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Field Manual for post-earthquake damage and safety assessment and short term countermeasures (AeDES)

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PREAMBLE

Earthquake and landslide risk is a public safety issue that requires appropriate mitigation measures and means to protect citizens, property, infrastructure and the built cultural heritage.

The LESSLOSS project (Risk Mitigation for Earthquakes and Landslides) addresses natural disasters, risk and impact assessment, natural hazard monitoring, mapping and management strategies, improved disaster preparedness and mitigation, development of advanced methods for risk assessment, methods of appraising environmental quality and relevant pre-normative research.

LESSLOSS was organized in 11 scientific sub-projects complemented with dissemination and training activities. The main objectives of the training activities are:

1) To produce training material (technical reports, presentations, CDs and web-based application) on the different topics covered by the project (state-of-the-art material and material resulting from the project research work);
2) to provide training of researchers, technical communities and local authorities (technical personnel) through a series of workshops taking place in different countries (nine workshops) and the final international workshop;
3) organization of training courses on emergency management (EM) issues (EM Systems and training of technicians) and production of corresponding training material;
4) work towards more harmonized approaches on Earthquake Emergency Management Systems in Europe.

The **LESSLOSS Training Activities comprised** two main lines of action: organisation of workshops and training courses and production of training material, as follows:

Workshops: one major International Workshop addressing Stakeholders and the relevant scientific/technical User Communities was organized (19-20 July, 2007). This event was scheduled for the end of the project and constituted a major instrument for training and dissemination, since it was devoted at disseminating the up-to-date and effective guidelines and recommendations for mitigating landslide and earthquake losses that are the product of the LESSLOSS project. The workshop took place in Belgirate (Italy) and included also presentation and approval of the Strategic Research Agenda (SRA) for the European Earthquake Engineering Community.

In addition, nine complementary scientific/technical workshops were organized by the different sub-projects in several European countries. These consisted of dedicated workshops organised by Sub-Project coordinators, meeting specific user groups needs (e.g., local professional associations, local city council members, etc.) with a view to describe and provide training guidance to local professionals on the basis of the results and activities of LESSLOSS.

Production of Training Material: Within the scope of the Dissemination and Exploitation plans, material such as leaflets, multimedia CDs, web-based applications, printed reports, etc., were produced and edited with the aim of not only serving as a means of results dissemination, but also of becoming valid and effective training and guidance tools to be used by relevant professionals. The most elucidative example of which is the **LESSLOSS Report Series,** which comprises the following titles: **1)** Landslides: From Mapping to Loss and Risk Estimation; **2)** European Manual for In-Situ Assessment of Important Existing Structures; **3)** Innovative Anti-Seismic Systems Users Manual; **4)** Guidelines for Seismic Vulnerability Reduction in the Urban Environment; **5)**

Guidelines for Displacement-based Design of Buildings and Bridges; **6)** Probabilistic Methods for Seismic Assessment of Existing Structures; **7)** Earthquake Disaster Scenario Prediction and Loss Modelling for Urban Areas **8)** Prediction of Ground Motion and Loss Scenarios for Selected Infrastructure Systems in European Urban Environments.

Other effective initiatives were developed during the project, namely the organization of a Training course on Emergency Management (Pavia) and discussions with Civil Protection Agencies in different European Countries were undertaken by the Italian civil protection agency – Dipartimento della Protezione Civile (DPC) – in order to work towards more harmonized approaches on Earthquake Emergency Management Systems in Europe.

The present report aims at contributing to a harmonized approach in Europe for damage assessment, short term countermeasures for damage limitation and evaluation of the post earthquake usability of ordinary buildings. It results from the Italian long-term and recent experiences (Assisi, San Giuliano di Puglia) on post-earthquake assessment and tagging of buildings and is considered important as there has been a sustained progress in Italy in this field, which can be shared with other European / Mediterranean countries with similar constructions.

The publication of this report by the JRC is justified by the fact that JRC, as coordinator of LESSLOSS Training Sub-project, has always encouraged DPC to foster for cooperation between European Civil Protection Agencies and to share its experience with European earthquake prone countries. Furthermore, the JRC, according to part of its mission should serve as facilitator for an extended European cooperation, especially in areas related to its institutional programme. The topics addressed in this report are also relevant to the objectives of the JRC institutional Action – SAFECONSTRUCTION.

The Editors are very grateful to the DPC, especially to the authors and translators of the report and further encourage them to pursue the overriding objective, which is to work towards an effective co-operation of the European Civil Protection Agencies and to achieve the most advanced methods and procedures for risk mitigation and emergency management.

Joint Research Centre (JRC), Ispra
July 2007

The Editors:
Artur Pinto and Fabio Taucer

FOREWORD

Among post-earthquake activities, significant issues are the damage and safety assessment, for post-earthquake usability. Usability actually defines the limit between people coming back to their houses and people waiting in provisional shelters or in temporary houses. This turns out in the limit between the continuity of the administrative and economical functions and the slowing down of the activity of an entire and complex social context. The consequences in terms of social and economical impact are apparent. However usability also represents a delicate diagnosis moment for the structure in view of possible strong aftershocks, on which the safety of all the people leaving there relies.

These activities have evolved during the years based only on the continuous experience of the technicians involved in this task. In order to be fast and effective, there is a need for procedures, technical instruments, trained personnel, operational management groups, collaboration of administrations and authorities.

All over the world, during post earthquake surveys, inspection forms have been extensively used, since they provide a series of advantages. They provide a *check list* guiding the surveyor; they standardise a damage survey for a whole building stock affected by the earthquake and improve judgement homogeneity; they facilitate immediate computerisation and, hence, statistical treatment of the collected data.

For long time, post earthquake surveys in Italy have been carried out using *vulnerability forms* prepared by the National Group for the Defence against Earthquakes (GNDT). Actually, these forms were conceived to detect vulnerability and damage, without any specific concern for building usability. For this reason, in the years 1996/7, a joint working group of the National Seismic Survey (SSN) and GNDT created a specific tool (AeDES) for damage assessment, short term countermeasures for damage limitation and evaluation of the post earthquake usability of ordinary buildings.

The AeDES survey form was optimised in order to limit the time required for each inspection, avoiding the request for information difficult to get during a visual inspection. However, it collects the information needed for an expert judgement on usability, based on as objective as possible data on vulnerability and damage. This choice results in a required inspection and evaluation time of the order of some hours. It is not, therefore, a tool for a fast usability assessment to be accomplished in the first hours or days after an earthquake, but rather for more sounded decisions, once the immediate emergency needs have been fulfilled.

The compulsory path that the surveyor must follow in its inspection, will lead to more uniform decisions about usability and eventually needed countermeasures. However, additional precious outcomes of this kind of survey are related to the availability of well structured and standardised databases. They are of paramount importance in the post-earthquake reconstruction process, e.g. for analytical cost evaluations or for detection and evaluation of seismic amplification effects, but also for scientific purposes, as it includes information on both damage, building features and vulnerability, all together necessary to obtain experimental fragility curves.

The occurrence of the Umbria-Marche earthquake on September 26, 1997, accelerated the application of the AeDES form, whose preliminary version was utilised by the Italian Civil Protection Department during the operations following this earthquake. The AeDES form, was then used also after the Pollino earthquake of September 1998, then at Patti and in the area of Frignano in 1999, and after the earthquake of Monti Tiburtini of 2000. It was subjected to some modifications, reaching the current final version in November 2000. It was then used after the S.Venerina earthquake and the S.Giuliano earthquake in 2002, and in all the subsequent small earthquakes that struck the Italian territory. Up to now the Italian experience with this survey tool is relevant to more than 100.000 buildings.

This ten years experience extended to all the Italian territory has proved the conceptual validity of the approach. We hope that the present English translation will extend its use and usefulness to other countries.

The advances in information and telecommunication technologies can improve the practical procedures, speeding up the survey organisation, the inspections, the data collection, the data check and transmission, the data base management. This is the direction the Italian Civil Protection Department is working, within the framework of the operations finalised to the general improvement of the Civil Protection System response.

Finally, all the people who have devoted for long time their work and enthusiasm to the realisation (some tens), application (some hundreds) and continuous improvement of this tool are greatly acknowledged.

Professor MAURO DOLCE
Director of the Seismic Risk and Post Emergency Office of the Italian Civil Protection Department

1 INTRODUCTION

1.1 Motivations and objectives

The first level form for post-earthquake damage assessment, short term countermeasures and usability assessment of ordinary buildings, AeDES, aims at surveying the typological, damage and usability characteristics of residential buildings, in the emergency phase following an earthquake.

Buildings are interpreted as structural units of ordinary constructional typology (typically masonry, reinforced concrete or steel, etc..), used for habitation and/or services. Therefore, the application of this form to buildings of very particular structural typology (industrial warehouses, sport structures, theatres, churches etc..) or to monuments is excluded.

The form allows a quick survey and a first identification of the building stock, with the collection of metrical and typological data of the buildings. These data, together with the damage data, are also useful for a first evaluation of the repair and/or retrofit costs, allowing to create costs scenarios for different unitary contributions associated to different damage thresholds.

Even if the final judgment remains a competence of the surveyor team, this form is a useful tool for the evaluation of usability. It indeed keeps track of the inspection and of the corresponding evaluation and it tries to establish a common language for the description of damage and vulnerability. Moreover, it provides a guided way which, starting from the surveyed components, takes to the evaluation of risk, and therefore to the evaluation of usability. Finally, it allows a better computerization of the data (which can even be obtained from the form through an optical reader).

The form is the outcome of the field experience, matured after several past earthquakes, when forms with different levels of detail were used (Irpinia ’80, Abruzzo ’84, Basilicata ’90, Reggio Emilia ’96). A previous version of the form, very similar to this one, has been tested with satisfactory results in the most recent earthquakes (Umbria-Marche ’97, Pollino ’98). Its long elaboration involved a group of researchers and experts of the National Group for the Defence against Earthquakes (GNDT) and the National Seismic Survey (SSN). The present form comes from the optimisation of the different needs of the way from the survey to the final decision (being it about usability or economical evaluation of damage), trying to avoid the collection of data which are not very significant for the scope of the survey, or which are difficult to know or unreliable, and always keeping in mind the emergency intervention purpose of the survey. It is thus possible that some characteristics, even if significant from the point of view of the seismic behaviour and vulnerability of the building, would not be included in the survey form.

The same group of researchers and experts has already scheduled the preparation of more accurate second and third level forms, for specific building typologies (such as buildings with reinforced concrete bearing structure), developed coherently with the first level forms. These more accurate forms are supposed to be used after the emergency for more detailed vulnerability analyses and/or for more precise reading and registration of the damage, or as a support to systematic programs for risk reduction.

A peculiar characteristic, distinguishing the AeDES form from the other forms used in the past, concerns the typological classification of the different constructional components. In the forms used until 1997, the typology was directly identified based on the characteristics of the materials, following a purely descriptive approach. This type of classification shows significant limits when applied to situations different from the reference one. In fact, although in the most recent releases of the first level GNDT form [1, 2] the typological classification of structural components was very detailed (for example, 18 different types of vertical bearing structure were considered and 9 types of horizontal structure), as a matter of fact, some ambiguities, inaccuracies and systematic mistakes (see for example [3]) in the typology classification have been found.

The figure of the surveyor was essentially limited to the role of recognizing by visual inspection the *aesthetical* characteristics which are as close as possible to those described in the form, without any reference to the vulnerability judgment. At the basis of this descriptive approach was the wish of obtaining an objective picture of the building characteristics, without any personal opinion or interpretation of the surveyor. As a matter of fact, this approach showed important limitations, mainly due to the following 4 factors:

1. impossibility of considering in the form all possible typologies of constructive components, even if operating within a limited context, such as the provincial or municipal scale;
2. difficulty in recognizing the different typologies;
3. variability of the typologies within the same building;
4. variability of the seismic behaviour of typologies which are "aesthetically" similar and which therefore are classified as equal.

The solution to these negative issues of the descriptive approach has been identified in the past in an increase of the possible typologies and in a more and more accurate description of the distribution of the types of different constructive components at different floors. All this, although necessary in the descriptive approach and in its general philosophy, led to an excessively heavy survey and to a lower reliability of the data.

The only possible solution to the issues described above was to overturn the philosophy of the survey, bringing back the classification to the interpretation of the seismic behaviour of the different constructive components and involving, hence, in the judgment the surveyor itself. Therefore, the approach has been changed from descriptive to behavioural. It is well recognized, in fact, that despite the many typological varieties of a single structural component (for instance, for masonry, the inert materials, their shape, their structure, the layout of the wall, the mortar, etc., all have a significant influence), the expected behaviours during a seismic event can be grouped in few types. Accordingly, the survey form becomes much simpler if reference is made only to these few types of behaviour. This simplification determines generally a higher reliability of the data, provided that the synthesis requested to the surveyor (i.e. the step from the *aesthetic* to the behaviour classification) is well guided.

1.2 The usability judgment

Despite the fact that, at least in Italy, a definition of usability has never been codified, usability may be related to the need of using the building during the seismic emergency, being reasonably safe from the risk of significant damage to people. For this reason, the usability assessment does not aim at safeguarding the construction from further damages, but only at preserving the life of occupants.

A quick and correct building evaluation is of great relevance for the retrieval of normal living conditions, but it is also very delicate and full of responsibility. It is relevant because it allows to reduce the troubles for the population affected by the event. It is delicate because it implies the public safety, in case usability is declared, while it requires to find alternative shelters, in the opposite case.

Usability surveys are characterised by a very large number of calls for inspection after the seismic event, by the need of providing answers in a short time and, more in general, by the emergency situation. They need to be carried out very quickly, based on information which can be immediately deduced and on their interpretation. For this reason, the usability judgment does not represent a safety assessment, nor it substitutes it. It is not generally supported by calculations, but it is only based on expert judgment; it is not definitive, but temporary; it does not have, finally, a precise objective in terms of risk.

Considering all this, usability can be defined as:

The evaluation of usability in the post earthquake emergency is a temporary and rough evaluation – i.e. based on an expert judgment and carried out in a short time, on the basis of a simple visual inspection and of data which can be easily collected – aiming at determining whether, in case of a seismic event, buildings affected by the earthquake can still be used, with a reasonable level of life safety.

This definition assumes the knowledge of the maximum intensity expected at the site during the seismic sequence, i.e. the knowledge of the event which can be used as a reference in the formulation of the usability judgment.

While in the design of a new structure, it is the code which defines the reference seismic action, in the usability judgment, the reference event has not been yet codified.

In particular, if the reference seismic event corresponds to the maximum intensity experienced at the site during the current seismic sequence, the usability judgment would be more certain and therefore the number of unusable buildings and of homeless people would be smaller. This hypothesis is generally on the safe side in the epicentral zones, where it is quite unlikely to have aftershocks stronger than the main event. Nevertheless, in case of migration of the epicentres, such as in the recent events of Umbria and Marche 1997, but also in the earthquake of Friuli 1976, it is possible to have, in non epicentral zones, aftershocks which are stronger than those felt up to that moment. In these zones, which are also the largest zones, the assumption of a reference event one or two degrees of intensity more severe than what has been felt, on one hand is on the safe side, but on the other hand it implies usability judgments which are less certain and it determines a significantly larger number of unusable buildings and homeless people.

Since the usability judgment must be as much as possible objective, it is appropriate that the reference event is the same for all the surveyors and hence it should be established before the survey. It is not, indeed, admissible, due to the specific skills (engineers, architects and draughtsmen do not have the specific knowledge required to establish the reference event), to the responsibilities and finally to the necessary homogeneity of judgment, that each surveyor, at least implicitly, assumes “his own” reference event, with respect to which he would formulate his usability judgment.

However, in the current emergency management politics, the reference event has not been explicitly defined, nor it has been established who is in charge of providing this event, for each site. The procedures used in other highly seismic countries, such as California and Greece, clearly suggest that the reference event for the usability judgment is comparable to the seismic event that has given reasons for the inspections. In this way, the analysis of the damage due to the earthquake may be the main, if not the only, *safety* indicator, since it is evidence of a more or less important modification of a state which has already been tested by the earthquake.

The observation and the interpretation of the apparent damage – detectable at a visual inspection – caused by the earthquake allows to identify the modifications suffered by the structural and non structural elements and also the seriousness of such modifications with respect to the reduction of safety of the building.

The observation of apparent damages allows, in case of significant damage (evident separation of walls, partial or total collapses, failure of frame joints), to immediately declare the unusability of the building for evident structural problems (and sometimes also the unusability of adjacent buildings due to the risk induced on other spaces and/or constructions). In case of non significant damages, on the other hand, it allows to understand which resistant mechanisms have been triggered, which modifications have been induced by the event on the structures and, hence, it allows to estimate the amount of reduction of the original resistance due to the seismic event.

It is not possible to provide clear rules on the quantification of the apparent damage, since it is obvious that also the sensibility of the surveyor plays a major role on this aspect. There are however some indications (see for example the contributions in [5]) to define the *seriousness* of the apparent damage: for instance, those codified by GNDT [1, 2] or those included in the recent european macroseismic scale EMS98 [4], to which reference is made in section 4 of the AeDES form and in § 4 of the current manual.

It is possible to base the usability judgment on the only damage experienced by the construction only in case the earthquake has been actually a *test* for the building. In non epicentral zones, however, a limited damage is not necessarily an indicator of a seismically resistant structure, since it may be due to a low seismic intensity. In these areas, and in case of migration of the epicentres, it may be worthy to formulate the usability judgment considering also some vulnerability indicators. These, indeed, may give an idea of the behaviour of the building in case of larger intensity earthquakes.

The main vulnerability indicators are codified in Section 3 of the AeDES form and are discussed in § 3 of the current manual. The set of vulnerability indicators is completed by the description of the morphology of the site where the building is located, reported in Section 7.

In order to facilitate a rough vulnerability evaluation by the surveyor, the required indicators are inserted in suitable cells having a grey background, with shade increasing as the contribution of the indicator to the vulnerability of the building increases. In particular, for masonry buildings, the three levels of grey may be considered as rough indications, useful to classify the building in the three classes of decreasing vulnerability A, B, C, as indicated in the european macroseismic scale EMS98 for ordinary buildings not designed according to seismic criteria. For unidentified structures, the scale of grey refers to the mean vulnerability of the possible configurations.

The vulnerability indicators, especially when particularly high, could imply an unusability judgment even in case of moderate or light damage (or in case of total absence of damage) if the reference event is of a degree higher than what felt by the building. This situation could happen, for example, in non epicentrale zones in case of a strong earthquake, when there are reasons to believe that the epicentre of following shocks could migrate.

1.3 Emergency management and surveyor's responsibility

In order to optimise the emergency management and the treatment of the collected data, the procedures should be unified on a national basis. They include for example:

- the definition of the reference event,
- the procedure for calling for an inspection,
- the *recruitment* and the management of the surveyors teams for what concerns a territorial limitation of the area of action,
- the compilation of the usability form,
- the computerization of the data included in the form,
- the procedures for the order of evacuation,
- the procedures for repeating some usability inspections in order to obtain a more detailed investigation and/or to evaluate variations of the building conditions.

In this organisational phase the responsibilities of the surveyor, both from an ethical and a juridical point of view, should also be defined.

In general terms, the definition of the juridical responsibilities of the surveyor - who is going to undertake, usually as a volunteer, the difficult task of deciding about the usability and hence about the normal use of a building, which can potentially be subjected to seismic shaking in the short period - is one of the crucial factors for the success of a good post-event management. It is evident that, first of all, the responsibility of the surveyor should not go behind his technical competences, which are those typical of people working in the technical field (engineers, architects, draughtsmen). It is hence not conceivable that the surveyor is charged with the choice of the reference event(s), that is a difficult task even for seismologists which are experts in this field. It is likewise evident that the assumption of responsibility by voluntary workers can only be limited to the correct execution of the survey and to the release of the consequent usability judgment, based on their professionalism. It is also evident that the responsibility of the surveyor should be limited in time, since it is related to an emergency condition, which ends at the moment of the following reconstruction. Finally, the responsibility will be smaller, since the judgment is less certain, in case the surveyor is asked, based on the level of damage and on the vulnerability of the building, to give his opinion on the behaviour of the building in relation to possible seismic events of much larger intensity than the one already experienced.

From what said above, the authors of this text derive the opinion that the responsibility of the surveyor can only include what is related to his bad faith or to his negligence in the fulfilment of his task.

This position is explicitly provided for by the Californian (USA) law, according to which disaster service workers are temporarily considered as non paid civil protection workers. As such, they benefit from the same privileges of officers and public workers and they receive the eventual refunds for accidents at work as established by the law [6]. The technicians evaluate the safety of the damaged buildings using their professional judgment at their best. According to the law, no disaster service worker operating by order of a recognized authority during the emergency phase can be civilly prosecuted for damages to things or people or for the death of someone, due to his action or omission during the service, unless the act is intentional [7].

The situation in Italy is somewhat different: the law concerning usability inspections in post seismic emergency is totally deficient and the jurisdiction is particularly penalizing the surveyor.

It is anyhow evident that the adoption of the present usability and damage form does not reduce the responsibility of the surveyor.

1.4 Manual contents

This manual extends the Instructions reported on page 4 of the form, with the aim of providing a tool for a correct training of the surveyors and for a full awareness of the principles of the form, as well as for the necessary homogeneity of judgment.

In Chapter 2, some information and guidelines on issues concerning the organisation of the damage and usability survey and the procedures for preparing and carrying out the building survey are given.

Chapter 3 provides a detailed description of each structural component, correlating it to the building component behaviour (thrusting or non thrusting roofs, masonry of good or bad quality, rigid or flexible floors, etc.). The layout of the data collection (i.e. of the form) relay on the personal opinion of the surveyor about the quality of the constructive components in the specific case under study. It is in fact possible that the manual does not consider a particular typology or that a given typology in a given area or in a specific building exhibits a seismic behaviour different from what can normally be expected, being it due to the maintenance state, or to the particular characteristics of a material used in that single case.

For the general considerations expressed in the previous sections, the guidelines of section 4, concerning the damage survey of the main structural components (Chapter 4), are very wide and exhaustive.

Chapters 3 and 4 have many pictures and figures attached, respectively in the abacus of the construction typologies and in the examples of seismic damage. They offer an important reference inventory for the surveyor, that can help him in understanding the relationships between the observed reality and the descriptive synthesis operated when compiling the form.

