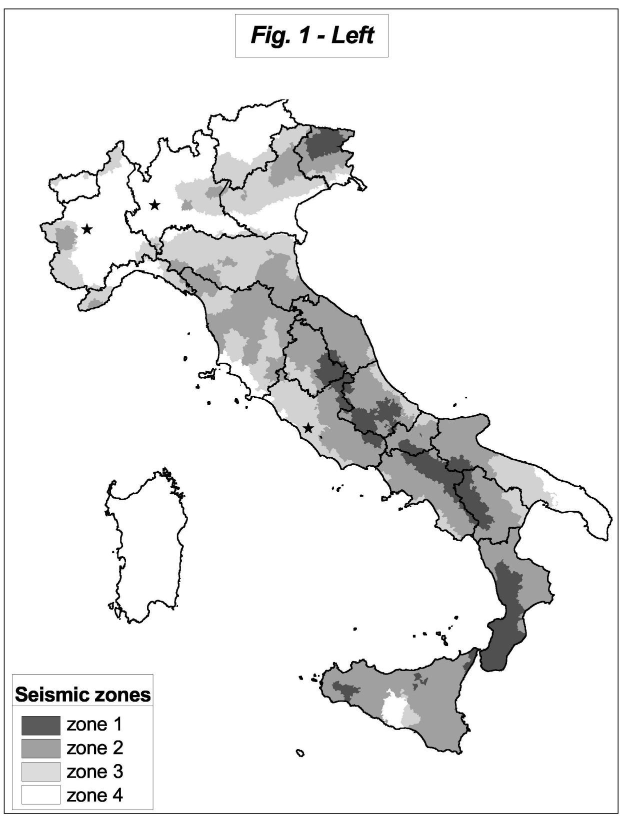
OBSERVATION ON CRITERIA APPLICATION AND ON THE TEMPORARY MAP

The temporary seismic map defined in the law [1] is shown in figure 1-left and the zonation criteria are summarized in table 1.

Tab. 1: seismic zonation criteria and reference horizontal peak ground acceleration

Zone	Horizontal peak ground acceleration with10% exceedance probability in 50 years [a_g/g]	Reference horizontal peak ground acceleration [a_g/g]
1	> 0.25	0.35
2	0.15 - 0.25	0.25
3	0.05 - 0.15	0.15
4	< 0.05	0.05

To evaluate the effects of new seismic criteria on zonation of the Italian territory, an application has been done: the criteria of table 1 have been applied to the hazard data SSN [2] used in the construction of the temporary seismic map (Fig. 1-left). The resulting map is also shown in figure 1-right.



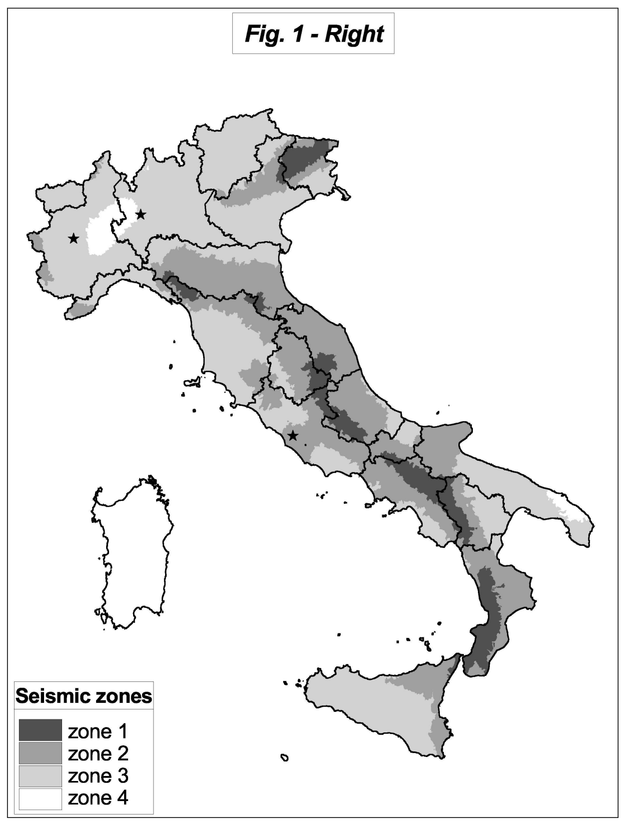


Fig. 1 – Left: temporary seismic zonation in Italy defined in the law [1]. Right: seismic zonation of Italy obtained from the application of new criteria at PGA value of SSN [2]

