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NEW POSTEARTHQUAKE BUILDING DAMAGE EVALUATION PROCEDURES AFTER RECENT EARTHQUAKES IN COLOMBIA

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SUMMARY

The aim of building damage evaluation is to identify the buildings seriously affected that represent a hazard for the community and also the safe constructions that may be occupied or used as temporary shelters after a moderate or severe earthquake. This kind of evaluation is based on the structural and nonstructural damage characterization as well as the geotechnical failures, which serve up to define the building habitability and the type of mitigation measures needed to provide safety to the community. This tool enables the decision making process and, in addition, gives a notion of the economic and social impact; issues relevant for the formulation of reconstruction projects and the identification of long term strategies to reduce the effects of future seismic events. Indirectly, it can be used for research, since it allows the identification of the most common failures of the different structural systems, the construction of empirical vulnerability curves, and the urban damage zoning according to ground site effects.

INTRODUCTION

As a result of the latest earthquakes that have taken place in different countries located in zones of high seismic hazard, it has become necessary to develop methods to evaluate damage of affected buildings, with the purpose of determining in a quick form if these are safe or if they should be evacuated in order to protect the life of their inhabitants and avoid that the number of victims increases in case of an aftershock. It has been demonstrated that the vulnerability assessment of buildings is important, but that it is also useful to have evaluation methods of the damage caused by earthquakes.

The formulation of a methodology and the elaboration of the necessary tools for evaluating the habitability of the buildings enables the identification, after a moderate or severe earthquake, of the buildings that have suffered severe damage and that may represent danger to the community, as well as safe buildings that can be used as temporary shelters to persons that have lost their homes or that have been evacuated since their safety and well-being was at risk. This type of evaluation not only enables the authorities to give safety recommendations to the affected people by determining the possible habitability or

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inhabitability of the houses, but it also provides technical recommendations regarding the zoning of unsafe areas, the shoring of buildings or unstable elements or the demolition of elements that might fall, among others.

In a complementary way, damage evaluations are not only useful to characterize structural and non-structural damage in buildings, it also allows the evaluation of the local effects of soils, to approximately estimate the social and economic impact, and to generate information for decision making processes on behalf of the authorities, for the posterior formulation of reconstruction projects and the definition of strategies that allow in the long term the possibility of reducing the effects of future seismic events. They enable, to make improvements to the construction codes, by identifying the failures in the structural systems and make it feasible to construct empirical vulnerability curves, which are also useful for the study of buildings.

"Asociación Colombiana de Ingeniería Sísmica" (Colombian Association for Earthquake Engineering) and some of its members have been undertaking a research on the topic of damage evaluation, by collecting bibliography on diverse methodologies that are in use worldwide, among which we can highlight those from Macedonia (the former Yugoslavia) [1], USA [2,3,4,5,6,7,8], Japan [9,10], Mexico [11,12], Italy [13,14], Turkey [14], Greece [15] and Colombia [16,17,18,19], by directly participating in many of these national experiences, particularly in the one obtained during the earthquakes of February 8,1995 and on January 25,1999 in the "Eje Cafetero" (coffee growing region).

CHARACTERIZATION OF THE DAMAGE EVALUATION

General characteristics

The inspection processes of buildings after an earthquake are different than vulnerability evaluations or other similar diagnostics that are made without an earthquake in different aspects:

- These must be done as soon as it is feasibly possible to do them in order to reduce the risk and discomfort of the persons, so it is impossible to make an evaluation by making a complete geometric survey of the building, taking samples for pathological analysis and by making a detailed numerical computer analysis. Thus, the habitability and damage evaluation shall be done by way of the visual inspection and expert criteria.
- Normally when the evaluations are done, the seismic crisis has not ended, this means that new aftershocks might take place that would reduce the safety level of buildings and a new visit will be necessary, especially after an event of certain magnitude.
- The inspections to be made are several at the same, then many inspectors are needed and thus, it is ended up recurring to non-expert professionals in the field.
- Additionally, due to the great volume and speed that is required in the delivery or handing in recommendations, information management and administration shall be efficient and thus, systematized.