It is evident that a correct use of the form requires a complete understanding of the expected seismic behaviour of different structural components. This way, he can develop an independent ability in associating the typology to the behaviour, ability that he should use any time the encountered typology is not described in detail in the manual. An unquestionable advantage of this approach lies also in its didactic potentiality towards the inspectors. The need of giving in any case an opinion about each constructive component induces a global opinion about the building vulnerability which, associated to the damage assessment, produces a mature usability assessment (Chapter 5).

2 GENERAL INSTRUCTIONS AND GUIDELINES FOR COMPILING SECTIONS 1 AND 2: BUILDING IDENTIFICATION AND DESCRIPTION

2.1 Organisation of the survey

In the context of the post earthquake emergency - i.e. of all the activities aiming at evaluating the effects of damage to buildings, environment and infrastructures and reducing their consequences - the assessment of the building usability plays a major role, as already noted, due to its importance with respect to the need of shelter for the population and also due to the large number of technicians involved. Even for medium-low intensity earthquakes, the number of inspections to be carried out may easily reach the order of magnitude of several thousands of buildings. For this reason, it is necessary to define a clear procedure for the organisation and management of the whole operation.

The procedures and the operational tools for the technical management of the emergency have firstly been collected in a Manual [8], in which the damage and usability survey is actually organized according to a scheme which will be briefly described here, in order to clarify how the inspection is carried out, how the form is filled up and the meaning of some of its contents.

The organisation in short requires that: the assessment of buildings begins after a request addressed by the citizens to the mayor. A first organisational work of these requests is carried out within the municipality, in order to associate all the requests, generally referred to building units, that refers to the same structural unit. The mayor will then forward these survey requests to the Mixed Operative Centre (COM) or to another similar structure, from where surveyors teams, registered and organized, are sent to carry out the inspection. The surveyors then go to the municipality to indicate the survey activity to be carried out, they check the relative data, they collect useful information with the help of the local structure, they complete their task and then inform the mayor about the result. The municipality must be organized for the collection of the results (registers and cartography) and for the openings of the provisions of its competence, including obviously the incidental ordinance of evacuation issued by the mayor. The surveyors go back to the COM, where they deliver the completed form. The data collected are then computerized and used both for the activities of the COM and for possible future elaborations of scenarios.

From this brief description, the need for a central organisational structure (COM or similar), able to activate and manage a large number of surveyors, and the fundamental role of the municipal structure, for its competences and also for the knowledge it can share, become evident. Also it is necessary to establish an efficient connection between these two levels, in order to obtain an effective functioning of the activity.

2.2 Procedures for the execution of the survey

The survey must be conducted initially from outside. In case there are elements indicating that the building is immediately unusable, the surveyor should not proceed to the subsequent survey from inside. On the other hand, the absence of damage outside the building does not imply necessarily absence of damage inside. Overturning mechanisms, for example, at least at their initial stage, are generally not visible from outside.

During the survey inside the building, it is suitable to check all the levels of the building, from the basements or garages, to the attic. From these, when possible, or from outside moving away from the building, it is suitable to take a look at the roof covering.

Rather than a generic inspection of the building, it is suitable to look for evidences of damage in certain positions and according to paths related to the most common damage mechanisms.

It is preferable, on the whole, to finish the inspection, to obtain a general idea of the conditions of the building and to formulate a first hypothesis of judgment. Only in a second time, compiling the form and going again through all its sections, it is possible to check whether the guided way of the form takes to the judgment that has been initially foreseen.

In some cases, it could be appropriate to perform small tests on the mortar of masonry walls, or to remove some portions of plaster to examine the direction of cracks. More rarely it could be necessary to test the consistency of concrete, removing some portions of the concrete cover.

To obtain the maximum effectiveness of the surveys and also for the surveyors safety, it is necessary to have a minimum equipment, i.e.:

- an electric torch, useful to examine rooms without light (such as basements or attics);
- a meter and a chisel to perform tests on the materials;
- a pair of binoculars to look at far away details;
- a level or a plumb line to evaluate eventual out of plumb;
- individual safety devices (helmet, gloves, boots);
- camera; very useful are instant cameras, which allow to attach immediately one or more images to Section 9 of the form.

In case of repeated inspections on the same building, it is preferable to have the previous reports and to identify eventual provisional interventions carried out (Sections 4, 5 and 6 of the usability and damage form), in order to correctly evaluate the modifications to the structural and non structural components, due to the sequence of events, and to the short term countermeasures (for example removal of tiles or overhangs).

2.3 General rules and instructions

The form is composed of the following nine sections on three pages and of a forth page with the explanatory remarks on how to compile it:

SECTION 1 - Building identification
SECTION 2 - Building description
SECTION 3 - Typology
SECTION 4 - Damage to structural elements and short term countermeasures carried out
SECTION 5 - Damage to non structural elements and short term countermeasures carried out
SECTION 6 - External damage due to other constructions and short term countermeasures carried out
SECTION 7 - Soil and foundations
SECTION 8 - Usability judgment
SECTION 9 - Other observations

The surveyor must compile the form, partially writing some information in predefined spaces, partially blackening some cells, in each case according to the indications reported in Table 2.1.

Table 2.1 – Instructions for compiling the fields of the form

GRAPHICAL ELEMENT	INSTRUCTIONS FOR COMPILING
________________	Text in capital letters in the space of the line
|__|__|__|__|__|	1) Texts: alphanumeric characters in capital letters must be written in the spaces and left justified; 2) Numbers: characters must be written in the spaces and right justified;
❍	The presence of these round cells in the lists and on the rows of matrixes indicate the possibility of selecting one single option among those available. (single answer)
❒	The presence of these square cells in the lists and on the rows of matrixes indicate the possibility of selecting more options among those available. (multiple answer)
100 10 1 0 0 0 1 1 1 2 2 2 3 3 3 4 4 4 5 5 5 6 6 6 7 7 7 8 8 8 9 9 9	A matrix to indicate an integer. This can have a number of digits corresponding to the number of columns. In the matrix shown in the left, any integer between 0 and 999 can be indicated. In order to register a number of 3 digits, the digit of the hundreds, the one of the tens and the one of the units should be marked respectively on the first (column 100), on the second (column 10) and on the third (column 1) column. In the example, the number 35 has been recorded indicating 0 in the hundreds, 3 in the tens and 5 in the units column.

2.4 Aggregates and buildings identification

On the cartography, it is necessary to indicate the single structural aggregates, to be intended as a set of non homogeneous buildings (structural elements), in contact or connected in a more or less effective way, which can interact in case of earthquake or, more in general, in case of any dynamic action. A structural aggregate may hence be constituted by a single building (as is often the case for reinforced concrete buildings) or by more buildings joined together, generally with different structural characteristics. The presence of an effective seismic joint determines the identification of two separate structural aggregates. Whenever it is not possible to identify a priori the presence or the position of a seismic joint, it is suitable to consider the whole block as a single aggregate and eventually to make some modifications during the inspection.

Aggregates should be numbered on the maps provided by the Municipality, through an unambiguous code. This code, when assigned by a single surveyor for the whole municipality, will have five digits according to a single progressive numbering (possible modifications on the field must be reported directly to the coordinator); if, on the other hand, the code is assigned by the surveyors teams, one option may be to have five digits, with the first three coinciding with the identification code of the team, and the last two following the progressive numbering assigned by the team to the surveyed aggregates. An example of identification and numbering of aggregates and buildings is represented in Figure 2.1 and in Tables 2.2.

Inside the structural aggregates, it is possible to identify buildings, defined as homogeneous units and generally distinguishable from adjacent buildings for structural typology, different height, age of construction, different storeys height, etc.

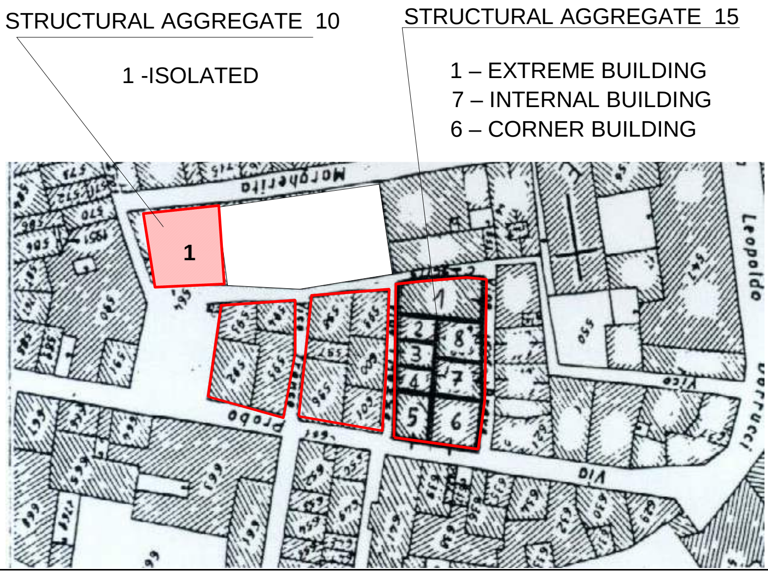


Fig. 2.1 – Example of aggregates and buildings identification on a cadastral *sheet* and indication of the *position* of some buildings.

Buildings are hence single static organisms and can be differentiated and identified based on the following criteria:

a) buildings constructed in different ages;
b) buildings constructed using different materials;
c) buildings constructed with floors at different heights.

The identification of buildings is not always easy and unambiguous, especially in case of masonry buildings aggregates, which are typical of historical centres. In particular, a masonry building can be defined as a building with structural continuity, delimited by vertical bearing walls extending for the entire height of its structure.

In case of reinforced concrete buildings, the definition is usually less complicated since, in general, buildings are considered as such in case they are isolated by spaces or joints, in conformity with the code (in that case, the building and the aggregate coincide).

Section 1 of the form contains information concerning the identification of both the building and its survey. The explicit capital letters writing of province, municipality and hamlet is useful for the management of the paper version of the forms. Very important, especially for the management of the computerized version of the data, are the two identification codes in the two cells at the top right, called *survey identification* and *building identification*. As shown in tables 2.2, they are constituted by more information linked together, in order to identify in an unambiguous way the building and the survey (in general, several surveys can be carried out on the same building).

Table 2.2. a - Example of survey identification

Example	015 0003 270997
Team	015: univocal number given to the team by the mixed operative centre (COM).
Form	0003: progressive number, within the same Municipality, given by the team to the survey form
Date	270997: Date of survey (day 27, month 09 and year 97)

Table 2.2. b - Example of building identification

Example	10 043 007 00005 023
Region Istat*	10: identification number given by Istat to the Region
Province Istat	043: identification number given by Istat to the Province
Municipality Istat	007: identification number given by Istat to the Municipality
Aggregate N°	00005: identification number of the aggregate previously assigned by the municipality or assigned after the survey by the team and the municipality
Building N°	023: identification number of the building previously assigned by the municipality or assigned after the survey by the team and the municipality

*National Institute of statistics

The unambiguous numbering of teams ensures an unambiguous identification of the survey form within the survey campaign. Similarly, the set of ISTAT data identifying the municipality (region + province + municipality), together with the aggregate number and the building number allows the unambiguous identification of the building. The combination of these two identification codes allows the information management, even in a nationally unified database. Also in relation to this particular aspect, it becomes evident how important it is to create a building registry as an instrument predisposed for the technical emergency management.

Table 2.3 – IDENTIFICATION CODES FOR PUBLIC SERVICES

CODE	DESTINATION	CODE	DESTINATION
S00	**Educational structures**	**S50**	**Military collective activities**
S01	Crêche	S51	Armed forces (carabinieri excluded)
S02	Nursery school	S52	Carabinieri and Public Safety
S03	Primary school	S53	Firemen
S04	Secondary school - mandatory	S54	Revenue Guard Corps
S05	High school	S55	National Forest Corps
S06	Liceo	**S60**	**Religious collective activities**
S07	Professional school	S61	Parish services
S08	Technical school	S62	Religious buildings
S09	University (arts faculties)	**S70**	**Technical network systems activities**
S10	University (scientific faculties)	S71	Water
S11	Academy and Academy of music	S72	Sewerage system
S12	Superintendency and rectorship offices	S73	Electric energy
S20	**Hospital and sanitary structures**	S74	Gas
S21	Hospital	S75	Telephones
S22	Nursing home	S76	Telecommunication systems
S23	Sanitary utility - Ambulatory	**S80**	**Mobility and transport structures**
S24	Health Unit	S81	Railway station
S25	INAM - INPS and similar	S82	Bus station
S30	**Civil collective activities**	S83	Airport
S31	State (technical offices)	S84	Naval station
S32	State (administrative, financial offices)		
S33	Region		
S34	Province		
S35	Consortium of communes in mountain areas		
S36	Municipality		
S37	Decentralized town hall		
S38	Prefecture		
S39	Postal and telegraph services		
S40	Civic centre– Meeting centre		
S41	Museum – Library		
S42	Jails		

The light grey background groups those information which can be partly previously assigned or given by the coordination or by the organisation at the municipal level. This is true, for example, for the *ISTAT codes for Region, Province, Municipality, Hamlet and census division*; these information are important for a more detailed mapping of the data on the consequences of the seismic event, with respect to the scale of the entire municipal territory.

The *type of map and number of map* identify (through the indication of the typology of *map* used and through an identification code) the map on which the building is identified; this indication is important in the general case in which the cartography of the municipal territory used is developed in several sheets.

The cadastral data, *sheet*, *allegato and parcels* are useful as additional identification elements and also as a connection to other data referenced to the cadastral cartography. The *building position* highlights its connections or contacts with other buildings.

In figure 2.1 some illustrative cases are reported.

In the field *building denomination* the effective denomination should be indicated in case of buildings with a relevant public or strategic function (offices used for institutions, public services or activities of public interest for the community), while in the case of residential buildings, the name of the condominium or the name of one of the owners should be indicated.

The *use code* helps in identifying in the database those buildings with public utility functions and may be chosen among those reported in Table 2.3. In the white space at the middle of the page, the indication *Photocopy of the structural aggregate with building indication* means that in this space it should be reported, possibly photocopied, the portion of the reference map including the structural aggregate and the building under survey, with the relative identification codes described above. The building contour must be highlighted.

2.5 Building description

Section 2 collects information concerning *metrical data*, *age*, with indication of the period of *construction* and eventually of *renovation* of the building, as well as type of *use* and *exposure*.

Metrical data must include the total *number of storeys* including basements, the *number of basements*, the *average storey height* and the *average storey surface*.

The *total number of storeys* refers to those which can be counted starting from the foundation level, including the eventual attic, but only when practicable. Basements floors are defined as those having an elevation above the ground level (i.e. the average elevation in case of buildings on slope) lower than half of the total storey height.

The values of *average storey height* and *average storey surface* are listed in ranges and the rule to be followed, in case of significant variation among different storeys, is to consider the average value better representing the total volume (for the height, the value better approximating the average of all storey heights will be indicated; for the surface, the range better characterising the average surface among all storeys must be indicated).

In the column concerning *age*, it must be highlighted the period of *construction* of the building and, eventually, the period relative to the *renovation,* if significant from the structural point of view.

For what concerns *use*, all types of use eventually coexistent in the building and the relative number of units have to be indicated.

With regard to this, it is important to specify that the use *offices* generally refers to private offices (such as banks, professional activities, etc.), while the use *public and strategic services* are essentially those listed in table 2.3. In particular, it should be considered as *strategic* a building which is absolutely necessary for the Civil Protection functions, such as hospitals, municipalities, firemen barracks, etc. Finally, for *warehouse* one should intend any premise used for storing material, where no fixed staff is present; garages or basements belonging to houses have to be excluded from this definition.

In the column concerning *utilisation* (which refers in any case to the pre-event conditions), it should be indicated the approximate percentage of utilisation of the building in spatial and/or temporal terms, according to three levels (<30%, 30%-65% and >65%). More in detail, this global utilisation is measured from the sum of the products between the percentages of volumes of the buildings and the relative percentages of temporal utilisation. Alternatively, it is possible to highlight the fact that the building is not used at all, either because, even if functional, there is practically no human presence (*not utilised*) or because *in construction*, or because it has been left *uncompleted* or, finally, because it is abandoned (bad maintenance and/or functionality conditions).

In the *number of occupants* the average number of people usually present should be indicated, i.e. the average number of people which, before the event, used to either work or live constantly in the building. For instance, the inhabitants of “second houses”, used only occasionally, should not be classified as occupants, not even if accidentally present at the time of the event. The number of occupants should be indicated by blackening the squares of the hundreds, of the tens and of the units.

The last information of this section concerns the type of *property*, distinguishing between public or private.

3 INSTRUCTIONS FOR COMPILING SECTION 3: BUILDING TYPOLOGY

3.1 Preliminary remarks and general instructions

Section 3 of the form has its main aim in leading the surveyor towards a deep knowledge of the building, guiding him to the usability classification highlighting the vulnerability indicators which may influence the seismic response. The two levels of grey used, in addition to the white, as a background for the cells, indicate increasing levels of vulnerability.

For what concerns the section compilation, the following general instructions should be observed, in addition to those reported in the section *Explanatory notes for compiling the form* reported in page 4 of the form. More precise instructions will follow in sections 3.2 and 3.3, for masonry buildings and buildings of other typologies respectively; in § 3.5, instructions concerning how to compile the form regarding the type of roof will be provided.

When possible, the survey should be preceded by an interview with local technicians and with the owner of the building, in order to collect general information about the building, such as age of construction, materials, structural typologies, modifications and/or enlargements occurred during the years, instabilities of the foundation soil, etc.

Only if neither the in situ investigation, nor the information collected are sufficient for the identification of the vertical and horizontal bearing structure typology, would the technician be allowed to use the *non identified* field of the form.

Section 3, for what concerns masonry buildings, allows multiple answers, with a maximum of two options to be referred to the cases considered most significant from a volumetric point of view. Hence, for what concerns masonry buildings, it is possible to mark two combinations of predominant horizontal and vertical structural components, associating in any case the bearing structure of one or more floors to the corresponding ceiling: for example, there can be vaults without tie rods and rubble stone masonry at the 1st level (2B) and rigid floors (in r.c.) and rubble stone masonry at the 2nd level (6B). It is important to note that, in the form, the number of storeys to which the combination refers to is not reported. The double answer should be used only when both the combinations are present to a significant extent; a second combination should not be indicated when it only concerns a small portion of the building.

Masonry is subdivided in two types, based on the quality (materials, mortar, construction quality); for each type, it is possible to identify also the presence of tie beams or tie rods, when significantly widespread.

Floors are subdivided into flexible, semirigid and rigid, in their plane. Usually, reinforced concrete floors are considered as rigid, those realised with iron beams and hollow clay tiles as semirigid, those realised with iron beams supporting shallow arch vaults or wooden floors are flexible, unless they have been stiffened. In this last case, they may be considered as rigid or semirigid, based on the level of connection among components.

It is also necessary to indicate:

- in column F the presence of isolated columns, being reinforced concrete, masonry, steel or wooden columns;
- in column G the presence of mixed vertical bearing structures in masonry and reinforced concrete (more generally, masonry and frame structures);
- in column H the presence of reinforced or strengthened masonry, carried out during the building construction or later, during repair or retrofit interventions.

Buildings should be considered as having reinforced concrete or steel frame structures when the entire bearing structure is in reinforced concrete or steel. Mixed vertical bearing structures (masonry – frames) should be indicated in column G of the *Masonry* section: for example, if the frame structure exists only at a single floor, while the other floors below this one are in masonry, the cell G1 will be marked (reinforced concrete or other frame structures over masonry); if the frame structure and the masonry structure are at the same level, the cell G3 will be marked (masonry and reinforced concrete in parallel at the same floors).

For frame structures, infill panels are irregular when they are not symmetric in plan and/or in elevation or when they are practically missing at one floor in at least one direction.

3.2 Masonry buildings

3.2.1 Vertical structures and masonry abacus

Masonry structures			
Type **I**		Type **II**	
Irregular layout or bad quality (Rubble stones, pebbles,..)		Regular layout and good quality (Blocks, bricks, squared stone,..)	
Without tie rods or tie beams	With tie rods or tie beams	Without tie rods or tie beams	With tie rods or tie beams
B	C	D	E
☐	☐	☐	☐
☐	☐	☐	☐
☐	☐	☐	☐
☐	☐	☐	☐
☐	☐	☐	☐
☐	☐	☐	☐

Accounting for the material used, its layout in the wall, the mortar quality and the constructive procedures, the form allows to distinguish masonry structures in two typologies:

Type **I** masonry: irregular layout or bad quality

This type of rubble stone masonry shows a very bad seismic behaviour, characterised by:

- significant vulnerability with respect to out of plane actions, with possible disgregation of the wall. This may be also due to instability, under vertical loads, of the single wythes, not effectively connected. It may happen even if the floors are well connected;
- low resistance to in plane actions, both due to the low resistance intrinsic of the materials and in particular of the mortar, and to the low friction which may develop among the stone elements, due to the configuration of the wall.

Type **II** masonry: *regular layout and good quality*

This type of natural or artificial stone masonry shows a favourable behaviour characterised by:

- low vulnerability with respect to out of plane actions, provided the wall is well connected, both in its upper and lower part, to rigid or semirigid floors, which are able to redistribute the seismic actions to the walls parallel to the action, with a monolithic behaviour of the wall;
- medium or high resistance to in plane actions, thanks to the intrinsic resistance of materials, specially of mortar, and/or to the friction which may develop among the blocks or the stone elements, due to the regular configuration of the wall.

A more detailed classification of the different types of masonry, considering the variety of situations typical of the Italian building stock, is provided in the annexed tables, with the aim of guiding the surveyor in recognizing and correctly assigning the building typology.

A graphical and photographic documentation is also provided; this is organised in summary abaci, in which, for each masonry typology, it is suggested whether it should be attributed to type **I** or type **II** masonry, as described in the form. This is just a suggestion for the surveyor, who is required to judge on site, based on his own sensitiveness and experience.

A first abacus (Table 3.2) proposes a classification based on the *analysis of the exterior wythe* (I° level of knowledge), which is the easiest part to be recognised by the surveyor at a first visual inspection of the external or internal surfaces without plaster. Based on this, masonry is classified into three large families:

- irregular masonry (code **A**), constituted by elements without any regular shape, which may be small or medium size river pebbles, smoothed and with rounded edges (coming from floods or from riverbeds) or may be "scapoli di cava", chips of stone, etc., or otherwise elements of different size with sharp edges, generally made of limestone or lava stone;
- hewn masonry (code **B**), constituted by elements only roughly worked, not perfectly rectangular dressed, which appear as semi-regular or flat-cut, called sometime "a soletti";
- regular masonry (code **C**), constituted by regular shape elements, perfectly rectangular dressed, as it is possible to obtain from tuff and some other stones, and also, as obvious, by bricks.