Comparing the two maps, it's possible to notice that the map obtained from the criteria application is significantly different from the other one: e.g., large cities, like Rome, Milan and Turin belong to different zones (Milan and Turin from zone 4 to zone 3 and Rome from zone 3 to zone 2). On the other hand, zone 4 is limited to a very little number of municipalities.

The differences are due to the fact that the temporary map has been obtained applying different criteria (Gruppo di lavoro 1998 [3]). The Gruppo di Lavoro, in fact, chose as parameter describing the hazard the spectral intensity, and not the peak ground acceleration, and assigned the municipalities to the seismic zones according to the values of such parameter referred to two different return periods, in order to attempt to consider both protection from collapse and from damage.

The new Italian code, as the majority of existing codes, prescribes two different protection level: no-collapse and limitation of damage; the seismic action for the damage is derived from the reference horizontal peak ground acceleration (Tab. 1) divided by a fixed factor of 2.5. Taking into account that, a more clear and quantitative analysis of a given zonation, has been done calculating both the exceedance probability in 50 years both of the collapse acceleration and of the beginning damage acceleration. Those parameters have been calculated using, the same hazard data and methodologies used by SSN [2]. The values of collapse acceleration for zones 1, 2, 3 have been calculated multiplying by 1.5 the values of reference horizontal peak ground acceleration (Tab. 1), as indicated in the Italian code for the evaluation of the existing buildings. For the zone 4, considering too little the values obtained in the same way than the other zones, the accelerations have been considered equal to those calculated for the zone 3.

In tables 2 and 3 the maximum, minimum and mean values respectively of exceedance probability of the collapse acceleration and of the beginning damage acceleration are presented.

Tab. 2 - Exceedance probability of the collapse acceleration: maximum, minimum and mean values among all the municipalities belonging to the different seismic zones according to the zonation in figure 1-right

	Exceedance probability of the collapse acceleration		
	maximum val.	**minimum val.**	**mean val.**
zone 1	0.0752	0.0046	0.0275
zone 2	0.0744	0.0003	0.0155
zone 3	0.0639	0.0000	0.0068
zone 4	0.0005	0.0000	0.0000

Tab. 3 - Exceedance probability of the beginning damage acceleration: maximum, minimum and mean values among all the municipalities belonging to the different seismic zones according to the zonation in figure 1-right

	Exceedance probability of the beginning damage acceleration		
	maximum val.	**minimum val.**	**mean val.**
zone 1	0.5136	0.3057	0.4221
zone 2	0.7307	0.1531	0.4285
zone 3	0.7787	0.0194	0.2913
zone 4	0.0656	0.0000	0.0074

Tables 2 and 3 clearly show very important differences between maximum and minimum values calculated for municipalities belonging to the same zone. Particularly relevant are the differences in the exceedance probability of the collapse acceleration for zones 2 and 3. Considering that the assignment to a common seismic zone should define areas with the same risk level for building responding to the relevant code, the differences noticed involve that there was something wrong in the assignments, that is to say the criteria.

ALTERNATIVE PROPOSALS

A possible way to improve the correspondence between zonation and accepted risk should introduce a multiple criteria approach. The parameters considered could be: the exceedance probability, in 50 years, of the collapse acceleration and of the beginning damage acceleration and the annual expected damage. Each of these parameters is connected to a different aspect: the first is related to people safety, the second one is important principally for economic aspects due to restoring of damages, the third one is important because it takes into account the entire probabilistic distribution of the events and not a single point of the curve, as the PGA for a given return period does.

