FAST RISK ASSESSMENT OF LOSSES IN R/C BUILDINGS

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Abstract

The evaluation of the existing r/c buildings are often based only on a seismic vulnerability assessment and usually the seismic-resistant capacity is evaluated correspondently to the attainment of the ultimate limit state of a single element. This can lead to an incorrect estimation of the actual risk of a building and can be misleading in taking a decision on the priorities of the constructions that have to be improved in their seismic capacity. The decision making process should be supported by a correct risk evaluation related to a seismic attack. A simplified procedure for the risk assessment of the consequences of a seismic attack on a r/c building is presented in the paper. It provides to take the seismic hazard from the probabilistic definition given by the national code and to evaluate the vulnerability of the structure according to a multi-scenario view. Three damage scenarios characterized by different extension of the structural collapses are considered for the risk evaluation. The expected consequences on the building and occupants, injured and casualties, are computed for each scenario. The calculation of the consequences is based on the evaluation of a damage indicator that takes into account the extension of collapses of structural and non-structural elements. A risk indicator expressed in terms of annual probability of expected losses is finally determined. Both the economic consequences and the consequences on the occupants can be computed. An application of the procedure to an actual sample building is also reported.

Keywords: Seismic risk, Risk assessment, Existing buildings, R/C structures

1. Introduction

In the last years wide campaigns for the seismic assessment of existing buildings have been launched in Italy especially concerning the public buildings like schools, hospitals, and government offices. Usually the seismic assessment consists on the evaluation of the building vulnerability expressed by a so called "risk index" computed as the ratio between the maximum ground acceleration for which the building attains an ultimate limit state (Capacity) and the design ground acceleration at the site (Demand). Actually such index do not express the seismic "risk" of the building, but only its seismic "vulnerability", furthermore computed in a conventional mode and for a single hazard level. This way to perform the seismic assessment of the existing constructions does not give the correct information to plan the decision on what to do (demolition, retrofitting, restoration, enhancement) and can lead to ambiguous and inappropriate judgements.

The conventional seismic vulnerability assessments of an existing r/c buildings, conceived and designed under the provisions of old codes and in some cases even in the absence of any seismic considerations, can result, and usually results, in very small capacity indexes. High values of seismic vulnerability, calculated in accordance with the criteria provided by the codes, does not automatically imply a high magnitude of the consequences on the occupants under a seismic attack. In some cases of existing buildings characterized by high values of vulnerability it has been observed that the risk of consequences on the occupants in a limited number of years is small and that some time for programming seismic enhancement works is available. Indeed the performance condition that identify the conventional limit state for the evaluation of the seismic vulnerability of the building provides the achievement of the capacity limit of a single structural element. This condition corresponds to a very localized damage not relevant in terms of consequences on the occupants. To know the actual condition of seismic risk related to the use of the building is necessary to carry out a proper risk analysis.

The risk assessment consists of the quantitative determination of the risk associated with a real situation of danger that is in the presence of a hazard for the safety of persons or the integrity of goods. The risk is expressed through two constitutive quantities and its numerical assessment requires the calculation of these two quantities: the value of the potential consequence (losses) connected to the occurrence of the hazard; the probability of occurrence of the consequence.

A fast procedure for the assessment of the risk of consequences of a seismic attack on existing r/c buildings is illustrated in the following. The procedure is based on some approximations and simplified assumptions allowing for a simplified and fast evaluation of the expected consequences. In particular only the probabilistic nature of the hazard is considered whilst a fully deterministic evaluation of the response parameters and related damage and losses is done. Therefore, the risk is calculated using the probability of occurrence of the event that produces the consequence instead of the probability of the consequence. The procedure provides a sequence of steps that, through the analysis of hazard, vulnerability and exposure, lead to estimate both the economic consequences and the consequences on the occupants. These data can be suitably used to define the priorities in planning the retrofit of a set of buildings. A sample application to a school building has been performed to show how the actual results are given and how they can be used in a decision making process. The obtained results also suggest some general and unconventional considerations on the motivations of the decision that private owners or government can adopt for the seismically inadequate existing buildings.

2. Description of the procedure

The procedure for a fast assessment of the risk of losses from earthquakes in buildings having a r/c framed structural system is organized in nine successive operational steps that are briefly described one by one.

2.1 Step 1

The first step of the procedure consists of the definition of the seismic hazard at the site expressed by the peak bedrock acceleration (PBA) and the parameters of the elastic response spectrum, as a function of the return period, provided by the Italian code [1]. The definition of the peak ground acceleration (PGA) accounts for the subsoil category according to the definition of NTC [1] and EC8 [2].