In any case, the layout may be (code **CR**) or not (code **SR**) strengthened with brick or regular stone layers at an almost constant spacing (of the same order of magnitude of the thickness).

The analysis of the external wythe, alone, can be insufficient for distinguishing between a bad quality (type **I**) and a good quality (type **II**) masonry. The Working Group that prepared this Manual asked several technicians and researchers with experience of observation of seismic damage to masonry buildings to classify the attached abacus. The statistics reported in the column *Assignments* of the abacus come from this discussion: it is evident that there is a significant uncertainty, especially concerning the hewn masonry (code **B**).

It is hence suitable to collect more information on:

the mortar quality (II° level of knowledge); evaluated in situ through a scratch test, in order to distinguish *bad quality mortars* very friable and easy to crumble (Mc), from *good quality mortars* which are more resistant (Mb: e.g. concrete mortars);

- *the wall section* (III° level of knowledge), distinguished in the two cases of masonry with *well connected wythes* (Pc) and *disconnected or not well connected wythes* (Ps; it is the case of many types of poor 'a sacco' masonry). In post-earthquake surveys, the section geometry can often be observed in partially collapsed buildings. Some typical cases are reported respectively in Figure 3.1 and 3.2.

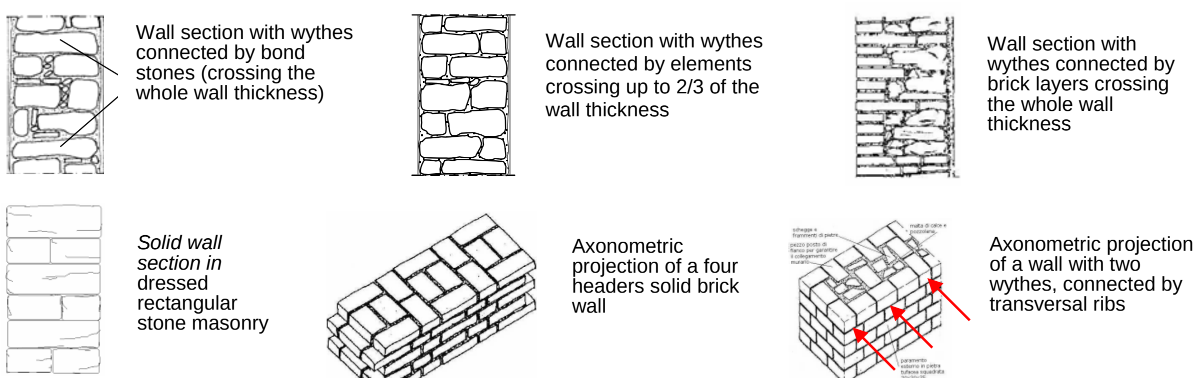


Fig. 3.1 Masonry wall with well connected wythes or with a single wythe (Pc)

Fig. 3.2 Masonry wall with non connected or badly connected wythes, as highlighted by the disastrous collapses due to the earthquake (Ps)

The attached abaci propose, through a suitable table, the most likely attribution of the observed masonry wall to either type **I** or **II** masonry, as a function of these additional variables. The classification uncertainties reduce progressively, even if in some cases they are still considerable, with the number of considered variables. In any case, the most suitable classification is left to the final judgement of the surveyor.

As an example, in Fig. 3.3 it is reported one of the attribution tables which are associated in the abaci to each typology of wall wythe (Tables 3.3 and 3.4 for irregular masonry; 3.5 for hewn masonry; 3.6 for regular masonry). The table reading helps in deciding the attribution to types **I** and **II** of the masonry under study; this is true both in case only the information on mortar is available (hint reported in the field II° level of knowledge) and in case both the quality of mortar and the type of wall section can be observed at the same time (hint reported in the field III° level of knowledge). Even with this additional information, some uncertain cases still exist, indicated in the abaci through the double identification **I/II**.

		I - II				I° level of knowledge
		M_c		M_b		
Mortar type	→	**I**		**II**		II° level of knowledge
		P_s	P_c	P_s	P_c	
Section type	→	**I**	**II**	**I/II**	**II**	III° level of knowledge

Fig. 3.3. Example of masonry classification as a function of the level of knowledge

3.2.2 Horizontal structures and abacus of the typologies of flat floors

It is not always easy to identify horizontal structures by visual inspection; to this aim, useful suggestions for the surveyor are:

- interview local technicians and/or the owner;
- survey rooms without plaster, such as cellars, basements, etc;
- analyse the structural characteristics of the overhangs, (balconies, eaves, cantilever roofs).

Only in case of strong uncertainties, the surveyor can use the field “not identified”.

1	Not Identified
2	Vaults without tie rods
3	Vaults with tie rods
4	Beams with **flexible** slab (wooden beams with a single layer of wooden planks, beams and shallow arch vaults,...)
5	Beams with **semirigid** slab (wooden beams with a double layer of wooden planks, beams and hollow flat blocks,...)
6	Beams with **rigid** slab (r.c. floors., beams well connected to r.c. slabs,...)

In the form, the main distinction is made between flat horizontal structures and vaulted horizontal structures. Within each of these two groups, there is a further distinction related to those characteristics that may have a significant influence on the behaviour of the structural organism as a whole.

For what concerns vaulted floors, the main distinction is made between:

- vaults without tie rods: i.e. structures already thrusting under vertical loads which may, increasing this thrust under the seismic action, induce an out of plane collapse of the walls;
- vaults with tie rods: i.e. structures whose thrust is eliminated thanks to the presence of well anchored tie rods, or is resisted by effective *buttresses*.

For what concerns flat structures (floors), the form distinguishes three typologies, in relation to their in plane flexibility:

- *Beams with flexible slab*: the flexibility and/or the reduced resistance of this typology, even if the floors are well connected to the walls (condition that is almost never met), does not allow to restrain the walls under the out of plane actions, nor to transfer the out of plane seismic force to the transversal walls. It may hence happen that these type of floors facilitate the out of plane collapse of the walls.

- *Beams with semirigid slab*: the stiffness and the resistance of this typology determine the fact that, if the floors are well connected to the vertical walls (condition mostly verified in case there are tie beams and/or dovetails and effective seams), they are able to act as a sufficiently rigid restrain for the out of plane overturning and to transfer the out of plane seismic force to the transversal walls. These floors, however, are not sufficiently rigid to enforce a rigid floor redistribution of the seismic forces among all the building walls.

- *Beams with rigid slab*: the stiffness and the resistance of this typology determine the fact that, if floors are well connected to the walls (condition mostly verified in case there are tie beams and/or dovetails and effective seams), they are able to restrain the out of plane overturning and to transfer the out of plane seismic force to the transversal walls. A proper global box behaviour occurs, in which the walls subjected to out of plane actions, being well connected to the floors, work according to a favourable scheme (either of beam or plate scheme restrained along the edges), and seismic forces are transferred to the ground through the walls parallel to them.

From an operative point of view, the following considerations are valid.

Wooden floors with single or double direction of spanning (beams and joists), with a simple wood plank or brick elements, eventually completed with a slab realised in incoherent material or debris may be considered flexible floors. Flexible floors may also be floors made of iron beams supporting shallow arch vaults made of bricks, stone or concrete. In both cases, if a stiffening element has been introduced, with two perpendicular layers of wood plank flooring or, even better, a reinforced slab well connected to the beams, such floors could be considered as rigid or semirigid, based on the level of connection among elements.

Several type of floors may be considered semirigid: wooden floors with two perpendicular layers of wood plank flooring, eventually completed with a reinforced concrete slab; floors mad of iron beams supporting hollow flat blocks with a flat intrados; floors constituted by prefabricated reinforced hollow clay tile floor beams, with reinforced concrete ring beams, without any upper reinforced concrete slab.

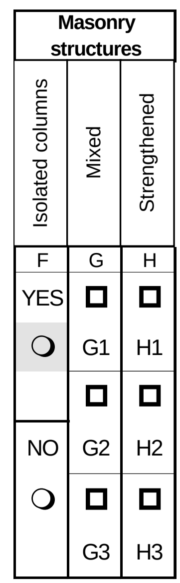
Solid slab reinforced concrete floors may be considered rigid floors, in addition to floors constituted by brick elements and reinforced concrete joists, either cast-in-place or prefabricated, or any kind of floor with an upper concrete slab suitably reinforced and connected to all the walls.

With the aim of guiding the surveyor in recognizing the horizontal typology, Table 3.7 shows an abacus, with a graphical and iconographical documentation, of the floor typologies considered in the form, as a function of the in plane floor flexibility.

Finally, it should be specified that if the roof is the only ceiling (as in case of buildings with a single storey), the ceiling typology must be described both in the table *Roof* and in the relevant row of the table *Masonry structures*.

3.2.3 Mixed and strengthened structures

In section 3 *Masonry structures*, the form allows to indicate, in addition to the previous information:



- the presence of isolated columns (single answer; column F);

- the presence of a mixed structure typology (column G) with 3 options (multiple answer) corresponding to:
  G1: RC (or other frame structures) over masonry;
  G2: masonry over RC (or other frame structures);
  G3: masonry and RC (or other frame structures) in parallel at the same floors;

- the presence of strengthened masonry with 3 options (multiple answer) corresponding to:
  H1: masonry strengthened with injections or unreinforced plasters;
  H2: reinforced masonry or masonry with reinforced plasters;
  H3: masonry with other or unidentified types of strengthening.

The existence of isolated columns should be indicated when, in a building with masonry or mixed vertical bearing structure, the presence of isolated bearing components of any typology, reinforced concrete, masonry, steel or wooden, is noticed. In general, in masonry buildings, the presence of concentrated vertical stresses in columns, especially when they are a consequence of renovation works, may indicate an increased building vulnerability.

On the other hand, according to what indicated in the current Italian seismic code, mixed structures (field G) are structures made of plane or reinforced masonry, in which additional vertical structural components, made of different material (reinforced concrete, steel, wood or other materials), have been added. These components must have some bearing function, i.e. they should be able at least to carry part of the vertical loads. Such structures may be in series (G1, G2: on different floors) or in parallel (G3) with respect to the masonry walls. Frequent typical cases are:

G1 – masonry buildings with the upper floor entirely constructed with reinforced concrete bearing structure;

G2 – reinforced concrete buildings with an added floor constructed with masonry bearing structure (not allowed in the code);

G3 – buildings with a bearing structure, at the same level, partly constructed with masonry walls and partly with reinforced concrete columns or walls; the most frequent case consists of masonry walls along the perimeter of the building and reinforced concrete frames inside.

When the extension of the frames is significant, also the section “other structures” should be filled in, indicating the characteristics of the frame structure.

The mixed character of the vertical structures is not necessarily an element of vulnerability, even if it often implies lack of homogeneity in the structural response and concentration of stresses which can cause local damage.

It is generally not easy to detect at sight the presence of strengthened walls in masonry buildings: when similar interventions are performed on several buildings of the same district, information can be obtained directly from the owners or from the local technicians. Strengthening interventions are generally performed during the repairing or retrofitting works on plane masonry buildings, through non reinforced (H1) or reinforced (H2) injection, or jacketing with reinforced concrete sandwich panels (H2), or composites (H2); the use of reinforced masonry directly in the construction phase, with horizontal and vertical steel bars (H2), is not common in Italy. More difficult is to judge about the quality of the intervention: it does not seem realistic to always assume that the intervention has been performed in the proper way and therefore to always classify strengthened masonry as type **II** masonry. If the surveyor is able to verify that the intervention has been well executed, he will indicate the prevailing typology(ies) in columns D or E, even in case the original masonry is of type **I**.

3.3 Other structures

Other structures	
R.c. frames	❑
R.c. shear walls	❑
Steel frames	❑

	REGULARITY	Irregular	Regular
		A	B
1	Plan and elevation	❍	❍
2	Infills distribution	❍	❍

Alternatively to masonry structures, the following types of structure can be specified (multiple answer):

- Reinforced concrete frame structures
- Reinforced concrete shear walls structures
- Steel frame structures.

Other types of structure (such as wooden structures) are not included in the form, since they are not very common in Italy. When they are present together with masonry structures, they can be identified as mixed structures in column G.

For the three above specified typologies, information about the regularity or irregularity of the building are required. This judgment must be indicated synthetically in field 1 (regularity in plan and in elevation) and 2 (infills distribution) of the form.

For these building types floors are supposed to be rigid in their plane; incidental irregularities in this sense must be indicated in section 9 of the form. Structures not falling in any of the typologies of the form must be indicated again in section 9.

In the following, some additional information concerning the previously described fields are given.

3.3.1 Regularity in plan and in elevation

Under this entry, the surveyor must evaluate the presence of:

- shape irregularity in plan, i.e. plans not having two orthogonal axes of symmetry, such as L, T, U, E, P shaped etc;

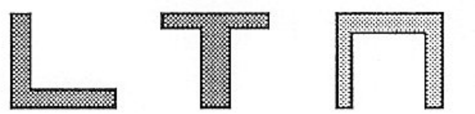


Fig. 3.4

- shape irregularity in elevation, i.e. macroscopic variations of surface (± 30%) with height, creating significant overhangs or setbacks;

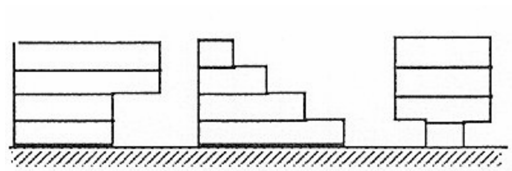


Fig. 3.5

- eccentric position of the staircase and/or of the elevator with respect to the axes of symmetry of the plan;

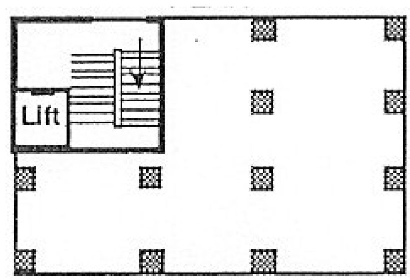


Fig. 3.6

- structural irregularities in plan, i.e. absence of frames in both the principal directions of the plan, unsymmetrical or badly distributed frames, presence of re-entrant corners (with projection greater than 20% of the planimetric dimension of the building in that direction), eccentric and not uniform distribution of the dead load and of the live load, etc.;

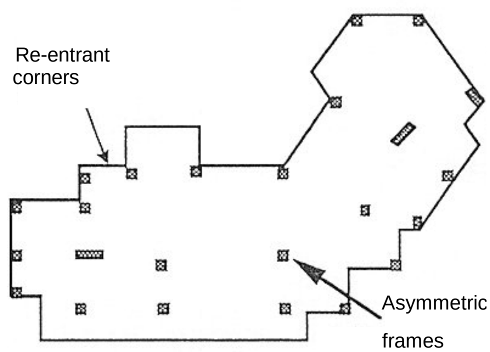


Fig. 3.7

- structural irregularities in elevation, i.e. presence of heavy slabs resting on slender columns, existence of storeys with dead or live load larger than that of the adjacent floors by more than 50%, etc.

3.3.2 Infill panels distribution

Under this entry, the surveyor must evaluate the presence of a general dissymmetry in the infill panels distribution and/or the presence of conditions of non structural vulnerability, such as:

- infill panels arranged externally with respect to the structure

- external infill panels with very unsymmetrical openings, for instance with large openings on the street side and almost no openings on the other sides. This dissymmetry may significantly modify the position of the centre of stiffness of the structures resisting the seismic actions at the different floors, It may therefore increase the eccentricity with respect to the centre of mass, inducing torsional effects.

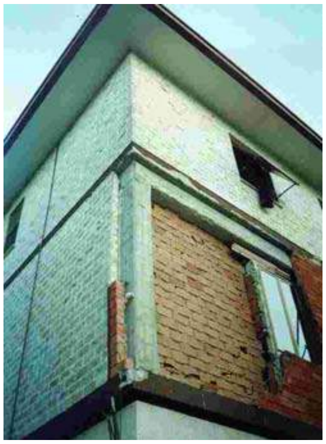


Fig. 3.8

- Presence of short columns, due to the presence of infill panels shorter than the frame height (for instance due to the presence of strip windows, Fig. 3.9), or due to irregular structural configurations such as foundations at different levels, floors at different levels, etc.

Fig. 3.9

3.4 Roofs

Roofs may influence the seismic behaviour of a building in a positive or negative way, essentially through two factors: their weight and their incidental thrust on the supporting walls.

In masonry buildings, the ideal condition is to have light, rigid and resistant roofs and well connected to the walls, i.e. roofs able to transmit low inertia forces (lightness) and to redistribute the seismic forces among the walls parallel to the actions, being at the same time

Roof		
1	❍	Thrusting heavy
2	❍	Non thrusting heavy
3	❍	Thrusting light
4	❍	Non thrusting light

an efficient constraint for the out of plane wall overturning.

These three conditions are rarely met in practice at the same time. In old buildings, roofs are often thrusting, i.e. they apply horizontal forces orthogonal to the walls on which they are supported, just because of vertical loads. This condition is worsened by seismic forces, which are both horizontal and vertical.

In the form, two parameters have been considered as essential, the weight and the thrusting/non thrusting character of the roof. In the following, the main consequences of these two characteristics on the structural behaviour are briefly described:

- *Thrusting and heavy*: this is certainly the worst condition, since the large mass induces significant seismic forces, while the thrusting effect facilitates the out of plane collapse of the walls below the roof;
- *Non thrusting and heavy*: in general the significant weight is associated to the reinforced concrete or brick floors, which however in general guarantee good in plane resistance and stiffness and thus are able to redistribute the seismic actions on the walls which are more suitable to resist them. On the other hand, the excessive weight may induce forces, both static and dynamic, which may exceed the masonry resistance, especially in case of poor quality masonry;
- *Thrusting and light*: the risks associated to this condition are essentially related to the increase of the horizontal thrust on the walls, due to seismic actions;
- *Non thrusting and light*: this is the best condition, due to the low values of seismic actions and to the absence of any thrusts on the walls; this condition would be even more favourable if the roof structure would have sufficient in plane stiffness and resistance, so that it could also direct towards a global box behaviour.

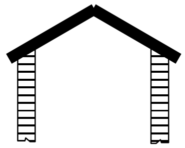
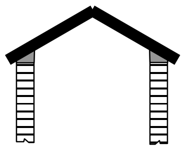
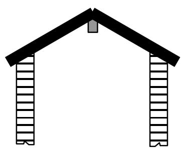
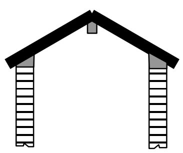
From an operational point of view, the following considerations are valid. For what concerns the weight, steel and wooden roofs are generally considered as light (unless they are covered with heavy plates or tiles, for example made of stone). Reinforced concrete roofs are generally considered as heavy.

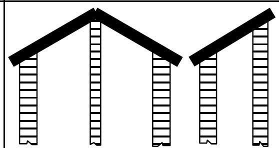
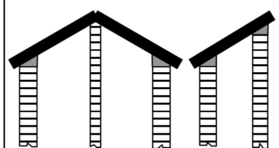
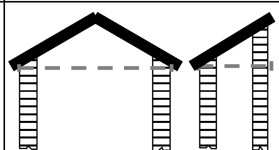
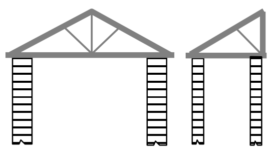
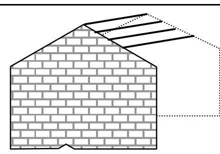
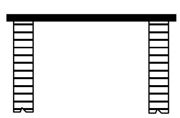
For what concerns the thrust, the presence and/or effectiveness of the following elements must be considered:

① tie beam
② internal wall
③ tie rods
④ rigid ridge beam
⑤ non thrusting trusses with longitudinal joists resting on them

Several cases that may occur are described in Table 3.1 (the field ① will indicate the presence of that element). It is important to note that the classification associated to the reported schemes are just indications that represent the most likely condition. They may be useful also in those cases where it is not possible to investigate in detail the restraint among components.