To assign a single municipality to a zone, possible criteria are (Tab. 4):

- a municipality is considered in zone 1 if its exceedance probability, in 50 years, of the collapse acceleration (0.525g) is greater than 0.01;
- a municipality is considered in zone 2 if it's not assigned to zone 1 and the annual expected damage is greater than 0.05%;
- a municipality is considered in zone 3 if it's not assigned to zone 1 and 2 and if its exceedance probability, in 50 years, of the beginning damage acceleration (0.06g) is greater than 0.4;
- a municipality is considered in zone 4 if it's not assigned to other zones.

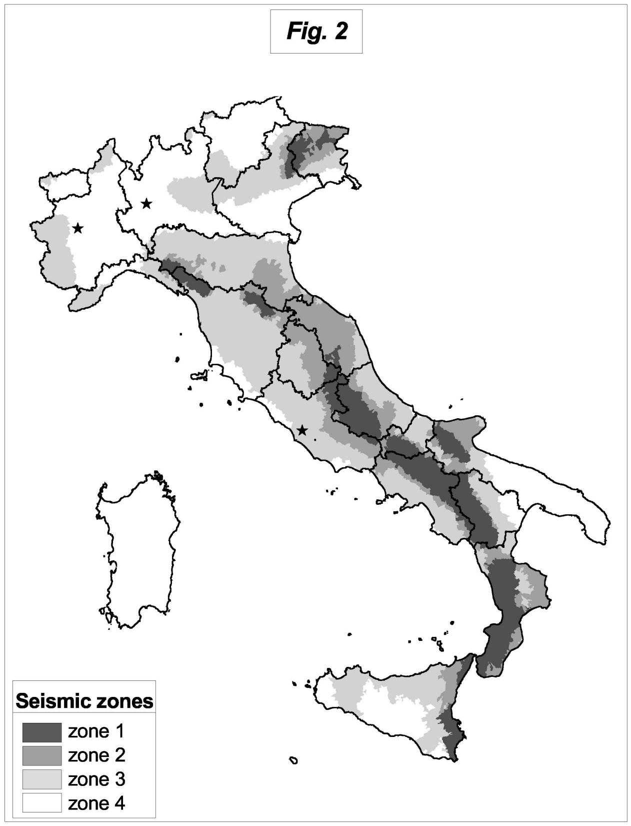
It's important to remember that the definition of all limit values, being equal residual accepted risk, depends on methods and hypothesis used in the hazard calculation that is at the base of the determination of the three parameters above mentioned. So, the limit values here presented are strictly connected to the hazard used in this work.

Another aspect that must be considered about the limits values fixed to define the different seismic zones, is that the last decision on these values would be taken by who has the responsibility of the government. This consideration is due to the fact that the definition of different limits implies different accepted residual risks that is to say different social-economical costs. On the other side, the scientific community would have the task to elaborate alternatives to be presented with their relative proprieties and limits.

Tab. 4: resume of proposed seismic criteria

	Zone1	Zone2	Zone3	Zone4
Exc. prob. collapse. acc. (coll. acc. = 0.525g)	≥ **0.01**			All municipalities not included in the other zones
Annual expected damage (coll. acc. =.375g b.d. acc.= 0.1g)		≥ **0.0005**		
Exc. prob. beg. damage acc. (b.d. acc.= 0.06g)			≥ **0.4**	

In Fig. 2 is represented the seismic zonation map, for Italy, obtained from the application of the proposed criteria. This map is, as expected, very different from the right one shown in Fig. 1. The left one is more similar, as far as zones 3 and 4 are considered; the differences are still significant for zones 1 and 2.



It must be explained that this map is the result of the direct application of the proposed criteria, and it has not been yet subjected to a successive adjustment process, necessary to remove all the inconsistent situations inevitably present as in every case in which an assignment depends on a fixed limit (e.g. single municipalities assigned to zone 2 located in an area all classified in zone 3).

Fig. 2: seismic zonation in Italy obtained from the application of proposed criteria

Four tables are now presented, reporting, as done in Tab. 2, 3, maximum, minimum e mean values of exceedance probability, in 50 years, of the collapse acceleration and of the beginning damage acceleration, relatives to the zones obtained by application of proposed criteria (Tab. 5, 6) and the ones defined by Italian law [1].

