A METHODOLOGY FOR POST-EARTHQUAKE DAMAGE INVESTIGATION AND SAFETY ASSESSMENT OF BUILDINGS IN ROMANIA, IN EURO-MEDITERRANEAN AND WORLDWIDE CONTEXT

Emil-Sever GEORGESCU[1], Liviu CRAINIC[2], Radu VACAREANU[2], Basarab CHESCA[3], Cristian BALAN[4], Cristian Paul STAMATIADE[5], Gabriela IONESCU[6]

[1] CE, PhD, Scientific Director, INCERC – The National Institute for Building Research / ECBR - European Center for Buildings Rehabilitation of Europa Major Hazards Agreement, Bucharest, Romania
Email: ssever@incerc2004.ro
[2] CE, PhD, Professor, UTCB – Technical University of Civil Engineering, Bucharest, Romania
[3] CE, NCSRR – National Center for Seismic Risk Reduction, Bucharest, Romania
[4] CE, IPCT SA, Bucharest, Romania
[5] Eng. General Director [6] PhD, MDPWH - Ministry of Development, Public Works and Housing, Bucharest, Romania

ABSTRACT :

The aim of this paper is to present the new methodology for emergency investigation of post-seismic safety of buildings and framework solutions for intervention, enforced in 2007 by the Ministry of Development, Public Works and Housing – MDPWH, Romania. The quick inspection is followed by a rapid evaluation, based on specific criteria and record forms, with application of four types of coloured placards, in view of building usability. The emergency intervention measures for safety of living inside buildings include techniques and drawings for provisional shoring and/or local repair. Specific requisites for management of logistics and informatized data bases, for local types of structures and materials, are given in the methodology. The experts, engineers and inspectors are appointed by MDPWH, being registered and trained by the inspectorates for constructions and/or local authorities, not volunteers. The Romanian approach is basically close to USA, ATC 20, but it takes into account the local seismicity, as well as the specifics of local buildings. The Japanese idea of using specific pictures that explain correspondence between damage and labelling was used, while the USA - California pre-certification approach and the New Zealand management of operations were adapted to local conditions. The further use of the methodology is discussed in the international context, and in Europe the framework of EUR-OPA Major Hazards Agreement and with reference to the recent experience of Italy, Turkey and Greece.

KEYWORDS: *earthquake damage, safety, usability, placards, methodology*

1. ROMANIAN EXPERIENCE IN POST-EARTHQUAKE SAFETY INSPECTIONS

The investigation of damaged buildings in Romania was mentioned as early as after the historical Vrancea earthquakes. After 11/23 January 1838 earthquake, the teams under the guidance of architect Xavier Villacrosse surveyed Bucharest districts building damage (Villacrosse -1800-1855 - was a Catalan who studied in France, lived, get married and make had a prestigious carrier in the Principality of Romanian Country in building and earthquake strengthening of churches, being a Chief Architect of Bucharest, from 1840 to 1848).
After November 10, 1940 earthquake, reports of damages were available in newspapers within 2 days. A safety and usability survey was performed in Bucharest by teams of engineers and architects.

Within a week, the City Hall sent official warnings to owners of inspected buildings about some compulsory evacuations, demolitions and partial demolitions, strengthening and repair works, and some addresses were published also in newspapers. Owners were warned that they were responsible and liable under the laws about for the quality of strengthening and repair works, as well as for any serious subsequent accidents and damages. However, the repairs were superficial and in fact the structural strengthening was neglected by owners, the 2-nd World War broke out, thus some of the buildings were declared at that time as safe after an additional inspection. Many buildings reported with serious damages in 1940 collapsed in 1977 earthquake.