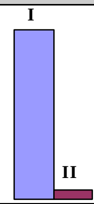
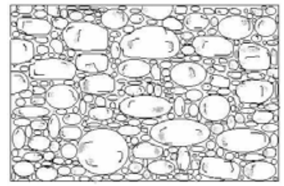
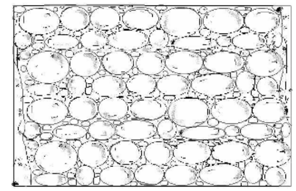
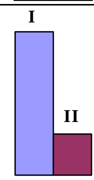
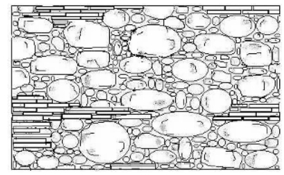
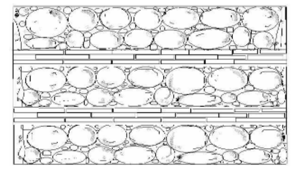
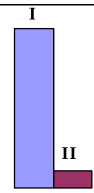
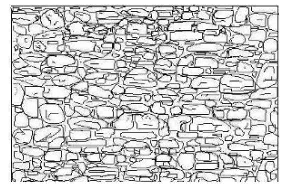
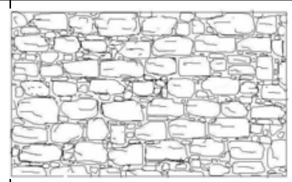
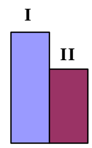
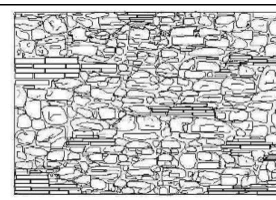
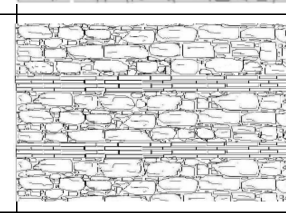
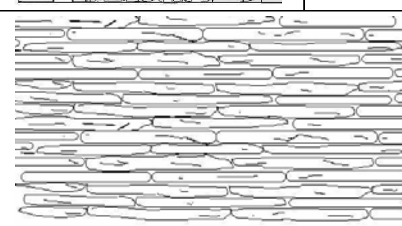
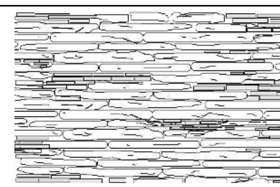
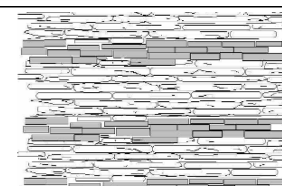
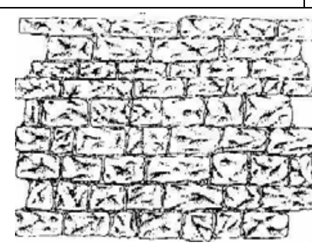
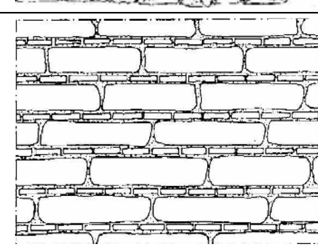
Table 3.1 - ROOFS ABACUS: Evaluation of the thrust

Roof	Static configuration	Remarks
thrusting	 ① ② ③ ④ ⑤ lack of tie beam lack of internal wall lack of tie rods lack of rigid ridge beam lack of trusses	
	 ① ② ③ ④ ⑤ presence of tie beam lack of internal wall lack of tie rods lack of rigid ridge beam lack of trusses	
Roof with thrust depending on the constraints	 ① ② ③ ④ ⑤ lack of tie beam lack of internal wall lack of tie rods presence of rigid ridge beam lack of trusses	The thrusting or non thrusting character of this scheme depends on the stiffness of the ridge beam. Slender beams do not allow to efficiently reduce the thrust, thus, in order to be conservative, it is suggested to consider this scheme as thrusting. However, if the rafters are well connected between each other and/or are well connected to the rigid ridge beam and to the tie beam, the roof can be considered as non thrusting.
	 ① ② ③ ④ ⑤ presence of tie beam lack of internal wall lack of tie rods presence of rigid ridge beam lack of trusses	

Roof	Static configuration	Remarks
Generally non thrusting roofs	 ① ② ③ ④ ⑤ lack of tie beam presence of internal wall lack of tie rods lack of rigid ridge beam lack of trusses	Boundary conditions should be verified (presence of effective connections among elements), in order to be sure that beams are transmitting only vertical loads to the supporting walls.
	 ① ② ③ ④ ⑤ presence of tie beam presence of internal wall lack of tie rods lack of rigid ridge beam lack of trusses	
Non thrusting roofs	 ① ② ③ ④ ⑤ lack of tie beam lack of internal wall presence of tie rods lack of rigid ridge beam lack of trusses	
	 ① ② ③ ④ ⑤ lack of tie beam lack of internal wall lack of tie rods lack of rigid ridge beam presence of trusses	
		Main direction of spanning longitudinal to the pitch inclination and resting on two external walls or on two non thrusting trusses
		Flat roof (presence of horizontal beams)

It must be noted that when the roof is not accessible, the section “roofs” should not be filled in and this situation must be reported in the final remarks.

Table 3.2 – Masonry abacus, based on the external wythe (1° level of knowledge)

Type	Type of elements	Type Code	Courses code	Category	**3.4.1.1 Examples of layout**	
IRREGULAR MASONRY ***CODE** A*	*Rounded stone or river pebbles of small or medium size*	A1	SR (no)			
			CR (yes)			
	Rubble stone: chips, various size stones	A2	SR (no)			
			CR (yes)			
HEWN MASONRY CODE **B**	*Flat-cut stone ("a soletti")*	B1	SR (no)			
			CR (yes)			
	Semi-regular elements roughly worked	B2	SR (no)			
			CR (yes)			

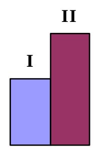
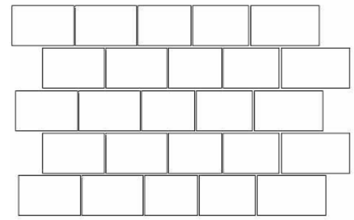
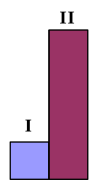
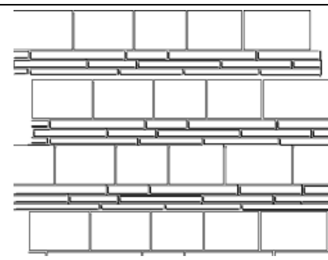
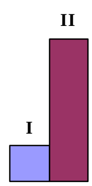
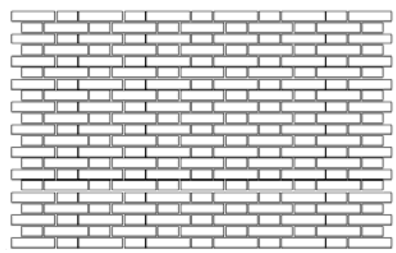
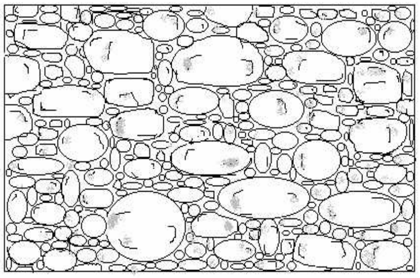
Type	Type of elements	Type Code	Courses code	Category	**3.4.1.2 Examples of layout**
Regular masonry	*Dressed rectangular stone* *(tuff, limestone, sandstone, etc.)*	C1	SR (no)		
			CR (yes)		
	Artificial stone (bricks)	C2			

Table 3.3 – Irregular masonry abacus (Code A1) (2° and 3° level of knowledge)

A1: ROUNDED STONE

Description: mainly constituted by smooth surface and rounded shape elements, or by small or medium size river pebbles; it may have both irregular and regular layout

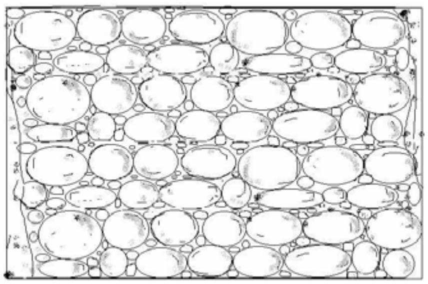
Without brick courses (S.R.)



Attribution

I			
Mc		Mb	
I		I	
Ps	Pc	Ps	Pc
I	I	I	I

Senise (PZ): pebbles with irregular layout

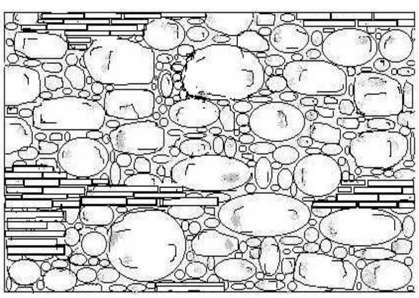


Attribution

I			
Mc		Mb	
I		I	
Ps	Pc	Ps	Pc
I	I	I	I

*Assisi: various types of pebbles with regular layout ***

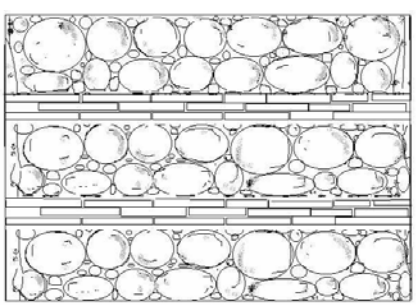
With brick courses (C.R.)



Attribution

I			
Mc		Mb	
I		I	
Ps	Pc	Ps	Pc
I	I	I	I

Sassuolo (MO): pebbles and bricks



Attribution

I			
Mc		Mb	
I		I	
Ps	Pc	Ps	Pc
I	I	I	II

Cast. dei Sauri(FG): Rubble stone masonry with brick courses

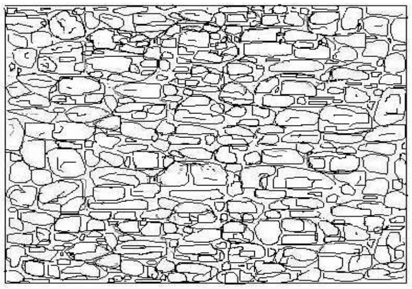
** picture taken from "Manuale per la riabilitazione e la ricostruzione postsismica degli edifici", Regione Umbria, ed DEI, Tipografia del Genio Civile, 1999

Table 3.4 – Irregular masonry abacus (Code A2) (2° and 3° level of knowledge)

A2: RUBBLE STONE

Description: mainly constituted by rubble stone, generally non dressed or difficult to dress: irregular shape elements of various size such as stone chips

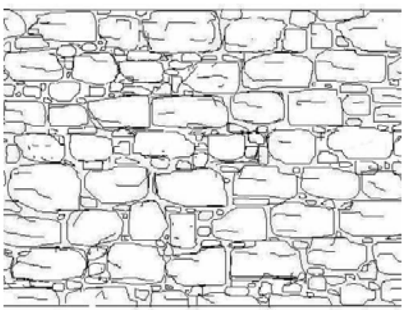
Without brick courses (S.R.)



Attribution

I			
Mc		Mb	
I		I	
Ps	Pc	Ps	Pc
I	I	I	I/II

Benevento: rubble stone with fairly regular layout

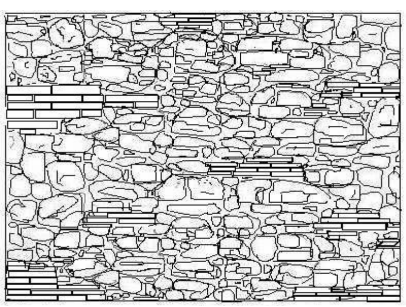


Attribution

I			
Mc		Mb	
I		I	
Ps	Pc	Ps	Pc
I	I	I	I/II

San Angelo Limosano (CB): rubble stone with irregular layout

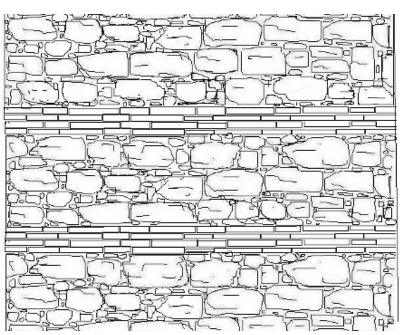
With brick courses (C.R.)



Attribution

I - II			
Mc		Mb	
I		I/II	
Ps	Pc	Ps	Pc
I	I/II	I	II

Alia (PA): irregular masonry with flat tiles and limestone



Attribution

I - II			
Mc		Mb	
I		I/II	
Ps	Pc	Ps	Pc
I	I/II	I	II

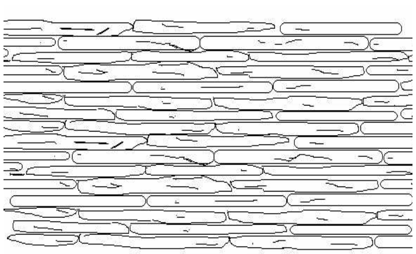
Benevento: rubble stone masonry with brick courses

Table 3.5 – Irregular masonry abacus (Code B) (2° and 3° level of knowledge)

B1: FLAT- CUT STONE

Description: generally constituted by semi-dressed elements, flat-cut ("a soletti" stone), obtained from low resistance stones, which tend to fracture along their horizontal plane. The semi-regular shape of the elements almost always excludes the irregular layout.

Without brick courses (S.R.)



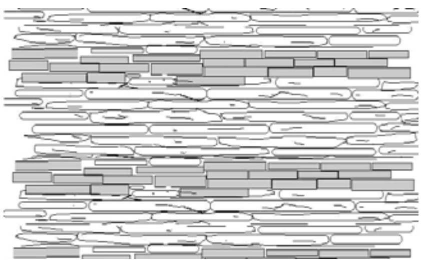
Attribution

I - II

M_c		M_b	
I		**I/II**	
P_s	P_c	P_s	P_c
I	**I/II**	**I**	**II**

*Nocera Umbra (PG) ***

With brick courses (C.R.)



Attribution

I - II

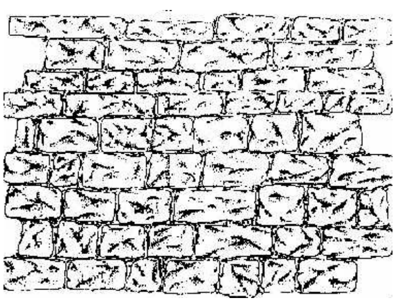
M_c		M_b	
I		**II**	
P_s	P_c	P_s	P_c
I	**II**	**II**	**II**

Isola del Piano (PS)

B2: SEMI-REGULAR STONE

Description: constituted by semi-dressed almost regular stones, of larger size than the previous type. The semi-regularity of the elements excludes the irregular layout.

Without brick courses (S.R.)



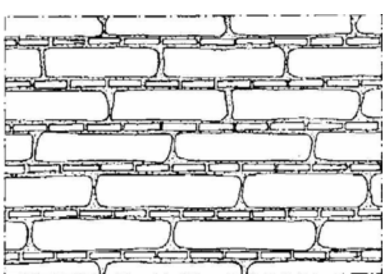
Attribution

I - II

M_c		M_b	
I/II		**I/II**	
P_s	P_c	P_s	P_c
I	**II**	**I**	**II**

Cerchiara (CS): semi-dressed calcareous stone

With brick courses (C.R.)



Attribution

I - II

M_c		M_b	
I/II		**II**	
P_s	P_c	P_s	P_c
I	**II**	**I**	**II**

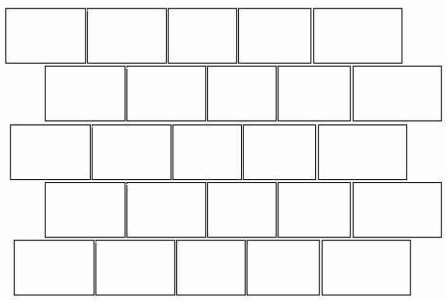
** picture taken from "Manuale per la riabilitazione e la ricostruzione postsismica degli edifici", Regione Umbria, ed DEI, Tipografia del Genio Civile, 1999

Table 3.6 – Regular masonry abacus (Code C) (2° and 3° level of knowledge)

C1: Dressed Rectangular Stone

Description: constituted by dressed rectangular stones of predefined shape. The elements regularity excludes the irregular layout

Without brick courses (S.R.)



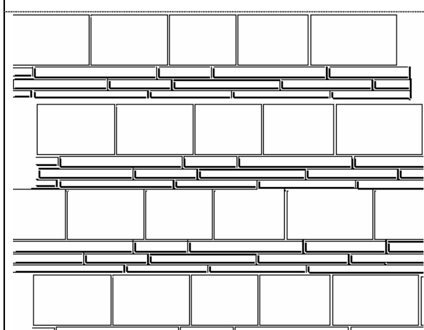
Attribution

I - II			
Mc		Mb	
I/II		II	
Ps	Pc	Ps	Pc
I	II	I/II	II

Benevento: volcanic tuff

Favignana (TP)

With brick courses (C.R.)



Attribution

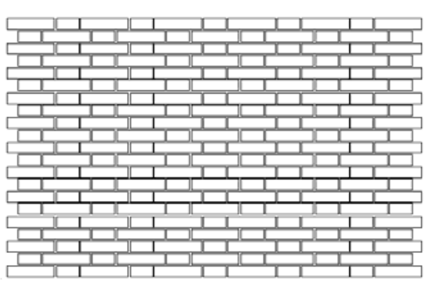
II			
Mc		Mb	
I/II		II	
Ps	Pc	Ps	Pc
I/II	II	II	II

Napoli: volcanic tuff and bricks

C2: Bricks

Description: constituted by brick elements which due to their regularity exclude the irregular layout

Without brick courses (S.R.)



Attribution

II			
Mc		Mb	
II		II	
Ps	Pc	Ps	Pc
I/II	II	II	II

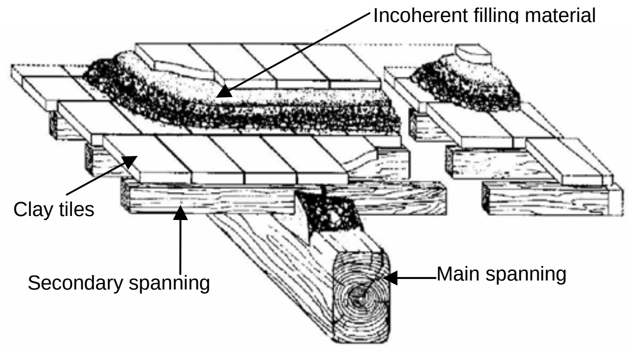
Nocera Umbra (PG)

Table 3.7 – Abacus of the flat floors typologies

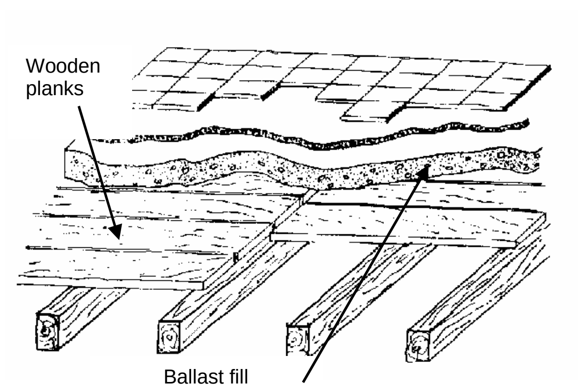
4: BEAMS WITH FLEXIBLE SLAB

Description:
Wooden floors with single or double direction of spanning (beams and joists), with simple wood planks or brick elements (clay tiles), eventually finished with incoherent filling material or debris. Floors constituted by iron beams supporting shallow arch vaults made of bricks, stone or concrete. In both cases, if the floor has been stiffened, with two perpendicular layers of wood plank or, even better, with a reinforced slab well connected to the beams, these floors could be considered as rigid or semirigid, depending on the level of connection among elements.

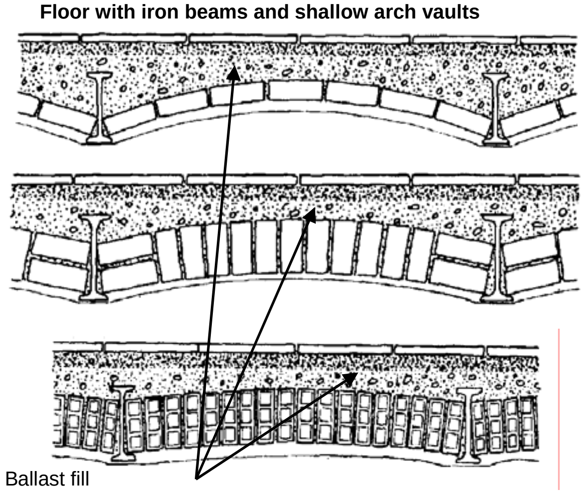
Wooden floor with clay tiles



Wooden floor with wooden planks in a single direction



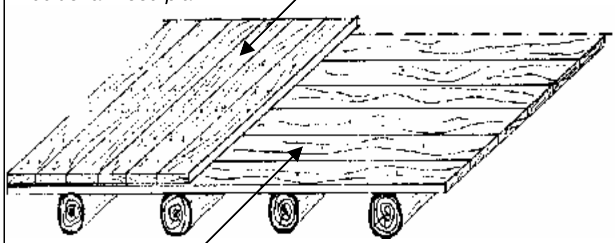
Floor with iron beams and shallow arch vaults



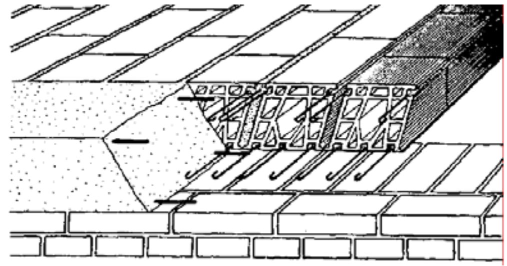
5: BEAMS WITH SEMIRIGID SLAB

Description:
Wooden floors with two perpendicular layers of wood plank flooring, eventually finished with a reinforced concrete slab. Flat floors constituted by iron beams supporting hollow clay tiles. Floors constituted by prefabricated reinforced hollow clay tile floor beams, with reinforced concrete ring beams.

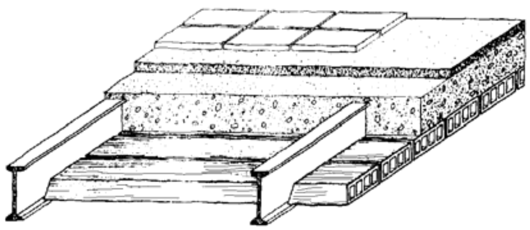
Wooden floor with two perpendicular layers of wood plank flooring



Floor made of prefabricated reinforced hollow clay tile floor beams, with reinforced concrete ring beams



Floor made of iron beams supporting hollow clay tiles

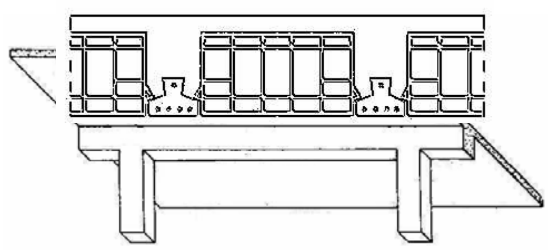


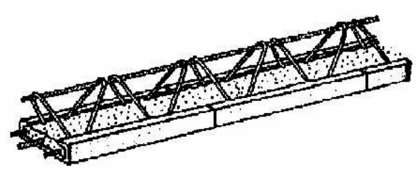
6: BEAMS WITH RIGID SLAB

Description:
Reinforced concrete floors with solid slab. Floors constituted by reinforced concrete joists with hollow clay tiles, either cast-in-place or prefabricated.

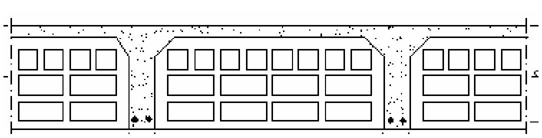
Reinforced concrete floor with prefabricated joists

Reinforced concrete floor with solid slab





Floor of hollow clay tiles with cast-in-place concrete joists and topping



4 INSTRUCTIONS FOR COMPILING SECTIONS 4, 5, 6 AND 7: DAMAGE TO STRUCTURAL AND NON STRUCTURAL COMPONENTS, EXTERNAL DANGER, SOIL AND FOUNDATION

4.1 Preamble

The damage assessment is aimed to estimate the structural and non structural risk (Section 8) in terms of modification of the building bearing capacity with respect to a reference original state. For buildings designed according to modern seismic codes, the original state corresponds to an accepted level of absolute safety; for the other buildings this safety level is not guaranteed.