2.2 Step 2

The second phase of the procedure provides for the definition of the structure data required in the subsequent calculation steps. Global data are required as building height, number of levels, total number of beams and columns, type of seismic analysis. Moreover data are required for each story: elevation; story height; number of columns and of main and secondary beams; total floor area; number of deck fields (in the numerical model); equivalent area ATS of the typical deck field (the ratio of the "total floor area" and "number of deck fields"); cantilevered surfaces; height and total length of claddings and partitions below the considered floor; walkable area below the deck with exposed people A_{EXP} (in general different from the floor area used to calculate ATS); occupancy index; prevention factor.

2.3 Step 3

The structure capacity and the consequences are evaluated for three different damage scenarios defined on the basis of the number of collapsed structural elements (beams and columns). For each damage level other response parameters required for the evaluation of the consequences are also considered: interstory drift ratio D_R, floor acceleration a_f, types of element collapses. The considered damage levels are described in the following.

Limited Damage (LD) scenario: it corresponds to performance conditions that, according to the Italian code [1], identify the life safety limit state and then the conventional vulnerability of r/c structures, that is the first "collapse" of a structural element. The collapse condition for a structural element corresponds to the attainment of an ultimate limit state condition within the element, i.e. the attainment of the shear resistance at a section along the element. The LD scenario is characterized by a PBA $a_{g,LD}$ with return period $T_{r,LD}$. The scenario corresponds to a very localized damage with limited consequences on the occupants.

Extended Damage (ED) scenario: it provides for performance conditions beyond the "collapse" of the first structural member, in fact it corresponds to the collapse of 10% of the vertical structural elements of the building or to the collapse of 20% of the structural elements of a single story. This scenario allows the possibility of local collapse of the construction involving relevant consequences for the occupants. The criterion used to define the scenario was recruited by analogy to the percentage of the collapsed portion of r/c buildings in the complete damage state estimated in the provisions of Hazus procedure [3] [4]. The scenario is characterized by a seismic intensity $a_{g,ED}$ (value of PBA) having a return period $T_{r,ED}$.

Extreme Damage (XD) scenario: it provides for the collapse of 50% of all the elements of the structure. It represents an extreme performance condition of the construction to which an extensive collapse with very serious consequences on the occupants corresponds. The Extreme Damage scenario can also corresponds to the formation of a mechanism (i.e. soft of weak story). In the last case there can be a limited number of collapsed elements but sufficient to activate a mechanism leading to the total collapse of the building. The XD scenario is characterized by a PBA $a_{g,XD}$ with return period $T_{r,XD}$.

2.4 Step 4

The structural damage is quantified through the floor area A_{SD} associated to the damaged elements of the scenario. Indeed a percentage of the typical field area ATS is imputed to each collapsed element taking into account the direct and indirect retrofitting costs for the element type: main beam (50%); secondary beam (20%); column (40%). Indirect costs include the cost of related works, such as removal and reconstruction of finishes and facilities, required to carry out the main repair or strengthening works. A coefficient accounting for the collapse type (1.0 for fragile failure, 0.5 for ductile failure, assumed as more resilient and less expensive to repair) then multiplies the floor area associated to the collapsed element. A floor area A_{SDP} associated to partially damaged elements is also considered. A partial damage status corresponds to a condition in which a plastic hinge is activated but it does not reach the last curvature. The parameter A_{SDP} is computed similarly to A_{SD} but using a reduction factor 0.50 considering the reduction of the direct and indirect costs associated to the partial damage.

The collapse location along the building height has a significant influence on the consequences due to the possible collapse propagation along the height. As an example, Fig. 1 reports the diagrams of the used amplification functions expressing the correlation between the floor level rate α (ratio of the number of the considered story to the total number of stories) and the amplification coefficient C_{ampl} of the deck area directly associated with the collapsed elements. The adopted method for attributing the floor areas can lead to impute an area that can be larger than the actual area associated to the single collapsed structural element.