Following the earthquake of 4th of March 1977, the emergency investigation of buildings in Bucharest, although not prepared in advance, was performed with civil engineers from all over the country, with both certain results (lists of "priorities to further safety evaluation"), and certain obvious errors (for instance the evacuation of the Emergency Hospital during the night of the earthquake). At that time any placard was used. In Bucharest, according to data of IPB-Proiect Bucuresti, there was an emergency inspection of thousands of buildings, resulting in 2 lists of higher buildings having been damaged: the first list with some 351 residential buildings and 134 social-cultural ones (GF+4 levels) and a second list with 302 residential and other 48 social-cultural buildings. The people evacuated from unsafe buildings were relocated in temporary shelters and state-owned housing.

A vulnerability survey based on MSK Scale, with some special adjustments and an algorithm to account for the spectral content, was made in 1977 on some 18.000 buildings, on other 800 standard design buildings in Bucharest and then on some hundreds of buildings in Iasi. Results have been published elsewhere by Sandi, Sandi et al. , Dolce et al, since 1982 and have been the subject object of studies within Working Groups of EAEE.

As a consequence of 30-31 August 1986 earthquakes, a study of damages was initiated by INCERC, but later on the knowledge information was not completely shared because of the general official policy of neglecting the effects of that earthquake. Following the earthquakes of 30th of May 1990, the effects upon the buildings were not spectacular but in the new social and political context a revision of the earthquake code was undertaken, with an emphasis on the assessment of and the intervention upon the existing buildings.

A first Manual for dealing with emergency post-seismic investigation, and establishing frame solutions for immediate / provisional safety intervention, was approved by MLPAT (presently MDPWH), indicative ME-003-99, published in the Bulletin of Constructions no. 2/1999. The present edition supersedes the 1999 edition and is has been highly improved.

2. GENERAL PROVISIONS OF THE METHODOLOGY FOR EMERGENCY INVESTIGATION OF POST-SEISMIC SAFETY OF BUILDINGS AND FRAMEWORK INTERVENTION SOLUTIONS FOR INTERVENTION

The object of the methodology is aimed at providing the stipulation of the ways and means of for the organization and performance of technical activities intended to secure the use of buildings under safe conditions after high intensity earthquakes. This level of shaking is broadly defined as any event causing overall or local collapses, significant damage and degradation on large areas. In this field, the management of actions regarding post-seismic investigation falls to:

- The National Committee for emergency situations, at national level;
- The Ministry Committee for emergency situations, organized by the Ministry of Development, Public Works and Housing, at central level;
- County Committees / The Committee of the City of Bucharest and local committees of its districts, municipal, town and village committees for emergency situations, in the territory;

Coordination, from a technical point of view, of the emergency investigation of buildings, including equipments will be performed as follows:

- At central level, by the Ministry Committee for emergency situations, with the Ministry of Development, Public Works and Housing, represented by:

  - The vice-chairman of The Ministry Committee and
  - The general inspector of the State Inspectorate for Constructions;
- At a territorial level, by the County Committees / The Committee of the City of Bucharest and local committees of its districts, municipal, town and village committees for emergency situations, by:
  - The prefect, mayors and their own staff and / or from the Inspectorate for emergency situations;
  - The Chief Inspector of the territorial / county / City of Bucharest Inspectorate and the staff designated by them.

This operation has been imposed by the applicable laws and orders in force, issued and approved by MDPWH, to be carried on by the local authorities and inspectorates for constructions authority. According to the regulations in force, the role of county inspectorate offices for constructions is important, since they may order the owners of buildings, irrespective of the form of property, to have technical evaluations and to check resistance and stability of the structures, in all cases where deemed necessary. They also provide training for specialists – appointed in the defense plans of the territorial administrative units – regarding post seismic inspection of buildings, organizes post seismic inspection and suggests immediate technical-organizational intervention actions for securing the temporary safety of damaged buildings and pursues the application of measures for limiting and removing the earthquake effects.

These activities refer mainly to the following aspects:

A. The assessment of the extent of buildings damage for taking decisions regarding their further use or end of use (evacuation, demolition);
B. Application of emergency measures for temporarily improving the safety of buildings affected by earthquake or to avoid risks.