Types of evaluations

The procedures of damage evaluation normally are applied through different levels or development phases, which have been classified in rapid evaluations, detailed evaluations and engineering evaluations.

The rapid evaluation of habitability of the edifications is commonly used to define from a few questions the possible occupation and utilization of the building short term, additionally a few recommendations are generated with the purpose of reducing the risk of the inhabitants. Normally, it is done by professionals with not too much experience, and they are used as a filter to define the need of more detailed evaluations undertaken by professionals that have more criteria.

The detailed methodologies or evaluations that depict or describe the level of structural damage and its classification may be done for many reasons, generally speaking these are done with the intention of reviewing or checking the safety of those buildings over which any kind of doubt is cast on them due to the short outreach of the fast evaluation and the very short experience of its inspectors. This type of evaluation normally has other objectives that will vary according to the country, for instance in Japan [7, 8], it is done with the purpose of determining the long term use of buildings, thus the result of the evaluation is a suggestion to the owner to get ready, to be prepared, to reinforce or demolish the building, whilst in Italy [11, 12] the purpose is to globally evaluate the direct economic losses and estimate the vulnerability functions of buildings, since the decision of the long term use of the construction is made by an engineering evaluation that is independently contracted by the owners, just as it happens in the USA (ATC-20) [5] and Mexico [12].

Most common problems

In both international and national experiences, it is easy to see that similar problems have surfaced in the process of post-seismic evaluation. The most relevant ones in general terms are the following:

- Lack of training and qualification of the inspectors in both the conceptual part as well as in the necessary procedures for the development of the methodology, which causes a lack of uniformity in the results and very little trustworthiness in the decisions.
- Subjectivity in the evaluations, due to lack of definitions and clear criteria to classify the damage, its implications in the safety of the buildings and thus in their habitability
- Problems in the location and identification of the land lots, which in certain cases led to errors like the wrong demolition of buildings
- Lack of planning of the visits, generating multiple trips to one same sector and an unnecessary delay in the evaluation process of all the buildings.
- Inadequate information management handled to the tenants of buildings, which makes them disregard the recommendations or causes unnecessary panic
- Lack of organization and systematisation of the records, which causes data accumulation, inefficiency in the application of safety measures, as well as repetition of evaluations

METHOD SUGGESTED FOR MANIZALES, COLOMBIA

General Purpose

Generate a methodology to evaluate the damage and safety of buildings after an earthquake that allows a quick definition of the habitability and the orientation of posterior actions in the rehabilitation and reconstruction of buildings.

Specific objectives

- Reduce the incidence of lesions and deaths of the tenants or occupants of damaged buildings caused by an earthquake, which might occur due to the existing structural damage, due the possible fall or turning over of objects or due to the occurrence of aftershocks after the main event.
- Record, classify and systematize the data regarding the magnitude of the disaster in terms of the number of habitable buildings, damaged or that collapsed, with the purpose of planning the rehabilitation and assistance process in the reconstruction phase and recovery of the affected zone.

- Identify the needs of the community respect to the safety of their buildings and the actions that the authorities of the system of prevention and attention of disasters shall undertake in order to preserve human lives, provide shelter to the affected ones and the handling of the emergency.
- Provide information for the preliminary estimates of direct economic losses due to damage in buildings.
- Provide technical information that permits an improvement of the earthquake resistant standards and the calibration of vulnerability curves and risk scenarios, with the purpose of determining the mid and long term actions for reducing seismic risk.

Scope

The classification of the building stability and its habitability is based upon the inspection results on the conditions that the building has in general or global terms, the damage in their non-structural and structural elements and the geotechnical conditions of its surroundings.

Out of reach of this work are the procedures to evaluate the need and definite feasibility of the buildings, for which it is required that each owner uses a structural engineer, to perform the removal of certain architectural elements to complete the inspection or undertake assays on material quality, the status of the reinforcement, or a detailed pathological study of the damage. This professional shall make a vulnerability analysis of the structure according to the requisites established in the earthquake construction standards.

Even though it may be used in preliminary form, it is not within the outreach of this work the evaluation of essential buildings to attend the community, of installations of public services or utilities and of industrial constructions or those that contain high risk material. This is due to the fact that for this type of evaluations, special diagnoses need to be made according to their functionality, the equipment and the substances that they hold.