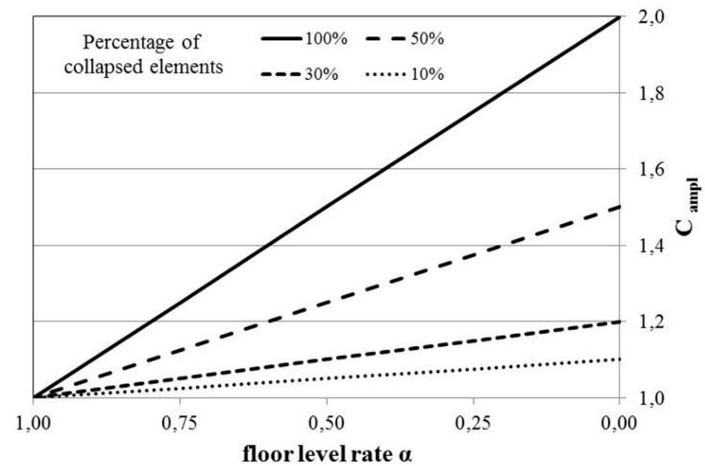


Fig. 1 – Diagrams of the amplification coefficient of the area imputed to collapsed elements at the level

2.5 Step 5

The damage of the non-structural elements, claddings and partitions, is estimated in function of the interstory drift ratio D_i and its activation depends on the attainment of a limit value D_i=D_{lim}. Only a percentage (30%) of non-structural elements is assumed to be damaged at D_{lim} while all the elements are damaged at the achievement of an ultimate drift D_{ult} (1%). The area of claddings and partitions involved in the damage scenario is expressed as an equivalent conventional floor area A_{NSD} through a conversion factor k_c accounting for the differences in the unit repair cost, or in the consequences for occupants [5], associated to the area of non-structural elements and floors. Considering the average Italian market costs the factor k_c results equal to 1.5. The k_c factor can also assume different values (even greater than 2.0) depending on the building typology and use [6].

2.6 Step 6

Also the damage of the contents is expressed in terms of an equivalent conventional floor area

$$A_{CD} = \beta_1 \cdot \beta_2 \cdot (A_{NSD} + A_{SD}) \tag{1}$$

defined as a function of the areas A_{SD} and A_{NSD} of the structural and non-structural elements, respectively, being β_1 the ratio of the contents cost to the total construction cost. In accordance with [5] a value β_1=0.20 can be assumed for residential or office buildings. The contents can be divided into classes (Table 1) and each class can be characterized by: the activation parameter, floor acceleration or interstory drift ratio and the cost percentage β_1 on the overall construction cost. The factor β_2 accounts for the actual presence of contents on each floor. β_2 factor can have values included between 0 and 1 and should be estimated according to the building knowledge or survey.

The activation acceleration values for the contents are obtained considering the limit equilibrium condition where the overturning action on the object equals the stabilizing one. In the absence of a direct dynamic analysis the floor acceleration is computed as ratio between the difference of shear forces above and below the level and the seismic mass of the floor.

Table 1 – Classes of contents and activation parameters

Class	Activation Parameter	Value	β_1
Furnishings (i.e. cupboards)	Floor acceleration	0.25g	0.067
Computers (or equivalent)	Floor acceleration	0.20g	0.067
Interior lights/false ceilings	Interstory drift ratio	0.5%	0.067

2.7 Step 7 - Economic consequences

The total equivalent damaged floor area computed in the considered scenario finally results

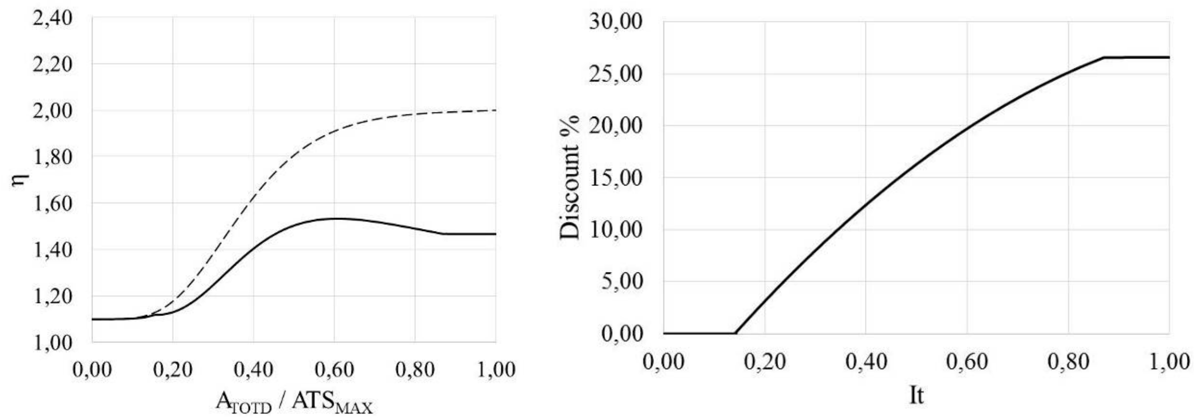
$$A_{TOTD} = A_{SD} + A_{SDP} + A_{NSD} + A_{CD} \tag{2}$$

and the correspondent cost of the damage C_{DI} is

$$C_{DI} = A_{TOTD} \times (\eta \cdot C_U) \tag{3}$$

where C_U represents the standard cost of restoration works per unit of area and η is a correction coefficient that is function of the extent of the works and expected discount.

