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DEFINITION OF A PRIORITISATION PROCEDURE FOR STRUCTURAL RETROFITTING OF ITALIAN SCHOOL BUILDINGS

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Abstract. *Most of the Italian school buildings were not designed according to seismic criteria and, therefore, they are vulnerable from a seismic point of view. A clear proof of this was the catastrophic collapse of the school at San Giuliano during the October 2002 earthquake: thirty people death, twenty seven of whom were young students and one their teacher. After this seismic event, the process for identifying the most seismic vulnerable school buildings was started in Italy, with the final aim of improving their strength. Furthermore, several school buildings, mainly located in the historical centre of the town, were damaged during the recent seismic event of L'Aquila (April 6, 2009), as reported by Salvatore et al. [1]. The proposed research work was driven by the idea of defining a methodology that implements different analysis phases with an increasing level of detail such that the number of buildings analysed decreases at each phase since only the buildings most at seismic risk are considered. The implemented procedure follows some well known works published in literature [2, 3]. The definition of a prioritisation scheme of intervention is strictly due to the high number of school buildings (almost 50000) that cannot be deeply analysed considering the limited available resources. The developed tool and procedure can be very helpful since they provide information extremely important for civil protection actions.*

1 INTRODUCTION

Italian seismic provisions and seismic zonation were updated several times during the last century. Therefore, a large portion of buildings has not been designed for an adequate level of seismic resistance required under modern design provisions. The majority of the Italian school buildings are especially vulnerable to seismic ground motion since they are judged to be seismically inadequate. An ad hoc seismic risk evaluation of the school buildings becomes therefore of fundamental importance for planning an accurate rehabilitation of these buildings and for saving their occupants.

The seismic vulnerability evaluation of the school buildings is a topic that has been discussed by several authors in the last decades [2, 3, 4, 5]. However, due to the limited amount of the available data, those methodologies were applied to a Regional level only.

To the authors' knowledge, the study presented herein is the first where the maps of conditional probability of damage and seismic risk are obtained at a national level, since it has been carried out considering most of the Italian school buildings. The available data refer to the survey of all school buildings ("Anagrafe Edilizia Scolastica") carried out by the Ministry of Education ("MIUR") to identify various safety-related parameters. The collected survey forms comprise about 70% of the Italian school buildings, and contain data that allow the geographical location of the building, as well as its structural characteristics (i.e., age, number of storeys, construction type, and preservation status), its security conditions and the features of rooms and sporting facilities.

2 ADOPTED PROCEDURE

This research work describes the method proposed for identifying the most seismic vulnerable Italian school buildings and for assigning priorities for the execution of detailed inspections and structural retrofitting measures. The adopted method is based on an initial proposal by Grant et al. [2]. It comprises multiple levels of assessment of increasing level of detail, each one substantially reducing the size of the building inventory since only the buildings most at seismic risk are considered. The procedure consists of two phases which correspond to the two levels of the available building information. In both phases the seismic risk is defined considering the probability of reaching or exceeding given limit states comparing the demand with the capacity in terms of displacements. The vulnerability of the school buildings is defined computing their capacity curves (known, in the technical literature, as pushover curves). The mechanics-based methodology SP-BELA (Simplified Pushover-Based Earthquake Loss Assessment), developed for large-scale vulnerability assessment, is used for performing the simplified pushover curves [6, 7] of the analysed buildings.

In the first phase of the assessment, the capacity is computed as a function of the number of storeys, structural vertical typology, and building age written in the questionnaires of the "Anagrafe Edilizia Scolastica". Based on these data, the buildings are subdivided in classes and random populations of buildings can be generated for each building class using Monte Carlo Simulation. For each randomly generated building, a simplified pushover analysis is carried out using SP-BELA (Figure 1), leading to the definition of the displacement capacity, vibration period and viscous damping of an equivalent single degree of freedom system [6, 7].

The second phase of the procedure is based on the data collected, at Regional level, through the 2nd Level Forms [8, 9, 10] of GNDT ("Gruppo Nazionale per la Difesa dai Terremoti"). In this second phase, only masonry buildings are taken into account since the information required, in the GNDT 2nd Level Form, for reinforced concrete (RC) buildings are not enough for defining their structural capacity, whereas they allow the Conventional Resistance

("Resistenza Convenzionale") to be calculated for masonry buildings. This Conventional Resistance is the lateral strength of the weakest storey of the building divided by the building weight. Therefore, the difference with respect to the first phase of the procedure is that the resistance factor of the capacity curve is computed directly with the data available within the form of the reference school building and not computed for each random generated building stock representative of the reference school building class.

Due to the incompleteness of the available database, the second phase of the procedure cannot be applied to the overall Italian school building stock. Therefore, the estimate of the reduction of the size of the building inventory moving from the first to the second phase of the procedure cannot be carried out. The study described herein does not apply the prioritization procedure as a whole, but represents its validation in order to indentify some possible shortcomings that need improvements.

2.1 Definition of the building capacity

As discussed above, in order to compute capacity curves SP-BELA makes use of a simplified pushover methodology that can be employed in the assessment of a large number of buildings with reasonable computational effort. SP-BELA can be applied to RC [6] and masonry buildings [7], which are representative of the majority of the school buildings "as built" in Italy. The capacity curve is defined by means of the building resistance and the displacements associated to specific structural limit states (LS). Three LS conditions have been taken into account [11]:

- Light damage: the building can be used after the earthquake without the need for repair and/or strengthening.
- Significant damage: the building cannot be used after the earthquake without strengthening.
- Collapse: the building becomes unsafe for its occupants as it is no longer capable of sustaining any further lateral force or the gravity loads for which it has been designed.