The methodology is limited to residential, socio-cultural and administrative buildings, as well as to buildings with other functions, as applicable. For buildings and facilities with other functions, one should apply specific regulations and if they do not exist one can tentatively take over provisions from this regulation. Under the current methodology, these buildings are classified, as follows:

- Class A: Buildings housing vital functions (central and local administration, telecommunications, police, fire departments, hospitals), irrespective of the number of levels and the building system;
- Class B: Current buildings with more than GF+4 levels;
- Class C: Current buildings with GF ... GF+4 levels.

The aim of the methodology is to define and exemplify procedures that would consistently apply uniformly, by securing a closer degree of safety to for all buildings. We also have to bear in mind the hierarchical ranking along simple criteria, the technical issues raised by the two types of activities, to achieve an efficient use of available specialists, with different degrees of training.

The assessment stages are defined as follows:

1. *(Quick) Post - Seismic inspection* – is meant to establish, by extremely simple means:
   (a) – obviously safe buildings, that may continue to be used without restrictions;
   (b) – obviously unsafe buildings, that cannot be used anymore, and which must be temporarily or fully abandoned (evacuated);
   (c) – buildings whose technical state does not fall into any of the two categories defined above, needing a more detailed investigation.
2. *Rapid Technical Evaluation* – is a more detailed investigation of the buildings that fall, after the post-seismic inspection, into category (c), an investigation by means of which one can state whether these buildings require taking technical steps of for temporarily making them safe in order to be used or whether they must be abandoned (evacuated);
3. *Technical Expert Evaluation* – is the assessment that is performed under the conditions specified by provisions from other specific normative acts and codes.

The current methodology includes criteria and methods for the first two stages, forms and placards to be used, with

detailed explanations.
For historical and architectural monuments, the technical expert assessment will be performed by specialists appointed by the respective competent ministry and the authorized public institutions using other technical documents as well as the current methodology, with adjustments.

Technical Expert Evaluation (point 3 in the classification above) uses basic principles and input data of the provisions applicable from the Code for Seismic Design Part I - "Design provisions for buildings", indicative P100-1/2006, and Code for Seismic Design. Part 3 "Provisions for the assessment and design of the strengthening of earthquake vulnerable buildings" indicative P100 – 3/2006, to be enforced in the next period. (For a period, one should use for existing buildings the chapters 11 and 12 of the former code P.100 -1992, which was superseded by P.100 -1/ 2006 on issues applied to new designs).

The stages and correlations of the emergency post-seismic activities are presented in the logical scheme in fig.1.