With the suggested procedures it is not pretended to quantify in a detailed manner the social and economic impact caused by the earthquake, but instead to make gross estimates on the magnitude of the disaster in order to be used as a tool to plan the rehabilitation and reconstruction processes.

Evaluation instruments

It has been necessary to develop the tools that allow for the application of building damage evaluation procedures after an earthquake, which includes the design of procedures, forms, a field handbook, habitability signs, legal instruments, an artificial intelligence system or expert system on damage evaluation, so that the set of these elements contribute towards the better management of seismic emergencies and the necessary posterior programs of recovery and reconstruction in the city.

Procedures

The building damage evaluation is a critical activity and an essential component in the preparation for disaster attention, so this was incorporated as an important component of the Emergency Plans, being aware that the damage evaluations shall be planned, systematically applied and regularly done during the recovery process after an earthquake. It is through damage evaluation that the persons in charge of the decision making processes can identify ¡ the needs that lead to the type of adequate aid, whilst being able to evaluate the mitigation and development opportunities.

In order to have a better and fast management of the evaluations, cities are divided into zones, and a form was suggested for the preliminary evaluation by zones with the purpose of being able to prioritise the most affected sectors, to be able to select and assign the most prepared personnel to the zones that experimented the most severe damage, before entering in a massive evaluation of individual buildings. Some recommendations were included on the responsibilities, organization and necessary concepts for building inspection after an earthquake.

Form of preliminary evaluation of zones

It is necessary to make a preliminary evaluation of damage per sectors in order to determine the geographic extension of the affected area, define or determine the relative degree of damage and the type of infrastructure involved. With this evaluation it is hoped to have a first approximation on the magnitude of the damage, the amount of affected buildings and the identification of the zones of highest impact, with the purpose of then being able to develop the work plan for the individual evaluation of buildings by adjusting the procedures planned beforehand to the circumstances generated by the event. For this purpose we designed a form based on the forms used for Damage Evaluation & Needs Analysis, as recommend by the Pan-American Health Organization PHO and the OFDA [10] for this purpose

Inspection form for buildings

From the comparative analysis of the different methodologies at an international and national level, it was possible to conclude that to make a rapid and detailed evaluation is to repeat very similar processes, this second time the process is done with much wider criteria basically because a verification of the doubtful evaluations is required or a person with much more criteria and experience in the process of making decisions is needed. These double evaluation takes a whole amount of time and it can be omitted if a very good training is provided to the persons that is going to participate in the process, the support instruments are delivered for decision making purposes and visits are planned based on a prior recognition or over flying of the region in such a way that the most critical zones can be allocated to the most experimented and talented professionals and the less experimented ones to those with the least amount of damage. It was decided that it was much more efficient to have only one evaluation form and that groups of inspectors be assembled of at least two persons each, in order to gain a much more trustworthiness in the concepts. It was also possible to conclude that in case of doubts and if a second professional opinion is needed, it is much easier to make it with the same form thus facilitating the systematization and comparison of results, though it is expected that these cases be the exception and not the rule.

The analysis of the different collected forms allowed determining the objectives that a unique form shall fulfil:

- To keep a record of the inspection and its results
- Establish a common vocabulary to be use in the description of the damage and the vulnerability of the building
- Guide the evaluation of the relevant elements that can affect the safety and habitability of the building
- Unify the criteria for ranking the habitability by trying to reduce as possible the subjectivity
- Provide the necessary information on the building and all the emergency procedures related with damage management or handling
- Provide certain basic data that allows a preliminary appraisal or valuation of economic losses due to damage in the buildings

A form divided into 17 sections was designed that allow the data collection: cadastre information, type of inspection, identification of the building, description of the structure, damage status of the building, global stability, geotechnical problems, damage in structural elements, damage to non-structural elements, percentage of global damage, classification of the habitability, pre-existing conditions (vulnerability), general recommendations and safety measures, effect on tenants or occupiers, occupation of the building, contact name, commentaries or remarks, inspection commission, date and time of inspection , building scheme and pictures.