A quick inspection on damaged buildings, such as the one carried out in emergency, cannot guarantee a predefined level of absolute safety (as already discussed in § 1.3). However, in many cases it is not even possible to consider only the modification with respect to the pre-event condition. This latter approach, in fact, is based on the twofold assumption that the building conditions before the event were satisfactory (socially accepted) and that usability is evaluated considering a shock of intensity not larger than what already experienced. The Italian building stock however includes a significant number of ancient buildings, on which, after the original construction, several modifications, restorations, damages of different nature and successive repairs have occurred.

In addition, in some cases, the original construction does not guarantee the accepted safety level, being related to spontaneous processes of construction. On those structures, the damage is the result of the process of damage accumulation. Hence, safety cannot be referred to the damage increase induced by the last event, but rather to the overall damage condition. This shows that it may be misleading to limit the damage assessment to the effects of the last seismic event. On the contrary, the total damage, as the cumulative effect of all the modifications occurred, should be considered. In this way, also, the surveyor's task is strongly simplified, reducing the possibility of misinterpretation. The form hence requires the assessment of pre-event conditions in global terms, with the aim of understanding what has been the effect of the seismic event in the actual conditions of the building.

In § 4.2, descriptions of the damage levels more detailed than what reported in the fourth sheet of the survey form are provided. In §§ 4.3 e 4.4 such descriptions are even more accurate for masonry and reinforced concrete buildings.

In order to allow a better understanding and to provide a common basis, some quantitative measures of damage are associated to the description of the different damage grades. This will not imply the need for the surveyor of actually measuring the width of cracks on site. Some hints are also given for the mechanical interpretation of the damage grades: these descriptions are not exhaustive and are referred to frequently observed cases. In particular conditions, the same apparent damage may be associated to different failure mechanisms, leading hence to a different damage assessment. Generally, the slight structural damage D1 is associated to low structural risk (even if a severe non structural damage cannot be excluded and hence the need of short term countermeasures), while the damage D4-D5 is in any case associated to high structural risk. The intermediate damage level D2-D3 includes a variety of situations which, depending on damage grade and extension, may lead to different conclusions on structural risk: its interpretation is hence more difficult and complex.

4.2 Grade and extension of damage to the structural components

	Level - extension / Structural component / Pre-existing damage	DAMAGE									
		D4-D5 Very heavy			D2-D3 Medium-severe			D1 Slight			Null
		> 2/3	1/3 - 2/3	< 1/3	> 2/3	1/3 - 2/3	< 1/3	> 2/3	1/3 - 2/3	< 1/3	
		A	B	C	D	E	F	G	H	I	L
1	Vertical structures	□	□	□	□	□	□	□	□	□	❍
2	Floors	□	□	□	□	□	□	□	□	□	❍
3	Stairs	□	□	□	□	□	□	□	□	□	❍
4	Roof	□	□	□	□	□	□	□	□	□	❍
5	Infills-partitions	□	□	□	□	□	□	□	□	□	❍
6	Pre-existing damage	□	□	□	□	□	□	□	□	□	❍

The damage to be reported in Section 4 is the apparent damage, i.e. what can be observed on the structural components during the survey, being it pre-existent or related to the earthquake.

The first 4 rows are relative to structural components; row 5 refers to non structural components of particular relevance (infills and partitions), which may modify the resistance and/or the response of the structure, in particular for frame structures; row 6 records the pre-event damage to the whole building. The columns are differentiated in order to allow the identification of the damage grade and extension.

The damage classification is simply done by checking the squares of the table relevant for the case under study, with the following considerations:

- Each square corresponds to a given damage grade and to a given extension of that damage grade;
- the whole list of components must be explicitly considered (rows 1 – 5): if no damage is noticed for any one of them, the option ‘null’ must be checked (circle) and the other options in the row should not be checked (squares). If some damage is observed, the corresponding squares should be checked. The surveyor is not allowed to leave blank any row in the damage table, unless the relative component is not present in the building under inspection;
- in the rows from 1 to 5, the total apparent damage to each component at the moment of the inspection is described, i.e. the visible changes with respect to an ideal original condition of the building, without any damage (cracks, out of plumb, etc.). In row 6 the pre-existing damage of the building, in global terms, presumably existing before the seismic event is described.

The damage extension has to be estimated for each component separately and with reference to the entire building. This means that, for each component, the surveyor has to:

a) evaluate the percentage of the building affected by each of the three damage grades. To this aim, it is necessary to appropriately combine the relative damage extension in each floor, (relative number or surface of damaged components in each floor) and the number of damaged storeys. It should be also noticed that if one of the three damage grades is not present for a given component, none of the corresponding extensions will be checked;

b) estimate the relative extension to be assigned to each damage grade.

For example, when, in a three storeys masonry building, the damage grade D2-D3 concerns only 60% of the walls at the first storey, the extension of damage grade D2-D3, referred to the whole building, would be 60% x 1/3 = 20% and hence the damage extension will be classify as <1/3 (row 1, column F).

Similarly, in a reinforced concrete three storey building, when only 90% of the first level joints is affected by damage grade D3, the relative extension would be 90% x 1/3 = 30% and hence <1/3.

For each component, the sum of the damaged relative extensions must not be larger than 1. It is not allowed, for example, to associate the damage extension >2/3 both to D1 and to D2-D3.

On the other hand, when, in one component, the sum of the relative extensions is less than 1, it means that somewhere in the building that component did not suffer any damage. For example, if in row 1, the extension <1/3 is associated both to D1 and D2-D3 and no extension is associated to damage grade D4-D5, it means that at least 1/3 of the building walls did not suffer any damage.

In case of floors, the relative extension may be evaluated considering the ratio between the number of floors (vaults or plain) presenting that considered damage level and the total number of floors in the building.

In case of stairs, the reference can be the total number of flights, including landings.

In case of roofs, reference can be made to the extension of the damaged roof surface (referred to the total covered area) or to the number of bearing components (referred in this case to the total number of bearing components).

In the case of pre-existing damage (row 6), the damage extension is to be evaluated according to the same principles, with the only difference that the extension refers to the whole building and, hence, to all the building components. The damage assessment is then based on a synthetic judgement of the surveyor, reasonably representing the general damage condition before the earthquake.

The definition of the observed damage grades is based on the European Macroseismic Scale EMS98 [4], integrated with the additional specifications introduced in the past in the GNDT [1, 2] survey forms.

The EMS98 scale includes six possible damage grades (from D0-no damage to D5-destruction) referred to the whole building, based on the level and on the extension of structural and non structural damage in the building. Since the form includes the classification of damage and of its extension for each structural component (Section 4), and the presence of damage in non structural components (Section 5), it seemed sufficient to graduate 3 damage levels, combining level D2 with D3 and D4 with D5. Their definition corresponds to the brief description reported in the following; more details are given in §§ 4.3 e 4.4.

D1 slight damage: it is a damage that *does not affect significantly the capacity of the structure* and does not jeopardise the occupants safety due to falling of non structural elements; the damage is slight when the falling of objects can immediately be avoided.

<u>Masonry</u>: cracks of width ≤ 1 mm, no matter how distributed in masonry walls and in floors, without material expulsion, limited separations or slight dislocations (≤ 1 mm) between parts of structures, for example between walls and floors or between walls and stairs or between orthogonal walls. Limited out of plumb, not associated to earthquake induced phenomena of wall separation in elevation or settlements, which, if present, has to be pre-existent and not influencing the structural capacity. Limited damage to the most flexible roofs (wood or steel) with consequent falling of some tiles at the edges. Falling of small portions of degraded plaster or stucco, not connected to the masonry.

<u>Reinforced concrete</u>: slight cracks in the beams (up to 1 mm), widespread, but not vertical, cracks (< 0.5 mm) in columns or in partitions. Cracks up to 2 mm due to separation of the infill walls from the structures, slight diagonal cracks in the infills (< 1 mm).

D2-D3 medium-severe damage: it is a damage that *changes significantly the capacity of the structure, without getting close to the limit of partial collapse of the main structural components*. Possible falling of non structural objects.

Masonry: more severe cracks with respect to D1, also with expulsion of material and few mm wide (up to approximately 1 cm) or wider, if close to the openings, symptoms of cracks due to crushing, significant separations between floors and/or stairs and walls and between orthogonal walls, some partial collapses in the secondary beams of the floors. Cracks of some mm in the vaults, and/or with symptoms of crushing. In wooden or steel roofs with tiles covering, damage in the secondary beams and falling of a significant portion of the tiles covering. Visible out of plumb, induced by the earthquake, but in any case not larger than approximately 1%.

Reinforced concrete: flexural cracks in beams up to 4-5 mm, cracks in columns and in shear walls up to 2-3 mm, beginning of buckling of the compressed bars in the columns, with spalling of the concrete cover, just perceptible residual out of plumb. Evident cracks (> 2 mm) in infill walls due to the separation from the structure, diagonal cracks up to few mm, evident crushing at the corners in contact with the bearing structures, sometimes with localised expulsion of material.

D4-D5 very heavy damage: it is a damage that *significantly modifies the capacity of the structure, bringing it close to the limit of partial or total collapse of the main structural components*. This state is characterised by damages heavier than the previous ones, including collapse.

4.3 Masonry buildings

The masonry typologies used in Italy may differ significantly (see section 3), both for what concerns the constituent materials (units and mortar) and the layout. It is important to take into account these elements when associating the apparent damage (e.g. type of crack and width) to the consequent level of structural risk. The indications given in the following should be considered as indicative and valid for masonry types in which the energy dissipation capacity is mainly related to friction phenomena, which guarantee a given level of capacity even after modest cracks: for example, masonry constituted by solid units, roughly or well dressed, with lime or mixed mortar. Masonry constituted by hollow units, even with very good quality mortar, may, on the other hand, have a more reduced residual capacity after cracks have occurred. Rubble masonry usually gets damaged more easily, and often has significant pre-existing damage. For moderate damage levels, this type of masonry does not suffer significant capacity reductions; on the other hand, when damage becomes more severe, it can have brittle behaviours, with sudden loss of geometry and hence of resistance and vertical loads bearing capacity.

Even greater caution should be used when analysing the damage occurred to buildings repaired in the pre-event with heavy interventions, such as injections or reinforced plaster. In such cases, and especially for reinforced plaster on bad quality masonry, the cracks visible on the surface of the plastered walls may correspond to a widespread internal disruption of the wall, with subsequent separation of the old masonry from the repair.

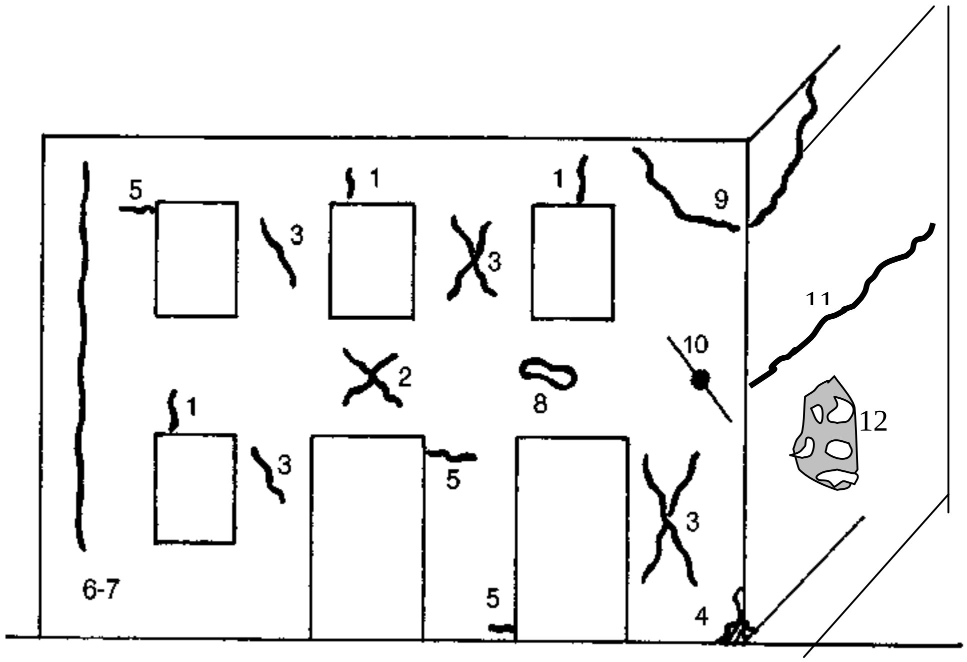


Fig.. 4.1 Reference scheme for cracks in masonry [modified from [1])
1: nearly vertical cracks on the opening lintels (Fig. 4.2);
2: diagonal cracks in the spandrel beams (window parapets, lintels) (Fig. 4.11);
3: diagonal cracks in vertical elements (masonry piers) (Fig. 4.8);
4: local crushing of masonry with or without material expulsion (Fig. 4.9, 4.20);
5: nearly horizontal cracks at the top and/or at the foot of masonry piers (Fig. 4.8);
6: nearly vertical cracks at walls intersections (Fig. 4.2, 4.4);
7: same as 6 but with through cracks (4.10, 4.11, 4.12);
8: material expulsion at the beam supports due to pounding;
9: formation of a displaced wedge at the intersection of two orthogonal walls (Fig. 4.13);
10: failure of tie rods or bond slippage;
11: horizontal cracks at the floor level (Fig. 4.12, 4.15) or at the attic level (Fig. 4.7);
12: separation of one of the wythes of a double-wythe wall (Fig. 4.14).

4.3.1 Level D0 - no damage

Cracks in the plaster due to shrinkage or damages occurred in the past, repaired and not reactivated, may be associated to this damage grade.

4.3.2 Level D1 – slight damage

4.3.2.1 Masonry

In what follows, reference is made to cracks on masonry walls and not only on the plaster.

Small flexural cracks at the top or at the foot of masonry piers (type 5 ≤ 1 mm) and at the openings corners or on the lintels of doors and windows (type 1 ≤ 1 mm, Fig. 4.2): the first type can be a symptom of a slight and temporary exceedance of the masonry tensile strength in the most stressed areas. The onset of these cracks is often due to the stress concentration at the corners of the openings.

Small cracks in the lintels may also be due to an arch behaviour and to the induced exceedance of the tensile strength in the portion of the wall beneath the arch (Fig. 4.3). In such cases, it is necessary to evaluate if the masonry zone underneath the arch is stable enough, otherwise it is necessary to insert a precautional propping of the opening. If the crack starts from the lintel and extends over the whole spandrel beam and similar cracks are present at the upper floors, then it is a likely symptom of a different mechanism, not anymore localised, which can be a prelude to the separation of all the vertical spandrel beams of the building. If the openings are small and no evidence of damage can be noticed in the soil, it may be inferred that the bearing capacity has not been significantly altered, especially if connections are present at every floor (tie beams or tie rods).

Diagonal cracks (due to shear) in masonry piers and in spandrel beams (type 2,3 ≤ 1 mm). This type of cracks indicates that the wall shear resistance has been exceeded, but the limited entity of the observed damage indicates that the force transfer through friction and through the connection between units has not significantly changed, so that the original bearing capacity is still available.

Small cracks due to crushing (type 4) (just perceptible and in any case < 1 mm). These cracks are due to local crushing of masonry, with crumbling of the mortar and/or stone or bricks, without any material expulsion. This type of damage may indicate that the masonry compressive strength has been locally exceeded, and may be facilitated by deterioration and/or lack of confinement, which are typical of corners. It should be evaluated with extreme care: if limited to a slight symptom, it can be included in this damage grade, otherwise it should be classified into the higher damage grade. Obviously, care must be used in order not to confuse this diagnosis with failure modes that may induce similar symptoms, such as, for example, the plaster expulsions due to the combined effect of humidity and of slight shaking (maybe vibrations due to traffic). In these cases it is possible to locally remove the plaster, to be able to inspect the masonry.

Cracks due to separation of the walls, at the wall intersections (type 6 – not through and 7 – through, of width smaller than approximately 1 mm, Fig. 4.2). This type of cracks, especially the through ones, indicates the loss of connection between orthogonal walls (Fig. 4.4). At damage grade D1, the failure mode is just at the beginning. Sometimes, it may be attributed to a reactivation of a pre-existing damage condition. It can be hence concluded that the initial capacity is not substantially changed and the damage can be classified as slight. Particular care should be given to ascertain the presence of effective restraints between walls and floors and/or roof. When these are not present, the lack of connection can create tall and slender isolated walls, susceptible of overturning or collapse due to orthogonal forces. This situation should be appropriately reported in the notes.

Cracks of type 8 are generally due to the localised thrust of wooden beams, struts, etc. If the wall damage is just perceptible, it may be assumed that neither the boundary conditions nor the capacity of the masonry (that obviously should not present out of plumb related to this failure mode) have been significantly altered.

Cracks of type 9 can be sometimes observed in the upper part of buildings, especially when appropriate connections are missing (tie beams, tie rods, confining rings, ties). The activated mechanism generally consists in sliding of a ‘wedge’ of the wall, due to the horizontal forces, which is not resisted by appropriate restraints. The failure may extend to lower floors if effective connections are missing. If the failure is very localised and cracks are not large, it may be considered as non dangerous, even in case of further shocks of similar intensity than the one that damaged the building; in any case, this failure mode should be reported in the notes, so that possible future inspections may check its evolution.

Slight damage to tie rods (type 10). The lengthening of tie rods or even the permanent deformation of anchorage zones (plates, wedges, underneath masonry) indicates an excessive stress on the structural component, which has induced plastic deformations. When no local collapse is present and when the plastic deformation is not very relevant, the structure, although deformed, may be considered to have reached a somehow stable configuration.

Visible out of plumb in ancient buildings, if stabilised and not reactivated by the earthquake (Fig. 4.5), could be considered as non influent on the safety, since they are by then part of a consolidated global static equilibrium. Obviously, when the entity of the out of plumb is significant, the whole building stability should be considered, in order to evaluate if the damage is really non influent. For example it is necessary to distinguish the case of out of plumb due to masonry deterioration from those indicating bulging of the whole wall. In any case, the structural risk associated to the wall out of plumb is conditioned by the effectiveness of the connection between wall and floors.

Horizontal cracks at the connection between walls and floors of type 11, with very limited dislocations (up to approximately 1 mm): they indicates the onset of sliding at the interface between the masonry and the floor or the roof (Fig. 4.6 at the level of the floor, just visible; Fig. 4.7 at the level of the attic).

4.3.2.2 Floors

Small cracks parallel to the spanning direction are often due to differential flexure among joists, a ‘physiologic’ phenomenon occurring under vertical loads in case of flexible floors (especially steel floors) facilitated by the discontinuity between joists and bricks, which tends to damage the plaster underneath. This failure mode does not reduce the resistance of the structure. Rarely, it may also happen that this failure mode is due to tensile forces orthogonal to the joists, generated by the connecting force exerted between two walls and the floor. In this case, cracks may indicate a modification of the initial scheme, but they should be visible also at the extrados (unless there is an elastic floor finish, such as rubber or wooden one). In any case, limited crack widths, such as those considered here, indicate the onset of the failure mode. Sometimes, the excessive floor out of plane flexibility (for example in wooden or steel floors) may also induce small cracks in the extrados plaster, orthogonal to the joists direction.

Substantial absence of displacements of the bearing beams at the supports.

4.3.2.3 Vaults and arches

In many types of vaults and in masonry arches, small cracks are physiological, especially in cloister vaults or in ribbed vaults of small thickness. The presence of tie rods, buttresses or massive walls tends to stabilise the structure but it does not completely eliminate these effects. When cracks are visible at the keystone or at the haunches, they are generally due to an eccentricity greater than the one for which the section is entirely compressed. Modest values of the crack opening, in relation to the thickness, may indicate that the eccentricity is not very significant and that the structure has reached a satisfactory configuration. In the risk evaluation, it is suitable to account both for the length of cracks, with respect to the element dimensions, and for the number and position of the cracks themselves.

4.3.2.4 Stairs

In case of cantilever stairs, made of stone, wood or steel steps: cracks up to 1 mm on the masonry at the fixed section. In case of masonry vaulted stairs: cracks up to 1 mm no matter how widespread.

4.3.2.5 Wooden or steel roofs with tiles covering

Wooden or steel roofs are generally more flexible than those in reinforced concrete. If the roof covering is made of tiles, they may easily disconnect due to vertical vibrations, with consequent sliding of the internal tiles and falling of the border ones in the pitched roofs. If these phenomena are limited and the structure is substantially intact, the damage, although limited to the roof functionality, may be significant for the safety of underneath areas. If the inspector perceives the presence of danger for the public, he must indicate in the short term countermeasures the removal of the dangerous components or the positioning of barriers.

4.3.3 Level D2-D3 – medium-severe damage

4.3.3.1 Masonry

Flexural cracks at the base or at the top of the masonry piers and on the lintels of doors and windows (type 1,5), opened up to 1-1.5 cm, may indicate a significant separation between the piers and the spandrel beams (Fig. 4.7). In this case, mainly for crack type 5, if the crack extension is relevant, it is reasonable to presume that in case of repeated event, the building could reach the higher damage grade. For crack type 1, when the damage is localised and propping of the opening may be applied, the structural risk can be considered low after countermeasures. On the contrary, if it is believed that many of the spandrel beams are not anymore able to restrain the masonry piers and hence that the static configuration has been significantly changed, then high structural risk will be considered. In this case, probably, several type 5 cracks will also be observed at the base of the most slender walls.

Diagonal shear cracks in masonry piers or spandrel beams (type 2,3 > 2 mm, up to approximately 1 cm) are generally due to the activation of a shear resistant mechanism producing visible dislocations (Figg. 4.8, 4.9). In case of slight dislocation and limited damage extension, the structural risk could be considered low, whilst in the opposite case, it will be considered high. In the right part of Fig. 4.8, shear cracks in the corner are not far from partial collapse. Sometimes, this type of cracks reveals the activation of a complex mechanism, including also out of plane deformations of the wall panel. In such cases, visible bulging is present, proving high risk for possible partial collapses.

Type 4 cracks of slight/medium width may be evidence of crushing failures. The behaviour of masonry with respect to this damage mechanism is generally rather brittle, especially for solid brick masonry and even more for hollow brick masonry; hence, this type of damage must be evaluated with great care. Its seriousness depends on the wall typology and geometry and on the damage extension, that indicates a more or less compromised vertical bearing capacity. If a strong concentration of vertical stresses occurred (for example due to the presence of openings reducing the resisting section), the structural risk can be considered high, especially in buildings of significant height and with poorly maintained masonry.