The nominal value of η is represented by the dashed curve in Fig. 2a and varies from a minimum 1.1 for $A_{TOTD}/ATS_{MAX} = 0$ to a maximum equal 2.0 for $A_{TOTD}/ATS_{MAX} = 1$. It includes the incidence of indirect costs. The actual value of η should account for the discount of the prices related to the quantity of works. The discount rate (Fig. 2b) is a function of the ratio I_T of the actual cost to the maximum potential cost of the building restoration and results from the analysis of the prices of the post-earthquake restoration works in Italy [7]. The actual value of η reduced for the discount rate is represented by the continuous curve in Fig. 2a.



(a) (b)

Fig. 2 – (a) Nominal (dashed line) and actual (continuous line) modification coefficient of the standard cost; (b) discount rate

Besides the direct and indirect costs C_{DI}, also the downtime costs should be evaluated. At this aim an exponential correlation of the downtime rate n_{DT} of the maximum expected downtime $D_{D,FULL}$ with the ratio A_{TOTD}/ATS_{MAX} (work extent) is reported in Fig. 3. $D_{D,FULL}$ (in days) is the downtime required by a full repairing of the whole building that depends on the typology of structural and non structural elements, types of repairing works, social and economic post-earthquake conditions. Therefore the actual downtime D_{DT} is calculated as

$$D_{DT} = n_{DT} \times D_{D,FULL} \tag{4}$$

and the correspondent cost is

$$C_{DT} = D_{DT} \times A_{BLDG} \times C_{UD} \tag{5}$$

where A_{BLDG} is the actual area of the building and C_{UD} represents the daily cost per unit of area. On the basis of a market research it is included between 0.05 and 0.40 €/m^2 depending on the building type and market conditions.

Finally the total cost for the considered scenario is $C_{TOT} = C_{DI} + C_{DT}$. The expected annual cost is calculated by summing the cost C_{TOT} of each scenario multiplied by the annual probability of that consequence, approximately assumed to be equal to the probability to attain or overcome the event causing the scenario. This value must be actualized and multiplied by the number of years of the residual building life to obtain the future cost.

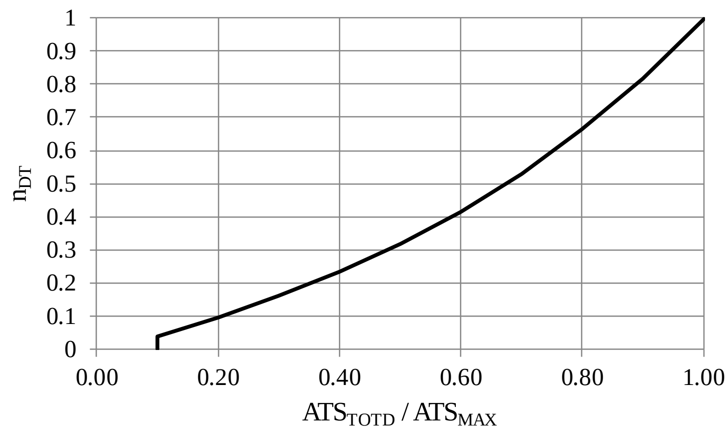


Fig. 3 – Downtime rate

2.8 Step 8 - Consequences on the occupants

The first stage consists of the calculation of the global damage index

$$\text{ID}=[\varphi_s\times(A_{SD}+A_{SDP})+\varphi_{ns}\times(A_{NSD}+A_{CD})]/\ (2\cdot A_{EXP}) \tag{6}$$

where A_{EXP} is the total walking floor area of the building that can be occupied by people and φ_s and φ_{ns} are scale factors required to have a maximum value of ID equal 1.0. The coefficients φ_s and φ_{ns} are calculated as ratio between the actually involved areas $A_{SD}+A_{SDP}$ and $A_{NSD}+A_{CD}$, respectively, and the maximum area that can be involved. Indeed, the total area A_{TOTD} involved in the damage scenario does not represent an actual walking floor area, but a quantity expressing the restoring costs of structural, non-structural and content loss in terms of floor area, calculated on the basis of equivalence criteria. On the basis of assessments made on sample buildings the adoption of factors $\varphi = 0.5$ is adequate. The assumption cannot be, however, generalized and must be adjusted in function of the number of stories and areas of the floors of the examined construction.