The limit state conditions previously described can be related to specific prescriptions of Italian design code [12, 13]. In particular, the reference limit state conditions for RC buildings are defined in relation to the chord rotation. For masonry structures, the damage is usually related to interstorey drift capacity, and the limit conditions have been identified through results from experimental tests as described in [7].

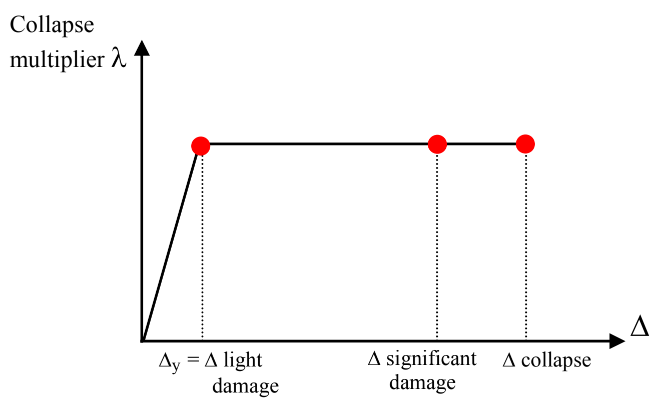

Figure 1: Capacity curve for elastic-perfectly-plastic structural behavior [7].

Within such framework, an elastic-perfectly-plastic behaviour of the structure is assumed (Figure 1), which effectively means that, in order to define the pushover curve, only the displacement capacity Δ corresponding to the three LS and the lowest collapse multiplier λ of all the considered mechanisms need to be defined. Multiplying λ by the total weight of the building gives the lateral strength of the weakest storey of the building. Therefore, λ corresponds to the Conventional Resistance of the GNDT 2nd Level Forms for the masonry buildings.

2.2 Classes of buildings

The methodology proposed in this research study for seismic risk evaluation considers 37 classes of buildings as plotted in Figure 2.

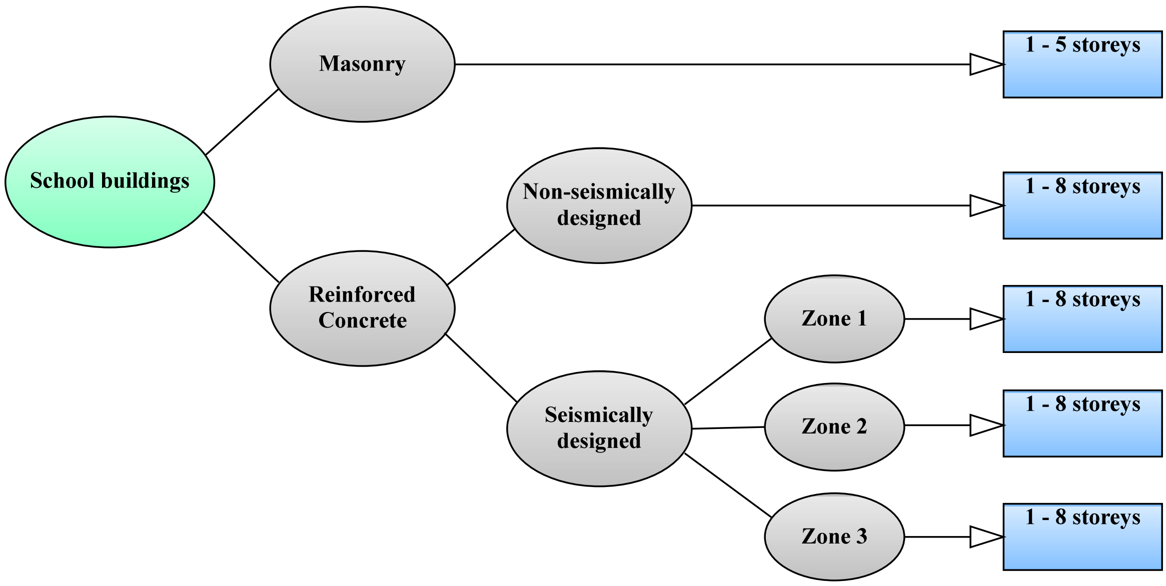

Figure 2: Classes of buildings considered in the study.

With reference to Figure 2, the masonry school buildings have been classified as a function of the number of stories (from 1 to 5), therefore five separate building classes have been defined. A different criterion has been applied for the RC buildings since they are subdivided in two main classes: RC buildings that have not been seismically designed and RC buildings seismically designed. Comparing the seismic zone to which the municipality has been assigned and the period of construction, it is possible to identify if a school building has been or not designed according to seismic design provisions. For seismically designed buildings, the seismic zone of the municipality at the period of the construction has to be taken into account since it can be used, together with the provisions of the design codes of the same period, for defining the value of the design lateral force as a percentage of the total building weight. Figure 2 refers to three seismic zones in Italy, since the fourth one [14] characterised by the smallest value of seismicity has been disregarded. In SP-BELA, the buildings are designed considering only gravity-load design before seismic classification; then following the classification and depending on the seismic zone to which the municipality was assigned, a base shear coefficient has been used to design the buildings. For buildings assigned to Zone 1, this coefficient has been taken as 10% of the weight, for buildings in Zone 2 as 7% and in Zone 3 as 4%. The number of storeys considered for RC school buildings is: 1, 2, 3, 4, 5, 6, 7, more or equal to 8 (Figure 2).

2.3 Conditional probability of damage

In SP-BELA the comparison between seismic capacity and demand is carried out in terms of displacement. The building displacement capacity has been introduced in Section 2.1. The seismic demand imposed by the earthquake to the structure is calculated with reference to the elastic spectrum related to the school building location, computed according to the formulation proposed in [12, 13]. This formulation has been obtained after the least-square interpolation of the mean acceleration spectrum derived from the probabilistic hazard study performed by DPC-INGV project [14] for a grid of points (each one at distance of 0.05 degrees) used for the whole country. The formula and the coefficients given by the Italian code [12, 13] allow the computation of the mean spectral accelerations for each point of the grid and for seismic events characterised by a return period (T_r) of 30, 50, 72, 101, 140, 201, 475, 975 and 2475 years, respectively.