Vertical cracks at wall corners, of the order of 2-5 mm when through (type 7, Figg. 4.10, 4.11, 4.12) or slightly wider if not through (type 6), prove that the failure mode, characterised by loss of connection between orthogonal walls, has been clearly activated and that the original static scheme of the construction has been surely changed. In these cases, the evaluation of the structural risk deserves great attention. In case of small crack width and when it is possible to rely on an effective restraint (able to contrast out of plane failures) at the floor and roof levels, the structural risk can be considered low or low after countermeasures. In the opposite case, a high structural risk will be considered. This situation requires short term countermeasures, if the public safety is involved in the possible collapse.

Type 8 cracks should be considered as medium-severe if there is a modification of the component boundary conditions, that may induce localised thrust, or if there is a reduction of the masonry bearing capacity, associated to out of plumb related to the pounding effect.

Type 9 cracks at this damage grade have an extent such that it is possible to clearly detect the wedge of the masonry structure which tends to separate (Fig. 4.13). When there are evident dislocations, denoting sliding of the wedge, the structural risk should be considered high. If the dislocations are just perceptible, the structural risk can be considered low after countermeasures (propping or support).

Isolated cases of tie rods failure or bond slippage (type 10) affecting localised portions of the structure, with modest out of plumb associated. If failure is due to the seismic event, a significant modification of the static configuration has clearly occurred, inducing an evaluation of high structural risk. The damage severity can be in any case related not to the tie rod element, but to the consequences on the masonry structure caused by the tie rod failure.

Evidences of out of plumb, not pre-existing but due to the seismic event, are generally associated to cracks of type 6 or 7, with possible separation between walls and floors. The structural risk is usually high. The out of plumb must be smaller than 1% and short term countermeasures must be arranged. When the out of plumb denotes the bulging of the masonry, attention should be paid to the masonry typology: if it is double-wythe masonry or ‘a sacco’ masonry (see Section 3), it is possible that significant separations between the two wythes have occurred, which may even indicate an imminent partial collapse. In such cases, damage is definitely severe and type 12 cracks become visible (in Fig. 4.14 a very severe and widespread damage is shown).

Type 11 cracks with dislocations of some mm indicate a more or less severe sliding between the floor and the masonry underneath (at this damage grade, damage is intermediate between the onset of sliding, just visible in Fig. 4.6 and 4.7 and the evident dislocation in Fig. 4.15). Often, this failure mode is localised at the level of the attic. In such cases, if the displacement is more than few mm (2-3) and is due to the thrusting of the roof, it is possible to have high structural risk, due to the combined effect of the roof vulnerability (thrusting roof) and the modification induced by the sliding.

4.3.3.2 Floors

At damage grade D2-D3, floors show a well defined separation from the bearing structures (Fig. 4.16), generally related to out of plane failure modes of the masonry walls, and often including sliding of the beams of the order of a centimetre.

The support of the floor beam on the external walls is generally not compromised. It is possible to observe relevant damages to the floor finishes and to the secondary beams, if present (wooden or steel floors). Some failures in the secondary or tertiary beams (wooden floors) may occur.

If the floor is essentially undamaged, even if slight beam sliding has occurred, the structural risk has to be associated only to damage to vertical structures. On the contrary, if the floor is damaged, the structural risk can be considered high, or low after countermeasures, apart from damage to the masonry walls. In this case, the risk could concern only a limited portion of the building.

4.3.3.3 Vaults and arches

Cracks of significant width and depth both at the keystone and at the haunches, especially if associated to significant dislocations, may indicate that the structural risk is high. In such cases the reduction of the resisting section produces significant stress concentrations (Figg. 4.17, 4.18).

In any case it is necessary to evaluate the importance of the vault in the global structural behaviour: small thickness vaults, generally used as false ceilings, play a negligible role in the global behaviour, being however a source of risk for the inhabitants. More important vaulted ceilings may interact with the vertical structures; in such cases damage to the vaults may be more critical and may be a source of risk for the whole building.

At this damage grade, a clear-cut separation with respect to the masonry walls, usually due to the wall's out of plane failure mode and facilitated by the thrust of the vaults, may occur (Fig. 4.18).

4.3.3.4 Stairs

Damage more severe than the previous grade D1, but without any significant collapse. In case of vaulted masonry stairs, cracks similar to those described for the vaults may occur, while in case of other types of stairs it is possible to refer to the floor damage classification.

4.3.3.5 Wooden or steel roofs with tiles covering

The general considerations on the failure modes discussed for damage grade D1 still hold. At damage grade D2-D3, it is possible to observe damage to the secondary beams and significant displacements at the beams supports (wooden or steel beams), localised failures of the secondary beams and/or falling of a significant amount of tiles with respect to the total amount (for example of the order of 20%). The structural risk evaluation will be in general high if important collapses occurred, while it may be low after countermeasures if the only falling of tiles or localised damages occurred. In case of reinforced concrete roofs, with tie beams and slabs, the failure modes just described will not occur; however, sliding between roof and masonry walls may occur. In this case, the structural risk will be either low after countermeasures or high (see also type 11 cracks on the masonry), depending on the importance of the phenomenon and on the possible consequences on the wall connections.

4.3.3.6 Reinforced concrete roofs

In the case of roofs constructed with reinforced concrete or prefabricated joists, but without any slab, the inspector has to ascertain the presence of effective tie beams and of thrusting configurations. Discontinuous tie beams, or tie beams unable to eliminate the thrust, may induce significant sliding of the roof with respect to the masonry walls, with a consequent high structural risk. Continuous tie beams, associated to non thrusting roofs without slab, may avoid global failures, but they are generally unable to contrast local failures of the bricks, with consequent localised risks.

4.3.3.7 Partition walls and other non structural components

Partial collapses with consequent high risk or low risk after countermeasures, depending on the extension and the position of the damage.

4.3.4 Level D4-D5 – very heavy damage and/or collapse

Damage to structural components more severe than the previous grade (D2-D3), with expulsion of a significant amount of structural material and/or localised collapse of bearing walls and of wall corners. In Fig. 4.19, the overturning of a façade close to collapse is reported (type 7), in Figg. 4.20 and 4.21, very severe diagonal cracks, in Fig. 4.22 a striking separation between floor and walls, in Fig. 4.15 a dangerous type 11 dislocation, in Fig. 4.23 a very severe out of plumb related to soil instability.

This damage grade includes also the partial collapses of floors, roofs and/or vaults, such as those reported in Figg. 4.6, 4.24, 4.25, as well as striking type 12 failures, such as the one reported in Fig. 4.14.

Total collapse of the building.

Fig. 4.2:
Vertical cracks in the spandrel beam between the two openings (type 1) and along the left transversal wall (type 6).
Damage grade: D1

(Tortora, CS, 1998)

Fig. 4.3
Vertical (type 1) and diagonal (type 2) cracks in the lintel. Propping has been inserted.
Damage grade: D1

(Correggio, RE, 1996)

Fig. 4.4
Vertical cracks along the two orthogonal walls (type 6)
Damage grade: D1

(Tortora CS, 1998)

Fig. 4.5
Pre-existing out of plumb in a building located in the historical centre. Pre-existing damage grade for the building: D1

Fig. 4.6
Vertical cracks and separation from the adjacent building (type 7); diagonal and horizontal cracks (type 3) at the floor level (type 11); partial collapse of the roof and of the walls supporting the roof.
Damage grade: D2-D3 to the vertical structures of the lower storeys; D4-D5 to the upper storey walls and to the roof.

(Busche, PG, 1998)

Fig. 4.7 Widespread vertical (type 1) and diagonal (type 3) cracks; almost horizontal crack (type 11) at the level of the attic. Damage grade to walls: D3 to be associated to the entire wall. (Busche, PG, 1998)	
Fig. 4.8 Diagonal cracks in the second storey masonry piers (type 3), connected to horizontal cracks (type 1); on the right, a large masonry wedge, displaced by more than 10 cm, can be noticed Damage grade: D4.	

Fig. 4.9
Diagonal crack (type 3) in a masonry pier, with dislocation at the base.
Damage grade: D3, not far from D4

(Fabriano, 1997)

Fig. 4.10
Vertical crack with separation of the orthogonal walls (type 7).
Damage grade: D2-D3

(Tortora, CS, 1998)

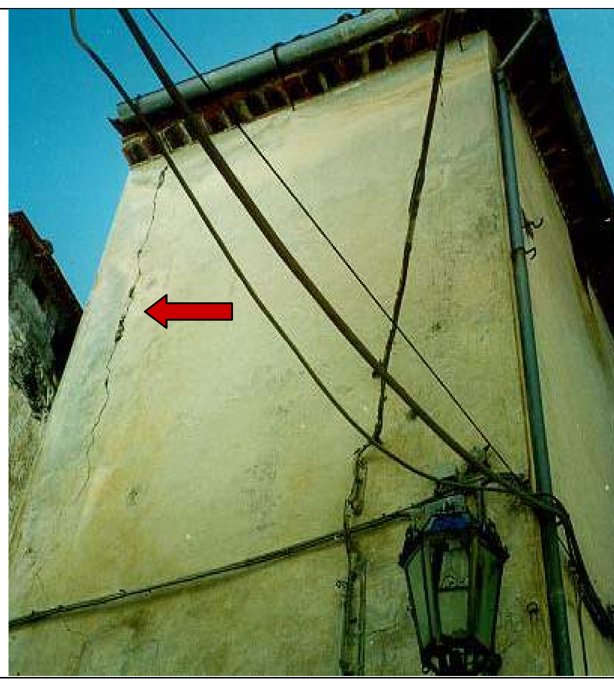


Fig. 4.11
Interior cracks with separation of the orthogonal walls at the corner (type 7)
Damage grade: D2-D3

(Tortora, CS, 1998)

Fig. 4.12
Vertical cracks with separation (type 7) of orthogonal walls.
Damage grade: D3 not far from D4

(Rivello, PZ, 1998)

Fig. 4.13
Crack with separation of the attic corner (type 9)
Damage grade: D2-D3

(Cerqueto, PG, 1998)

Fig. 4.14
Partial collapse of ‘a sacco’ masonry near old openings, due to widespread separation of the external wythe (type 12); on the right, a severe diagonal crack (type 3), interesting a large portion of the wall and displaced by several cm, can be observed.
Damage level: D4

(Busche, PG, 1996)

Fig. 4.15
Severe sliding at the level of the attic tie beam due to the thrust of the reinforced concrete roof (type 12; the same crack is symmetrically present on the parallel opposite external wall); crack at the corner (type 9).
Damage grade: D4-D5

(Busche, PG, 1998)

Fig. 4.16
Separation of the wooden floor from the masonry wall. Beam sliding is also evident (view from below).
Damage grade to horizontal structures: D2-D3

(Treia, 1998)

Fig. 4.17 Cracks on brick stretcher bond vaults with tie rod. Damage grade to horizontal structures: D2-D3 (Correggio, 1996)	
Fig. 4.18 Longitudinal crack at the keystone of a cross vault and separation from the gable. Damage grade to horizontal structures: D2-D3 (Correggio, 1996)	

Fig. 4.19
Very severe vertical crack (type 7). Incipient out of plane failure of the façade.
Damage grade to vertical structures: D4

(Rivello, 1998)

Fig. 4.20
On the left, vertical cracks due to wall separation (type 7); on the right, diagonal crack (type 3) on the masonry pier.
Masonry is made of tuff units.
Damage grade to the wall: D3

Fig. 4.21
Diagonal cracks (type 3) associated to an out of plane overturning failure mode, with considerable out of plumb.
Damage grade: D4

(Grello, PG, 1998)

Fig. 4.22
Damage to the ceiling, due to the wall separation and the consequent loss of support of the hollow clay tiles.
Damage grade to ceiling: D4
Damage grade to vertical structures: D4

Fig. 4.23
Out of plumb (approximately 8%), related to pre-existing soil instability due to the presence of an active landslide.
The pre-existing damage grade to the building is D4, only slightly aggravated by the earthquake.

(Lauria, 1998)

Fig. 4.24
Partial collapse of masonry walls and roof.
Damage grade to the wall: D4-D5
Damage grade to the roof: D4-D5

(Busche, PG, 1998)

Fig. 4.25
Partial collapse of the roof made of reinforced concrete joists and hollow clay tiles without slab.
Damage grade to the roof: D4-D5

4.4 Reinforced concrete buildings

4.4.1 Level D0 – no damage

Cracks in structural components within the width limits reported by the code (in the range of 0.2–0.4 mm).

4.4.2 Level D1 – slight damage

4.4.2.1 Beams and columns

Crack widths of the order of 1 mm orthogonal to the beam axis are just above the code limitations and hence may be due to the seismic action, especially in under-reinforced structures. Usually, no yielding of steel occurs during the earthquake and, even if this is the case, once the earthquake is ended, steel yielding should reduce to an internal stress state that is not detrimental to the building capacity. Obviously, cracks exposed for long time to an aggressive environment may induce steel corrosion an hence reduce the bearing capacity. For this reason the phenomenon, if present, must be reported in the form.

At the same damage grade, the width of cracks perpendicular to the column axis is generally smaller than the one in beams, thanks to the column normal stress which tends to close the cracks. Hence, cracks in columns smaller than a mm would be considered slight. On the other hand, care must be used when considering vertical cracks, even smaller than a mm; when it is believed that they may indicate the onset of a crushing failure mode, the damage grade should be considered at least D2. When, instead, they can be due to other causes, for example volume increase due to reinforcement oxidation with consequent onset of spalling of concrete cover, the damage level may be considered D1.

At this damage grade, cracks in the joints wider than few tenth of mm must be excluded. Similarly, perceptible out of plumb caused by the earthquake and by the associated structural deformation must be excluded. In some cases, out of plumb is due to foundation settlements that induce a rigid motion of the structure. In this case, it is necessary to investigate the failure mode with accuracy and, if necessary, to require a more detailed inspection, suitably compiling Section 7 and 8. In this case, the possibility of having a high geotechnical risk should also be considered.

4.4.2.2 Floors and roof

For what concerns the damage to floors, what has been said about masonry buildings still holds. Cracks parallel to the joists may occur due to non uniform joist flexure that may also cause slight damage at the bottom of the floor hollow bricks, in case they have been cast-in-place already damaged. If the cracks do not reach the floor extrados, the continuity of the floor is not lost. Then the original diaphragm function is maintained and the original structural static scheme can be considered essentially unchanged. Possible transversal cracks at the connection of the joists to the flat slab must be considered with care. If a crack in that position occurs and it runs along the position of the joist, it is possible that the continuity between main and secondary structure has been lost, at least partially, and hence there may be the need of provisional propping.

Slight cracks (1 mm) transversal to the joist direction could be caused by the increased load due to the seismic vertical component and may be more evident in large and flexible floors. Such increment does not in general constitute a risk, unless the structure is unable to bear the vertical loads themselves.

For what concerns roofs, apart from the evidence of structural damage, the falling of tiles from the roof edges, when occurred, should be reported in Section 5.

4.4.2.3 Infills

At this damage level, cracks in the infills are essentially due to a small separation of the masonry panels from the structure (≤ 2 mm), due to horizontal displacements which are generally acceptable in reinforced concrete structures. Small diagonal cracks (≤ 1 mm), proving the infill contribution to the overall capacity, can be observed.

It is necessary to pay attention to the possible out of plane overturning of the infill, that comes out of the frame in which it is inserted. This can easily occur in case of hanging covering in front of the bearing structure and not connected to it. In such cases, this failure mode, even at this damage grade, may indicate a significant non structural risk in case of a further shock. Hence, this damage, in absence of a more severe damage in the structural components, may lead to a low or “low after countermeasures” non structural risk. In case of completely disconnected hanging covering, the evaluation might even be of high non structural risk. In this latter case, it is necessary to indicate the appropriate short term countermeasures (1, 2, 8 or 9 in Section 8), able to guarantee the safety of the underneath area.

4.4.2.4 Stairs

Stairs connected to the load bearing structure act as braces under seismic loads. Their damage provides an indication of how much the whole structure has been stressed during the event.

At this damage grade, crack widths are very small and similar to those in beams and columns, so that in general it can be assumed that the earthquake has not significantly reduced the structural bearing capacity.

4.4.3 Level D2-D3 – medium-severe damage

4.4.3.1 Beams and columns

In the less severe damage grade (D2), cracks are similar to those described for level D1, but with slightly larger width; hence, similar considerations on the building failure mechanisms and the building safety still hold. In the more severe damage grade (D3), the increased crack width indicates that widespread yielding of the reinforcement, possibly inducing bond slippage between steel and concrete and the initial stage of buckling of the bars, has occurred. In such situations, the safety with respect to collapse in case of future shocks relies on structural redundancy and material quality. Both elements may be qualitatively assessed for the determination of the structural risk level.

In Figure 4.26, the damage to the short column may be classified as D3 in case of effective stirrups, but it may become D4 if stirrups are widely spaced. The consequence on the building safety also depends on the possibility that other columns, or walls, are able to withstand horizontal forces. It is also necessary to pay attention to the possibility of very large cracks having eliminated some mechanisms of shear transfer (aggregate interlock, dowel action).

Generally, a crack pattern characterised by cracks orthogonal to the beam axis, even of the order of few millimetres, and by the absence of cracks parallel to the column axis, may indicate a ‘seismically correct’ dissipative mechanism, which can still offer large margins of safety in case of strong aftershock. It is necessary, however, to make sure that other important modifications have not occurred, such as for example severe and widespread damage to infills, which could significantly reduce the seismic capacity, both in terms of resistance and dissipation capacity (Figg, 4.27a, b, c). In the most favourable case (widespread damage, infills not collapsed, regular structure), the structural risk could even be low with countermeasures (for example local propping of the beams, to ensure their capacity of shear transfer).

Particular attention should be paid to cracks which can be related to concrete crushing, causing spalling of concrete cover and onset of buckling of the rebars (Figg. 4.28, 4.29). This type of damage significantly reduces the section capacity of tolerating further cycles of stress and may lead to a high structural risk in case of no redundancy. An example is when it affects the top section of many columns at the same storey (in Fig. 4.30 this type of damage is shown, with damage grade D4).

Diagonal cracks in the joints, wider than few tenths of a mm up to approximately 2 mm, without appropriate reinforcement (very common situation in buildings designed before 1996) may indicate a significant loss of stiffness and resistance of the joint (Fig. 4.31 shows a damage grade D3, not far from D4).

At this damage grade, a perceptible out of plumb due to the earthquake may occur, but without causing a significant stress increase due to second order effects: for example, an interstorey displacement negligible with respect to the column section dimensions. Such permanent displacement is an evidence of the permanent damage of the structure, which could influence its future behaviour in case of aftershocks. Like for the slight damage level, in case of possible foundation settlement, it is better to dispel any doubt about the cause of the out of plumb, requiring, if necessary, a more detailed inspection by compiling appropriately section 7 and 8.

4.4.3.2 Floors and roof

Generally, reinforced concrete buildings floors get damaged with the same failure mode already described at the lower damage grade. Particular care must be given to the possible separation between floors and flat slabs or between floors and beams parallel to them which could indicate, if widespread, a significant change in the static scheme. At this damage level, cracks of this type are generally of the order of 2–4 mm. Attention should also be paid to the roofs, often without structural continuity with the frame or even thrusting. To these categories belong for example pitched roofs built on “muricci” (hollow brick walls supporting the roof joists) or roofs with joists built afterwards and hence connected to the structure below in an uncertain manner. In these cases, the damage assessment must be accurate, in order to detect any damage in the roof components exerting an improper function (e.g. “muricci”) and the observed damage must be reported in the row concerning structural damage to the roof. It is also appropriate to report in the notes cases of this type. Cases of tiles falling from the roof edge must be reported in Section 5 of the form.

4.4.3.3 Infills

At this damage grade, failure modes in the infill walls consist in significant separations from the structure (2–5 mm; Fig. 4.32), diagonal cracks or displacements of few mm, visible crushing at the infills corners. It is also possible to observe spalling of material or even limited partial collapses. All these damages prove a significant contribution of the infills to the building response. At the same time, the infills, in case of repeated event, would not be able to offer the same contribution.

When the damage is widespread, provided that the infills were effective and well arranged, the loss of building capacity could be significant and hence the infill damage may lead to high structural risk if the bearing structure is also damaged. On the contrary, if the damage is more localised and/or the infills were arranged in such a way to worsen the structural response, the infill damage could be insignificant for the structural safety, leading to a more favourable structural risk evaluation. In both cases, it is important to take into account the non structural risk associated to the infill damage, compiling sections 5 and 8. Cracks proving the activation of an overturning failure mode are more pronounced then those associated to the D1 grade, and generally would lead to a high non structural risk.

4.4.3.4 Stairs

Damage to stairs in RC buildings is generally due to their bracing behaviour in the framed structure. It is then important to pay attention to the connection between the frame and the stair components, for example at the connection between the stair beam and the column, at mid height. In such zones, the beam-column joint creates short columns that exhibit less ductile, or even brittle, behaviour. This damage grade may induce the loss of the stair functionality; in such cases, the structural risk evaluation may be high or low after countermeasures, independently on the damage grade assessed in other parts of the structure.

4.4.4 Level D4-D5 - very heavy damage and/or collapse

Damages more serious than those described for the grade D2-D3: cracks > 5 mm in beams and > 3 mm in columns and walls, with significant spalling of the concrete cover, and affecting also the core, significant buckling of the columns reinforcement, out of plumb larger than 1-2% of the interstorey height, large and widespread separations between the bearing structure and floors or roofs, total collapse of infill panels (Figg. 4.33 and 4.34), partial collapse of the structural components up to the complete building destruction. In most cases, the structural risk associated to this damage grade is high, unless the damage is limited to a very small portion of the building. Examples of this damage grade are reported in Figure 4.30, 4.35, 4.36 and 4.37.