Considering the consequences on the occupants associated with the damage of the construction, in the present procedure the persons affected by the event are grouped in three groups: unharmed, injured, fatalities. As shown in Table 2 the three groups include the five classes of severity usually reported in the literature and corresponding to the criteria for the basic triage provided for mass events. Therefore the unharmed group includes the light and very light injured (classes of severity 0 and 1); the injured group includes injured of medium or significant severity (classes of severity 2 and 3); the fatalities group include the class of severity 4.

Table 2 – Adopted classification of the consequences on the occupants and correlation with triage

Consequence	**Severity Class**	**Code**	**Description of the result**
Unharmed	0	White	Unharmed or slight self-treatable wounds.
	1	Green	Wounds requiring a minimum medical support that can be provided by paramedical staff.
Injured	2	Yellow	Wounds that require higher level of medical care and use of medical technologies but devoid of evolution with risk for life.
	3	Red	Wounds that can determine a risk to the life if not appropriately and promptly treated.
Fatalities	4	Blue/Black	Immediate death or fatal injuries.

With the aim of calculating the percentage of occupants accordingly attributable to the three groups, reference is made to correlation curves (Fig. 4) that, as a function of the index of global damage, express the percent of injured or fatalities among the occupants. The functions have been defined on the basis of statistical surveys on the impact of past seismic events reported in literature [8] [4].

For values of the global damage index lower than 0.1 (limited damage) the percentage of victims is null, in fact, in real events, in these situations usually do not occur victims. A damage index equal 0.6 resulting from the procedure corresponds to a situation of very extensive damage, equivalent to the conventional collapse conditions of buildings reported in literature and to which a percentage of fatalities of 10% is usually attributed. The ultimate damage scenario corresponding to ID=1.0 can be associated to a total collapse of the construction for which a percentage of expected fatalities equal to 20% of the occupants was assumed.

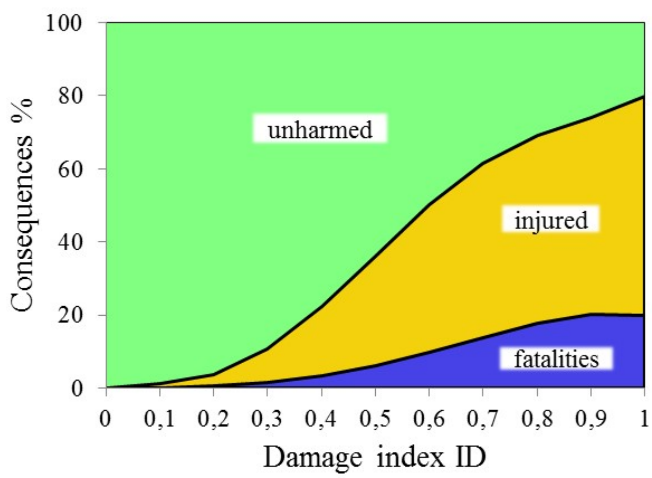


Fig. 4 – Correlations between global damage index and consequences on the occupants

A factor I_{DD}, function of the interstory drift ratios, modifies the calculated values of the consequences. I_{DD} allows to take into account situations of existing buildings in which the parameters of the global response are not related to the damage state of the structural elements. The modification factor I_{DD} is defined as a function of the average value of the interstory drift ratios of the building

$$I_{DD} = max \left| 1 , \left(\sum_{i=1}^{N} D_i \cdot A_{f,i} \right) / \sum_{i=1}^{N} A_{f,i} \right| \qquad (7)$$

where D_i and $A_{f,i}$ are the percent interstory drift ratio and the floor area of the i-th level, respectively.

The absolute values of the consequences on the occupants depends on the actual exposure, that is on the occupation index I_O, expressed as average number of people daily present per unit of floor area, and on the prevention factor FP, variable between 0 and 1, which takes into account the prevention conditions, both physical and cultural, in the areas subjected to assessment. The total number of exposed people is

$$N_{EXP} = \mathrm{FP} \times I_O \times A_{EXP} \quad (8)$$

that, multiplied by the percentages of injured, fatalities and unharmed people, gives the expected number of persons in each of the classes of consequences.

2.9 Step 9

The probability of the consequences of a damage scenario in a number of years is approximately assumed to be equal to the probability, in the considered period, to attain or overcome the event causing the scenario:

$$p = 1 - (1 - 1 / T_r)^n \quad (9)$$

where n is the considered period and T_r is the return period of the event. The approximation arises from considering, as shown in the description of the previous steps, the probabilistic nature only for the hazard while the response parameters and related consequences result from fully deterministic evaluations.