In this study, the least-square interpolation method has been applied to the mean acceleration spectrum (50th percentile) plus and minus one standard deviation for deriving the parameters that allow the computation of the 84th and 16th percentile spectral accelerations, respectively. Therefore, the seismic demand imposed by the earthquake to the structure is computed with respect to the 16th, 50th and 84th percentile acceleration spectra. Flat rock soil has been assumed for the Italian territory, since no data were available for the evaluation of the effects of the site conditions where the school buildings are located.

The seismic demand is derived from the elastic response spectrum knowing the location of the school building, for a given return period and a selected percentile (16th, 50th, and 84th). From SP-BELA method, the vibration period T of the building and the equivalent viscous damping ξ are computed for each limit state. Knowing the response period, the spectral ordinate is directly derived for each LS. Knowing the equivalent viscous damping, the spectra reduction factor η, used to take into account the energy dissipation capacity of a given structure for a given LS, is then computed, as suggested for instance in [15]:

$$\eta = \sqrt{\frac{7}{2+\xi}} \tag{1}$$

For RC frames, the equivalent viscous damping ξ in Equation (1) has been obtained as a function of the ductility, using Equation (2) [15]. For masonry buildings, the damping values suggested in [16], for each limit state, have been adopted (5%, 10% and 15%, respectively).

$$\xi = 0.05 + 0.565\left(\frac{\mu - 1}{\pi\mu}\right) \tag{2}$$

The displacement spectral ordinates are defined starting from the spectral accelerations:

$$S_d = S_a\left(\frac{T}{2\pi}\right)^2 \tag{3}$$

where S_d represents the displacement demand, S_a the acceleration demand and T the period of vibration of the building.

Based on the previously introduced ingredients, the conditional probability of damage, where the condition is that a given seismic event will occurs, can been computed for the nine return periods T_r considered in the Italian seismic code [12]. Random populations of buildings are generated for each building class (1000 buildings for each one of the 37 classes shown in Figure 2) using Monte Carlo Simulation. The period of vibration T and the displacement capacity Δ at the three different damage limit states (Figure 1) can be calculated for each randomly generated building through a simplified pushover analysis performed using SP-BELA (Section 2.1). Knowing T at each LS and for a given overdamped (using Equation 1) displacement response spectrum, the displacement demand of a given building in the random population can be predicted and compared with its limit state displacement capacity. This procedure is repeated for the 1000 buildings randomly generated for each class of school buildings (Figure 2). The sum of all buildings whose displacement capacity is lower than the displacement demand divided by the total number of buildings gives an estimation of the probability of the exceeding a given limit state. The output of these computations is the conditional probability of damage, given the occurrence of a seismic event characterised by a given return period T_r.

2.4 Computation of the seismic risk

The seismic risk is computed knowing the hazard curve of the place where the school building is located. It gives the recurrence probability of a seismic event with a given level of severity in a specific exposure time t_d. Severity can be expressed in terms of the Annual Frequency of Exceedance (*AFE*), which is the reciprocal of the return period T_r. The hazard curve represents the relationship between *AFE* and a ground motion parameter, herein assumed as the spectral displacement S_d. The logarithm of the S_d and the logarithm of the corresponding *AFE* ($=1/T_r$) can be assumed to be linearly-related, at least for return periods of engineering interest. The gradient of the log-log hazard curve is named $-k$, according to the definition in Part 1 of the Eurocode 8 [17]. As an example, Figure 3 plots the spectral ordinates S_d for a vibration period of 0.1 seconds. Since the values are linearly related, the hazard curve is defined knowing a value of S_d corresponding to a return period T_r and the slope k of the line interpolating all the other points and passing from a reference point.

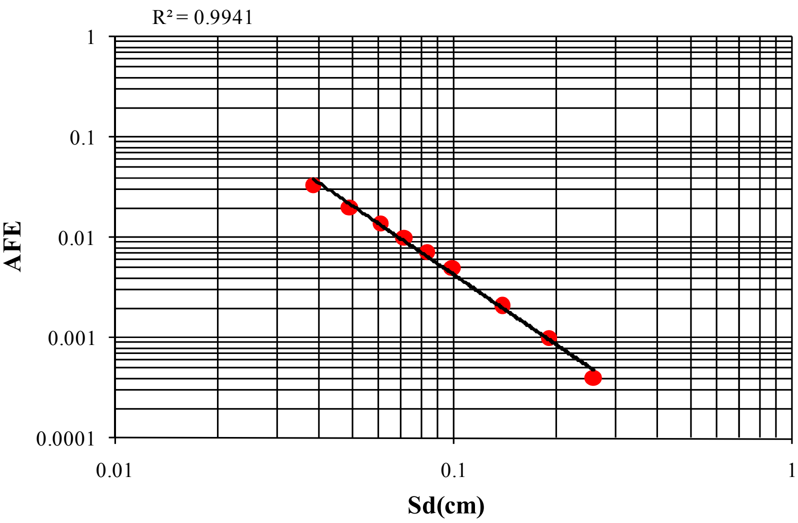

Figure 3: Relationship between the annual frequency of exceedance (*AFE*) and S_d(T=0.1 sec).

This reference point is here conventionally assumed equal to value at 475 year return period, and the hazard curve is defined by the following relationship:

$$AFE = AFE_{475}\left(\frac{S_{d475}}{S_d}\right)^k \tag{4}$$

where AFE_{475} and S_{d475} are, respectively, the annual frequency of exceedance and the spectral displacement corresponding to the 475 year return period.