Field book
As a support tool a pocket size handbook was designed, illustrated with pictures and figures that help the professionals to fill out each one of the blank sections of the form.

In this document the necessary procedures are detailed for the individual evaluation of each building, the criteria for ranking the damage, definition of risk levels and definite ranking of habitability. In the same manner it was included a brief description of the failure mechanisms of the different structural systems for a better comprehension of the type of damage and its implications.

Expert system
In order to undertake a good evaluation process of the damage, it is important to have access to experimented inspectors that have expertise in this area. However, when a seismic event happens of considerable magnitude, the damage in the area can be so generalized, that it is not possible that the experts be put in charge of making all the evaluations. This problem makes it necessary that a considerable number of the evaluations be made by professionals with very little or no experience at all, that are possibly not aware or ignore the kind of damage that is related or caused by seismic movements.

Usually, for neophytes, the impact when they see the damage is so great that they tend to rate them as a more severe case than what they really are, and thus, on many occasions they underestimate really severe cases that do not seem to be as severe. It is possible, due to what has been explained, that due to the inexperience of the inspectors many errors are made like demolishing buildings that perhaps were not under so severe conditions, or have them evacuated without a real need, which turns up to be really severe and serious in the case of essential buildings. It is also possible to ignore or undetect building failures that compromise its stability, thus risking the lives of their occupants.

The proposed model uses the fuzzy logic approach motivated by the incomplete and subjective character of the information. Post earthquake damage evaluations use qualitative and linguistic expressions that are appropriately handled by the fuzzy sets approach. On the other hand, an artificial neural network (ANN) is used to calibrate the expert system using the criterion of specialists. This enables the use of computational intelligence for the evaluation of damage by neophytes. The model has been implemented as a Visual BASIC 6.0 computer program, and has been called Earthquake Damage Evaluation of Buildings, EDE. The module is user-friendly and offers aids to the inspector, such as detailed descriptions and damage pictures [20].

Methodology of the evaluation
The methodology allows: the evaluation of the extension and severity of the damage; the definition of the severity of the damage into five (5) categories (*none, light, moderate, heavy, and severe*) according to each and every type of elements and each and every structural system; the classification or ranking of damage oriented towards the definition of risk criteria related with the global stability of the structure, geotechnical problems, structural damage and the dangers for the safety of the occupants which are represented by damage caused to the non-structural elements; the definition and classification of the risk into four categories (*low, low after measures*, *high and very high*) from the evaluation of the severity and extension of damage; establishes the form of combining the different risk levels to define the habitability of the buildings from the four types of risk *(global stability, geotechnical problems, structural damage and non structural damage)* and the four risk levels; the inclusion of elements that allow by shadows to orient or guide the ranking or classification of the risk by taking into consideration the safety measures, discriminate the safety measures according to the type of elements affected; we have also included in the manual or handbook the description of the failure mechanisms of the different structural systems for a more adequate comprehension of the type of damage and its implications.

Hereinafter we describe the criteria used to evaluate the status of the building and classify or rank the habitability based on the quantification of the extension and the severity of damage.

GLOBAL STABILITY OF THE BUILDING

To evaluate the stability of a building it has been included two (2) aspects: the presence or absence of a collapse by establishing if it is *total, partial and lower than the 50% or greater than the 50%* of the area of the building, and the possible leaning of the building, which is classified into *evident, with doubts or none*.

The revision of the global stability of a building is the best indicator that the structure or some elements of the structural system have reached an ultimate limit state. These has to do with a structural collapse of the whole or part of the structure and it happens due to different causes Arango, Jesús H [21] :

- **Loss of balance** of a part or of the whole structure, when it is considered as a rigid body. Such kind of failure generally involves the sliding of the whole structure and this happens when the necessary reactions for balance cannot be obtained.
- **Breakage of critical parts** of the structure generating a partial or total collapse of the structure.
- **Progressive collapse:** In certain cases, a minor local failure can cause the adjacent members to be overcharged and fail, causing at the same time overloads to other members until the whole structure collapses.
- **Formation of a plastic mechanism:** This happens when plastic joins are formed on various sections of elements, which make the structure to become unstable.
- **Instability due to deformations of the structure:** This kind of failure includes local bending due to the effects of gravity loads.
- **Fatigue:** The fracture of members due to repeated cycles of stress that can cause the collapse of a part or of the whole structure. This is considered to be an ultimate limit status since it leads to a structural collapse despite the fact that failures due to fatigue result from the applications of repeated service loads.