Tab. 5 - Exceedance probability of the collapse acceleration: maximum, minimum and mean values among all the municipalities belonging to the different seismic zones according to the zonation in figure 2

	Exceedance probability of the collapse acceleration		
	maximum val.	**minimum val.**	**mean val.**
zone 1	0.0752	0.0095	0.0234
zone 2	0.0344	0.0060	0.0178
zone 3	0.0797	0.0006	0.0262
zone 4	0.0314	0.0000	0.0017

Tab. 6 - Exceedance probability of the beginning damage acceleration: maximum, minimum and mean values among all the municipalities belonging to the different seismic zones according to the zonation in figure 2

	Exceedance probability of the beginning damage acceleration		
	maximum val.	minimum val.	mean val.
zone 1	0.5136	0.1551	0.3696
zone 2	0.7899	0.2808	0.4983
zone 3	0.9004	0.3951	0.6137
zone 4	0.3949	0.0000	0.1329

Tab. 7 - Exceedance probability of the collapse acceleration: maximum, minimum and mean values among all the municipalities belonging to the different seismic zones according to the zonation in figure 1-left

	Exceedance probability of the collapse acceleration		
	maximum val.	minimum val.	mean val.
zone 1	0.0752	0.00025	0.0239
zone 2	0.0525	0.00000	0.0130
zone 3	0.0984	0.00003	0.0179
zone 4	0.0191	0.00000	0.0016

Tab. 8 - Exceedance probability of the beginning damage acceleration: maximum, minimum and mean values among all the municipalities belonging to the different seismic zones according to the zonation in figure 1-left

	Exceedance probability of the beginning damage acceleration		
	maximum val.	minimum val.	mean val.
zone 1	0.5061	0.0545	0.3846
zone 2	0.7900	0.0023	0.3779
zone 3	0.9110	0.1117	0.5114
zone 4	0.6325	0.0000	0.1236

Comparing the results obtained for the three zonations presented, observing the ratio between maximum and minimum values calculated for every zone, it's possible to notice that the application of the proposed criteria permits an improvement in terms of equity of residual accepted risk, among municipalities belonging to the same zone. This fact is particularly evident considering zone 2 and 3 in tab. 2, 5 and 7 relatives to probability of the collapse acceleration, but it's also present in most of the other ones both for exceedance probability of the collapse acceleration and of the beginning damage acceleration.
Another proposal that can be useful to obviate the problem of the differences among municipalities in the same zone, is the definition of a double level of the seismic zonation: one connected to collapse risk and one aimed to reduce expected damages. In this way, finally, two different maps are created:

- in the first the seismic zones are defined by the limit values of the exceedance probability of the chosen parameter (e.g. peak ground acceleration or spectral Intensity) referred to the beginning damage; this map would have the aim to control the accepted damage level;
- in the second one the seismic zones are defined by the limit values of the exceedance probability of the chosen parameter correspondent to the ultimate limit state (great damages but not collapse); this map would has the aim to control the residual risk relevant to people safety.

This procedure, obviously, implies that every municipality belongs to two different zones in the two maps and that a different confidence has to be considered in strength and ductility in the municipalities of the Italian territory.

CONCLUSIONS

All the considerations illustrated in the paper have as consequence the fact that a too simplified seismic zonation based on a single parameter, dependent on a single return period (PGA corresponding to a return period of 475 years), causes too many imbalances, also among municipalities belonging to the same zone, in terms of residual accepted risk levels. A first improvement can be obtained applying more articulated criteria, as the ones presented in the paper.

But, to have a more efficient solution, it would be necessary to define a zonation procedure that consider these two requirements:

- the choice responsibility of the residual accepted risk levels has to be political and not technical. The scientific community has in fact the task to propose a series of alternatives whose characteristics and limits have to be well specified;
- it's necessary to define clearly and separately the limits for accepted collapse and damage risks and to avoid the decision on how much consider strength and ductility. A single zonation and a fixed ratio between collapse reference acceleration and damage reference acceleration for all municipalities, has the consequence, as mentioned in the paper, to create too large differences among levels of accepted collapse and damage risks. A possible solution to solve this problem can be the use of two different zonation: one referred to collapse risk and one referred to damage risk.

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