Knowing the vibration period T of the structure, nine values of spectral accelerations S_a are computed in correspondence of the nine return periods T_r listed in [12]; using Equation (3), the S_a values are converted in spectral displacements S_d; the next step is the derivation, in a log-log plane, of the line interpolating these points and passing for the point computed at a 475 year return period, and the slope k is finally derived. Therefore, the hazard curve is directly derived and the displacement demand can be computed whatever return period is considered. It derives that all the events that could happen in a specific exposure time t_d can be taken into account. Hence, the seismic demand is then computed and compared with the capacity for each event, obtaining the conditional probability of exceeding a given limit state.

The seismic risk is the unconditional probability of failure of the limit state condition, because the condition on the occurrence of the seismic event is removed by considering the probability that the event occurs in the selected exposure time. For its computation, the hazard curve previously expressed as a function of the frequency has to be given in terms of probability. The occurrence of the events is assumed to follow the Poisson process, that is a memoryless distribution such that each event occurs independently of one another. Therefore, the occurrence probability (q) of an event with severity *AFE*, in the exposure time t_d, is given by the following equation:

$$q = 1 - e^{-t_d AFE} \tag{5}$$

Since *AFE* is related to the spectral displacement S_d according to Equation 4, the probabilistic hazard curve can be expressed as a function of S_d:

$$q = 1 - e^{-t_d AFE_{475} \left(Sd_{475} / Sd \right)^k} \tag{6}$$

Three exposure times t_d are taken into account in this study: 1 year, 10 years and 50 years. If, for example, the annual collapse risk has to be computed, the corresponding hazard curve is obtained from Equation 6 with $t_d = 1$. The derived curve gives the annual probability of occurrence of an event with severity *AFE* expressed as a function of S_d. The hazard curve has to be related to the conditional probability of collapse, i.e. the vulnerability, where the condition is the occurrence of an event for a given return period T_r. Knowing that T_r can be expressed as a function of *AFE* and *AFE* is related to S_d according to Equation 4, the conditional probability of damage is then obtained and the condition is expressed as a function of S_d. Therefore, since two curves are available – the hazard curve and the vulnerability curve – both expressed as a function of S_d, the exceedance curve of a given limit state in the exposure time t_d can be constructed as a discrete function.

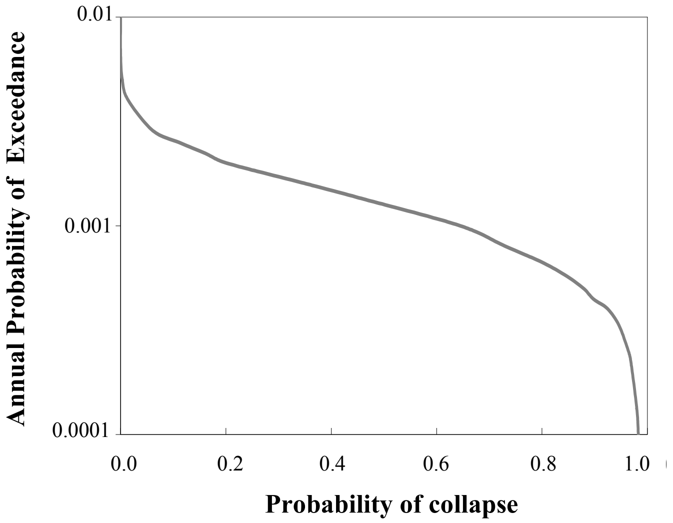

Figure 4: Exceedance curve of the collapse limit state in an exposure time of 1 year, for a given class of buildings.

Shown in Figure 4 is the exceedance curve for a exposure time t_d of 1 year and the collapse limit state. The annual seismic risk is given by the analytical integration of this curve, using the following equation:

$$Seismic\ Risk = \sum_{i=0}^{+\infty}\left[\frac{APE_{2(i+1)} - APE_{2i}}{6}\right]\cdot\left[P_{collapse_{2i}} + 4P_{collapse_{2(i+0.5)}} + P_{collapse_{2(i+1)}}\right] \qquad (7)$$

where APE is the annual probability of exceedance, and $P_{collapse}$ the probability of collapse.

If the exposure time t_d is different from 1 year, the ordinates of the derived plot are the probability of exceedance in the considered t_d.

3 AVAILABLE DATABASES

The procedure described for the evaluation of the seismic risk has been applied for processing the data of two databases: the survey forms of the “Anagrafe Edilizia Scolastica” (used in the first phase of the procedure) and the GNDT 2nd Level forms (used in the second phase of the procedure). The school buildings of the “Anagrafe Edilizia Scolastica” forms have been georeferenced based on the street address. Then, a correspondence between these buildings and the ones of the GNDT forms has been derived in order to compare the two sets of data. Since there is no a common identification to be associated to the school buildings of the two databases, the correspondence has been carried out using the geographical location. The georeferenced buildings belonging to the “Anagrafe Edilizia Scolastica” database are 49503, whereas the ones belonging to the GNDT database and with a correspondence in the first database are 3553.

3.1 School buildings analysed in the first phase of the procedure

As previously introduced with Figure 2, the school buildings of the “Anagrafe Edilizia Scolastica” database have been subdivided in 37 classes. However, there are 17328 buildings of this database without the specification of their structural typology or the number of storeys; therefore, they could not be introduced in one of the classes of Figure 2. Hence, some assumptions have been done in order to automatically assign the needed information for classifying these school buildings. Furthermore, additional hypotheses have been required for assigning one of the two main structural typology considered in this study (masonry and reinforced concrete) to those buildings with a mixed typology. The “reinforced concrete and masonry” or “masonry and other typology” structures have been analysed as masonry buildings, whereas the “reinforced concrete and other typology” structures have been classified as “reinforced concrete” buildings. With these assumptions, it was possible to include 7211 buildings of those 17328 without clear specifications. Therefore, there are 10117 school buildings of the “Anagrafe Edilizia Scolastica” database that cannot be analysed since there are no enough information for assigning a structural typology or because their assigned structural typology in the forms was “other”. Starting from the available 49503 school buildings of the “Anagrafe Edilizia Scolastica” database, the buildings analysed in the first phase of the procedure are 39386, subdivided in 19749 masonry structures and 19637 RC structures.