RISK DUE TO GLOBAL STABILITY

Whenever an building has undergone a partial collapse or it is leaned it is considered as unsafe or as something that represents risk, depending on the failure mechanism, the percentage of the affected area, the floor level where it takes place, etc., since the weight of the failing portion can cause additional momentums on the structure and therefore causing the over turning of the construction or it can produce the total collapse as a cause of an aftershock. These conditions are classified under Table 1 with the purpose of guiding in an approximate manner the general risk definition of the building.

Table 1. Classification of Risk Level with respect to damage

Risk Level	Description of Damage
Very High	Buildings that have reached ultimate limit states, with total collapse or partial above 50%, notoriously inclined, with floors wholly leaned that represent a danger if entered, or to surrounding buildings or to the circulation of vehicles or pedestrians in its surroundings
High	Buildings with partial collapse of less than 50% and above 5%, whose part of the non collapsed structure is not overloaded or in conditions of suffering a progressive collapse

Risk Level	Description of Damage
Low after measures	There is a collapse or very punctual leaning of some elements (less than 5%), which once these are shored representing a danger for the stability of the building or the safety of its occupants
Low	There is no collapse, building inclination or leaning of any floor

GEOTECHNICAL PROBLEMS

Within this group there are two (2) variables, namely: soil settling or liquefaction and slope failure or mass movements in general. This group of variables, affects the global condition of the building, so even though the severity of the phenomenon goes unrated it is important however to take into consideration the extension and the degree of compromise to building stability when it comes to safety evaluation.

With the purpose of finding out if the mass movement is due to or not to old processes of instability, its source is classified in four categories: *1. Produced by the earthquake, 2. Aggravated by the earthquake, 3. Pre-existing and 4. With doubts*.

The site morphology permits the description of the topographic position of the building, by way of denominations such as: *summit, divisory of peak, slope shoulder, slope, footslope, floodplain or toe slope, river bank and channel*. When these are related with cuts that are anthropically done, for road development, urban development or any other type of intervention these will be classified as oversteeped slopes.

According to the characteristics of the time in which the visit is done to the evaluated site, and to the visible signs the reactivation potential can be classified in the following form:

- **Low probability:** The phenomenon has evidence of reaching its stability, and it does not exhibit any particular signs of deterioration or advance either over the displaced mass or over the related infrastructure.

- **Probable:** Despite the fact that the phenomenon exhibits evidence of reaching its stability and that it does not exhibit any particular signs of deterioration or advancement either over the displaced mass or over the related infrastructure, its surroundings exhibit unfavourable conditions to reach the balance.

- **Very probable:** There are signs like stress cracks, unevenness and recent steeps that are slowly advancing, some terraces are exhibited, cracks or deformation of civilian works that have happened in the past few months, moderate to low contribution of waters towards the unstable mass. In the same way, when masses or blocks can be differentiated as being moderately unstable to collapse or land slides, whether this happens due to structural failure (i.e. loose or friable material, or material with matrix lost or very high fracturing) or due to the relative position at the slope under the action of the tangential component of the gravity that exhibits a reactivation potential in the mid term (various months).

- **Imminent:** There are signs like stress cracks, uneveness and steeps that are very recent which advance in the last days or weeks, evident terraces, cracks or deformation of civil works of recent occurrence and an abundant contribution of waters towards the unstable mass. In the same way, when masses can be clearly differentiated as masses or unstable blocks to collapse or sliding, whether due to structural failure (i.e. loose or friable material, or material with matrix lost or very high fracturing) or due to the relative position in the slope under the action of the tangential component of the gravity, that shows evident reactivation potential in the very short term (days, weeks, or a few months).