The estimate of losses expected in a number of years can be finally calculated by summing the consequence expected for each scenario multiplied by the probability to get that consequence.

3. Case study

A sample application of the procedure has been carried out on a school building. The building has two stories in elevation and a small basement. The structure consists of r/c frames and walls. It has a gable roof characterized by a ridge beam 24 m long. The total floor area (A_{EXP}) is equal to 1305 m^2. Fig. 5 shows an external view of the building and the ground floor plan.

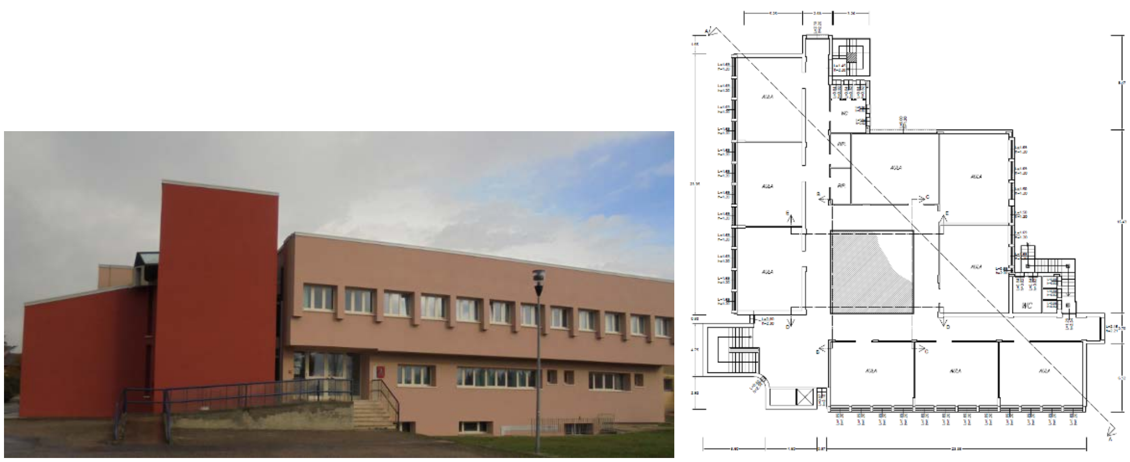
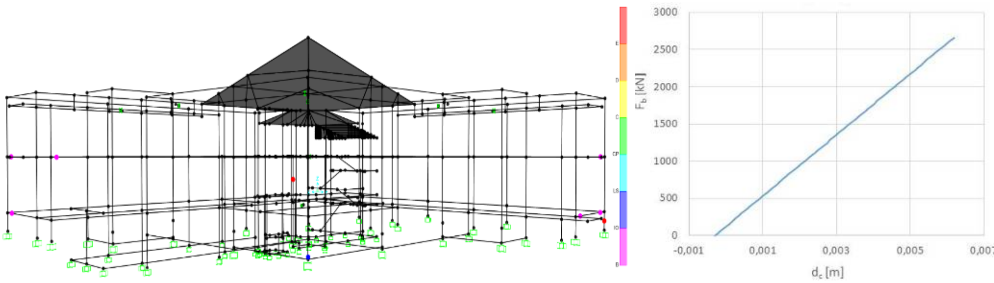


Fig. 5 – View and plan of the building

The structure has been modeled through a FEM model made of beam elements. The nonlinearity has been reproduced considering a concentrated plasticity model through the definition of potential flexural ductile hinges and fragile shear hinges. Pushover analyses have been performed to evaluate the seismic capacity of the building according to the current Italian code and guidelines. The building is inadequate to sustain the expected earthquakes since a Capacity/Demand ratio equal to 0.20 results. A preliminary design of the retrofitting works allowing to reach an adequate seismic resistance has been carried out. The cost of these works is equal to about € 650 000. This amount does not account for the cost of the downtime associated to the execution of the works.