Figure 5 shows, on the left, the map with the location of the 49503 georeferenced school buildings of the “Anagrafe Edilizia Scolastica” database, and, on the right, a bar chart with the numbers of buildings considered (additionally subdivided according to their structural typology) or omitted in the proposed procedure.

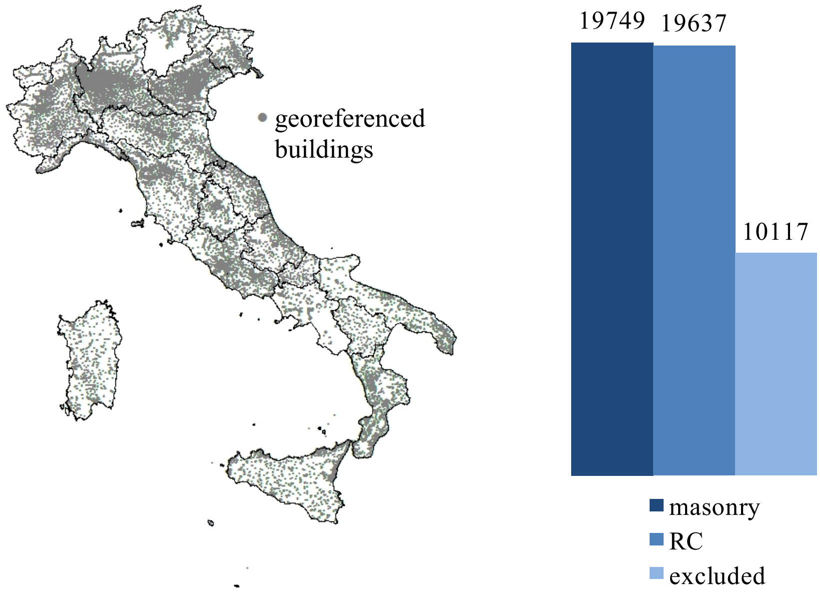

Figure 5: Georeferenced school buildings (on the left) and their classification as a function of their structural typology (on the right).

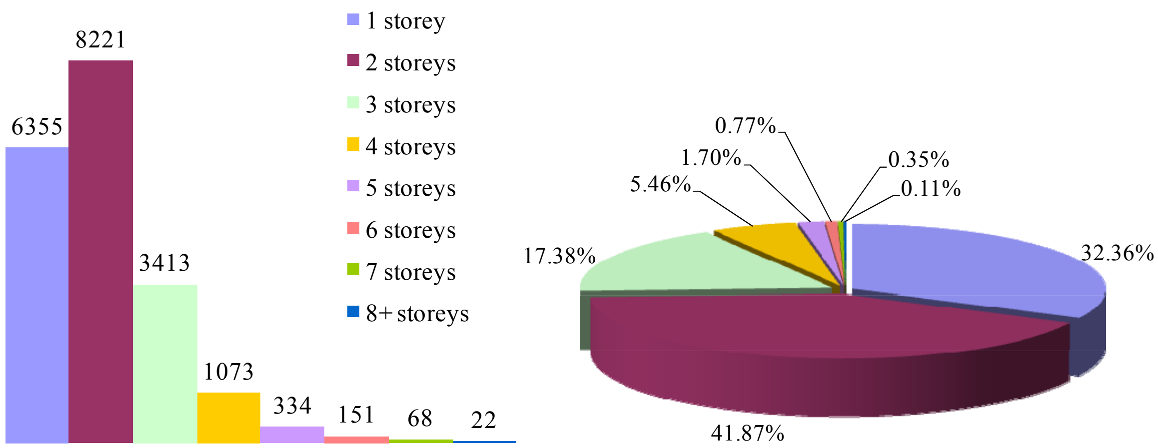

Figure 6: RC school buildings analysed in phase 1 and organised by the number of storeys.

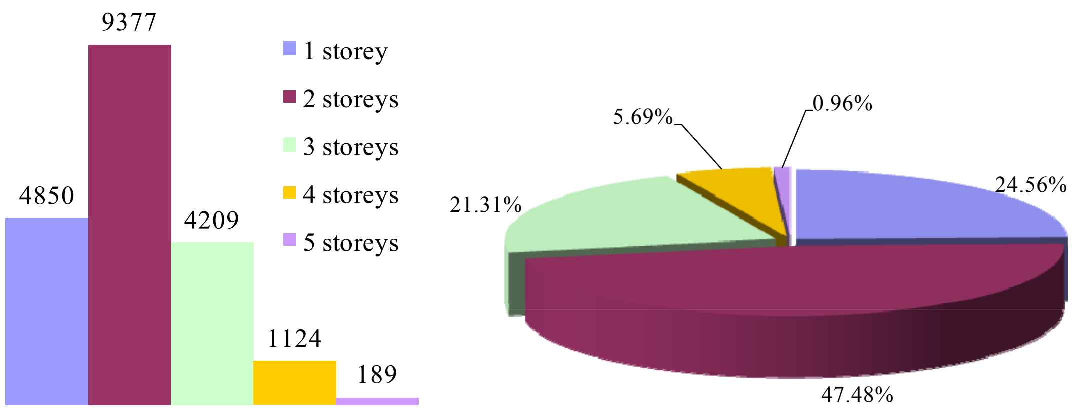

Figure 7: Masonry school buildings analysed in phase 1 and organised by the number of storeys.