GEOTECHNICAL RISK

In order to classify the geotechnical risk, it is recommended to take into consideration aspects like the advance status of the phenomenon and its reactivation potential, the localization and relative proximity of the buildings with regards to the area of the occurred event, or the area of potential influence in front of a reactivation or advance of the phenomenon, Campos and Guzmán [22]. The distances between the buildings and the potential area of influence due to advancement or reactivation, cannot be established in a rigid form, since these will be a function of the type of phenomenon, its dimensions, the characteristics of the topography, the type of soils, the existence or non-existence of certain characteristics (stress cracks, water, etc.). In the same manner, the relative position of the building with respect to the phenomenon (above or to the base of the crest, to the lateral limits, over the body or adjacent to it, etc.) and other geotechnical aspects and geological aspects that shall be selected for each particular case under the professional criteria of the individual in charge of performing the inspection. Under such considerations the geotechnical risk classification is established in Table 2.

Table 2. Classification of Geotechnical Risk

Risk level	Description of damage
Very High	• The geotechnical phenomenon (mass movement, subsidence or liquefaction), produced severe failures in the foundation structures or there are problems like sinking, deformation, or leaning of the building. • Whenever the building, regardless of the fact that it has suffered damages or not, is located on or very near to the area of potential influence due to advancement or reactivation of the phenomenon, and the potential of reactivation is imminent or very probable.
High	• The geotechnical phenomenon is localized but suggests a very meaningful decrease of the soil capacity to resist the vertical loads of the building. • When the building, whether it suffered damage or not, is located at a certain distance, that is still insufficient to exclude it from the area of potential influence due to advancement or reactivation of the phenomenon, and the reactivation potential is considered to be imminent to very probable.
Low after measures	• When the building unit is not located in the area of influence of the phenomenon, but it is near it and there are clearly no conditions whatsoever that can make the occupation of the construction something unsafe, though certain recommended preventive measures are given considering the fact that the reactivation is probable.
Low	• When the phenomenon did not produce damage on the building and it has been classified with a lower reactivation probability.

DAMAGE TO STRUCTURAL ELEMENTS

The structural elements being evaluated depend on the structural system with which the construction was built with: beams, joints, columns, walls, etc. For each one of the structural systems and at each damage level *none, slight, moderate, heavy or severe* a brief description is given that facilitates its classification (see example Table 3) a percentage shall be assigned (equivalent to the amount of extension) of the damage depending on what was detected or perceived by the inspector. From the information of the damage (level and percentage) that occurs in each type of element and to the one from the remaining structural elements involved we obtain the idea of the gravity or seriousness of the damage on the floor or the plant with the heavier damage. The percentage of damage is determined as the proportion between the number, area or longitude of affected elements and the number, area or total longitude of elements of this type on the floor.

Table 3. Description of damage levels in reinforced concrete elements

Damage Levels:	Damage Description
None / very slight	Visible but narrow cracks on concrete surface. Crack width is less than 0.2 mm.
Slight:	Visible clear cracks on concrete surface. Crack width between 0.2 mm and 1.0 mm.
Moderate:	Cracks width on concrete surface between 1.0 and 2.0 mm. Spalling of concrete covers.
Heavy:	Remarkable crush of concrete, loss of concrete covers with exposed bars.
Severe:	Rebars bent, core concrete crush, visible vertical deformation of column or shear wall, visible settlement and or excessive inclination.

STRUCTURAL RISK

According to the structural system of the building being inspected, there are a few elements, whose importance within the structure is so noteworthy, that if these have suffered very severe damage, even though the rest of elements do not present any important damage, the building is at risk of losing its stability. In Table 4 a detailed description is provided of the risk level according to the damage on the structural elements, considering a combination of severity and extension.