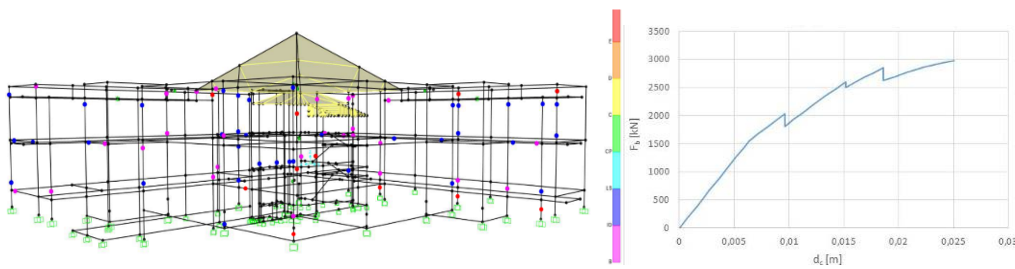
Pushover analyses have been then performed to evaluate the seismic capacity for different scenarios according to the illustrated risk assessment procedure. In particular the LD scenario and ED where computed. Fig. 6 and Fig. 7 show the damage state and the capacity curve for the LD and ED scenario, respectively. The damage state is represented by the status of the hinges in a color scale with the following meaning: magenta =

light damage; blue = moderate damage; orange = heavy damage; red = ultimate state (conventional collapse). The main parameters resulting from the analyses to be used for the evaluation of the consequences are reported in Table 3.



a) b)

Fig. 6 – LD scenario: (a) damage state; (b) Capacity curve



a) b)

Fig. 7 – ED scenario: (a) damage state; (b) Capacity curve

Table 3 – Main parameters for the consequences evaluation

Scenario	a_g	T_r	A_{SD}	A_{SDP}	A_{NSD}	A_{CD}	A_{TOTD}	A_{TOTD}/ATS_{MAX}	**ID**
	g	*years*	m^2	m^2	m^2	m^2	m^2		
LD	0.04	14	34.36	0.00	0.00	1.58	35.94	0.01	0.01
ED	0.13	260	110.26	139.69	767.00	74.59	1091.54	0.29	0.27

The economic consequences are computed according to the method provided by the Step 7 of the procedure assuming C_U = 500 €/m^2 . From Fig. 2 it results η = 1.10 for LD and η = 1.28 for ED. Therefore the total cost of the direct and indirect consequences result $C_{DI,LD}$ = 19767 € for LD and $C_{DI,ED}$ = 698857 € for ED. For the evaluation of the downtime cost a value C_{UD} = 0.40 €/m^2/day is assumed. From the diagram of Fig. 3 it results a downtime ratio n_D = 0 for LD (the damage extent is very limited and the repairing works do not influence the internal activities) and n_D = 0.164 for ED. Therefore, being $D_{D,FULL}$ = 912 days, the downtime results $D_{D,LD}$ = 0 for LD scenario and $D_{DT,ED}$ = 210 days for the ED scenario with a downtime cost C_{DT} = 109620 €. Finally the total cost of the consequences is equal to € 19 767 and € 808 477 for the LD and ED scenario, respectively.

The expected cost in a planning term of *n* years can be evaluated considering the probability distribution of the seismic event and particularly of the events corresponding to the computed scenarios. The expected costs for three significant time intervals have been evaluated, that is for *n* = 5 years (short-term planning or limited objective), for *n* = 30 years (medium-term planning or generational objectives), for *n* = 100 years (long-term planning or approximate building life). The results are resumed in Table 4, where for each planning term the expected cost is reported. The results can be also represented in terms of probability, in the three considered periods, to spend an amount equal to the present cost of the retrofitting works. These values are reported in Table 5.

Table 4 – Results of the economic consequences evaluation

Scenario	C_{TOT} **(€)**	**short-term**		**medium-term**		**long-term**	
		$n = 5$		$n = 30$		$n = 100$	
		p	C_{EXP}	p	C_{EXP}	p	C_{EXP}
LD	€ 19 767	0.310	€ 21 489	0.890	€ 105 717	0.999	€ 277 651
ED	€ 808 477	0.019		0.109		0.319	

Table 5 – Probability to spend an amount equal to the retrofitting cost

	short-term	**medium-term**	**long-term**
	$n = 5$	$n = 30$	$n = 100$
Probability	0.019	0.109	0.319

The consequences on the occupants are computed according to the method provided by the Step 8 of the procedure. Using the damage indexes ID reported in Table 3 and considering an average occupation index I_O = 0.115 person/m^2 resulting from a total number of exposed people N_{EXP} = 150 and a floor area A_{EXP} = 1305 m^2. The percentages of fatalities and injured have been calculated using the diagrams in Fig. 4, then the total number has been computed. The values for the two scenarios are reported in Table 6.

Table 6 – Percent and number of fatalities and injured for the scenarios

Scenario	N_{EXP}	**Injured**		**Fatalities**	
	number	**%**	**number**	**%**	**number**
LD	150	0.25	0.38	0.00	0.00
ED	150	8.15	12.23	1.12	1.68

Similarly to the expected costs, also the expected victims in a term of n years can be evaluated considering the probability distribution of the event and particularly of the events corresponding to the computed scenarios. The expected victims for the three significant time intervals have been evaluated and the results are resumed in Table 7, where for each planning term the expected number of victims is reported. An alternative presentation of the results is given in Table 8 where for each planning term the probability to have a bad consequence, that is one fatality or one casualty, is reported.