Shown in Figures 6 and 7 are the RC and masonry school buildings analysed in the first phase of the procedure and divided in classes according to the number of storeys.

3.2 School buildings analysed in the second phase of the procedure

The school buildings of the GNDT database whose data of the 2nd Level forms allow the calculation of the Conventional Resistance and with a correspondence in the "Anagrafe Edilizia Scolastica" database are 3553. However, five of these masonry buildings cannot be analysed since the data of the compiled survey forms are not coherent. Therefore, the school buildings considered in the second phase of the methodology are 3548, divided in five classes according to the number of storeys (Table 1).

N° of storeys	N° of buildings
1 storey	785
2 storeys	1215
3 storeys	1156
4 storeys	356
5 storeys	36

Table 1: Masonry school buildings analysed in the second phase of the procedure.

The map shown on the left of Figure 8 gives the location of the school buildings analysed in the second phase of the methodology. In addition, the following figure shows the distribution of such buildings for the different seismic zones (from 1 to 3). It has to be pointed out that there are no school buildings belonging to seismic zone 4 (characterised by the smallest seismic hazard) since the compilation of the GNDT 2nd Level forms has been carried out only for the buildings located in zones with medium – high seismicity.

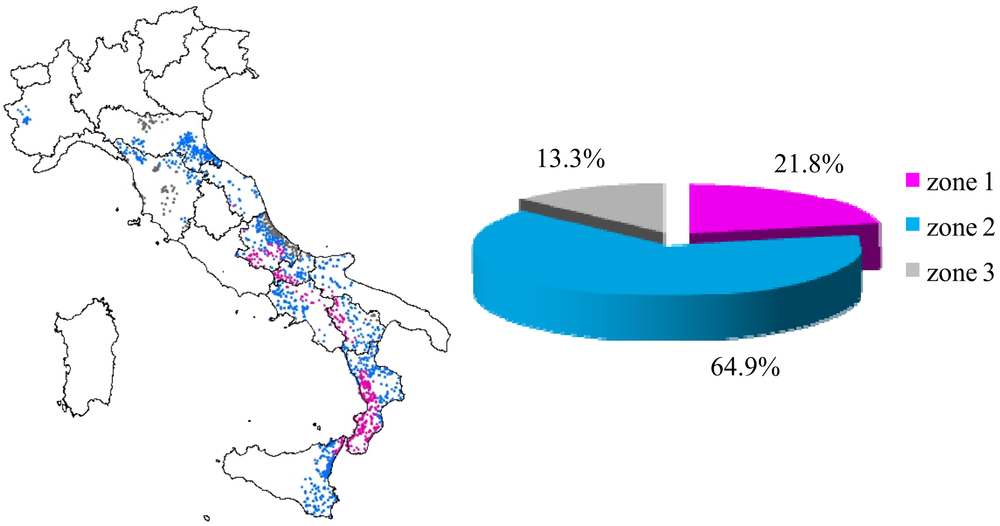

Figure 8: School buildings analysed in the second phase of the procedure and organised by seismic zone.

The Conventional Resistance has been computed for each one of the 3548 school buildings previously described. Knowing this value and its correspondence with the collapse multiplier λ (as anticipated in Section 2.1), the plateaux of the simplified capacity curve is automatically defined for each one the analysed masonry school buildings.

4 DISCUSSION OF THE RESULTS

Using the data collected during the first phase of the procedure (Section 3.1), the maps of conditional probability of damage and seismic risk have been calculated for the three limit state conditions (light damage, severe damage and collapse). The maps representing the conditional probability of damage have been computed for the 9 return periods recommended in [12]. The variability of the spectrum is taken into account considering the mean spectral accelerations plus and minus one standard deviation. Figure 9 shows the conditional probability of exceeding the severe limit state for a seismic event with a 475 year return period, computed with respect to the 16th, 50th and 84th percentile acceleration spectra.

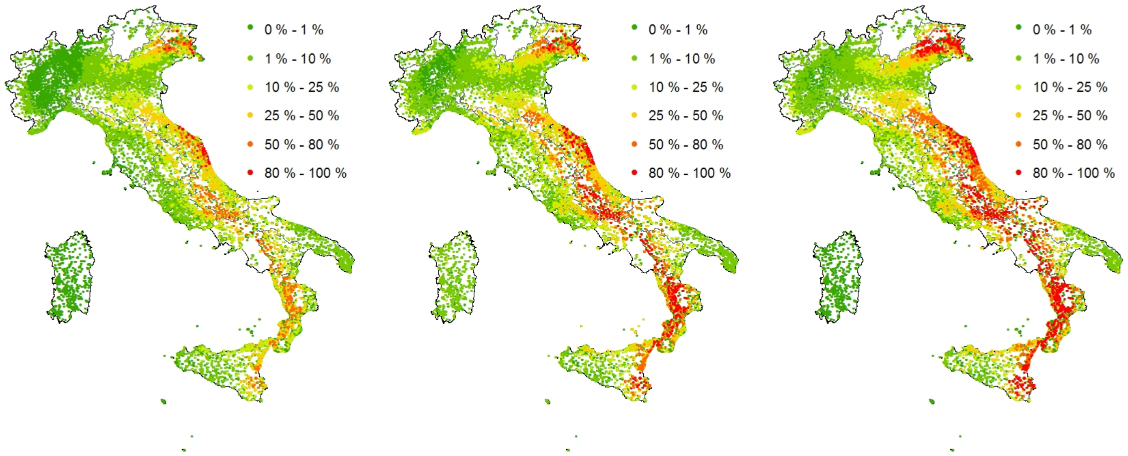

Figure 9: Conditional probability of exceeding the severe limit state computed in the first phase of the proposed procedure, for a 475 year return period (from the left: 16th, 50th and 84th percentile).