Table 4. Classification of Risk level due to damage on structural elements

Risk level	Description of damage
Very High	• Buildings that suffered permanent damage (severe) to its structural vertical elements (columns) in structural systems based on momentum resistant frame or systems based on structural walls: Severe damage in most of 15% of all vertical elements Severe damage to more than 20% of beams or slabs • Notorious decrease of the capacity to resist vertical or lateral loads in such a proportion that there is potential unstableness. Heavy damage to more than 30% and moderate damage to over 60% of the vertical elements Heavy damage to more than 40% of horizontal elements • The floor system on which these vertical elements find their support on presents settlements or vertical deformations near to a condition of leaning, the structure will not have the sufficient amount of resistance in front of lateral forces to support an aftershock of the main event. Also in certain cases in which the degree of damage in columns and structural walls presents permanent deformations in the same, will make to think that the capability of these elements to support the floor system will be seriously affected.
High	• Decrease in the capacity to resist vertical or lateral loads but there is no potential unstableness. • Buildings that suffered important or considerable damage in their vertical structural elements: Severe damage between 5 and 15% of the elements, heave damage between

Risk level	Description of damage
	10 and 30% or moderate or slight damage between 30 and 60% • There is a risk associated to the entry, use or occupation of the building, due to the decrease of its earthquake resistance capacity, due to the extension of the damage or due to the presence of elements that might fall at the principal exits and staircases. • Access to building shall be controlled its usability should be conditioned to its reinforcement or shore up.
Low after measures	• There is a punctual danger for damage to structural elements, (severe damage in less than 5%, heavy in less than 10% and moderate in less than 30%), but they do not reduce their global capacity of resistance nor endanger the stability of the structure. • There are clearly no conditions that make the occupation of the building unsafe, but the damage observed impedes that a total occupation can be obtained and the access to certain sectors should be restricted, whose occupation can be conditioned to the repair or shore up of the elements that represent a danger.
Low	• Buildings that suffered very punctual slight damage to the structural elements (in less than 30% of the elements), that do not endanger the inhabitants or the structure. • Buildings that do not seem to have any type of damage

DAMAGE IN NON-STRUCTURAL ELEMENTS

The non structural damages are due to the inadequate union between the filling walls, the installations and the structure, or to the lack of stiffness of the structure, which translates into excessive deformations that cannot be absorbed by this type of components. The most common damages are the cracking of the masonry filling walls, the crushing of the joints between the structures and the non-structural elements, the falling off of finishing details and window breaking and of installations of different sorts. The failure or falling off of non structural elements can represent a risk for the life but it generally does not generate the collapse of buildings.

To evaluate this type of damage, the elements that have been considered are those that even though they do not put at risk the stability of the building they do represent a risk for the life and safety of its occupants. A rating is given to each one of the variables within the five possible levels of damage that are described for each type of elements. The rating shall be assigned depending on what the inspector sees that predominates at the building, because it will always be possible to find elements with different levels of damage in different floors.

NON-STRUCTURAL RISK

Damage that has occurred on non.-structural elements, generally do not imply a danger to the global stability of the building, but they can put in danger the lives of the occupants, though in some cases this danger can be depleted or minimized with safety measures of easy and quick application. Due to the above, normally only three risk categories are considered (*low, low after measures and high*).

Risk on the non-structural elements is evaluated by considering if these have been loosen, if they have the possibility of falling off or collapsing and affect the strategic zones like the entrees to buildings, or apartments, circulations, etc or are damage that endanger the lives or the integrity of the occupants.

Table 5. Definition of Risk level due to Non-Structural Damage

Risk level	Damage Description
High	• There are generalized severe or heavy damage and they are dispersed all around the building • Facade elements, balconies, parapets, ceilings, elevated or raised tanks or other elements that might fall • Presence of toxic spills, danger due to broken gas lines or fallen power lines
Low after measures	• Damage is concentrated around a small area and it is possible to restrict the access to unsafe areas by placing barriers that restrict the passage of vehicles or pedestrians
Low	• Damage is minor and very punctual and they do not generate any danger to the integrity of people • There are no damages in non-structural elements

CLASSIFICATION OF THE HABITABILITY OF A BUILDING

The habitability of a building can be defined by the safety and comfort requisites that permit to consider that it is still functional despite the damage. There are no clear definitions of habitability in the literature, but it was considered to be pertinent to adopt the Italian proposal, of Goretti [12], as a definition of habitability we have: *"The post earthquake usability evaluation is a fast and temporarily limited assessment, based on expert judgment, on visual screening and on data easy to collect, aimed to detect if, during the actual seismic crisis, buildings damage by earthquake can be used, being reasonable safeguarded the human life"*.