Fig. 4.26 Crack due to shear and axial force in a brittle short column. Damage grade: D3, not far from D4 (Castelluccio Inferiore, PZ, 1998)	

Fig. 4.27
Cracks in several columns, facilitated by oxidation of the reinforcement. Insufficient stirrups. Total damage grade to vertical structures: D2-D3
(Fabriano, 1997)

Fig. 4.28
Concrete spalling at the column top section, slight vertical cracks.
Damage grade: D2-D3
(Bagnolo, RE, 1996)

Fig. 4.29
Damage to the beam-column joint with concrete spalling.
Crushing of the infill panel.
Damage level to vertical structures: D4

Fig. 4.30
Very heavy damage to a reinforced concrete framed structure; out of plumb and plastic hinges formation at the top and bottom of the columns of the ground storey.
Damage grade: D4-D5
(Turkey, 1999)

Fig. 4.31
Damage to the beam-column joint; concrete spalling, horizontal crack and onset of buckling of the reinforcement.
Damage grade to vertical structures: D3
(Fabriano, 1997)

Fig. 4.32
Horizontal and vertical cracks to the infill panel, causing separation from the RC structure; partial collapse of the infill panel between the two doors.
Damage grade to infills: widespread D2, locally D4.
(Castelluccio Inferiore, PZ, 1998)

Fig. 4.33
Severe cracks in weak infills.
Damage grade to infills: D4
(Castelluccio Inferiore, PZ,1998)

Fig. 4.34
Out of plane overturning of brick hangings not connected to the RC structure.
Damage grade to infills: D4
(Fabriano, 1997)

Fig. 4.35
Very heavy damage to a reinforced concrete framed structure, with collapse of several columns at the first and second storey.
Damage grade: D4-D5
(Turkey, 1999)

Fig. 4.36
Total collapse (pancake) of a reinforced concrete building, similar to the one under construction in the background.
Damage grade: D5
(Turkey, 1999)

Fig. 4.37
Collapse due to soft storey at the ground floor.
Damage grade: D5
(Turkey, 1999)

4.5 Damage to non structural components

SECTION 5 Damage to non structural components and existing short term countermeasures

	Damage	PRESENT	EXISTING SHORT TERM COUNTERMEASURES					
			None	Removal	Propping	Repair	No entry	Barriers or passage protection
		A	B	C	D	E	F	G
1	Falling of plaster, coverings, false-ceilings	❍	❍	☐	☐	☐	☐	☐
2	Falling of tiles, chimneys...	❍	❍	☐	☐	☐	☐	☐
3	Falling of eaves, parapets…	❍	❍	☐	☐	☐	☐	☐
4	Falling of other internal or external objects	❍	❍	☐	☐	☐	☐	☐
5	Damage to hydraulic or sewage systems	❍	❍			☐	☐	☐
6	Damage to electric or gas systems	❍	❍			☐	☐	☐

The damage caused by the earthquake to non structural components is important both for the usability classification and for the estimate of the repair costs. Typical damages to non structural components are those concerning plasters, coatings, stuccos, false ceilings, infill panels, non structural roof components, covering, eaves and parapets. Damages to the water, gas or electricity plants are also included.

In Section 5, the presence of damage to non structural component is registered together with the presence of existing short term countermeasures. Four rows of Section 5 concern the possible falling and separation of different components, while the last two rows concern damage to plants; for each of them the presence of damage should be reported in the first column. For what concerns the existing short term countermeasures, for each type of damage reported in the rows of Section 5, the possible presence of several kinds of countermeasures may be listed; if no short term countermeasures have been inserted before the inspection, the correspondent circular cell of the column *None* should be marked.

It is necessary to carefully evaluate the risk associated to the damage to non structural components, especially if they endanger people as a consequence of loss of stability or induced effects. The latter case may happen in case of damage to plants. When the risk is so high that the building should be classified unusable (outcome B in Section 8), it is important as well to carefully evaluate the possibility of using short term countermeasures in order to remove the dangerous components.

Countermeasures have to be reported in Section 8 and possibly to be made explicit in the notes of Section 9.

4.6 External risk induced by other constructions

SECTION 6 External risk induced by other constructions and existing short term countermeasures

Potential cause		Risk on			Existing short term countermeasures	
		Building	Entry road	Lateral roads	No entry	Barriers or passage protection
		A	B	C	D	E
1	Objects falling from adjacent buildings	☐	☐	☐	☐	☐
2	Failure of distribution systems	☐	☐	☐	☐	☐

Another factor of risk, which is important to ascertain during the safety inspection, is related to damage to components that are external to the building under survey. Danger may derive from instability of adjacent buildings (risk of collapses or objects falling), or from unsafe conditions of the distribution systems.

In Section 6, reference is made to these two situations. In addition it has to be evaluated, with a possible multiple answer, whether the risk affects directly the building, the entry road or the lateral roads.

Also in this case, possible existing short term countermeasures should be reported and, as in the previous section, attention should be paid to the unusability classification when short term countermeasures may be effective. Very frequent is the case of buildings located within the historical centre in which the induced risk is caused by a danger on the entry roads. It is, hence, very important to have correct information on the buildings involved. Very important as well is to indicate in the map such situations, in order to be able to manage the short term countermeasures which may render safe even entire blocks or districts.

4.7 Soil and foundations

SECTION 7

4.7.1.1.1 Soil and Foundation

SITE MORPHOLOGY				DAMAGE (present or possible): ❑ Slopes ❑ Foundation Soil			
1 ❍ Crest	2 ❍ Steep slope	3 ❍ Mild slope	4 ❍ Plain	A ❍ Absent	B ❍ Produced by eqk.	C ❍ Worsened	D ❍ Preexistent

In Section 7, qualitative information concerning the soil and the foundation, needed for the geotechnical risk evaluation, are collected. They have to be considered an evidence of damage rather than a geotechnical assessment. The information includes the description of the *morphology of the site* where the building is located and the possible presence of visible *soil instabilities*, with a distinction between *instable slopes* and *settlements affecting* the building *foundations*. In case of soil instabilities, the inspector has to evaluate if the instabilities are due to the earthquake or, instead, if they were there before the event.

Buildings located on a *crest* are usually more vulnerable due to local amplification of the seismic motion; foundations located on a *steep slope* or at different levels may induce soil or foundation settlements, especially in presence of soil instabilities. For this reason, the background of these cells is filled with grey.

The safety assessment, therefore, accounts for the geotechnical risk in a way consistent with the *quick* character of the survey.

In post-earthquake emergency, landslides are also inspected and hence it is very likely that buildings on landslides will be identified during the landslide inspection; however, the opposite may also occur, that is the soil instability may be identified during the inspection of buildings resting on that soil.

Possible situations of external risk induced by the soil, which may concern, for example, the entry roads and which must be evaluated with care, as previously discussed, should be reported in this section.

5 INSTRUCTIONS FOR COMPILING SECTIONS 8 AND 9: USABILITY CLASSIFICATION AND SHORT TERM COUNTERMEASURES

5.1 Preamble

Section 8 is devoted to the usability classification and to short term countermeasures. It is composed of four parts:

1. *Risk evaluation*: where the observations reported in the previous sections (from 3 to 7) are summarised in terms of risk, with the aim of providing some guidance for the usability classification.
2. *Usability classification*: where five possible outcomes are reported.
3. *Unusable building units, families and people to be evacuated*: where the consequences of the delivered judgement are quantified in social terms.
4. *Short term countermeasures*: where short term countermeasures are proposed. Short term countermeasures guarantee the private and/or the public safety. In the first case they should be easily and quickly inserted.

It is duty of the Mayor, being responsible of the citizen’s public safety, to issue the orders of evacuation in case of unusable building. The surveyor usability classification, transmitted to the Technical Municipal Offices, is to be considered as a proposal, which could hence be modified from the Mayor. From what said, it is also possible for the Mayor to issue independently an order of evacuation, after having consulted, if necessary, a reliable technician.

5.2 Risk Evaluation

RISK	*STRUCTURAL (Sect. 3 and 4)*	*NON STRUCTURAL (Sect. 5)*	*EXTERNAL (sect. 6)*	*GEOTECHNICAL (sect. 7)*
LOW	❍	❍	❍	❍
LOW WITH COUNTERMEASURES	❍	❍	❍	
HIGH	❍	❍	❍	❍

The observations reported in the previous sections must be summarised in order to judge on the following types of risk:

- Structural risk related to the conditions (typology and damage) of the bearing elements (vertical structures, horizontal structures, infill panels significantly contributing to the seismic resistance of the building, etc. - Sections 3 and 4);
- non structural risk, related to the conditions of those elements not having a bearing function (partition walls, tiles, chimneys, technological networks, etc), which can threaten the private or public safety (Sections 4 and 5);
- external risk, induced by possible partial or total collapses of adjacent buildings, on the building under study or on the streets leading to it (Section 6);
- geotechnical risk, related to the conditions of soil and foundations (Section 7).

It is required to always fill in the “risk” table, indicating “Low Risk” even in case of no damage or in case of particularly favourable vulnerability indicators.

In case that every type of risk is low, the surveyor will judge the building usable, while if at least one of them can be considered high, the building will be classified as partial or total unusable. When the risk, although elevated, can be reduced by short term countermeasures, quick to be inserted and not too demanding, the building can be considered usable after countermeasures.

To provide a rough evaluation of the risk associated to the four previous indicators, the risk conditions have to be indicated in proper cells having a grey background, with darker grey indicating a higher level of risk.

The risk, in particular for what concerns the structural risk, must be classified referring to the usability definition reported and discussed in § 1.3 of the present manual: hence it is generally and mainly based on the apparent damage induced by the earthquake (Section 4), except for cases in which the reference event has been explicitly indicated as having an intensity larger than the recent *earthquake*, or when the damage is concentrated in the range D2-D3, with large uncertainties on the consequences in terms of reduction of the original capacity. In these cases, the vulnerability indicators associated to the building (Section 3) and to the site morphology (Section 7) may become important.

Section 3 of the form indicates, for masonry buildings, the following vulnerability indicators: the quality of masonry in the walls (regular layout and good quality masonry, irregular layout or bad quality masonry), the deformability and the thrust of the floors (vaults, flexible, semirigid and rigid structures), the presence of tie rods, the presence of isolated columns, the type of roof (heavy or light, thrusting or not thrusting) and the shape regularity of the building. For reinforced concrete or steel buildings, the form indicates: the presence or absence of frames and/or walls, the shape regularity of the building in plan and/or in elevation and the regular or irregular distribution of infill panels (which may lead, for example, to a soft story mechanism).

Even some items referred to the building identification (Section 1) or description (Section 2) may be useful to assess the building vulnerability: in case of complex aggregates, buildings interact and the position of the building may be significant, in the sense that extreme or corner buildings are often more vulnerable. On the other hand, in case of isolated buildings, a significant number of storeys or a significant slenderness (ratio of total height over square root of average surface in plan) may increase the vulnerability in buildings not designed according to anti-seismic criteria.

For further discussions on the vulnerability indicators, the reader is referred to the second level GNDT forms and the relative field manual [1].

In case of vulnerability indicators particularly elevated, they may induce to judge the structural risk as high, even in case of light damage or total absence of damage, if the reference earthquake has a higher degree than what felt by the building during this seismic crisis.

5.3 Usability classification

For reasons of uniformity of behaviour and of procedures and also for the needs of data management, the usability classification must correspond to one of the possible six alternatives considered in the form:

A	**USABLE building**	❍
B	**TEMPORARILY UNUSABLE building (totally or partially) but USABLE with short term countermeasures**	❍
C	**PARTIALLY UNUSABLE building**	❍
D	**TEMPORARILY UNUSABLE building requiring a more detailed investigation**	❍
E	**UNUSABLE building**	❍
F	**UNUSABLE building for external risk**	❍

A *Usable building*

The building can be used in all its parts without any threat to the inhabitants life, without any short term countermeasure. This does not mean that the building has not suffered any damage, but only that the repair of damage is not a necessary condition for the usage of the whole building. In case of usable building, there are not unusable building units nor families and/or people to be evacuated.

B *Temporarily unusable building (totally or partially), but usable after short term countermeasures*

The building, in its current state, is at least partially unusable, but it may be sufficient to insert short term countermeasures in order to reduce the risk to the inhabitants to an acceptable level. It is necessary, in this case, to indicate in the form the countermeasures necessary to allow for the use of the building and to be sure that the countermeasures are notified to the municipality. It is not however a surveyor's task to check whether these countermeasures are actually realised.

It should be noticed that these countermeasures should actually be "short term", i.e. they have to be performed in short term, with moderate expense and without any precise design intervention. Otherwise, the building must be considered as unusable, totally or partially.

It is in any case desirable to compile the part of the section concerning unusable building units and the number of families and/or people to be evacuated.

C *Partially unusable building*

The damage condition in limited parts of the building can be such to imply an elevated risk to their occupants and hence to determine an outcome of unusability. In case it can be believed that further possible damages in this area will not jeopardise the stability of the remaining parts of the building, nor impede the access to it, and will not constitute a danger for the occupants, then the building may be judged partial unusable.

In case of partially unusable buildings, it is necessary to clearly indicate in Section 9 (Notes) which parts of the building are considered as inaccessible and to be sure that such areas are notified to the municipality. It is not, however, the surveyor's task to check that the entrance to the areas considered inaccessible is actually prevented.

It may happen that in building classified partially unusable some building units may be unusable and families and/or people may be evacuated.

D *Temporary unusable building requiring a more detailed investigation*

The building shows characteristics such that it is not possible to judge about the building usability. A further, more detailed, inspection is required and/or carried out by more expert technicians. Until the new inspection, the building is to be considered as unusable and the part of the section concerning unusable building units and families and/or people to be evacuated is to be compiled.

This classification has to be used only in cases of actual need, since it implies a significant increase of the survey activity.

E, F *Unusable building*

For management needs, the case of actual unusability of the building due to structural, non structural or geotechnical risk (E) is distinguished from the case of unusability due to severe external risk (F), without any significant damage to the building itself.

The building cannot be used in any of its parts, not even after short term countermeasures. This does not necessarily mean that damages cannot be repaired, but it means that the repair requires an intervention which, for the time required by the design and the realisation, and for its costs, must be considered as part of the reconstruction process.

In the notes, it should be indicated whether the unusability condition is due to pre-event conditions. In any case, the usability classification must be notified to the municipality. It is not a surveyor's task to check that access to the building is actually prevented. It is necessary to compile the part of the section concerning unusable building units and families and/or people to be evacuated.

In case of outcome B, the classification and the indication of the short term countermeasures are indissoluble. However, even in the other cases, it is necessary to indicate the countermeasures required, if necessary, to guarantee the public safety, even if they do not have any consequence on the usability outcome of the building under study. For example, a building which has been declared unusable for structural damage, may threaten a street, due to the danger of tiles falling down from the roofing. The building remains unusable even after the removal of the dangerous tiles, but the safety of people passing by could be guaranteed if no other risks of collapse on the street itself exist. Another example could be the case of a usable building looking on to a street with a blind façade, with unsafe tiles. The building itself is usable, but it could be a threat for the street, hence the tiles removal would allow to eliminate the risk for people passing by. In all these cases, it is necessary to notify to the municipality the proposed interventions.

5.4 Unusable building units, evacuated families and people

Unusable building units. The number of building units affected by the unusability classification must be registered. It coincides with the number of building units of the building only in case of unusable or temporary unusable buildings and is smaller in case of partially unusable buildings. It is suitable to include the residential units, even if not used, and also the productive units, if the activity is practiced permanently. This information may be useful to estimate the building units which cannot be used as shelters.

Families to be evacuated. The number of families, living in the building, which would be evacuated due to the unusability classification must be registered. This includes both those families which have spontaneously evacuated the building after the earthquake (which could come back to their houses after a positive usability judgement), and those families actually present at the moment of the inspection. If a person lives alone, it constitutes in any case a family. This information may be useful to estimate the number of shelters to be predisposed.

Number of people to be evacuated. The number of people, living in the building, belonging to the families to be evacuated, must be registered. This information may be useful to estimate the total number of homeless people.

5.5 Limited or extended short term countermeasures

The most frequent short term countermeasures are indicated in the form. The list has the twofold scope of helping the computerised data management, but also of clarifying the difference among these countermeasures, such as application of strands, tightening, propping, etc., and those typical of a reconstruction phase, such as the execution of reinforced plasters, reinforced injections, etc. It is evident that the proposed list is not exhaustive and that the surveyor may propose other kind of countermeasures, provided they may be considered short term countermeasures. For this purpose, two empty lines are available at the end of the proposed list. In case these would not be enough, or in case a wider description of the proposed countermeasure is required, the Section 9 devoted to notes may be used.

The countermeasures included in the form can be grouped in the following categories:

a) removal of unsafe parts;
b) small repairs;
c) propping;
d) tightening and application of strands;
e) repair of utility systems.

The first category does not require any particular explanation. The removal must be executed with caution and must be limited to unsafe parts of small extension, in order not to be considered as demolition. The second category includes, usually, small interventions on secondary elements such as partition walls, infill walls, roofings, eaves, which may even have a definite character.

Categories c) and d) deserve a particular attention, especially as to the choice, since the two categories do not always provide equally valid alternatives.

Propping is the most frequent intervention carried out in the emergency phase, both for the rapidity and for the possibility of operating, in almost all the cases, from the outside of the building. When suggesting their execution, it is important to account for possible inconveniences, such as the occupation of the street, which may be critical in the very narrow streets typical of many historical centres. In contrasting propping between adjacent buildings, dangerous interactions, even for the entire building, may be induced. It may also happen that interventions that were thought to be temporary will remain in place for long time, ending up by deteriorating and loosing effectiveness (e.g. wooden propping). Finally it is important not to forget that propping, if effective for static loads (vertical loads, soil thrusts, etc.), are much less effective for seismic loads. This issue should not be neglected when operating in zones where strong aftershocks may occur.

Countermeasures of type d) have many advantages when damage is mainly related to the lack of connection among structural components. In these cases, instead of restoring, with provisional measures, the original building stability, it is possible to re-establish the connections which allow the structure itself to reach a good level of safety under static actions and a satisfying behaviour in case of earthquake.

It is believed by the authors, and it is a criterion adopted for example after the earthquake of 9.9.98 in Basilicata and Calabria, that the structure can be made safe using interventions other than propping any time their realisation is compatible with the building geometry and the damage condition, being often more effective, less cumbersome and sometimes also functional to the final interventions.

In what follows, a brief description of the short term countermeasures included in the form and of their conditions of use is reported.

Barriers and protected passages

An area, accessible for the public, may be unsafe due to presence of instable buildings, or parts of them, or due to the presence of other risks such as falling rocks or soil instabilities. In these cases, protected covered passages or barriers, preventing access to the dangerous area, may be proposed.

Tightening and application of strands

Tightening and application of strands have the double scope of impeding the evolution of the local failure mechanism and of reinstating the continuity of the resistant component. In general they are effective when an out of plane mechanism of the façade walls is occurring or in case of discontinuity between walls or between walls and floors. They may also absorb the thrust of damaged thrusting structures, such as arches, vaults or thrusting roofs (see Section 3). Usable materials are both traditional steel wires or steel profiles and plastic or carbon fibres.

Repair of light damages to infill panels and partition walls

It should be considered when cracks to infill panels and partition walls may cause the falling of brick and/or plaster elements. Instead of the repair, it is possible to consider partial removals, if they do not jeopardise the building resistance.

Roof repair

In order to remove the danger of objects falling in the internal and external areas or to restore the weather-resistance, the repair of secondary elements of the roof, such as purlins, or of the roof covering may be considered.

Stairs propping

It should be carried out when damage to the stairs is spatially limited and an adequate safety may be obtained by supporting the damaged parts. This condition may happen, for instance, in reinforced concrete buildings, when the first flight is constructed with a structure different from the other flights. In these cases, if damage is limited to the lower flights, propping will allow the access to the upper floors of the building.

Removal of plasters, coverings, false ceilings

It should be considered when the removal of unsafe components eliminates the danger of object falling down in the internal spaces.

Removal of tiles, chimneys, parapets

It should be considered when the removal of unsafe components of the roof eliminates the danger of object falling down in the space below.

Removal of eaves, parapets, overhangs

It should be performed when the removal of unsafe components in the facade eliminates the danger of object falling down in the space below.

Removal of other internal or external objects

Heavy or not anchored components may slide and/or overturn. Moving these elements to the floor or connecting them correctly to the walls or to the floors, make possible to safely use the area. The removal of components hanging from damaged walls should also be kept in mind, especially if there is the possibility of dangerous substances spilling out.

Repair of utility systems

The repair of utility systems guarantees the habitability of building units and eliminates the risk that substances dangerous for men and for structures spill out. If the repair is not feasible in the short term and a danger is noticed (for example for gas coming out), the need of providing barriers and possibly interrupting the flow should be indicated.

5.6 Notes

SECTION 9	Notes	
On damage, short term countermeasures, usability, etc.		
Topic	*Notes*	*Picture of the building*
	______________________________	
	The surveyors (capital letters)	*Signature*

In Section 8, information concerning the *survey accuracy* or the reasons why the survey has not be carried out must be registered. The latter information is needed in order to document the outcome of each planned survey, even if not carried out.

Section 9 is devoted to the surveyor's notes used to clarify the contents of the other sections of the form. Notes must be reported in the appropriate rows, possibly with capital letters to help the reader, marking in the left column the section and the topic they refer to.

Pictures may be stapled, as indicated, in the apposite space.

All information intended to specify the usability classification and the appropriate short term countermeasures should be reported in the notes, as specified in the note of Section 8, concerning the risk evaluation and the usability classification. With regard to this, in Table 5.1 some useful suggestions are provided.

Table 5.1 – Suggestion for the notes according to the usability classification

	USABILITY CLASSIFICATION	SUGGESTION FOR THE NOTES
B	TEMPORARILY UNUSABLE building (partially or totally) but USABLE after short term countermeasures	Specify which parts of the building are unusable or the total unusability; specify in detail the short term countermeasures necessary to remove the unusability and to guarantee the public safety.
C	PARTIALLY UNUSABLE building	Specify which parts of the building are unusable and the short term countermeasures necessary to guarantee the public safety.
D	TEMPORARILY UNUSALE building requiring a more detailed investigation	Specify why a more detailed inspection is needed; if an inspection by experts is needed and which experts are required; indicate in any case the short term countermeasures necessary to guarantee the public safety.
E	UNUSABLE building	Indicate the short term countermeasures necessary to guarantee the public safety.
F	UNUSABLE building due to external risk	Specify the causes of external risk and the short term countermeasures necessary to guarantee the public safety.

6 Postscript

The AeDES form and the present Field Manual should be considered as one of the deliverables of the Working Group composed by National Group for the Defence against Earthquakes (GNDT) and National Seismic Survey (SSN) and established for the building seismic damage and vulnerability assessment at the beginning of 1997. In particular, for what concerns the SSN, the participants were *R. Colozza*, *A. Goretti*, *G. Di Pasquale, G. Orsini*, *F. Papa*; while the GNDT research units were University of Naples "Federico II" (*A. Baratta, G. Zuccaro, M. Della Bella*), Basilicata (*M. Dolce*), Roma Tre (*A. Giuffrè*, and, after his death *C. Baggio*, *C. Carocci*), Padova (*A. Bernardini*, the group coordinator), L'Aquila (*A. Martinelli, L. Corazza, A. Petracca*).