Unconditional failure probability has been then computed for the three limit state conditions and three exposure times (t_d = 1 years, 10 years, 50 years). The seismic risk maps obtained for the exposure time of 50 years are plotted in Figure 10.

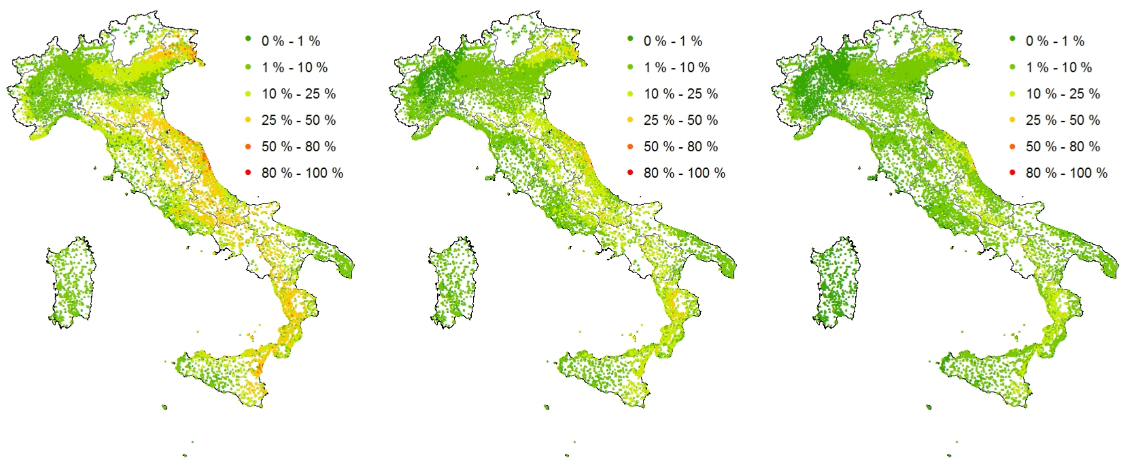

Figure 10: Seismic risk maps for the exposure time of 50 years computed in the first phase of the proposed procedure (form the left: light damage, severe damage and collapse limit state).

The results in Figures 9 and 10 show that the school buildings with the highest probability of exceeding a given limit state are located in Friuli Venezia Giulia, Marche, Umbria, Abruzzo, a reduced zone of Campania (since a small amount of “Anagrafe Edilizia Scolastica” forms have been collected in the whole of the region), the North of Puglia, Basilicata, Calabria and eastern Sicily.

As a result of the second phase of the proposed procedure, the maps of conditional probability of damage and seismic risk have been computed for the 3548 masonry school buildings accounted for. In particular, the plotted results have been calculated comparing the seismic displacement demand derived from the spectra with the seismic capacity obtained from the Conventional Resistance. The maps of Figure 11 show the conditional probability of exceeding the severe damage limit state for a seismic event with a 475 year return period (16th, 50th, and 84th percentile). The maps in Figure 12 show the unconditional failure probability for an exposure time of 50 years (light damage, severe damage, and collapse).

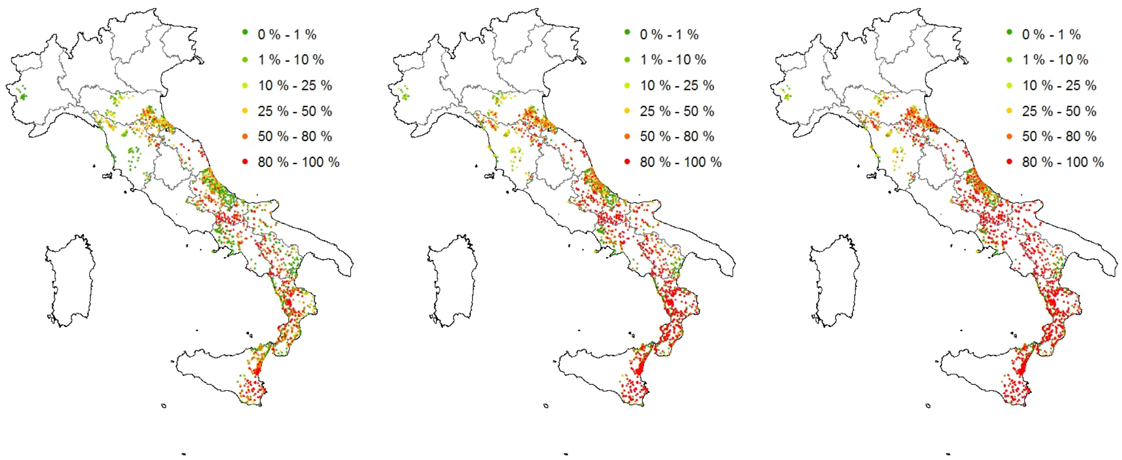

Figure 11: Conditional probability of exceeding the severe limit state computed in the second phase of the proposed procedure, for a 475 year return period (from the left: 16th, 50th and 84th percentile).