It is deduced that more damage can occur in case of an aftershock, but in order to declare it as usable it is important to check if the building can still be considered safe for life. It is important to consider, that it is not desirable to cause unnecessary problems to the occupants by determining to make an evacuation of a building with minor damage, but on the other hand, it is important to avoid exposing them to unnecessary risks.

Once the inspection of the building has been done and being aware of its capacity to resist loads, its ductility and redundance and the possibility of a fall or overturning of objects that represent a danger for the life and if the danger can disappear by removing the non-structural elements, the habitability of the building is classified into four categories: *Usable, Restricted Use, Unusable and Collapse Danger* according to the criteria established in Table 6 being aware of : *the risk for global stability, the risk due to geotechnical problems, risk due to structural damages, and the risk due to non-structural damages*.

Table 6. Classification of the habitability based on risk levels

Usability	**Risk Level Description**
Danger of collapse	If one or more assessments are classified as VERY HIGH RISK or two or more of HIGH RISK are given
Non unusable	If at least one rating of HIGH RISK was given
Restricted Use	If at least one rating of LOW RISK AFTER MEASURES is given
Usable	If the four risk classifications were LOW

In addition to the already mentioned aspects the pre-existing conditions are also evaluated, which can be included or left out within the damage evaluation according to the criteria of the inspector, considering the fact that in some cases the damage in structural elements is so severe, that the presence of some good pre-existing conditions do not help in improving the building appraisal. The idea of evaluating the pre-existing conditions is to know about the seismic vulnerability of the building, in other words its susceptibility to suffer additional damage in case of a particular seismic event. The seismic vulnerability is evaluated as a function of aspects like the geometry of the structure, building aspects, structural aspects, damage and repairs due to former seismic events and land conditions.

CONCLUSIONS

The main elements to take under consideration for a methodology of post-seismic evaluation are: the classification of damage, the definition of the usage possibilities of the buildings that suffered the damage, the reorganization of the data collecting and the analysis and data processing. In order to perform this task in an efficient manner, it is fundamental to first establish the inspection commissions that have to be very well trained in each sector and prepare the systematic inspection plans. The success of the procedure of data collection mainly depends on, besides the training of the professionals, on the adequacy of the instruments used such forms, the evaluation manual, the supporting software for the non-expert inspectors, and data processing; all the instruments shall be consistent among them and should be considered for the city contingency plan due to earthquakes.

The fast and detailed evaluations that are suggested by the different methodologies are not too different, they are based on the needs of making a first filter with the least experienced professionals, which with good training procedures and the aid of an expert system (computer program) that can support the decisions of the neophytes is capable of solving the problem of having to visit the same building twice. It was concluded that it is much more efficient to have a unique evaluation form and constitute very well trained and conformed inspection groups by at least two (2) persons in order to have a greater trustworthiness in the concepts. If a second professional concept becomes necessary, it is better to make it with the same form and simply schedule a second visit made by an expert, hoping that these cases are the exception and not the rule.

The classification or ranking of the damage of the building and of its habitability, based on the results of the inspection on the global conditions, the damage to its non-structural and structural elements and the geotechnical conditions of its surroundings, with a very good definition of damage levels *none, light, moderate, heavy and severe*, a description of the risk level based on the combination of the severity of the damage and the extension of the same, as well as the implications that this might have in the habitability of the buildings, are a very meaningful advance, since it provides more and better criteria to the inspectors.

It is important to remember that the criteria and experience are essential to determine the damage and the risk level that these represent as well as to determine the habitability of a building. Not all the dangerous situations are possible to be included in a handbook or manual, thus the good judgment and experience of the inspectors will always be necessary and if they have doubts, additional help shall be obtained from more experimented persons.

Perhaps one of the most important and novel contributions of this work, not only in the country but also internationally speaking, is the elaboration of a computer application or expert system based on artificial neuronal networks, to support the evaluation done by non-specialist professionals that enables the possibility of providing more trustworthiness to the process, trying to avoid the serious errors that have systematically been made in the past due to lack of experience and criteria of the most inexpert inspectors.

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