Contributions have been also given by other researchers belonging to SSN (*D. Molin, M. Bellizzi, A.G. Pizza*), GNDT (*A. Cherubini, L. Decanini, A. De Stefano, E. Speranza, C. Gavarini, A. Corsanego*), National Institute of Geophysics and Volcanology (INGV) (*C. Gasparini, L. Tertulliani*), Department of Civil Protection (DPC) (*M. Severino, S. Loni*), Fire Brigades. Moreover, the International Seminar held in Monselice (Padua) in June 1998 on "Measures of seismic damage to masonry buildings" [5], has allowed a useful discussion among the Italian Working Group and foreign researchers, with experience in the post-earthquake damage assessment in other countries, particularly in Eastern Europe and in the Balkans.

A first draft of the form (09/97) has been used for collecting damages to ordinary buildings during the seismic emergency in the Marche Region (1997; approximately 38.000 inspected buildings) and in Pollino (1998; approximately 15.000 inspected buildings). These experiences have lead to a second version of the form (05/98) and finally to the version presented here (AeDES-05/2000bis). Reference should also be made to the conclusions of the Working Group DPC-GNDT-SSN, for the "Definition of a technical-operative plan for the usability survey of buildings and lifelines damaged by seismic events" (February 2000).

The content of the AeDES- 05/2000 bis form is, from a technical point of view, identical to that of the AeDES- 05/2000 form. The identification code of the form has been updated to allow for the modifications occurred in the institutional structure.

In the present manual, the basic documents have been written by:

- Introduction (*M. Dolce*, GNDT and *A. Goretti*, SSN)
- Instructions for Sections 1, 2, 5, 6, 7, 9 (*A. Martinelli*, GNDT)
- Instructions for Section 3 (*F. Papa*, SSN, *M. Della Bella* and *G. Zuccaro,* GNDT)
- Instructions for Section 4 (*G. Di Pasquale*, SSN and *G. Orsini*, SSN)
- Instructions for Section 8 (*G. Di Pasquale*, SSN, *M. Dolce*, GNDT and *A. Goretti*, SSN)

Many of the concepts presented here have been developed within the GNDT and SSN activities carried out in recent years, in occasion of earthquakes occurred in Italy (Umbria-Marche 1997, Pollino 1998) and abroad (Turkey, 1999, Athens, 1999). In particular, it may be useful to mention the following reports :

- "Post-earthquake usability", Document following the *Two days workshop on usability*, Fabriano 14-15 July 1998 (in Italian);
- "Workshop on Lesson learnt from the use of public servant for post-earthquake building safety assessment" based on the experience of technicians belonging to the Emilia-Romagna Region after the Umbria-Marche 1997 earthquake, Bologna, 16 January 1998 (in Italian);
- "Recommendations to the damage and usability inspection teams", Coordination Group SSN-GNDT, Rev.2, 7 April 1998 (in Italian);
- "Recommendations to the damage and usability inspection teams", Technical Committee established according to the Ordinance 2847/98, after the Pollino 1998 earthquake (in Italian);

7 References

[1] GNDT, Emilia-Romagna Region, Tuscany Region, (1986). *Field Manual for the completion of the building vulnerability GNDT form*. Litografia della Giunta Regionale (in Italian).

[2] GNDT, (1993). *Seismic Risk of Public Buildings, Part I: Methodology*. Tipografia Moderna, Bologna, Italy (in Italian).

[3] Dolce, M., Lucia, C., Masi, A., Vona, M., (1997). Building types in Basilicata Region for vulnerability classification. *Proceedings VIII National Conference on Earthquake Engineering*, Taormina, Italy (in Italian).

[4] Gruntal G. (ed), (1998). *European Macroseismic Scale 1998*. Cahiers du Centre Européen de Géodynamique et de Séismologie, Volume 15, Luxembourg.

[5] Bernardini, A. (ed), (1999). Seismic Damage to Masonry Buildings. *Proceedings of the International Workshop on Measures of Seismic Damage to Masonry Buildings*. Monselice, Padua, Italy, 25-26 June 1998, Balkema, Rotterdam.

[6] California Government Code, Sections 8580; 8567(a), e Labor Code, Sections 4351 - 4355

[7] California Civil Code, Section 1714.5

[8] SSN/ GNDT (1998). *Manual for the COM management, Release 1.5* (in Italian).

APPENDIX

The AeDES form, release 05/2000

Presidenza del Consiglio dei Ministri
DIPARTIMENTO DEI SERVIZI
TECNICI NAZIONALI

Presidenza del Consiglio dei Ministri
DIPARTIMENTO NAZIONALE DELLA PROTEZIONE CIVILE

Consiglio Nazionale delle Ricerche
GRUPPO NAZIONALE PER LA
DIFESA DAI TERREMOTI

7.1.1.1 1° LEVEL FORM FOR POST-EARTHQUAKE DAMAGE AND USABILITY ASSESSMENT

7.1.1.1.1 AND EMERGENCY COUNTERMEASURES IN RESIDENTIAL BUILDINGS

Request code |__|__|__|__|__|__|__|__|__|

(AeDES 05/2000)

SECTION 1 Building identification

SURVEY IDENTIFICATION day month year

Team |__|__|__| Form n.|__|__|__|__|

Date |__|__| |__|__| |__|__|

Province: ____________________

Municipality: ____________________

1.1. BUILDING IDENTIFICATION

Locality: ____________________

Region Istat	Province Istat	Municipality Istat	Aggregate No.	Building No.
|__|__|__|	|__|__|__|	|__|__|__|	|__|__|__|__|__|	|__|__|__|

Istat Hamlet code |__|__|__|__| Type of map

Istat Census code |__|__|__| Map No. |__|__|__|__|

Address

1 ○ Street
2 ○ Road
3 ○ Alley
4 ○ Square
5 ○ Other

Number | | | | |

Cadastral data Sheet |__|__|__| Allegato |__|__|

Parcels |__|__|__|__| |__|__|__|__| |__|__|__|__| |__|__|__|__|

Building position 1 ○ Isolated 2 ○ Internal 3 ○ Extreme 4 ○ Corner .

Building denomination or owner's name |__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|

Destination Code |**S** |__|__|

Photocopy of the structural aggregate with building indication

SECTION 2 Building description

Metrical data						*Age*	*Use*					
Total number of stories		***Average storey height*** [m]	***Average storey surface*** [m^2]		***Construction and renovation*** [max 2]	***Use***	***No. of units in use***	***Utilisation***	***No. of occupants***		
									100	10	1
						A ○ Residential	|__|__|		0	0	0
○ 1	○ 9	1 ○ ≤ 2.50	A ○ ≤ 50	I ○ 400 ÷500	1 ○ ≤ 1919	B ○ Production	|__|__|	A ○ > 65%	1	1	1
○ 2	○ 10	2 ○ 2.50÷3.50	B ○ 50 ÷ 70	L ○ 500 ÷650	2 ○ 19 ÷ 45	C ○ Business	|__|__|	B ○ 30÷65%	2	2	2
○ 3	○ 11	3 ○ 3.50÷5.0	C ○ 70 ÷ 100	M ○ 650 ÷900	3 ○ 46 ÷ 61	D ○ Offices	|__|__|	C ○ < 30%	3	3	3
○ 4	○ 12	4 ○ > 5.0	D ○ 100 ÷ 130	N ○ 900 ÷1200	4 ○ 62 ÷ 71	E ○ Public services	|__|__|	D ○ Not utilised	4	4	4
○ 5	○ >12		E ○ 130 ÷ 170	O ○ 1200 ÷1600	5 ○ 72 ÷ 81	F ○ Warehouse	|__|__|	E ○ In construction	5	5	5
○ 6		***No. of basements***	F ○ 170 ÷ 230	P ○ 1600 ÷2200	6 ○ 82 ÷ 91	G ○ Strategic services	|__|__|	F ○ Uncompleted	6	6	6
○ 7		A ○ 0 C ○ 2	G ○ 230 ÷ 300	Q ○ 2200 ÷3000	7 ○ 92 ÷ 01	H ○ Touristic	|__|__|	G ○ Abandoned	7	7	7
○ 8		B ○ 1 D ○ ≥3	H ○ 300÷ 400	R ○ > 3000	8 ○ ≥ 2002		***Property***	A ○ Public	B ○ Private		
									8	8	8
									9	9	9

SECTION 3 Building Typology (multiple answer; for masonry buildings indicate max 2 combinations of vertical and horizontal structures)

Horizontal Structures \ Vertical structures	Unknown	Masonry buildings: Irregular layout or bad quality (rubble stones, pebbles,..) – W/O tie rods or tie beams	Masonry buildings: Irregular layout or bad quality – With ties rods or tie beams	Masonry buildings: Regular layout and good quality (Blocks, bricks, squared stone..) – W/O tie rods or tie beams	Masonry buildings: Regular layout and good quality – With tie rods or tie beams	Isolated columns	Mixed	Strengthened
	A	B	C	D	E	F	G	H
1 Not identified	○	☐	☐	☐	☐	SI	☐	☐
2 Vaults without tie rods	☐	☐	☐	☐	☐	○	G1	H1
3 Vaults with tie rods	☐	☐	☐	☐	☐		☐	☐
4 Beams with **flexible** slab (wooden beams with a single layer of wooden planks, beams and shallow arch vaults,…)	☐	☐	☐	☐	☐	NO	G2	H2
5 Beams with **semirigid** slab (wooden beams with a double layer of wooden planks, beams and hollow flat blocks,…)	☐	☐	☐	☐	☐	○	☐	☐
6 Beams with **rigid** slab (r.c. floors, beams well connected to r.c. slabs,…)	☐	☐	☐	☐	☐		G3	H3

Other structures	
R.c. frames	☐
R.c. shear walls	☐
Steel frames	☐

REGULARITY	Irregular	Regular
	A	B
1 Plan and elevation	○	○
2 Infills distribution	○	○

Roof

1 ○ Thrusting heavy
2 ○ Non thrusting heavy
3 ○ Thrusting light
4 ○ Non thrusting light

SECTION 4 Damage to structural elements and existing short term countermeasures

Structural component / Pre-existing damage \ Damage level - extension	DAMAGE [1] D4-D5 Very Heavy > 2/3	D4-D5 1/3 - 2/3	D4-D5 < 1/3	D2-D3 Medium-Severe > 2/3	D2-D3 1/3 - 2/3	D2-D3 < 1/3	D1 Light > 2/3	D1 1/3 - 2/3	D1 < 1/3	Null	EXISTING SHORT TERM COUNTERMEASURES: None	Removal	Ties	Repair	Propping	Barriers or passage protection
	A	B	C	D	E	F	G	H	I	L	A	B	C	D	E	F
1 Vertical structures	☐	☐	☐	☐	☐	☐	☐	☐	☐	○	○	☐	☐	☐	☐	☐
2 Floors	☐	☐	☐	☐	☐	☐	☐	☐	☐	○	○	☐	☐	☐	☐	☐
3 Stairs	☐	☐	☐	☐	☐	☐	☐	☐	☐	○	○	☐	☐	☐	☐	☐
4 Roof	☐	☐	☐	☐	☐	☐	☐	☐	☐	○	○	☐	☐	☐	☐	☐
5 Infills and partitions	☐	☐	☐	☐	☐	☐	☐	☐	☐	○	○	☐		☐	☐	☐
6 Pre-existing damage	☐	☐	☐	☐	☐	☐	☐	☐	☐	○						

(1) - The damage extension must be filled only if the corresponding damage level is present in the building.

SECTION 5 Damage to non-structural elements and existing short term countermeasures

Damage	PRESENT	EXISTING SHORT TERM COUNTERMEASURES: None	Removal	Propping	Repair	No entry	Barrier or passage protection
	A	B	C	D	E	F	G
1 Falling of plaster, coverings, false-ceilings	○	○	☐	☐	☐	☐	☐
2 Falling of tiles, chimneys…	○	○	☐	☐	☐	☐	☐
3 Falling of eaves, parapets,…	○	○	☐	☐	☐	☐	☐
4 Falling of other internal or external objects	○	○	☐	☐	☐	☐	☐
5 Damage to hydraulic or sewage systems	○	○			☐	☐	☐
6 Damage to electric or gas systems	○	○			☐	☐	☐

SECTION 6 External risk induced by other constructions and existing short term countermeasures

Potential cause	Risk on: Building	Entry road	Lateral roads	Existing short term countermeasures: No entry	Barriers or passage protection
	A	B	C	D	E
1 Objects falling from adjacent buildings	☐	☐	☐	☐	☐
2 Failure of distribution systems	☐	☐	☐	☐	☐

SECTION 7 Soil and Foundation

SITE MORPHOLOGY				DAMAGE (present or possible): ☐ Slopes ☐ Foundation Soil			
1 ❍Crest	2 ❍Steep slope	3 ❍Mild slope	4 ❍Plain	A ❍Absent	B ❍Produced by eqk.	C ❍Worsened	D ❍Preexistent

Province Istat |__|__|__| Municipality Istat |__|__|__|	Team |__|__| Form No.|__|__|__|__|__| Date |__|__|__|__|__|__|

SECTION 8 Usability assessment

Risk evaluation

RISK	STRUCTUAL (Sect. 3 e 4)	NONSTRUCTURAL (Sect. 5)	EXTERNAL (sect. 6)	GEOTECHNICAL (sect. 7)
LOW	❍	❍	❍	❍
LOW WITH COUNTERMEASURES	❍	❍	❍	❍
HIGH	❍	❍	❍	❍

Usability Classification

A	**USABLE building**	❍
B	**UNUSABLE building (totally or partially), but USABLE after short term countermeasures**	❍
C	**PARTIALLY UNUSABLE building (1)**	❍
D	**TEMPORARILY UNUSABLE building requiring a more detailed investigation**	❍
E	**UNUSABLE building**	❍
F	**UNUSABLE building due to external risk (1)**	❍

(1) Restrictions on building use must be clearly reported in the notes when building is classified as B or C; causes of external risk when building is classified as F.

Survey accuracy

1 ◯ Only from outside
2 ◯ Partial
3 ◯ Complete (> 2/3)

4 ◯ Not surveyed because of: a ◯ Survey refused b ◯ Ruins c ◯ Demolished d ◯ Absent owner e ◯ Other ……………………………..

……………………..………. ………………………………………………………...

Suggested short term countermeasures, limited (*) or extended (**)

*	**	Suggested short term countermeasures	*	**	Suggested short term countermeasures
1 ❒	❒	Tightening and application of strands	7 ❒	❒	Removal of eaves, parapets, overhangs
2 ❒	❒	Repair of light damages to infill panels and partition walls	8 ❒	❒	Removal of other internal or external objects
3 ❒	❒	Roof repair	9 ❒	❒	Barriers and passage protection
4 ❒	❒	Stairs propping	10 ❒	❒	Repair of utility systems
5 ❒	❒	Removal of plasters, coverings, false ceilings	11 ❒	❒	
6 ❒	❒	Removal of tiles, chimneys, parapets	12 ❒	❒	

Unusable building units, families and people to be evacuated

Unusable building units \|__\|__\| Families to be evacuated \|__\|__\| People to be evacuated \|__\|__\|__\|

SECTION 9 Notes

On damage, short term countermeasures, usability, etc.

Topic	*Notes* *Picture of the building*

The surveyors (capital letters)	***Signature***
_	

EXPLANATORY NOTES FOR COMPILING THE AeDES 05/2000 FORM

The form must be compiled for an entire building, meaning by "building" a structurally homogeneous unit, generally distinguishable from adjacent buildings for structural typology, different height, age of construction, different storeys height, etc.

The form is subdivided in **9 sections**. Information are generally defined blackening the corresponding cells; in some sections, squared cells ( ) indicate the possibility of **multiple answers**: in such cases more than one answer is allowed; round cells (❍) indicate the possibility of a single choice. When cells like |__| are present, it is necessary to write in capital letters, left justifying text and right justifying numbers.

Section 1 – Building identification.

Please indicate location data: province, municipality and locality.

SURVEY IDENTIFICATION: the surveyor indicates the identification number of the team, assigned by the inspection management, the progressive number of the form and the date of the survey.

BUILDING IDENTIFICATION

The inspection are managed by the coordination centre with the collaboration of the technical municipal offices. The latter ones should support the surveyors in identifying the buildings and carrying out the survey. When the building is not pre-identified, the surveyor must identify it on the cartography, that should then reported on the first sheet of the form. The identification code, the map number, the Istat code and the cadastral data, are assigned by local authorities and inspectors. At local level, the aggregate and building numbering must be recorded on a map, or on a GIS, so that inspection forms may be immediately associated to the inspected buildings. Building position: if the building is not isolated, its position within the aggregate must be indicated (internal, extreme, corner). Building denomination or owner: indicate the building denomination if it is a public building, the name of the condominium or the name of one of the owners if it is a private building (e.g. : Condominium Verde, Rossi Mario).

Section 2 – Building description

No. of storeys including basement: indicate the total number of storeys of the building from the foundation level, including the attic only when practicable. Basement floors are defined as those having an elevation above the ground level lower than half of the total storey height. Average storey height: indicate the height better approximating the average storey height. Average storey surface: indicate the interval including the average of the storey surfaces. Age (2 options): it is possible to provide 2 indications: the first is always the age of construction, the second is the eventual year of significant interventions on structural components. Use (multiple answer): indicate the types of use coexisting in the building. Utilisation: the indication *abandoned* refers to the case of *not utilised in bad conditions*.

Section 3 – Building typology (maximum 2 options)

For masonry buildings, 2 combinations describes the prevailing or most vulnerable horizontal and vertical structures; for example: vaults without tie rods and rubble stone masonry at the 1st storey (2B) and rigid floors (RC) and rubble stone masonry at the 2nd storey (6B). Masonry is subdivided in two types based on the quality (materials, mortar, construction quality); for each type, it is possible to identify also the presence of tie beams or tie rods, when significantly widespread. Also the eventual presence of isolated columns, being them in RC, masonry, steel or wood and/or the presence of mixed structures and frame structures should be indicated. Buildings should be considered as having reinforced concrete or steel frame structures when the entire bearing structure is in reinforced concrete or steel. Mixed vertical bearing structures (masonry – frames) or strengthening elements should be indicated, with the multiple answer option, in columns G and H of the "masonry" section.

G1:RC (or other frame structures) over masonry
G2:masonry over RC (or other frame structures)
G3:masonry and RC (or other frame structures) at the same floors

H1: masonry strengthened with injections or unreinforced plasters
H2: reinforced masonry or masonry with reinforced plasters
H3: masonry with other or unidentified types of strengthening

For frame structures, infill panels are irregular when they are not symmetric in plan and/or in elevation or when they are practically missing at one floor in at least one direction.

Section 4 – Damage to MAIN STRUCTURAL COMPONENTS

The damage to be reported in Section 4 is the apparent damage, i.e. the one that can be observed during the survey. Each row of the table refers to a structural component, while the columns represent the damage level on that component and its relative extension, in percentage, with respect to the total extension of the component in the building. The observed damage level definition is very relevant and is based on the European Macroseismic Scale EMS98, integrated with the definitions used in the GNDT survey form. In particular, a brief damage description is reported in the following; more details are given in the Manual.

D1 light damage: this damage grade does not affect significantly the capacity of the structure and does not jeopardise the occupants safety due to falling of non structural elements; the damage is light even when the falling of objects can rapidly be avoided.

D2-D3 medium-severe damage: this damage grade could change significantly the capacity of the structure, without getting close to the limit of partial collapse of the main structural components.

D4-D5 very heavy damage: this damage grade significantly modifies the capacity of the structure, bringing it close to the limit of partial or total collapse of the main structural components. This grade is characterised by damages heavier than the previous ones, including the total collapse.

Existing short term countermeasures: are those measures able to quickly eliminate the risk or reduce it to an acceptable level; only existing short term countermeasures should be indicated.

Section 5 – Damage to NON STRUCTURAL ELEMENTS

For non structural elements, it is necessary to indicate, making use of the multiple answer option, both the presence of damage and the possible existing short term countermeasures.

Section 6 - EXTERNAL risk and existing short term countermeasures

Indicate the risk induced by adjacent buildings and the possible short term countermeasures, making use of the multiple answer option.

Section 7 – Soil and foundation

It is necessary to individuate the site morphology and possible or existing instabilities of the soil and/or the foundation.

Section 8 - USABILITY assessment

The surveyor has to define the building risk (table *risk evaluation*) based on the collected information, on the visual inspection and on his own considerations. The analysis should consider the structural conditions (Section 3 and 4 – Building typology and damage), the condition of non structural components (Section 5), the external risk induced by other constructions (Section 6) and the geotechnical situation (Section 7). Outcome **B** should be indicated when the risk reduction can be obtained with short term countermeasures (i.e. limited, quick and easy interventions, able to make the building usable). Outcome **D** should be indicated only in really difficult cases and in particular for public buildings whose unusability would compromise important functions.

Unusable building units, families and people to be evacuated: the consequences of the unusability (families and people to be evacuated, in addition to those having already left the building) must be indicated. Short term countermeasures: the inspector has to indicate the short term countermeasures necessary to make the building usable and/or to eliminate the induced risk.

Section 9 - Notes

Survey accuracy: indicate the level of accuracy and completeness of the survey.

On damage, short term countermeasures, usability, etc: indicate the notes which are considered important for a better characterisation of the different aspects of the survey. A picture of the building may be stapled in the top right corner of this section.

European Commission

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Author(s): Carlo BAGGIO, Alberto BERNARDINI, Riccardo COLOZZA, Livio CORAZZA, Marianna DELLA BELLA, Giacomo DI PASQUALE, Mauro DOLCE Agostino GORETTI, Antonio MARTINELLI, Giampiero ORSINI, Filomena PAPA, Giulio ZUCCARO. Editors: Artur V. PINTO, Fabio TAUCER
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Abstract
The present report aims at contributing to a harmonized approach in Europe for damage assessment, short term countermeasures for damage limitation and evaluation of the post earthquake usability of ordinary buildings. It results from the Italian long-term and recent experiences (Assisi, San Giuliano di Puglia) on post-earthquake assessment and tagging of buildings and is considered important as there has been a sustained progress in Italy in this field, which can be shared with other European / Mediterranean countries with similar constructions.

The mission of the JRC is to provide customer-driven scientific and technical support for the conception, development, implementation and monitoring of EU policies. As a service of the European Commission, the JRC functions as a reference centre of science and technology for the Union. Close to the policy-making process, it serves the common interest of the Member States, while being independent of special interests, whether private or national.

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