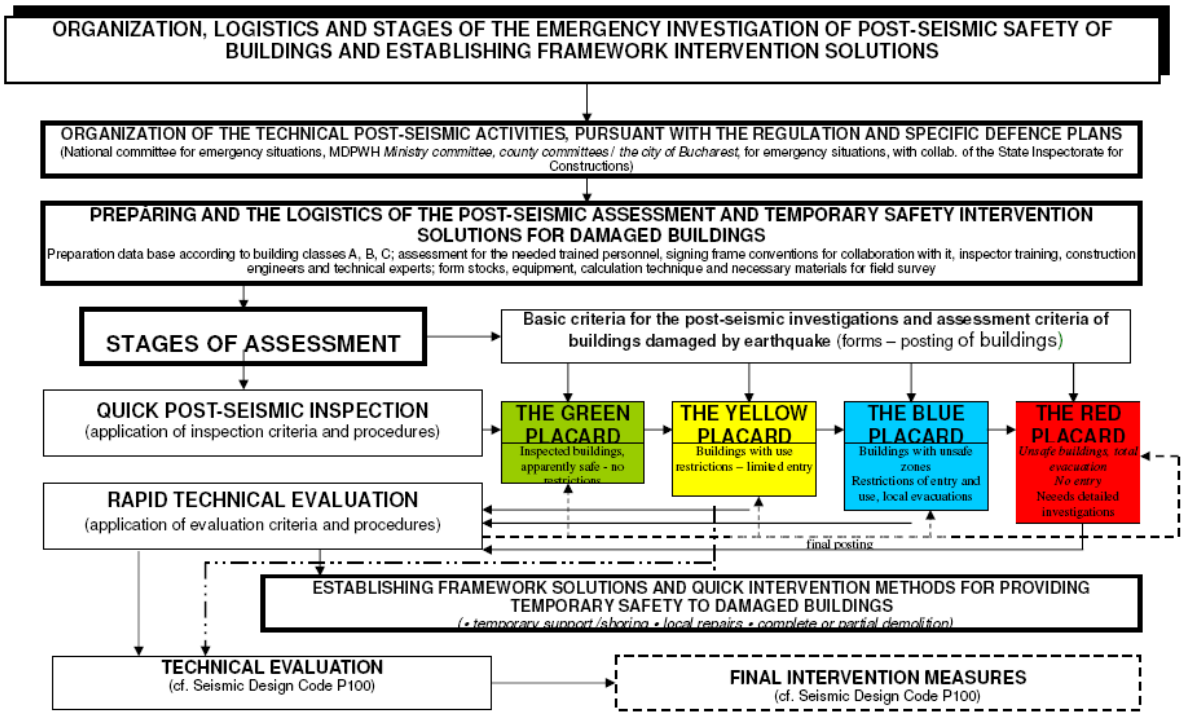

Fig. 1. Scheme of organization, logistics and stages of emergency investigation of post-seismic safety of buildings and establishment of framework intervention solutions for intervention, under the new methodology MEE 003-2007 in Romania

Posting of buildings is made in accordance with the results of the analysis, as the text explains in detail. Coloured placards are as follows:

- The green background: INSPECTED BUILDING (Apparently safe) – MAY BE USED WITHOUT RESTRICTIONS
- The yellow background: BUILDING WITH LIMITED ENTRY / ACCESS (Use restrictions)
- The blue background: BUILDING WITH UNSAFE ZONES (Restrictions of entry - local evacuations in some zones)
- The red background UNSAFE BUILDING – NO ENTRY (Structure is heavily damaged - a final decision may be reached only after a detailed engineering assessment).

The technical staff that performs the post-seismic activities falls into the following categories:

1. Inspectors – civil engineers, architects and technicians with medium experience in the field of design / assessment of buildings. During these activities they wear a white coloured badge which mentions: the name and surname, the title "inspector", the registry number in the centralized record.
2. Engineers certified for design of structures and researchers in structural and / or seismic engineering, with an experience of at least 5 years. During these activities they wear a light blue coloured badge.
3. Technical experts certified by the relevant authorities – wearing a dark blue coloured badge.

The technical personnel in different categories, as they have been defined by current methodology, may check the performance of buildings as follows:

- *The inspectors* are allowed to perform post-seismic inspections of buildings in class C, as defined in methodology;
- *Engineers* are allowed to perform the post-seismic inspection and the quick technical assessment of buildings in classes B and C defined under the current methodology;
- *Certified technical experts* are allowed to perform the post-seismic inspection, the quick technical assessment and the technical expert evaluation of buildings in classes A, B and C.

Post-seismic emergency intervention

In order to provide safety to the occupants of buildings affected by the an earthquake, in order to prevent the damage spreading as well as in order to protect the neighbouring buildings, measures for emergency intervention are taken as follows:

- temporary support / shoring of the damaged building or of their parts;
- local repairs of the damaged elements;
- partial or complete demolition of the building.

3. SPECIFIC ISSUES AND IMPROVED REQUIREMENTS IN THE METHODOLOGY

The basic text and commentaries provisions make a good connection with the management plans for emergency situations and other acts of the authorities of local government, concerning:

- The legal and technical-administrative status of staff used and remuneration of their activity, relationships with other authorities (police, gendarmerie);
- Information technology resources for collection and storage of information regarding the existing building stock, informational databases – creation, maintaining and management of information, organization of storage places for the primary documents of the investigations;
- Suggestive images taken after past earthquakes in Romania and abroad, with examples of damage presented quantitatively and qualitatively, to explain correspondence between damage and posting with placards;
- Drawings on emergency intervention measures on damaged buildings, rules for making the temporary shoring / supports, local repairs;
- The logistics securing for the immediate intervention activities by the authorities (Prefecture, City Hall), by correlating the measures with the actual provisions from the local budget and the Intervention Plan in cases of emergency situations.
- The problems regarding personal protection and labor safety (protection helmets, training for accessing the damaged buildings and behaviour to post-seismic responses during ground investigations, the problem of accommodation of the guest inspectors and other additional expenses);
- Training of a number of specialists acting as legally certified trainers for courses in the territory, in view of a consistent application of the methodology;
- Regular training and retraining of a number of inspectors and technicians etc. at the level of local councils and other territorial units and of qualified engineers, taking into account the number of existing structures in the town/county and their vulnerability;
- Dissemination and explanation of these activities in order to ensure the cooperation of the population and compliance of the restrictions / prohibitions of use for dangerous buildings.

Some provisions that have implications on other subsequent activities have been reformulated, such as the relation between the post-seismic inspection and the subsequent stages of performing the strengthening of the existing buildings, according to risk classes. The earthquake resistance evaluation for final strengthening is based on another code and it uses engineering approaches and calculations. In Romania, a Government Ordinance no. 20/1994 on seismic risk reduction is in force, with application on buildings with high vulnerability, which represent a public danger.

In Romania boasts a large number of engineers who have been granted, and they received certificates and stamps (after examination) by the authority of MDPWH in order to legally check designs and projects, or to be experts, according to the Law no. 10/1995 on quality in constructions. However, a number of staff, included in the inspector category will have less qualification, but they will be trained to inspect only low-rise buildings. Volunteers are not considered. A coordination team will be organized with the technical experts having special experience in order to summarize information and give consultancy advice in the special cases according to the types of structures.

In order to avoid disorderly assessments and not block the assignment of specialists only to this type of activities a for a very long time, the local authorities should prepare an anticipated distribution of teams, an information of about the assigned areas and a correlation of sending the teams sent to in the various city areas, with the available technical staff, the number of expected buildings and damages, bearing in mind certain priorities:

- the areas / blocks with tall buildings and a large number of occupants, made before the codes for seismic design were enforced (for instance before 1940), identified as vulnerable by previous studies and surveys;
- the areas / blocks with buildings made using according to repetitive / standard projects, with a large number of occupants, with the application of codes for seismic design before 1977, susceptible to certain sensitivity and / or local damages to seismic loads;
- similar areas / buildings, which are not expected to undergo special damages in the case of seismic loads;
- districts with traditional, low-rise buildings;
- districts with relatively new buildings of medium height or/ and low-rise buildings.

4. CONCLUSIONS ON THE POSSIBILITY OF HARMONIZATION OF ROMANIAN APPROACHES WITH EURO-MEDITERRANEAN AND WORLDWIDE PROCEDURES

Presently, the Romanian experience covers the vulnerability survey at the knowledge level of information specific to 1977 event practice, while the building inspection and posting with placards is only in the stage of methodological dissemination and training, as it started after 1999. This is the beginning of a new path.

The Romanian approach takes into account the local seismicity, as well as the specifics of local buildings. The USA ATC-20 regulations, California pre-certification approach (BORP) and the New Zealand management of the operations were also used too as models, as well as some experience of Italy and Greece.

Post-seismic inspection in order to decide on the safety of buildings leads to major demands for specialists, with an activity in a very short period, under the pressure of the population, mass-media and authorities and with extremely important consequences. The excessive requirements may generate massive evacuations and a great number of homeless to be sheltered, while a less careful assessment may expose the residents to risks in buildings with an uncertain degree of damage.