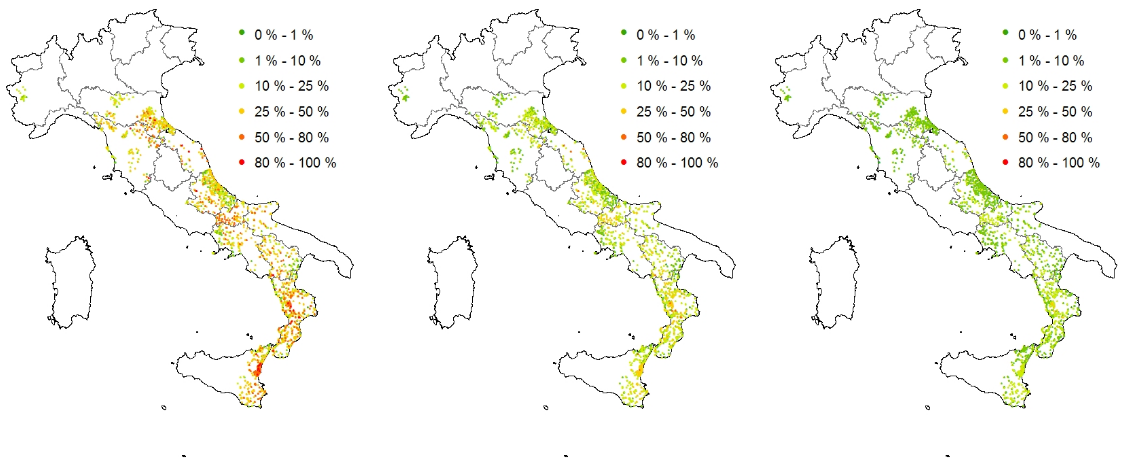

Figure 12: Seismic risk maps for the exposure time of 50 years computed in the second phase of the proposed procedure (form the left: light damage, severe damage and collapse limit state).

According to the results plotted in Figure 11 and Figure 12, the school buildings with the highest probability of exceeding a given limit state are located at the border between Emilia-Romagna and Marche, in Abruzzo, Molise, a zone of the Campania, the North part of the Puglia, Basilicata, Calabria and eastern Sicily. A further step for verifying the accuracy of the described multiphase procedure is the study of the correlation between the results of the first and second phase. The school buildings with high values of seismic risk in the second phase should be characterised by high values even in first phase; if not, it would mean that the first phase of the procedure does not allow the right identification of the highest seismic risk buildings. Therefore, the latter could not be investigated in the next phase of the analysis because they result safe.

The correlation between the results obtained in the two phases of the procedure for the 3548 masonry school buildings is plotted in Figure 13 in terms of seismic risk for an exposure time of 50 years.

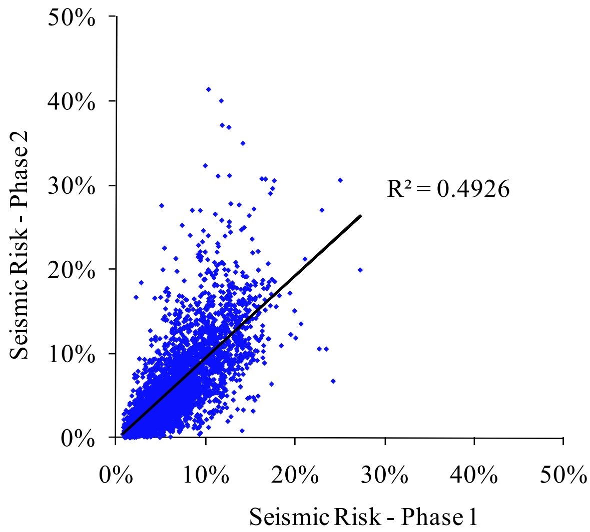

Figure 13: Correlation between the results obtained from the two phases of the proposed procedure.

Figure 13 shows that the correlation between the results from the two phases of the procedure is quite satisfactory. The data points over the line of best fit represent an underestimation of the seismic risk in the first phase of the analysis. This finding could be due to the different evaluation of the seismic vulnerability of the masonry structures. In the first phase of the procedure, good mechanical characteristics have been assigned to all the masonry buildings of the analysed five classes. In the second phase of the procedure, the Conventional Resistance is computed from the data of the survey forms and this resistance could be less than the one assumed in the first phase of the procedure, leading to more vulnerable buildings.

In order to improve the correlation between the results of the two phases of the methodology and to increase the accuracy of seismic risk maps, a refined calibration procedure is under development. This latter could give the possibility to calibrate the seismic vulnerability evaluation of the first phase of the methodology taking into account different masonry typologies also belonging to the worst classes of vulnerability. The calibration could be carried out using additional information collected in the "Anagrafe Edilizia Scolastica" database, such as the typology of the horizontal structures (e.g. the floor stiffness).

5 CLOSURE

The novelty of this research study is represented by the maps of seismic risk for school buildings at a national scale. These maps give an overall view for the definition of a prioritisation procedure for surveys and detailed structural retrofitting measures.

A multiphase procedure has been proposed for the evaluation of the amount of school buildings requiring additional investigations. The methodology implements two analysis phases with an increasing level of detail such that the number of buildings analysed decreases at each step since only the buildings most at risk are considered.

The generation of seismic risk maps at a national scale is an outcome of the first phase of the proposed procedure. The data used for the map generation are based on the collected survey forms of the 70% of the Italian school buildings. However, a reduced number of school buildings (3500) was available during the second phase of the procedure. In fact, additional information on the building resistance should be collected and used during this analysis phase. In this study, this information was available for the school buildings of some regions of Italy and for masonry structures only.

Further improvements of the proposed multiphase methodology are still required. In particular, the seismic vulnerability evaluation of the masonry structures carried out during the first phase has to be improved. The improvement should be related to the computation of the seismic vulnerability as a function of the number of storeys and additional parameters related to the quality of the masonry structures that could strongly affect the seismic response.

Finally, it should be extremely useful to complete the collection of the data related to the school building resistance in all Italian regions and for all the structural typologies in order to allow a more accurate estimate of the seismic vulnerability of these buildings and the application of the second phase of the procedure at a national scale. Therefore, it would be possible to apply the proposed procedure for the identification of the school buildings requiring priority of intervention.

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