Table 7 – Results of the evaluation of consequences on the occupants

Consequences	**short-term**	**medium-term**	**long-term**
	$n = 5$	$n = 30$	$n = 100$
Fatalities (no.)	0.03	0.2	0.5
Injured (no.)	0.3	1.6	4.2

Table 8 – Probability to have a bad consequence (one victim) on the occupants

Consequences	**short-term**	**medium-term**	**long-term**
	$n = 5$	$n = 30$	$n = 100$
One fatality	0.02	0.13	0.43
One injured	0.29	1.00	1.00

4. Reflections on the decision strategy in seismic enhancement of buildings

The results obtained for the sample building are very interesting and can be used to make some general considerations about the strategies of seismic enhancement of the building stock from both the public and the private point of view.

It can be seen that, from a pure economic point of view and within the ambit of a short term vision, it seems not convenient to invest in the seismic enhancement of the building since the expected cost for the seismic events (Table 4) is about 33 times lower than the present cost of the enhancement work, or, what is the same thing in other words, the probability to spend for the post-earthquake repairing works an amount equal to the present cost of the seismic enhancement is equal to only 1.9% (Table 5). Since the considered short-term period (5 years) is more or less coincident with the duration of a government, the performed evaluations seem to explain some "inertia" of the governments to invest in the seismic enhancement of the building stock.

Moreover, the considered medium-term period (30 years) can be considered correspondent to a generational time period, therefore the data associated to this time interval can be attributed to the decision process of a private owner. Under this vision it seems not convenient to invest in the seismic enhancement of the building since the expected cost for the seismic events is about 6 times lower than the present cost of the enhancement works or, with more impact, the probability to spend for the post-earthquake repairing works an amount equal to the present cost of the seismic enhancement is equal to only 11%. These data can explain the usual reluctance of the private owners to invest in the seismic enhancement of the building.

Only within a long-term vision, that is within a nationwide strategic point of view, an economic convenience can be found, but this concerns a very long period equal or longer that the conventional building life, therefore in this case the cost of the enhancement works can be regarded or interpreted as the cost for the building substitution or for its deep rehabilitation, so losing the meaning of works for the seismic improvement.

Maybe the results can lead to a different conclusion if the consequences on the occupants are considered, but also in this case different visions should be considered. If the human life is considered an intangible value, as it is considered in many other situations, a probability of 2% to have one fatality or a probability of 30% to have one injured in the next five years (Table 8) can represent an unacceptable value for a school building. Similarly a probability of 13% to have one fatality or a probability of 100% to have one injured in the next thirty years (Table 8) can represent an unacceptable value for a home building. Under this assumptions the investment on enhancement works can be regarded as a duty for the public administration to avoid consequences on the citizens and for the private owner to avoid consequences on himself and his family. A different vision provides that also the consequences on the occupants are represented with their monetary value as the other damage: on the other hand this assumption is currently adopted in other fields like the insurance of road or work accidents. Under this assumptions the consequences on the occupants can be analyzed in terms of cost as provided for the damage and downtime costs.

Anyway, whatever will be the philosophy adopted in interpreting the results from the proposed fast risk evaluation and the decision politics, the computed values represent an objective and actual evaluation of the building seismic capacity based on the consequences of the earthquake on the construction allowing for a correct comparison among different buildings. Therefore the evaluation can be suitably used to support the decision makers when the funds for the enhancement works are limited and it is required to establish a priority scale among various buildings to be improved.

5. Conclusions

A procedure is outlined allowing for a fast calculation of the risk of consequences from a seismic attack on the construction and on the occupants of a r/c framed building. The procedure is based on seismic assessments performed for some damage scenarios differentiated for the extension of the structural collapses. The quantitative assessment of the risk of consequences - economic losses or consequences on the occupants - provides a realistic value of the risk related to the use of the building and represents a rational way to express the actual seismic capacity of the building. The results evidence some critical aspects concerning the opportunity of the seismic enhancement of existing buildings: under only economic considerations the investment in seismic enhancement can result not convenient in comparison with investment in other fields. This explains some instinctive and unaffected behaviors of both public administrations and private owners characterized by inertia and reluctance to invest in seismic safety. In any case the risk assessment allows a correct method to schedule suitable actions for the enhancement of buildings based on programming the available financial resources and the use of the buildings.

6. References

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