The framework of JICA-Romania project for seismic risk reduction, 2002-2008, was beneficial in this respect, providing knowledge from the Japanese manual for quick inspection, with a special reference to reinforced concrete buildings. The collaboration between the National Centre for Seismic Risk Reduction and the Japanese experts has revealed the fact that the general inspection principles, for assessment and application of placards are similar. The Japanese guide classifies the damages to the reinforced concrete structures by reference to the behaviour-crack parameters calibrated on the basis of other types of seismic movements and building makeup, so

that the criteria cannot be directly taken over. In the current stage it was possible to take over some examples from this guide as well as suggestive images for degrees of damage, to explain correspondence between damage and posting with placards, drafted and applied by JICA specialists in Turkey in 1999.

The LESSLOSS project (Risk Mitigation for Earthquakes and Landslides) lead to the 2007 Edition of the Field Manual for post-earthquake damage and safety assessment and short term countermeasures (AeDES), EUR 22868 EN – 2007, JRC, reflects the Italian building types and concepts, with the last decade experience. It aims at collecting more detailed information on assessment of damage degrees corresponding to European Macroseismic Scale 1998 and to serve for further vulnerability and risk evaluations. The next-generation innovative approach is foreseen as with a wider use of satellite images and GIS mapping, GSM address coding, combined with pre-event inventory. In this respect only some pilot projects (e.g. STEP Project, Karlsruhe University Projects etc) addressed this issue for urban building stock mapping.

Where one would intend to use the one-step inspection in order to get also vulnerability data in Romania, the forms must be more detailed and a better training will be necessary for inspecting staff. A possible approach can be to expand the forms so as to include minimum items from vulnerability survey forms. Since our methodology includes assessment criteria for specific types of structures and materials, this can be beneficial for extended evaluation forms. The feasibility of this possible approach must be evaluated with care and the recent experience of the most advanced EU countries should be considered.

The experience of recent earthquakes in Italy, Greece and Turkey, but also that of Japan and USA, proves that the introduction of a post-seismic investigation system needs long periods of time, years, and the field operations may last from 10-12 days to some 1-2 months in the well-coordinated cases, for instance Athens, Greece, 1999, a city comparable to Bucharest.

In correlation with the requirements that come to Romania after accession to the European Union, in case of destructive earthquakes we need an efficient intervention mechanism for life, environment and property protection, which depends to a great extent on the situation of buildings safety. A harmonization of concepts, criteria and forms in EU can be beneficial, considering also the November 14, 2007 request of the European Parliament for adopting the new regulation on the EU solidarity fund, under a technical protocol for an EU common action in the event of a major earthquake disaster. These topics are also relevant to the objectives of the JRC institutional Action – SAFECONSTRUCTION.

ACKNOWLEDGEMENTS

This project was financed by the MDPWH – General Technical Directorate in Constructions. The paramount contribution of Prof. Dr. Eng. Horea Sandi in initiating and development of conceptual aspects and vulnerability studies in INCERC, Romania and Europe, referred to, is especially acknowledged. The framework of EUROPA Major Hazards Agreement - ECBR - European Center for Buildings Rehabilitation in INCERC is beneficial for integrating Romanian approaches in Euro-Mediterranean developments. We acknowledge with thanks the support provided by Dr. Agostino Goretti and Prof. Mauro Dolce, Italian Civil protection, to attend a workshop in the STEP Project. Thanks are addressed to Japanese Experts working in NCSRR during the Project on Seismic Risk Reduction, financed by JICA and Romanian Government (2002-2008).

REFERENCES

Methodology for emergency investigation of post-seismic safety of buildings and establishing of framework solutions for intervention („Metodologie privind investigarea de urgenta a sigurantei post- seism a cladirilor si stabilirea solutiilor cadru de interventie"). Indicativ ME-003-2007. Official Gazette No. 562 / 2007; Buletinul Constructiilor, Vol. 8 / 2007. MTCT-INCERC.

Balan St., Cristescu V. and Cornea I., (coordinators). (1982): "The Romania Earthquake of 4 March 1977 " (in Romanian). Editura Academiei, Bucharest.
Sandi, H. (1983): Introductory Report. Seminar on Vulnerability Analysis. UNDP/UNESCO/UNDRO Project RER/79/014, Bucharest,.UNDRO.
Sandi, H. (1983): A Report on Vulnerability Analysis Carried out in the Balkan Region. *Proc. 8-th World Conf. on Earthquake Engineering*, San Francisco, 1984.
Sandi, H., Cazacu, D., Constantinescu, C., Stancu, M. (1985) : A summary of Studies on the Seismic Vulnerability of Buildings, Carried out in Bucharest Subsequent to the March 4, 1977, Earthquake. *Proc. Joint US-Romanian Seminar on Earthquakes and Energy. Vol. 2, Earthquakes,* pp. 194-231. Editors Samuel Aroni and Romulus Constantinescu. Bucharest, 2-9 September 1985.
Sandi, H. (1986): ECEE Working Group on Vulnerability and Risk Analysis For Individual Structures and Systems. *Report to the 8 th ECEE*, Lisbon, Portugal.
UNDP/UNIDO: Project RER/79/015 (1985) "Building Construction Under Seismic Conditions in the Balkan Region". "Post- Earthquake Damage Evaluation and Strength Assessment of Buildings Under Seismic Conditions" Manual, UNIDO, Vienna, 1985.
Sandi, H., Dolce, M., Coburn, A. W., Goschy, B. (1990): „Report to the 9-th ECEE of EAEE/WG 3, "Vulnerability and risk analysis" *Proc. 9th European Conf. on Earthquake Engineering,* Moscow.
Sandi, H. (1998): „A format for vulnerability analysis of damaged structures". *Proc. 11th European Conf. on Earthquake Engineering,* Paris.
Sandi, H., Pomonis, A., Francis, S., Georgescu, E. S., Mohindra, R., Borcia, I. S. (2007): "Development of a nation wide seismic vulnerability estimation system", *Symposium "Thirty Years from the Romania Earthquake of March 4, 1977",* UTCB, Bucharest, Romania, 1-3 March 2007.
Sandi, H., Pomonis, A., Francis, S., Georgescu, E. S., Mohindra, R., Borcia, I. S. (2007): "Seismic vulnerability assessment. Methodological elements and applications to the case of Romania", *International Symposium on Strong Vrancea Earthquakes and Risk Mitigation,* October 4-6, 2007, Bucharest, Romania.
Goretti, A., Di Pasquale, G. (2002): An Overview of Post-Earthquake Damage Assessment in Italy. EERI Invitational Workshop, 2002, Pasadena, California, USA.
Goretti, A., Di Pasquale, G., Rota, M. (2007): Post-Earthquake Safety Assessment. A State of the art Report in European Countries. *Lessloss Final Workshop. Risk Mitigation for Earthquakes and Landslides Integrated Project*. European Integrated Project GOCE-CT-2003-505488, 19-20 July 2007, Belgirate, Italy.
Pinto, A. V., Taucer, F. - Editors (2007): Field Manual for post-earthquake damage and safety assessment and short term countermeasures (AeDES). JRC Scientific and Technical Reports. EUR 22868 EN – 2007. European Applied Technological Council, ATC 20 (1989) Procedures for post-earthquake safety evaluations of buildings. ATC 20–1 (1989) Field Manual for post-earthquake safety evaluations of buildings. ATC 20-2 (1995) Addendum to ATC 20 post-earthquake building safety evaluation procedures.
Applied Technological Council (1988), ATC-21-1: "Rapid Visual Screening of Buildings for Potential Seismic Hazards: Supporting Documentation".
Kaminosono, T., Kumazawa, F., Nakano, Y. (2002): Quick inspection manual for damaged reinforced concrete buildings due to earthquakes. Based on the Disaster of 1999 Kocaeli Earthquake in Turkey. National Institute of Land and Infrastructure Management, Ministry of Land, Infrastructure and Transport, Japan
New Zealand Society for Earthquake Engineering Inc. (1998): Post-earthquake building safety evaluation procedures. Preparedness checklist and response plan for territorial authorities.
EPPO and European Centre on Prevention and Forecasting of Earthquakes (2000): Risk elements removal, temporal support and propping. Handbook no. 2, Athens, Greece.